

Evaluating Creel Survey Efficiency for Estimating Walleye Fishery Metrics in Northern Wisconsin Lakes

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Abstract.—To determine whether creel survey efficiency can be improved in northern Wisconsin lakes, we compared estimates of effort, harvest rate, harvest, recapture rate for previously marked fish (*R/C* ratio), and recaptures of walleyes *Sander vitreus* from four reduced-sampling-effort schemes (eliminating 1 week per month, 2 weeks per month, odd-numbered weeks, and even-numbered weeks) in each month of the angling season with estimates from creel surveys during 1991–2002. Estimates of angler-hours from each reduced-sampling-effort scheme differed significantly from those from the full sampling effort in several months, and variances differed significantly in nearly all months. Estimates of walleyes harvested per hour from each reduced-sampling-effort scheme differed significantly from those from the full sampling effort only in May or June, and variances differed significantly in several months for all sampling effort schemes except that of 1 week per month. Estimates of walleye harvest from all reduced-sampling-effort schemes differed significantly from those from the full sampling effort for at most 2 months, but variances did not differ significantly in several months. Estimates of the *R/C* ratio from all reduced-sampling-effort schemes differed significantly from those from the full sampling effort for at most 2 months, but variances differed significantly in several months. Estimates of the number of recaptures differed significantly from those from the full sampling effort for several months with the elimination of 1 week per month and 2 weeks per month but did not differ significantly with the elimination of odd- or even-numbered weeks, and variances differed significantly in several months for all reduced-sampling-effort schemes. Creel survey efficiency cannot be improved using these sampling effort reductions without causing significant losses in accuracy and precision.

Angler surveys provide estimates of fishery metrics (e.g., exploitation rate, effort, harvest rate, and harvest) that are necessary to manage fish stocks and to evaluate regulations (Essig and Holliday 1991; Osburn and Osborn 1991; Weithman and Haverland 1991; Malvestuto 1996; Lester and Dunlop 2003), but they are costly (Osburn and Osborn 1991; Guy et al. 1996; Van Den Avyle and Hayward 1999). Consequently, sampling effort must be determined because sampling effort drives the cost of the program and affects the precision of estimates (Lester et al. 1991). Standards do not exist for acceptable levels of precision but, rather, must be determined by program goals (Bayley et al. 1991; Sztramko 1991). Because fisheries are unique in their human and ecological attributes, each system requires its own creel survey design (Phippen and Bergersen 1991) to sample anglers of concern, meet

study objectives, and fit spatial and temporal bounds (Pollock et al. 1994).

To be statistically valid, all anglers in the study area or the sampling units under which anglers participate must be assigned a probability of being sampled (Malvestuto 1996). A simple random sampling design divides the spatial and temporal characteristics of the fishery into nonoverlapping sampling units from which a sample is randomly selected. To reduce sampling variance, populations can be stratified into subpopulations that are then randomly sampled (Pollock et al. 1994). In a stratified two-stage sampling design, subpopulations are further stratified into secondary sampling units, which are also assigned an appropriate probability. Stratification is based on the premise that subpopulations are homogeneous but of sufficient contrast to explain a significant amount of variability (Malvestuto 1996). The smaller the time blocks within the survey period, the more the temporal variability of estimates will be controlled by the survey design (Hayne 1991). For example, the precision of estimates of effort increased with stratification into day types (weekend days and weekdays) in the Tallapoosa River,

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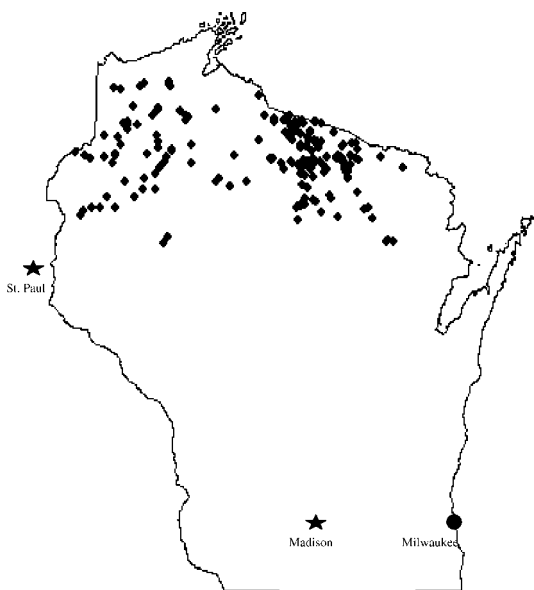


FIGURE 1.—Map showing the locations of the 192 northern Wisconsin lakes included in this analysis.

Alabama (Malvestuto and Knight 1991). In 47 Ontario lakes, among-day variance of catch per unit effort was 10% less than within-day variance (Lester et al. 1991). In Pomme de Terre Lake, Missouri, creel surveys could be eliminated during March and November with minimal loss of the precision of estimates of effort and harvest (Dent and Wagner 1991).

