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FISHERIES DIVISION**

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A Survey of Sport Fishing in Lake Superior Waters at Isle Royale, Michigan, 1998

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Abstract.—An on-site, direct-contact creel survey was conducted in the Lake Superior waters of Isle Royale National Park during June-August 1998 to estimate fishing effort, sport catch, sport harvest, and residency of non-charter anglers. The sport harvest of lake trout and coaster brook trout was of particular concern. Estimates were based on boat counts from air flights and from the ferry vessel *Voyageur II*, as well as from boating-party interviews at Isle Royale ports, at Grand Portage, MN, and onboard the ferry vessel *Ranger III*. Total boating effort at Isle Royale during June-August was 29,273 hours, of which 19,340 hours (66%) were by fishing boats. Total angler hours for the period were 62,232. Lake trout numerically made up over 90% of the sport catch, with an estimated harvest of 9,612 and an additional 10,760 caught and released. Eight other species were reported in the catch but variance associated with the much lower estimates precluded a comparison of harvest among these species. Coaster brook trout were not reported in the catch but splake were, and these are believed to be misidentified coaster brook trout or lake trout. Harvest estimates indicate that the current level of fishing is not harming any Isle Royale fish stock, but future creel surveys similar to this one are recommended.

Isle Royale is located in extreme northwestern Michigan waters of Lake Superior. It is about 45 miles long and 9 miles wide. Isle Royale and associated smaller islands were

established as Isle Royale National Park (IRNP) by an act of Congress in 1931. The IRNP boundary includes Lake Superior from the shore of Isle Royale lakeward 4.5 miles, including the

associated smaller islands. The Michigan Department of Natural Resources (MDNR) retains fishery management jurisdiction in Lake Superior waters of the park, but collaborates with IRNP in regulating sport and commercial assessment fisheries in these waters.

Isle Royale has long been a place of resource harvesting, including copper mining, timber, and fishing. Ojibwa, and even pre-Ojibwa, peoples gathered on the island for these activities (DuFresne 1991, Gale and Gale 1995). European settlers were likewise attracted to the resources of Isle Royale. The fur-trading companies initiated large-scale commercial fishing for mainly lake trout (all scientific names are listed in Table 1), but also for lake whitefish and lake herring, as early as the late 1700s by the Northwest Fur Company, and in the 1830s by the American Fur Company (DuFresne 1991). Although these commercial fisheries reduced the abundance of previously unexploited fish stocks, a sustainable harvest continued until the 1950s (Curtis et al. in press). Lake trout and other fish stocks declined during the 1950s because they could not sustain the fishery and the additional mortality caused by sea lamprey predation. Michigan closed commercial fishing for lake trout in all of its waters in the early 1960s. National Park Service Policy regarding commercial activity led to further restriction of commercial fishing at IRNP, consequently only two small commercial fisheries currently exist there under special assessment permits with very restrictive catch quotas. Restrictions to commercial harvest and effective control of sea lamprey since the early 1960s resulted in restoration of Isle Royale fish populations (Koziol 1982, Curtis et al., in press). Samples from the two permit commercial fisheries during the 1990s indicate a healthy lake trout population with better growth and lower mortality than in other Michigan waters of Lake Superior (Marquette Fisheries Station, MDNR, unpublished data).

The restored populations of large lake trout at Isle Royale have attracted sport anglers, including charter-boat fisheries. Isle Royale National Park personnel noted the increased sport fishing activity and they, MDNR, and eventually the other agencies that make up the Lake Superior Technical Committee became concerned regarding the impact of this fishery

on the fish stocks, especially lake trout and coaster brook trout. Isle Royale is considered to be a showcase example of lake trout restoration for the Great Lakes, and parameters from these stocks will be used as a yardstick to measure restoration in other areas. Anecdotal information from former commercial fishermen indicated that Isle Royale was home to numerous discrete stocks of the lean form of lake trout (Organ et al. 1972), and preliminary analysis indicates that, although several local stocks were lost in the 1960s, little genetic diversity has been lost (M. K. Burnham-Curtis, U. S. Geological Survey-Biological Resources Division [USGS-BRD], Ann Arbor, personal communication). Isle Royale is one of the two remaining areas in Michigan waters of Lake Superior containing wild coaster brook trout populations (Newman and DuBois 1997).

Since 1990, the MDNR has required charter-boats operating in Michigan waters to report their daily catches (Rakoczy and Rogers 1991), but only limited information has been available for the non-charter sport fishery. Many non-charter anglers visit Isle Royale waters and fish by traveling in their own boats from ports like Grand Portage, MN and Copper Harbor, MI, or by having their boats transported to the island aboard the ferries from Houghton, MI and Copper Harbor, MI. Efforts to estimate the non-charter sport catch have been limited to a state-wide mail survey by the MDNR during 1971-82, and a voluntary angler report card survey during 1992-93 of anglers fishing Isle Royale out of Grand Portage, MN, in cooperation with the Minnesota Department of Natural Resources. The mail survey was abandoned after 1982 because it was found to produce much higher than actual estimates of effort and catch (Rybacki and Keller 1978; Patriarche 1980), which at the time were believed due to response and recollection differences between successful and non-successful anglers. Subsequent evaluations of mail surveys of freshwater fisheries indicate over estimation of this nature is common and due to recall bias (Fisher et al. 1991). The Michigan mail survey was also inappropriate for Isle Royale because it omitted the large numbers of anglers from other states, especially Minnesota, which is closer than mainland Michigan. The angler report card survey did include the major Minnesota access port to Isle

Royale (Grand Portage), but total fishing effort and catch were not determined because it surveyed mostly Minnesota anglers, an unknown portion of anglers were given cards, and an even smaller portion returned them. The MDNR and IRNP concluded that only a survey that estimated fishing effort and included on-site direct-contact interviews to determine catch composition would provide a satisfactory estimate of sport fishing at Isle Royale.

During the summer months of 1998 such an angler survey was conducted on the Lake Superior waters surrounding Isle Royale. The purpose of this survey was to estimate fishing and non-fishing boating activity, harvest and catch-and-release by species, and residency of boaters using this area. Three categories of boating type are represented in this report: registered charter fishing boats, non-charter fishing boats, and non-fishing pleasure boats. Non-fishing pleasure boats were primarily motorized boats, but included canoes and kayaks.

Methods

Sampling Period

Angler survey began 30 May and ran through 31 August 1998. Estimates were made for multiple day periods (weekdays and weekend days [including holidays]) within each month. May 30 and 31 were included in June weekend day period and reported June estimates include these two days. Estimates were summed to provide month and season estimates by boating type.

Sampling area

The near-shore waters surrounding Isle Royale were divided into 14 sampling grids (Figure 1). Sampling grids were selected based on prior observations by IRNP personnel of fishing activity. Boundary margins were assumed to encompass, rather than split individual fishing areas, and corresponded to obvious landform characteristics. These grids allowed for accurate enumeration of fishing

activity by independent observers on the water and in the air.

