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Comparison of fall estimates of population size of juvenile Walleye from two different sampling designs

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Abstract - We compared fall population estimates of juvenile (200 to 320 mm TL) Walleye made with marking and recapture in fall (FF estimates) with those made with marking in fall and recapture the following spring (FS estimates) in two Minnesota lakes. All samples were collected with boom electrofishing, and estimates were made with the modified Schnabel estimator. In both lakes, point FS estimates exceeded point FF estimates, and 95% confidence limits of FF and FS estimates in one lake did not overlap. Furthermore, the total number of fall- and spring-marked Walleye was included in the 95% confidence limits of FF estimates in one lake, and nearly did in the other lake. Thus, these FF estimates appear negatively biased because portions of these Walleye populations may not have been vulnerable to capture with fall electrofishing.

INTRODUCTION

Mark-recapture estimates of population size of yearling or juvenile Walleye *Sander vitreus* are often conducted in fall using either Petersen or Schnabel estimators, a fall mark/fall recapture design (FF estimates), batch marking, and using electrofishing for both marking and recapture (Mraz 1968; Hauber 1983; Serns 1983; Larscheid et al. 2001; Shaw and Sass 2020). These estimates were usually made to evaluate boom electrofishing catch per unit effort (CPUE) as an index of abundance of this length group of Walleye or evaluate success of Walleye stocking. Authors of all these studies presumed that the assumption of equal capture probabilities of marked and unmarked Walleye was met in all reported FF estimates, a requirement for unbiased Petersen and Schnabel estimates (Ricker 1975).

Evaluations of FF estimates of Walleye are few, however. Mraz (1968) reported that FF estimates of yearling Walleye in a Wisconsin lake made with the Petersen estimator often differed from those made with the Schnabel estimator, and differences in point estimates were high enough that assessments of annual mortality differed. Larscheid et al. (2001) reported that recapture to capture ratios increased with the number of marked Walleye at large in Iowa lakes, which should occur in modified Schnabel experiments.

Adding a spring capture period to those fall capture periods could help assess whether or not capture probabilities of marked and unmarked Walleye are equal. For example, McInerny and Cross (1999; 2005) compared FF estimates of Largemouth Bass *Micropterus salmoides* and Black Crappie *Pomoxis nigromaculatus* with estimates made with marking in fall and recapture in spring (FS estimates), and found that FS estimates of both species usually exceeded FF estimates in the same lakes. Furthermore, additional evidence suggested that some FF estimates of Largemouth Bass were negatively biased and FF estimates of Black Crappie could be negatively biased because a portion of their populations were too far off shore to be captured with nearshore capture gears (electrofishing or trap netting) in fall. Walleye could inhabit different areas of lakes in fall than in spring. For example, Schall et al. (2020) found that data collected with standardized sampling in fall provided different estimates of age structure, growth, mortality, and yield of Walleye than data collected with spring standardized sampling in a Nebraska reservoir, suggesting seasonal differences in distribution of Walleye.

Interpretations of relationships between electrofishing CPUE and population density of juvenile Walleye and evaluations of stocking success of Walleye could change if FF estimates of juvenile Walleye are biased. Furthermore, comparisons between FF and FS estimates could reveal potential biases made with either design. Therefore, we compared FF and FS estimates of juvenile Walleye in two Minnesota lakes, and evaluated for potential bias estimates made with each design.

METHODS

Study lakes

Lakes Little Swan (Meeker County) and Elkhorn (Kandiyohi County) are two small, dimictic lakes located in south central Minnesota. Little Swan Lake is 18 ha with a maximum depth of 9.4 m, and Elkhorn Lake is 35 ha with a maximum depth of 12.5 m. Walleye fisheries in both lakes were maintained primarily by fingerling stocking (usually age 0 fingerlings) from different sources; however, some natural reproduction was documented in Little Swan Lake.

