# ILLINOIS NATURAL HISTORY SURVEY

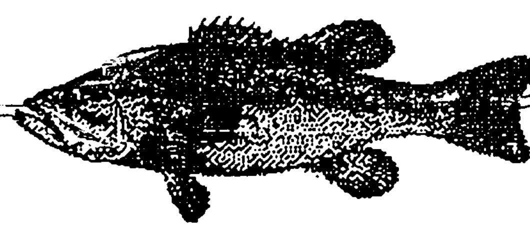
## The Fisheries Analysis System (FAS): Creel Survey Analyses

Final Report to
Division of Fisheries
Illinois Department of Conservation

## Center for Aquatic Ecology

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

June 1993



Aquatic Ecology Technical Report 93/7

Illinois Natural History Survey
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# THE FISHERIES ANALYSIS SYSTEM (FAS): CREEL SURVEY ANALYSES

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## SUMMARY OF PROJECT

Data Base Management and Analysis of Fisheries in Illinois (Project F-69-R(4-6)) is a continuation of F-69-R(1-3) and F-46-R with significant additions. The Final report is divided into four Aquatic Ecology Technical Reports 93/6 through 93/9:

'Fisheries Analysis System (FAS): STATE FAS Database and Programs' (93/6) describes the design of the new statewide database based on Paradox 4.0. Uploading, text outputs, and reporting procedures are described. A new set of stand-alone programs to output catch-per-unit-effort, stock indices, length frequencies, and condition factors from the statewide database are described. Updates to DOC9 DISTRICT FAS programs are described, in addition to a new program that outputs limnological data.

'Fisheries Analysis System (FAS): Creel Survey Analyses' (93/7) summarizes results from 107 annual daytime creels begun in F-69-R(1-3), F-29-D, and continued through F-69-R(4-6). 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, which included impoundments ranging from 13 to 18,900 acres. Increasing the proportion of day-periods sampled from 30 to 45-55% improved the precision of estimates on smaller lakes, but precision was already relatively low for large lakes (with more than one section) at the 25-35% level. Therefore, sampling costs could be reduced on larger lakes with minimal loss in precision. Seventy-eight percent of the variation in log(harvest/area) was explained by log(angler-hours/area). This strong, linear relationship indicated that high angling intensities did not result in a reduction in total harvest. Also, a preliminary analysis across lakes suggested that high yields were not obtained at the expense of smaller fish.

'Environmental Classification of Illinois Lakes and Relationships with fish communities' (93/8) is the first analysis that attempts to classify Illinois lakes according to physicochemical features and relate this classification to fish species and guilds. This provides a first step towards understanding, and eventually managing, groups of ecologically similar lakes, and to utilizing group members as treatments and controls in experimental management programs.

Finally, the 'Compendium of 144 Illinois Lakes: bathimetry, physicochemical features, and Habitats' (93/9, 2 volumes) contains the first detailed information on a large set of Illinois lakes of use to managers and researchers. This is a culmination of field work begun during F-46-R in 1985. Maps indicate bathimetry, shoreline habitat types, and Illinois Department of Conservation fish sampling locations. Tables describe physical, chemical, and historical information on each lake.

This technical report is part of the final report of Project F-69-R (4-6), 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.

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# Preface

This report contains a series of special studies which were part of Project F-69-R(4-6). It comprises a general analysis of creels to date, and includes comparisons of confidence intervals of total yield and effort with the amount of creel sampling (Chapter 1), and an exploratory analysis of the relationship between yield and angler effort (Chapter 2).

## Acknowledgments

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# Chapter 1. Confidence intervals of creel surveys

## Introduction

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) developed under this and previous (Sobaski and Bayley 1990) contracts. 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. One can improve precision on a particular lake by changing the design and sampling effort based on experience gained from analysis of the first creels. Also, we need to be able to allocate the quantity and distribution of sampling effort by the creel clerks on new lakes and be reasonably certain that an acceptably low error (high precision) will be obtained.

Initial precision estimates were determined from the first two years of creel data (Bayley et al. 1990b; Bayley et al. 1991). Here, results from the first six years of this program, comprising 107 annual daytime creels (night creels were omitted from this analysis) are compared in order to estimate the amount of sampling required to achieve a given relative precision. Following that analysis, sampling was intensified on a number of lakes in an attempt to improve the precision of harvest estimates.

The lakes and associated tailwaters surveyed are highly variable in terms of size (5 to 22202 acres), 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 other factors on precision from 107 annual creels.

## Comparative Analysis of Creels

One hundred-and-seven annual creels from 1987 to 1992 were analyzed. The dependent variable of interest, Relative Precision, and the independent variables, Sampling Percentage and Effort Percentage, were calculated for each creel as described below. Very few creels since 1988 required coalescing of strata, therefore Stratification Percentage (Bayley et al. 1991) was not analyzed further.

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). Relative Precision for Harvest is denoted as HARV95PC and for Effort as EFF95PC. These are 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 (1.97-2.16) 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 (SAMPRAT) 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.

Effort Percentage (EFFRATIO) is the percentage of the total angler-hours of fishing effort estimated from the creel that were recorded directly by complete and incomplete interviews from the creel clerks. A value of 100% would be a creel census, in that all hours fished by every angler would be recorded.Even on smaller lakes this is not achieved, nor is it desirable from the point of view of sampling efficiency or of having to make excessive requests to anglers.

**Results and Discussion**

A general idea of the precision obtained is shown for harvest of all species and total effort in Fig. 1.

