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An evaluation of standard trap netting as a sampling gear for White Crappie in Minnesota lakes

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Abstract – We used trap net catch data and available literature to evaluate standard trap nets used by the Minnesota Department of Natural Resources fisheries staff as gear for sampling White Crappie *Pomoxis annularis* in Minnesota lakes. Examination of total length (TL) distributions in three study lakes showed that trap nets did not effectively capture White Crappie < 200 mm TL. Trap net catch per unit effort (CPUE) of quality (≥ 200 mm TL) White Crappie varied inconsistently among monthly sample periods from June through the following May in two years in two lakes, and among four monthly sample periods in another. We found in one lake that trap net CPUE of quality White Crappie differed consistently among trap net locations among all sample periods. However, CPUE in two other lakes also differed among trap net locations, but not consistently among sample periods. Trap netting protocols used to successfully estimate population size of quality Black Crappie *P. nigromaculatus* in these three lakes usually failed to provide sufficient samples to estimate population size of quality White Crappie. Trap net catchability *q* of quality White Crappie usually differed from *q* of quality Black Crappie, and proportions of the total crappie catch consisting of White Crappie differed among sample periods within lakes. Thus, fisheries managers should not conclude with a trap net assessment, the proportions of quality White Crappie to quality Black Crappie in a given lake at any time. Lastly, because other tagging and netting studies indicated that White Crappie were usually found deeper and farther offshore than trap nets are set, standard trap netting could be an ineffective sampling gear for White Crappie.

INTRODUCTION

White Crappie *Pomoxis annularis* along with Black Crappie *P. nigromaculatus* are important game fishes in southern Minnesota. Together these two species rank second behind Walleye in popularity among Minnesota's anglers, and White Crappie compose more than half of the crappies caught by anglers in some lakes in the southern half of the state (Schroeder 2012a; Minnesota Department of Natural Resources (MNDNR) creel survey database). The MNDNR uses standard trap netting to sample panfishes in nearshore habitats, and panfishes are composed of several species including White Crappie (MNDNR 2017). The standard trap net used by MNDNR consists of two 0.9-X 1.8-m frames, a single 12.2-m lead, a cod end with five 0.8-m diameter hoops and two throats, and 19-mm bar-mesh webbing, with leads typically tied to shore. Trap netting occurs primarily during summer (June through August), and, once established in the initial survey, all subsequent trap netting within lakes usually occurs during the same time in summer (MNDNR 1993; 2017).

Temporal variation in trap net catch per lift (CPUE) and location of trap net sets within lakes could affect interpretation of trap net CPUE of White Crappie. For most gamefish species, MNDNR staff use a system of CPUE by lake class to evaluate a lake-specific CPUE, but this system does not account for temporal variation in net CPUE. This system is composed of periodically calculated quartiles of trap net and gill net CPUE (excluding zero CPUEs) of each game species, including White Crappie, for up to 43 lake classes. For panfishes, MNDNR staff compare their trap net CPUE in a given lake with those quartiles of trap net CPUE calculated from all lakes within the same lake class. For White Crappie, analysis of lake surveys before 1993 suggested relatively high trap net CPUE in August and June and relatively low CPUE in mid-July (MNDNR 1993; 2017). However, these trends were drawn from one-time surveys among many lakes and years, and not from monthly trap net samples within lakes (MDNNR 1993). The current MNDNR Lake Survey Manual also recommended that trap nets be set in a variety of habitats, and once selected, these locations should be used for all subsequent surveys or assessments (MNDNR 1993; 2017). Thus, odds were good that trap net locations could act as fixed rather than random samplers (i.e., nets at specific locations consistently caught the most or fewest crappies), and trap net CPUE estimates could be a function of location of net sets within lakes.

Studies in Minnesota and elsewhere suggested temporal variation in White Crappie catches in trap nets or similar gear set near shore. Kelley (1953) found peaks of CPUE in trap nets with 25-mm bar mesh netting in May, July, and late September in Pool 8 of the Mississippi River. Additionally, Sheik et al. (1998) found that White Crappie < 130 mm in a backwater of the Missouri River in northwest North Dakota were caught primarily in nets with 9.5-mm bar mesh set in September, but higher CPUE of longer crappies occurred in May and September than in July. Peaks in CPUE in shoreline hoop-nets with 25-mm bar mesh occurred in March and April and September or October in an Illinois reservoir (Hansen 1951). Although temporal variation in CPUE occurred in these outstate studies, mesh sizes in these nets differed from those in MNDNR trap nets. McInerny et al. (1993) found that fall sampling with MNDNR standard trap nets in 12 southern Minnesota lakes caught wider length ranges of White Crappie than June, July, or August trap netting in the same lakes, but this study was not designed to determine if temporal trends in CPUE differed among lakes. Thus, a more thorough analysis of temporal variation in trap net CPUE in Minnesota lakes should provide better information for MNDNR managers of White Crappie fisheries.

Other state agencies conduct trap net assessments in spring or fall, rather than in summer, and spring or fall trap netting by MNDNR could provide meaningful data on White Crappie. Trap net assessments of White Crappie in Missouri, Nebraska, and Oklahoma have been done in fall, but mesh sizes of webbing were smaller (13- to 16-mm bar mesh) and leads were longer (16.8 to 25.9 m) than on those used by MNDNR (Colvin and Vasey 1986; Boxrucker and Ploskey 1989; Jackson and Bauer 2000). Additionally, nets were also set offshore and in deeper water than nets set by MNDNR staff.

Even though CPUE in spring exceeded CPUE in fall, fall netting sampled wider range of lengths including age 0; thus, biologists felt confident they could assess year-class strengths of White Crappie by netting in fall (Boxrucker and Ploskey 1989). Nets with 13-mm bar mesh webbing, with similar frame dimensions as MNDNR trap nets, captured higher proportions of White Crappie < 120 mm than nets with 16-mm bar mesh webbing, and trap nets with 25-mm bar mesh webbing failed to capture any White Crappie < 120 mm in the same lakes (Willis et al. 1984; Jackson and Bauer 2000). Thus, it's likely that the MNDNR trap nets with 19-mm bar mesh webbing will not be efficient at capturing smaller White Crappie. Spring or fall trap net assessments of White Crappie conducted with the current standardized methodology in the Lake Survey Manual have not been done on Minnesota lakes; thus, catches of all lengths of White Crappie between summer, spring, or fall trap netting cannot be compared.

Nearly all Minnesota lakes with White Crappie also support populations of Black Crappie, but it is not known if trap net catchability or temporal trends in CPUE differs between these two species. No consistent temporal trends in CPUE of Black Crappie ≥ 200 mm TL occurred among seven Minnesota lakes; instead, temporal trends appeared lake-specific (McInerny et al. 2020). Spawning temperatures of both species are similar (Pope and Willis 1997; Siefert 1968; Mitzner 1991), which could affect CPUE of both species similarly. However, White Crappie often show greater piscivory and often grow faster than Black Crappie in the same waters (Ellison 1984; McInerny and Cross 2008), and growth and behaviors associated with feeding could affect CPUE differently between species.