Walleye sampling

All samples were collected with boom electrofishing, and although sampling focused primarily on Largemouth Bass, Walleye in these two lakes were also sampled when observed. Sampling consisted of several electrofishing circuits around the entire shoreline of each lake over a two to four week period; one circuit per day or night in fall and the following spring (McInerny and Cross 1996). The boom electrofisher was equipped with a Coffelt VVP 2E electrofisher powered by a 3.5 KW generator that supplied pulsed DC from the boat hull to a single sphere anode. A single netter dipped stunned bass and Walleye of all lengths. Because one of the study objectives was to compare day and night electrofishing catches of Largemouth Bass, a minimum of two sets of day and two sets of night electrofishing circuits were completed at each lake. At both lakes, one day electrofishing circuit occurred just before one night electrofishing circuit, and the other day circuit occurred the day after a night electrofishing circuit. Additional circuits were needed for estimating population size of Largemouth Bass, but no additional circuits were conducted for estimating population size of Walleye. At Little Swan Lake, three night and two daytime electrofishing circuits were completed from 13 September through 7 October 1993, and two night and two daytime electrofishing circuits were completed from 10 through 23 May 1994 (three additional daytime circuits for Largemouth Bass occurred after 23 May, but no Walleye were caught). Two daytime and five night electrofishing circuits were completed at Elkhorn Lake from 15 September through 17 October 1994, and two daytime and two night electrofishing circuits were completed from 15 to 22 May 1995. Fall water temperatures ranged from 12 to 19 °C at Little Swan Lake and from 13 to 23 °C at Elkhorn Lake, and spring water temperatures ranged from 14 to 22 °C at Little Swan Lake and 16 to 17 °C at Elkhorn Lake. Captured Walleye were measured (total length in mm), examined for presence of season-specific fin clips (either anal or upper caudal fin), given a season-specific fin clip if unmarked, and released.

We used the modified Schnabel estimator to estimate population size for each design. With one exception, each electrofishing circuit when Walleye were sampled was treated as an independent capture period for FF estimates. A single un-marked Walleye captured during a day electrofishing run the next day after a night electrofishing run at Elkhorn Lake was fin-clipped and included with the electrofishing sample the night before. Cumulative samples of *M*, *C*, and *R* during fall were used for FF estimates. For FS estimates, *M* equaled the total number of fall-marked Walleye and was presumed constant during spring sampling. Each spring electrofishing circuit when Walleye were captured was treated as an independent capture period. The single recaptured spring-marked Walleye was excluded from *C* in the FS estimate at Elkhorn Lake. Ninety five percent confidence limits were calculated by using *R* as a Poisson variable, and *R* needed to equal or exceeded 4, the minimum number for a statistically unbiased estimate (Ricker 1975). We used length-frequency distributions to distinguish juvenile (age 1 and possibly some age 2 in fall; age 2 and possibly some age 3 in spring) from age 0 Walleye and Walleye > age 2 in fall and from Walleye age 1 and ≥ age 3 in spring (Quist et al. 2012).

We could not directly determine bias in either design because population size of juvenile Walleye was not known in either lake; thus, we examined indirectly for potential bias in each design. We first summed the total number of fall-marked, spring-marked, and all unmarked Walleye examined in the last capture period in spring and compared those sums with FF estimates. FF estimates could be negatively biased if 95% confidence intervals included these sums coupled with relatively low *R* to *C* ratios in spring recapture samples (assuming equal mortalities of marked and unmarked Walleye after the last fall recapture period). We then plotted proportions of *R* to *C* as a function of *M* to determine if proportions of *R* to *C* increased proportionately with increasing *M*. For FF estimates, we calculated upper and lower 95% confidence limits of individual proportions estimated at each *M* by using formulae in Hansen et al. (2007). For FS estimates, we calculated standard errors of *R* to *C* in spring samples because proportions were estimated at least twice with the same *M*. Although capture probabilities often differ among sample events, proportions of *R* to *C* should ultimately increase with increasing *M* (Ricker 1975; Otis et al. 1978). Lastly, we applied Kolmogorov-Smirnov tests to determine if length distributions differed between *M* and *C* in FS estimates. We concluded recruitment did not occur if length distributions did not differ significantly ($P < 0.05$).

RESULTS

Point estimates of juvenile Walleye (20 to 32 cm TL) made with the fall mark/fall recapture design were lower than point estimates made with the fall mark/spring recapture design in both lakes (Figure 1). However, 95% confidence limits of FF and FS estimates at Little Swan Lake overlapped (Figure 1). In contrast, confidence limits of FF and FS estimates made with the modified Schnabel estimator at Elkhorn Lake did not overlap (Figure 1).