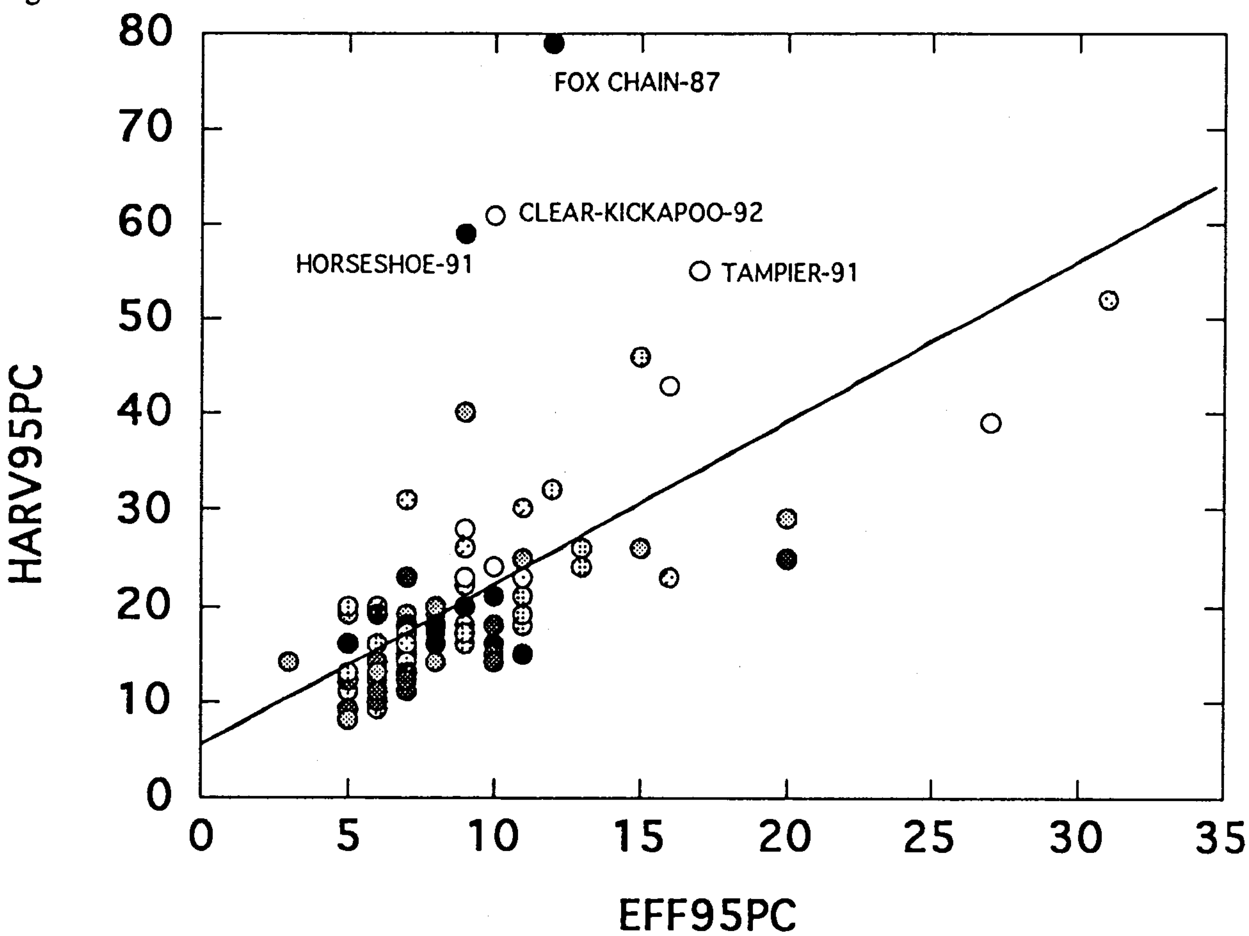


Fig. 1. Relative Precision of Harvest (HARV95PC) vs. Relative Precision of Effort (EFF95PC) for all 107 lakes (including two reservoir tailwaters estimated separately). Symbol shading is proportional to total harvest on log scale.

The Relative Precision values for effort are about twice as good (i.e., half the relative 95% confidence interval) as those for harvest for most lakes. The positive relationship is partly due to the harvest values in each day-period being estimated from effort multiplied by catch-per-effort. Departures from the general relationship are due to differences in the temporal and spatial distribution of catch per effort.