Because summer trap netting has been viewed as the primary gear to be used for sampling crappies, MNDNR managers of White Crappie fisheries wanted to improve their interpretations of net catches of crappies. Therefore, objectives were to examine past data collections, determine temporal patterns in trap net CPUE of White Crappie, and to determine if temporal variation and catchability of White Crappie is similar to Black Crappie in the same lakes. Because other studies suggested higher or consistent trap net catchability in spring and fall, we also assessed these times for sampling White Crappie. An evaluation of temporal variation in trap net catches of Black Crappie in Minnesota lakes led to the development of targeted survey procedures for this species in the MNDNR Lake Survey Manual (MNDNR 2017), but no such protocol exists for White Crappie because data on trap net catches have not been evaluated.

METHODS

Study lakes

Dog and French lakes in Wright County and Richardson Lake in Meeker County are relatively small, deep lakes that support White Crappie and Black Crappie populations (Table 1). All three lakes are dimictic and their hypolimnions become nearly anoxic by early to mid-summer. Dog Lake was classified as a Lake Class 30 lake, and French and Richardson lakes are Lake Class 24. Summer submergent aquatic plant densities were relatively sparse at French and Richardson lakes, and moderately dense at Dog Lake. During this study, winter angling for crappies occurred at Dog and French lakes, but not at Richardson Lake. Based on anecdotal observations, open water angling occurred at Dog, French, and Richardson lakes, but pressure appeared light.

TABLE 1. Name, county of location, surface area (ha), percent littoral area (area of lake < 4.6 m), maximum depth (Z_{max}; m), and years when trap netting for White Crappie and Black Crappie occurred in three Minnesota lakes.

Lake name	County	Surface area	Littoral area	Z_{max}	Years sampled
French	Wright	134	47	15.2	1990, 1997-1999
Dog	Wright	38	79	7.6	1999-2001
Richardson	Meeker	45	40	14.3	1991, 2000-2001

Trap net sampling of crappies

At French and Dog lakes, standard trap nets were set at nine standard locations for two to four consecutive days during one week of each month from June through October for two consecutive years (McInerny et al. 2020). Two other sampling periods, early spring (ES) and late spring (LS), were also sampled after the October sampling period, but start dates depended on when ice completely melted from these lakes. The ES sample period started one to two weeks after ice out, and the LS sample period began about three to four weeks after the end of the ES sampling period. Thus, the ES sample period ranged from early April to early May, and the LS sample period ranged from mid-May to early June. Extra trap netting was also done during the ES and LS sample periods because attempts were made to estimate population size (see section on trap net catchability). Richardson Lake was sampled in the September, October, ES, and LS sample periods on the same days as Dog Lake in fall 2000 and spring 2001; this sampling was done primarily for estimating population size of both species. All crappies were identified to species, measured to the nearest mm TL, and scales were removed from up to five individuals per cm length group in June, July, August, and September sampling. Some scale samples were also collected in the October, ES, and LS sample periods, but only from individuals in 10-mm length bins not filled in September. Surface water temperature was measured off shore during each day trap nets were lifted.

We constructed length-frequency distributions of White Crappie to provide an approximate estimate of size-selectivity of trap netting, and these distributions were used to choose meaningful length groups for calculating CPUE. For each lake, all lengths from all samples were pooled and the proportion per 10-mm length bin was calculated. We assumed negligible size-selectivity if the proportion of White Crappie < 200 mm, a standard length for proportional stock distributions (Neumann et al. 2012), exceeded the proportion of quality (≥ 200 mm TL) White Crappie. However, we concluded that trap nets were ineffective in capturing crappies < 200 mm if the converse occurred. Lastly, trap net CPUE (with standard errors) of length groups judged to be effectively sampled was calculated for each sample period.

We applied analysis of variance (ANOVA) to test if trap net catch of White Crappie was affected by net location similarly during all sample periods (White Crappie catch = f (net location + sample period + net location* sample period). If the ANOVA suggested that net location affected catch of White Crappie coupled with an insignificant sample period*net location interaction, then each day within each sample period would be the sample unit rather than individual nets. This analysis was done for those length groups effectively sampled with trap nets.

To aid in interpreting temporal variation of trap net catch, we estimated for each sample period in each lake year-class strengths and length at capture for the most frequently captured year-classes (n ≥ 2 in four or more sample periods). Age was estimated by counting annuli on scales. To estimate year class strengths and length at capture, unaged crappie were assigned an age based on the age-length key developed for each sample period. We then calculated for each sampling period mean trap net CPUE of each year-class and mean total length of those year-classes most frequently caught. Lastly, we used a linear mixed-effects model to test for surface water temperature effects on trap net CPUE in fall (September and October) and spring (ES and LS sample periods) when growth and recruitment should be negligible within seasons. The model was: CPUE of White Crappie = f (lake + water temperature) with variable lake set as a random effect and temperature as a fixed effect. We then used bias-corrected Akaike Information Criteria (AICc) coupled with the examination of *t*-statistics to select the best fitting model. Only the model with the lowest AICc score will be reported (Burnham and Anderson 2002). We concluded the effect of temperature was significant ($P < 0.05$) if the *t*-statistic exceeded 2 or was below -2 (Luke 2017). We used the *lme4* package in R (version 3.6.2) for mixed effects modeling (Bates et al. 2015).

Estimating trap net catchability from CPUE and population size

Initial attempts to estimate population size of White Crappie and Black Crappie were made in French Lake in fall 1990 and in Richardson Lake in fall 1991, and information gained from this effort was used to determine the sampling effort needed to estimate population size of both species during this study. Trap nets were set at 15 locations roughly equidistant from each other in mid-September (French Lake) or late September and early October (Richardson Lake) and then lifted the following day (McInerny and Cross 1993). At French Lake, all 15 nets were set in one day and lifted the next, but sets of five nets were set in one day and lifted the next during a three-day period at Richardson Lake. All crappies were measured, fin-clipped (lower caudal fin), and released if alive. Recapture sampling occurred during the second week of May the following year. At each lake, a total of 15 trap nets were set on one day and lifted the following day, and all crappies were measured and examined for the fall fin clip.

This initial sampling suggested that estimates of population size of both species could be made in fall and spring in these four study lakes if trap net efforts were increased. Fall population size was estimated by marking in fall (September and October) and recapture in the following spring, and spring population size was estimated by marking in the early spring (ES) period and recapture in the late spring (LS) period (McInerny and Cross 2005). Because standard trap nets selected against Black Crappie < 200 mm and *q* of Black Crappies 150 to 199 mm decreased with increasing population density (McInerny and Cross 2006), estimates of population size were made for quality crappies. For fall estimates, the marked population consisted of all crappies fin-clipped in September and October, and the recapture sample was composed of all crappies sampled in spring minus the number of spring-marked crappies caught in the ES period. For spring estimates, the marked population was composed of all crappies fin-clipped in the ES period and the recapture sample was composed of all crappies examined during the LS period. Either the soft dorsal fin or anal fin was clipped, but the fall fin-clip differed from the spring fin-clip. Crappies were not fin-clipped during the LS period. The Chapman modification of the Petersen method was used to estimate population size of quality White Crappie and Black Crappie when at least four marked crappies were recaptured, the minimum needed for an unbiased estimate of population size (Ricker 1975).

