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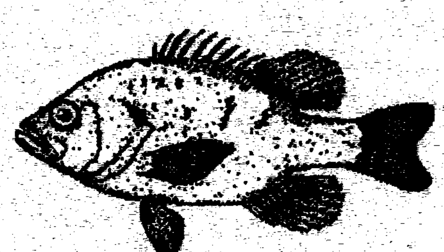
ILLINOIS NATURAL HISTORY SURVEY

THE FISHERIES ANALYSIS SYSTEM (FAS): CREEL SURVEY AND LAKE ANALYSES

Center for Aquatic Ecology

Peter B. Bayley, Stephen T. Sobaski, & Douglas J. Austen

October 1990



Aquatic Ecology Technical Report 90/12

DOUGLAS J. AUSTEN

Illinois Natural History Survey
Aquatic Biology Section Special Technical Report 90/12

THE FISHERIES ANALYSIS SYSTEM (FAS): CREEL SURVEY AND LAKE ANALYSES

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SUMMARY OF PROJECT

Data Base Management and Analysis of Fisheries in Illinois (Project F-69-R(1-3)) is a continuation of F-46-R with significant additions. A statewide system of creel surveys was implemented and resulted in 52 annual, daytime creels and 13 nightime creels being completed on impoundments ranging from 13 to 18,900 acres. A highly stratified random design produced 95% confidence limits of ±10-30% of mean total harvest and ±5-15% of total angling effort for most of the daytime creel surveys. Comprehensive software packages were developed for statistical analyses of creel surveys and incorporation of creel data into the State Fisheries Analysis System data base.

The Final report is divided into four Aquatic Ecology Technical Reports 90/9 through 90/12. The 'Manual for Fish Population Surveys (DOC9 package) for the District Fisheries Analysis System (FAS)' (90/9) updates the package of data entry and analysis at the District level, which has so far provided data from 231 state-managed impoundments that occupy 14 Mbytes on the statewide data base. The 'Creel Survey Manual for the District Fisheries Analysis System (FAS)' (90/10) is a major update on the package for statistical analysis and reporting of creels. 'The State Fisheries Analysis System (State FAS)' (90/11) describes the layout and function of the fish population survey and creel data components of the statewide data base, the procedure for uploading creel summary data, and output programs. Finally, 'The Fisheries Analysis System (FAS): Creel Survey and Lake Analyses' (90/12) contains an analysis of precision of creel surveys, a study that predicts numbers of active anglers from car lot counts by season and lake type, an analysis of the diurnal variation of anglers by season to correct for bias in fishing intensity estimates, and an update on the lake documentation program.

This technical report is part of the final report of Project F-69-R (1-3), Data Base Management and Analysis of Fisheries in Impoundments, which was conducted under a memorandum of understanding between the Illinois Department of Conservation and the Board of Trustees of the University of Illinois. The actual work was performed by the Illinois Natural History Survey, a division of the Department of Energy and Natural Resources. The project was supported through Federal Aid in Sport Fish Restoration (Dingell-Johnson) by the U.S. Fish and Wildlife Service, the Illinois Department of Conservation, and the Illinois Natural History Survey. The form, content, and data interpretation are the responsibility of the University of Illinois and the Illinois Natural History Survey, and not that of the Illinois Department of Conservation.

PREFACE

This report contains a series of special studies which were part of Project F-69-R(1-3). It includes a description of the design and analysis of creels and a comparison of confidence intervals (Chapter 1), an exploratory analysis of the relationship between vehicle counts and instantaneous counts of anglers (Chapter 2), a graphical analysis on the variation of instantaneous angler counts by time of day and year (Chapter 3), and an update on the lake mapping program (Chapter 4).

Acknowledgments

Mike Halter, Jim Van Voorhis, Cheryl Jacobs, Frank Jakubicek, Jim Peterson, Joseph Stepping, Mark Thompson, Alan Citterman, Jim Mick, Department of Conservation District Managers, and numerous, dedicated creel clerks are thanked for their assistance and support.

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Chapter 1. Design, computation, and comparisons of creel surveys

Introduction

A major goal in the design and execution of creel surveys is to obtain acceptable precision in angling effort and harvest estimates with minimal cost. It is simple to improve precision on a particular lake by changing the design and sampling effort based on experience gained from analysis of the first creels. However, it may not be possible to formulate reliable management decisions that incorporate results from the first one or two years. Designing the distribution and intensity of sampling effort on a new lake is the greatest challenge.

This study is part of a long term program in which creel data are integrated with population survey data under the Fisheries Analysis System of Illinois (Bayley and Austen 1989). Results from the first two years of this program are compared in order to estimate the amount of sampling required for a given relative precision when lakes are creeled for the first time. The man-made lakes surveyed are highly variable in terms of size (13 to 18,900 hectares), shape, access points per unit area, and the proportion of shore and boat anglers, making implementation of a purely roving-creel or access-point design across all lakes impossible. Also, the completed trip information provided by access point interviews, such as the quantity of certain species harvested per trip or the angling trip duration, is important for management. Therefore, although the roving-creel approach was appropriate for the majority of lakes, we included in the design a small proportion of access point interviews from those lakes. The proportion of roving-creel versus access point information has not affected the results in this analysis, but a more detailed comparison is planned on a larger data base in the future. This chapter describes the design and the effects of sampling effort and stratification on precision from 52 annual creels.

Statistical Design and Calculation of each Creel

The design is based on a stratified random design after Cochran (1963). The strata are as follows (maximum numbers of categories per stratum in parentheses):

Year-period (12)
Section (physical division of the lake) (10)
Day-period (time period within a day) (3)
Angler-type (boat or shore) (2)
Day-type (weekday or weekend/holiday) (2)

Year-periods are defined according to expected changes in angling intensity rather than by arbitrary time periods such as calendar months. This flexibility also permits times of day-periods to be adjusted according to changes in daylight hours and year-periods to correspond to distinct activities such as ice fishing.

A section is defined as an area of the lake where (1) an 'instantaneous' count of anglers can be made within 60 minutes and (2) the area is of particular interest or may have a distinct harvest rate or angling intensity, e.g., a warm-water arm of a cooling lake.

Day-periods have been used because diurnal changes in both effort and catch rate are evident.

During warmer months, catch rates tend to be higher early and late in the day. During week-days, effort is higher outside normal working hours. On some creels, not presented here, a separate night period has been defined.

Three 'primary statistical units' are calculated for each day-period sampled in each section-year-period and by angler-type: (1) the angling effort (*e.g.*, angler-hours of shore anglers), (2) harvest or catch (=harvested plus released fish) (*e.g.*, harvest of bluegill by boat anglers), and (3) harvest- or catch-per-unit-effort (or catch rate, in terms of numbers or weight of fish per angler-hour).

The day is divided into morning (day-period 1), mid-day (day-period 2), and evening (day-period 3). For example, from May to September day-period 1 ends at 1000 hours and day-period 2 at 1600 hours. Only interviews whose time falls within the limits of each day-period are included in the appropriate day-period stratum. If an angler had started fishing during a previous day-period, he or she is asked to 'split' the information from their trip by differentiating between catch and harvest during the previous period(s) and that taken during the current period. On occasions when an angler is unable to do this, the total data are allocated to the current day-period. ('Split interviews' that comprise a completed trip are tagged in the data base so that statistics relating to completed trips can be computed (Aquatic Ecology Technical Report 90/10); in the analysis presented here data from all trips, whether completed or not, are included.)

Within a section and day-period, the clerk begins interviews going clockwise or counterclockwise depending on the toss of a coin. He or she attempts to interview all angling parties. If this is not possible, they are required to interview systematically (every second or third party) in an attempt to cover the whole area. A mid-point is established for each section. If this point is not reached by half time, the second half of the day-period commences from that point. In sections with access points, the last 30 min of the day-period are reserved for making completed trip interviews. In a minority of lakes, there is a single access point from which the clerk can be fully occupied obtaining most interviews from completed trips.

Clerks measure all fish harvested, except when large numbers of a species within a narrow size range are encountered. In such cases a subsample is measured and the remainder counted and recorded as a 'group count' along with the minimum and maximum length. Group counts are subsequently processed by allocating frequencies to 1-cm length groups in proportion to the length distribution of that species in the particular lake and during the appropriate time of year. Lengths are converted to weights using parameters derived from length/weight regressions of corresponding species from statewide fish population surveys (DOC9 data base) except when the relationship for the lake and species concerned differs.

