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Comparison of Interval and Aerial Count Methods for Estimating Boating Effort in Lake Michigan Statistical District MM-6

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Abstract.–Interval and aerial angler creel survey counting methods were compared for Lake Michigan Statistical District MM-6 to evaluate potential underestimation of the interval method in 2000 and 2001. Two, 0.5-h interval boat counts were made per sample day at all five access ports. On the same sample days, boats in 3 out of 18 MM-6 grids were counted from aircraft. Both seasonal and monthly estimates of boating effort were compared. Seasonal boating effort estimates based on aerial and interval counts during open water periods in 2000 and 2001 were not significantly different ($P > 0.17$). Estimated boating hours using the interval count method were 247,117 in 2000 and 219,097 in 2001. Estimated boating hours using the aerial count method were 250,387 in 2000 and 177,532 in 2001. Similarly, comparisons of boating effort by month within each year did not detect significant differences ($P > 0.01$). Aerial estimates were more precise than interval estimates. Interval precision (2 SE/estimate) was 21.42% in 2000 and 24.54% in 2001. Aerial precision was 14.84% in 2000 and 15.53% in 2001. Similarly, predicted power ($1-\beta$) was greater for aerial estimates than interval estimates. Potential power of future interval estimates to detect a 25% change with $\alpha = 0.05$ was 0.38 based on 2000 data and 0.30 based on 2001 data. Aerial estimates provided power estimates of 0.66 based on 2000 data and 0.62 based on 2001 data. At least four, 0.5-h interval counts per sample day are needed to match the precision and power of three aerial counts. While both count types were made on the same sample days and at approximately the same (random) times each sample day, each method relied on unique estimation methods. Comparable, independent estimates establish reliability of these two methods.

Introduction

Fisheries Division of the Michigan Department of Natural Resources conducts direct contact, complemented, angler creel surveys on the Great Lakes annually to estimate angling effort, harvest, and harvest rate (e.g., Rakoczy and Svoboda 1997). These surveys follow instantaneous-access, interval-access, or aerial-access designs (Lockwood 2000). Design type (e.g., interval-access) is determined by the physical nature of a fishing site and the characteristics of the fishery. Instantaneous-access designs are best used at sites where access points are well defined and all anglers or boats are visible from shore. Interval-access designs are best used at sites where access points are well defined, not all boats are visible from shore, and all anglers travel from a mooring facility (or access site). Aerial-access designs are best used at sites where access points are not well defined and boats are not visible from shore. The last design is most appropriate for fisheries where there are many private access points (e.g., cottages or homes) and/or small public access points (e.g., road endings).

Most of Michigan's Great Lakes fisheries have well defined port access sites. Anglers usually trailer their boats to a port or moor their boats at a port. Wave action, steep bluffs, and limited public land restrict access to areas between ports. Consequently, the interval-access design is often used to provide fishery data by port.

Port estimates of angling effort and harvest (using interval-access design) are then summed to provide statistical district or lake-wide estimates of angling activity (e.g., Rakoczy and Svoboda 1997). Appropriateness of this method has relied on the limited access to Great Lakes waters. It has been assumed that sampling large access points provide an approximate estimate of angling activity within Michigan waters. The current interval-access design would underestimate angling effort and catch if substantial access to the fishery occurs in areas between access ports.

Catch and effort estimates are used to manage sport fisheries, both locally and lakewide, in cooperation with neighboring states and the Treaty of 1836 Consent Decree. In addition, these estimates provide status and trends data on Michigan's angling population, and data for numerous research studies. Consequently, it is essential that Michigan's Great Lakes angler survey methods be reliable (i.e., accurate and precise).

An alternative to an interval-access design is an aerial-access design. It is appropriate to use the aerial-access design if all boats within a lake area can be counted irrespective of where they originate. If so, then underestimation of boating effort should not occur.

The goal of the Michigan angler survey program is to use survey designs that produce accurate and precise estimates of angling activity as inexpensively as possible. We hypothesized that current methods do not significantly underestimate boating effort because counts are limited to the major ports along Lake Michigan in the MM-6 Statistical District. The purpose of this study was to compare independent sampling methods to evaluate this hypothesis. The objective of this study was to compare accuracy, precision, and power of interval count and aerial count designs.

Methods

Study Area

Michigan waters of Lake Michigan are divided into eight statistical districts (Figure 1; Smith et al. 1961). Statistical District MM-6 was chosen to compare port estimates with aerial estimates of boating effort. Statistical District MM-6 is 1,677.2 mi^2 in size and is further divided into 18 grids varying in size from 37.0 mi^2 to 114.2 mi^2 (Figure 2; Table 1). The interval count method was historically used at all five ports for estimating boating effort. Thus, our study results would not be obscured by multiple survey designs. Statistical District MM-6 has characteristic limited access to Lake Michigan between ports and a substantial amount of angler boating effort occurs within MM-6. In addition, few if any anglers accessing Lake Michigan from other ports (north and south of Statistical District MM-6 boundaries) would fish in MM-6. These adjacent ports are located considerable distances from MM-6 boundaries.

Estimation Methods

Interval Count.–Interval-access angler creel surveys were conducted at the five MM-6 ports (Figure 1). Survey period was from June 1 to September 30 during 2000 and 2001. Count and interview data were collected by port, and all estimates were made by port. We stratified samples by day type (weekday and weekend day) within each month (Pollock et al. 1994). Counting times were randomly selected on every weekend day and three randomly selected weekdays per week. Holidays were not sampled, but were included in the weekend strata for each monthly expansion. Holidays during sample periods were July 4, 2000 and 2001, and Labor Day (September 4, 2000 and September 3, 2001). Interval count and access interview methods are described in Lockwood et al. (1999) and Fabrizio et al. (1991) with specific estimation methodology provided here for clarity.