Our objective was to determine whether creel survey efficiency can be improved by reallocating sampling effort within months to minimize bias and maximize the precision of the resulting estimates of angling fishery metrics for walleye *Sander vitreus* that are used to estimate the exploitation rate in northern Wisconsin lakes. Creel surveys are used to estimate walleye exploitation rates in northern Wisconsin, where fisheries are managed cooperatively by state and tribal agencies, at the cost of \$2,000/lake for mark-recapture studies and \$25,000/lake for creel surveys. We evaluated the potential to improve the efficiency of creel surveys by reallocating sampling effort within months, specifically by eliminating sampling weeks within months. The reductions in sampling effort that we considered were limited by the requirement for a 40-h workweek for creel clerks, so we did not consider many other feasible sampling effort reductions. By allocating sampling effort in a more cost-effective manner, the Wisconsin Department of Natural Resources may be able to eliminate sampling effort or increase the number of lakes sampled, thereby increasing sampling efficiency. Our approach to evaluating creel

survey efficiency is unique because we used regional fishery profiles to draw conclusions on a broad scale rather than an individual-lake approach (Lester and Dunlop 2003; Deroba et al. 2007, this issue).

Methods

Study area.—The walleye angling fisheries included in our analysis are located within a land mass that includes 14,336,000 acres in northern Wisconsin (Figure 1). Lake surface areas ranged from 22 to 15,300 acres and walleye densities ranged from 1 to 100 fish per acre (U.S. Department of the Interior 1991; Hansen et al. 2000). The fisheries in northern Wisconsin generate an estimated US\$340 million per year in revenue for Wisconsin's economy (Staggs et al. 1990). Walleye fisheries in this area are subject to a joint recreational angling and tribal-spearfishing fishery.

Fishery surveys.—Mark-recapture surveys were used to estimate walleye abundance in about 16–40 lakes per year during 1991–2002. Adult walleyes were captured shortly after ice-out in late spring (usually April), as they moved inshore to spawn on shallow reefs, with 0.5-in-mesh fyke nets with leads of 50 or 100 ft (Beard et al. 1997; Hansen et al. 2000). In northern Wisconsin, male walleyes usually mature by 12 in total length and female walleyes usually mature by 15 in, so adults were defined as all fish of both determined and undetermined sex longer than 15 in (Beard et al. 1997). Each fish was marked by a partial removal of one or more fins, lengths were recorded, and dorsal spines were removed from a subsample of 5–10 fish per 0.5-in length class to estimate age. Ten percent of the mature walleyes in each lake were targeted for marking during peak walleye spawning (Hansen et al. 2000).

Creel surveys were used to estimate the total numbers of walleyes recaptured and harvested. The total harvest was estimated as the product of independent estimates of angler effort and harvest rate (Staggs et al. 1990; Rasmussen et al. 1998). Instantaneous counts were conducted to estimate effort, and complete-trip interviews were conducted to estimate harvest rate (Rasmussen et al. 1998). Total recaptures were estimated as the product of the observed recapture rate of previously marked walleyes (the R/C ratio, calculated from complete-trip interviews) and estimated total harvest (Newman et al. 1997; Fayram et al. 2001; Beard et al. 2003; Deroba et al. 2005). Creel surveys were conducted from the first Saturday in May through March 1 of the following year, a period covering the legal angling season for walleyes in most Wisconsin waters (Beard et al. 1997). Creel surveys were not conducted in November because the ice conditions were dangerous and angler effort was low. Surveys were conducted at randomly selected access

points following a random stratified roving access design (Pollock et al. 1994) that was shown to produce unbiased estimates of angling effort, harvest and catch rate, and harvest and catch (Rasmussen et al. 1998). Days were stratified into weekdays and weekend days, and all weekend days and 1–3 randomly selected weekdays were sampled each week (Beard et al. 1997). During the open-water season, days were divided into two nonoverlapping periods of equal length and surveys were conducted during randomly selected periods. During the ice-fishing season, entire days were sampled because the period of daylight was shortened (Beard et al. 1997). Two instantaneous counts of anglers were conducted on each surveyed day, one randomly scheduled during the first half of a shift and the second conducted a half-shift later (Rasmussen et al. 1998). During interviews, clerks recorded the number caught and the length and number of marked fish caught for each species.

Data analysis.—During 1991–2002, creel surveys were conducted on 192 different lakes, and clerks completed 169,282 complete-trip angler interviews and 111,177 instantaneous angler counts. Instantaneous counts and angler interviews were used to estimate effort, harvest rate, harvest, *R/C* ratio, and number of recaptures as described in Rasmussen et al. (1998) and Deroba et al. (2005).