Counts

Boats (both fishing and non-fishing) were scheduled for counting each week by an airplane flying out of International Falls, MN. One randomly selected day each week of the survey period was scheduled for boat counts. The airplane circled the island on randomly selected days and counted total number of boats within each grid. No effort was made to discern boating activity (fishing or non-fishing). Time was recorded as each grid was counted, and all counting occurred during mid-day, 1100h to 1500h. Specific count time was determined by plane availability. However, these times (1100h to 1500h) were presumed to correspond with peak boating activity.

Similar to plane counts, boats were counted from the ferry vessel *Voyageur II* as it circled the island and no attempt was made to discern type of boating activity. The *Voyageur II* followed a set schedule (non-random) and circled the island in a clock-wise direction. On Monday, Wednesday and Saturday of each week the vessel left Grand Portage, MN and traveled to Washington Harbor located at the southern end of Isle Royale. The clerk boarded the vessel at Windigo in Washington Harbor. The vessel left Washington Harbor at about 1200h on each of these days and traveled through grids 10-14 and 2-3, making numerous stops at island bays along the way, before stopping at Rock Harbor on the northeast end of the island. The clerk counted boats in each of these grids and noted the time to the nearest minute as the vessel was in the approximate middle of a grid. On Sunday, Tuesday and Thursday the vessel left Rock Harbor and continued in a clockwise direction around the island, again stopping at numerous island bays along the way. As before, the clerk counted boats and noted times as the vessel proceeded through grids 4-9. The clerk departed the vessel when it stopped at Windigo in Washington Harbor, the vessel then proceeded to Grand Portage, MN. During this circuit of Isle Royale, grid 1 was not visible, so no counts were made there by the clerk aboard *Voyageur II*.

In addition to visual boat counts made by the clerk riding Voyageur II, counts were also made using the vessel's radar system. Radar setting was for 1 nautical mile and any boats appearing were recorded. Radar counts and visual counts were compared by time period within each month using linear regression techniques.

Interviews

Three clerks obtained interviews of both fishing and non-fishing boaters at Isle Royale. The interview form is depicted in Figure 2 with species codes and common and scientific names of fishes expected to be encountered by the clerks in Table 1. Each clerk was instructed to query boaters to ensure that duplicate interviews of boating trips did not occur. That is, only one interview record, regardless of which clerk was interviewing a party, was to be collected for each boating trip. A trip was defined as the period in which a boat was partaking in an activity within one or more grid, and did not include time spent moored or anchored in a harbor or inlet. Consider this example: A boating party returns to Grand Portage, MN after spending several days at Isle Royale. On their first day at the island they leave camp at 0800h and motor to a fishing spot in grid 2. They return to camp at 1700h. This is one trip and one interview form could be filled out. If they fish again in the evening of that same day, a second interview form would be filled out. This same process would continue for each day the group was at the island. Thus, boaters were also reporting activity (catch etc.) on days when no clerk was present to witness their activity. All times were recorded as Eastern Daylight Time and both numbers of fish kept and caught and released were recorded.

One clerk was stationed at Grand Portage, MN and interviewed anglers as they returned to the Grand Portage Tribal Marina and Voyageurs Marina. In an attempt to interview the most Isle Royale boaters returning to Grand Portage, the clerk worked two shifts: 0700h – 1000h and 1600h – 2000h each scheduled day. Casual observation by IRNP personnel indicated these were the hours most boaters returned to the mainland from Isle Royale. Both weekend days and three randomly selected weekdays were

scheduled for sampling each week. In addition, July 3 was sampled and considered a weekend day.

A second clerk interviewed boating parties from the Voyageur II. The vessel made numerous stops as it circled the island and at each stop the clerk interviewed any boating parties present.

A third clerk rode aboard the Ranger III from Houghton, MI. This vessel traveled from Houghton to Rock Harbor and back twice per week, with two days required for a single round trip. Six randomly selected dates (two per month) were chosen for this clerk to travel aboard the Ranger III and interview any boaters transporting their boats back from Isle Royale.

Effort

Effort for all three categories of boating is reported as boat hours. Boat angler hours and angling trips are given for charter and non-charter fishing boats. Boat hours are the total hours boats spent in the sample area. Boat angler hours are the total hours boat anglers spent in the sample area and are the product of mean anglers per boat and boat hours. Angling trips are the total number of individual fishing trips made by anglers and are the quotient of angler hours and mean length of angling trip. Further descriptions of these terms are found in Lockwood et al. (1999).

Charter boat fishing effort for 1998 were summed to provide effort by time period, [day type within months] (J. Rakoczy, MDNR, personal communication). Time periods were summed for monthly and seasonal effort.

Mean boating effort \bar{E} was estimated following methods similar to those found in McNeish and Trial (1991) and Parker (1956). From the interview data set, a distribution was created of boating parties b present each hour t of the day during time period p . As an example, distribution of June weekend boating parties is given in Figure 3. Factors for expanding counts are:

$$\hat{b}_t = \frac{1}{b_t} \sum_{i=1}^{24} b_i . \quad (1)$$

Variance of individual \hat{b}_t was estimated using bootstrapping techniques with 10,000 replications (Efron and Tibshirani 1993). Individual count B was then expanded by \hat{b}_t and the number of days D in that time period:

$$E_{pt} = B_{pt} D_p \hat{b}_{pt}. \quad (2)$$

Variance of E for period p based on hour t then was estimated following Freese (1962) as:

$$Var(E_p) = (B_{pt} D_p)^2 Var(\hat{b}_p). \quad (3)$$

Averaging over n counts then, \bar{E} is estimated as:

$$\bar{E}_p = \frac{1}{n_p} \sum_{i=1}^{n_p} E_{pi}. \quad (4)$$

Estimated variance of \bar{E} for period p then is (Cochran 1977):

$$Var(\bar{E})_p = \left[\left(1 - \frac{n_p}{D_p} \right) \left(\frac{\sum_{i=1}^{n_p} (\bar{E}_p - E_p)^2}{n_p (n_p - 1)} \right) \right] + \left[\left(\frac{1}{D_p n_p} \right) \left(\sum_{i=1}^{n_p} Var(\hat{b}_p) \right) \right]. \quad (5)$$

Charter boat effort was subtracted from total estimated boating effort. Since no charter boats were interviewed by any of the clerks, remaining estimated boat effort was partitioned into estimated fishing and estimated non-fishing effort using methods for multiple day periods given in Lockwood et al. (1999). Estimation of boat angling effort and boat angling trips also follow the methods for multiple day periods (Lockwood et al. 1999).

Catch

Only completed-trip angler party interviews were collected, no incompleted trip interviews were collected or used. Ratio-of-means catch rate estimator was used and all catch (harvest as

well as catch and release) were estimated using methods for multiple day periods given in Lockwood et al. (1999).

Statistical Significance

Unless otherwise noted, all estimates are given with two standard errors (error bounds) which give statistical significance of 75% to 95% (Dixon and Massey 1957:292).

Results

Airplane Counts

A total of 14 counts by airplane were scheduled for sampling. Two counts were canceled and not rescheduled due to weather factors. Two additional counts were canceled and rescheduled. Thus, a total of 12 counts were made by airplane.