In MM-6, survey clerks counted all boats that passed an access site during 0.5 h, twice per day. Sailboats and commercial non-fishing boats (e.g., freighters) were not counted. However, all powerboats were counted because airborne observers could not distinguish between fishing and non-fishing powerboats. (Ground-based counters can usually distinguish between the two.)

Interview data collected per fishing boat (party) included: start and finish time of the trip, number of persons, date, species targeted, fishing method, and number of fish harvested by species.

Note that for surveys in which clerks cannot differentiate between fishing and non-fishing powerboats, all fishing and non-fishing power boating parties are interviewed, and ratios of fishing to total boating parties are used to estimate fishing boat effort from total boating effort (Lockwood et al. 1999). This was not done here because the same ratios would have been applied to both interval and aerial estimates and would have only served to increase variation. However, this means that the estimates of boating effort presented in this report include fishing effort plus power boating activity.

In 2001, one of the five ports (Pentwater) could not be used to estimate effort because of improper collection of interval count data. Aerial estimates were adjusted by removing the grid counts that were adjacent to the missing port (southern tier of grids 7, 10, 11, and 12).

Estimated number of boats *B* on day *d* from interval count *j* at port *s* was estimated as:

$$B_{sdj} = F_{sd} \frac{b_{sdj}}{L_{sdj}}, \tag{1}$$

where *F* is the number of fishable hours (hours within the sample period day *d*), *b* the number of boats counted, and *L* the duration (in hours) of the count. Mean number of boats $\overline{B}$ on day *d* then was:

$$\overline{B}_{sd} = \frac{\sum_{j=1}^{n_{sd}} B_{sdj}}{n_{sd}}, \tag{2}$$

with *n* counts made on day *d*. Estimated variance of mean number of boats $\overline{B}$ on day *d* was:

$$V\hat{a}r(\overline{B}_{sd}) = \frac{1}{n_{sd}(n_{sd}-1)} \sum_{j=1}^{n_{sd}} (\overline{B}_{sd} - B_{sdj})^2 . \tag{3}$$

From the access interview data set, mean length of boat-party trip $\overline{e}$ on day *d* was estimated as:

$$\overline{e}_{sd} = \frac{1}{k_{sd}} \sum_{i=1}^{k_{sd}} \tilde{h}_{sdi} , \tag{4}$$

for *k* boat angling parties interviewed on day *d* with $\tilde{h}$ boat hours by party *i*. Estimated variance of mean length of party trip $\overline{e}_{sd}$ was:

$$V\hat{a}r(\bar{e}_{sd}) = \frac{1}{k_{sd}(k_{sd}-1)}\sum_{i=1}^{k_{sd}}(\bar{e}_{sd} - \tilde{h}_{sdi})^2 \quad (5)$$

Estimated boat hours on day *d* were:

$$E_{sd} = \bar{B}_{sd}\bar{e}_{sd}\,, \quad (6)$$

with estimated variance (Goodman 1960):

$$V\hat{a}r(E_{sd}) = \bar{B}_{sd}^2 V\hat{a}r(\bar{e}_{sd}) + \bar{e}_{sd}^2 V\hat{a}r(\bar{B}_{sd}) - V\hat{a}r(\bar{e}_{sd})V\hat{a}r(\bar{B}_{sd})\,. \quad (7)$$

Daily boat effort estimates were summed by day type (weekday or weekend day) for period *p* (month) for each port:

$$E_{sp} = \frac{D_{sp}\sum_{d=1}^{m_{sp}} E_{sd}}{m_{sp}}\,, \quad (8)$$

having a total of *D* days with *m* days sampled. Variance of E_p was estimated as:

$$V\hat{a}r(E_{sp}) = \frac{D_{sp}^2}{m_{sp}}\left(1 - \frac{m_{sp}}{D_{sp}}\right)\left[\frac{\sum_{d=1}^{m_{sp}}(\bar{E}_{sp} - E_{sd})^2}{(m_{sp}-1)}\right] + \frac{D_{sp}}{m_{sp}}\sum_{d=1}^{m_{sp}} V\hat{a}r(E_{sd})\,. \quad (9)$$

Aerial Count.–Aerial counts of boating effort were made on the same day and at approximately the same time as one of the shore-based counts. One flight was made per sample day. We stratified aerial counts by grid distance from land (Figure 2) because we reasoned that nearshore grids would have greater boating effort and greater variance than offshore grids. The stratification made it possible to devote more sampling effort to strata with greater boating effort and variance; therefore, pilots counted two grids nearshore and only one grid offshore per sample day.

Individual offshore strata *l* counts *C* were expanded by the number of area units *A*, and total sample period day type (weekday or weekend day) hours *F* within period *p* to give an estimate of boating effort based on day *j*:

$$E_j = C_j A F_p\,. \quad (10)$$

Averaging for m_p days sampled within multiple-day period *p*, estimated day type effort was:

$$\hat{E}_{lp} = \frac{\sum_{i=1}^{m_p} E_{pi}}{m_p}\,. \quad (11)$$

Variance of $\hat{E}_{lp}$ was estimated as:

$$V\hat{a}r(\hat{E}_{lp}) = \frac{D_p - m_p}{D_p}\,\frac{\sum_{i=1}^{m_p}(\hat{E}_{lp} - E_{pi})^2}{m_p(m_p-1)}\,. \quad (12)$$

For the near shore stratum *h* estimated boat effort based on day *j* for period *p* with total sample period day type hours *F* was:

$$\overline{E}_j = \frac{\sum_{i=1}^{n} C_i A F_p}{n} . \quad (13)$$

Estimated variance of $\overline{E}_{hp}$ was:

$$V\hat{a}r(\overline{E}_{hp}) = \frac{\sum_{i=1}^{n} (\overline{E}_{hp} - C_i A F_p)^2}{n(n-1)} . \quad (14)$$

Total estimated boating effort with *m* days sampled in multiple-day period *p* was:

$$\hat{E}_{hp} = \frac{\sum_{i=1}^{m_p} \overline{E}_{hi}}{m_p} , \quad (15)$$

with estimated variance of $\hat{E}_{hp}$:

$$V\hat{a}r(\hat{E}_{hp}) = \frac{D_p^2}{m_p}\left(1 - \frac{m_p}{D_p}\right)\left[\frac{\sum_{d=1}^{m_p} (\hat{E}_{hp} - \overline{E}_{hd})^2}{(m_p - 1)}\right] + \frac{D_p}{m_p}\sum_{d=1}^{m_p} V\hat{a}r(\overline{E}_{hd}) . \quad (16)$$

Near shore and offshore estimates $\hat{E}_l$ and $\hat{E}_h$ were summed for total statistical district estimate of multiple-day period *p* boating effort. Similarly, $V\hat{a}r(\hat{E}_l)$ and $V\hat{a}r(\hat{E}_h)$ were summed to estimate variance of total statistical district estimate of multiple-day period *p* boating effort.