The creel survey design and work schedule is based on randomly chosen day-periods in each stratum combination of day-period, day-type, section, and year-period (e.g., day-period 3 on week-days in the east arm during 1 May-15 June). It is not convenient for most creel clerks to work a shift as short as an individual day-period. Therefore creel clerks work half-day shifts. The first shift includes day-period 1 and half of day-period 2, the second shift includes the second half of day period 2 and day-period 3. Currently, numbers of shifts are allocated equally between shift 1 and 2 and equally between day-types. Therefore, the random allocation of shifts results in the random allocation of pairs of adjacent day-periods. Although this design results in day-period 2 being sampled twice as frequently as the other day-periods, only half of day-period 2 is sampled each time, resulting in a similar sampling intensity. Numbers of shifts were originally allocated to year-period/section combinations according to estimates of relative angling intensity. They are now allocated according to expected relative harvest. These estimates have been based on data from previous creels. In each stratum shifts are randomly chosen within two-week intervals to avoid chance clumping of samples within short periods or long intervals of inactivity, either of which are likely to reduce creel clerk performance.

Associated with each day-period sample of interviews is an instantaneous count taken midway through day-period 1 or 3, or midway through the first or second half of day-period 2. Using standard rather than random count times reduces the high variance caused by far fewer anglers fishing early or late in the day. The positive bias inherent in this approach is currently being reduced by multiplying the instantaneous count of anglers by a time period shorter than that of day-period 1 or 3, based on rough estimates by local fishery managers. For example, the count from a day-period 1 lasting 4-h would typically be multiplied by 3.5h (see H_{ij} in (1) below). The real bias is being estimated by taking time series of instantaneous counts throughout each day-period in different strata on a number of typical lakes (Chapter 3). Any current biases should not affect the results of this paper which analyzes precision. Counts are made of shore anglers, boat anglers, and fishing boats. Fishing boat counts are not used in the following analysis.

The three primary statistical units are calculated for each stratum combination as follows. The angling effort is estimated from the number of anglers multiplied by the hours fished in the time interval is for that unit:

$$E_{ij} = A_{ij} \cdot H_{ij} \qquad (1)$$

where E_{ij} = effort (angler-hours) (the subscript j denotes the sample number for a specific date; i is the stratum denoting a particular combination of year-period, section, day-period, day-type, and boat/shore fishing), A_{ij} = instantaneous count of anglers, and H_{ij} = number of hours of fishing in the day-period concerned. Occasionally, in particular when few anglers are present, total angler-hours interviewed exceeds $A_{ij} \cdot H_{ij}$. In these cases the interviewed angler-hours are used instead. The harvest- or catch-per-unit-effort is the total number (or weight) of fish caught divided by the number of hours fished by all boat or shore anglers interviewed in i, j:

$$S_{ij} = C_{ij}/h_{ij} \qquad (2)$$

where S_{ij} = catch rate in number or weight of fish per angler-hour fished, C_{ij} = total number or weight of fish caught by anglers interviewed during the time interval in i, and h_{ij} = total number of angler-hours fished (party size times hours fished at time of each interview summed over all interviews in i, j). S_{ij} is therefore the mean of the angler party catch rates, each of which is weighted by the angler-hours fished. The analysis combines completed and incomplete trips, which therefore assumes that the catch rate is independent of the degree of completeness of each fishing trip. Catch of fish is then estimated by multiplying effort by catch rate:

$$Y_{ij} = E_{ij} \cdot S_{ij} \qquad (3)$$

where Y_{ij} = harvest or catch of fish by number or weight in i, j. E_{ij} and S_{ij} are as above.

Thus for each date and day-period sampled, there is a value for effort (angler-hours), harvest or catch (number of fish), and harvest or catch per unit effort (number or weight of fish per angler-hour) for selected species and all species combined.

For each stratum i, a mean (eq. 4) and a variance (eq. 5) is calculated for each of the three primary statistical units in (1), (2), and (3):

$$\bar{X}_i = \frac{\sum_{j=1}^{n} X_{ij}}{n_i} \quad (4)$$

$$VAR(\bar{X}_i) = \frac{\Sigma(X_{ij})^2 - [(\Sigma X_{ij})^2/n_i]}{n_i - 1} \quad (5)$$

where X_{ij} = either effort (E_{ij}), catch (Y_{ij}), or catch rate (S_{ij}) for stratum i and sample j, and n_i = sample size in stratum i (*i.e.*, number of dates creeled for a given stratum). Strata are combined to give means and variances for the new groups, which may include any combination of year-periods and sections (Cochran 1963):

$$\bar{X}_{ST} = \sum_{i=1}^{L}[(N_i/N) \cdot \bar{X}_i] \quad (6)$$

$$VAR(\bar{X}_{ST}) = \sum_{i=1}^{L} [(W_i^2 \cdot S_i^2)/n_i] \quad (7)$$

where $W_i = N_i/N$ = stratum weight, N_i = maximum number of samples (i.e. dates) possible in stratum i, N = maximum number of samples possible in all strata, and L = number of strata being combined, S_i^2 = sample variance in stratum i, and n_i as in eqs. (4) and (5).

The finite population correction is not used in eq. (7) (cf. Malvestuto et al. 1978) because the variance would be zero if all possible day-periods within a stratum were sampled. A finite population correction would be clearly unrealistic because a census of total catch or effort in each day-period sampled is not being taken. Even if all anglers were interviewed, there are typically a majority of interviews based on incomplete trips. A census is only possible on occasional day-periods in a minority of lakes in which completed trip sampling is possible.

Mean values per stratum for harvest or catch and effort are scaled up to estimate totals by multiplying by N:

$$X_{TOT} = \bar{X}_{ST} \cdot N \quad (8)$$

where X_{TOT} = estimated total for harvest, catch, or effort. Variance for total harvest or catch and effort is scaled by N^2:

$$VAR(X_{TOT}) = VAR(\bar{X}_{ST}) \cdot N^2 \quad (9)$$

Mean harvest- or catch-per-unit-effort (CPUE) is given directly by (6) and variance of mean CPUE from eq. (7). For all values that have variances associated with them, a confidence interval is calculated.

$$\bar{X} \pm t_{\alpha}(SE) \qquad (10)$$

where t_{α} = t value from tables at α significance level and SE = standard error. For harvest or catch and effort

$$SE = \sqrt{VAR\ (X_{TOT})}$$

and for CPUE

$$SE = \sqrt{VAR\ (\bar{X}_{ST})}$$

with

$$\text{Approximate degrees of freedom} = \frac{[\Sigma(N_i(N_i - n_i)/n_i) \cdot S_i^2]^2}{\Sigma[((N_i^2(N_i - n_i)^2/n_i^2) \cdot S_i^4)/(n_i - 1)]} \qquad (11)$$

from (Cochran 1963).

Outputs can be based on any combination of year-periods and sections, and contains a breakdown of shore and boat angling, day-types, and day-periods. Any year-period/sections that had negligible or no fishing activity are excluded from the design. Coalescing of strata (destratification) can be performed on any combination of year-periods and sections, and/or angler-types, day-types and/or day-periods. Coalescing is often performed across sections that were only delimited for practical reasons or to combine data when any combination of strata had insufficient samples because the design could not be fully implemented.

Comparative Analysis of Creels

Fifty-two annual creels from 1987 to 1989 were analyzed. Thirty-three creels that were completed during 1987 and 1988 were designed on the basis of allocation of effort. Although three lakes were creeled in both years, results from the first year could not be analyzed before the second year creel was implemented. Therefore creels from the first two years were designed without previous knowledge of precision. The 19 creels completed in 1989 were designed on the basis of expected relative harvest using data from the first two years of the project. The dependent variable of interest, Relative Precision, and the independent variables, Sampling Percentage and Stratification Percentage, were calculated for each creel as follows:

Relative Precision (Harvest or Effort) is the percentage by which the upper 95% confidence limit exceeds the mean value of the harvest (kg of all species) or effort (total angler hours). This is calculated as: (upper 95% limit - mean)x100/mean. Because normal distributions were assumed, this is the same as the percentage by which the lower 95% confidence limit is below the mean value. We prefer to use Relative Precision over proportional standard error because it derives a direct estimate of the confidence range that will help managers understand precision. The Relative Precision is approximately twice (1.98-2.2) the proportional standard error for these data. A principal goal of creel surveys is to reduce the Relative Precision or proportional standard error to acceptable, low values at minimal cost.

Sampling Percentage is the percentage of all possible day-period/lake-section combinations in the design that were sampled. A value of 100% would mean that all lake sections were sampled every day-period of every day during the creel year, except any year-period/sections that were excluded from the design due to lack of fishing activity.

Stratification Percentage is a measure of the number of strata retained in the analysis and is defined as the percentage of all strata combinations in the design that were implemented. Therefore it would be expected to reflect the value of stratification in improving Relative Precision. Lower values of Stratification Percentage reflect an increase in the amount of coalescing performed on the strata. For example, a lake with 2 sections, 6 year-periods, 3 day-periods, 2 day-types, and boat/shore strata would have 2x6x3x2x2 = 144 strata combinations in the design (which excludes periods of no fishing). If two of the six year-periods and the two sections were coalesced, 1x5x3x2x2 = 60 strata combinations would be analyzed, resulting in a Stratification Percentage of 60x100/144 = 41.7%. Typically sections or adjacent year-periods were coalesced in preference to other strata. Coalescing of strata does not affect Sampling Percentage.