Angling effort, harvest rate, harvest, *R/C* ratio, and recaptures were calculated for all creel surveys during 1991–2002 for the full sampling effort and for four reductions in sampling effort: eliminating 1 random week each month, 2 random weeks each month, odd-numbered weeks, and even-numbered weeks. These sampling effort reductions were chosen because creel clerks work a 40-hour week in northern Wisconsin, and these schemes would allow reallocation of staff time while maintaining the required 40-hour week. To test for significant differences between the full sampling effort and reduced sampling effort, estimates and their variances for the full sampling effort were compared with estimates for the four reductions in sampling effort for each year, month, water body, and day type using paired *t*-tests ($P < 0.05$). We used these strata (i.e., each year, month, water body, day type combination equals one stratum) because they are used to estimate the exploitation rate on walleyes in northern Wisconsin lakes. Furthermore, the results for the estimates of recaptures are the same as those that would occur for estimates of exploitation rate because the denominator of estimates of exploitation rate is the same for biased and unbiased estimates of recaptures. Therefore, the results for recaptures are the same as those for exploitation rate (Deroba et al. 2005). Changes in accuracy and precision were reported as percent

relative bias and relative precision, or the mean difference between the estimate or variance from the reduced sampling effort and the full sampling effort, divided by the mean estimate or variance from the full sampling effort, multiplied by 100.

Results

Effort

Significant losses in the accuracy and precision of estimates of angler effort were observed in several months with reductions in sampling effort from the full creel survey. For each sampling effort reduction scheme, estimates of angler effort were generally biased (i.e., significantly less accurate) high in June, except for the elimination of even-numbered weeks, when bias was low (Figure 2). The biases observed with the elimination of odd-numbered weeks occurred in the same months as the elimination of even-numbered weeks but in the opposite direction (Figure 2). Significant bias occurred in other months but without a general pattern. Significant losses in precision (i.e., significantly increased variance) occurred in most months but not in February (Figure 2).

Harvest Rate

Reductions in sampling effort resulted in the loss of harvest rate estimates for strata during 1991–2002 because in many cases the selected week accounted for all interviews in that stratum. Elimination of 1 random week per month resulted in the loss of estimates for 77 strata, elimination of 2 random weeks per month resulted in the loss of 251 strata, elimination of odd-numbered weeks resulted in the loss of 268 strata, and elimination of even-numbered weeks resulted in the loss of 232 strata.

Significant losses in the accuracy and precision of estimates of harvest rate were observed in several months with reductions in sampling effort from the full creel survey. For each sampling effort reduction scheme, estimates of harvest rate were biased in the months of May and June (Figure 3). Few other months exhibited significant bias for any of the sampling effort reductions. The bias in June on weekdays was also in the opposite direction for the elimination of even- and odd-numbered weeks. Significant losses in precision occurred in most months for each sampling effort reduction scheme, except for the elimination of 1 week per month, when precision was not significantly different from that of the full creel survey (Figure 3).

Harvest

Significant losses in the accuracy and precision of estimates of harvest were observed in several months with reductions in sampling effort from the full creel

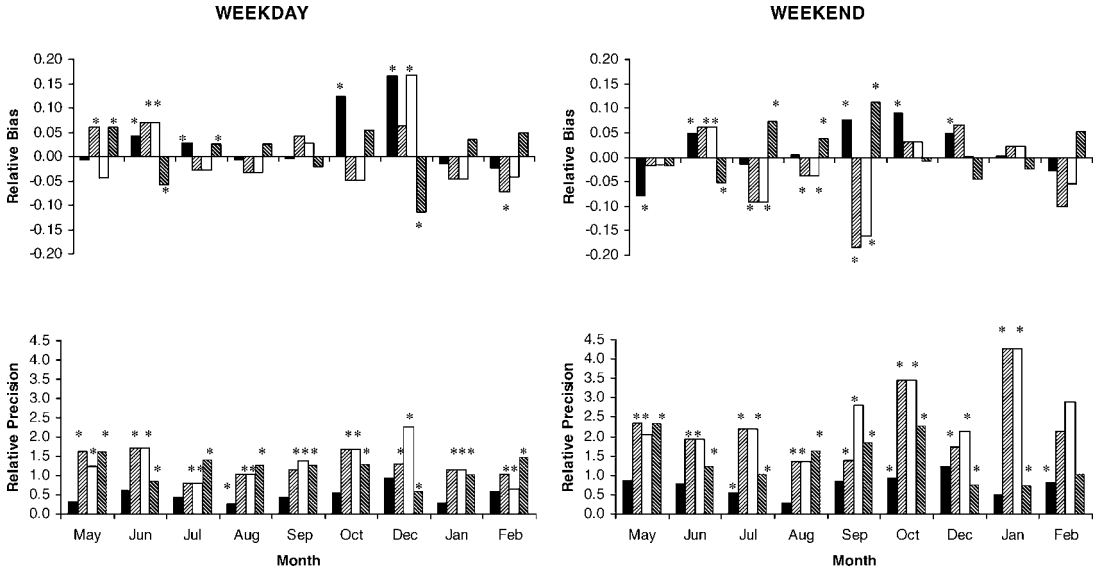


FIGURE 2.—Relative bias and relative precision of the estimated number of angler-hours with the elimination of 1 week (solid bars), 2 weeks (white bars with black stripes), odd-numbered weeks (open bars), and even-numbered weeks (black bars with white stripes) from the sampling regime each month on lakes in northern Wisconsin during 1991–2002. Significant losses in accuracy and precision are indicated by asterisks ($P < 0.05$).