Comparison of Interval and Aerial Estimates.–We computed annual fishing effort with both estimation methods and compared the two estimates for each month and season with multiple t-tests with Bonferonni adjustments (Miller 1981; Snedecor and Cochran 1989). In some cases the equal variance assumption, required for parametric statistical tests, was violated. In these cases, the Welch approximation was used to estimate degrees of freedom (Remington and Schork 1970).

To further evaluate near-shore and offshore stratification, variance of annual estimates was compared with multiple F-tests with Bonferonni adjustments (Miller 1981; Snedecor and Cochran 1989). Note that P was significant at 0.05 when P-value was less than 0.05/18 = 0.0028.

Comparisons were considered different at $\alpha_{0.05}$ adjusted by number of comparisons. Unless otherwise noted, estimates are given with 2 SE.

Precision and Power.–Precision *P* of annual estimates was made by sample year and estimated as:

$$P = \frac{2(SD/\sqrt{N})}{\hat{E}} , \quad (17)$$

with *N* counts made per year. Measures of precision using SE relative to the estimate provide direct measures of variability and are common measures of angler survey precision (e.g., Fabrizio et al.

1991; Newman et al. 1997). Interval survey precision was evaluated for 2 to 16 counts per sample day (421 to 3,368 total counts in year 2000; 316 to 2,528 total counts in year 2001). Precision of aerial estimates was evaluated for 3 to 16 counts per sample day (225 to 1,125 total counts in year 2000; 140 to 700 total counts in year 2001).

Potential power (1-β) was evaluated for each sample year using PASS (power analysis and sample size) software (NCSS, version 6.0). Interval counts were varied from 2 to 16 counts per day for power to detect a 25% change in boating effort (t-test, equal variance, $\alpha = 0.05$). Similarly, potential power of aerial estimates was evaluated for 3 to 16 counts per sample day.

Results

Aerial and Interval Estimates

In 2000, the aerial estimate of seasonal effort was not significantly different from the interval estimate ($P = 0.92$, df = 643; Table 2). The aerial estimate of boating effort was 250,387 hours and the interval estimate was 247,117 hours. Similarly, for the eight day-type, within-month comparisons no significant differences ($P < 0.0028$) were detected ($P = 0.29$ to 0.99, df = 58 to 95; Figure 3 and Table 3).

In 2001, the aerial estimate of seasonal effort was not significantly different from the interval estimate ($P = 0.17$, df = 434; Table 2). The aerial estimate of boating effort was 177,532 hours and the interval estimate was 219,097 hours. Similarly, for the eight day-type, within-month comparisons no significant differences ($P < 0.0028$) were detected ($P = 0.01$ to 0.99, df = 34 to 70; Figure 4 and Table 3).

Offshore and Nearshore Estimates

Estimated variances were significantly different for both sample years. Estimated offshore variance in 2000 was 2,389,589, significantly smaller than the estimated nearshore variance of 342,633,138 ($P < 0.0001$, df = 74,149). During 2001, offshore variance was also smaller, 1,560,456 and was significantly different from estimated nearshore variance of 188,468,008 ($P < 0.0001$, df = 39,99).

Precision and Power

Interval count estimates were most precise in 2000 (Figure 5 and Table 4). Two counts per sample day provided precision of 21.42% in 2000 and 24.54% in 2001. Aerial estimates followed a similar trend, with 2000 estimates more precise than 2001 estimates. Aerial estimates had precision of 14.84% in 2000 and 15.58% in 2001.

Aerial estimates were more precise than interval estimates each sample year. To attain similar precision (~15%) using 2000 interval count data, 842 season counts (4 counts per day) would be necessary and 1,053 season counts (5 counts per day) would be necessary based on 2001 data (Table 4).

Both aerial and interval methods would require increases in counting effort to attain precision of ~10% (Table 4). Interval count data from 2000 would require 1,895 season counts (9 counts per day) and 2001 interval count data would require 1,896 season counts (12 counts per day). Aerial count data from 2000 would require 450 season counts (6 counts per day) and 2001 aerial count data would require 327 season counts (7 counts per day).

Evaluation of power, likelihood of making a Type II Error, also indicated that additional aerial or interval counts were necessary. Potential power of future interval count surveys (Hoenig and Heisen

2001) to detect a 25% change in effort with $\alpha = 0.05$ provided power of 0.38 based on 2000 data with 421 season counts and 0.30 based on 2001 data with 316 season counts (Figure 6 and Table 5).

Potential power of future aerial surveys ($\Delta = 25\%$, $\alpha = 0.05$) was greater for each sample year. Year 2000 data provided potential power of 0.66 with 225 season counts, and 2001 data provided potential power of 0.62 with 140 season counts. To attain similar power using interval counts, 2000 data predict 842 season counts (4 per day) and 2001 data predict 790 season counts (5 per day) would be required.

Both aerial and interval methods required substantial increases in counting effort to attain power of ~0.90. Interval count data from 2000 would require 1,684 season counts (8 per day) and 2001 interval count data would require 1,580 season counts (10 per day). The 2000 aerial data would require 450 season counts (6 per day) and 2001 aerial data would require 280 season counts (6 per day).

