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MANAGEMENT BRIEF

A Comparison of Two Methods for Sampling Bluegill and Redear Sunfish in Small Impoundments

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Abstract
Bluegill *Lepomis macrochirus* and Redear Sunfish *L. microlophus* are highly regarded recreational species throughout North America. Management of these species relies on sampling methods that accurately and efficiently describe population characteristics of the target population. Largemouth Bass *Micropterus salmoides* and crappies *Pomoxis* spp. are commonly sampled with spring electrofishing and fall fyke netting, respectively. If lepomids can be effectively sampled concurrently with Largemouth Bass or crappies with one of these sampling methods, it would improve sampling efficiency in small impoundments. Our objective was to compare two sampling methods (North American standard fyke netting and electrofishing) for sampling Bluegill and Redear Sunfish populations in small impoundments by comparing size structure, sampling precision (relative standard error), and sampling efficiency (effort needed to collect 125 stock-length fish). Typically, spring electrofishing caught a wider size range of Bluegill and Redear Sunfish than fyke nets, but proportional size distribution was similar between gears. However, length frequencies differed between gears in all impoundments for Bluegill and in three of five impoundments for Redear Sunfish. Electrofishing typically caught a greater proportion of large lepomids than fyke nets in those cases, though the differences were subtle and management decisions would likely be similar using data from either gear. With the exception of Pawhuska Lake (which had low catch rates leading to poor precision for both species and both gears), catch rates were typically high enough to collect sufficient numbers (125 stock-length fish) of Bluegill to adequately describe size structure with 5–20 net-nights for fyke nets or 4–28 transects for electrofishing, but Redear Sunfish sampling would require considerably more sampling effort to produce sufficient amounts of fish in most cases (24–79 net-nights for fyke nets or 12–57 transects for electrofishing). Spring electrofishing is the more precise (lower relative standard error) of the two sampling methods for collecting lepomids.

Standardization of sampling methods allows for consistent data collection and comparison of fish populations through time or across aquatic systems within a state or region (Bonar et al. 2009). Selection and standardization of an appropriate sampling procedure also ensures collection of accurate size structure and relative abundance information, which is critical when managing fish populations (Bonar et al. 2009). In warmwater systems, spring boat electrofishing and fall fyke netting are two methods that are suitable for sampling lepomids (sunfish *Lepomis* spp.) (Bonar et al. 2009; ODWC 2016). Electrofishing is often used to target Largemouth Bass *Micropterus salmoides* and fyke nets to target crappies *Pomoxis* spp. because these two species are the most popular among anglers in some parts of the United States (USFWS and U.S. Census Bureau 2014). It would be efficient to collect lepomid data coincidentally with Largemouth Bass electrofishing or crappie fyke-net samples. Therefore, it is important to know how lepomid samples from these two gears compare in order to pick the best gear to collect precise lepomid population data.

Both boat electrofishing and fyke nets have been effectively used to collect size structure and relative abundance data for lepomids (Kosa and Hale 1998; Schultz and Haines 2005; Fischer et al. 2010; Rypel 2015). A comparison of spring boat electrofishing to fall samples with

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North American standard fyke nets for sampling lepomids has not been conducted. However, two single-lake studies comparing the relative efficiency of electrofishing and other fyke-net designs have been conducted (spring: Schultz and Haines 2005; fall: Porreca et al. 2013). In both studies, fyke nets captured larger lepomids than boat electrofishing (Schultz and Haines 2005; Porreca et al. 2013). However, Largemouth Bass electrofishing is usually conducted during spring (Kosa and Hale 1998; Schultz and Haines 2005; Patterson 2014) and fyke nets are often set for crappies during the fall (Boxrucker and Ploskey 1989; Fischer et al. 2010; Koch et al. 2014; Krogman 2019; Porta et al. 2020). If lepomids can be effectively sampled concurrently to crappies or Largemouth Bass using one of these approaches, it would improve sampling efficiency in small impoundments, which is critical for natural resources agencies that face shrinking budgets and increasing staff demands (Boxrucker 1997). Therefore, we sought to evaluate electrofishing and fyke nets for sampling populations of Bluegill *Lepomis macrochirus* and Redear Sunfish *L. microlophus* in small southern impoundments by comparing size structure, sampling precision (relative standard error; RSE), and sampling efficiency (effort required to achieve a RSE of 25% and to collect 125 stock-length fish).