Since grid 1 could not be counted by the clerk aboard the *Voyageur II*, the ratio of estimated effort in grids 1-14 to effort in grids 2-14 was established based on airplane counts (Table 2). These ratios were used to expand total effort in grids 2-14 (estimated from airplane and *Voyageur II* counts) to estimate total boating effort in all 14 grids. Grid 1 represented a small fraction of the total effort and seasonal multiplier for grids 2-14 was 1.0349 ± 0.3650 (2SE).

Voyageur II

Radar and visual boat counts were compared by day type for each grid; month stratification was ignored. Linear regression analyses showed significant relationships ($F \leq 0.05$) between radar counts and visual counts for 22 of 26 comparisons and more than 60% of the variability in radar counts was accounted for by variability in visual counts ($r^2 > 0.60$) in 16 of 26 comparisons (Table 3).

Interview Sources

The three clerks interviewed 856 boating parties. Significantly more ($\alpha=0.05$) boating parties were fishing, rather than non-fishing, during both weekdays and weekend days for June and July, and during weekdays in August (Table 4). No significant difference between number of boating parties in the two categories was detected during August weekend days.

The clerk aboard the *Voyageur II* collected 65.19% of all boating interviews (Table 5). Most interviews by this clerk were collected at Rock Harbor marina and Tookers Island on the east side, and at Windigo, Beaver Island and Grace Island on the west side. The clerk stationed at Grand Portage MN collected 25.58% and the clerk aboard the *Ranger III* collected 8.76% of all boating interviews.

Interview Records

Number of interview records collected from non-charter fishing parties in each grid and month varied from 0 to 22 with 39% of the 224 strata having fewer than 5 interviews (Table 6). Strata with few interview records may not accurately reflect catch rates or distribution of anglers. Also, variances of ratio estimates, such as catch rates, become biased when sample sizes are small and variances cannot be calculated when only one record is collected. As a result, individual grid distribution of boating parties and catch rates were not considered different. Interviews were combined for all grids within a given time period.

Following this pooling, interviews from non-charter fishing parties per time strata varied from 59 during August weekend days to 162 during July weekdays with three of the six strata having more than 100 interview records. Jones et al. (1995) showed that true 95% confidence limits are attainable when 100 or more completed trip interviews are collected. Necessity of large sample size is due to skewed distribution of catch rates (most anglers catch 0 fish). Therefore, error bounds presented in this survey for catch of lake trout (predominant species caught) approximate 95% confidence limits. For less frequently caught species, 75% confidence limits are assumed.

Boating effort

An estimated $29,273 \pm 8,332$ boat hours of effort occurred on the Lake Superior waters surrounding Isle Royale during our survey period (Table 7). Broken down, this represents 696 charter boat hours, $19,340 \pm 5,356$ non-charter fishing boat hours, and $9,237 \pm 3,229$ non-fishing boat hours. Non-charter fishing boat effort varied by grid with most fishing activity occurring in grids 3-8, 10 and 14 (Table 8).

Catch and harvest

Lake trout were the predominant fish species caught, making up 96% of the total catch and 94% of the total harvest in the non-charter fishery. Non-charter anglers fished $62,232 \pm 17,731$ hours and harvested $9,612 \pm 2,622$ lake trout (Table 9). An additional $10,760 \pm 3,075$ lake trout were caught and released by these anglers. Coho salmon, northern pike, and rainbow trout ranked a distant second, third, and fourth behind lake trout in the non-charter catch, and five additional species were caught but in such low numbers that variation precluded reasonable estimates. Anglers fishing aboard charter boats fished 3,148 hours and harvested 871 lake trout, which made up 90% of the harvest in the charter boat fishery (Table 10). Other species in the charter boat catch included coho salmon, chinook salmon, rainbow trout, and brown trout. Harvest catch rates were significantly better for charter boat anglers than for non-charter boat anglers, 0.2767 vs. 0.1545 ± 0.0609 . Catch-and-release information for charter boats was not available. Total estimated harvest of lake trout by charter and non-charter fishers was $10,483 \pm 2,622$ (Table 10). Total estimated effort for both fishing groups was $65,380 \pm 17,731$ hours. Catch estimates for other species are also given in Tables 9-11.

Residency

Non-charter anglers were predominantly from Minnesota (53%) and Michigan (42%), but included anglers from as far away as California (Table 12). Most non-fishing boaters were from Michigan (33%) and Minnesota (33%), with

Australia being the most distant origin (Table 13).

Discussion

Sport fishing was the most popular boating activity at Isle Royale during June-August 1998, and fishing effort exceeded that at the most popular fishing ports on Michigan's mainland shore of Lake Superior. Comparing Isle Royale to any one port is probably not appropriate given its more than 100 miles of shoreline, but fishing effort at Isle Royale was not different from the combined total 48,800 angler hours for June-August at Marquette, AuTrain, and Munising (J. Rakoczy, MDNR, Charlevoix, unpublished data). Total harvest of lake trout during June-August at these three mainland ports was 11,776 indicating a similar catch rate. However, these catch rates may not be directly comparable because catch and release was not estimated at the mainland ports in 1998 and it is likely that a greater percentage of fish are released at Isle Royale. Since anglers at Isle Royale are away from home-based preservation facilities (freezers, canners, etc.), it is likely that a greater percentage of fish are released because of limited storage space and the necessity to comply with the legal possession limit which is the daily possession limit. Also, a greater percentage of lake trout may be released at Isle Royale than in mainland fisheries because they are bigger. Mean total length of lake trout in the two commercial assessment fisheries at Isle Royale in 1997 was 27-29 inches, whereas it was 22-24 inches in assessment fisheries along the mainland shore (Marquette Fisheries Station, MDNR, unpublished data). Big lake trout may be considered by anglers to represent spawning fish or simply poor table fare. The estimated release of 53% of lake trout caught was similar to the 48-49% reported from the voluntary angler reports at Grand Portage, MN in 1992 and 1993 (Marquette Fisheries Station, MDNR, unpublished data). For most other species the low numbers caught likely contributed to the lower percentage released, except species like northern pike and rock bass which probably do not rank as high as salmonines as table fare with most Isle Royale anglers.

The predominance of lake trout in the June-August Isle Royale sport fishery was typical for mainland Michigan ports of Lake Superior for all years since creel surveys were initiated in the 1980s (J. Rakoczy, MDNR, Charlevoix, unpublished data). Even in the mid 1980s when salmon were much more abundant, lake trout still dominated the catch during June-August (Peck 1992).

The level of harvest estimated in 1998 does not appear to be sufficient to have a negative impact on any fish stock at Isle Royale, and especially not on lake trout. Although June-August was not the entire fishing season, this period represented 89% of the lake trout harvest based on monthly catch distribution in the 1992 voluntary angler survey and mandatory charter boat report (Marquette Fisheries Station and Charlevoix Fisheries Station, MDNR, unpublished data). Extrapolating our non-charter lake trout harvest estimate to account for non-surveyed fishing months of May, September, and October, adding the charter boat catch, and assuming the commercial assessment fisheries would take their entire 1,000 fish quota results in a total estimated harvest of about 12,700. This figure is considerably less than the harvest of 50-60,000 lake trout (164,220 kg) that was sustained at Isle Royale from 1929 through the early 1950s (Curtis et al. in press). Harvest of most other species is incidental and small in comparison to harvest in other Lake Superior waters.