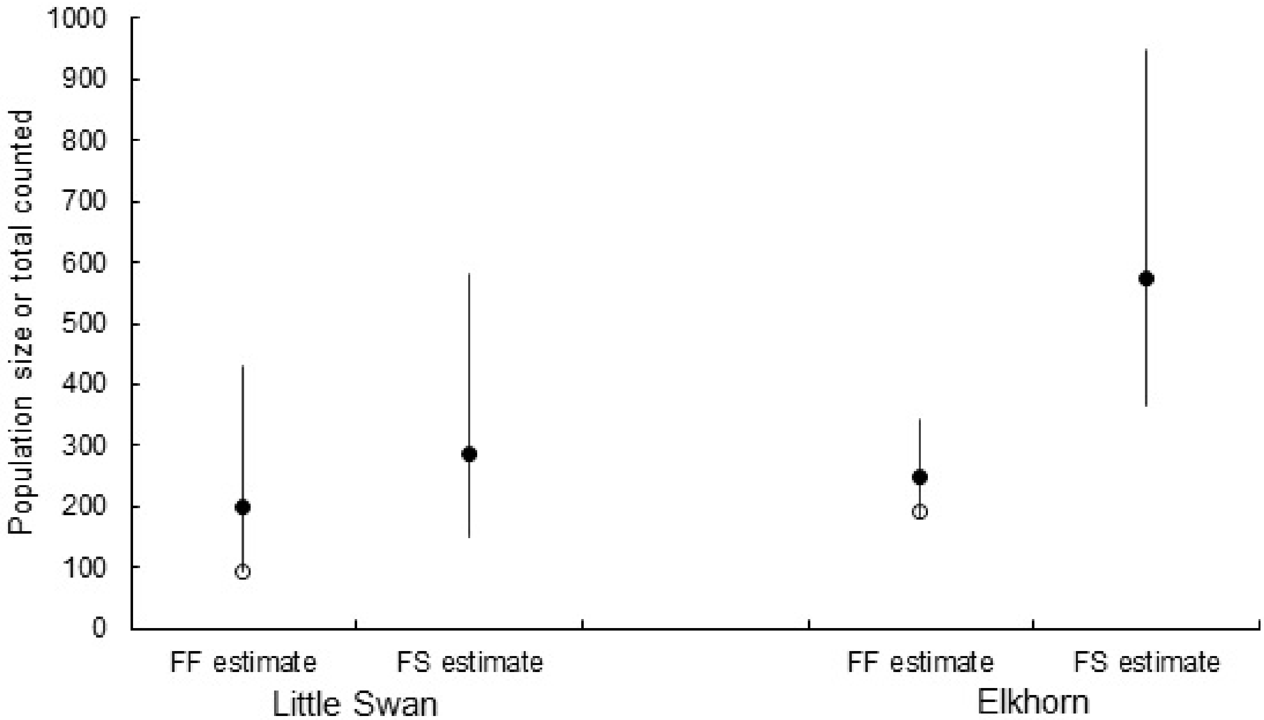

FIGURE 1. Estimates of population size (solid circles; vertical bars denote 95% confidence limits) of juvenile Walleye at Little Swan (Meeker County) and Elkhorn (Kandiyohi County) lakes made with a fall mark-fall recapture design (FF estimate) and a fall mark-spring recapture design (FS estimate), and the total number of fall-marked and spring-marked Walleye counted in fall and spring (open circles).

Estimates made with the FF design appeared negatively biased relative to FS estimates in both lakes, but bias of FS estimates could not be directly evaluated. The total number of Walleye marked in fall and spring were either very near the lower 95% confidence limit (Little Swan Lake) or were within 95% confidence limits (Elkhorn Lake) of FF estimates made with either estimator (Figure 1). At Little Swan Lake, the proportion of *R* to *C* in nighttime recapture samples did not increase with increasing *M,* but the proportion of *R* to *C* did increase with increasing *M* at Elkhorn Lake (Figure 2). Proportions of *R* to *C* differed little between nighttime capture events in spring at both lakes, but proportions in spring did not exceed proportions observed during the last capture periods in fall (Figure 2). Proportions of *R* to *C* were not calculated for day electrofishing circuits because no Walleye were captured during daytime electrofishing in fall or spring at Little Swan Lake, and only three Walleye were caught during the day at Elkhorn Lake in spring (one of which had a fall fin-clip). Length distributions of *M* and *C* in FS estimates at Little Swan Lake differed significantly (D = 0.285; n = 61, 42; P = 0.0352). However, modes and length ranges were similar between *M* and *C*; *C* was composed of relatively few Walleye < 25 cm (Figure 3). At Elkhorn Lake, length distributions of *M* and *C* did not differ (D = 0.139; n = 134, 75; P = 0.3099; Figure 3). Thus, recruitment of unmarked Walleye probably did not occur at either lake.