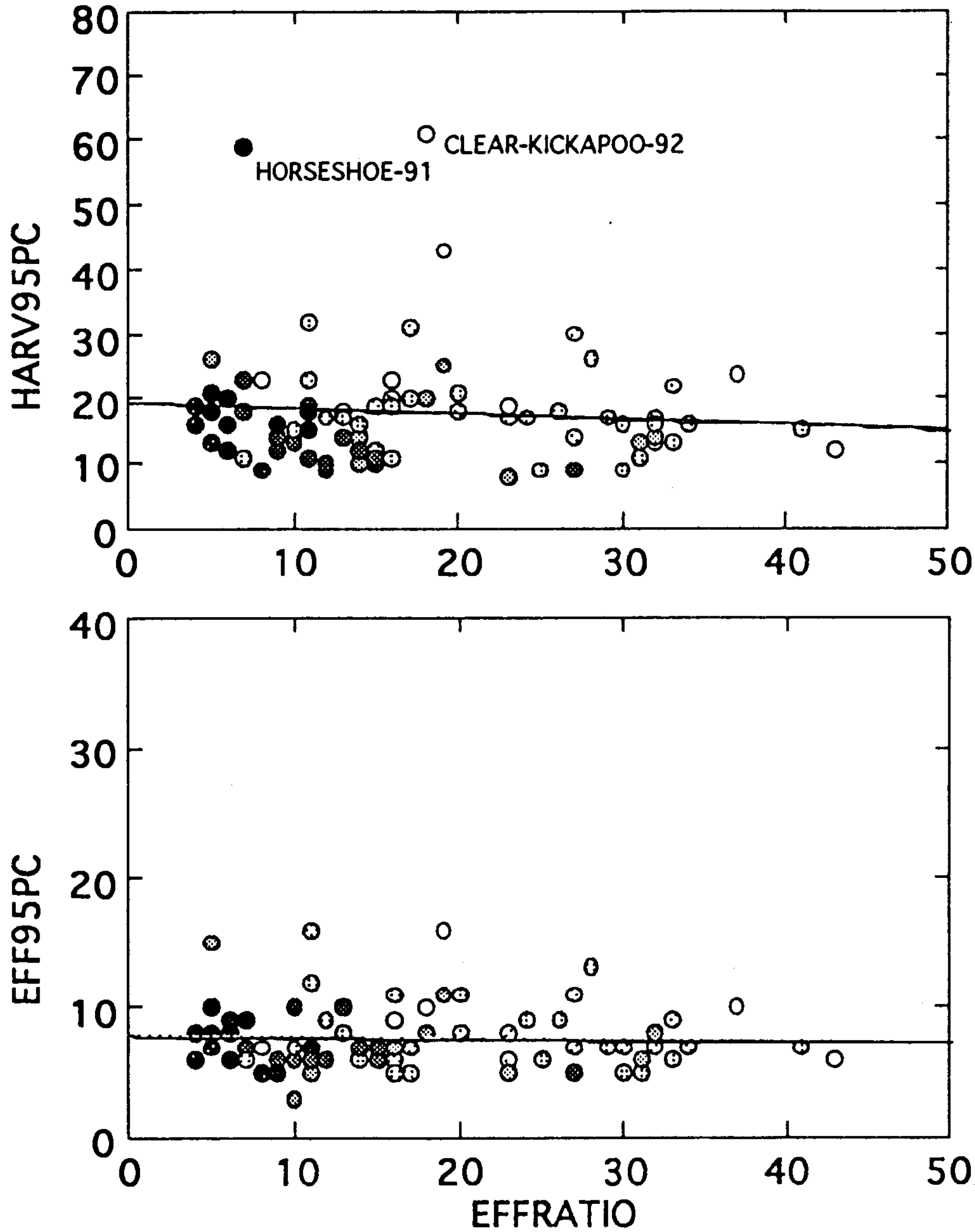


Fig. 2. Relative Precision of Harvest (HARV95PC) and of Effort (EFF95PC) versus Effort Percentage (EFFRATIO) for 82 lakes for which EFFRATIO has been computed. Symbol shading is proportional to total harvest on log scale. Regression lines are linear.

With the exception of Fox Chain Lakes and Horseshoe Lake, lakes with lower harvests generally exhibit higher variances (Fig. 1). We now explore factors which can describe the errors of harvest and effort separately. Effort Percentage (EFFRATIO) had no significant effect on HARV95PC or EFF95PC (Fig. 2).

Note that EFFRATIO accounts for angler-hours not sampled even when the creel clerk is on duty, as well as other day-periods not sampled. This effect is reflected by the larger harvests, associated with larger lakes, are associated with the lower EFFRATIO values (Fig. 2). As might be expected, creel clerks interview a smaller percentage of anglers on large lakes. The lack of reduction of relative precision for large EFFRATIO percentages may in part be due to the finite population correction not being included in the computation, for reasons explained by Bayley et al. (1991). Therefore, relative precision estimates may be conservative for large values of EFFRATIO.

Sampling Percentage (SAMPRAT) directly reflects the proportion of all possible statistical units (year-period-section-day-period combinations) sampled. It partly accounted for variation in HARV95PC (Fig. 3).

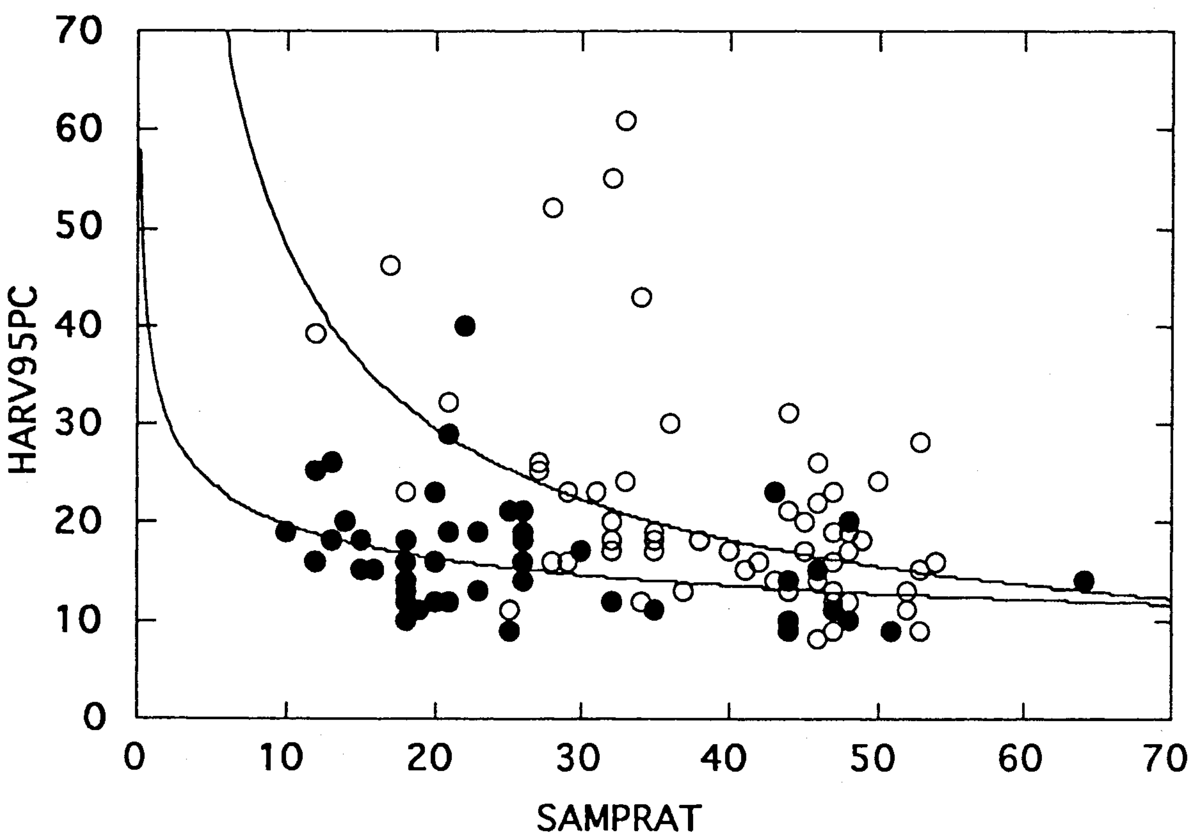


Fig. 3. Relative Precision of Harvest (HARV95PC) versus Sampling Percentage (SAMPRAT) for 105 lakes (outliers Fox Chain and Horseshoe excluded). Open symbols are from creels with total harvests ≤11,000 lbs. (5,000 kg), solid symbols with total harvests >11,000 lbs, with respective power regression lines for each set.