Discussion

The interval-access survey design is appropriate for the Great Lakes fishery because it relies on limited, well-defined access sites. The physical characteristics of the Great Lakes and their shorelines restrict boat size and access. Wave action, sudden storms, and necessity to travel some distance from shore (often several miles) limit the use of small boats that do not require formal launch ramps. Similarly, wave action prevents construction of launch ramps on unprotected shoreline. Launch ramps are typically constructed in rivers and occasionally in sheltered bays. Frequently, these launch facilities have mooring facilities nearby. Also, much of the Great Lakes shoreline is in private ownership.

The aerial-access method allows nearly complete enumeration of boating effort over an area regardless of access point. The aerial count method is used on large inland lakes where access points are numerous and not well defined (e.g., Clark et al. 2004). There, anglers have access from cottages, public boat launches, or road endings. Assigning a clerk to count boats accessing the lake from a single, or even several, locations would underestimate boating effort.

The instantaneous count (e.g., aerial) method to estimate angling effort has been extensively evaluated and shown to provide unbiased estimates of angling effort. Pierce and Bindman (1994) made paired comparisons between continuous monitoring of a fishery (complete census) and instantaneous counts from a stratified random creel survey. Their analysis showed the instantaneous counts had a one-to-one relationship with the census. Similarly, Newman et al. (1997) compared estimated effort from random instantaneous counts with a complete census and found no significant difference ($P > 0.05$). The point estimate of effort from that study was 7% less than total census effort. Rasmussen et al. (1998) simulated instantaneous count creel surveys using complete creel census data and found no evidence of bias.

Evaluations have demonstrated the accurate, unbiased nature of instantaneous count method for estimating angling effort and, consequently, it has become the standard to evaluate alternative counting methods. Lockwood et al. (2001) evaluated the proportional method (Parker 1956; McNeish and Trial 1991) of estimating angling effort using a study site and instantaneous counts from historic Michigan angler surveys. They found that the proportional method provided reliable estimates of angling effort.

Comparisons of interval count and aerial count boating effort estimates in the study described here support our hypothesis that the interval count method does not significantly underestimate boating effort. Day-type, within month, and seasonal estimates were not significantly different during both years of the study.

This study also serves as a comparison of independent methods and reinforces reliability of interval and aerial count methods. Aerial estimates of effort use instantaneous counts of boating effort expanded by the number of hours and days within a period. Interval estimates of effort use counts of boats entering the survey area during a time interval; they are expanded by the number of time intervals in a day, the mean length of party fishing trips (from the access interview records), and the days in the period (Pollock et al. 1994:154; Lockwood et al. 1999). The interval method relies on representative random counts of effort and representative random samples of boating party length of trip. Previous evaluation of interval method has not been done.

Nearshore and offshore aerial stratification was appropriate. Estimated variances of boating effort were significantly different between nearshore and offshore areas each year. Without stratification, variability of estimates would have been increased and reliability and usefulness of comparisons would have been greatly diminished.

While each counting method provided reliable estimates of boating effort, each has advantages and disadvantages. For example, aerial counts cannot be made during periods of thunderstorms, fog, or low cloud cover. To ensure comparability of the interval and aerial estimates for this study, counts were scheduled on the same days and at approximately one of the two daily interval counting times. On days when weather prevented flights and no aerial count was made, interval counts for that day were removed from the data set. Cancellations of flights were rare and fewer than five flights were canceled each year. Conversely, ability to make interval counts is not weather dependent.

The aerial method adds additional expense because access site clerks are still required to conduct interviews. Flights cost US$12,792 during the 2000 survey and $16,485 during the 2001 survey. Shifting to an aerial design would result in expenses that may require a downsizing in regional coverage to stay within budget. Inadequate regional coverage or inadequate methods for estimating unsampled areas would limit reliability and utility of Michigan Great Lakes angler surveys.

Aerial boating effort estimates were more precise than interval estimates for each year of study. Similarly, power was greater for aerial estimates than for interval estimates. Four to five interval counts per sample day would be required to attain precision and power of three aerial counts per sample day. Attaining or exceeding the aerial precision and power values is not without cost. Currently, each clerk spends 1 h per sample day counting boats. The remaining time is spent interviewing anglers. Increasing the number of counts per day decreases the time available for interviewing, thus reducing the number of interviews collected. Jones et al. (1995) reported that approximately 100 access interviews are necessary to attain true 95% confidence intervals. Similarly, Lockwood (1997) found that 90 access interviews were necessary to detect a 20% difference in catch rates (catch per hour ≥0.10). Since, additional counts would be done at the expense of interview time, improving precision and power of effort may result in reduction of precision and power of catch rates. Hiring additional clerks would be necessary to increase precision and power of interval estimates.

This study shows the appropriateness of the interval-access design in Lake Michigan Statistical District MM-6. It suggests the interval-access design provides accurate estimates of boating effort for other districts with limited access between ports. It also implies that instantaneous-access designs used in certain other Lake Michigan statistical districts are reliable. We recommend evaluations of interval-access and instantaneous-access methods be conducted for other statistical districts. Similar to this current study, we recommend at least 2 years of data collection.