Results

Exponential curves best described the relationships between Relative Precision and independent variables (Figs. 1,2) for the 1987 and 1988 data. Statistical results are reported as least squares regressions of log(Relative Precision) on untransformed independent variables.

Relative Precision (Effort) decreased significantly with increasing Sampling Percentage (Fig. 1A, $P=0.002$). Stratification Percentage had a similar negative effect (Fig. 1B, $P=0.023$). High Stratification Percentage values were associated with high Sampling Percentage values (Fig 1A). However, when creels with Stratification Percentages ≥60% were analyzed, Stratification Percentage had no effect ($P<0.1$) on Relative Precision (Effort), whereas Sampling Percentage for these creels still had a significant negative effect ($P=0.007$) on Relative Precision.

Relative Precision (Harvest) decreased with increasing Sampling Percentage (Fig. 2A, $P=0.089$). Stratification Percentage had a stronger effect (Fig. 2B, $P=0.016$), but high values were associated with high Sampling Percentage values (Fig 2A).

This analysis of data from the first two years resulted in minor changes in design and increased sampling ratios in some lakes during 1989. Sampling effort in 1989 was apportioned among year-periods according to total harvest rates from creels during 1987 and 1988. Formerly, the creels were designed on the basis of presumed seasonal variation in fishing effort. The 1989 data is compared with previous years in Figures 3A and 3B, which clearly show an improvement in precision over previous years.

Discussion

The required precision depends on the program's goals. Analysis of trends from long time series does not require as high a precision as do short-term management decisions.

The Relative Precision values for effort are about twice as good as those for harvest. If values of within ±20% are deemed to be satisfactory for management purposes, this would include 31 of 33 creels reported here.

In contrast, the Relative Precision values for harvest estimates need improvement, especially because values for individual species tend to be higher. If values within ±20% are regarded as being acceptable for management, under the current design scheme the Sampling Percentage needs to be about 60-70% when combined with a Stratification Percentage of at least 60%.

The improvement in precision of the 1989 creels (Figure 3) may be due to the allocation of effort according to seasonal differences in harvest. However, in practice the design of many creels did not change radically when estimated harvest is used instead of effort. Other improvements such as in training and supervising creel clerks may have influenced the improvement.

The 1989 data do not indicate an effect of sampling ratio on precision (Figure 3). The lower sampling ratios are associated with larger lakes, which showed surprisingly good precision. Possibly the fisheries in larger lakes are more uniform, and the sections, which were mostly delimited for practical reasons, are relatively uniform.

An improved allocation of effort should mitigate the increased cost of a higher Sampling Percentage. However, there is an upper limit to the Sampling Percentage for a sampling strategy based on either expected effort or harvest. When 100% sampling during week-ends is allocated during the busiest weeks of the year, this is only equivalent to a Sampling Percentage of about 65% for a typical creel design. The upper limit to the Sampling Percentage can only be exceeded by a less efficient design in which more sampling is allocated to less busy year-periods or to weekdays. As implied previously, '100% sampling' does not comprise a census because all the anglers are not interviewed. In order to increase the effectiveness of a given Sampling Percentage the additional cost of more clerks, boats, and motors would be needed for each lake section during busy times of the year.

This is the first analysis from a long term project in which we will attempt to improve the precision and accuracy of creels on the same lakes and on new ones across Illinois. When more creels are obtained during F-69-R(4-6) a detailed comparisons will be possible. For instance, individual lakes can be compared among years. Also, the effect of the proportion of total fishing effort interviewed can be tested.

There will, of course, be a minimum component of the variance that cannot be reduced under the current strategy and budgetary restraints. A large part of this variation is suspected to be due to short term (within year-periods) changes in weather that can affect angling effort and catch per unit effort. An analysis of the effect of weather, in particular temperature, wind, and rain, on effort and catch may result in improved precision estimates being obtained for a similar investment.

Chapter 2. Vehicle Counts as Estimators of Fishing Effort

Introduction

Intuitively there must be some relation between the total number of vehicles parked at a state or public fishing lake and the number of people currently engaged in fishing. If a relation exists with sufficient precision for prediction, there is the attractive possibility of economically monitoring fishing effort on lakes. Creel surveys are expensive and therefore only a small subset of state-managed lakes can be studied each year. Although fishing effort estimates do not provide all the information desirable from a fishery, such estimates from a large set of lakes could provide information on angling pressure that affects diverse sets of lakes across the State.

Methods

'Instantaneous counts' were made of boat anglers and shore anglers as described in Chapter 1, but not only at the normal times established for each day-period. Immediately after each instantaneous count, counts of plain vehicles, vehicles with trailers, and other vehicles (e.g. motorcycles), were made at all parking lots and camp sites on the lake. Weekends and holidays were included. Data were omitted that were based on three or fewer vehicles. Lakes were avoided that have a significant quantity of private riparian residences. Also, for this preliminary study, large lakes with more than one section were avoided because of logistical limitations. Lakes Shabbona, Beaver Dam, Sam Parr, Baldwin, Jones, and Murphysboro were sampled between 1988 and 1989, from April through November.

Results and Discussion

Figure 4 shows the results combined as log(total anglers) versus log(total vehicles). Points from lakes Jones and Murphysboro showed that for given numbers of anglers there were much larger quantities of vehicles compared with the other lakes. It is known that these 'multi-use' lakes attract a larger proportion of non-fishermen, such as students from Southern Illinois University who provide their own entertainment. Apart from this major division, much of the variability in Figure 4 was found to be due to time of day and type of day.

Weekends and public holidays during 'summer' (memorial- to labor-day) and times during other weekend/holidays when air temperature exceeded 15°C (59°F) attracted relatively more non-anglers, as might be expected. Data corresponding to this 'minor' group were separated from data of the corresponding 'major' group (i.e., all week-days plus weekend/holidays outside the memorial- to labor-day season when temperatures were less than 15°C). Figure 5 shows plots from the 'minor' group corresponding to times of the day when instantaneous counts were taken on standard creels (Chapter 1) for all lakes other than Jones and Murphysboro. Similarly, Figure 6 shows the corresponding plots for the 'anglers' data. It is evident that much of the variability evident in Figure 4 has been removed, and that reasonable predictions can be made for this class of lakes (Table 1). There were insufficient data from Jones and Murphysboro to provide good statistical results from a corresponding 'major/minor' split. The combined data for those lakes, termed 'multi-use' for corresponding diurnal periods show greater variability (Figure 6). The term 'multi-use' is relative. All the groups have some non-angling recreation in descending order 'multi-use', 'minor', and 'major'.

Surprisingly, slightly better precision was obtained for the 'minor' data (Table 1, Figure 5) than from the 'major' data (Table 1, Figure 6), although the latter still provide reasonable predictions. Greater numbers of vehicles and anglers that correspond to the 'minor' group may explain this. Within either group, there does not appear to be a superior time of the day for prediction of angler numbers among the four periods tested.

Some exploratory analysis was performed on vehicles with trailers versus boat anglers and plain vehicles versus shore anglers. The first group showed slightly better precision, and the latter inferior precision than the models for the combined data presented here. On some lakes a significant quantity of rental boats sometimes present a problem of allocation because individual parking lots dominated by renting visitors may not be identifiable and consequently counted as equivalent to boats with trailers. Summing all anglers and all boats circumvents this problem but loses information on the proportion of boat anglers.

The major variation in the total data set is due to the two 'multi-use' lakes that have smaller proportions of fishermen at any time of the year or week (Figure 7). When these lakes are separated, the predictive equations (Table 1) can only be useful if such lakes can be characterized by samples taken at critical periods. Better predictive equations for lakes with large non-fishing communities need more comprehensive sampling of anglers, vehicles, and weather factors to provide good estimators on an individual lake basis. However, even this preliminary data should provide the basis for making broad estimates of fishing effort across large sets of lakes for the relatively small investment of counting vehicles during critical periods. Additional data collected during F-69-R(4-6) may allow a more definitive classification of lakes so that automatic vehicle counters might be profitably utilized.

Chapter 3. Diurnal Variation in Instantaneous counts

Introduction

An instantaneous count of anglers does not provide an estimate of fishing effort without a time component. A day-period (or full day in many creel surveys in other States) comprises an arbitrary time period. If a day-period is defined from 0600-1000 hours, is the total angling effort for a particular period best estimated by the product of the instantaneous count and the time difference (=4 h)? One solution is to randomly choose the period for the instantaneous count. This has two problems. First, the diurnal variation in angling pressure follows a trend: this will result in high variance due to some random times, such as starting at 6 am when very few anglers have begun fishing. Second, good creel clerk performance is related to a set of strict rules for the days' work which are difficult to apply when operations have to be performed in a different order each time.