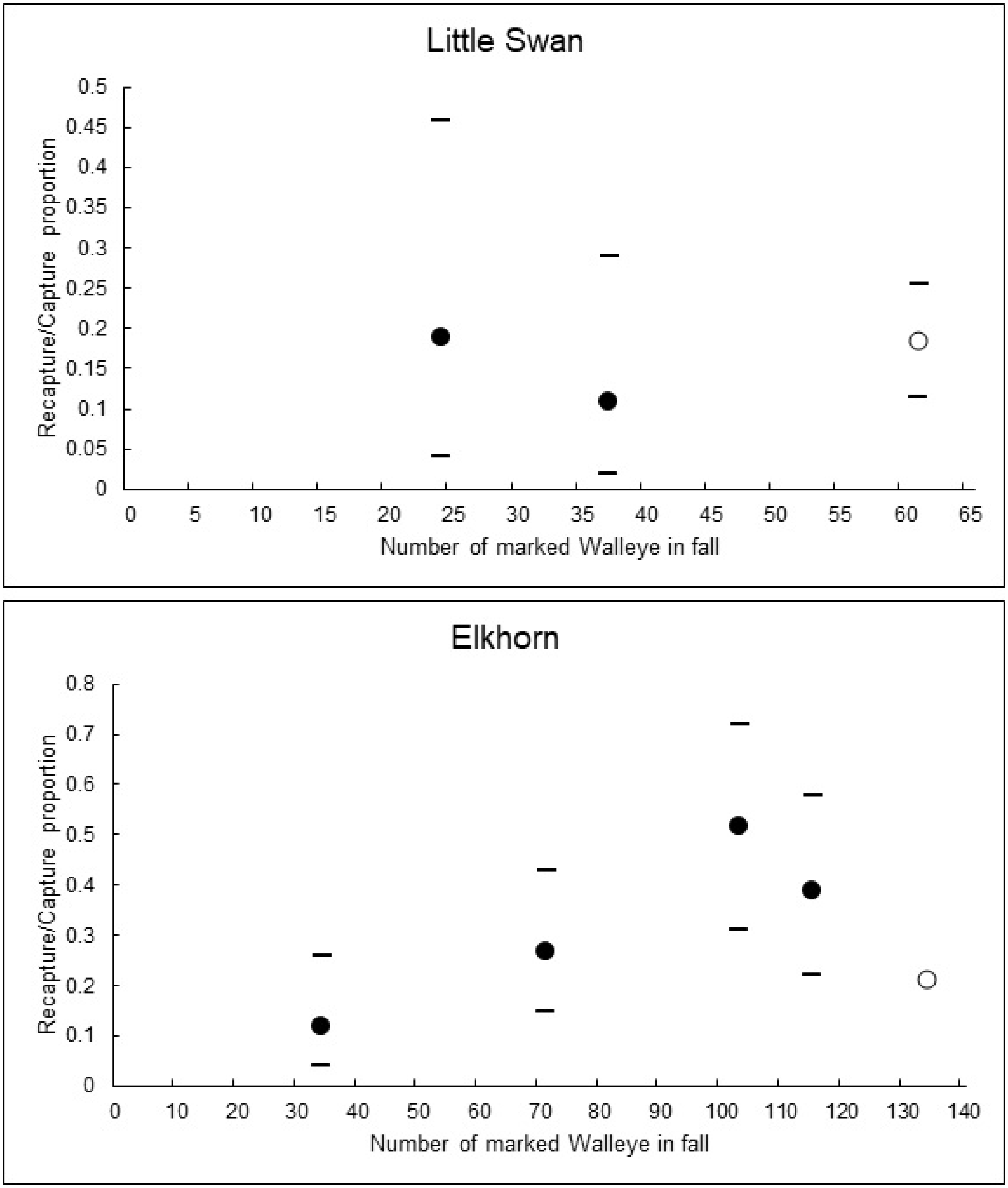

FIGURE 2. Proportion (solid circles) of the nighttime recapture samples of juvenile Walleye that were marked as a function of the total number of Walleye marked at large in fall, and the proportion (open circles) of fall-marked walleye captured in the spring nighttime recapture samples in lakes Little Swan and Elkhorn, Minnesota (upper and lower horizontal lines denote 95% confidence limits of proportions in fall, and 2X standard error in spring at Little Swan; standard error for proportions at Elkhorn not shown because they reside within the respective open circle).