Coaster brook trout were not reported in our survey but their numbers are probably few and could be affected by a small amount of targeted fishing effort. The MDNR has enacted regulations to severely restrict harvest of coaster brook trout at Isle Royale in recent years, reducing the possession limit from three to one and increasing the minimum size limit from 10 inches to 18 inches. Biological monitoring of these coaster populations should be done periodically to determine if more stringent regulations are needed.

Perhaps the only surprise in the small numbers and variety of fishes other than lake trout caught at Isle Royale was the capture of splake. Splake, a female lake trout and male brook trout cross, are stocked at several sites in Lake Superior with the nearest being Copper Harbor, MI some 50 miles away. Although

splake tend to remain near stocking sites and provide the best return to the creel of fish stocked at a given site (Peck 1992), it is possible that some of those stocked at Copper Harbor could have found their way to Isle Royale. Splake have been identified as a potential threat to coaster brook trout because of the possibility of back-crossing, competition, or because they can be confused with coaster brook trout which complicates regulation of the fishery (Newman et al. 1998). However, a more likely explanation is that splake reported in this survey were misidentified lake trout or coaster brook trout. Sometimes trained fisheries personnel have difficulty separating splake from brook trout and lake trout, and a pyloric caeca count is required for conclusive identification. The creel clerks were not all trained fisheries personnel and did not see all of the four splake that were reported by anglers. Lake trout at Isle Royale exhibit a great deal of morphological diversity and some may present anglers with a picture of lake trout unlike any they have seen before. Few Lake Superior anglers are familiar with big lake-run brook trout and are much more familiar with splake in their mainland Great Lakes and inland fisheries. Also, no splake have been reported in the two permit commercial fisheries (Marquette Fisheries Station, MDNR, unpublished data), nor in the past few years of coaster brook trout survey work conducted with nets and electrofishing gear at Isle Royale by the U. S. Fish and Wildlife Service (USFWS), Fishery Resource Office (FRO) at Ashland, WI (H. Quinlan, USFWS-FRO, Ashland, personal communication). Our survey was not intense enough to produce a reliable estimate based on four fish. If all four were coaster brook trout, it would certainly be more significant than if they were lake trout, but without an accurate estimate and positive identification we cannot say if sport fishing is having any effect on coaster brook trout at Isle Royale.

Our survey of angling and non-angling boaters in the Lake Superior waters near Isle Royale relied heavily upon two assumptions. First was the proportional relationship between hourly distribution of boating effort in the targeted population and that of the interview data set. Using traditional roving methods, hourly instantaneous random counts of effort are expanded by number of hours in the sample time

period and then averaged (Hayne 1991, Lockwood et al. 1999). Proportional method expands hourly instantaneous counts made at non-random times using distribution of count units present at that hour in the interview data set. For example (using data in Figure 3), summing the frequency of boats present per hour yields 437 boat hours. At 1000h 44 boat hours of effort were recorded in the interview data set. Thus, 1000h represented 10.07% of total boat effort for a day (inverse used for multiplication is 9.9305). If 7 boats were counted at 1000h, estimated effort for the day would be $7 \times 9.9305 = 69.5$. Multiplying by the number of days in the time period then produces an estimate for that time period.

Lockwood (1999) compared angling effort estimates using roving and proportional methods for various Michigan fisheries (see roving-access design in Pollock et al. 1994). In that study (Lockwood 1999), roving estimates were compared to proportional estimates using randomized counts from historical data sets as well as non-randomized counts collected specifically for that study. From the historical data sets, 8 of 11 comparisons differed by <10% and 3 by >18% of roving method. No significant trend in difference was detected (Wilcoxon Signed Ranks Test, $P=0.343$). Estimated boating effort from roving counts was compared with non-random counts made at 1200 h and expanded using proportional method. Estimate using proportional method differed by <9% of randomized method estimate.

The second assumption relates to non-randomness of counting done by the clerk aboard the *Voyageur II*. This clerk counted grids 9-14 and 2-3 on Saturday, Monday, and Wednesday only. Similarly, the clerk counted grids 4-9 on Sunday, Tuesday and Wednesday only. Air counts were made on a randomized schedule four times per month. These counts included all 14 grids and each of seven days per week was available for sampling.

Both methods of counting, air and vessel, have strengths and weaknesses. Non-randomness of day selection for counting from *Voyageur II* has obvious concerns. To accurately portray boating effort, days when counting was done must have had effort which was not different from unsampled days. However, the *Voyageur II* circled the island

under a wide variety of weather conditions. Only when wind speeds exceed 45 knots was the vessel restricted from its assigned schedule. Also, fog was not a deterrent due to the good relationship between visual and radar counts. No sample days were missed during our survey. In contrast, the air counts could be made on randomly scheduled days, but were easily deterred by weather. Two of 14 counts were missed due to weather and two others were rescheduled. If poor weather days (when less boat effort than average was expected to occur) were sampled disproportionately, effort was overestimated.

Comparison of these two counting methods highlights the difficulty in surveying this remote island. While counting boats from aircraft allows for a randomized schedule, it is potentially unreliable and expensive. Cost of current survey was approximately \$15,000. Previously, costs using air counts during entire survey period were estimated at approximately \$40,000 (R. Schorfhaar, MDNR, Charlevoix, personal communication). Similarly, assigning adequate number of clerks to be stationed at counting sites around the island appears impractical due to additional salary costs.

McNeish and Trial (1991) made all proportional counts between 1100h and 1400h and initially treated their interview data set as a binomial distribution. Effort was estimated by dividing count B by the fraction of anglers present in a given hour. Using this binomial approach then:

$$\hat{b}'_t = \frac{1}{\sum_{i=1}^{24} b_i} b_t, \quad (6)$$

and variance,

$$Var(\hat{b}'_t) = \frac{1}{\sum_{i=1}^{24} b_i} (\hat{b}'_t (1 - \hat{b}'_t)). \quad (7)$$

In their study, estimated variation associated with equation (7) was shown to be small relative to between day variation (0.02% to 0.08%) and variation from equation (7) was disregarded entirely. Within day variation from our study

also was relatively small compared to between day variation, 0.10% to 7.78% (Figure 4). However, understanding differences in binomial and bootstrap approach are important.

Equation (7) is greatly influenced by relationship (closeness) of \hat{b}'_t (6) to 0.0 or 1.0.

That is, an estimate of \hat{b}'_t (6) yielding a very small number (close to 0.0) or a very large number (close to 1.0) will give a smaller estimate of $Var(\hat{b}'_t)$ (7) than an estimate of \hat{b}'_t (6) close to 0.5. Equation (7) does not report sampling variation, rather it gives a value based on the distance \hat{b}'_t (6) is from 0.5. Also, equation (7) uses total hours anglers were fishing ($\sum_{i=1}^{24} b_i$) as a measure of sample size.

