North American Journal of Fisheries Management 27:717–727, 2007

DOI: 10.1577/M06-125.1

[Article]

Temporal Profiles of Walleye Angling Effort, Harvest Rate, and Harvest in Northern Wisconsin Lakes

JONATHAN J. DEROBA*[1] AND MICHAEL J. HANSEN
College of Natural Resources, University of Wisconsin–Stevens Point,
800 Reserve Street, Stevens Point, Wisconsin 54481, USA

NANCY A. NATE AND JOSEPH M. HENNESSY
Wisconsin Department of Natural Resources, Bureau of Fisheries Management and Habitat Protection,
101 South Webster Street, Madison, Wisconsin 53707-7921, USA

Abstract.—In regions where water resources are abundant, broad-scale fisheries management requires quantifying fishery trends on a representative sample of lakes and then using these data to evaluate management actions and assess fishery status. Therefore, we quantified regional fishery profiles of the average number of complete-trip interviews, effort per acre, the number of walleyes *Sander vitreus* harvested per angler-hour, and the number of walleyes harvested per acre among hours, seasons, and years from 1991 to 2002 in northern Wisconsin lakes. The average number of interviews within days was similar between weekday and weekend day types but differed between open-water and ice-fishing seasons, peaking at midday and late afternoon during open water and midday during ice fishing. The average harvest rate within days was similar between day types and seasons and was highest in the morning and afternoon. The average angler effort during the angling season differed between day types and peaked in July on weekdays and in May on weekends. The average harvest rate during the angling season differed between day types and peaked in May on weekdays but also December on weekends. The average harvest per acre during the angling season was similar between day types and declined from May to February. The cumulative average angler effort was higher on weekdays than on weekends during 1991–2002, but the harvest rate and harvest per acre were similar between day types. Angler effort, harvest rate, and harvest per acre did not change significantly among years. Angler use and success changed systematically within days and among seasons but not among years, which suggests that walleye populations and the associated fishery were stable. The regional fishery profiles for each estimate were similar to the results from smaller-scale studies, suggesting that regional profiles can accurately depict patterns on a smaller scale.

Fishery profiles (e.g., angler effort, harvest rate, and harvest) quantified over a broad spatial and temporal scale can indicate the status of a fishery and progress toward management objectives (Claytor and O'Neil 1991; Crone and Malvestuto 1991; Hayne 1991; Palsson 1991; Hayes et al. 2003). Quantifying fishery profiles across a broad scale provides an index for the resource that cannot be gained from an individual-lake approach to management (Lester and Dunlop 2003). For example, effort is positively correlated with stock size and harvest rate (Palsson 1991), which suggests that angler harvest rate increases with fish population density (Beard et al. 1997). In northern Wisconsin lakes, population density of walleye *Sander vitreus* was used to predict angler catch rates (Beard et al. 1997). Goals for restoration of lake trout *Salvelinus namaycush* in Lake Superior were stated in terms of abundance, indexed as harvest rate, and harvest rate served as a basis for comparison between historical and modern abundances (Hansen et al. 1995). Declining harvest rates of predatory ocean fishes were used to conclude that abundances have significantly decreased (Myers and Worm 2003). In northern Wisconsin lakes, 65% of the walleye harvest was composed of fish less than 15 in long, suggesting a potential problem with recruitment overfishing (Staggs et al. 1990). Assessing the well-being of a fishery or determining progress toward management objectives cannot be accomplished through an individual-lake approach when fish populations are dispersed among lakes across a broad geographic region (Hayes et al. 2003; Lester and Dunlop 2003). Consequently, an approach that broadens the spatial and temporal focus of management is required (Lester and Dunlop 2003).

Creel surveys are often used to estimate effort, harvest rate, and harvest and to evaluate regulations (Osburn and Osborn 1991; Weithman and Haverland 1991; Guy et al. 1996; Van Den Avyle and Hayward 1999), but creel surveys are labor intensive and costly

---

* Corresponding author: derobajo@msu.edu

[1] Present address: Michigan State University, Department of Fisheries and Wildlife, 13 Natural Resources Building, East Lansing, Michigan 48823, USA.

Received April 26, 2006; accepted September 7, 2006

(Osburn and Osborn 1991; Guy et al. 1996; Van Den Avyle and Hayward 1999). Choice of creel survey design can strongly influence the resulting estimates (Ney 1993), but the efficiency of creel survey designs has rarely been evaluated (Malvestuto 1996). Patterns in fishery profiles in a particular stratum, such as day type (weekend versus weekday), can be used to allocate the amount of time required for sampling (e.g., Lester et al. 1991; Malvestuto and Knight 1991; Deroba et al. 2007, this issue).

Our objective was to use existing creel survey data to quantify patterns in walleye angler use and success across a broad spatial and temporal scale and to use the results to make inferences about the status of the walleye fishery in northern Wisconsin lakes. Walleye management in northern Wisconsin assumes that the walleye fisheries in the area exhibit a level of homogeneity that allows most lakes in the region to be managed with a maximum sustainable exploitation rate of 35%. However, walleye management in northern Wisconsin has long been conducted on an individual-lake basis, and attributes of the walleye fishery have not been assessed across the entire region. The numerous, relatively homogeneous walleye fisheries and the broad geographic range create a prime instance for the development of a broader management approach, as suggested by Lester et al. (2003) and Lester and Dunlop (2003). This requires the estimation of fishery profiles across a broad spatial and temporal scale (Lester and Dunlop 2003). Creel surveys that have been conducted in northern Wisconsin since 1991 provide data to create fishery profiles across a broad spatial and temporal scale and can provide insight into the status of the walleye fishery. Additionally, trends in walleye susceptibility to angling are not widely published in the literature, although walleyes are often assumed to be most susceptible to angling at dawn and dusk and early in the angling season when they are still spawning inshore on shallow shoals (Olson 1958; Newman et al. 2001; Parsons et al. 1991). To evaluate temporal changes in angler use, we examined trends in the average number of complete-trip interviews within days and angler effort (angler-hours/acre) among months during the angling season (May–February) and among years from 1991 to 2002. To evaluate temporal trends in angler success, we examined trends in harvest rate (fish/angler-hour) within days and harvest rate and harvest (fish/acre) among months during the angling season.