METHODS

Surveys of sunfish were conducted at lakes Elmer, New Spiro, Pawhuska, Sparks, and Stilwell City, Oklahoma. These impoundments ranged from 6.5 to 101 ha and supported populations of Largemouth Bass, Bluegill, crappies (Black Crappie *Pomoxis nigromaculatus* and/or White Crappie *P. annularis*), and Redear Sunfish.

The five study impoundments were sampled in fall 2016–2018 (October and November, except that Pawhuska Lake was not sampled in 2016) with North American standard fyke nets (Miranda and Boxrucker 2009; Pope et al. 2009). The shoreline perimeter of each lake was stratified into individually numbered 50-m transects. Fyke-net sites were randomly selected from the pool of numbered shoreline transects, and new sites were selected prior to each survey to ensure that all available habitat types had the potential to be sampled. Fyke nets were usually set at the center of transects but may have been shifted slightly to avoid habitats that would entangle the net. At least 6 net-nights (ranged from 6 to 13) were conducted per lake each year (following minimum-effort recommendations for reservoirs ≤121 ha; Koch et al. 2014). Additional sampling effort was used when the availability of fyke nets and time allowed. Fyke nets were set perpendicular to the shoreline in water depths that allowed the frames and hoops to be submerged but still above the thermocline in cases where a thermocline existed. All crappies, Bluegill, and Redear Sunfish were measured for total length (TL; mm) and released.

During spring 2017–2019 (April and May), all five impoundments were surveyed with daytime boat electrofishing (500 V, 60 Hz pulsed DC, 6–8 amps, optimized for water conductivity by adjusting percent of range; Smith Root GPP, Vancouver, Washington; Patterson 2014; ODWC 2016). At each lake, a minimum of six 10-min transects or the entire shoreline perimeter (actual effort = 6–23 transects per lake each year) was sampled during each survey (prescribed minimum effort for reservoirs ≤101 ha; Koch et al. 2014). Electrofishing on any given day was limited to the number of transects available based on shoreline length; no sites were sampled twice on the same trip. A single, bow-positioned dip netter collected all black bass *Micropterus* spp., Bluegill, and Redear Sunfish encountered. At the end of each transect, Bluegill and Redear Sunfish were measured for TL, and all black bass were measured (TL) and weighed (g). All fish were released at a location away from the next transect to avoid encountering fish that had already been captured.

Catch per unit effort (CPUE) was calculated as the number of stock-length and larger Bluegill (i.e., ≥80 mm TL) and Redear Sunfish (i.e., ≥100 mm TL) captured per net-night for fyke nets or per 10-min electrofishing transect. Bluegill and Redear Sunfish size structure was described using proportional size distribution (PSD; Gabelhouse 1984), pooling samples taken within the same year at each lake for each gear type. The PSDs (transformed as the arcsine of the square root of PSD/100 to normalize residuals) were compared between gears (as a fixed factor) for each species with general linear mixed models (GLMMs), specifying lake as a random factor. The GLMMs were fit using the lmer() function of the lmerTest package in program R (Kuznetsova et al 2017). Degrees of freedom for the GLMMs were estimated using Satterthwaite approximations. Length frequencies from each gear within a species (combining data across years within reservoirs) were compared with Fisher's exact test on the counts of fish in each length-class using the fisher.test() function (R Core Team 2019), with post hoc tests performed between gear types using the row_wise_fisher_test() function of the rstatix package (Kassambara 2020).

Relative standard error [RSE = (100 × SE of estimate)/estimate] was calculated to describe sampling precision for electrofishing and fyke-net CPUE. Further, the minimum effective number of samples needed to attain a RSE of 25% (RSE25) for CPUE (pooled across years to improve sample sizes) was calculated using a Monte Carlo bootstrapping method developed by Dumont and Schlechte (2004). This was done by resampling CPUE data 1,000 times with replacement for each reservoir and species (Dumont and Schlechte 2004; Stewart and Long 2012).

The resampling method estimated the number of sampling sites required to achieve RSE25 at the 80th percentile, which is a sufficient level of certainty when evaluating sampling precision (Dumont and Schlechte 2004). This process was repeated to estimate the effort required to capture 125 stock-length lepomids (N_{125}, minimum recommended sample size for calculating PSD; Quist et al. 2009). A minimum of 3 and a maximum of 100 samples were used as the lower and upper bound for the resampling analyses (Dumont and Schlechte 2004).