Note that while SAMPRAT has an effect, lakes with lower harvests have worse (higher) precision values. In a power regression (taking logarithms of all variables) SAMPRAT and total harvest have highly significant effects and together account for 41% of the variance in log(HARV95PC ). The effect of total harvest is an important statistical artifact, due to increasingly skewed distributions at low harvest values. It is also probably due to mean values being affected by relatively few good days or anglers sampled on smaller lakes. Sampling more anglers and different sections on larger lakes, which are associated with higher harvests, will tend to mitigate these effects and reduce variability for a given SAMPRAT value.

However, improvements in HARV95PC within a set of smaller lakes repeatedly sampled is generally evident as SAMPRAT was increased from 30-40% in 1987-88 to 40-65% in later years (Fig. 4).

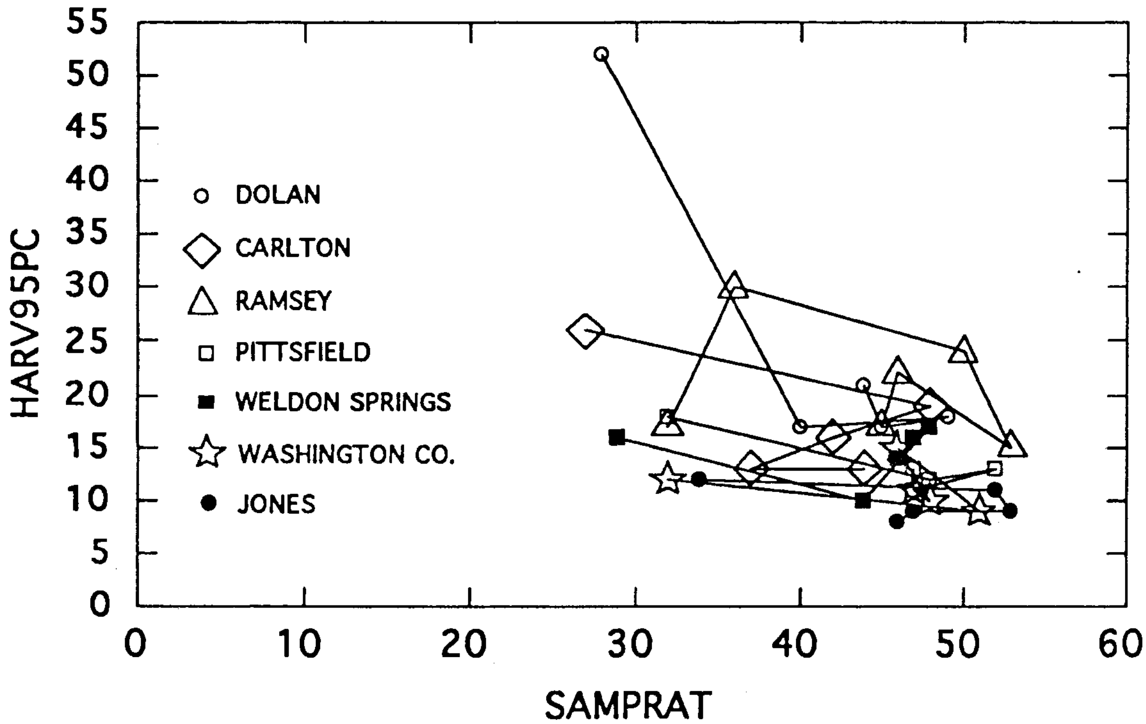


Fig. 4. Relative Precision of Harvest (HARV95PC) versus Sampling Percentage (SAMPRAT) for 7 smaller lakes regularly creeled since 1987 or 1988. Lines join annual creel estimates in chronological order, with the first year creeled associated with the smallest SAMPRAT values.

Sampling Percentage (SAMPRAT) also partly accounted for variation in EFF95PC (Fig. 5). In this case, all 107 data points were included.

Note that, in parallel with the analysis of HARV95PC, while SAMPRAT has an effect, lakes with lower angling effort have worse (higher) precision values. In a power regression (taking logarithms of all variables) SAMPRAT and total effort have highly significant effects and together account for 47% of the variance in log(EFF95PC ). As with harvest and

HARV95PC, the effect of total angler effort is an important statistical artifact due to increasingly skewed distributions at low effort values. It is also probably due to mean values being affected by relatively few fine days that attract large quantities of anglers on smaller lakes. Sampling more anglers and different sections on larger lakes, which are associated with higher angling effort, will tend to mitigate these effects and reduce variability for a given SAMPRAT value.