survey. For each sampling effort reduction scheme, estimates of harvest were biased in May on weekends, except for the elimination of 1 week per month, when estimates were not significantly different from the full

creel survey (Figure 4). Few other months exhibited significant bias for any of the sampling effort reductions. The bias in May on weekends was also in the opposite direction for the elimination of even- and

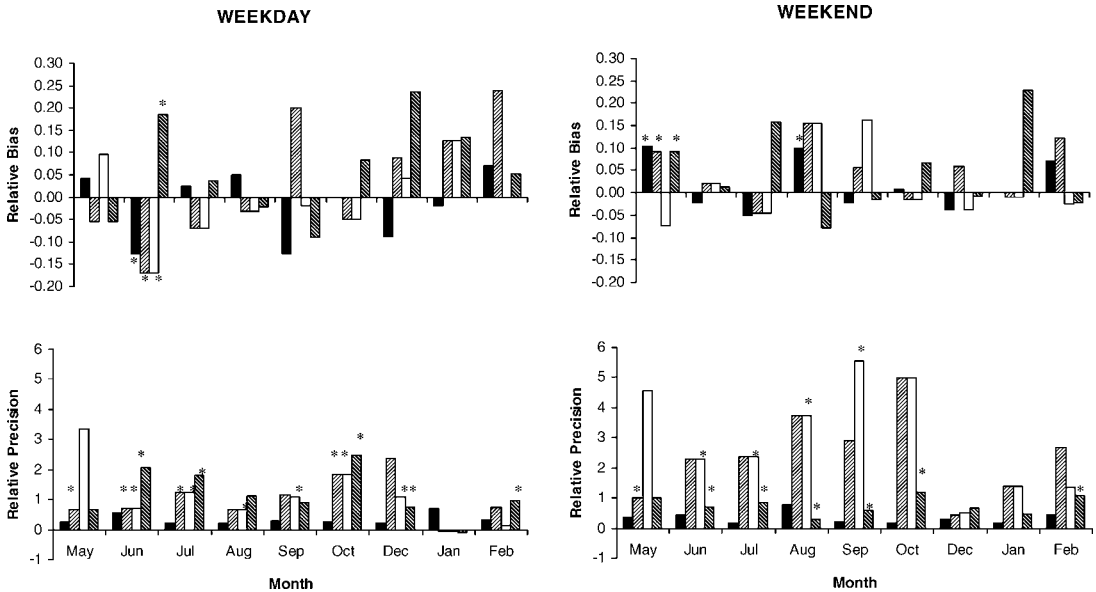


FIGURE 3.—Relative bias and relative precision of the estimated number of walleyes harvested per hour with the elimination of 1 week, 2 weeks, odd-numbered weeks, and even-numbered weeks from the sampling regime each month on lakes in northern Wisconsin during 1991–2002. See Figure 2 for additional details.