Methods

Study area.—The walleye angling fisheries included in our analysis are located in lakes within 14,336,000 acres of northern Wisconsin (Figure 1). The lake surface areas ranged from 22 to 15,300 acres, and walleye population density ranged from 1 to 100 fish/acre (U.S. Department of the Interior 1991; Hansen et al. 2000). The fisheries in northern Wisconsin generate an estimated US$340 million/year in revenue for Wisconsin's economy (Staggs et al. 1990). Walleye fisheries in northern Wisconsin are subjected to a joint angling and spearing fishery, and the maximum annual sustainable exploitation rate is 35% on each lake (Hansen et al. 1991; U.S. Department of the Interior 1991). Tribal harvest occurs during spring spawning, and daily angler bag limits are set at 0–5 fish, depending on tribal harvest declarations for each lake and the type of walleye population estimate used to estimate the harvest quota (Hansen et al. 1991; U.S. Department of the Interior 1991).

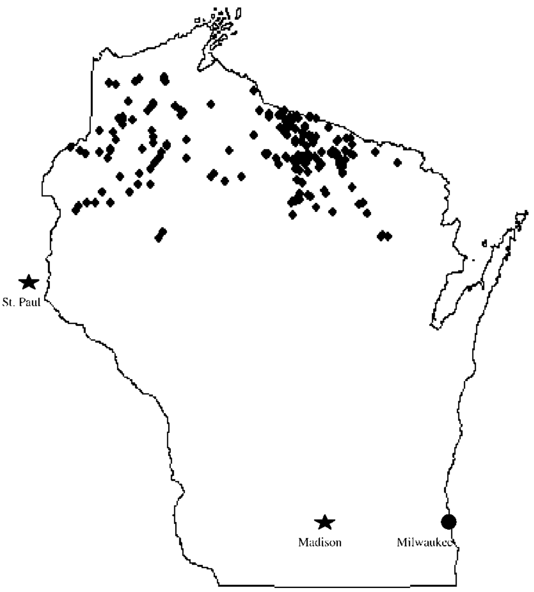

FIGURE 1.—Map showing the locations of the 192 northern Wisconsin lakes included in this analysis.

Creel surveys.—Creel surveys were used to estimate the effort, harvest rate, and total number of walleyes harvested by anglers on 16–40 randomly selected walleye lakes each year. 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). For our estimate of effort, we used general angler-hours instead of walleye-specific angler-hours because this is the protocol used by the Wisconsin Department of Natural Resources and also because walleyes are often caught when they are not being targeted. Using species-specific angler-hours would have caused our estimates of harvest to be biased low. However, this involves a trade-off because our estimates of walleye harvest rate may be biased if anglers systematically switch from targeting walleye to other species. 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 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, randomly selected periods of equal length. During the ice-fishing season, entire days were sampled because the day length 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. From 1991 to 2002, creel surveys were conducted on 192 different lakes, and clerks completed 169,282 complete-trip angler interviews and 111,177 instantaneous angler counts.

Data analysis.—We quantified trends in the average number of complete-trip interviews, effort per acre, number of walleyes harvested per angler-hour, and number of walleyes harvested per acre among hours, seasons, and years from 1991 to 2002 in northern Wisconsin lakes. To examine within-day trends, we averaged the number of interviews and harvest rate, based on the time of completion of the interview, for each hour (0600 to 2400 hours) across lakes and years (1991–2002) for both day types (weekday and weekend) and for open-water (May through October) and ice-fishing (December through February) seasons. Because our estimates of harvest rate by hour were based on the time the interview was completed, our trends in harvest rate may be inaccurate. However, capture time must be correlated to interview time with some lag, so the emergent patterns can still be informative. To examine trends among months (May to February), we averaged effort per acre, harvest rate, and harvest per acre for each month across lakes and years (1991–2002). To examine trends among years, we averaged effort per acre, harvest rate, and harvest per acre across lakes within each year (1991–2002). We used analysis of variance (ANOVA) to test for significant differences ($P \leq 0.05$) among hours, months, and years (independent variables) in the average number of interviews, effort per acre, harvest rate, and harvest per acre (dependent variables).

Results

The patterns in the average number of complete-trip interviews were similar between weekday and weekend day types but differed between open-water and ice-fishing seasons. During the open-water season, the average number of interviews on weekdays and weekends increased from 0600 to 1200 hours, decreased until 1400 hours, remained stable until 1800 hours, increased until 2000 hours, and then declined for the rest of the day (weekdays: $F_{18,4,276} = 33.14$, $P < 0.001$; weekends: $F_{18,4,330} = 31.98$, $P < 0.001$; Figure 2). During the ice-fishing season, the average number of interviews on weekdays and weekends increased from 0600 to 1700 hours and then declined for the rest of the day (weekdays: $F_{18,1,661} = 11.84$, $P < 0.001$; weekends: $F_{19,2,215} = 19.48$, $P < 0.001$; Figure 2).

The patterns in the average number of walleyes harvested per hour (harvest rate) were similar between weekday and weekend day types and open-water and ice-fishing seasons. During the open-water season, the harvest rate on weekdays and weekends decreased from 0600 to 0900 hours, remained stable until 2100 hours, increased until 2300 hours, then decreased for the rest of the day (weekdays: $F_{18,4,155} = 13.13$, $P < 0.001$; weekends: $F_{18,4,236} = 11.13$, $P < 0.001$; Figure 3). During the ice-fishing season, the harvest rate on weekdays increased from 0600 to 0800 hours, decreased until 1000 hours, remained stable until 1600 hours, increased until 2100 hours, and then decreased for the rest of the day ($F_{18,1,494} = 5.61$, $P < 0.001$); the harvest rate on weekends decreased from 0600 to 1000 hours, remained stable until 1600 hours, and then increased for the rest of the day ($F_{18,2,038} = 13.97$, $P < 0.001$; Figure 3).