RESULTS

Totals of 10,215 Bluegill and 2,581 Redear Sunfish were captured during this evaluation (Table 1). More lepomids were captured with electrofishing (6,000 Bluegill and 1,884 Redear Sunfish) than with fyke nets (4,215 Bluegill and 697 Redear Sunfish). The size ranges of Bluegill (23–244 mm TL) and Redear Sunfish (43–284 mm TL) caught with electrofishing were slightly larger than those for fish captured during fall fyke-net efforts (Bluegill = 25–228 mm TL, Redear Sunfish = 58–270 mm TL; Figure 1). The PSD of Bluegill ($F_{1,\ 23} = 23.26$, $P = 0.86$) and Redear Sunfish ($F_{1,\ 23} = 23.00$, $P = 0.77$) did not differ between gears (Table 2). The length frequencies of Bluegill collected with fyke nets and electrofishing differed at all lakes (all Fisher exact P-values < 0.01; Table 2; Figure 1). Length-frequency distributions of Redear Sunfish differed between electrofishing and fyke netting at Pawhuska, Sparks, and Stilwell City lakes ($P < 0.01$) but were similar in the remaining two lakes (Table 2; Figure 2). With the exception of Sparks Lake, electrofishing captured larger lepomids than fyke nets in cases where the length frequencies differed (Table 2); however, the overall differences were subtle (i.e., differences between lakes were typically more extreme than differences between gears).

Precision of CPUE of stock-length fish was always better (lower RSE) for electrofishing samples than fyke-net samples for both species (Table 1). Correspondingly, less effort was required to achieve RSE25 for electrofishing CPUE (6–29 samples for Bluegill, 8–39 samples for Redear Sunfish) than fyke-net CPUE (18–48 samples for Bluegill, 20–49 samples for Redear Sunfish; Table 3). Similarly, the number of samples needed to collect 125 stock-length individuals (N_{125}) for length analyses was similar or lower using electrofishing (4–28 samples for Bluegill, 12–57 samples for Redear Sunfish) compared with fyke nets (5–20 samples for Bluegill, 24–79 samples for Redear Sunfish; Table 3).

Sampling precision was higher for Largemouth Bass collected with spring electrofishing than for crappies captured with fyke nets while concurrently sampling sunfish (Table 4). Sampling precision of Largemouth Bass was high (mean RSE = 10.5; range = 8.1–13.7) with spring electrofishing. Although, sampling precision was lower for crappies captured with fyke nets (mean RSE = 20.9; range = 15.0–30.1), it usually fell well below acceptable levels for evaluating sampling precision (RSE < 25%), while collecting sunfish simultaneously.

DISCUSSION

Sunfish management relies on sampling that efficiently captures enough fish to describe the relative abundance and size structure of the target population. We effectively collected Bluegill and Redear Sunfish while concurrently sampling Largemouth Bass with electrofishing and crappies with fyke nets. However, CPUE was more precise using electrofishing than fyke nets, particularly for Redear Sunfish. We collected 125 stock-length individuals more efficiently for Bluegill than for Redear Sunfish. Quist et al. (2009) recommended the use of at least 125 fish when describing the PSD of a fish population. Similarly, Miranda (2007) determined that 75–160 fish were required to describe PSD and mean length of fish populations. Considerably more fish are recommended when constructing length-frequency histograms (150–1,200 fish; Miranda 2007; Quist et al. 2009) or age structure and population characteristics (500–1,000 fish; Coggins et al. 2013). Based on our results, it appears that Bluegill are captured at high enough rates that sufficient fish for a detailed description of size structure could be captured with reasonable effort ($N_{125} = 5–20$ net-nights for fyke nets or 4–28 transects for electrofishing) with either gear. However, considerable effort would be required to achieve these target sample sizes for Redear Sunfish with either sampling method, but electrofishing would be more practical than fyke nets (N_{125} required 24–79 fyke-net sets or 12–57 electrofishing transects).