We compared trap net *q* to determine if *q* differed between the two crappie species. Trap net catchability *q* of quality White Crappie and Black Crappie in September, October, ES, and LS sample periods was estimated by dividing trap net catch per lift by population size in all cases where population size of both species was estimated. The delta method was used to estimate variances of *q* from variances of trap net CPUE and population estimates (Rao 1965; Ricker 1975), and standard error of *q* was estimated as the square root of the variance of *q* divided by the square root of the number of trap nets set. We assumed that population size of both species changed little between the September and October sample periods and between the ES and LS sample periods.

RESULTS

Trap net catches of White Crappie

Standard trap nets captured a total of 1,189 White Crappie in French Lake and 948 in Dog Lake among 14 sampling periods over two years. Standard trap nets caught a total 2,135 White Crappie among four sampling periods at Richardson Lake. Examination of length-frequency distributions suggested that standard trap nets failed to sample smaller White Crappie in these lakes. Although these nets captured wide length ranges (90 to 393 mm TL), modal lengths ranged from 190 to 220 mm among these lakes (Figure 1). Proportions of White Crappie ≥ 250 mm were also low in all three lakes.

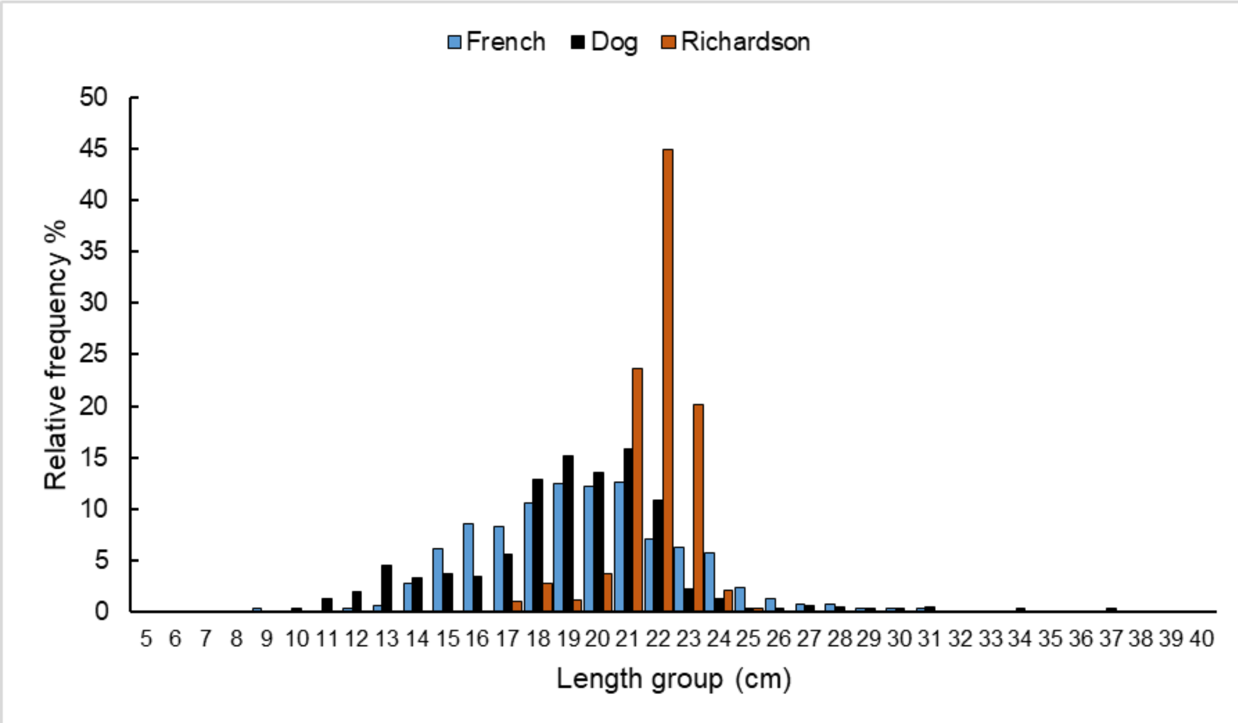

FIGURE 1. Relative length frequency distributions (all sample periods combined) of White Crappies caught in standard trap nets set in French (June 1997 through May 1999), Dog (June 1999 through May 2001), and Richardson (September 2000 through May 2001) lakes, Minnesota.

Trap net CPUE of quality White Crappie varied temporally in each lake, but patterns usually differed among lakes. Relatively high CPUE occurred during August and low CPUE occurred in the ES and LS sample periods at French Lake, but high CPUE occurred during the LS sample period at Dog Lake (Figure 2). A common trend among lakes were drops in CPUE from September to October in all three lakes (Figure 2). Trap net CPUE in French and Dog lakes increased from the ES to LS periods in spring, but the converse occurred at Richardson Lake. Interestingly, trap net catches of White Crappie ≥ 300 mm occurred only in during the ES, LS and June sample periods in French and Dog lakes. Temporal trends in trap net CPUE of White Crappie < 200 mm were not determined because nets failed to effectively sample these smaller crappies (Figure 1).

Net location appeared to affect CPUE of quality White Crappie at Dog Lake during all sampling periods, but net location inconsistently affected CPUE among sampling periods at French and Richardson lakes (Figure 3). The ANOVA suggested that trap net CPUE at Dog Lake differed among net locations (F = 11.00; d.f. = 1; P = 0.0010) and sample periods (F = 5.80; d.f. = 6; P < 0.0001), but the interaction was insignificant (F = 1.06; d.f. = 6; P = 0.3872). Trap net CPUE was consistently low at two locations (locations 5 and 8) and consistently high at two locations (locations 4 and 9) (Figure 3). However, significant interactions between net location and sampling period occurred at French (F = 3.05; d.f. = 6; P = 0.0062) and Richardson (F = 3.42; d.f. = 4; P = 0.0193) lakes; suggesting location effects occurred within sampling periods but inconsistently among sampling periods (Figure 3).