Thus, increasing the mean length of trip, while the number of anglers contacted remains constant reduces $Var(\hat{b}'_t)$ (7).

In our survey, different hours of the day were sampled (counted) making the binomial variance inappropriate. A single distribution was created from interviews collected over many days within a day type. Estimating \hat{b}'_t for several values of t treats this distribution as multinomial rather than binomial and invalidates the use of equation (7).

Bootstrap estimates of variance are not without criticism. Notably, this method may underestimate variance. However, their application in this situation seems very appropriate. Assuming sample size is constant, as \hat{b}'_t (1) increases estimated variance decreases.

Conversely, only as \hat{b}'_t (6) departs from 0.5, either by increasing or decreasing, does variation decrease. Thus, the variation associated with expanding counts at a time of day when 50% of anglers are present would yield greater variation than when 1% were present. When a greater percentage of anglers are present, counts are expanded by a relatively smaller fraction, more angling effort information is known, and less variability associated with expansion of counts is reasonable. When a smaller percentage of anglers are present, counts are expanded by a larger fraction, less angling effort information is known, and greater variability is anticipated.

Recommendations

A creel survey in Isle Royale waters of Lake Superior should be conducted at least every 5-10 years to track changes in sport fishing effort and harvest. Although we have concluded that our 1998 survey was adequate to estimate harvest of the dominant species (lake trout), back-to-back annual estimates would provide a better analysis of the variation associated with our survey methods and provide a better basis for fine-tuning them. Otherwise, methods similar to the ones described for this current angler survey of the Lake Superior waters near Isle Royale are recommended for any future surveys. Non-random counts made from the ferry vessel should be augmented with aerial counts. Ideally, additional aerial counts should be made to more accurately compare vessel and aerial counts. Interview records should again be collected from clerks stationed at Grand Portage, MN and Isle Royale. Anglers returning to Michigan, such as those riding the *Ranger III*, may be interviewed more efficiently by a clerk stationed at Rock Harbor. More frequent surveys are probably not

necessary unless sport fishing increases substantially or assessments indicate decreasing populations of major fish species.

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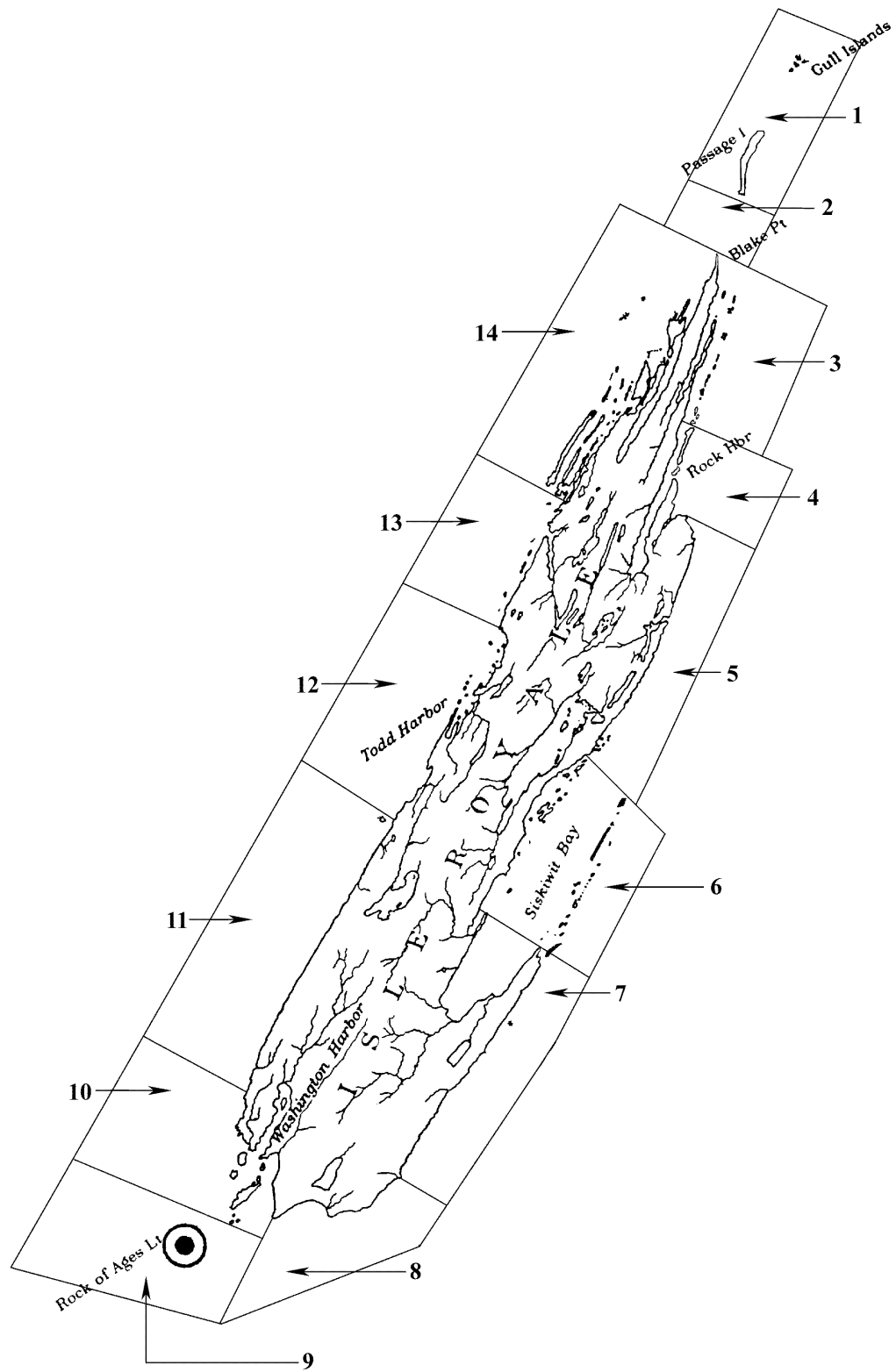


Figure 1.—Creel survey sampling grids, Lake Superior waters at Isle Royale, 1998.

ANGLER PARTY INTERVIEW FORM

Interview Location: _____

Boating Grid: _____

Date: ____/____/____

Mode: **Fishing** **Non-fishing**

Start Fishing Time (E.D.T.): _____ am pm

End Fishing Time (E.D.T.): _____ am pm

Anglers in Party: _____

State of Residence: _____

Party Catch

	kept	released		kept	released
species	no.	no.	species	no.	no.
WAE	_____	_____	LAT	_____	_____
NOP	_____	_____	RBT	_____	_____
RKB	_____	_____	COH	_____	_____
YEP	_____	_____	LWF	_____	_____
BKT	_____	_____	LHR	_____	_____
CHS	_____	_____	OTHER _____	_____	_____

Figure 2.—Interview form used to record boating activity in the Lake Superior waters at Isle Royale, 1998. Species codes are given in Table 1.