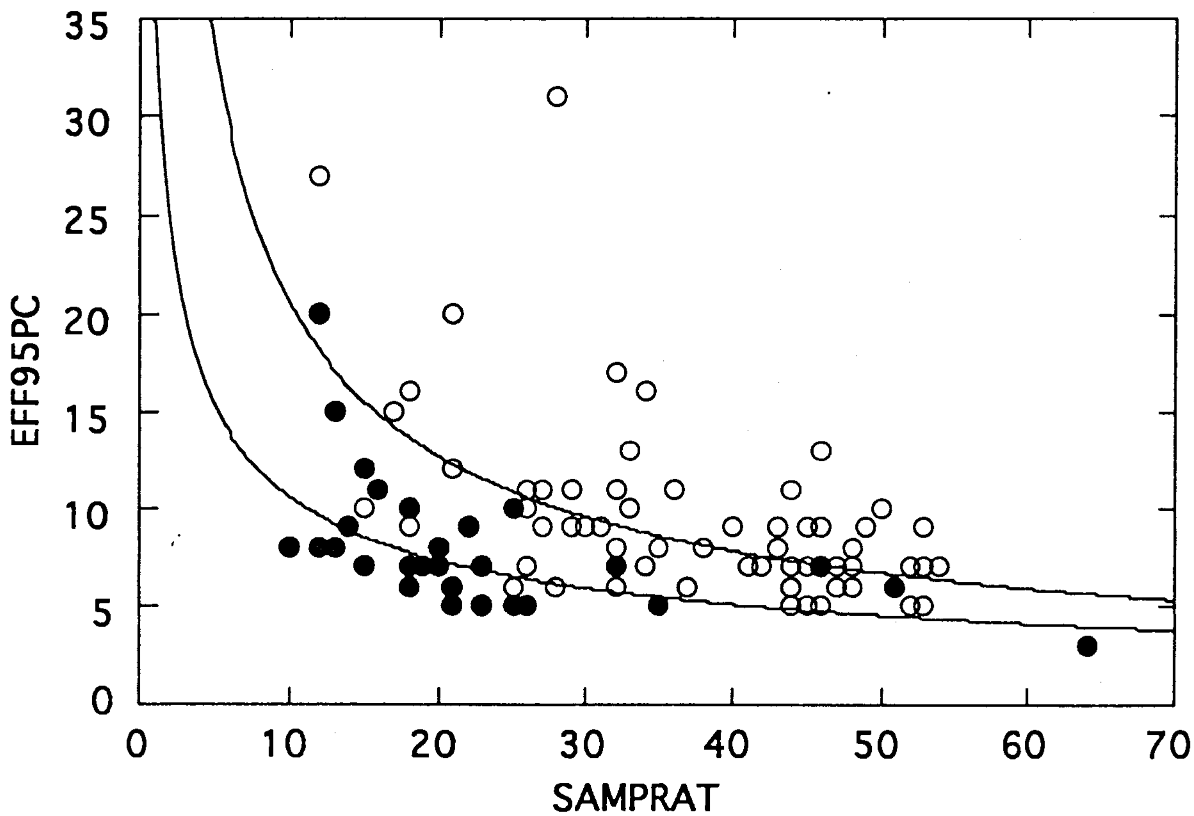


Fig. 5. Relative Precision of Effort (EFF95PC) versus Sampling Percentage (SAMPRAT) for 107 lakes (none excluded). Open symbols are from creels with total effort ≤70,000 angler-hrs., solid symbols with total effort >70,000 angler-hrs., with respective power regression lines for each set.

As with HARV95PC, improvements in EFF95PC within a set of smaller lakes repeatedly sampled is generally evident as SAMPRAT was reduced from 30-40% in 1987-88 to 40-65% in later years (Fig. 6). In both cases, increasing SAMPRAT above 55-60% results in an inefficient design. This is because in that SAMPRAT range, most or all weekend-holidays during the most productive year-period (May 1-June 15) are sampled, and additional samples would have to be allocated to other strata, such as weekdays or other year-periods, that contribute less per unit time to the total harvest.

A preliminary analysis from a subset of years on selected single species was undertaken. Relative Precision of Harvest values for individual species tend to be higher (i.e., worse) than for the total harvests reported here, because any single species is encountered less frequently, and may have more clumped distributions in space and time. Also, precision is strongly related to total harvest of the species considered.

HARV95PC values for bluegill average about 12 percentage points more than corresponding total harvest values if the total harvest exceeds about 550 lbs. (250 kg), whereas for smaller yields, precision is more variable but on average about 18 points higher. HARV95PC values for largemouth bass average about 20 percentage points more than corresponding total harvest values if the total harvest exceeds about 2200 lbs. (1000 kg), whereas for smaller yields, precision is more variable but on average much worse. Estimates are less precise for largemouth bass mainly because their numbers and biomass are less. Less common species can have confidence intervals exceeding their total values, due to larger proportions of zero catches which produce positively skewed distributions that are not rectified through the Central Limit Theorem.

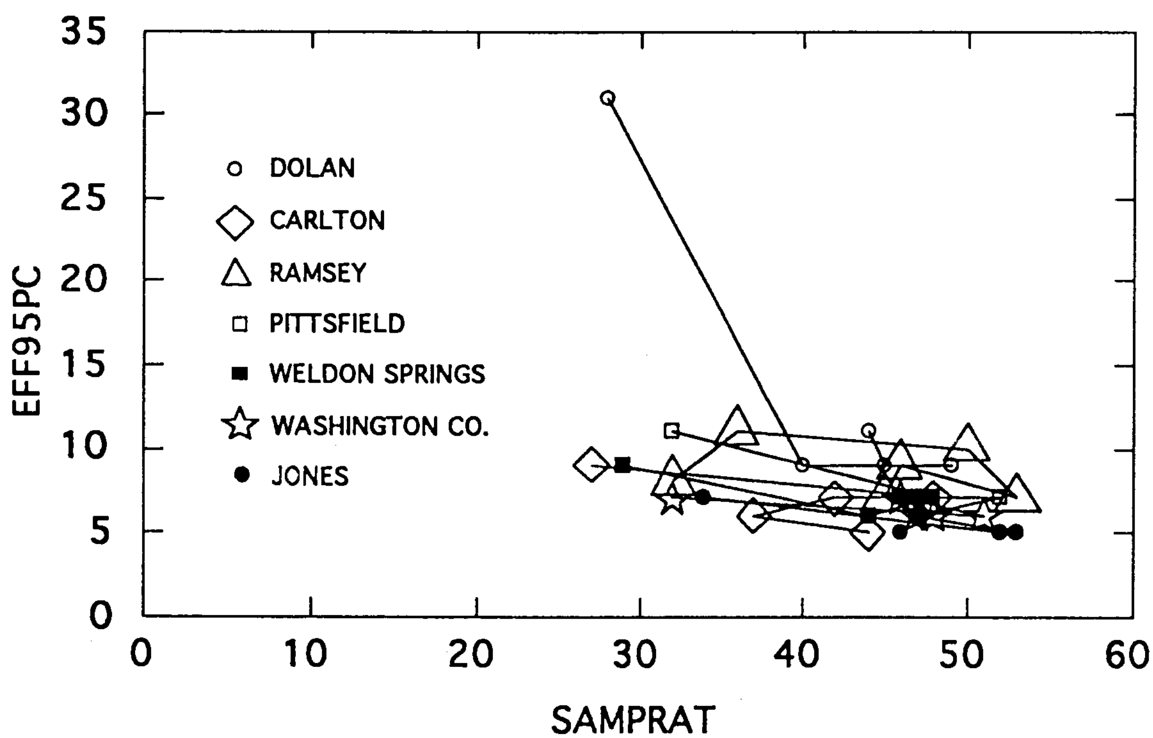


Fig. 6. Relative Precision of Effort (EFF95PC) versus Sampling Percentage (SAMPRAT) for 7 smaller lakes regularly creeled since 1987 or 1988. Lines join annual creel estimates in chronological order, with the first year creeled associated with the smallest SAMPRAT values.