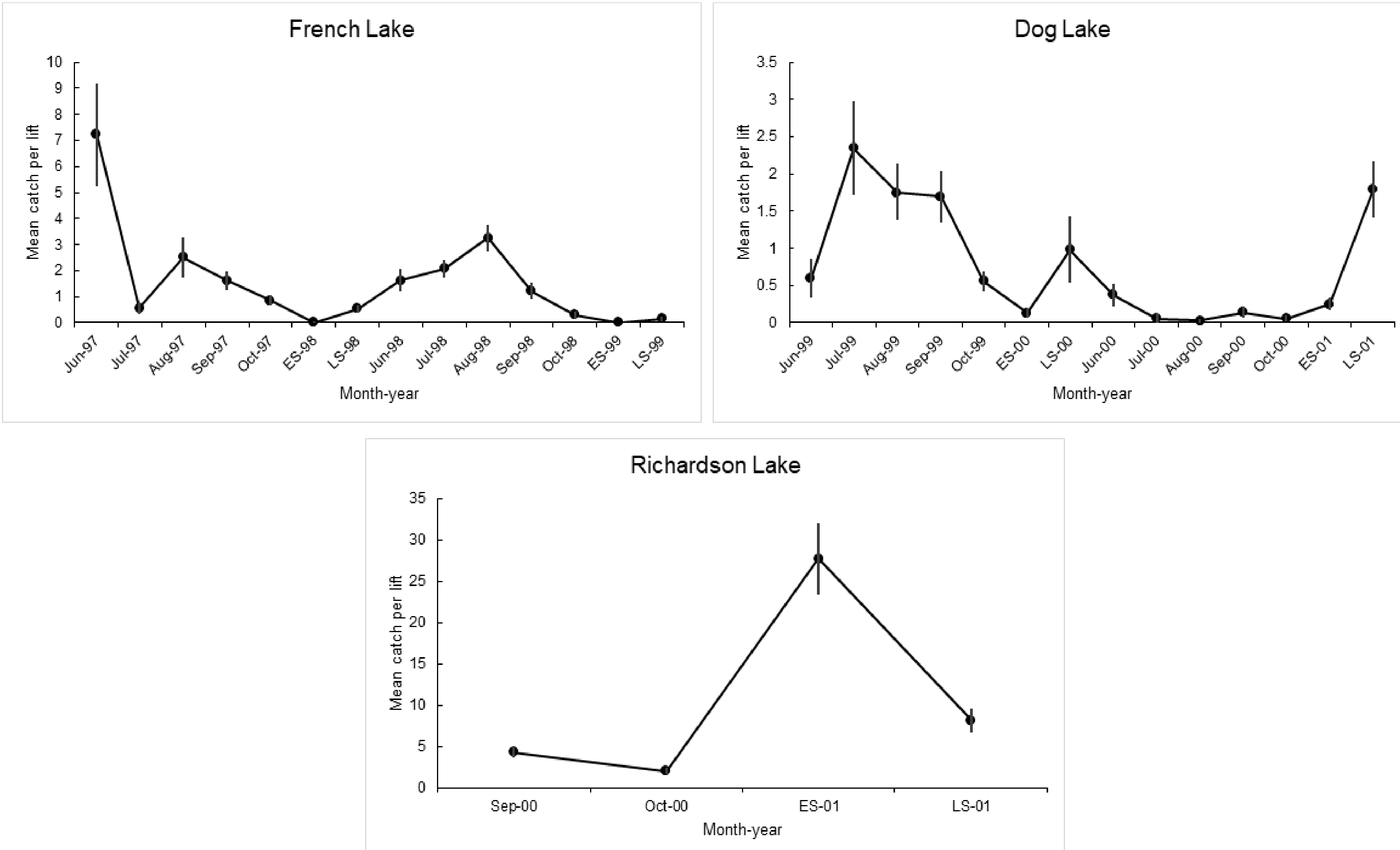

FIGURE 2. Mean trap net catch per lift (vertical bars = s.e.) of White Crappie ≥ 200 mm TL among consecutive monthly sample periods in French, Dog, and Richardson lakes, Minnesota (ES = early spring; LS = late spring).

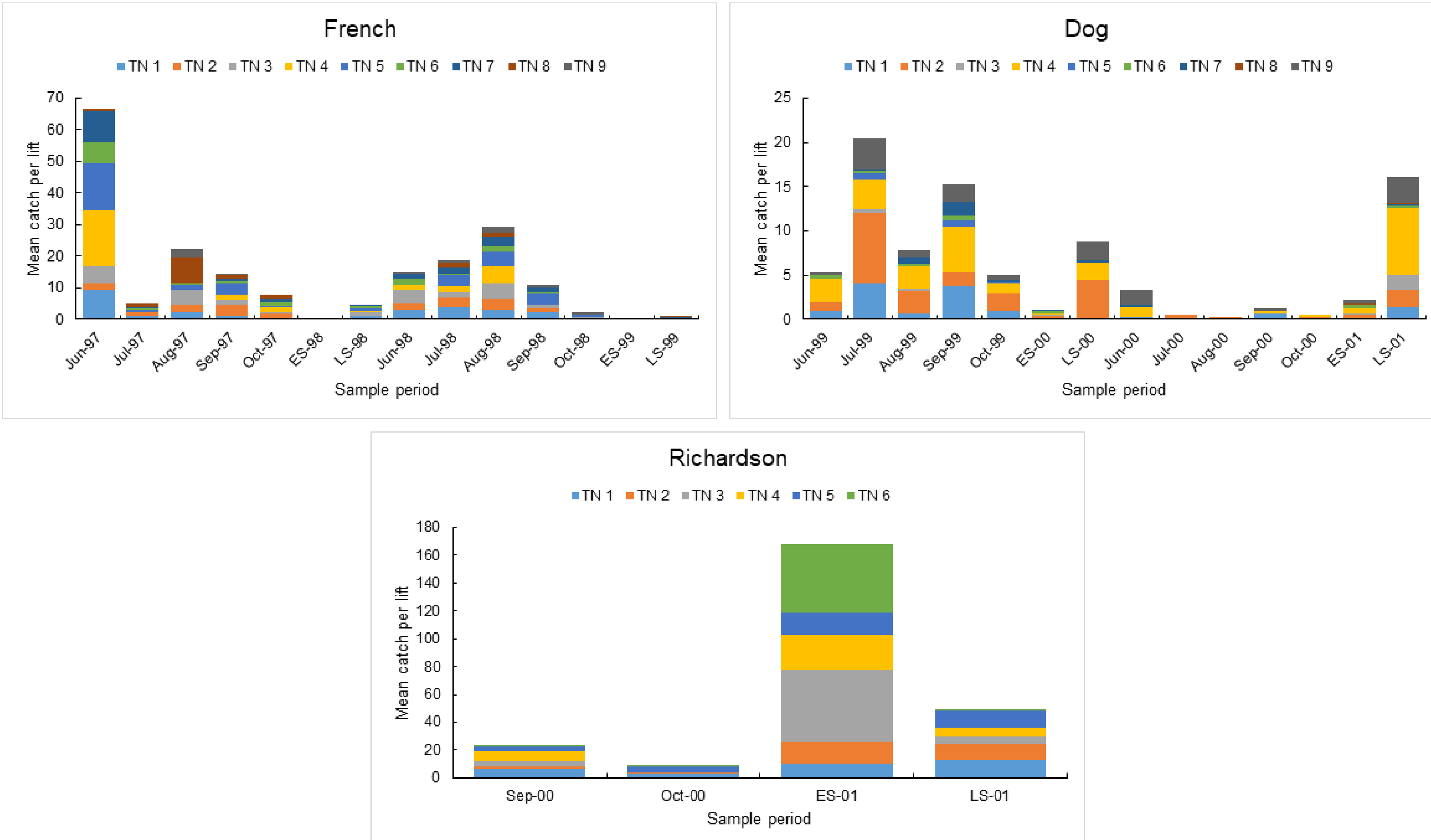

FIGURE 3. Mean catch per lift of White Crappie ≥ 200 mm TL in trap net at locations 1 through 9 among 14 sampling periods over two years at French and Dog lakes, and in nets set at six locations among four sampling periods in one year at Richardson Lake.