Disparities in length-frequency distributions between gears at some reservoirs may be explained by seasonal sampling differences (i.e., spring electrofishing versus fall fyke netting). For example, Schultz and Haines (2005) found that larger Bluegill were captured with spring electrofishing than in fall electrofishing samples. Schultz and Haines (2005) also suggested that electrofishing could be applied across a diversity of habitat types, particularly where small fish are encountered, which may explain the broader lepomid size structure captured with this gear. Further, the capture of large Bluegills in fyke nets declined from spring through fall in Minnesota lakes (Cross et al. 1995). However, our finding that electrofishing captured larger lepomids than fyke nets contradicts findings of Schultz and Haines (2005), who found PSD and size structure were greater for Bluegill captured with trap nets than for those captured by electrofishing in a large Kansas reservoir. Similarly, Porreca et al. (2013) found that larger Bluegill and Redear Sunfish were captured with fyke nets

TABLE 1. Catch statistics (pooled across years) of Bluegill (≥80 mm TL) and Redear Sunfish (≥100 mm TL) captured from five small Oklahoma impoundments using fyke nets and electrofishing from fall 2016 to spring 2019. Effort is the number of net-nights for fyke nets or 10-min transects for electrofishing. Abbreviations are as follows: N = the total number of fish captured, CPUE = the number of fish caught per fyke-net set or number of fish captured per 10-min electrofishing transect, and RSE = relative standard error of CPUE, where RSE = (100 × SE of estimate)/estimate.

		Fyke nets				Electrofishing			
Species	Reservoir	Effort	N	CPUE (SE)	RSE	Effort	N	CPUE (SE)	RSE
Bluegill	Elmer	26	1,030	39.6 (7.6)	19.2	50	2,439	48.8 (3.4)	7.1
	New Spiro	32	1,688	52.8 (12.2)	23.1	61	1,459	23.9 (2.7)	11.1
	Pawhuska	20	160	8.0 (1.9)	23.8	47	271	5.8 (1.0)	18.1
	Sparks	22	916	41.6 (12.1)	28.9	18	350	19.4 (4.6)	23.7
	Stilwell City	29	421	14.5 (4.5)	30.9	47	1,481	31.5 (4.8)	15.3
Redear Sunfish	Elmer	26	99	3.8 (1.0)	25.8	50	635	12.7 (1.1)	8.6
	New Spiro	32	207	6.5 (1.2)	17.9	61	511	8.4 (1.0)	11.4
	Pawhuska	20	37	1.9 (0.6)	31.9	47	103	2.2 (0.4)	20.5
	Sparks	22	139	6.3 (1.4)	22.7	18	102	5.7 (1.0)	17.0
	Stilwell City	29	215	7.4 (2.3)	30.4	47	533	11.3 (1.9)	16.4