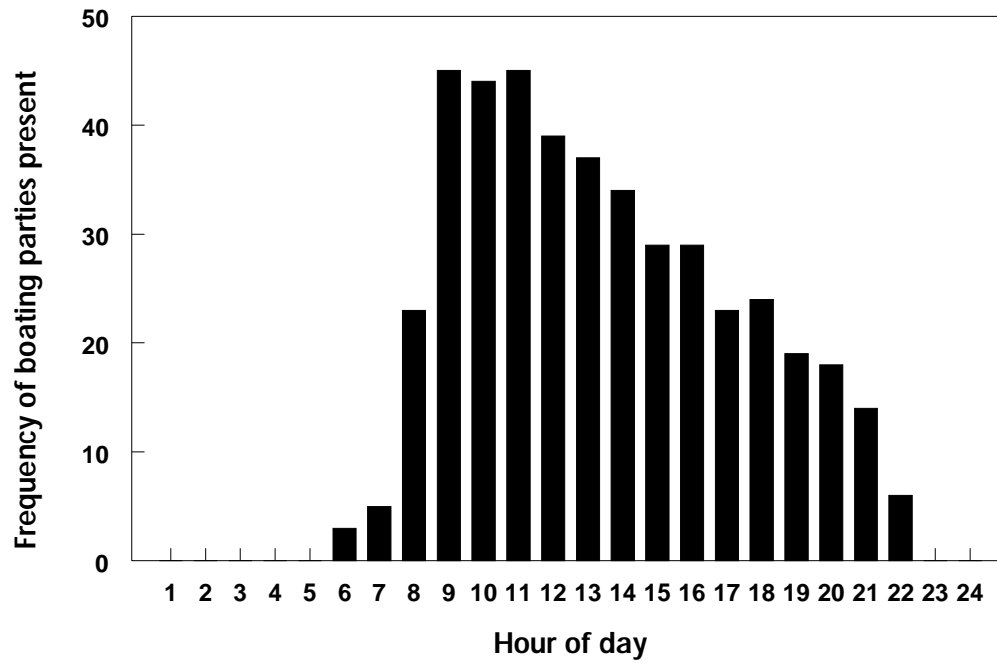


Figure 3.—Hourly distribution of boating-party interviews during June weekend days in Lake Superior at Isle Royale, 1998.

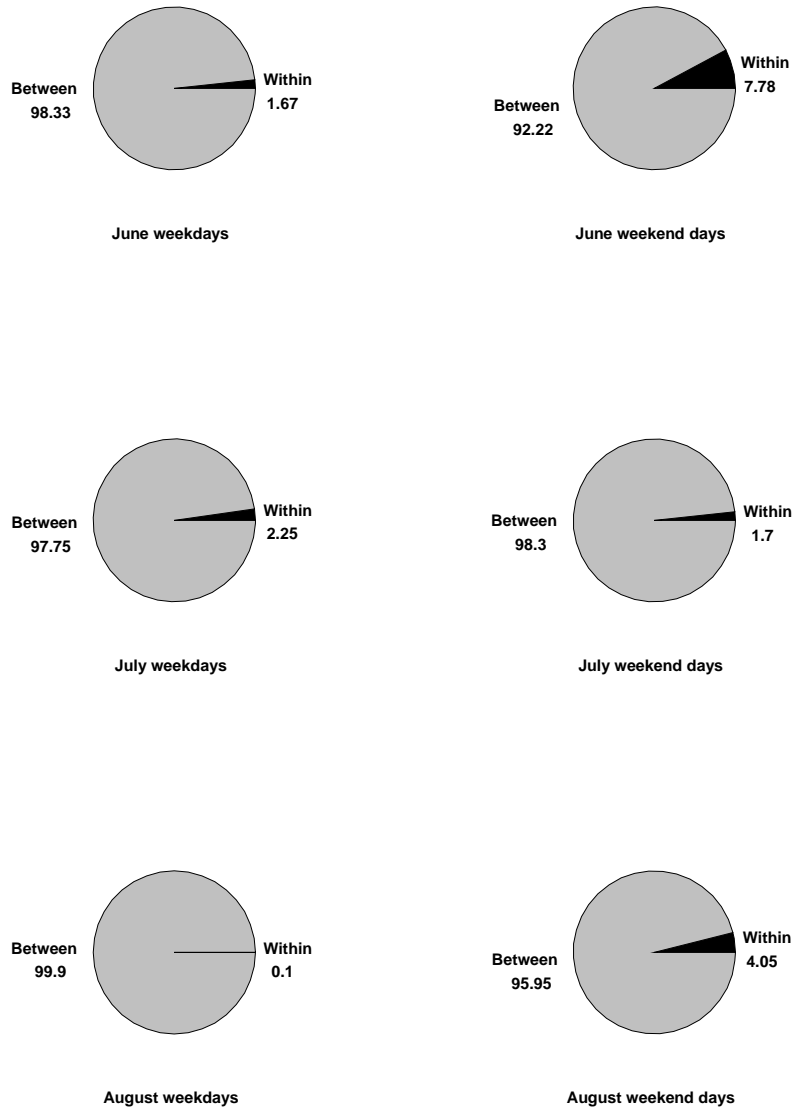


Figure 4.—Percent contribution to total variability by between-day variability and within-day variability from boat counts in Isle Royale creel survey grids 2-14, 1998.

Table 1.—Species code (from interview form), common name, and scientific name of fish species encountered or expected in the Lake Superior creel survey at Isle Royale, 1998.

Species code	Common name	Scientific name
WAE	Walleye	<i>Stizostedion vitreum vitreum</i>
NOP	Northern pike	<i>Esox lucius</i>
RKB	Rock bass	<i>Ambloplites rupestris</i>
YEP	Yellow perch	<i>Perca flavescens</i>
BKT	Brook trout	<i>Salvelinus fontinalis</i>
CHS	Chinook salmon	<i>Oncorhynchus tshawytscha</i>
LAT	Lake trout	<i>Salvelinus namaycush</i>
RBT	Rainbow trout	<i>Oncorhynchus mykiss</i>
COH	Coho salmon	<i>Oncorhynchus kisutch</i>
LWF	Lake whitefish	<i>Coregonus clupeaformis</i>
LHR	Lake herring	<i>Coregonus artedii</i>
	Splake	<i>S. fontinalis</i> x <i>S. namaycush</i>

Table 2.—Adjustment factors used to estimate total boating effort (boat hours) in creel-survey grids 1-14 from grids 2-14 in Lake Superior at Isle Royale, 1998. Estimates are from aerial method for estimating boating effort.

Month	Day of week	Grid 1		Grid 2-14		Adjustment factor	
		Estimate	Variance	Estimate	Variance	Estimate	Variance
June	Weekday	0	0	3,985	766,318	-	-
June	Weekend	230	29	1,874	242,716	1.1228	0.0878
July	Weekday	272	27,939	7,181	711,266	1.0379	0.4219
July	Weekend	330	6	3,803	89	1.0868	0.0001
August	Weekday	0	0	7,352	777,574	-	-
August	Weekend	171	3	4,551	187	1.0376	0.0001
Season		1,003	27,976	28,746	2,498,150	1.0349	0.0333

Table 3.—Relationship of radar boat counts to visual boat counts, from the *Voyageur II*, by grid and day type, based on linear regression analysis in the Lake Superior creel survey at Isle Royale, 1998.