Year-class composition and mean lengths at capture also differed among lakes. Trap net catches of quality White Crappie in each sampling period at French Lake was usually composed of several year-classes; however, the Dog Lake catch in most sample periods was composed mostly of single year-classes (Figure 4). At Dog Lake, the 1996 year-class dominated the trap net catch from June 1999 through June 2000, and the 1998 year-class predominated from September 2000 through late spring 2001. Similar to Dog Lake, the 1997 year-class composed 95 to 99% of the trap net catch of quality White Crappie among the four sample periods at Richardson Lake (data not shown). Less than 10 individuals of the 1995, 1996, and 1998 year-classes were caught in all sampling periods combined at Richardson Lake. At French Lake, mean lengths at capture of the 1993, 1994, 1995, and 1996 year-classes increased from June through October; however, mean lengths at capture of 1995, 1996, and 1997 year-classes at Dog Lake changed little from June 1999 through June 2000 (Figure 5).

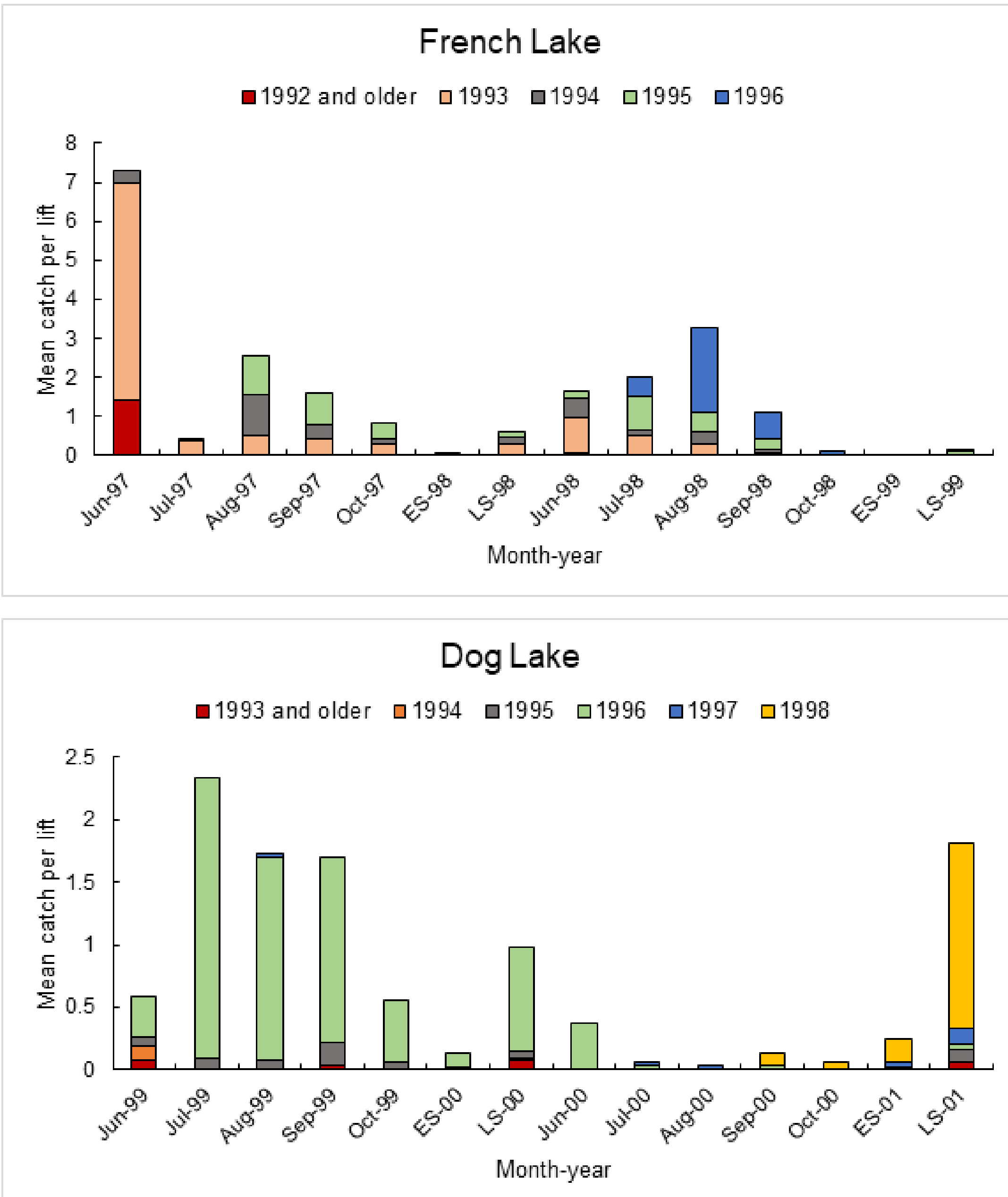

FIGURE 4. Mean catch per lift of each year-class of White Crappie > 200 mm TL captured in trap nets in French and Dog lakes during 14 sampling periods.