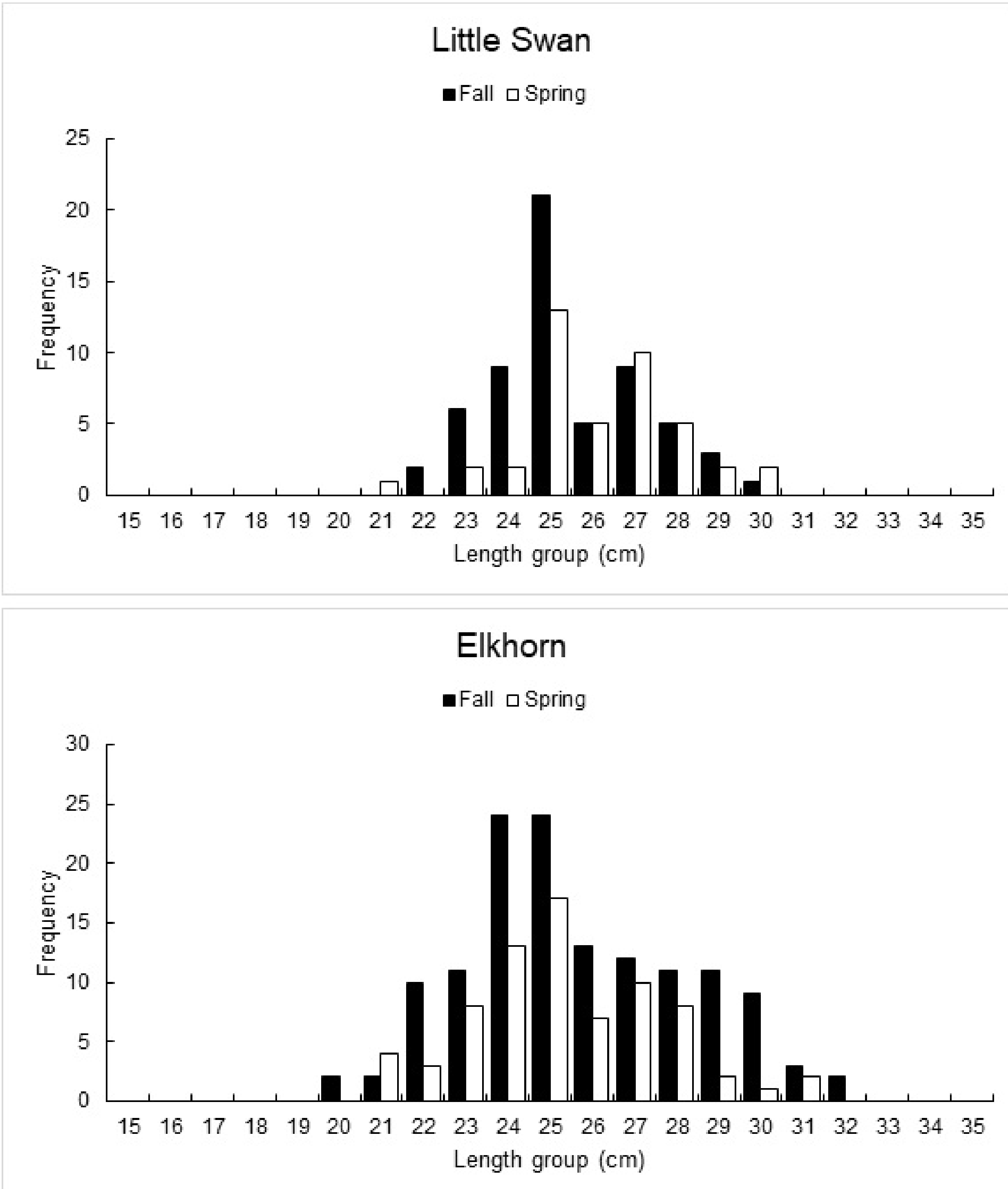

FIGURE 3. Length frequency distributions of marked juvenile Walleye at large in fall and the following spring in lakes Little Swan and Elkhorn, Minnesota.