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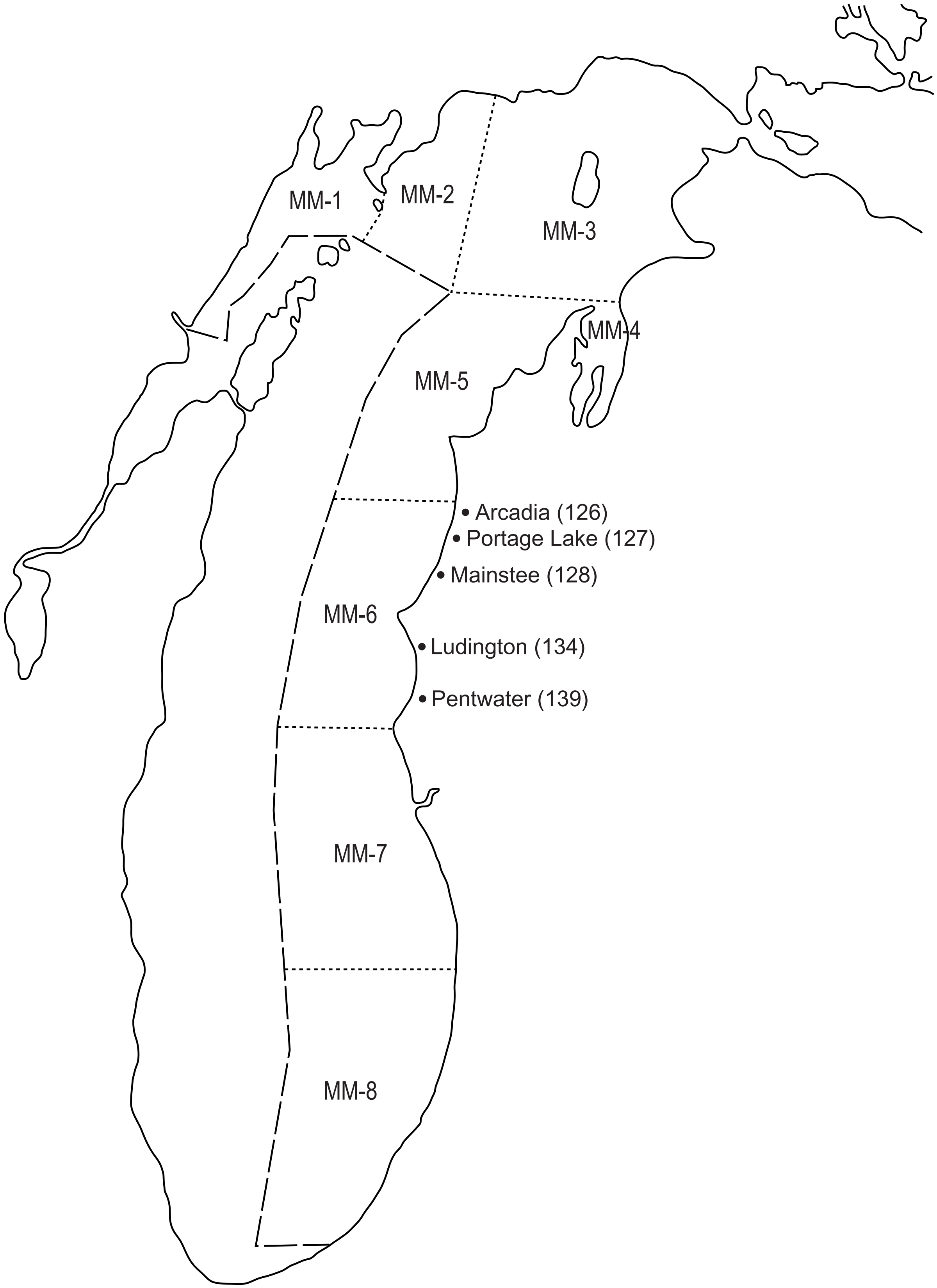

Figure 1.–Statistical Districts MM-1 through MM-8 and angler survey ports in MM-6 (site codes in parentheses) along the Michigan waters of Lake Michigan.