Grid	Day type	r ²	F	Slope	SE of slope
2	Weekday	0.81	<0.01	0.94	0.15
2	Weekend	1.00	0.00	1.00	0.00
3	Weekday	0.17	0.05	0.75	0.35
3	Weekend	0.64	<0.01	1.22	0.18
4	Weekday	0.22	0.12	1.00	0.59
4	Weekend	0.75	<0.01	1.42	0.24
5	Weekday	0.84	<0.01	1.13	0.16
5	Weekend	0.89	<0.01	1.11	0.12
6	Weekday	0.56	<0.01	1.05	0.30
6	Weekend	0.47	0.01	1.32	0.43
7	Weekday	0.85	<0.01	1.06	0.14
7	Weekend	0.96	<0.01	1.15	0.07
8	Weekday	0.92	<0.01	1.02	0.09
8	Weekend	0.11	0.26	0.77	0.64
9	Weekday	0.51	<0.01	0.88	0.20
9	Weekend	<0.01	0.91	-0.11	0.96
10	Weekday	0.39	<0.01	0.74	0.20
10	Weekend	0.75	<0.01	1.36	0.16
11	Weekday	0.99	<0.01	1.14	0.02
11	Weekend	0.74	<0.01	0.99	0.17
12	Weekday	0.98	<0.01	1.22	0.06
12	Weekend	0.56	<0.01	0.93	0.24
13	Weekday	0.75	<0.01	1.09	0.20
13	Weekend	0.84	<0.01	1.00	0.13
14	Weekday	0.14	0.22	0.74	0.57
14	Weekend	0.84	<0.01	1.11	0.14

Table 4.—Fraction of interviewed boating parties categorized as fishing or non-fishing by month and day type in the Lake Superior creel survey at Isle Royale, 1998. Total boating interviews (fishing + non-fishing) are noted by “n”.

Day type	Category	June	July	August
Weekday	Fishing	0.8831	0.6207	0.6080
	Non-fishing	0.1169	0.3793	0.3920
	Variance	(0.0013)	(0.0009)	(0.0014)
	n	77	261	176
Weekend	Fishing	0.9048	0.6795	0.5784
	Non-fishing	0.0952	0.3205	0.4216
	Variance	(0.0014)	(0.0014)	(0.0024)
	n	84	156	102

Table 5.—Percentage of boating parties interviewed at three locations in the Lake Superior creel survey at Isle Royale, 1998. Sample size is reported immediately below percentages.

Interview location	June	July	August	Season
Grand Portage	19.88 32	29.98 125	22.30 62	25.58 219
Voyageur II	60.24 97	64.02 267	69.79 194	65.19 558
Ranger III	19.88 32	6.00 25	6.47 18	8.76 75
Unknown	0.00 0	0.00 0	1.44 4	0.47 4
Total parties	161	417	278	856

Table 6.—Number of non-charter fishing parties interviewed by grid, month and day type in the Lake Superior creel survey at Isle Royale, 1998.

Grid	June		July		August		Total
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	
1	8	6	17	8	1	4	44
2	5	3	10	3	15	7	43
3	9	7	22	13	9	14	74
4	11	12	10	2	5	0	40
5	3	2	7	6	4	1	23
6	7	12	17	16	6	3	61
7	0	2	15	7	5	4	33
8	1	1	3	6	20	7	38
9	0	1	8	10	7	0	26
10	9	17	13	20	11	4	74
11	1	5	7	5	4	5	27
12	2	1	6	2	3	1	15
13	1	5	5	2	2	0	15
14	11	5	21	5	15	8	65
Total	68	79	161	105	107	58	578

Table 7.—Boating effort in Lake Superior at Isle Royale, 1998. Effort is measured in boat hours. Two standard errors are given in parentheses.

Boating mode	Effort			
	June	July	August	Season
Charter fishing boat	12	372	312	696
Fishing boat (non-charter)	5,432 (1,519)	6,503 (5,025)	7,405 (1,060)	19,340 (5,356)
Pleasure boat (non-fishing)	659 (345)	3,600 (3,084)	4,978 (892)	9,237 (3,229)
Total boat	6,103 (1,660)	10,475 (8,066)	12,695 (1,267)	29,273 (8,332)

Table 8.—Non-charter fishing boat effort by month and season for each creel-survey grid at Lake Superior at Isle Royale, 1998. Two standard errors are given in parentheses.

Survey grid	Fishing boat effort			
	June	July	August	Season
1	243 (1,180)	350 (4,943)	85 (98)	678 (5,083)
2	141 (120)	120 (123)	102 (68)	363 (184)
3	1,171 (431)	1,279 (218)	1,266 (199)	3,715 (522)
4	467 (255)	726 (195)	1,186 (438)	2,379 (543)
5	149 (139)	458 (156)	657 (284)	1,264 (352)
6	222 (164)	434 (84)	410 (175)	1,065 (255)
7	134 (146)	616 (250)	518 (136)	1,269 (320)
8	327 (221)	197 (111)	625 (275)	1,148 (370)
9	217 (215)	143 (53)	213 (109)	572 (247)
10	558 (146)	569 (112)	571 (126)	1,698 (223)
11	127 (128)	258 (193)	505 (240)	890 (333)
12	234 (156)	120 (76)	250 (158)	605 (234)
13	197 (207)	208 (120)	284 (95)	689 (257)
14	1,244 (540)	1,026 (347)	734 (263)	3,004 (694)

Table 9.—Estimated total harvest, catch and release, and angling effort by non-charter boat anglers fishing Lake Superior at Isle Royale, 1998. All estimates are given with 2 standard errors in parentheses.

Species	Catch/hour	Catch			
		June	July	August	Season
Chinook salmon - kept	0.0009 (0.0008)	0 (0)	15 (13)	43 (47)	58 (49)
Coho salmon - kept	0.0032 (0.0019)	18 (27)	22 (22)	159 (99)	199 (105)
Coho salmon - released	0.0002 (0.0003)	0 (0)	15 (23)	0 (0)	15 (23)
Lake trout - kept	0.1545 (0.0609)	2,119 (760)	3,027 (2,307)	4,466 (987)	9,612 (2,622)
Lake trout - released	0.1729 (0.0698)	4,098 (1,879)	2,682 (1,984)	3,980 (1,411)	10,760 (3,075)
Lake whitefish - kept	0.0006 (0.0007)	6 (14)	21 (43)	10 (2)	37 (45)
Lake whitefish - released	0.0001 (0.0001)	0 (0)	5 (7)	0 (0)	5 (7)
Northern pike - kept	0.0023 (0.0023)	89 (115)	0 (0)	53 (74)	142 (137)
Northern pike - released	0.0021 (0.0025)	104 (145)	27 (44)	0 (0)	131 (152)
Rainbow trout - kept	0.0017 (0.0012)	10 (19)	22 (25)	72 (57)	104 (65)
Rainbow trout - released	0.0001 (0.0001)	0 (0)	5 (7)	0 (0)	5 (7)
Rock bass - released	0.0002 (0.0001)	0 (0)	0 (0)	10 (2)	10 (2)
Salmon sp. - released	0.0001 (<0.0001)	0 (0)	5 (1)	0 (0)	5 (1)
Splake - kept	0.0007 (0.0008)	10 (19)	21 (43)	10 (2)	41 (47)
Walleye - kept	0.0001 (0.0001)	0 (0)	5 (7)	0 (0)	5 (7)
Total - kept	0.1587 (0.0619)	2,218 (769)	3,088 (2,308)	4,572 (991)	9,878 (2,627)
Total - released	0.1808 (0.0715)	4,236 (1,885)	2,784 (1,985)	4,231 (1,416)	11,251 (3,082)
Total catch	0.3395 (0.1166)	6,454 (2,036)	5,872 (3,044)	8,803 (1,728)	21,129 (4,049)
Angler hours		16,349 (4,800)	21,421 (16,651)	24,462 (3,755)	62,232 (17,731)
Angler trips		3,148 (974)	4,615 (3,570)	5,623 (1,011)	13,386 (3,836)