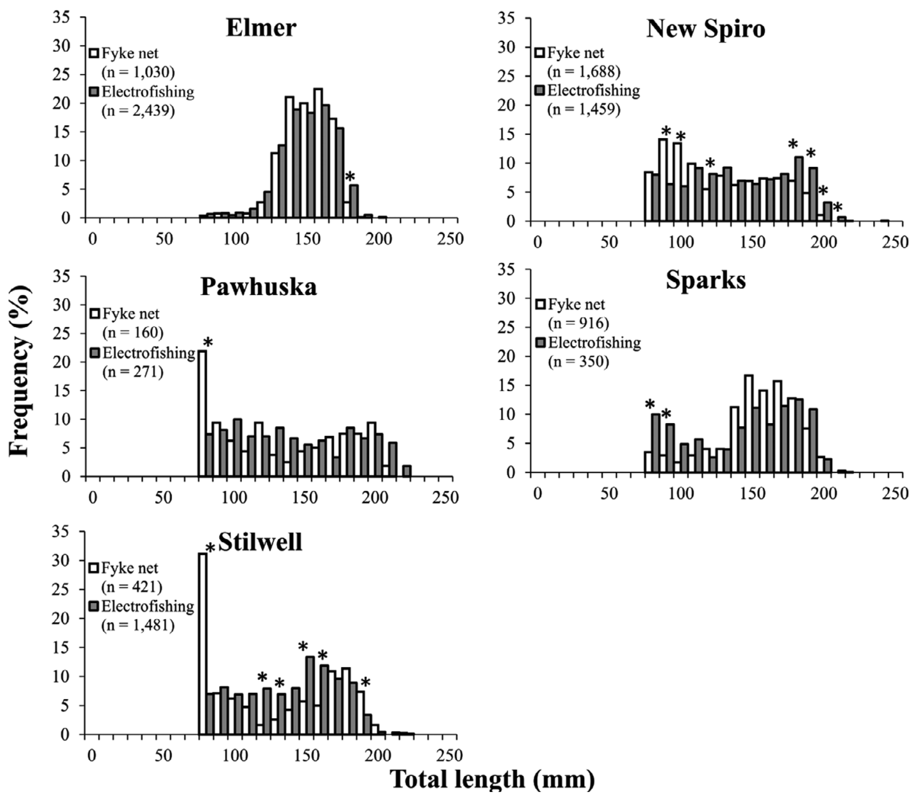

FIGURE 1. Length frequencies of Bluegill (≥80 mm TL) captured during standardized spring boat electrofishing and fall fyke-net sampling efforts in five small Oklahoma impoundments from fall 2016 to spring 2019. Asterisks above the bars denote a significant difference in size-class between gears.

than with electrofishing at Coffeen Lake, Illinois. However, these evaluations compared sampling methods in the same season (spring: Schultz and Haines 2005; fall: Porreca et al. 2013) and both were conducted at a single lake (so results could simply be driven by lake-specific differences as we observed for Sparks Lake versus the other

TABLE 2. Fisher's exact test results and proportional size distribution (PSD; confidence intervals in parentheses) used to compare size structure of Bluegill and Redear Sunfish (≥ stock length) captured with fyke nets and electrofishing from five small Oklahoma impoundments from fall 2016 to spring 2019. Significance was tested at $P = 0.01$ (Bonferroni correction = 0.05/5). Asterisks denote a significant difference in size structure between gears.

Species	Reservoir	Fisher's exact *P*-value	PSD fyke net	PSD electrofishing
Bluegill	Elmer	0.0005*	63 (60–66)	60 (58–62)
	New Spiro	0.0005*	35 (33–37)	46 (42–50)
	Pawhuska	0.0010*	43 (35–51)	45 (39–51)
	Sparks	0.0005*	72 (69–75)	57 (51–63)
	Stilwell City	0.0005*	42 (37–47)	48 (45–51)
Redear Sunfish	Elmer	0.5382	95 (90–100)	87 (84–90)
	New Spiro	0.0540	56 (49–63)	65 (60–70)
	Pawhuska	0.0005*	89 (76–102)	100 (99–101)
	Sparks	0.0005*	84 (77–91)	57 (46–68)
	Stilwell City	0.0005*	28 (21–35)	43 (39–47)