DISCUSSION

The assumption of equal capture probabilities of all juvenile Walleye may not have been met for FF estimates, and the assumption of equal mortality of marked and unmarked juvenile Walleye may not have been met for FS estimates. Negative bias in FF estimates could be caused by a portion of the Walleye population not being vulnerable to capture with electrofishing in fall. Van den Avyle (1976) reported that a substantial portion of age 1 Largemouth Bass in a 3-ha Iowa impoundment were not vulnerable to capture with electrofishing in fall but became vulnerable to capture in spring. A similar seasonal change in distribution of juvenile Walleye would cause negative bias in FF estimates in our study lakes. McInerny and Cross (1999) also found that 95% confidence intervals of several FF estimates of Largemouth Bass ≥ 200 mm made with marking and recapture with electrofishing also included the total number of bass marked in fall and spring. Lastly, findings of this study were also consistent with that found for Black Crappie where FS estimates always exceeded FF estimates (marking and recapture made with nearshore trap netting in both designs) in several Minnesota lakes (McInerny and Cross 2005). Conversely, disproportionately higher mortality of marked Walleye relative to unmarked Walleye would cause positive bias in FS estimates, although no dead fin-clipped Walleye were observed during sampling.

We could not determine if assumptions of no emigration of marked Walleye or no immigration of unmarked Walleye were met because we batch-marked rather than marked Walleye with individual tags. Although both lakes lacked inlets and outlets allowing for migration of fish, it was possible that complete mixing (relative to the path of the electrofishing boat) of the populations did not occur. Applying unique marks to each Walleye coupled with application of Program Mark could have assessed whether or not these assumptions were met.

The remaining assumptions for unbiased Schnabel estimates appeared to be met (Ricker 1975). Analysis of fall and spring length distributions suggested no recruitment of unmarked Walleye. Because of negligible over-winter growth, clipped fins did not regenerate, and the caudal and anal fin clips were easily observed when placed flat on measuring boards. Therefore, marks were not lost and no marked Walleye were missed during examination.

The number of recaptures for the FF estimate at Little Swan Lake appeared marginally adequate, but *R* appeared sufficient for the FF estimates at Elkhorn Lake and for FS estimates at each lake. By design, all estimates were made with more than four recaptures of marked Walleye; thus, statistical negative bias should have been avoided (Ricker 1975). For their study, Shaw and Sass (2020) excluded from their study estimates of age 1 Walleye made with less than seven recaptures; however, their sampling continued until the proportion of marked to unmarked Walleye in the last capture period exceeded 10%. The FF estimate at Little Swan Lake was made with a total of six recaptures, but the proportion of marked to unmarked Walleye in the last recapture sample equaled 11%. On the other hand, the cumulative R = 42 and the proportion of marked to unmarked Walleye in the last recapture sample equaled 39% for the FF estimate at Elkhorn Lake. For FS estimates, cumulative R = 8 at Little Swan and cumulative R = 17 at Elkhorn Lake, and proportions of marked to unmarked Walleye in spring electrofishing circuits ranged from 15 to 22% at Little Swan Lake and 20 to 22% at Elkhorn Lake.

If negative bias in FF estimates is shown true in future examples, then interpretations of fall electrofishing CPUE of yearling Walleye and stocking success of Walleye could change, especially if the proportion of the population vulnerable to shoreline electrofishing in fall varies within and among lakes. Although Larscheid et al. (2001) and Shaw and Sass (2020) found that electrofishing CPUE in fall was positively correlated with FF estimates among lakes in Iowa and Wisconsin, Madsen (2008) reported that electrofishing CPUE of age 1 Walleye was not a useful predictor of year-class strengths in future spawning stocks of Walleye in northern Wisconsin lakes. Madsen (2008) speculated that year-class strengths of Walleye in northern Wisconsin might not become set until after age 1; however, electrofishing CPUE may not reflect actual density of age 1 Walleye if substantial portions of the population are shown invulnerable to electrofishing in fall.

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