## Conclusions

The estimates of precision on total angling effort on the majority of creels appear satisfactory for management and research needs. There are clear limitations to the precision obtainable for harvests with creel surveys, despite the detailed stratification and apportioning of sampling effort among seasons and sections according to their expected yields. However, the precision are attractive when compared with the sampling variation frequently obtained using direct sampling methods, such as electrofishing or gillnetting. Whether this is an advantage in terms of cost effectiveness remains to be assessed. However, it is unlikely that estimates from younger, returned fish from creel surveys will provide better estimates of pre-recruits than some direct sampling methods. From the creel point of view, well-conducted creel surveys are the only way to measure the end-product and ultimately evaluate management and environmental effects on the fishery itself.

The effect of total harvest or effort on precision is as marked as that of the Sampling Percentage (SAMPRAT). This is important to remember when attempting to monitor less common species or creels during part of a year. The power relationships indicated by the data (Figs. 3,5) result in less gain from increasing SAMPRAT from lakes with higher yields, which are generally the larger lakes. The data do suggest that we will lose little in precision by reducing SAMPRAT values by about 10% on larger lakes. This would result in significant savings on those creels which are more expensive per interview because of higher gasoline costs, higher boat and motor maintenance costs, and more days lost through bad weather.

A significant component of variation is suspected to be due to short term (within year-periods) changes in weather that can affect angling effort, catch per unit effort, and thereby harvest and catch. 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. Weather data is being obtained so that possible effects can be analyzed in the future.

# Chapter 2. Harvest versus Fishing Effort

## Introduction

There is a well-established logistic relationship between equilibrium yield (harvest) and fishing effort for single species fisheries (Graham 1935; Schaefer 1954) in which yield reaches a maximum as effort increases, and then declines with further increases in effort. Similar relationships have been obtained for multispecies fisheries (Pauly and Murphy 1982; Bayley 1988). In this exploratory analysis, total harvest of all species is compared with total effort. This multispecies harvest can be regarded as a measure of overall quality of a fishery (fishermen do not usually retain fish that have no value) for a given effort, and allows comparisons among different lakes that may have different dominant species.

## Methods

The methods of designing and operating creels, and calculating the results have been described elsewhere (Bayley et al. 1990a; Bayley et al. 1991). About half the creels were maintained on eight key lakes which are representative of major classes of lakes (Austen et al. 1993, Vol.1). These lakes cover a range of common types, sizes, and latitudes in Illinois. The remaining creels included the three U.S. Army Corps reservoirs, each of which was sampled every three years, and single creels or short time-series on other lakes of specific interest

## Results and Discussion

Total harvest versus total angling effort on logarithmic scales showed an excellent linear relationship (Fig. 7), which included all the daytime creels completed to date. The linear relationship represents a power curve, $\text{Harvest} = 0.391\text{Effort}^{0.906}$, where harvest and effort are standardized on a per unit area basis. In the linear regression from which this power relationship is derived, angling intensity explained 78% of the variance in total harvest per unit area. This is a remarkable relationship considering the variety of lakes, fisheries, and year-to-year variation included.

Most of the difference in absolute values of harvest per unit area is explained by lake area (Fig. 7); the larger lakes, including all the reservoirs, have lower values, but these values correspond to lower values of angling intensity. Conversely, the small tailwater fisheries represent the most intensive and productive sport fisheries in the state on a unit area basis. However, there is no indication that larger lakes tend to lie below the regression line (Fig. 7), indicating that catch per effort, or fishing success, is not sacrificed in the less-intensive fisheries. This suggests that the 'angler population' spreads its effort among the public waters so that there are not marked differences in fishing success among lakes.

The exponent of Effort Intensity, 0.906, is only marginally less than 1.0 (which would represent a proportional relationship) at $P$=0.05, indicating that there is only a slight reduction in catch per effort as effort increases. The power relationship indicates that there is no multispecies harvest maximum from these data. In other words,there is no indication of a reduction in total yield at higher fishing intensities. Also, a preliminary analysis on a subset of the non-tailwater data indicated that higher harvests per acre were not achieved at the cost of a reduced mean size of fish. For example, the high Weldon Springs harvests are dominated by quality-sized largemouth bass. However, this lack of relationship with size is not necessarily true for all individual species stocks within lakes. This will be analyzed in the future when longer time-series are available.