The patterns in the average number of angler-hours per acre (effort) differed between weekday and weekend day types during the angling season. On weekdays, effort increased from May to July and then decreased throughout the rest of the season ($F_{8,2,537} = 161.10$, $P < 0.001$; Figure 4). On weekends, effort decreased from May to December and then increased to January and remained stable for the rest of the season ($F_{8,2,535} = 118.01$, $P < 0.001$; Figure 4).

The patterns in the average number of walleyes harvested per hour (harvest rate) differed between

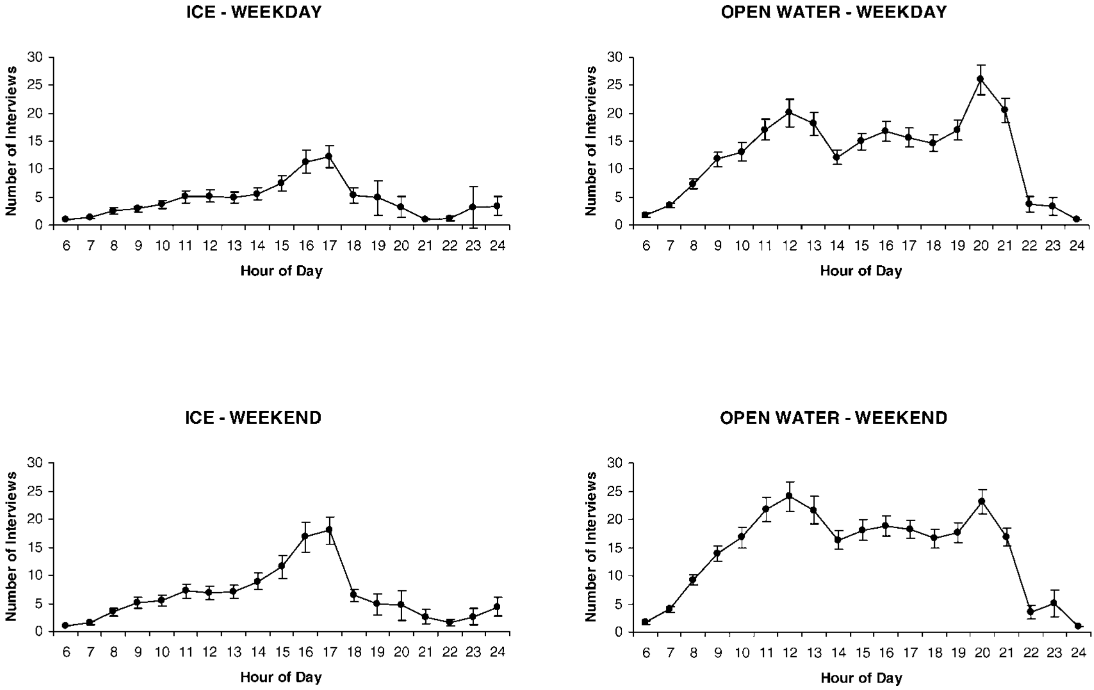

FIGURE 2.—Number of complete-trip interviews (mean ± 2 SEs) from 0600 to 2400 hours on weekdays and weekends during the open-water and ice-fishing seasons on northern Wisconsin lakes from 1991 to 2002.

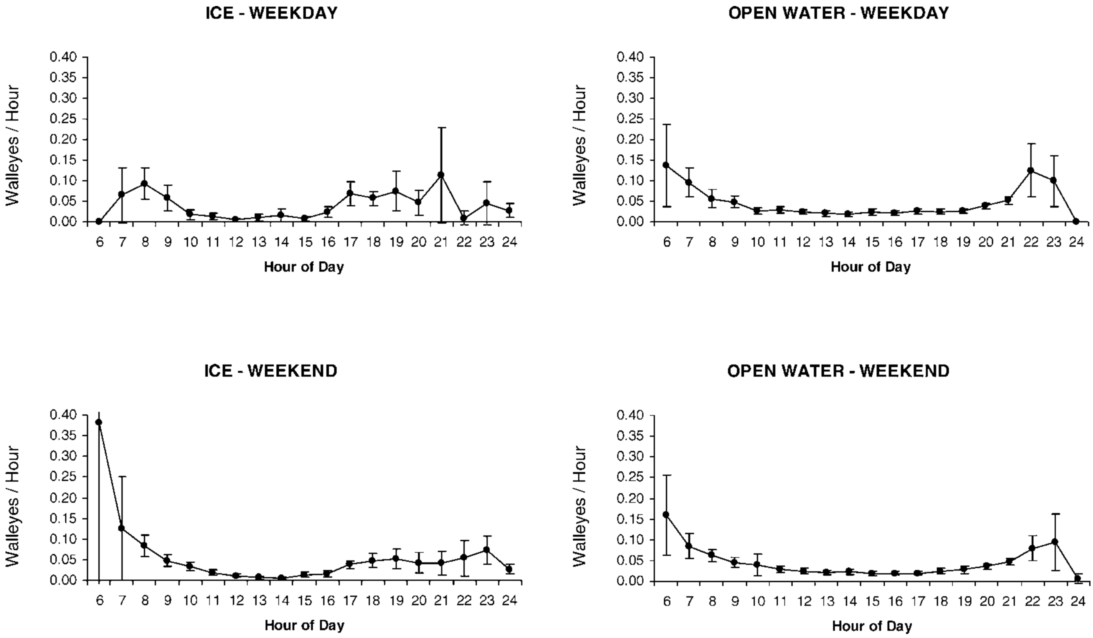

FIGURE 3.—Walleyes harvested per hour (mean ± 2 SEs), as estimated from complete-trip interviews from 0600 to 2400 hours on weekdays and weekends for the open-water and ice-fishing seasons on northern Wisconsin lakes from 1991 to 2002.