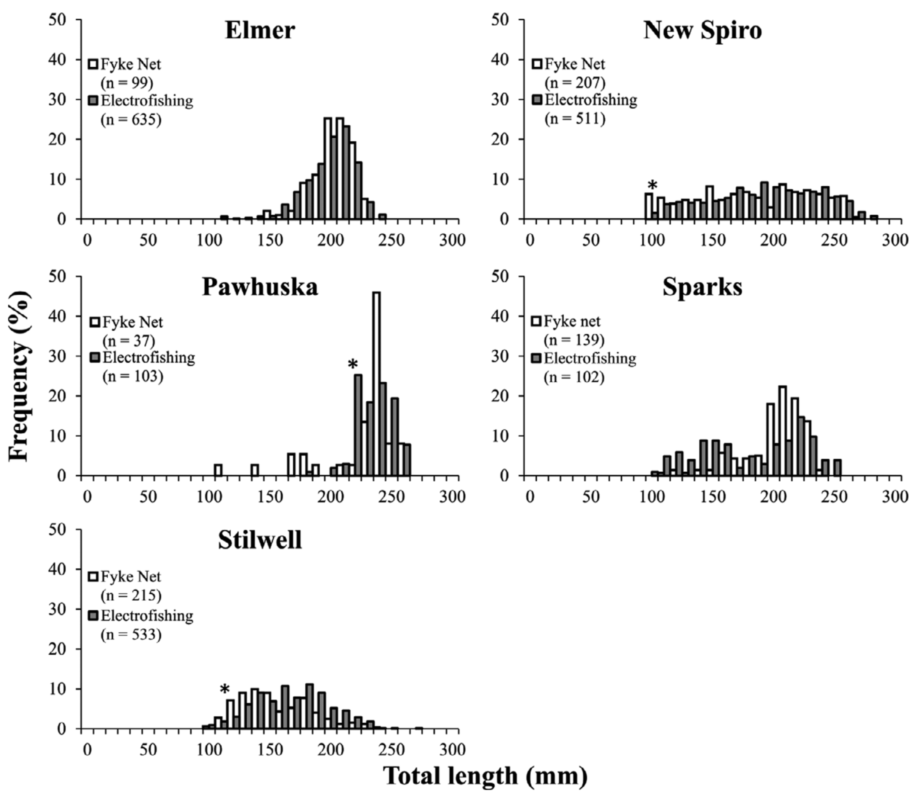

FIGURE 2. Length frequencies of Redear Sunfish (≥100 mm TL) captured during standardized spring boat electrofishing and fall fyke-net sampling efforts in five small Oklahoma impoundments from fall 2016 to spring 2019. Asterisks above the bars denote a significant difference in size-class between gears.

four lakes). Our evaluation of multiple small impoundments suggests that some reservoir-specific variability may have influenced the differences in length frequencies we observed between sampling methods. However, differences in length frequencies do not appear drastic enough to alter management recommendations, suggesting that either gear is likely adequate for sampling lepomid size structure.

Fish sampling protocols often prescribe a minimum amount of effort, which is typically assigned based on reservoir size or sampling objectives (Bonar et al. 2009;

TABLE 3. Catch statistics of Bluegill (≥80 mm TL) and Redear Sunfish (≥100 mm TL) and required effort to achieve a relative standard error [RSE = (100 × SE of estimate)/estimate] of CPUE equal to 25% (RSE25) and collect 125 stock-length (N_{125}) Bluegill and Redear Sunfish with fyke nets and electrofishing from five small Oklahoma impoundments from fall 2016 to spring 2019. Effort is the number of net-nights for fyke nets or number of 10-min transects for electrofishing, and N = total number of fish captured.

		Year											
		2016		2017		2018		2019		Combined			
Species	Reservoir	Effort	N	Effort	N	Effort	N	Effort	N	Effort	N	RSE25	N_{125}
					Fyke net								
Bluegill	Elmer	6	356	10	363	10	311			26	1,030	18	6
	New Spiro	13	727	9	394	10	567			32	1,688	31	5
	Pawhuska			10	81	10	79			20	160	22	20
	Sparks	6	666	8	163	8	87			22	916	34	6
	Stilwell City	9	207	10	144	10	70			29	421	48	14
Redear Sunfish	Elmer	6	20	10	48	10	31			26	99	32	40
	New Spiro	13	107	9	43	10	57			32	207	20	24
	Pawhuska			10	19	10	18			20	37	37	79
	Sparks	6	51	8	68	8	20			22	139	21	25
	Stilwell City	9	96	10	88	10	31			29	215	49	25
					Electrofishing								
Bluegill	Elmer			17	1,153	19	781	14	505	50	2,439	6	4
	New Spiro			21	906	22	179	18	374	61	1,459	15	8
	Pawhuska			20	96	13	22	14	153	47	271	29	28
	Sparks			6	124	6	69	6	157	18	350	17	10
	Stilwell City			7	185	23	1,009	17	287	47	1,481	22	7
Redear Sunfish	Elmer			17	196	19	290	14	149	50	635	8	12
	New Spiro			21	290	22	96	18	125	61	511	15	19
	Pawhuska			20	55	13	34	14	14	47	103	39	57
	Sparks			6	33	6	14	6	55	18	102	11	25
	Stilwell City			7	35	23	376	17	122	47	533	25	15

TABLE 4. Catch statistics for crappies and Largemouth Bass (≥ stock length) captured from five small Oklahoma impoundments from fall 2016 to spring 2019. Crappies were collected during fall fyke-net surveys, and Largemouth Bass were collected during spring electrofishing surveys. Largemouth Bass catch data for Pawhuska Lake combines Largemouth Bass and Spotted Bass *Micropterus punctulatus*. Effort is the number of net-nights for fyke nets or number of 10-min transects for electrofishing. Abbreviations are as follows: N = total number of fish captured, CPUE = number of fish caught per fyke-net set or number of fish captured per 10-min electrofishing transect, and RSE = relative standard error of CPUE, where RSE = (100 × SE of estimate)/estimate.