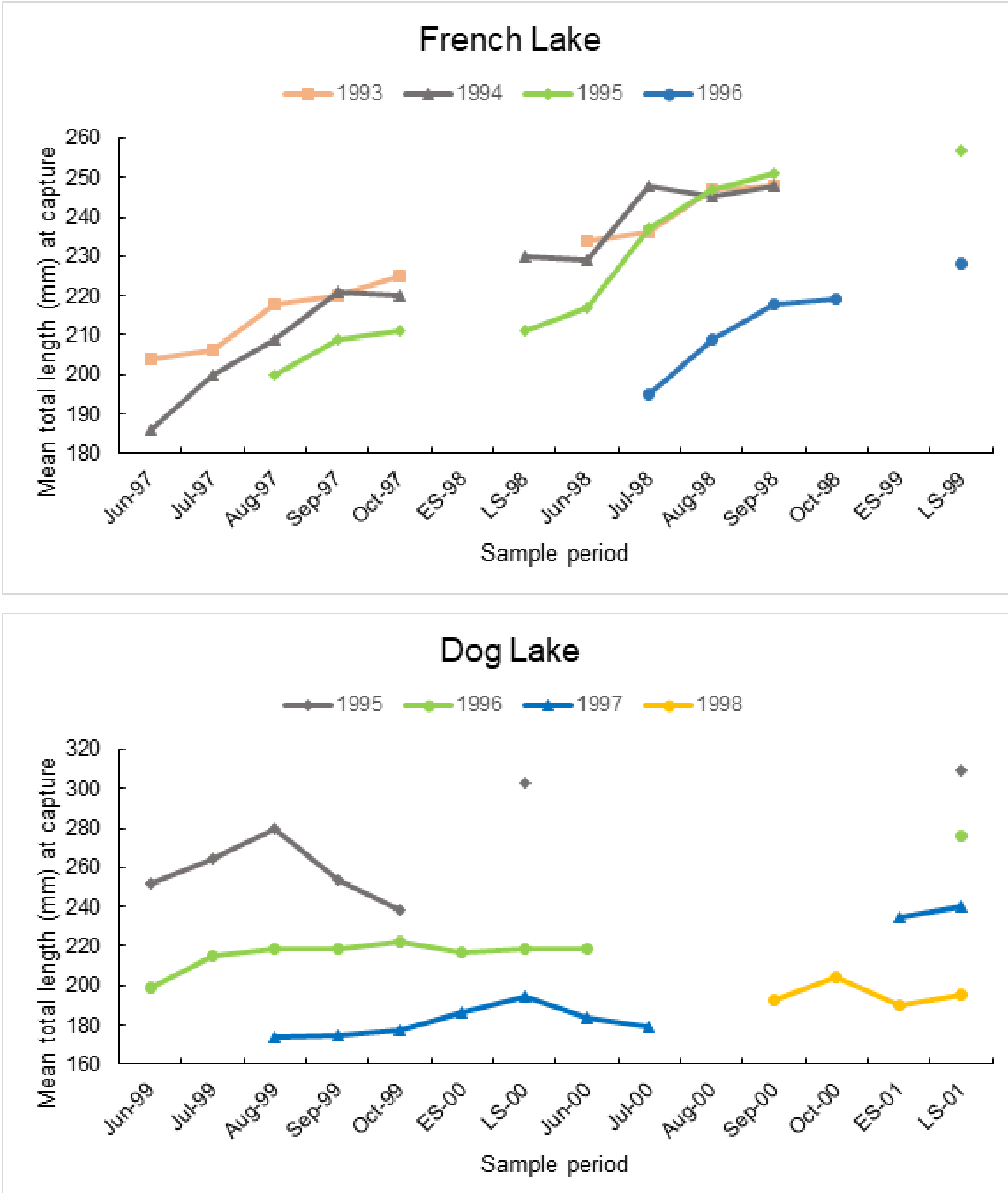

FIGURE 5. Mean total length at capture of the stronger year-classes of White Crappie caught in trap nets set in French and Dog lakes, Minnesota.

Water temperature appeared to affect trap net CPUE of quality White Crappie in fall but not in spring. In both spring and fall, mixed-effects modeling suggested that the lake + temperature model was the best of the three possible models (54.4 AICc lower than the next best model in spring; 71 AICc lower than the next best model in fall). However, when accounting for the variable *lake*, CPUE in spring was weakly associated with water temperature (t = - 1.033), but CPUE in fall decreased with decreasing water temperature (t = 4.709). Trap net CPUE in fall was lower at water temperatures of 9 to 14°C than at 17 to 22°C (Figure 6).

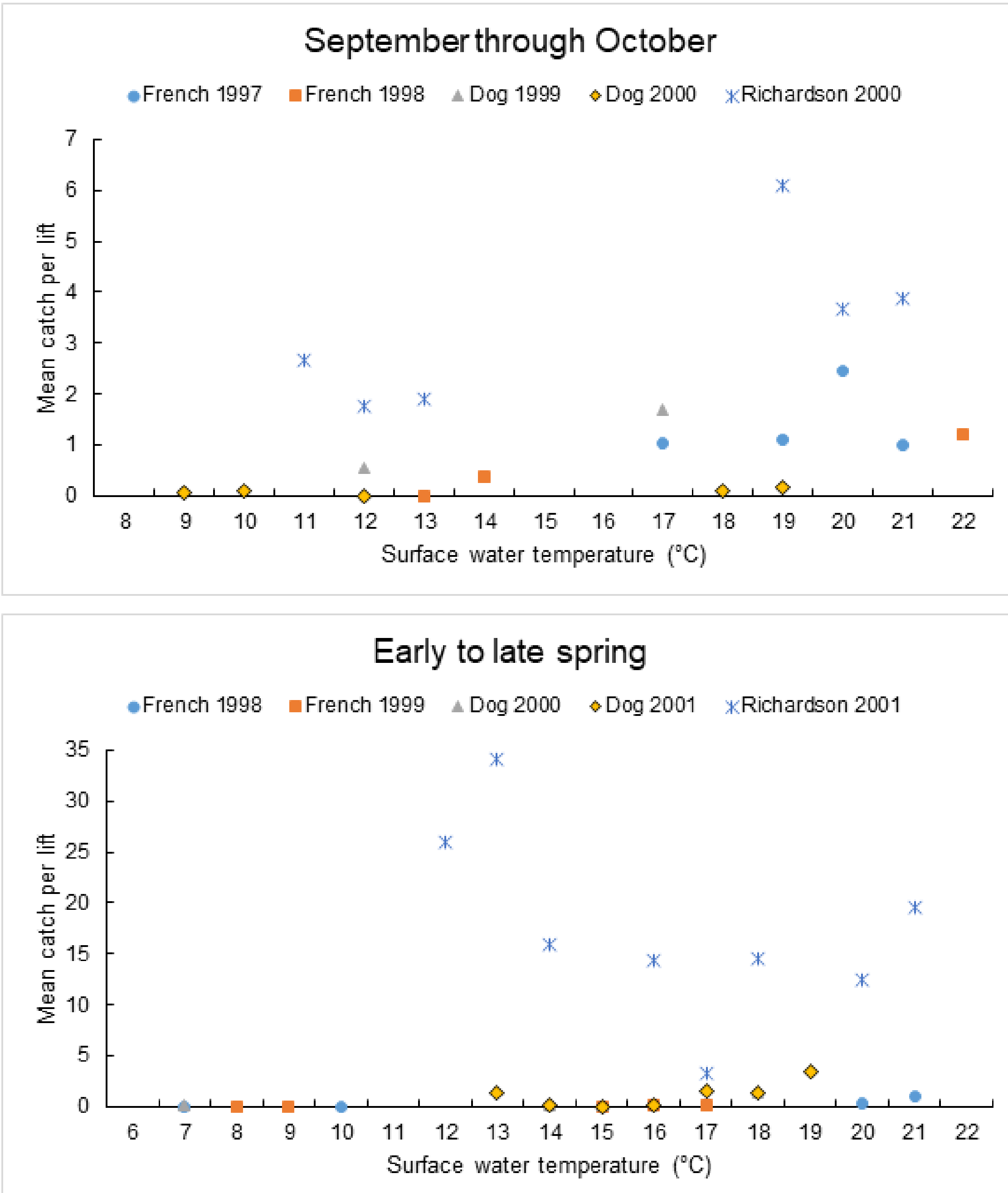

FIGURE 6. Mean catch per lift of White Crappie ≥ 200 mm as a function of surface water temperature in French, Dog, and Richardson lakes in fall and spring.

Comparisons between trap netting of White Crappie and Black Crappie

White Crappie usually made up less than 50% of the total catch of quality crappie in trap nets, but temporal patterns in species composition of quality crappies differed among lakes (Figure 7). Black Crappie composed nearly the entire trap net catch in both ES and LS sample periods at French Lake, but White Crappie composed over 50% of the June and August samples (Figure 7). Variation in catch composition appeared more random at Dog Lake where White Crappie composed most of the summer crappie catch in one year but contributed relatively little to the summer crappie catch the following year (Figure 7). Proportions of White Crappie in the crappie catch also varied considerably at Richardson Lake (Figure 7).