The definition of the period is arbitrary and also affects the effort estimates. In our daytime creels the beginning of day-period 1 and the end of day-period 3 are adjusted seasonally to be as close as possible to the periods of sunrise and sunset, respectively.

The procedure of a fixed instantaneous count period (Chapter 1) requires that any bias be corrected. Up to now we have estimated this bias without hard data, because for day-periods 1 and 3 it is evident that multiplying the instantaneous count by the full duration of the day-period will overestimate the anger effort. Typically we have used an 'effective hours' period of 30 min. less than the 1st and 3rd day-period length, and no correction for day-period 2. Thus effective hours of 3.5 for a day-period 1 from 6-10 am with an instantaneous count made at 8-9 am would be equivalent to the angler count starting at zero at 6 am, increasing to a maximum by 7 am, and maintaining that maximum until 10 am. Many other scenarios could be consistent with the same effective hours. Mathematically, the angling effort is the area under a curve describing numbers of anglers over time. The effective hours is that area divided by the instantaneous count.

This chapter contains a preliminary analysis of data collected so far. The short term purpose is to assess how serious the bias might be in the creels analyzed so far.

Methods

As in Chapter 2, 'instantaneous counts' were made of boat anglers and shore anglers at frequent intervals (30-60 min) throughout the day on a variety of lakes. Also, for this preliminary study, large lakes with more than one section were avoided because of logistical reasons. Lakes Pierce, Washington County, Shabbona, Beaver Dam, Sam Parr, Baldwin, Jones, and Murphysboro were sampled between 1988 and 1989, and from April through November. Weekends and holidays were included. The year was divided into three seasons: Mid-April-May, June-August, and September-mid-November.

In order to combine data from lakes and dates with different angler numbers, instantaneous count data were scaled as a percentage of the maximum count during each day-period.

Results and Discussion

There were no apparent differences between lakes, but some differences between weekend/holidays and weekdays were suspected. The variation in the plots combined across lakes (Fig. 8) is not surprising, because no averaging of data was undertaken and only data were omitted that were based on fewer than 10 maximum anglers (Figs. 8 A-E) or 4 maximum anglers (Fig 8F) during each day-period. Much of the noise was due to changing weather. However, there is indication of reduction of effort early and late in the day as would be expected. All combinations indicate a rise in fishing effort to a maximum or plateau at about 0900h.This is illustrated in Figure 8 by fitting Distance Weighted Least Squares curves (McClain 1974) with constant, default tension parameters using SYSTAT™, to each plot.

In the summer period (Fig. 8C, D) there is not the drop at the end of the day as at other times of the year. In summer weekdays (Fig. 8D), there is a strong suggestion of a mid-afternoon period of reduced angling activity. This may reflect relatively higher proportions of serious anglers during weekdays who do not fish during hot afternoons. The dip for summer weekends/holidays (Fig. 8C) may not be significant. Effort during this time of day is more variable, possibly due to temperature variation. Overall, there is no clear distinction between different lakes, and even weekend/holidays and weekends may not be statistically different.

Comparing the average periods of instantaneous counts for each season with the proportion of maximum angler counts (Figure 8) indicates that a serious positive bias would have resulted in day periods 1 and 2 if the effective hours had been presumed to be the same as the day-period durations. Table 2 shows estimates of effective hours based on areas measured under the curve in Figure 8 divided by mean relative angler counts corresponding to instantaneous count times during each season and day type (estimated by the height of the curve at the corresponding time in Figure 8).

Despite the current paucity of data, the biases suggested by the difference between the day-period duration and the effective hours (Table 2) show consistency with previous assumptions. The overall mean bias for day-period 1 was 0.57 h. Our original estimate used in creel analyses to date was 0.5 h. For day-period 2 we had assumed that effective hours equalled day-period length (i.e., no bias) of 6.0 h in most creels. The overall mean for day period 2 in Table 2 was 5.93 h. The highest effective hours of 6.2 and 6.3 h were in Shift 2 (afternoon counts) during the first two seasons, and is suggestive of the afternoon reduction in fishing noted above but cannot currently be tested statistically. Finally, for day-period 3 the mean bias was 0.45 h, compared to 0.5 h presumed in the analyses to date. However, a seasonal variation in the bias is suggested by the highest values in the summer period, when more anglers continue fishing to sunset.

These preliminary results indicate that for annual creels any bias resulting from our earlier estimates of effective hours is negligible compared with the standard errors of effort or harvest. They demonstrate that creels with non-random instantaneous count times that failed to account for this bias, such as many performed in Illinois prior to this project, overestimated effort and harvest by about 5-9%. More data are being collected to allow better estimates during shorter year-periods that correspond to those in the creel design. In the future, a better model may result from patterns predicted from weather reports.

Chapter 4. Impoundment description

Of the 133 lakes and impoundments listed in Table 4 of the 1988 Annual progress report for this project (F-69-R2) field work has been completed on all but 21 of the water bodies. This includes bathymetric mapping, rating shoreline habitat, and obtaining water chemistry information. In addition much work has been accomplished on the incorporation of this material into the Geographic Information System (GIS) for eventual map plotting and calculation of morphometric data. Each of these topics is discussed below.

The total number of lakes has far exceeded the quantity originally estimated because more new lakes have been added to the Fisheries Analysis System data base during this project. This work is due to be completed during F-69-R(4-6) by publishing the maps and summarizing the results in a comprehensive reference.

Lake mapping

For each lake we contacted the responsible agency in an attempt to obtain pre-impoundment maps or maps showing recent survey work. Where these were unavailable or where the map had become outdated by excessive siltation we mapped the waterbody ourselves. Mapping consisted of obtaining aerial photographs or a lake outline from a 7.5' USGS topographic map and then running known transects at a constant speed and bearing while recording water depth using graphing sonar. The strip charts were then transcribed on to the lake outline and contours drawn using proportional scaling of the transects plotted on the lake outline. Maps have been obtained or produced for 112 of the 133 lakes of interest. The remaining 21 will be completed in 1990.

Habitat rating

Each district biologist has provided us with diagrams of where they take standardized annual electrofishing and net samples. In many smaller lakes these electrofishing samples encompass the whole shoreline. In larger lakes, however, the biologist must select areas to be sampled with the assumption being that the sites selected are indicative of the lake as a whole. By mapping habitat of the entire lake we can compare sampled areas to unsampled areas to explore biases in sampling procedure. We can also use this information in making inter-lake comparisons by correcting for differences in sampling procedures between lakes. Finally, habitat information can be utilized when applying calibration formulae to the electrofishing samples in estimating efficiency of the samples.

Habitat is mapped according to three main categories: Hard cover (rated 0-3), in-water habitat descriptor (emergent vegetation, standing timber, etc) and shore habitat (grassy bank, open eroded bank, etc.). This information is incorporated into the GIS coverage of lake outline along with the sampling information forming a file that contains, for each section of shoreline, the information on sampling status and the three habitat descriptors. As with the hydrographic maps a lake habitat map has been produced for 112 of the 133 lakes of interest. The remaining 21 will be completed in 1990.

Water chemistry information

For each lake visited we sampled for conductivity, total alkalinity, DO, and water temperature profile (only during July and August of each year), pH, and secchi disk depth. Again, these data were collected for 112 of the 133 lakes of interest. The remaining 21 will be completed in 1990. In addition, data have been obtained from the Illinois Environmental Protection Agency from their ambient lake monitoring program for the 305B reports and their Volunteer lake monitoring program.

Use of Geographic Information System (GIS)

All lake map and habitat information are input into the ARC/INFO GIS system running on the INHS Prime computer. Ninety-six of the 112 lakes have been completely loaded into the GIS with draft plots made for each of these lakes. Habitat information has been entered for approximately half of the 96 lakes for which bathymetric maps have been digitized. The remainder of these lakes will be loaded in 1990-91. For lakes with bathymetric maps loaded, we have calculated the following morphometric parameters: surface area, volume, shoreline length, maximum length and width, maximum and mean depth, percent mean slope, volume development index, shoreline development index, and hypsographic curves relating volume by depth.

Summary

Number of lakes at each stage of completion

Completion stage:	Hydrographic map	Habitat	Digitize	Draft
Plots completed by 12/31/89	112	112	96	81
Plots to be completed 1990-91	21	21	37	52
Total number of lakes	133			

References

Bayley, P. B., and D. J. Austen. 1989. The fisheries analysis system (FAS). Pages 199-205. *In* Mathematical Analysis of Fish Stock Dynamics. E. F. Edwards and B. A. Megrey, editors. American Fisheries Society Symposium 6.

Cochran, W. G. 1963. Sampling techniques, 2nd ed. John Wiley and Sons, New York.