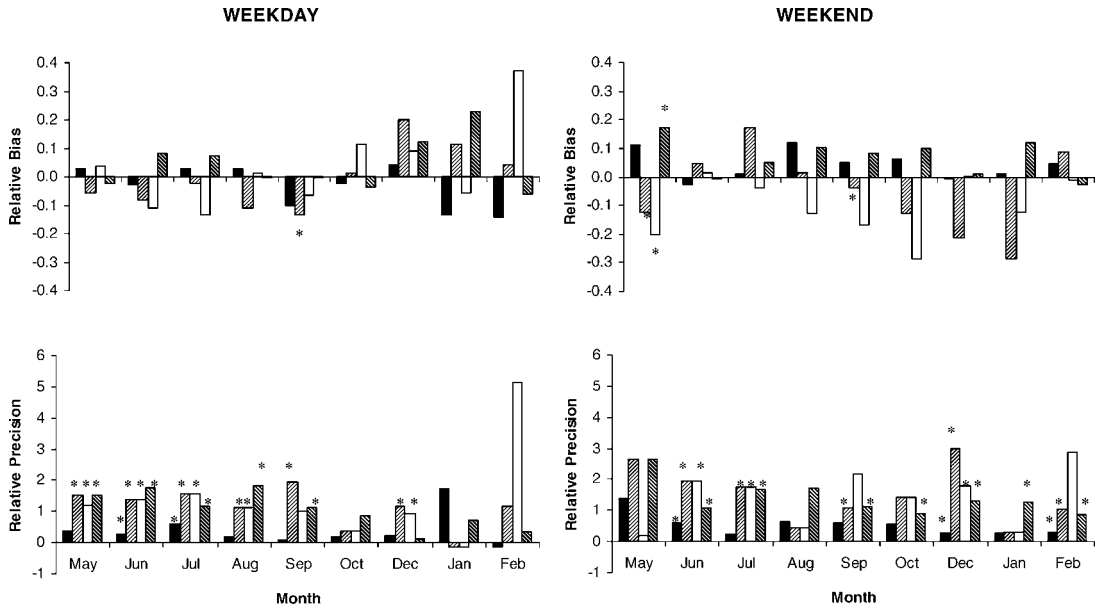


FIGURE 4.—Relative bias and relative precision of the estimated number of walleyes harvested per acre with the elimination of 1 week, 2 weeks, odd-numbered weeks, and even-numbered weeks from the sampling regime each month on lakes in northern Wisconsin during 1991–2002. See Figure 2 for additional details.

odd-numbered weeks. Significant losses in precision occurred in most months for each sampling effort reduction scheme, particularly June and July, when estimates were significantly less for all sampling effort reduction schemes and day types (Figure 4).

R/C Ratio

The number of strata lost for estimates of *R/C* from the elimination of sampling effort was greater than the number lost for harvest rate and harvest because, in many cases, the selected week accounted for either all the interviews conducted or all the interviews in which a fish was harvested, which would require the denominator of *R/C* to be zero so that the ratio was not estimable. Elimination of 1 random week per month resulted in the loss of 288 strata, elimination of 2 random weeks per month resulted in the loss of 759 strata, elimination of odd-numbered weeks resulted in the loss of 810 strata, and elimination of even-numbered weeks resulted in the loss of 587 strata.

Significant losses in the accuracy and precision of estimates of *R/C* were observed in several months with reductions in sampling effort from the full creel survey. Few months exhibited significant bias except for May and January, which were significantly biased for most sampling effort reductions and day types (Figure 5). Significant losses in precision occurred in most months for each sampling effort reduction scheme (Figure 5).

Recaptures

For each reduction in sampling effort of 2 weeks per month (i.e., elimination of 2 random weeks, even-numbered weeks, and odd-numbered weeks), the accuracy of the estimates of recaptures was not significantly different from that of the full creel survey in any month, except September on weekdays for the elimination of 2 random weeks (Figure 6). For the elimination of 1 week per month, significant losses in accuracy occurred in several months (Figure 6). Significant losses in precision occurred for most months with any reduction in sampling effort (Figure 6).

Discussion

We found significant losses in accuracy (i.e., significant bias) in estimates of angler effort in some months, but not others, for each reduction in sampling effort, and relative bias was always less than 0.20, which suggests that estimates of effort are robust to the total number of sample days. Similarly, Newman et al. (1997) found that 95% confidence intervals of estimates of total angling effort from a creel survey conducted for 20 h per week and 10 d per month during May–July 1988 always contained the actual value from a creel census on Escanaba Lake, Wisconsin. In this study, estimates of angler effort were also always biased in the month of June, which suggests some systemic change in angling effort in that month that