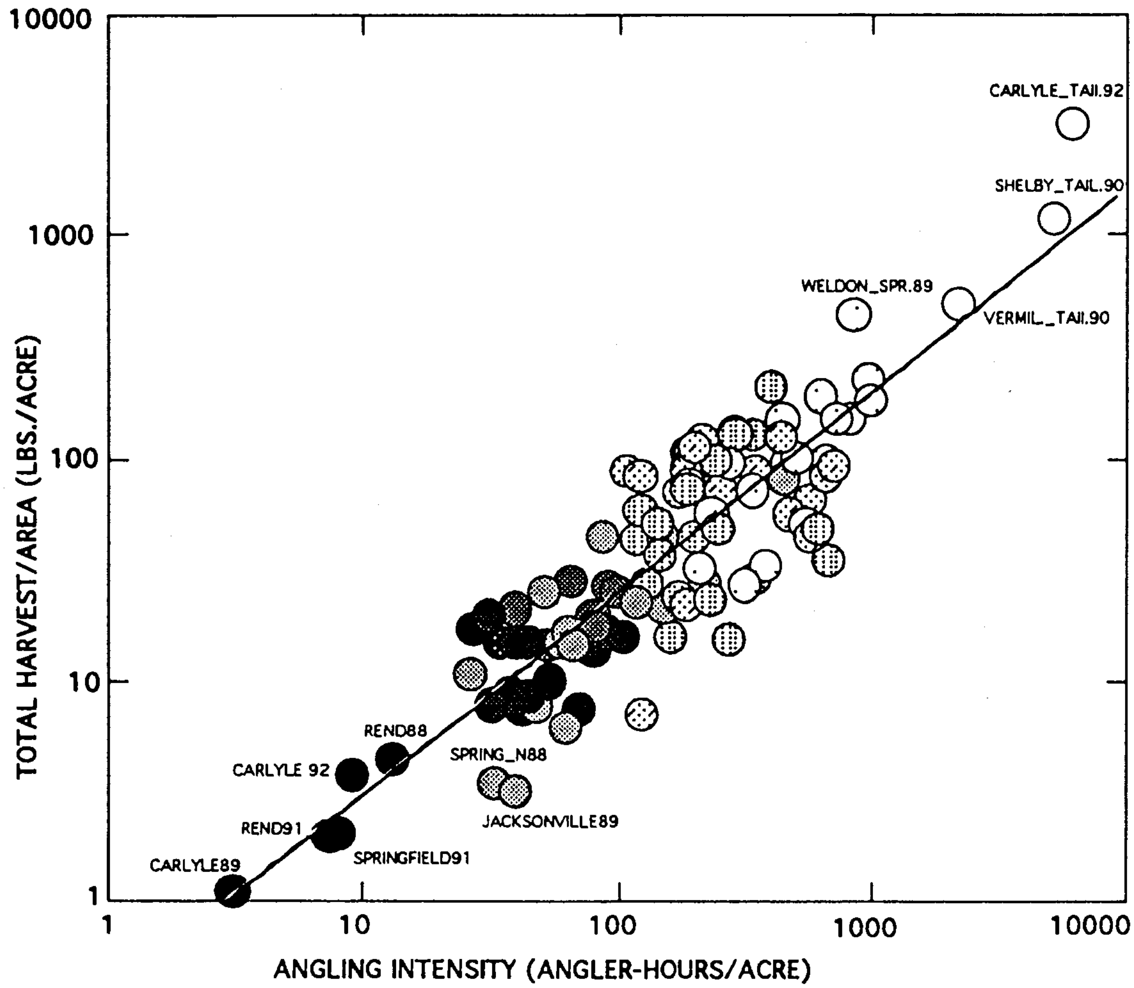


Fig. 7. Total harvest (all species) per lake area versus total angling intensity on log scales for 107 lakes (none excluded). Identities of creels are shown at the extremities of the plot, while those of the remaining creels are shown in Fig. 8. Symbol shading is proportional to lake area on log scale. Regression line linear on the log-transformed variables. Note that the three most intensive fisheries were in tailwaters below dams.

Although the linear relationship in Fig. 7 is very convincing when the wide range of harvest and angling intensities are plotted, the logarithmic scale must be inspected to estimate the absolute ranges in harvest intensities. A closer look at the central concentration of data (Fig. 8) indicates that the range of harvest intensities for a given angler intensity can vary over a 5- to 10-fold range. To what extent is this variation due to attributes of different lakes (such as different biological productivities or domination by different species), or variation within lakes?

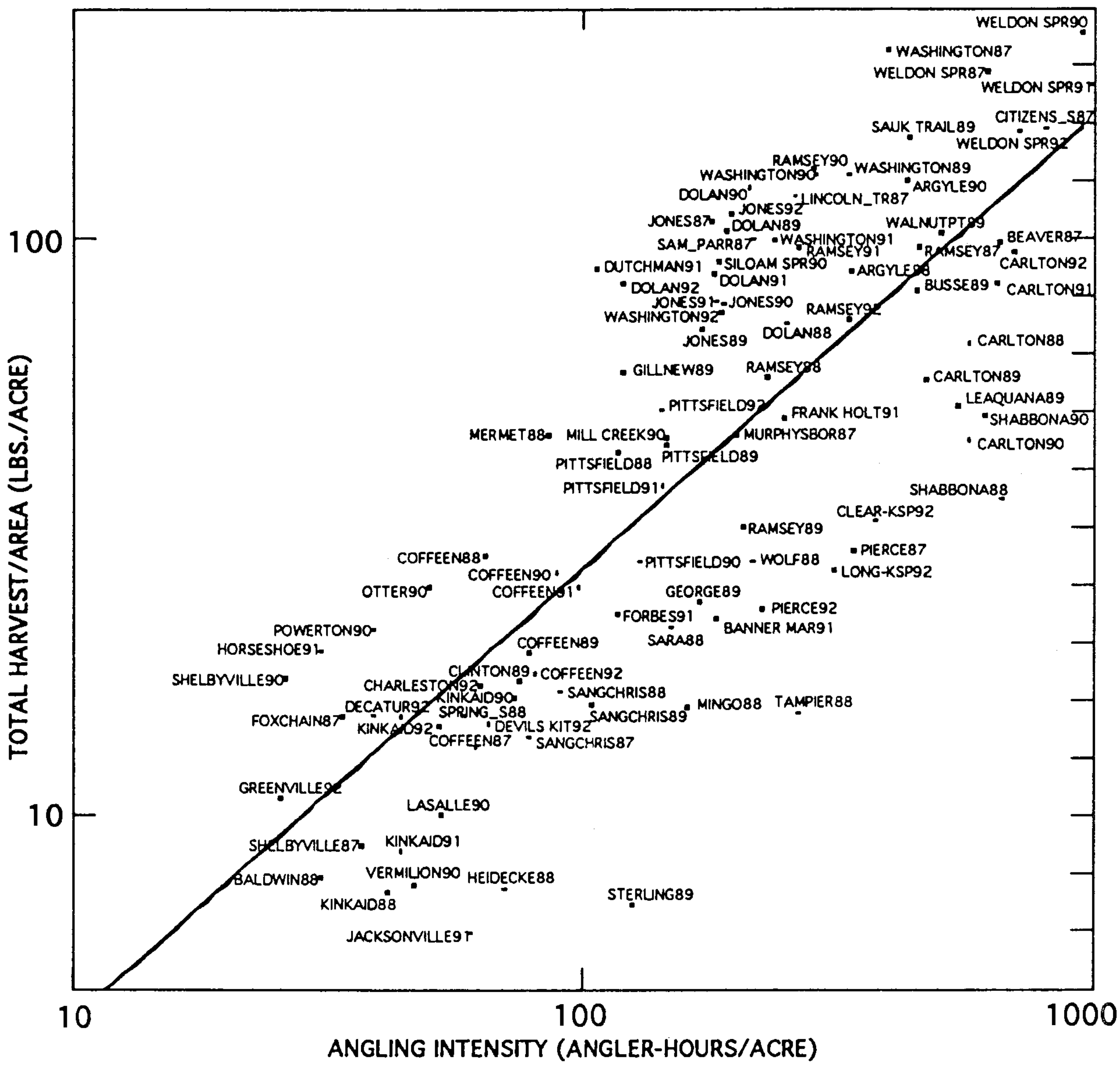


Fig. 8. Magnification of central data points from Fig. 7 with identification of annual creels. Regression line linear on the log-transformed variables from all 107 points depicted in Fig. 7.