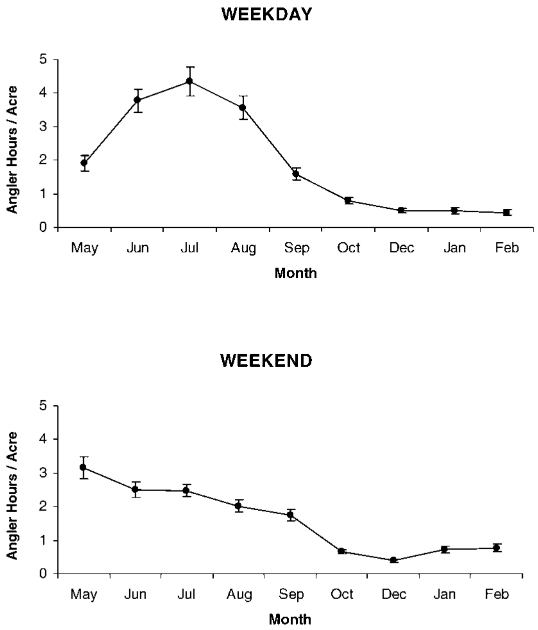

FIGURE 4.—Angler-hours per acre (mean ± 2 SEs), as estimated from instantaneous counts on weekdays and weekends from May to February on northern Wisconsin lakes from 1991 to 2002.

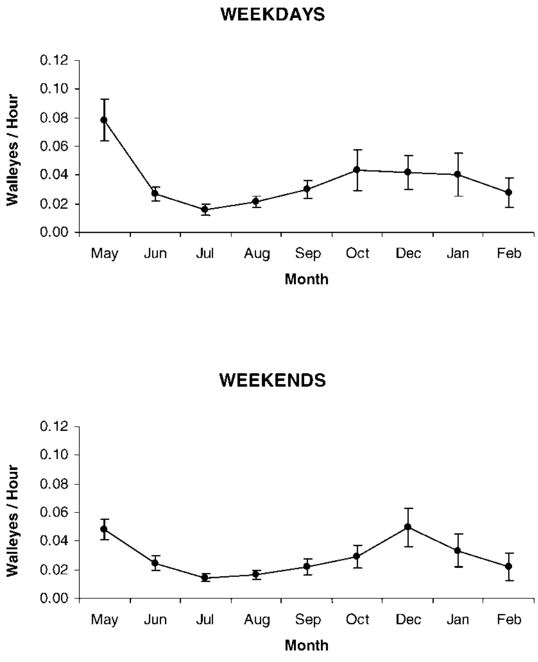

FIGURE 5.—Walleyes harvested per hour (mean ± 2 SEs), as estimated from complete-trip interviews on weekdays and weekends from May to February on northern Wisconsin lakes from 1991 to 2002.

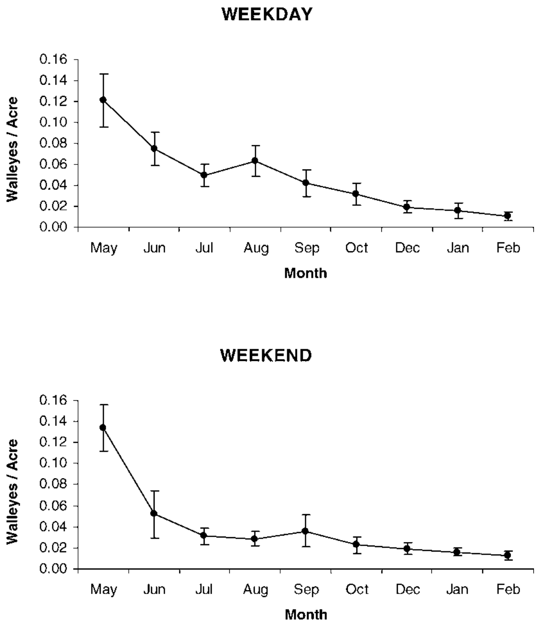

FIGURE 6.—Walleyes harvested per acre (mean ± 2 SEs), as estimated as the product of independent estimates of effort and harvest rate on weekdays and weekends from May to February on northern Wisconsin lakes from 1991 to 2002.

weekday and weekend day types during the angling season. On weekdays, the harvest rate decreased from May to July, increased to October, and then remained stable for the rest of the season ($F_{8,2,298} = 14.97$, $P < 0.001$; Figure 5). On weekends, the harvest rate decreased from May to July, increased to December, and then declined for the rest of the season ($F_{8,2,387} = 11.33$, $P < 0.001$; Figure 5).

The patterns in the average harvest per acre (harvest) were similar between weekday and weekend day types during the angling season. The average harvest per acre was 0.05 walleyes on weekdays and 0.04 walleyes on weekends and declined from May to February (weekdays: $F_{8,2,294} = 23.65$, $P < 0.001$; weekends: $F_{8,2,382} = 31.78$, $P < 0.001$; Figure 6).

The average cumulative number of angler-hours per acre (effort) during 1991–2002 was higher on weekdays than on weekends, but the patterns of effort among years were similar between day types. Angler effort on individual weekdays averaged about half the effort of weekend days (weekdays: mean = 0.09; SD = 0.06; weekends: mean = 0.17; SD = 0.11). However, with 2.5 times as many weekdays in a year as weekend days, the average cumulative effort was 16.40 angler-hours/acre on weekdays and 12.96 angler-hours/acre on weekends, and it did not change significantly from

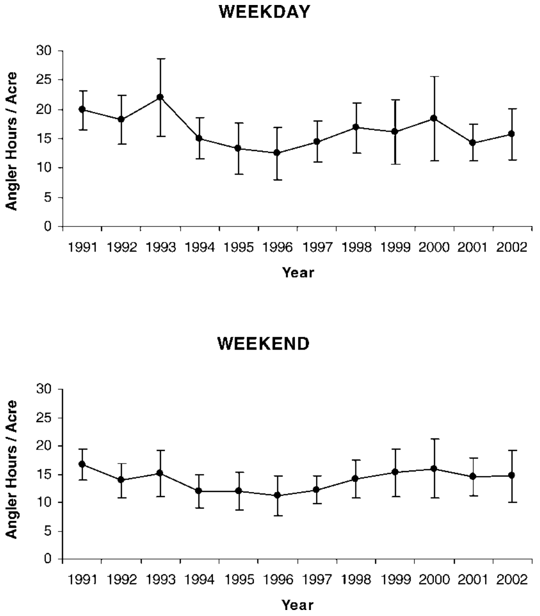

FIGURE 7.—Angler-hours per acre (mean ± 2 SEs), as estimated from instantaneous counts on weekdays and weekends on northern Wisconsin lakes from 1991 to 2002.