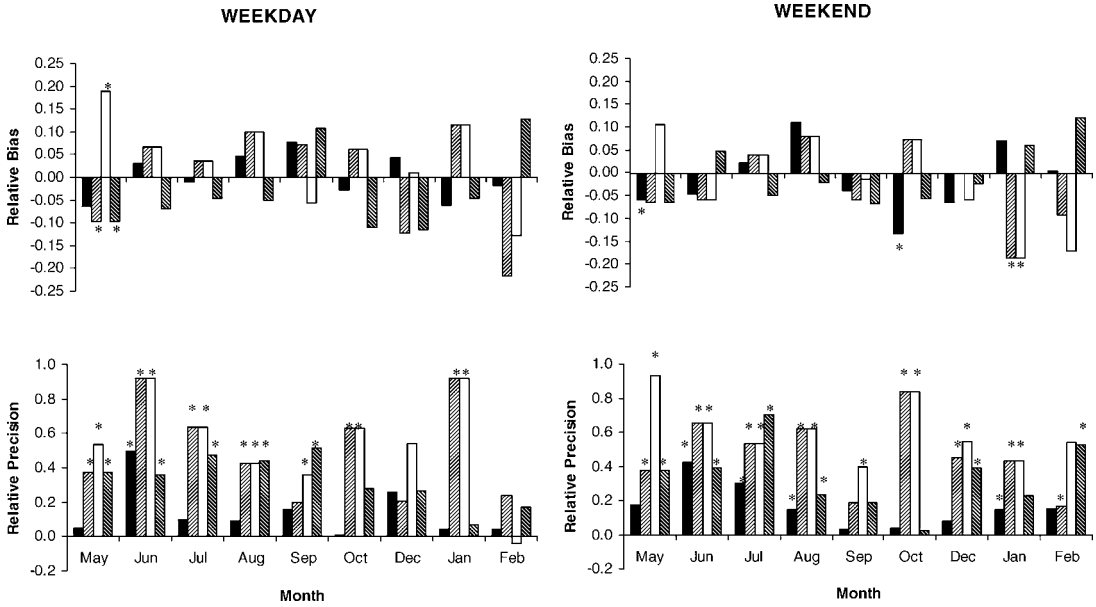


FIGURE 5.—Relative bias and relative precision of the estimated R/C ratio with the elimination of 1 week, 2 weeks, odd-numbered weeks, and even-numbered weeks from the sampling regime each month on lakes in northern Wisconsin during 1991–2002. See Figure 2 for additional details.

does not allow sampling effort reductions like those we considered. One possible explanation might be the steady increase in tourism that likely occurs throughout that month in northern Wisconsin, which would cause a

systemic increase in angling effort. Deroba et al. (2007) showed that angler effort increased steadily from May through July in northern Wisconsin, particularly on weekdays.

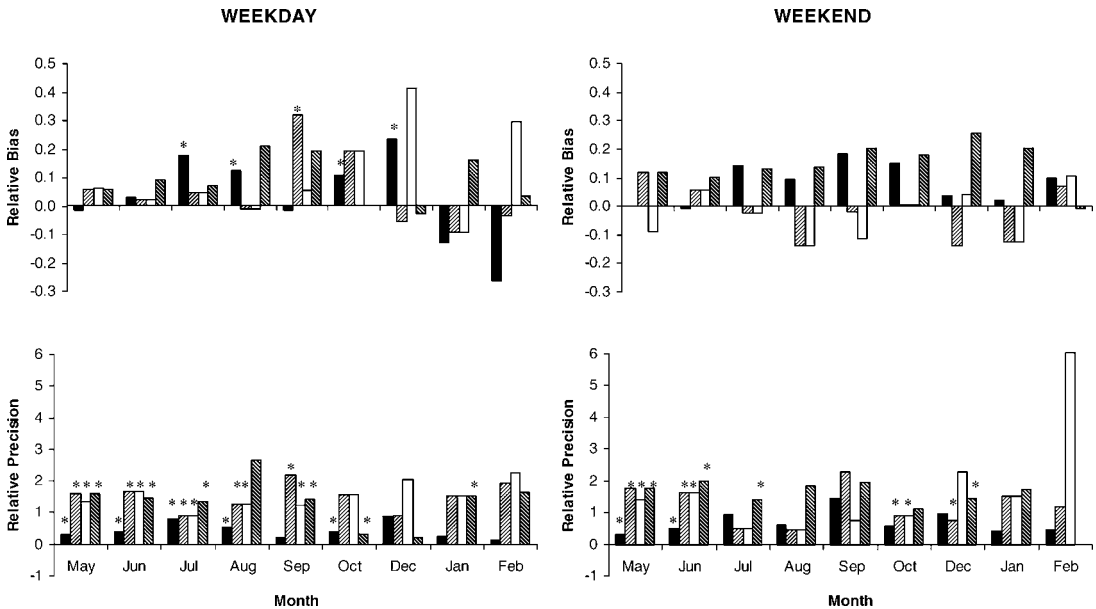


FIGURE 6.—Relative bias and relative precision of the estimated number of recaptures with the elimination of 1 week, 2 weeks, odd-numbered weeks, and even-numbered weeks from the sampling regime each month on lakes in northern Wisconsin during 1991–2002. See Figure 2 for additional details.

The significant losses in precision (i.e., significant increases in variance) of estimates of angler effort in nearly all months for all reductions in sampling effort suggest that variances of estimated effort are sensitive to the number of days sampled, as has been found in other studies (Bayley et al. 1991; Malvestuto and Knight 1991; Newman et al. 1997). For example, the among-day variance of estimates of angler effort in Escanaba Lake, Wisconsin, was 130% greater than the within-day variance, so increasing the number of sample days would effectively decrease the variance of effort (Newman et al. 1997). Similarly, Malvestuto and Knight (1991) concluded that increasing the number of sample days per month would be more effective than increasing the sampling hours within days to reduce the variance of estimated effort on Lakes Thurlow and Yates, Alabama. The relative precision of estimated angler effort decreased with an increase in the percentage of strata sampled each year in 1987 and 1988 on 33 lakes in Illinois (Bayley et al. 1991). Conversely, Dent and Wagner (1991) concluded that reduction of weekday sampling effort during open water from 8 to 5 d per month would not affect the precision of estimated effort on Pomme de Terre Lake, Missouri. Similarly, reduction of sampling effort from 10 to 5 d per month during April–September 1976 did not affect the precision of estimated angler effort on West Point Reservoir, Georgia (Malvestuto et al. 1978). Reduction of sampling effort from 10 to 6 d per month did not affect the precision of estimated mean annual effort during 1978–1981 on West Point Lake, Georgia–Alabama (Knight and Malvestuto 1991).