Preliminary sampling in the early 1990s at French and Richardson lakes suggested that estimates of population size of both crappie species could be made with marking in fall and recapture in spring. Two of 238 Black Crappie and three of 158 White Crappie examined from captures in May 1991 at French Lake had the fall fin-clip; thus, doubling the trap net effort in fall and spring should have been sufficient to capture the minimum of four marked crappies needed for an unbiased estimate of population size of both species. At Richardson Lake, four of the 408 Black Crappie and 51 of the 1,385 White Crappie captured in May were fin-clipped the prior fall. Estimates of population size of both species were made at Richardson Lake (Table 2), and increasing trap net effort at both lakes would have improved precision of these estimates.

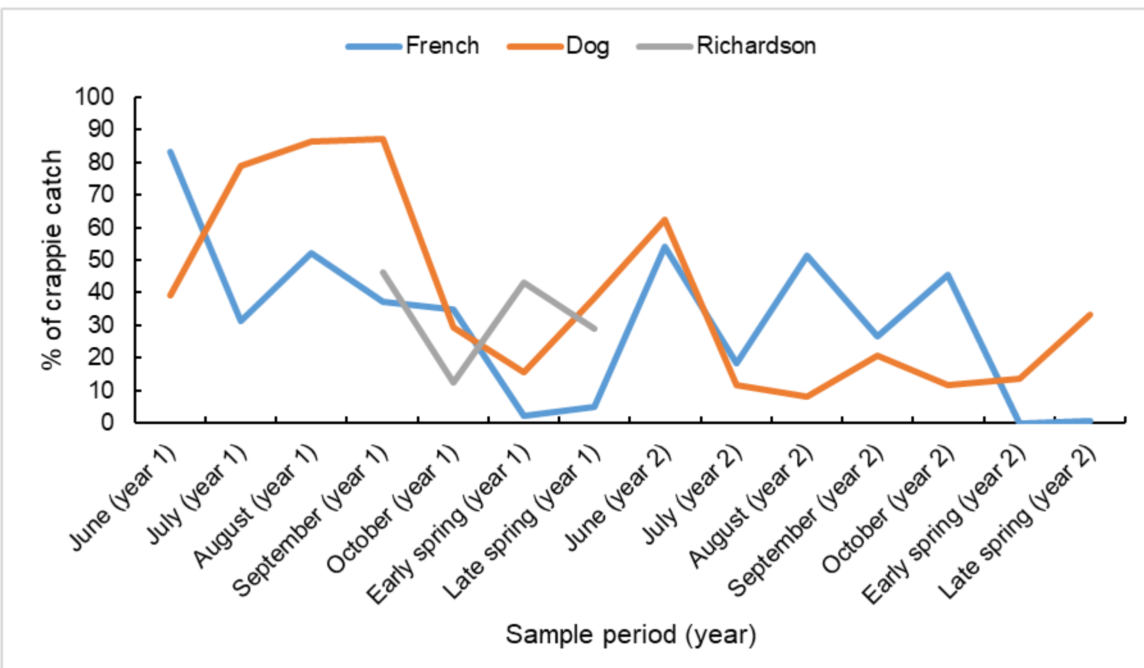

FIGURE 7. Percent of the total crappie catch (White Crappie and Black Crappie ≥ 200 mm TL) in trap nets composed by White Crappie ≥ 200 mm among seven sampling periods over two years at French and Dog lakes, and among four sampling periods over one year at Richardson Lake.

TABLE 2. Fall and spring estimates of population size (95% confidence limits in parentheses) of White Crappie ≥ 200 mm TL and Black Crappie ≥ 200 mm TL in three Minnesota lakes.

Lake	Year	White Crappie	Black Crappie
		Fall	
French	1997	No estimate made	6,507 (3,456-13,309)
French	1998	No estimate made	6,534 (4,394-10,155)
Dog	1999	No estimate made	1,263 (627-2,764)
Dog	2000	No estimate made	1,694 (841-3,705)
Richardson	1991	7,356 (5,705-9,863)	5,726 (2,556-14,315)
Richardson	2000	8,586 (6,325-11,967)	23,465 (18,839-30,070)
		Spring	
French	1998	No estimate made	3,568 (1,771-7,805)
French	1999	No estimate made	3,981 (2,602-6,370)
Dog	2000	No estimate made	339 (208-585)
Dog	2001	583 (290-1,277)	512 (401-679)
Richardson	2001	5,481 (4,589-6,666)	6,426 (5,736-7,250)

Despite the promising results from sampling in the early 1990s, most attempts to estimate population size of quality White Crappie failed while all attempts to estimate population size of quality Black Crappie succeeded. Increasing by 4.8 times the fall trap net effort for marking and increasing by over eight times spring trap net effort for recapture resulted in only one successful fall population estimate (Richardson Lake) of White Crappie (Table 2). Conversely, fall population estimates of Black Crappie were made in each of the five attempts in the three study lakes (Table 2). Similarly, estimates of population size of White Crappie were made at Dog Lake during one spring and at Richardson Lake while estimates of population size of Black Crappie were made in all five attempts at these three lakes (Table 2).

Examination of the few estimates of q suggested that trap net q differed, but inconsistently between the two crappie species. At Richardson Lake q of White Crappie exceeded q of Black Crappie in September 2000 and in September/October 1991 while the converse occurred in October 2000 (Table 3). Catchability in the ES sample period at Richardson Lake was similar between the two species, but q of Black Crappie exceeded q of White Crappie in the LS sample period (Table 3). At Dog Lake, catchability of Black Crappie exceeded q of White Crappie in both ES and LS sample periods in 2001 (Table 3).

DISCUSSION

The inconsistent temporal variation of White Crappie catches makes the interpretation of catch data from standard trap netting unreliable. Furthermore, the 19-mm mesh size was too large to effectively sample smaller White Crappie. Spatial and temporal variation in net location effects, CPUE, and q could be a function of variable recruitment, schooling behavior, spawning, water temperature, and the relative location of White Crappie with respect to the location of nets within lakes. Because of these factors, standard trap netting appears ineffective for sampling White Crappie in Minnesota lakes.

The mesh size (19-mm bar) of webbing on MNDNR standard trap nets was too large to effectively sample White Crappie < 200 mm. Proportions of White Crappie < 200 mm greatly exceeded proportions of White Crappie ≥ 200 mm in trap nets with 13-mm bar mesh webbing (Willis et al. 1984; Jackson and Bauer 2000), whereas, proportions of shorter to longer White Crappie in this study were closer to 1:1 or lower. Because White Crappie < 200 mm were captured in all study lakes, proportions of short to long crappies probably would have increased if nets were wrapped with smaller bar mesh.

Trap net location affected CPUE in one lake, but not in two other lakes suggesting variable temporal movements of White Crappie among lakes. Tagging studies suggest that White Crappie form loose aggregations, have home ranges of 0.6 to 1.2 ha, and can favor specific habitats in reservoirs (Grinstead 1969; Markham et al. 1991) which could explain consistent location effects in Dog Lake. However, tagging studies also show that White Crappie moved up to 3 km, longer than the longest fetch in the study lakes, and they moved at different rates seasonally (Grinstead 1969; Markham et al. 1991; Guy et al. 1994). Thus, aggregations of White Crappie could easily be found in different locations at different times in lakes such as French and Richardson.