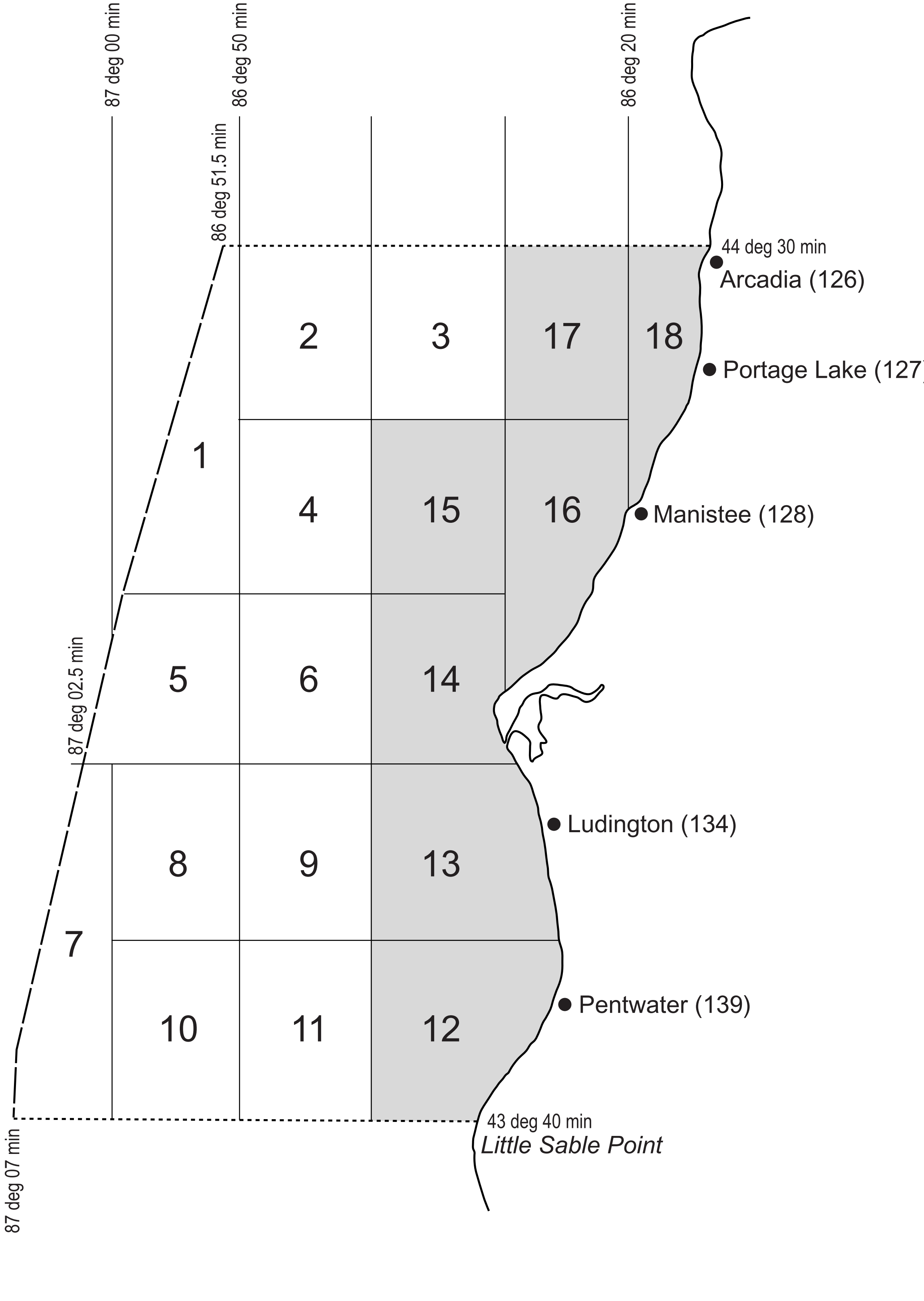

Figure 2.–Counting grids in Lake Michigan Statistical District MM-6. Grids 1-11 are offshore strata and grids 12-18 are nearshore strata. Port reference number is in parentheses.

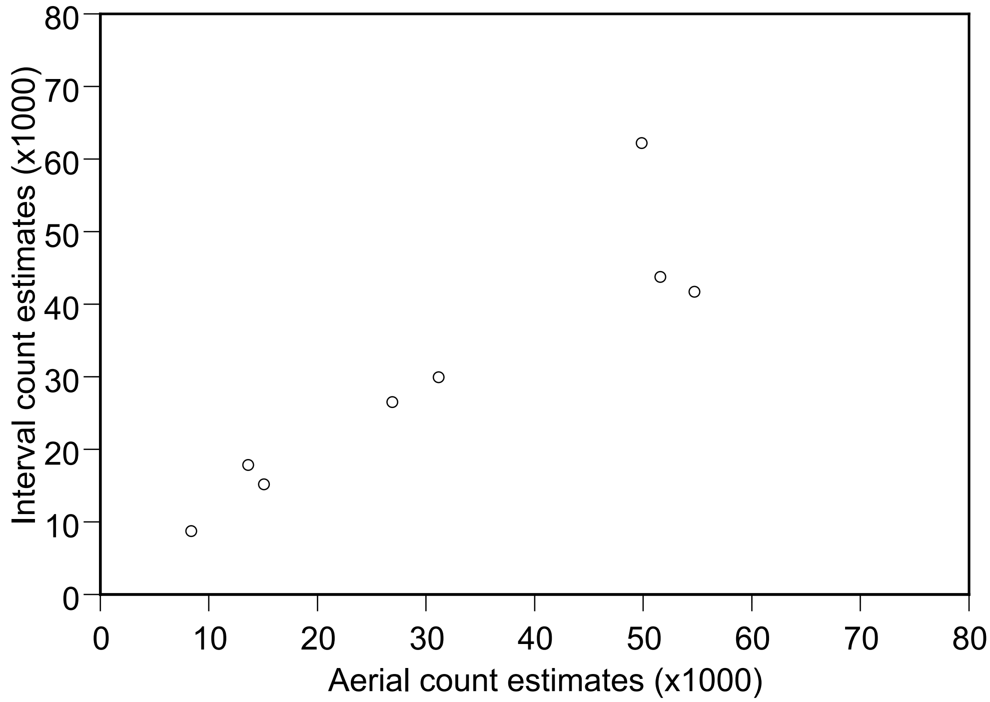

Figure 3.−Year 2000, day-type by month comparisons of interval count estimates and aerial count estimates of boat effort in Lake Michigan Statistical District MM-6.

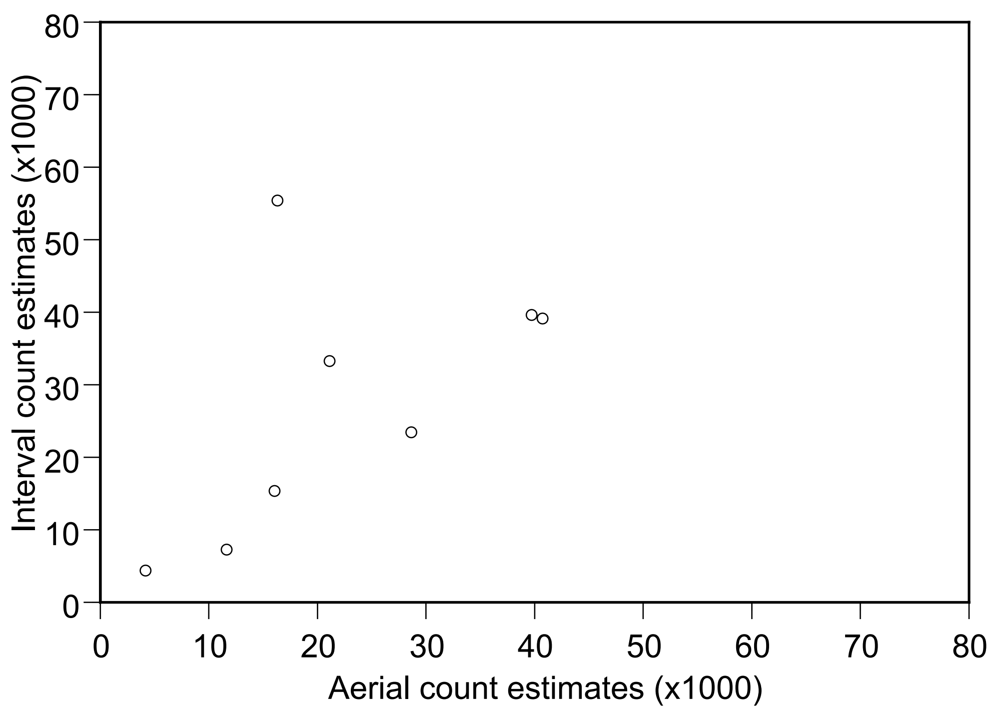

Figure 4.−Year 2001, day-type by month comparisons of interval count estimates and aerial count estimates of boat effort in Lake Michigan Statistical District MM-6.