Malvestuto, S. P., W. D. Davies, and W. L. Shelton. 1978. An evaluation of the roving creel survey with non-uniform probability sampling. Transaction of the American Fisheries Society 107:255-262.

McClain, D. 1974. Drawing contours from arbitrary points. The Computer Journal 17 : 318-324.

TABLE 1. Regression statistics corresponding to plots in Figure 5 ('minor' group), Figure 6 ('major' group), and Figure 7 ('multi-use' group = substantial non-angler activity). Regression equation: LOG10(total angler count) = a + bLOG(total vehicle count)

Group	time period	standard error	degrees freedom	Coefficient	s.e. of Coeff.	t-ratio
MINOR	8.00-9.00	0.0363	7	a = 0.318708	0.0564	5.64
				b = 0.928859	0.0357	26.0
MINOR	11.00-12.00	0.0785	7	a = 0.333974	0.0901	3.70
				b = 0.865323	0.0572	15.1
MINOR	14.00-15.00	0.0797	12	a = 0.477090	0.0792	6.02
				b = 0.750305	0.0451	16.6
MINOR	16.00-18.00	0.0838	17	a = 0.384037	0.1024	3.74
				b = 0.782195	0.0570	13.7
MAJOR	8.00-9.00	0.1449	9	a = -0.362111	0.1822	-1.98
				b = 1.36333	0.1559	8.74
MAJOR	11.00-12.00	0.1117	5	a = -0.018857	0.1638	-0.115
				b = 1.10053	0.1144	9.61
MAJOR	14.00-15.00	0.1141	14	a = 0.397216	0.1231	3.22
				b = 0.759764	0.0907	8.37
MAJOR	16.00-18.00	0.1283	19	a = 0.056969	0.1555	0.366
				b = 1.04491	0.1253	8.33
MULTI-USE	8.00-9.00	0.2925	3	a = -0.271572	0.5832	-0.465
				b = 0.696902	0.4842	1.43
MULTI-USE	11.00-12.00	0.1279	3	a = -1.17643	0.2244	-5.24
				b = 1.40647	0.1755	8.01
MULTI-USE	14.00-15.00	0.1155	15	a = 0.091906	0.1627	0.564
				b = 0.682041	0.1265	5.38
MULTI-USE	16.00-18.00	0.1685	21	a = 0.135787	0.1181	1.14
				b = 0.627564	0.0882	7.11

TABLE 2. Approximate effective hours for different seasons, day types, and day periods (calculated from areas under curves in Figure 8, and from relative instantaneous counts at mean times in each season)

Season	Day Type	Day-period	mean day-period (h)	Approx.Effective hours
April-May	W'kend/Hol.	1	4.0	3.5
	Weekday	1	4.0	3.3
June-August	W'kend/Hol.	1	4.0	3.2
	Weekday	1	4.0	2.8
Sep.-Nov.	W'kend/Hol.	1	3.0	2.8
	Weekday	1	3.0	2.9
April-May	W'kend/Hol.	2 (shift 1)	6.0	6.0
	W'kend/Hol.	2 (shift 2)	6.0	5.7
	Weekday	2 (shift 1)	6.0	5.9
	Weekday	2 (shift 2)	6.0	6.3
June-August	W'kend/Hol.	2 (shift 1)	6.0	6.0
	W'kend/Hol.	2 (shift 2)	6.0	5.8
	Weekday	2 (shift 1)	6.0	5.5
	Weekday	2 (shift 2)	6.0	6.2
Sep.-Nov.	W'kend/Hol.	2 (shift 1)	6.0	5.8
	W'kend/Hol.	2 (shift 2)	6.0	6.1
	Weekday	2 (shift 1)	6.0	5.9
	Weekday	2 (shift 2)	6.0	6.0
April-May	W'kend/Hol.	3	4.0	3.1
	Weekday	3	4.0	3.4
June-August	W'kend/Hol.	3	4.0	4.0
	Weekday	3	4.0	4.0
Sep.-Nov.	W'kend/Hol.	3	3.0	2.5
	Weekday	3	3.0	2.3

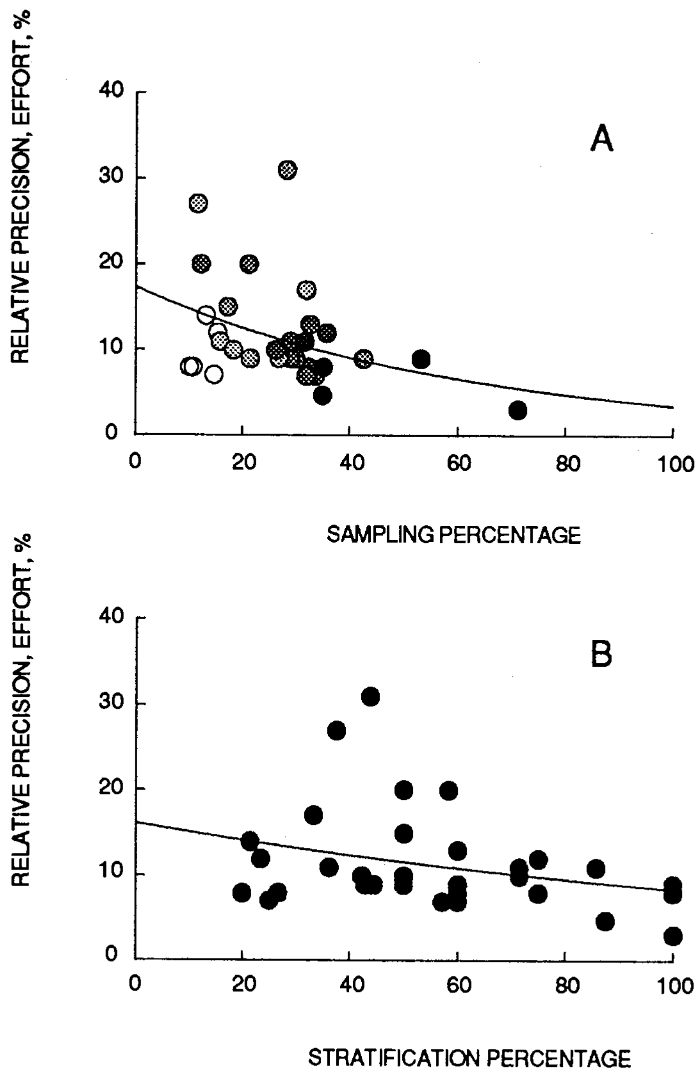

FIGURE 1. Relative Precision (effort) versus (A) Sampling Percentage, (B) Stratification Percentage for 1987 and 1988 creels. See Chapter 1 for definitions. Degree of symbol shading in (A) is proportional to the Stratification Percentage. Curves are exponential, least squares fits.

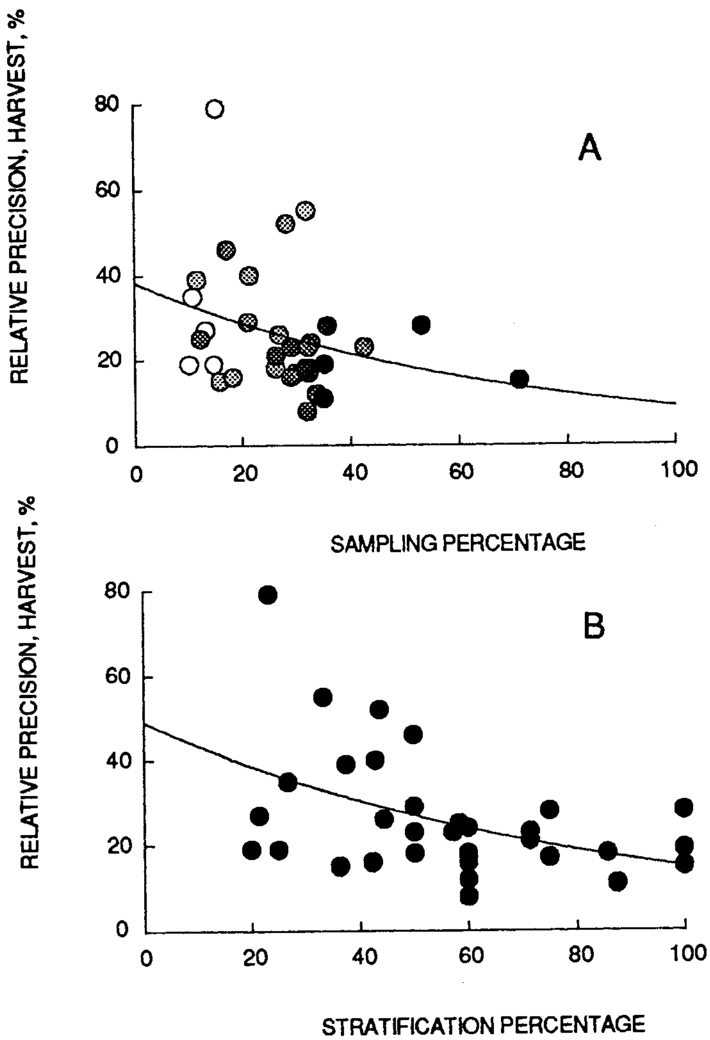

FIGURE 2. Relative Precision (harvest) versus (A) Sampling Percentage, (B) Stratification Percentage for 1987 and 1988 creels. See Chapter 1 for definitions. Degree of symbol shading in (A) is proportional to the Stratification Percentage. Curves are exponential, least squares fits.