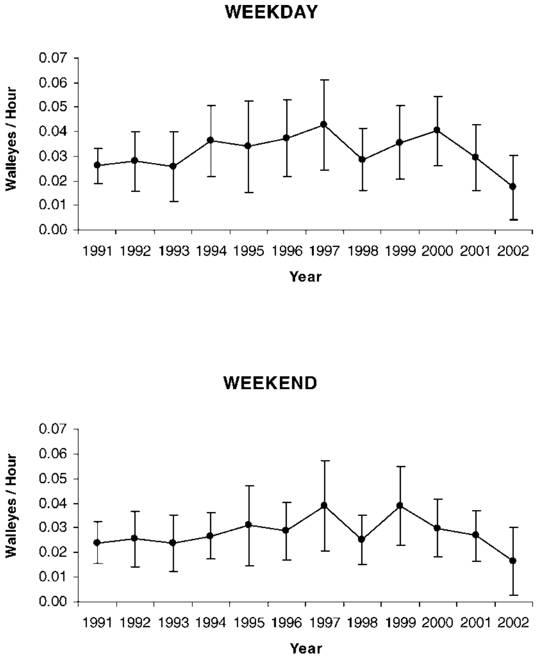

FIGURE 8.—Walleyes harvested per hour (mean ± 2 SEs), as estimated from complete-trip interviews on weekdays and weekends on northern Wisconsin lakes from 1991 to 2002.

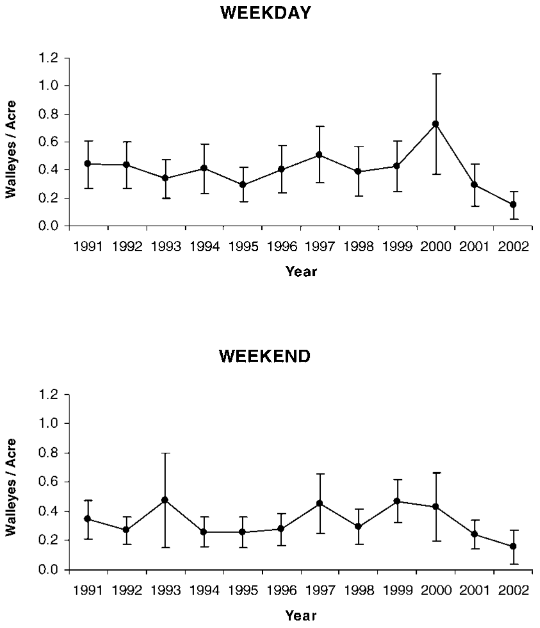

FIGURE 9.—Walleyes harvested per acre (mean ± 2 SEs), as estimated as the product of independent estimates of effort and harvest rate on weekdays and weekends on northern Wisconsin lakes from 1991 to 2002.

1991 to 2002 (weekdays: $F_{11,282} = 1.44$, $P = 0.15$; weekends: $F_{11,279} = 0.92$, $P = 0.52$; Figure 7).

The average number of walleyes harvested per hour (harvest rate) during 1991–2002 was similar between weekday and weekend day types, and the patterns among years were similar between day types. The average harvest rate was 0.03 walleyes/h for both day types and did not change significantly from 1991 to 2002 (weekdays: $F_{11,280} = 0.93$, $P = 0.51$; weekends: $F_{11,280} = 0.91$, $P = 0.53$; Figure 8).

The average number of walleyes harvested per acre (harvest) during 1991–2002 was similar between weekday and weekend day types, and patterns among years were similar between day types. The average number of walleyes harvested per acre was 0.40 weekdays and 0.33 on weekends, and it did not change significantly from 1991 to 2002 (weekdays: $F_{11,279} = 1.81$, $P = 0.052$; weekends: $F_{11,279} = 1.18$, $P = 0.30$; Figure 9).

Discussion

The fishery profiles developed in this study could be used to manage walleyes in northern Wisconsin lakes using a regional approach as opposed to an individual-lake approach. Historical individual-lake management has sometimes failed to protect fish populations adequately because fish populations are dispersed among lakes, and anglers move freely among lakes

(Lester et al. 2003). Consequently, regulations on one lake can cause anglers to shift effort to adjacent lakes or to concentrate effort on a single lake. This results in fishery management problems being shifted among lakes but never solved and creates a never-ending demand for more complex regulations (Lester et al. 2003; Lester and Dunlop 2003). In this study, the stability of the fishery profiles indicates that the individual-lake approach to management has not failed. However, the use of an individual-lake approach to management provides an increased opportunity for failure, and a regional approach to management should be considered if walleye populations ever decline. Furthermore, detailed stock assessments cannot be conducted on all lakes, and the success of management actions cannot be evaluated from case studies of individual lakes (Shuter et al. 1998). Rather, regional-scale experiments are required (Shuter et al. 1998; Lester et al. 2003). Regional fisheries management requires the assessment of key fishery parameters on a representative sample of lakes across the region of interest (Lester and Dunlop 2003). Such assessment is a cost-effective and scientifically valid assessment method (Jones and Stockwell 1995; Lester and Dunlop 2003). Jones and Stockwell (1995) developed a rapid assessment technique for estimating salmonid populations in Ontario streams based on single-pass electrofishing as opposed to the three-pass electrofishing conducted in the past. Lester and Dunlop (2003) suggest several rapid assessment techniques for estimation of abundance, mortality rate, and angling effort. For example, they suggest that estimates of angler effort be estimated from aerial surveys, angler diaries, or instantaneous counts of anglers multiplied by a correction factor developed from a "fishery effort profile," such as we developed in the present study. A random sample of walleye lakes each year provided a representative sample of walleye lakes in northern Wisconsin. Therefore, this profile could be used to focus instantaneous counts during times of day that minimize bias and maximize precision of effort estimates across northern Wisconsin (Lester and Dunlop 2003).