Significant losses in the accuracy of estimates of walleye harvest rate generally occurred in the months of May and June for each reduction in sampling effort, which suggests some systemic change in the susceptibility of walleyes to angling during those months that does not allow sampling effort reductions like those we considered. Walleyes may become less susceptible to angling from spring to summer when they move from shallow spawning shoals to more pelagic areas (Deroba et al. 2007). Another possibility is that tourists are less effective anglers than local residents (Rupp 1961; Parsons et al. 1991), and the fishing pressure from tourists increases steadily through May and June and causes subsequent declines in harvest rate (Deroba et al. 2007). Consequently, elimination of entire weeks of sampling during those months would not capture these changes and would lead to bias.

The relative bias in the estimates of harvest rate was always less than 0.20, which suggests that estimates of walleye harvest rate are robust to the total number of sample days, a finding that is similar to the that of Newman et al. (1997). The 95% confidence interval of

walleye harvest rate estimated from a creel survey conducted for 20 h per week and 10 d per month on Escanaba Lake, Wisconsin, during May–July 1988 contained the actual value from a creel census conducted during the same time period (Newman et al. 1997). However, 95% confidence intervals of estimates of walleye harvest rate in Escanaba Lake in each month did not contain the actual value from the creel census because too few interviews were conducted, which may also explain the significant differences we observed (Newman et al. 1997). Similarly, Phippen and Bergersen (1991) concluded that the accuracy of estimated harvest rate was a function of sample size, so sampling effort should attempt to maximize the number of interviews. In northern Wisconsin lakes, interviews could be maximized through use of the within-day trends in the number of complete trip interviews quantified by Deroba et al. (2007).

We found significant losses in the precision of estimates of walleye harvest rate in several months for each 2-week reduction in sampling effort, which suggests that variance of estimated harvest rate was sensitive to sample size, as has been found in some studies but not others (Dent and Wagner 1991; Weithman and Haverland 1991; Newman et al. 1997). The coefficients of variation of estimated walleye harvest rate were larger for individual strata than for all strata combined because estimates were based on fewer interviews during May–July 1988 on Escanaba Lake, Wisconsin (Newman et al. 1997). Weithman and Haverland (1991) concluded that lower harvest rates have relatively larger variances, and detecting significant changes may require more interviews. Conversely, Dent and Wagner (1991) concluded that reduction of weekday sampling effort during open water from 8 to 5 d per month would not affect the precision of estimates of harvest rate of all species on Pomme de Terre Lake, Missouri. In northern Wisconsin, the variance in estimates of harvest rate, and other estimates, could be reduced by focusing sampling effort during times of day that maximize the number of complete trip interviews, as suggested by Deroba et al. (2007).

We found that significant losses in the accuracy of estimates of angler effort and harvest rate did not always cause a significant bias in the estimates of harvest, which is similar to the findings of another study (Phippen and Bergersen 1991) but differs from the conclusions of Malvestuto et al. (1978). For example, on Parvin Lake, Colorado, biased estimates of harvest rate of all species did not cause biased estimates of harvest (Phippen and Bergersen 1991). Conversely, on West Point Reservoir, Georgia, Malvestuto et al. (1978) concluded that because estimates

of angler effort and harvest rate of all species were unbiased, estimates of harvest would also be unbiased. We found this not to be true, so bias in estimates of harvest should be tested separately from estimates of effort and harvest rate.

The significant losses in the precision of estimates of walleye harvest in several months for each reduction in sampling effort suggest that the variance of estimates of harvest is sensitive to sample size, which is congruent with one study (Bayley et al. 1991) but not another (Malvestuto et al. 1978). The relative precision of estimated harvest of all species decreased with an increase in the percentage of strata sampled each year in 1987 and 1988 on 33 lakes in Illinois (Bayley et al. 1991). Conversely, a reduction of sampling effort from 10 to 5 d per month during April–September 1976 did not affect the precision of estimated harvest on West Point Reservoir, Georgia (Malvestuto et al. 1978). Similarly, Dent and Wagner (1991) concluded that a reduction of weekday sampling effort during open water from 8 to 5 d per month would not affect the precision of estimated harvest on Pomme de Terre Lake, Missouri.

The significant losses in the accuracy of estimates of the R/C ratio that we observed generally occurred during the months of May and January, suggesting that the R/C ratio may change systemically in these months. Deroba et al. (2005) found that the R/C ratio changed significantly from May to February, suggesting some systemic change in the susceptibility of marked fish. The R/C ratio in May also increased with length category. These systemic changes may prevent reductions of creel survey sampling effort like those we considered because estimates of R/C ratio would not reflect these changes and would result in bias.

The relative bias in estimates of R/C was always less than 0.20, which suggests that estimates of R/C ratio are robust to the total number of sample days, as in another study (Newman et al. 1997). Estimates of R/C ratios for walleyes and yellow perch *Perca flavescens* from a creel survey conducted for 20 h per week and 10 d per month during May–July 1988 did not differ significantly from R/C ratios from a complete creel census on Escanaba Lake, Wisconsin (Newman et al. 1997).

We found significant losses in the precision of estimates of R/C ratio for several months for each reduction in sampling effort, which suggests that variances of estimates of the R/C ratio are sensitive to sample size. Similarly, Newman et al. (1997) concluded that coefficients of variation of estimates of R/C ratios for walleyes and yellow perch from a creel survey conducted for 20 h per week and 10 d per month during May–July 1988 were beyond acceptable levels for management purposes. As a result, Newman

et al. (1997) recommended increasing the number of marked fish observed by focusing sampling effort during times of high harvest, or increasing the number of marked fish, so that observations of a few recaptures would not have such a large effect on estimates of the R/C ratio. Future research and creel survey sampling effort in northern Wisconsin could be focused on the effects of allocating sampling effort during times of high harvest using the seasonal description of walleye harvest developed by Deroba et al. (2007).

We found few significant losses in the accuracy of estimates of the number of recaptured walleyes and no differences for even- and odd-numbered weekly reductions in sampling effort, which suggests that significant losses in the accuracy of estimates of the R/C ratio and harvest were in opposite directions. Newman et al. (1997) concluded that losses in the accuracy of estimates of the R/C ratio would create losses in the accuracy of estimates of recaptures and exploitation rate unless they were offset by harvest differences in the opposite direction. Our results confirm this conclusion.

We found significant losses in the precision of estimates of recaptures in several months for each of the reduced-sampling-effort eliminations, which suggests that large variances in estimates of the R/C ratio may create large variances in estimates of the number of recaptures. Newman et al. (1997) concluded that variance of estimates of the R/C ratio that were beyond acceptable levels for management purposes would also create levels of variance in estimates of recaptures and exploitation rate that were beyond acceptable levels. As suggested above, the variances of estimates could be better controlled by focusing sampling effort during times that maximize the number of interviews or the number of fish observed (Deroba et al. 2007).

Significant losses in the accuracy of estimates of angler effort, harvest rate, and harvest were in the opposite direction for the elimination of even- and odd-numbered weeks, which suggests some systemic change in these fishery attributes within months. These systemic changes could cause bias in estimates resulting from creel surveys if representative samples are not taken. Consequently, future allocations of sampling effort should first consider what systemic changes might be occurring and whether the sampling design will be representative. Systemic changes likely occur in other fisheries, and so sampling designs elsewhere should also consider this possibility.

Creel survey efficiency cannot be improved using the sampling effort reductions we considered without incurring significant losses in accuracy and precision for estimates of most angling fishery metrics. If current levels of accuracy are desirable for estimates of all

fishery attributes, reductions in sampling effort through the elimination of weeks within months may not be possible. We also found substantial losses in the precision of all estimates. The level of acceptable precision would need to be determined before reducing the sampling effort of creel surveys that are similar in design to those we evaluated (Bayley et al. 1991; Sztramko 1991).

The reductions in sampling effort that we considered were limited by the requirement for a 40-h workweek for creel clerks, so we did not consider many other feasible sampling effort reductions. Future research should focus on other sampling effort allocations, as in other fisheries (Malvestuto et al. 1979; Bayley et al. 1991; Dent and Wagner 1991; Jones and Robson 1991; Malvestuto and Knight 1991; McNeish and Trial 1991; Osburn and Osborn 1991; Sztramko 1991). For example, creel surveys in Texas are cancelled on "bad weather" days when angling effort is assumed to be zero, and sampling effort is focused on times of day that maximize the number of complete-trip interviews (Osburn and Osborn 1991). Similarly, Malvestuto et al. (1979) developed a multiple regression equation based on climatic variables that explained 83% of the variation in estimated effort, and sampling effort was then allocated based on expected variation. Another option is to use nonuniform probability sampling, in which sampling units are assigned an unequal probability of selection based on expected effort or harvest (Malvestuto et al. 1978; Hayne 1991; Osburn and Osborn 1991; Pollock et al. 1994). For example, on West Point Reservoir, Georgia, days are divided into four time blocks and chosen with nonuniform probability based on expected fishing effort (Malvestuto et al. 1978). Bayley et al. (1991) recommended that sampling effort be allocated based on expected harvest of all species because they found that precision of estimated harvest was twice as high as effort on 33 lakes in Illinois. Similarly, Newman et al. (1997) recommended that the precision of estimates of walleye harvest could be improved with nonuniform probability sampling based on expected times of high harvest. Management agencies designing creel survey programs should consider the most efficient methods based on program goals and required levels of accuracy and precision.

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