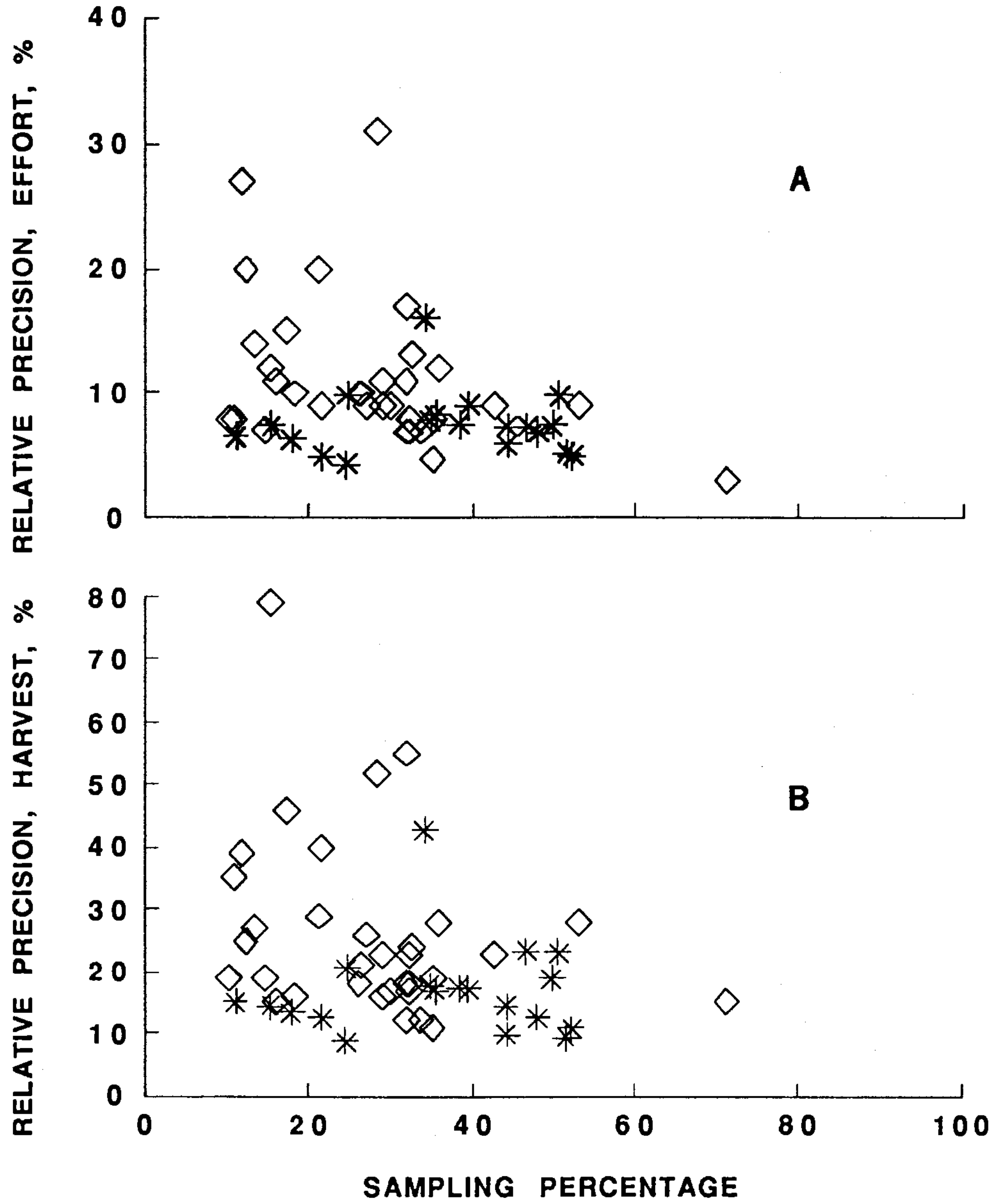

FIGURE 3. RELATIVE PRECISION OF EFFORT (A) AND HARVEST (B) BY SAMPLING PERCENTAGE (SEE CHAPTER 1)

DIAMONDS = 1987 and 1988 CREELS

ASTERISKS = 1989 CREELS

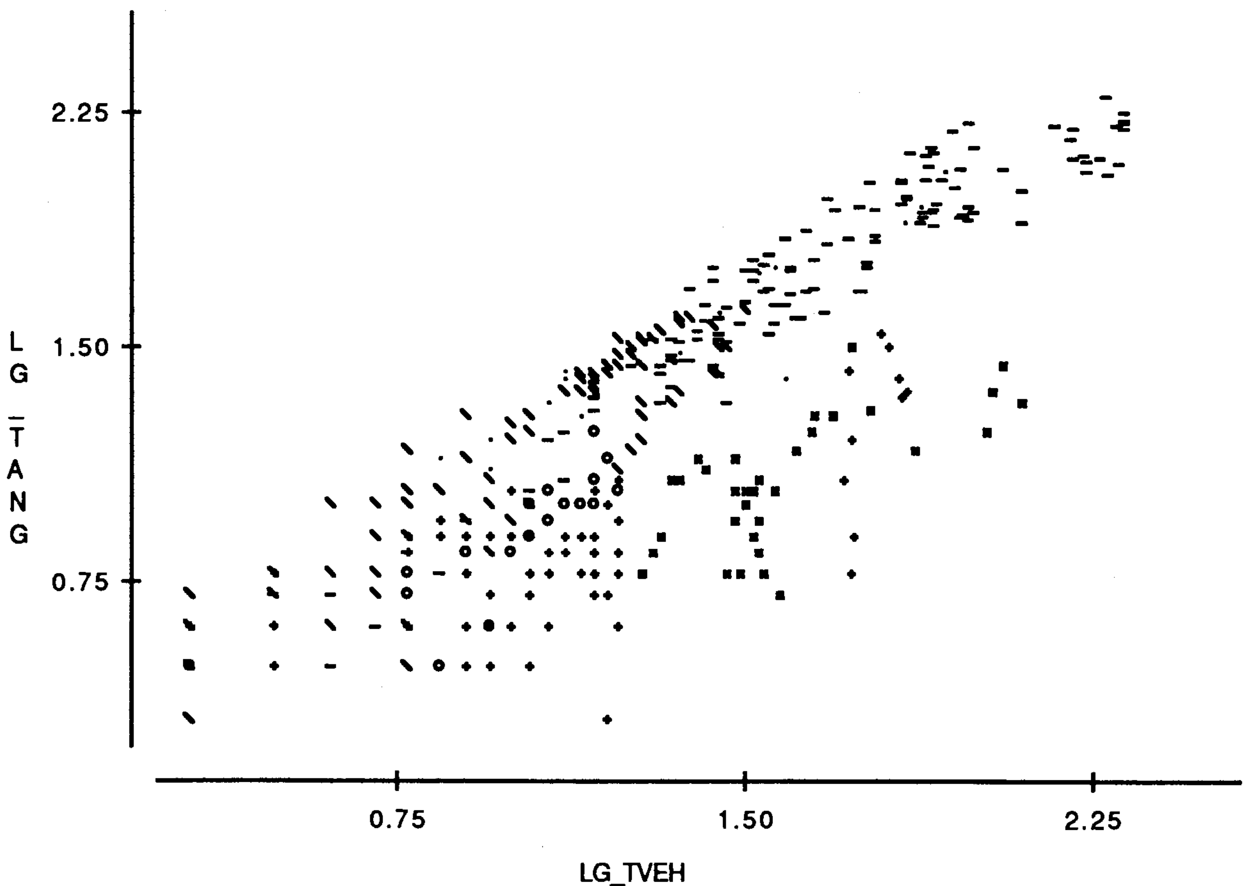

FIGURE 4. LOG(TOTAL ANGLERS) [LG_TANG] VERSUS LOG(TOTAL VEHICLES) [LG_TVEH] FOR VARIOUS LAKES, TIMES OF DAY AND YEAR.
(LOGS TO BASE 10, THEREFORE LOG(10)=1, LOG(100)=2 ETC).