We hypothesized that age structure, recruitment, spawning, and avoidance of colder water affected temporal trends in trap net CPUE of White Crappie ≥ 200 mm; however, temporal trends appear unique to each lake. The more random patterns in Dog Lake could be a function of net catches being composed of single, strong year-classes that recruited into the gear coupled with losses from unknown mortality over time. Conversely, the multiple age classes in the trap net catch at French Lake could have contributed to the similar temporal trends in both sample years because recruitment of younger year-classes offset mortality of older year classes. For Black Crappie, consistent temporal patterns of trap net CPUE of quality Black Crappie occurred in both sample years in two of seven Minnesota lakes, and catches in these two lakes (one of which was Dog Lake sampled simultaneously with White Crappie), consisted of two or more year-classes of similar strengths (McInerny et al. 2020). The trap net catch of Black Crappie at French Lake, sampled simultaneously with White Crappie, was composed primarily of a single year-class, and temporal trends in trap net CPUE of Black Crappie appeared more random (McInerny et al. 2020).

Timing of spawning probably affected temporal trends in trap net CPUE of White Crappie ≥ 200 mm, but spawning-related effects on CPUE also appear unpredictable. White Crappie in Dog and Richardson lakes and elsewhere have been observed spawning at depths less than one meter (Siefert 1968; authors' observations); thus, spawning places some mature adults at depths where trap nets were set. Most if not all quality White Crappie in these study lakes were mature and could have spawned; lengths at maturity of this species range from 157 to 184 mm TL (Hansen 1951; Siefert 1969). Spring water temperatures in the study lakes ranged from 14°C, when some adults start spawning, to 23°C (Siefert 1968; Mitzner 1991). However, these two studies found peak spawning occurring at water temperatures of 16 to 21°C, and spawning periods per lake can range from 20 to 47 days. Thus, spawning was probably occurring sometime during the LS and June sample periods in our study lakes. Assuming trap net q is a function of movement, Guy et al. (1994) found ultrasonic tagged White Crappie 265 to 327 mm in a South Dakota lake (slightly lower latitude from our study lakes) moved relatively little in April and June compared to May, which fit CPUE trends in Dog Lake but not at French or Richardson lakes. Spawning females could have been vulnerable to trap netting throughout the spawning season, but vulnerability of males probably varied. Females nest with several males, and they move from shallow to deep water during spawning (Siefert 1968). Conversely, nesting males spawn within a day after building nests, guard eggs for one to four days, and guard broods for another two to seven days (Siefert 1968); thus would not have been vulnerable to trap netting when on or near nests. Some males also nest a second time but at different locations than their first nesting site (Siefert 1968). White Crappie adults in the South Dakota lake showing limited movement in June were also found at depths less than 1.5 m (Guy et al. 1994).

Changes in water temperature could explain changes in CPUE of quality White Crappie in fall, but not at other times of the year. Studies showed that White Crappie prefer water temperatures close to 27°C, and if White Crappie behave like Black Crappie, White Crappies would have sought warmer water temperatures when actual water temperatures fall below 27°C (Edwards 1982; Knights et al. 1995). In fall, the warmest water in dimictic lakes is usually deep and offshore, which could explain declines in CPUE from September to October in the study lakes. Warming water temperatures in spring could explain the higher CPUE at Richardson Lake during early spring, but not at Dog or French lakes.

The lake-specific temporal trends of CPUE of quality White Crappie could be expected because McInerny et al. (2020) found lake-specific temporal variation in trap net CPUE of quality Black Crappie among seven Minnesota lakes including French and Dog lakes. Lastly, additional variation could be explained by unpredictable environmental events. For example, Markham et al. (1991) reported greater movement of radio-tagged White Crappie 271 to 352 mm during periods of high or stable barometric pressures than during periods of unstable or low barometric pressures. Other than monitoring surface water temperature, we did not keep track of environmental events that could have affected trap net CPUE.

Studies in Minnesota and elsewhere suggest that White Crappie favor offshore habitats whereby nearshore sampling with trap nets constructed with 19-mm bar mesh, overall, could be an ineffective gear for sampling this species. Fall trap netting with 13-mm bar mesh is the standard assessment gear for White Crappie in Missouri and Oklahoma primarily because age 0 White Crappies were effectively sampled (Colvin and Vasey 1986; Boxrucker and Ploskey 1988). However, fall sampling with 19-mm bar mesh in fall seldom captured age 0 White Crappie in the study lakes. Vertical and horizontal gill netting in Oklahoma reservoirs found that average depths occupied by White Crappie equaled or exceeded three meters from June through August (Gebhart and Summerfelt 1975). Bonds and Schlechte (2007) tracked ultrasonic tagged White Crappie > 320 g in a Texas reservoir from November through April and could not increase trap net CPUE in nets set near core-use areas because these crappies occurred deeper or farther offshore than nets were set. Guy et al. (1994) also found ultrasonic tagged White Crappie 265 to 327 mm in a South Dakota lake actively moved from July through October but were usually deeper than 1.5 m and were almost always found more than 20 m offshore. Lastly, standardized gill netting in summer (when gill nets are set in deeper water and more offshore than standard trap nets; MNDNR 2017) captured significantly more White Crappie than summer trap netting in the same lakes across their range in Minnesota, and catch rates between summer trap netting and fall trap netting did not consistently differ within the same lakes (McInerny et al. 1993).

MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

Results from these data suggest that trap nets may not effectively sample White Crappie, and therefore, the quartile system that MNDNR staff use to assess White Crappie populations may not be appropriate. Thus, if White Crappie provide an important component of a given lake's crappie fishery, managers should rely on standard gill netting if their current standard trap net protocols fail to provide enough data to assess the fishery. The current quartile system used by MNDNR does not account for the probable among-lake differences in temporal variation in trap net CPUE found in this study, but it is not known how much this temporal variation affects these quartiles. Nearly all Minnesota waters with White Crappie also support Black Crappie populations; however, our results suggest that fisheries managers cannot conclude from a trap net survey the relative proportion of one crappie species to the other in lakes.

Our results suggest that different trap netting protocols were needed for mark-recapture estimates of population size of White Crappie than for Black Crappie. We recommend for fall estimates, trap netting for marking should done in September at water temperatures ≥ 14 °C (the high *q* at Richardson Lake in 1991 occurred at 14 °C). The recapture period should not begin until late May the following year when trap net *q* becomes adequate but netting should end by mid-June before White Crappie start growing. Similar to Black Crappie and Largemouth Bass, a fall mark-fall recapture design will probably provide negatively biased estimates of population size because some unmarked White Crappie will not be vulnerable to capture (McInerny and Cross 1999; 2005). If trap nets are the only gear used for sampling, closed-population methods for spring estimates may not be applicable for estimating population size of White Crappie in lakes like Dog and French because trap net *q* is too low when recruitment is negligible.

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