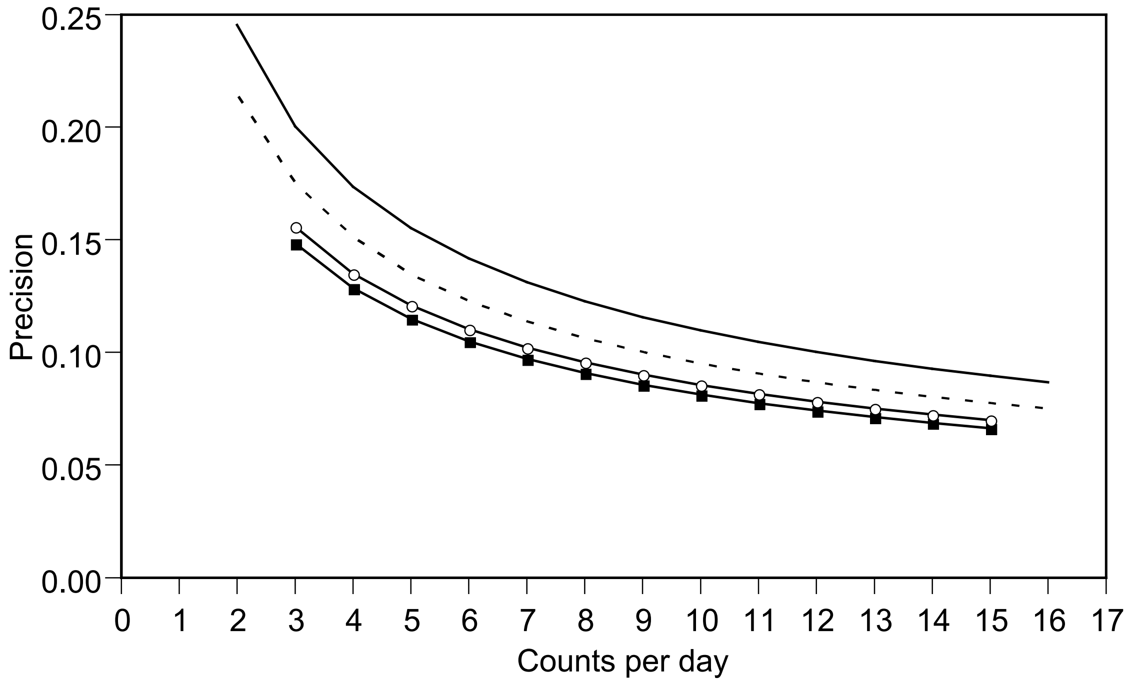

Figure 5.−Estimated precision of boating effort based on number of interval counts per day, Lake Michigan Statistical District MM-6. Dashed line is 2000 interval boat count precision, solid line is 2001 interval boat count precision, solid line with boxes is 2000 aerial boat count precision, and solid line with circles is 2001 aerial boat count precision.

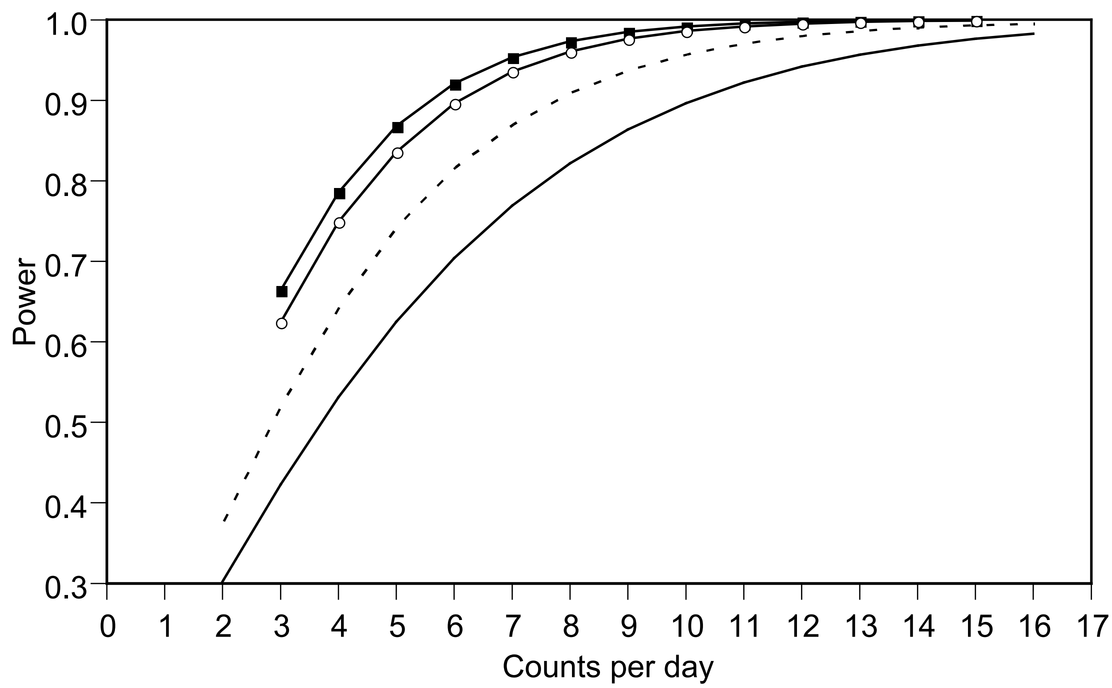

Figure 6.−Potential power to detect a 25% reduction in estimated boating effort based on current data, Lake Michigan Statistical District MM-6. Power estimates were based on t-test comparison of two estimates with equal SD. Dashed line is 2000 interval boat count power, solid line is 2001 interval boat count power, solid line with boxes is 2000 aerial boat count power, and solid line with circles is 2001 aerial boat count power.