In addition to their utility in estimating angler effort, fishery profiles can be used to evaluate bias for a suite of fishery estimates from creel surveys, such as harvest rate, harvest, and exploitation rate, and to evaluate sampling efficiency for each season and day type, as in other studies (Deroba et al. 2005, 2007, this issue). Using creel survey estimates of the recapture rate of marked walleyes in northern Wisconsin, Deroba et al. (2005) concluded that estimates of angling exploitation rate may be biased across the region. Consequently, marking protocol and creel survey design in northern Wisconsin needed to be reevaluated. Rasmussen et al. (1998) concluded that the estimators we used for effort, harvest rate, and harvest were unbiased. Deroba et al. (2007) then used these profiles as a basis for comparing reduced-sampling-effort, creel-survey designs across northern Wisconsin. These fishery profiles can also be used to identify the most appropriate times to allocate sampling effort. For walleyes, Newman et al. (1997) recommended increasing sampling effort during late evening or whenever the harvest was highest. Similarly, Bayley et al. (1991) recommended that sampling effort should be allocated toward times of high harvest to maximize the precision of estimated effort and harvest. However, these types of sampling designs (e.g., sampling only when harvest is high) require assumptions about the times that are not sampled or use of bias correction factors from fishery profiles like those developed in this study.

The usefulness of fishery profiles developed over broad spatial and temporal scales also applies to other systems. The techniques used to develop fishery profiles in this study and those recommended by Lester and Dunlop (2003) can be applied in any system where a similar data collection technique has been in place or is being developed. For example, creel surveys have been used to estimate effort, harvest, and exploitation rate for salmonids in Lake Michigan, Atlantic salmon *Salmo salar* in Canada and Europe, and various species in Missouri (Claytor and O'Neil 1991; Dent and Wagner 1991; Fabrizio et al. 1991). Fishery profiles could be developed and fishery assessments and management moved to a broader scale for any of these species and areas.

Several patterns emerged for each fishery profile developed in this study, and although directly comparable profiles on such a broad scale have not yet been published, some parallels can be seen in studies completed elsewhere. We found that most interviews were conducted at 1700 hours during the ice-fishing season and at 1200 and 2000 hours during the open-water season, which corresponds with dusk in each season, and at lunchtime during the open-water season, a pattern also observed in other fisheries (McEachron 1979; Dent and Wagner 1991; Newman et al. 1997). For example, the number of anglers completing their trips peaked after 2000 hours during spring and summer on Escanaba Lake, Wisconsin (Newman et al. 1997). Furthermore, in Texas saltwater fisheries, 91% of complete-trip interviews were between 1000 and 1800 hours, thereby allowing the elimination of sampling outside those times (McEachron 1979). Similarly, on Pomme de Terre Lake, Missouri, counts of anglers decreased sharply at 1200 hours between May and September, which suggests that many anglers completed their trips at that time, and counts of anglers increased in the afternoon, which suggests that many anglers completed their trips at dusk (Dent and Wagner 1991). Creel surveys aimed at maximizing interviews should focus more sampling effort around midday and dusk. Similarly, diel patterns could be used to construct an expansion factor for fishing effort, as suggested by Lester and Dunlop (2003), to eliminate sampling effort for much of the day.

We found that harvest rates were generally higher early and late in the day, which coincides with times of day when walleyes most actively feed in Wisconsin (Niemuth et al. 1972; Becker 1983) and should therefore be most vulnerable to angling. Walleyes are nocturnal; they migrate to shallow bars and shoals at dusk to feed, which makes them most susceptible to angling at twilight and early morning (Niemuth et al. 1972; Becker 1983). For example, walleye harvest rates peaked after 2000 hours during spring and summer on Escanaba Lake, Wisconsin (Newman et al. 1997). Although this pattern of walleye susceptibility to angling has long been inferred from their feeding habits, a quantified description of this pattern has not yet been published over such broad spatial and temporal scales. Furthermore, creel surveys should be designed to obtain a representative sample of walleye harvest rates within days, which could be accomplished by creating a fishery profile and correction factor that accounts for changes in walleye catchability, as suggested by Lester and Dunlop (2003), or by randomly sampling stratified portions of the day. The results of this study for the patterns of harvest rate within days should be interpreted cautiously because harvest rates were calculated based on the time of interview completion and therefore may be inaccurate.

In this study, effort per acre was highest during summer and lowest during winter, which is probably due to the increased susceptibility of walleyes early in the season, the schedule of the tourism industry, and the weather, as was found in other studies (Parsons et al. 1991; Sztramko 1991; Newman et al. 2001, 2002). High effort in May on weekends is probably an angler response to higher walleye susceptibility at the opening of the angling season (Niemuth et al. 1972). Other studies have documented changes in fishing effort similar to our results. Effort on Long Point Bay, Lake Erie, was more than three times greater for the first 10 d after the opening of the season for smallmouth bass *Micropterus dolomieu* than during the rest of the year (Sztramko 1991). Effort decreased from an average of more than 14 angler-hours/acre during May–August to an average of 3 angler-hours/acre after Labor Day on Lakes Mary, Ida, and Miltona in Minnesota (Parsons et al. 1991). Similarly, from 1991 to 2002, effort decreased from 28 to 30 angler-hours/acre during open-water season to 3–4 angler-hours/acre during ice-fishing season on Escanaba Lake, from 54–60 angler-hours/acre to 0.13–0.17 angler-hours/acre on Nebish Lake, from 15–16 angler-hours/acre to 0.0 angler-hours/acre on Spruce Lake, and from 8–9 angler-hours/acre to 0.05–0.5 angler-hours/acre on Pallette Lake, Wisconsin (Newman et al. 2001, 2002). Creel surveys designed to maximize the number of interviews should focus more sampling effort early in the season and over summer months. Maximizing the number of interviews would be most efficient for increasing the sample size used for estimation of fishery parameters (e.g., exploitation rate) and would increase the precision of estimates (Deroba et al. 2007). Law enforcement officials could also use these patterns to maximize the number of anglers checked for compliance.