Table 10.—Total harvest and angling effort by charter boat anglers fishing Lake Superior at Isle Royale, 1998. No released fish were reported by charter boat services, only kept fish were reported.

Species	Catch/hour	Harvest			Season
		June	July	August	
Brown trout - kept	0.0003		1		1
Chinook salmon - kept	0.0102		1	31	32
Coho salmon - kept	0.0127		8	32	40
Lake trout - kept	0.2767	11	484	376	871
Rainbow trout - kept	0.0076		9	15	24
Total - kept	0.3075	11	503	454	968
Angler hours		24	1,659	1,465	3,148
Angler trips		3	55	43	101

Table 11.—Estimated total harvest, catch and release, and angling effort by non-charter and charter boat anglers fishing Lake Superior at Isle Royale, 1998. All estimates are given with 2 standard errors in parentheses. Note: Charter boat catch and effort does not include released fish, only harvested fish were reported.

Species	Catch/hour	Catch			
		June	July	August	Season
Brown trout - kept	<0.0001 (<0.0001)	0 (0)	1 (0)	0 (0)	1 (0)
Chinook salmon - kept	0.0014 (0.0009)	0 (0)	16 (13)	74 (47)	90 (49)
Coho salmon - kept	0.0037 (0.0019)	18 (27)	30 (22)	191 (99)	239 (105)
Coho salmon - released	0.0002 (0.0003)	0 (0)	15 (23)	0 (0)	15 (23)
Lake trout - kept	0.1603 (0.0591)	2,130 (760)	3,511 (2,307)	4,842 (987)	10,483 (2,622)
Lake trout - released	0.1646 (0.0648)	4,098 (1,879)	2,682 (1,984)	3,980 (1,411)	10,760 (3,075)
Lake whitefish - kept	0.0006 (0.0007)	6 (14)	21 (43)	10 (2)	37 (45)
Lake whitefish - released	0.0001 (0.0001)	0 (0)	5 (7)	0 (0)	5 (7)
Northern pike - kept	0.0022 (0.0022)	89 (115)	0 (0)	53 (74)	142 (137)
Northern pike - released	0.0020 (0.0024)	104 (145)	27 (44)	0 (0)	131 (152)
Rainbow trout - kept	0.0020 (0.0012)	10 (19)	31 (25)	87 (57)	128 (65)
Rainbow trout - released	0.0001 (0.0001)	0 (0)	5 (7)	0 (0)	5 (7)
Rock bass - released	0.0002 (0.0001)	0 (0)	0 (0)	10 (2)	10 (2)
Salmon sp. - released	0.0001 (<0.0001)	0 (0)	5 (1)	0 (0)	5 (1)
Splake - kept	0.0006 (0.0007)	10 (19)	21 (43)	10 (2)	41 (47)
Walleye - kept	0.0001 (0.0001)	0 (0)	5 (7)	0 (0)	5 (7)
Total - kept	0.1659 (0.0603)	2,229 (769)	3,591 (2,308)	5,026 (991)	10,846 (2,627)
Total - released	0.1721 (0.0663)	4,236 (1,885)	2,784 (1,985)	4,231 (1,416)	11,251 (3,082)
Total catch	0.3380 (0.1106)	6,465 (2,036)	6,375 (3,044)	9,257 (1,728)	22,097 (4,049)
Angler hours		16,373 (4,800)	23,080 (16,651)	25,927 (3,755)	65,380 (17,731)
Angler trips		3,151 (974)	4,670 (3,570)	5,666 (1,011)	13,487 (3,836)

Table 12.—Percentage of non-charter anglers interviewed by state of residency for each month and season total in the Lake Superior creel survey at Isle Royale, 1998. Two standard errors are given in parentheses.

State of residence	Percent of non-charter of anglers			
	June	July	August	Season
Alabama	0 (0)	0 (0)	0.61 (1.21)	0.17 (0.35)
California	0 (0)	0 (0)	0.61 (1.21)	0.17 (0.35)
Michigan	55.55 (8.28)	34.46 (5.82)	41.21 (7.66)	41.67 (4.11)
Minnesota	43.06 (8.25)	58.05 (6.04)	53.93 (7.76)	53.14 (4.16)
Indiana	0 (0)	0 (0)	0.61 (1.21)	0.17 (0.35)
New Mexico	0 (0)	0 (0)	0.61 (1.21)	0.17 (0.35)
Texas	0 (0)	1.50 (1.49)	0 (0)	0.69 (0.69)
Wisconsin	1.39 (1.95)	5.99 (2.91)	2.42 (2.39)	3.82 (1.60)
Total anglers interviewed	144	267	165	576

Table 13.—Percentage of non-fishing boaters interviewed by state or country of residency for each month and season total in the Lake Superior creel survey at Isle Royale, 1998. Two standard errors are given in parentheses.

State of residence	Percent of non-fishing of boaters			
	June	July	August	Season
Australia	0 (0)	0 (0)	5.50 (4.37)	2.23 (1.80)
Canada	0 (0)	2.80 (2.76)	6.42 (4.70)	4.09 (2.41)
Illinois	11.76 (15.63)	4.90 (3.61)	0 (0)	3.35 (2.19)
Massachusetts	0 (0)	0 (0)	1.83 (2.57)	0.74 (1.05)
Michigan	52.95 (24.21)	33.56 (7.90)	30.28 (8.80)	33.46 (5.75)
Minnesota	35.29 (23.18)	38.45 (8.14)	34.86 (9.13)	36.80 (5.88)
Missouri	0 (0)	0 (0)	0.92 (1.83)	0.37 (0.74)
North Dakota	0 (0)	4.90 (3.61)	0 (0)	2.60 (1.94)
Texas	0 (0)	3.50 (3.50)	0 (0)	1.86 (1.65)
Vermont	0 (0)	0 (0)	4.59 (4.01)	1.86 (1.65)
Virginia	0 (0)	2.10 (2.40)	0 (0)	1.12 (1.28)
Wisconsin	0 (0)	9.79 (4.97)	15.60 (6.95)	11.52 (3.89)
Total boaters interviewed	17	143	109	269

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