Table 1.–Area of Statistical District MM-6 counting grids. Total area for MM-6 is 1,677.2 mi^2.

Grid	Area (mi^2)	Grid	Area (mi^2)
1	87.0	10	95.2
2	95.2	11	95.2
3	95.2	12	112.0
4	95.2	13	113.1
5	114.2	14	95.2
6	95.2	15	95.2
7	67.2	16	99.5
8	95.2	17	95.2
9	95.2	18	37.0

Table 2.–Total seasonal boating effort estimates by aerial and interval counting methods. The Bonferroni technique for multiple comparisons of aerial and interval estimates was used to adjust P values (0.05/18 = 0.0028). Estimated degrees of freedom (df) are given for each comparison. Two standard errors of estimates are given in parentheses.

Year	Aerial	Interval	df	P
2000	250,387 (37,150)	247,117 (52,931)	643	0.9194
2001	177,532 (27,570)	219,097 (53,761)	434	0.1696

Table 3.–Boating effort estimates by aerial and interval counting methods for each time period. Bonferroni technique for multiple comparisons was used to adjust P values (0.05/18 = 0.0028). Estimated degrees of freedom (df) are given for each comparison. Two standard errors of estimates are given in parentheses.

		Weekday				Weekend			
Year	Period	Aerial	Interval	df	P	Aerial	Interval	df	P
2000									
	June	8,260 (2,504)	8,888 (5,254)	95	0.8296	13,508 (5,604)	18,003 (7,502)	60	0.3410
	July	54,594 (14,451)	41,843 (15,725)	90	0.2910	31,055 (13,374)	30,081 (17,819)	69	0.9305
	August	49,752 (17,649)	62,362 (32,262)	92	0.4942	51,470 (20,395)	43,926 (18,023)	58	0.6022
	September	14,959 (11,846)	15,344 (20,507)	73	0.9736	26,788 (9,324)	26,670 (19,152)	64	0.9911
2001									
	June	11,534 (2,176)	7,431 (4,774)	62	0.1227	15,930 (4,767)	15,490 (7,167)	44	0.9378
	July	40,625 (12,767)	39,306 (15,248)	68	0.9091	21,018 (10,898)	33,417 (25,233)	43	0.3720
	August	16,209 (12,425)	55,550 (27,994)	70	0.0123	39,626 (13,396)	39,766 (25,778)	34	0.9948
	September	4,056 (2,958)	4,518 (3,215)	53	0.8599	28,535 (10,408)	23,621 (22,100)	48	0.6892

Table 4.–Estimated precision of interval count and aerial count seasonal estimates of boating effort at various levels of sampling effort, based on survey years 2000 and 2001. Precision was equal to the quotient of 2 SE of an estimate divided by the estimate, and is reported as a percentage.

	Interval counts				Aerial counts			
	2000		2001		2000		2001	
Counts/ day	Counts/ season	Precision (%)	Counts/ Season	Precision (%)	Counts/ season	Precision (%)	Counts/ season	Precision (%)
2	421	21.42	316	24.54				
3	632	17.49	474	20.03	225	14.84	140	15.58
4	842	15.15	632	17.35	300	12.85	187	13.49
5	1,053	13.55	790	15.52	375	11.49	233	12.09
6	1,263	12.37	948	14.17	450	10.49	280	11.03
7	1,474	11.45	1,106	13.12	525	9.71	327	10.21
8	1,684	10.71	1,264	12.27	600	9.09	373	9.56
9	1,895	10.10	1,422	11.57	675	8.57	420	9.02
10	2,105	9.58	1,580	10.97	750	8.13	467	8.55
11	2,316	9.13	1,738	10.46	825	7.75	513	8.16
12	2,526	8.74	1,896	10.02	900	7.42	560	7.81
13	2,737	8.40	2,054	9.62	975	7.13	607	7.51
14	2,947	8.10	2,212	9.27	1,050	6.87	653	7.24
15	3,158	7.82	2,370	8.96	1,125	6.64	700	7.00
16	3,368	7.57	2,528	8.68	1,200	6.42	746	6.78

Table 5.–Potential power of interval count and aerial count estimates of seasonal boating effort at various levels sampling effort, based on survey years 2000 and 2001. Power is based on detection of a 25% change in boating effort (t-test, equal variance, α = 0.05).

	Interval counts				Aerial counts			
	2000		2001		2000		2001	
Counts/ day	Counts/ season	Power	Counts/ season	Power	Counts/ season	Power	Counts/ season	Power
2	421	0.38	316	0.30				
3	632	0.52	474	0.42	225	0.66	140	0.62
4	842	0.65	632	0.53	300	0.79	187	0.75
5	1,053	0.75	790	0.62	375	0.87	233	0.84
6	1,263	0.82	948	0.70	450	0.92	280	0.90
7	1,474	0.87	1,106	0.77	525	0.95	327	0.94
8	1,684	0.91	1,264	0.82	600	0.97	373	0.96
9	1,895	0.94	1,422	0.86	675	0.98	420	0.98
10	2,105	0.96	1,580	0.90	750	0.99	467	0.99
11	2,316	0.97	1,738	0.92	825	1.00	513	0.99
12	2,526	0.98	1,896	0.94	900	1.00	560	1.00
13	2,737	0.99	2,054	0.96	975	1.00	607	1.00
14	2,947	0.99	2,212	0.97	1,050	1.00	653	1.00
15	3,158	0.99	2,370	0.98	1,125	1.00	700	1.00
16	3,368	1.00	2,528	0.98	1,200	1.00	746	1.00

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