SYMBOL	LAKE
-	SHABBONA
\	SAM PARR
.	BALDWIN
o	BEAVER DAM
x	MURPHYSBORO
+	JONES

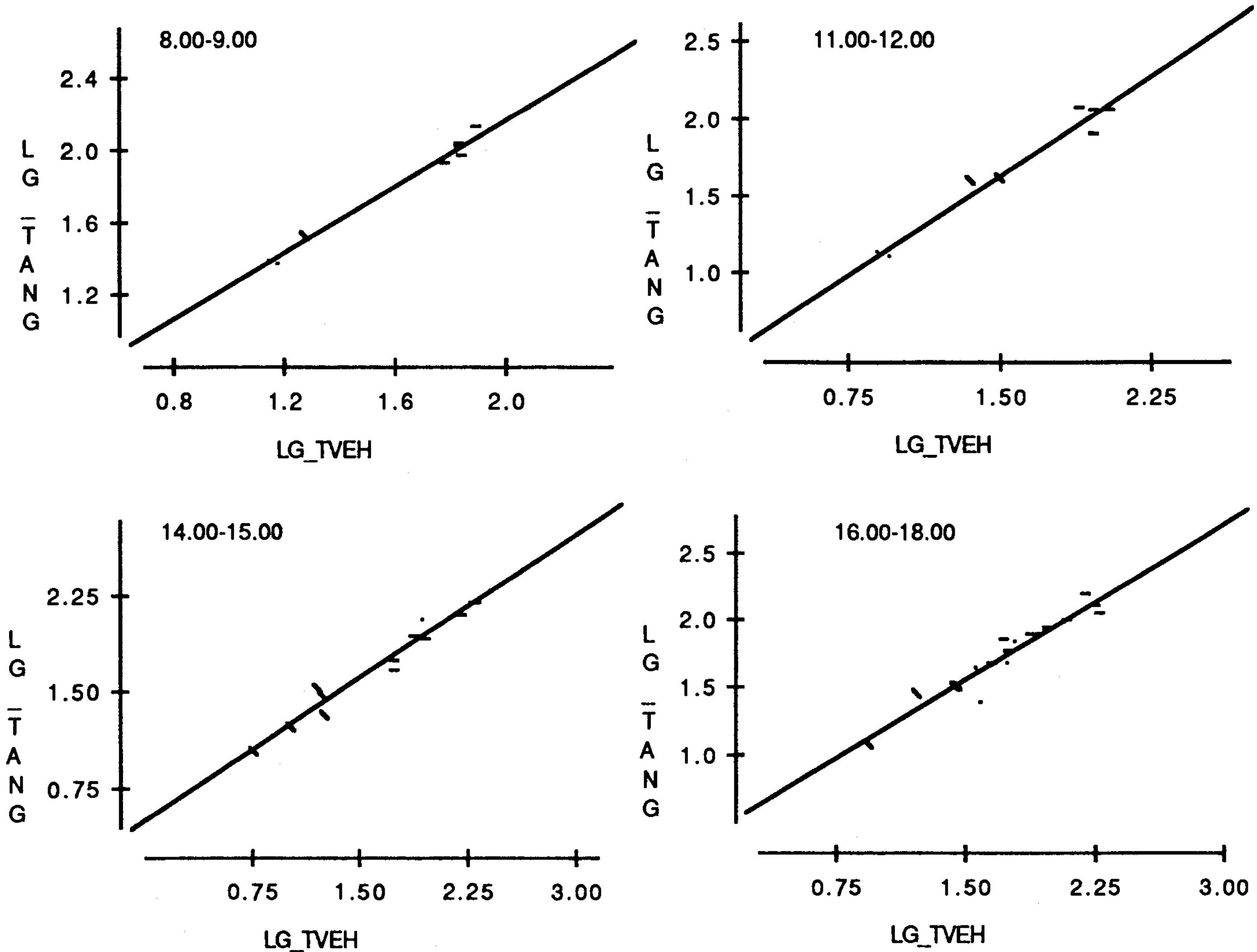

FIGURE 5. LOG(TOTAL ANGLERS) [LG_TANG, BASE 10] VERSUS LOG(TOTAL VEHICLES) [LG_TVEH, BASE 10] FOR 'MINOR' GROUP CORRESPONDING TO TIMES OF LESS ANGLING COMPARED TO OTHER RECREATIONAL PURSUITS (SEE CHAPTER 2).
EACH GRAPH REPRESENTS THE TIME PERIOD WHICH CORRESPONDS TO WHEN INSTANTANEOUS COUNTS ARE ROUTINELY MADE.

SYMBOL	LAKE
-	SHABBONA
\	SAM PARR
.	BALDWIN

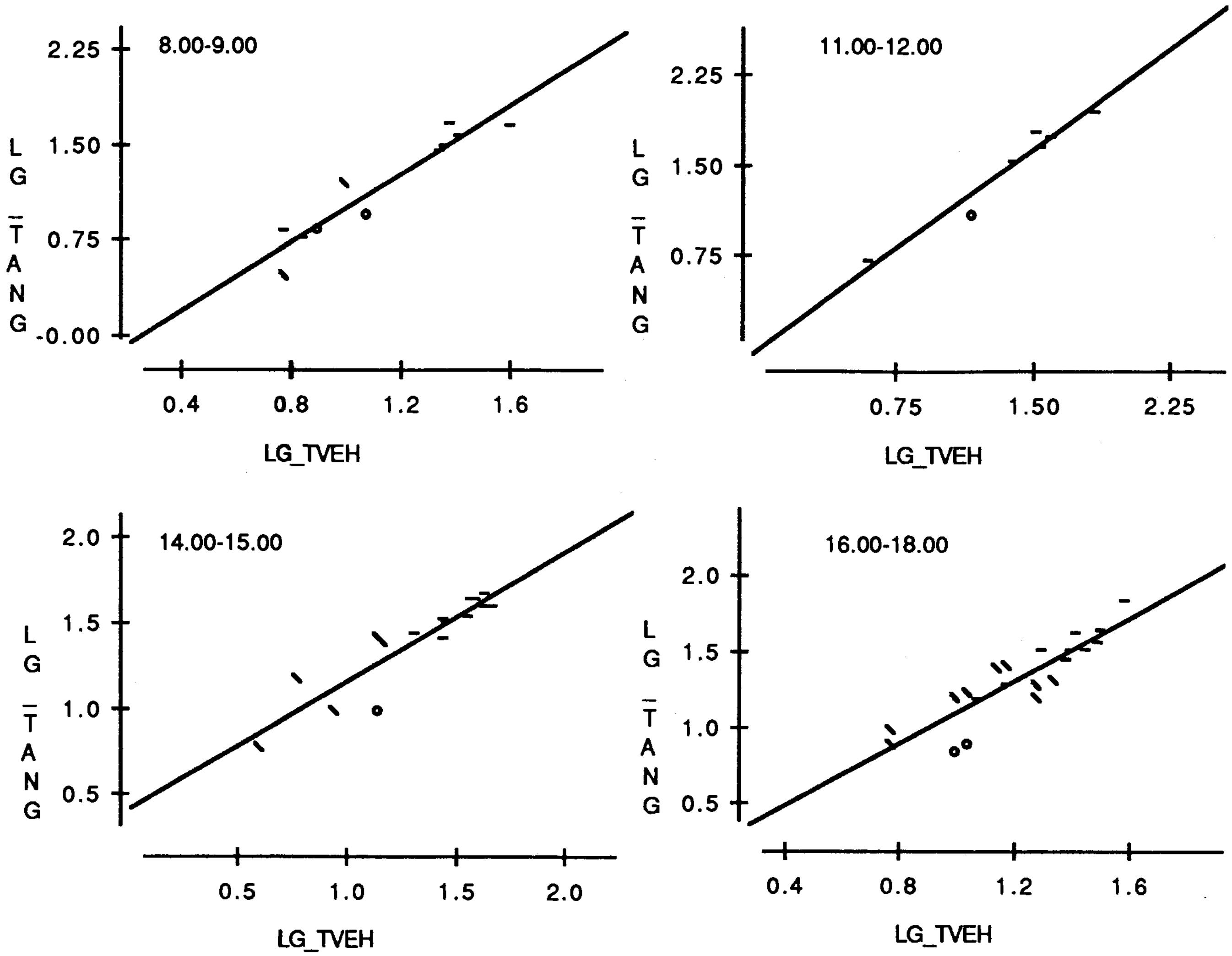

FIGURE 6. LOG(TOTAL ANGLERS) [LG_TANG, BASE 10] VERSUS LOG(TOTAL VEHICLES) [LG_TVEH, BASE 10] FOR 'MAJOR' GROUP CORRESPONDING TO ANGLER-DOMINATED TIMES (SEE CHAPTER 2). EACH GRAPH REPRESENTS THE TIME PERIOD WHICH CORRESPONDS TO WHEN INSTANTANEOUS COUNTS ARE ROUTINELY MADE.