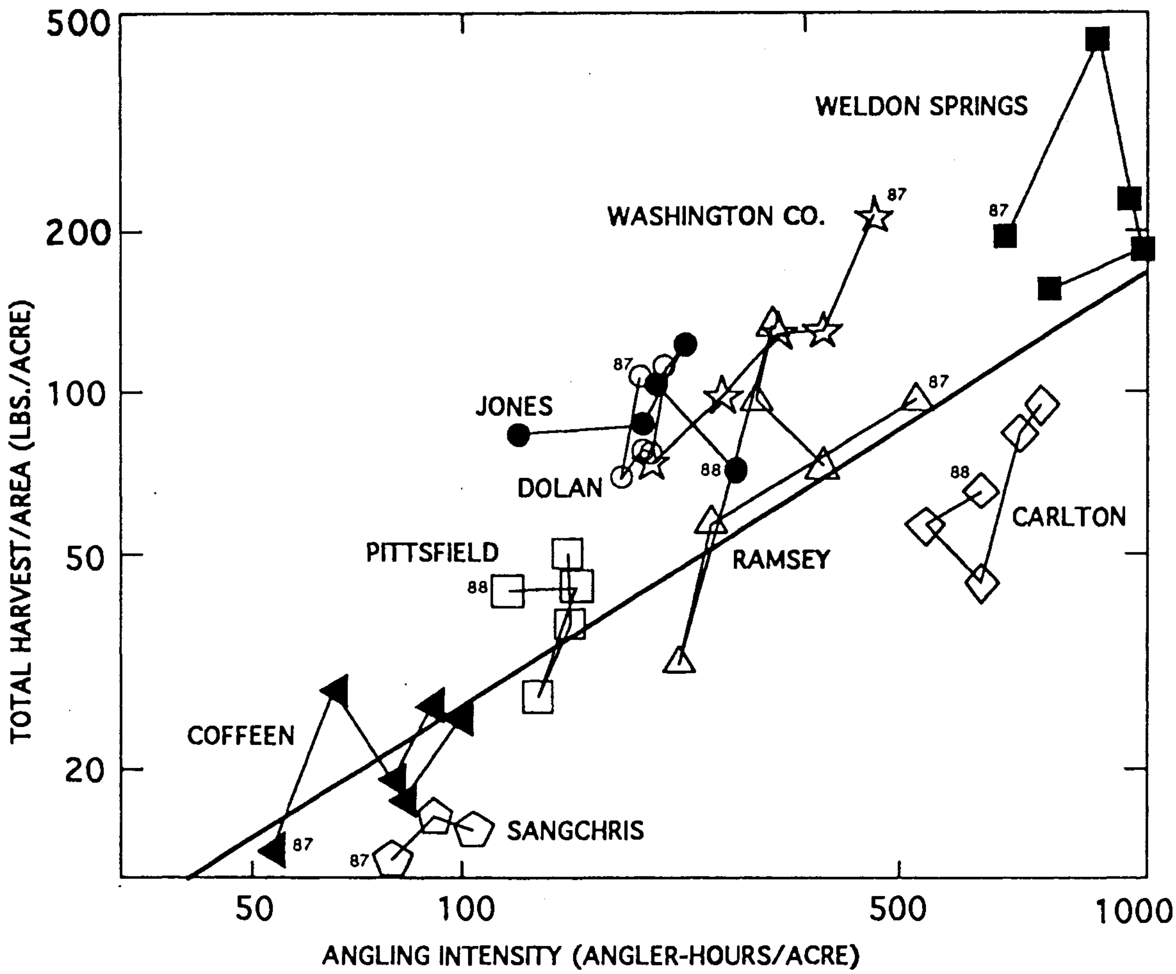


Fig. 9. Time series of annual daytime creels from nine lakes creeled since 1987 or 1988, showing total harvest (all species) per lake area versus total angling intensity on log scales. Lines join annual creel estimates in chronological order, with the first year indicated. Regression line linear on the log-transformed variables is from all 107 creels depicted in Fig. 7.

Time series of harvest and effort intensity values from nine lakes representing a variety of classes (Austen et al. 1993) are depicted in Fig. 9. The most striking feature is that each lake covers a relatively small area in the total harvest/angling intensity domain. Also, some lakes are consistently above or below the average catch-per-effort or 'success' line represented in Fig. 9 by the regression line from Fig. 7. However, there is still variation in excess of the precision of the estimates within most of these lakes. The explanation of this variation will require the incorporation of population dynamic information, such as recruitment variation of key species, obtained from direct sampling together with a breakdown of the yield information into size and age classes by species. Population dynamic influences, possibly resulting from environmental or management changes, will require longer parallel time series so that changes can be predicted. In the shorter term, we hope that consistent differences among lakes, including those with shorter time-series, can be explained by utilizing fish population and community structure and environmental information (Austen et al. 1993). These prediction can be tested against the results from other lakes which have been creeled less frequently. It should be obvious from these preliminary analyses of creels that such analyses involving harvest or catch must account for the very significant effect of angling intensity.

## Conclusions

There is no evidence for multispecies overexploitation in impoundments by recreational or commercial fishermen, in which overexploitation is defined as a decrease in total yield when fishing effort increases.

Total harvest has been strongly positively related to fishing effort in all impoundments sampled in recent years (Fig. 7), and preliminary analyses across lakes indicated that higher harvest rates were not obtained at the cost of inferior fish species or smaller fish. Overexploitation of the total fish resource, which would have been indicated with a flat or negative relationship between harvest and effort, is evidently not a concern.

Although there is a strong overall relationship between harvest and angling intensity, many individual lakes creeled repeatedly indicate consistent differences. The challenge in meeting fisheries management goals is to explain the differences among and within sets of lakes, so that predictions can be made on these and similar lakes and that differences between management actions and environmental changes can be elucidated. The data series being accumulated by the creel program, together with the fish population and environmental data being accumulated over a larger set of lakes, makes the Fisheries Analysis System an essential tool in aiding the management of these resources.

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