We found that harvest of walleyes per angler-hour was highest in May, decreased through July, and then increased during the ice-fishing season, probably because of the variation in walleye susceptibility and angler expertise (Olson 1958; Rupp 1961; Niemuth et al. 1972; Parsons et al. 1991). For example, Niemuth et al. (1972) concluded that walleyes in Wisconsin were highly susceptible to angling in May while they were still spawning in shallow water immediately after ice-out. Low harvest rates during summer are probably due to increased effort from tourism and tourists' lack of expertise (Rupp 1961; Parsons et al. 1991). For example, on lakes Mary, Ida, and Miltona in Minnesota, local anglers caught more walleyes per trip than tourists (Parsons et al. 1991). The increase in harvest rates that we observed during the ice-fishing season also may be a result of decreased angler effort, especially from tourists, and increased susceptibility of walleyes to angling immediately after ice formation (Niemuth et al. 1972). Olson (1958) also reported the pattern of high harvest rates in the spring, low harvest rates in the summer, and increased harvest rates in the fall for Many Point Lake, Minnesota, although no reason was suggested for this pattern. To avoid bias in estimates of harvest rate, creel surveys should be stratified seasonally to account for temporal changes in walleye catchability, as observed in this study. Fishery managers also could use these patterns to protect walleye stocks when they are most vulnerable to harvest.

The declining trend of walleye harvest throughout the angling season that we observed has also been reported in other studies (Parsons et al. 1991; Newman et al. 2001, 2002). For example, in Escanaba Lake, Wisconsin, during 2000 and 2001, harvest decreased from 2.43–3.15 fish/acre during the open-water season to 0.13–0.49 fish/acre during the ice-fishing season (Newman et al. 2001, 2002). Likewise, during 1987 on Lake Mary, Minnesota, the harvest decreased from 1.1 fish/acre in spring to 0.30 fish/acre in summer and 0.06 fish/acre in fall (Parsons et al. 1991). Creel surveys designed to maximize sampling effort during times of high walleye harvest, as suggested by Bayley et al. (1991) and Newman et al. (1997), should focus effort early in the season.

We found that angling effort did not change significantly during 1991–2002, which suggests that our estimates of angler harvest rates accurately reflect walleye density. Changes in walleye angling harvest rate may not serve as an accurate index of abundance when fishing effort changes (Lester and Dunlop 2003). For example, lakes with higher fishing effort had lower walleye catch per effort for 76 fisheries in Ontario, Wisconsin, Minnesota, and Colorado (Baccante and Colby 1991). Similarly, angler effort was positively correlated with catch rates for Pacific cod *Gadus macrocephalus* and lingcod *Ophiodon elongatus* in Puget Sound, Washington (Palsson 1991). However, if fishing effort remains stable, as in this study, walleye angling harvest rates more accurately reflect walleye density. Caution should still be used when applying angler harvest rates as an index of abundance because angling catchability can change as a result of factors other than effort (Lester and Dunlop 2003). Regardless, if angling catch rates are found to be positively correlated to walleye density, as in the northern Wisconsin walleye fishery (Beard et al. 1997), then angling catch rates can be used as a rapid assessment technique for estimating walleye density (Lester and Dunlop 2003). One possible source of error in this study is our use of general angler-hours instead of specific angler-hours. If walleye angling success declined, then anglers may have shifted angling pressure to another species, and therefore, general angler-hours would not reflect this change.

We found that harvest rate and harvest did not change significantly from 1991 to 2002, which suggests that walleye population abundance did not decrease. Walleye angler catch rates reflected population density in northern Wisconsin lakes (Beard et al. 1997), and so our results suggest that angler success and walleye population density did not change significantly from 1991 to 2002 in northern Wisconsin lakes. Managers developing a spatially and temporally broad-scale management system could also use angling harvest rates as an index of fish density, if angling effort is constant and harvest rates are correlated with population density, as was the case in this study (Lester and Dunlop 2003).

The parallels between our fishery profiles and those of smaller-scale studies suggest that certain aspects of angler behavior and creel survey design can be applied beyond our study system and that large-scale fishery profiles accurately reflect trends across regions. Consequently, fishery managers charged with the task of designing or modifying a creel survey can assume these trends apply and create an efficient survey that minimizes bias and maximizes precision of resulting estimates from the start.

Acknowledgments

We are grateful to the many biologists and technicians of the Wisconsin Department of Natural Resources for data collection. We thank Amy Schueller and three anonymous reviewers for comments on an earlier draft of this manuscript. Funding for this project was provided by the Wisconsin Department of Natural Resources.

References

Baccante, D. A., and P. J. Colby. 1991. Quantifying walleye angling success. Pages 397–405 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Bayley, P. B., S. T. Sobaski, M. J. Halter, and D. J. Austen. 1991. Comparisons of Illinois creel surveys and the precision of their estimates. Pages 206–211 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Beard, T. D., Jr., S. W. Hewett, Q. Yang, R. M. King, and S. J. Gilbert. 1997. Prediction of angler catch rates based on walleye population density. North American Journal of Fisheries Management 17:621–627.

Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison.

Claytor, R. R., and S. F. O'Neil. 1991. Using small creel surveys and mark–recapture experiments to interpret angling statistics. Pages 195–205 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Crone, P. R., and S. P. Malvestuto. 1991. Comparison of five estimators of fishing success from creel survey data on three Alabama reservoirs. Pages 61–66 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Dent, R. J., and B. Wagner. 1991. Changes in sampling design to reduce variability in selected estimates from a roving creel survey conducted on Pomme de Terre Lake. Pages 88–96 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Deroba, J. J., M. J. Hansen, N. A. Nate, and J. M. Hennessy. 2005. Evaluating assumptions of mark–recapture studies for estimating angling exploitation of walleyes in northern Wisconsin lakes. North American Journal of Fisheries Management 25:890–896.

Deroba, J. J., M. J. Hansen, N. A. Nate, and J. M. Hennessy. 2007. Evaluating creel survey efficiency for estimating walleye fishery metrics in northern Wisconsin lakes. North American Journal of Fisheries Management. 27:707–716.

Fabrizio, M. C., J. R. Ryckman, and R. N. Lockwood. 1991. Evaluation of sampling methodologies of the Lake Michigan creel survey. Pages 162–176 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Guy, C. S., H. L. Blankenship, and L. A. Nielsen. 1996. Tagging and marking. Pages 353–383 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Hansen, M. J., T. D. Beard, Jr., and S. W. Hewett. 2000. Catch rates and catchability of walleyes in angling and spearing fisheries in northern Wisconsin lakes. North American Journal of Fisheries Management 20:109–118.