SYMBOL	LAKE
-	SHABBONA
\	SAM PARR
o	BEAVER DAM

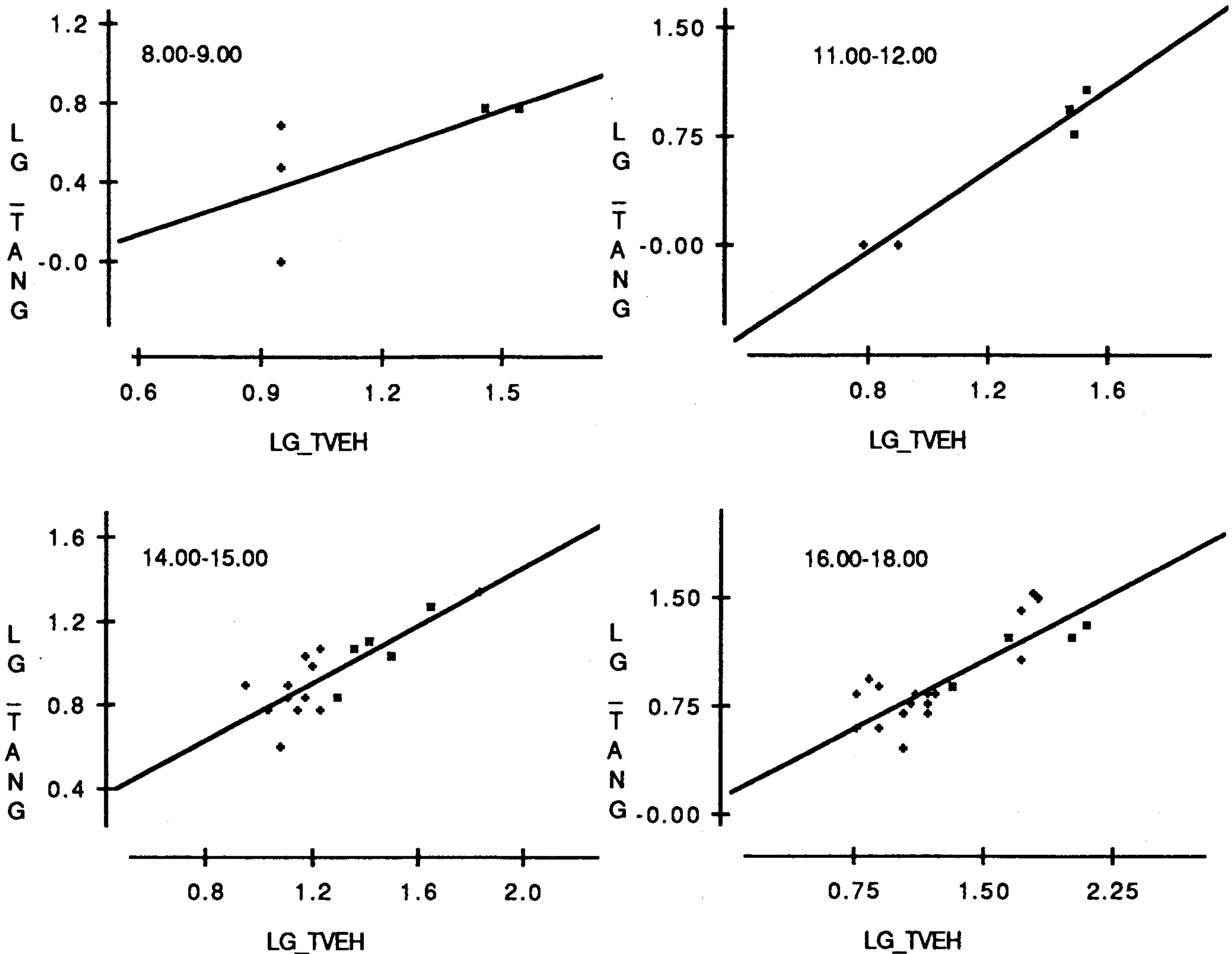

FIGURE 7. LOG(TOTAL ANGLERS) [LG_TANG, BASE 10] VERSUS LOG(TOTAL VEHICLES) [LG_TVEH, BASE 10] FOR 'MULTI-USE' LAKES WITH SUBSTANTIAL NON-ANGLER ACTIVITY (SEE CHAPTER 2). EACH GRAPH REPRESENTS THE TIME PERIOD WHICH CORRESPONDS TO WHEN INSTANTANEOUS COUNTS ARE ROUTINELY MADE.

SYMBOL	LAKE
x	MURPHYSBORO
+	JONES

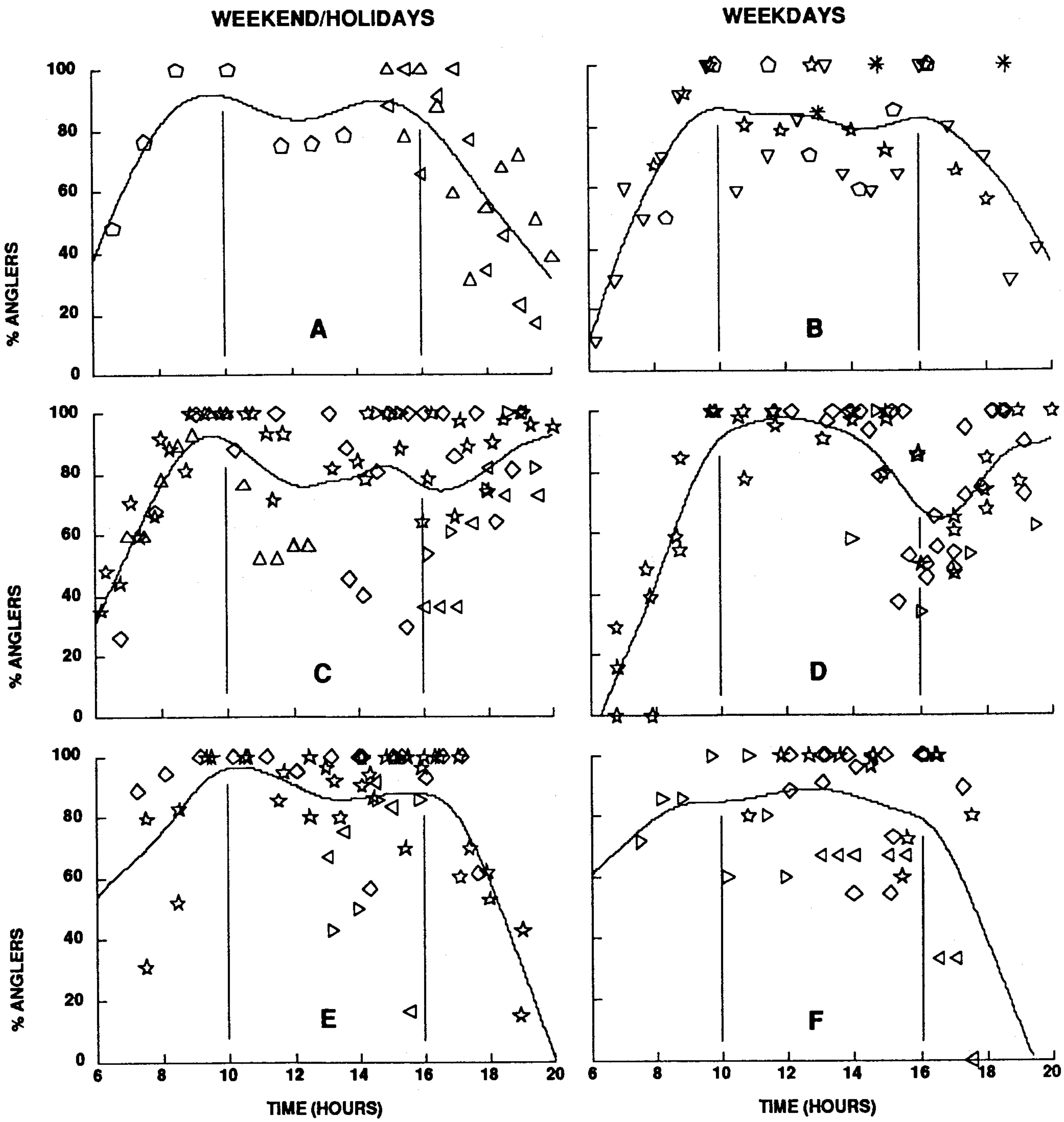

FIGURE 8. Total angler counts as a percentage of the maximum counted within each day-period versus time of day. Vertical lines at 10.00 and 16.00 are dividing times between day periods 1, 2, and 3.

A April-May	weekends/holidays	B April-May	weekdays
C June-August	" "	D June -August	"
E September-November	" "	F September-November	"

☆ Shabbona
◇ Sam Parr
△ Baldwin
▽ Beaver Dam
▷ Murphysboro
◁ Jones
⬠ Washington County
✳ Pierce