	Crappies				Largemouth Bass			
Reservoir	Effort	N	CPUE (SE)	RSE	Effort	N	CPUE (SE)	RSE
Elmer	26	1,958	75.3 (11.3)	15.0	50	697	13.9 (1.1)	8.2
New Spiro	32	293	9.2 (1.8)	19.7	61	266	4.4 (0.4)	8.1
Pawhuska	20	25	1.3 (0.4)	30.1	47	439	9.3 (0.8)	8.7
Sparks	22	137	6.2 (1.1)	17.7	18	205	11.4 (1.6)	13.7
Stilwell City	29	150	5.2 (1.1)	22.1	50	579	11.6 (1.6)	13.6

Stewart and Long 2012; Koch et al. 2014). For small impoundments in Oklahoma, a minimum of six 10-min transects are recommended when sampling Largemouth Bass with spring electrofishing and 15 net-nights when conducting fall fyke-net surveys targeting crappies (for impoundments <202 ha; ODWC 2016). We determined that the effort needed to achieve RSE25 in our study varied considerably between gears (mean values were 31 net-nights of fyke nets and 18 electrofishing units for Bluegill; 32 net-nights of fyke nets and 20 electrofishing units for Redear Sunfish). An RSE25 was achieved with the minimum suggested sampling effort in one case (six electrofishing transects for Bluegill at Elmer Lake). Sampling variability was high for both species with both sampling methods; however, catch rates of Bluegill were high enough to describe size structure of these populations with reasonable effort (i.e., mean N_{125} was 10 fyke-net sets or 11 electrofishing transects), whereas Redear Sunfish would have required substantially more effort to meet precision goals (mean N_{125} was 39 fyke-net sets or 26 electrofishing transects). Overall, less effort was required to capture 125 stock-length lepomids than to reach RSE25. Therefore, fisheries managers need to determine if CPUE precision (RSE25) or describing size structure of lepomid populations (N_{125}) is more important as these objectives determine the sampling effort required at a particular reservoir. This decision is particularly important when using electrofishing as the number of transects required to attain an RSE25 sometimes exceeded the number of transects required to sample the entire perimeter of a reservoir. Therefore, fisheries managers may have to return to a lake to conduct additional electrofishing transects to achieve their sampling precision goals.

The sampling methods evaluated in this study are used primarily to target Largemouth Bass (spring electrofishing) and crappies (fall fyke netting); however, we effectively sampled lepomids alongside both target species. Our results suggest that spring electrofishing is more efficient at sampling lepomids than fyke nets in small impoundments. Further, Largemouth Bass were sampled with greater precision with spring electrofishing than crappies were with fyke nets. Sampling precision (RSE) of Largemouth Bass CPUE in this study ranged from 8.1 to 13.7, while also netting Bluegill and Redear Sunfish. Our results are comparable to precision rates determined from electrofishing surveys of Kentucky small impoundments (CV = 6–39%, mean = 14%; Kosa and Hale 1998), even though they did not collect Largemouth Bass and lepomids concurrently and they used two dipnetters. Although we made no observations that a single dipnetter was overwhelmed by the abundance of fish collected in our study, it is possible that the use of a second dipnetter could aid in reducing variability of lepomid catch rates.

There are numerous additional benefits to collecting lepomids during spring. Perhaps the most valuable benefit of spring electrofishing is the ability to capture Largemouth Bass and lepomids simultaneously (Kosa and Hale 1998; Schultz and Haines 2005). Largemouth Bass are typically the most abundant lepomid predator in small impoundments, and the Largemouth Bass–lepomid interactions in these systems may influence lepomid size structure (Boxrucker 1987; Guy and Willis 1990), so the ability to effectively characterize both populations is critical for lepomid management. Sampling lepomids during spring is also critical for understanding life history strategies that may explain lepomid growth rates. Age and size at maturity can strongly influence size structure in lepomid populations (Drake et al. 1997; Jennings et al. 1997; Aday et al. 2006; Peterson et al. 2010), so sampling lepomids near spawning times (spring or early summer), when gonadal development and maturity can be evaluated, may be important for describing lepomid population dynamics.

Our results suggest that managers can gain valuable fishery data for Bluegill and Redear Sunfish populations by collecting these species concurrent with spring Largemouth Bass electrofishing or fall crappie fyke-net sampling. If given a choice, our study found that spring samples are probably best for sampling Bluegill and Redear Sunfish because electrofishing produced the best precision (although catch rates varied substantially); however, PSD was similar between gears in many cases suggesting that either gear would be acceptable.

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