Hansen, M. J., R. G. Schorfhaar, J. W. Peck, J. H. Selgeby, and W. W. Taylor. 1995. Abundance indices for determining the status of lake trout restoration in Michigan waters of Lake Superior. North American Journal of Fisheries Management 15:830–837.

Hansen, M. J., M. D. Staggs, and M. H. Hoff. 1991. Derivation of safety factors in setting harvest quotas on adult walleyes from past estimates of abundance. Transactions of the American Fisheries Society 120:620–628.

Hayes, D., E. Baker, R. Bednarz, D. Borgeson, Jr., J. Braunscheidel, J. Breck, M. Bremigan, A. Harrington, R. Hay, R. Lockwood, A. Nuhfer, J. Schneider, P. Seelbach, J. Waybrant, and T. Zorn. 2003. Developing a standardized sampling program: the Michigan experience. Fisheries 28(7):18–25.

Hayne, D. W. 1991. The access point creel survey: procedures and comparison with the roving-clerk creel survey. Pages 123–138 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Jones, M. L., and J. D. Stockwell. 1995. A rapid assessment procedure for the enumeration of salmonine populations in streams. North American Journal of Fisheries Management 15:551–562.

Lester, N. P., and W. I. Dunlop. 2003. Monitoring the state of the lake trout resource: a landscape approach. Pages 293–328 *in* J. Gunn, R. Steedman, and R. Ryder, editors. Boreal watersheds: lake trout ecosystems in a changing environment. Lewis/CRC Press, Boca Raton, Florida.

Lester, N. P., T. R. Marshall, K. Armstrong, W. I. Dunlop, and B. Ritchie. 2003. A broad-scale approach to management of Ontario's recreational fisheries. North American Journal of Fisheries Management 23:1312–1328.

Lester, N. P., M. M. Petzold, and W. I. Dunlop. 1991. Sample size determination in roving creel surveys. Pages 25–39 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Malvestuto, S. P. 1996. Sampling the recreational creel. Pages 591–623 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Malvestuto, S. P., and S. S. Knight. 1991. Evaluation of components of variance for a stratified two-staged roving creel survey design with implications for sample size allocation. Pages 108–115 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

McEachron, L. W. 1979. An evaluation of diurnal and roving count data to determine optimum interview and pressure periods in Texas marine creel surveys. Master's thesis. University of Houston, Clear Lake City, Texas.

Myers, R. A., and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. Nature (London) 423:280–283.

Newman, S. P., D. S. Dreikosen, and G. R. Kubenik. 2001. Northern highland fishery research area population and harvest monitoring annual report. Wisconsin Department of Natural Resources, Annual Report, Project F-95-P, Madison.

Newman, S. P., D. S. Dreikosen, and G. R. Kubenik. 2002. Northern highland fishery research area population and harvest monitoring annual report. Wisconsin Department of Natural Resources, Annual Report, Project F-95-P, Madison.

Newman, S. P., P. W. Rasmussen, and L. M. Andrews. 1997. Comparison of a stratified, instantaneous-count creel survey with a complete mandatory creel census on Escanaba Lake, Wisconsin. North American Journal of Fisheries Management 17:321–330.

Ney, J. 1993. Biological statistics. Pages 137–158 *in* C. C. Kohler and W. A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Niemuth, W., W. Churchill, and T. Wirth. 1972. Walleye: its life history, ecology, and management. Wisconsin Department of Natural Resources, Publication 227-72, Madison.

Olson, D. E. 1958. Statistics of a walleye sport fishery in a Minnesota lake. Transactions of the American Fisheries Society 87:52–72.

Osburn, H. R., and M. F. Osborn. 1991. Increasing the efficiency of Texas saltwater creel surveys. Pages 155–161 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M.

Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Palsson, W. A. 1991. Using creel surveys to evaluate angler success in discrete fisheries. Pages 139–154 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Parsons, B. G., D. L. Pereira, and D. H. Schupp. 1991. A resort-based head collection program for expanding recreational harvest information on walleyes. Pages 507–514 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

Pollock, K. H., C. M. Jones, and T. L. Brown. 1994. Angler survey methods and their applications in fisheries management. American Fisheries Society, Special Publication 25, Bethesda, Maryland.

Rasmussen, P. W., M. D. Staggs, T. D. Beard, Jr., and S. P. Newman. 1998. Bias and confidence interval coverage of creel survey estimators evaluated by simulation. Transactions of the American Fisheries Society 127:469–480.

Rupp, R. S. 1961. Measurement of potential fishing quality. Transactions of the American Fisheries Society 90: 165–169.

Shuter, B. J., M. L. Jones, R. M. Korver, and N. P. Lester. 1998. A general, life-history-based model for regional management of fish stocks: the inland lake trout fisheries of Ontario. Canadian Journal of Fisheries and Aquatic Sciences 55:2161–2177.

Staggs, M. D., R. C. Moody, M. J. Hansen, and M. H. Hoff. 1990. Spearing and sport angling for walleye in Wisconsin's ceded territory. Wisconsin Department of Natural Resources, Administrative Report 31, Madison.

Sztramko, L. K. 1991. Improving precision of roving creel survey estimates: implications for fisheries with a closed season. Pages 116–121 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.

U.S. Department of the Interior. 1991. Casting light upon the waters: a joint fishery assessment of the Wisconsin ceded territory. U.S. Department of the Interior, Bureau of Indian Affairs, Minneapolis, Minnesota.

Van Den Avyle, M. J., and R. S. Hayward. 1999. Dynamics of exploited fish populations. Pages 127–163 *in* C. C. Kohler and W. A. Hubert, editors. Inland fisheries management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Weithman, A. S., and P. Haverland. 1991. Comparability of data collected by telephone and roving creel surveys. Pages 67–73 *in* D. Guthrie, J. M. Hoenig, M. Holliday, C. M. Jones, M. J. Mills, S. A. Moberly, K. H. Pollack, and D. R. Talhelm, editors. Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland.