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Fixed Versus Random Sampling Designs in Small South Dakota Glacial Lakes

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ABSTRACT Choice of sampling design is fundamental when planning surveys to monitor fisheries resources. However, little is known about the impact that different sampling designs may have on commonly collected fish population metrics used to index relative abundance, size structure, and diversity in small (<200 ha) glacial lakes. To address this issue, we sampled three small glacial lakes in eastern South Dakota with modified fyke nets and gill nets at fixed sites used by South Dakota Game, Fish and Parks and a complement of nets at randomized sites. Catch per unit effort (CPUE), proportional size distribution (PSD), and PSD-preferred (PSD-P) were compared between fixed and random designs for each species and gear by lake while Bray-Curtis distances were calculated between sample designs for each gear type in each lake. Precision of CPUE estimates for routinely indexed species were calculated for both gears used by each sampling design. No consistent bias in calculated population metrics was detected between sampling designs for any species collected with either gear type in the three lakes. Sampling precision of CPUE estimates were low for both gears and study designs; though randomized sites tended to yield lower precision. Power analyses indicated that current levels of sampling effort are insufficient to detect differences in CPUE or PSD/PSD-P between fixed and random sampling designs. In addition to being small, study lakes had relatively homogenous habitat allowing for effective sampling resulting in similar values of CPUE and PSD/PSD-P for both fixed and random study designs, and high assemblage overlap. We conclude that fixed sampling sites provide adequate representation of fish communities in small glacial lakes and are sufficient for monitoring temporal changes in these small, but numerous, systems.

KEY WORDS Experimental design, gill net, glacial lakes, modified fyke net, monitoring, sampling, sampling precision, South Dakota.

Fisheries scientists require accurate information on fish communities to make effective management decisions (Quist et al. 2006). Fisheries managers typically rely on standardized sampling data to make population inferences (Bonar et al. 2009a). However, for an estimate of any population parameter to be meaningful, the gear used must be deployed at a place and time so that it collects a representative sample of the population of interest (Jacobsen and Kushlan 1987, Hansen et al. 2007).

Fixed sampling designs are the most common sampling strategies used by management agencies to collect data used to calculate indices (King et al. 1981, Noble et al. 2007), but completely randomized designs are the most statistically defensible (Krebs 1999). Fixed sites are subjectively selected by the investigator for qualities (i.e. habitat, fish density, ease of access; Noble et al. 2007) that typically result in higher catch rates and diversity (Hubbard and Miranda 1986, McClelland and Sass 2012). Fixed sampling designs may be more effective at detecting temporal trends within a community (Quist et al. 2006, McClelland and Sass 2012) and have been used for long-term monitoring programs (Pegg and McClelland 2004). Unfortunately, selecting subjective sites for convenience can introduce bias that leads to misrepresentation of catch per unit effort (CPUE), size structure, and diversity (Hubbard and Miranda 1986, Bodine et al. 2011, McClelland and Sass 2012), and can over-represent habitats that are easier to sample (Balkenbush and Fisher 1997). Alternatively, a randomized sample design uses a probability-based approach for choosing sampling sites (Brown and Austen 1996). Randomized sampling data can be more easily compared to other study areas and better captures spatial variation between populations. Comparisons between fixed and random sampling designs in streams, large rivers, and reservoirs have found that choice of sampling design may significantly impact estimations of catch per unit effort (CPUE), size structure, and diversity, though we are unaware of examples from small glacial lakes.

South Dakota Department of Game, Fish and Parks (SDGFP) conducts standard summer fish population sampling in lakes and reservoirs with modified fyke nets and gill nets using a fixed sampling design and has done so for approximately 20 years (B. Blackwell, South Dakota Department of Game, Fish and Parks, personal communication). Fixed sites were originally chosen in a systematic fashion to spread sampling effort evenly across each lake. Commonly used indices, such as proportional size distribution (PSD), PSD of preferred length fish (PSD-P), and CPUE are calculated from data collected during standard summer sampling and used to make informed management decisions. Potential biases in population metrics resulting from use of fixed sampling design are unknown for the numerous small glacial lakes of eastern South Dakota. Given this uncertainty we compared the influence of sample design (i.e. fixed or random) on measures of size structure, relative abundance, assemblage overlap, and sampling precision for modified fyke nets and gill nets in three small glacial lakes of eastern South Dakota. Additional analyses were performed to estimate the number of gear deployments required to detect differences in CPUE and PSD/PSD-P between fixed and random study designs, and collect a representative sample (i.e. 125 individuals) for calculation of PSD/PSD-P.

STUDY AREA

Three lakes in eastern South Dakota (i.e., Bullhead, Cochrane, and Wall) were sampled concurrent with annual fish population sampling by SDGFP during June 2014. Bullhead Lake (68 ha; Fig. 1), Lake Cochrane (144 ha; Fig. 2), and Wall Lake (84 ha; Fig. 3) are small, eutrophic, glacial lakes (i.e., TSI; Carlson 1977) and are representative of many eastern South Dakota lakes. Approximately half of all lakes routinely sampled by SDGFP in eastern South Dakota have a surface area less than 200 ha. Bullhead Lake has mostly un-

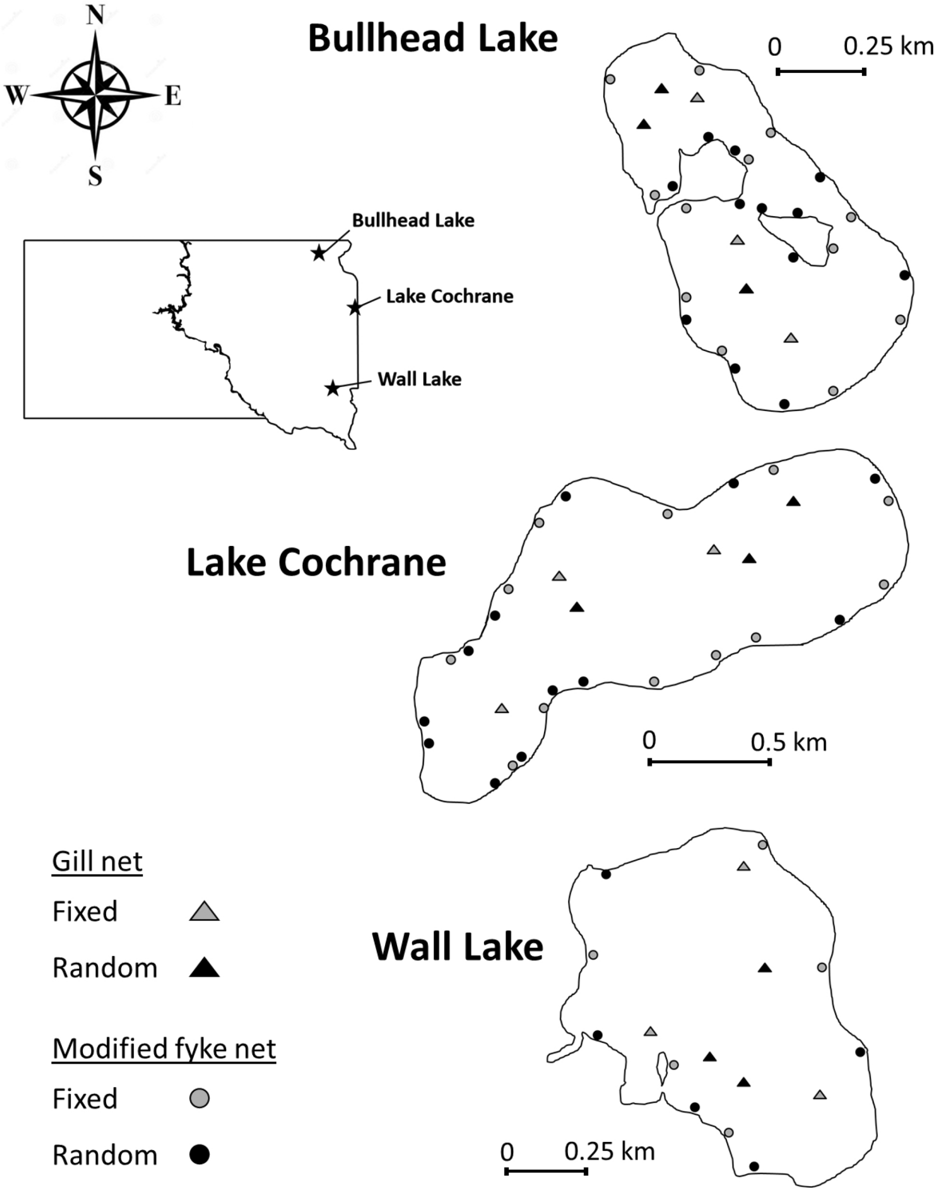

Figure 1. Map of Bullhead Lake, Lake Cochrane, and Wall Lake showing fixed (grey) and random (black) sites sampled with North American Standard experimental gill nets (triangles) and modified fyke nets (circles) during June 2014.

disturbed wooded shorelines while Lake Cochrane and Wall Lake have mostly developed shorelines. Fish communities are dominated by fishes of the families Centrarchidae, Ictaluridae, Percidae, and Esocidae.

METHODS

Gear description.—Gears were constructed to specifications outlined in *Standard Methods for Sampling North American Freshwater Fishes*, hereafter referred to as Standard (Bonar et al. 2009b). Standard modified fyke nets (0.9 m x 1.8 m frames) were constructed using 13-mm knotless bar mesh and 10-mm rolled steel bar and possessed a single throat stretched between the second and fourth hoops that tapered to a 203-mm opening at the cod end with a restriction to reduce escapement as described by Sullivan and Gale (1999). Standard gill nets were 24.8-m long and contained eight randomly ordered panels of monofilament mesh (19, 25, 32, 38, 44, 51, 57, 64-mm bar mesh).

Experimental design.—We set fixed gears at SDGFP sampling sites and an equal amount of effort at randomized sites in each lake. Random sampling sites were chosen by overlaying a map of each lake with a grid and assigning each grid a number. We used shoreline grids to assign modified fyke net sites, and grids in open water areas to assign gill net sites. To choose which grid cells to sample we used a random number generator without replacement. Standard sampling on Bullhead Lake (Fig. 1) and Lake Cochrane (Fig. 2) consisted of three gill net/nights and 12 modified fyke net/nights of effort for each sampling design, and Wall Lake (Fig. 3) was sampled with three gill net/nights and 5 modified fyke net/nights of effort for each sampling design. All nets were fished for 24 hr and all fish were identified, measured for total length (TL; mm), and weighed (g).

Statistical analyses.—Comparisons of CPUE, size structure, and precision were gear, lake, and species-specific. Fish assemblage comparisons were gear and lake-specific. To compare CPUE we performed either a *t*-test or Wilcoxon Rank-Sum Test depending on normality of the data. Normality was tested using the Shapiro-Wilk Test and if data were non-normal then the Wilcoxon Rank-Sum Test was used. We compared size structure using proportional size distribution (PSD) and PSD of preferred length fish (PSD-P) and were calculated as

$$\text{PSD} = \frac{Number\ of\ fish \geq minimum\ quality\ length}{Number\ of\ fish \geq minimum\ stock\ length} \text{ x } 100$$

$$\text{PSD-P} = \frac{Number\ of\ fish \geq minimum\ preferred\ length}{Number\ of\ fish \geq minimum\ stock\ length} \text{ x } 100$$

where species-specific stock, quality, and preferred lengths correspond to 20–26%, 36–41%, and 45–55% world-record lengths, respectively (Gabelhouse 1984). Size structure indices were calculated for species with sample sizes ≥ 125 individuals (Quist et al. 2009) and 95% confidence intervals were calculated where appropriate (Gustafson 1988). To compare index values between fixed and random sites we used the Chi-square test (Conover 1999). We estimated the number of net sets required to obtain 125 fish for calculations of PSD, as recommended by Quist et al. (2009), using bootstrap resampling techniques. Samples were drawn at random (i.e., 2–100 in steps of 1) from a vector of empirical catch data for each species, gear, lake, and sample design combination then 10,000 iterations were performed at each step. The point at which the 90% confidence interval exceeded the minimum threshold of 125 fish was identified as the number of nets required to obtain 125 fish. To compare gear and lake-specific fish assemblages between fixed and random sites we used the Bray-Curtis coefficient. This coefficient is calculated by dividing the sum of the absolute differences in species-specific abundance between two assemblages by the total abundance of all species collected for both assemblages, resulting in a value between 0-1 where 0 indicates complete assemblage overlap and 1 indicates no assemblage overlap (Bray and Curtis 1957). We calculated the coefficient of variation (CV; SD/mean) to measure sampling precision for gears typically used to index targeted species. To estimate minimum total required sample sizes needed to be 90% confident of detecting a significant difference in CPUE and PSD/PSD-P between fixed and random sampling designs we used a priori power analyses. We used empirical catch data from this study to calculate effect sizes used for power analyses. To perform power analyses we used G* Power 3.1.7 (Faul et al. 2007) and all other calculations were performed using R version 3.2.3 “Wooden Christmas-Tree” (The R Foundation for Statistical Computing 2015) assuming an $\alpha = 0.05$ for all tests.

RESULTS

No consistent bias in CPUE, size structure, or assemblage overlap was detected between fixed and random study designs. Sufficient data was available to make 18 species, gear, and lake-specific CPUE comparisons, of which, seven were analyzed by non-parametric methods. No significant difference in CPUE was detected between study designs for any species collected with modified fyke nets (Table 1) or gill nets (Table 2) in the three study lakes.

Only one comparison yielded significant differences in size structure between study designs. Values of PSD were greater for bluegill (*Lepomis macrochirus*) in the randomized fyke nets in Lake Cochrane ($\chi^2 = 8.603$, $P = 0.003$; Table 3). No difference in PSD-P was detected between study designs for any species sampled with either gear type in the three lakes. Confidence intervals for several estimates of PSD/PSD-P overlapped 0 or 100 and were left unreported (Table 3). Bootstrap resampling analyses indicated that current levels of sampling effort for both sampling designs were gener-

Table 1. Catch per unit effort (± standard error) by lake and species for fish collected with modified fyke nets during June 2014 using two study designs (i.e. fixed or random). For species with enough data to conduct statistical comparisons (i.e. ≥ ≈15 fish captured between both gears for a particular gear and lake) t-tests are reported with a *t*-statistic and Wilcoxon Rank-Sum tests are reported with a W-statistic.

Lake	Species	Fixed	Random
Bullhead	Black Bullhead	4.50 ± 2.26	7.08 ± 1.69
	Black Crappie	1.33 ± 0.40	1.33 ± 0.74
	Bluegill	4.58 ± 2.75	9.42 ± 2.83
	Green Sunfish	0	0.17 ± 0.17
	Northern Pike	2.42 ± 0.53	1.50 ± 0.45
	Yellow Perch	9.67 ± 8.19	11.50 ± 4.66
Cochrane	Black Crappie	1.17 ± 0.52	3.33 ± 1.49
	Bluegill	29.00 ± 4.24	24.67 ± 5.28
	Green Sunfish	3.08 ± 1.71	1.00 ± 0.52
	Northern Pike	0	0.33 ± 0.19
	Walleye	0.17 ± 0.11	0
	Yellow Bullhead	0.18 ± 0.08	0
	Yellow Perch	2.33 ± 1.32	2.33 ± 1.13
Wall	Black Bullhead	78.20 ± 19.36	115.80 ± 35.98
	Black Crappie	1.60 ± 0.68	1.20 ± 0.97
	Bluegill	0.80 ± 0.20	0.20 ± 0.20
	Channel Catfish	1.00 ± 0.45	0.80 ± 0.80
	Common Carp	1.00 ± 0.77	0.80 ± 0.58
	White Sucker	0.40 ± 0.24	0

ally insufficient to collect the 125 individuals necessary to compute PSD/PSD-P. Exceptions to this observation included bluegill collected in Lake Cochrane with fyke nets, black bullhead (*Ameiurus melas*) collected with fyke nets in Wall Lake, and yellow perch (*Perca flavescens*) collected with gill nets in Lake Cochrane where current levels of effort for both study designs provided the required sample size to compute PSD/PSD-P.

Measures of gear and lake-specific assemblage differences using Bray-Curtis distances indicated that sampling design had limited influence. Bray-Curtis distances were 0.193, 0.137, and 0.195 for modified fyke net comparisons in Bullhead, Cochrane, and Wall Lakes, respectively. Bray-Curtis distances were 0.429, 0.146, and 0.172 for gill nets in Bullhead, Cochrane, and Wall Lakes, respectively. The highest value of dissimilarity (i.e., gill nets in Bullhead Lake) was attributable to capture of several individuals of species not typically sampled with gill nets (i.e., black crappie [*Pomoxis nigromaculatus*], bluegill, and largemouth bass [*Micropterus salmoides*]) by the random design.

Sampling precision was generally low (CV > 1.00) and highly variable across lakes and species for both gears and sampling designs (Table 4). The lowest observed measures of CV came from gill nets and included northern pike (*Esox lucius*) sampled in Bullhead Lake (fixed CV = 0.36; random CV = 0.29), yellow perch from Lake Cochrane (fixed CV = 0.25; random CV = 0.46), and channel catfish (*Ictalurus punctatus*) (fixed CV = 0.28; random CV = 0.35) collected in Wall Lake (Table 4). The highest measures of CV were produced by modified fyke nets (Table 4). Random sites tended to produce higher CV for both gear types indicating reduced precision of CPUE estimates with random sampling designs.

Power analyses indicated that current levels of effort are insufficient to detect significant differences in CPUE and PSD/PSD-P between sampling designs. In most instances over 100 units of combined effort would be required to detect significant differences (Table 5). Effect sizes used were highly variable and ranged from 0 to 0.928 (Table 5).

Table 2. Catch per unit effort (± standard error) by lake and species for fish collected with experimental gill nets during June 2014 using two study designs (i.e., fixed or random). For species with enough data to conduct statistical comparisons (i.e., ≥ 15 fish captured between both gears for a particular gear and lake) t-tests are reported with a *t*-statistic.

Lake	Species	Fixed	Random
Bullhead	Black Bullhead	2.33 ± 2.33	6.33 ± 2.91
	Black Crappie	0	0.67 ± 0.67
	Bluegill	0	0.67 ± 0.67
	Largemouth Bass	0	1.00 ± 1.00
	Northern Pike	6.33 ± 1.33	6.00 ± 1.00
	Walleye	0.33 ± 0.33	1.33 ± 0.88
	White Sucker	0.67 ± 0.33	0
	Yellow Perch	11.33 ± 8.09	2.67 ± 2.19
Cochrane	Black Crappie	0.67 ± 0.33	2.33 ± 2.33
	Bluegill	0	0.33 ± 0.33
	Largemouth Bass	0.67 ± 0.67	0.67 ± 0.67
	Northern Pike	1.00 ± 0.58	0.33 ± 0.33
	Walleye	1.67 ± 0.67	2.67 ± 2.19
	Yellow Perch	88.67 ± 12.99	68.00 ± 18.18
Wall	Black Bullhead	25.00 ± 2.65	18.00 ± 6.35
	Black Crappie	0.33 ± 0.33	0.33 ± 0.33
	Channel Catfish	16.33 ± 2.60	11.67 ± 2.33
	Common Carp	0	1.00 ± 1.00
	Northern Pike	0.33 ± 0.33	0.33 ± 0.33
	Walleye	0.33 ± 0.33	0.33 ± 0.33
	Yellow Perch	0.67 ± 0.33	1.00 ± 1.00

DISCUSSION

Our results differ from previous studies that reported biases in sampling fixed sites in streams, large rivers, and reservoirs. Dauwalter et al. (2004) reported that stream sampling sites are often chosen subjectively based on accessibility and can be unrepresentative of the larger stream system. Reduced abundance of Centrarchidae species in Glover River, Oklahoma was found at remote versus public access sampling sites, indicating bias related to accessibility sampling (Balkenbush and Fisher 1997). Even where access is not as limited (e.g., natural lakes, reservoirs, large rivers) agencies often choose to sample at fixed sites and depending on the complexity of the system sampled, may not obtain representative measures of relative abundance and size structure. Sampling largemouth bass at sites subjectively chosen by biologists can yield higher relative abundance and larger size structure estimates when compared to randomly assigned sites (Hubbard and Miranda 1986). Unlike previous studies, our three study lakes were small (< 200 ha), habitat was relatively homogenous, and the entire lake was accessible to our sampling gears. Under these circumstances, both randomized and fixed sites produced similar population metrics for commonly collected species.

An alternative explanation for our failure to detect differences in CPUE between sampling designs may be related to poor precision of CPUE estimates. Measures of CV were high and variable, likely obscuring potential differences in CPUE between fixed and random sampling designs. A previous investigation of gill net sampling precision for indexing mean gill net CPUE of yellow perch in South Dakota found that CV was greater than 0.40 for all lakes sampled (Isermann 2003). To improve precision of mean total CPUE, Isermann (2003) recommended large increases in sampling effort but

Table 3. Comparison of size structure indexed using proportional size distribution (PSD) and PSD of preferred length fish (PSD-P) between fixed and random sampling designs for two gears (i.e., modified fyke nets and gill nets) used to sample three lakes in eastern South Dakota during June 2014. Test statistics reported are for chi-square goodness of fit tests where α = 0.05 for all comparisons and index values of PSD/PSD-P are reported with 95% confidence intervals where appropriate.

			PSD		PSD-P	
Gear	Lake	Species	Fixed	Random	Fixed	Random
Fyke net	Bullhead	Black Bullhead	43	33	2	7
		Bluegill	3	3		
		Northern Pike	69	69	7	0
		Yellow Perch	9	14		
	Cochrane	Bluegill	52	64	5	4
		Yellow Perch	32	32		
	Wall	Black Bullhead	98	96	0	1
Gill net	Bullhead	Northern Pike	84	56	11	28
		Yellow Perch	29	0		
	Cochrane	Yellow Perch	28	27	5	4
	Wall	Black Bullhead	93	96		
		Channel Catfish	76	69	0	3

acknowledged that such increases in effort were unrealistic due to time and resource constraints. Only limited effort can be used on each lake because SDGFP, similar to other fisheries agencies (Hayes et al. 2003), has many lakes to sample each season. Our a priori power analyses indicated that no realistic amount of effort could be used to detect differences in CPUE between fixed and random designs, largely due to poor precision of CPUE data. Two possible explanations for the high variability of mean total CPUE estimates are that there is no difference in mean total CPUE between sampling designs, or poor sampling precision obscures potential differences. We contend that despite low sampling precision, it is unlikely that choice of sampling design had a significant impact on measures of mean total CPUE. This assertion is supported by comparisons of mean total CPUE for species, lake, and gear-specific comparisons where precision was relatively high (e.g., channel catfish captured with gill nets in Wall Lake) but no significant difference in mean total CPUE was detected. Estimates of Bray-Curtis distance, which incorporates elements of diversity and evenness, also support our position that choice of sampling design made no biologically relevant difference.

Our study lakes were easily saturated with gear (i.e., fyke nets per shoreline km, gill nets per surface ha) compared to large lakes. South Dakota Department of Game, Fish and Parks often samples much larger lakes than our study lakes with similar levels of effort due to time and equipment constraints. For example, Lake Thompson (16,236 ha, 71.8 km shoreline) is sampled with 10 fyke net nights of effort while Bullhead Lake (68 ha, 4.5 km shoreline) is sampled with 12 fyke net nights of effort resulting in 1 net/7.2 km of shoreline for Lake Thompson and 1 net/0.4 km of shoreline for Bullhead Lake. Due to this difference in scale and sampling effort, we do not recommend extrapolating the results of this study to larger water bodies. It would be unrealistic to use a similar effort on large lakes and sampling precision would likely be lower than observed on small lakes. However, for small lakes with relatively homogenous habitats, we contend that our results should be broadly applicable.

Choice of sampling design is specific to the research or management question (Hayes et al. 2003, Hansen et al. 2007). Randomization is typically preferred when investigating spatial differences between systems but fixed sites may be acceptable when the goal is to monitor temporal changes within

Table 4. Coefficient of variation (CV; SD/mean) calculated for species commonly targeted by South Dakota Department of Game, Fish and Parks. Modified fyke nets and experimental gill nets were built to specifications outlined by Bonar et al. (2009*b*) and used to sample three lakes in eastern South Dakota during June 2014.

		Fyke net		Gill net	
Lake	Species	Fixed CV	Random CV	Fixed CV	Random CV
Bullhead	Black Bullhead	1.74	0.83	na	na
	Black Crappie	1.03	1.93	na	na
	Bluegill	2.08	1.04	na	na
	Northern Pike	na	na	0.36	0.29
	Walleye	na	na	1.75	1.15
	Yellow Perch	na	na	1.24	1.42
Cochrane	Black Crappie	1.54	1.55	na	na
	Bluegill	0.51	0.74	na	na
	Northern Pike	na	na	1.00	1.75
	Walleye	na	na	0.69	1.42
	Yellow Perch	na	na	0.25	0.46
Wall	Black Bullhead	0.55	0.69	0.18	0.61
	Black Crappie	0.95	1.81	na	na
	Bluegill	0.56	2.24	na	na
	Channel Catfish	1.00	2.24	0.28	0.35
	Northern Pike	na	na	1.75	1.75
	Walleye	na	na	1.75	1.75
	Yellow Perch	na	na	0.86	1.73

a system (Hubbard and Miranda 1986, Urquhart et al. 1999). For indexing size structure of blue catfish (*Ictalurus furcatus*) in reservoirs, Bodine et al. (2011) recommended sampling randomized sites stratified by habitat, because these fish use different habitats as they grow. Oversampling one habitat would bias size structure estimates for the whole system. Pegg and McClelland (2004) described the use of fixed sites for detecting temporal changes in species richness in the Illinois River, though results could not be extrapolated to the whole river due to the limitations of a fixed-site design. A comparison of calculated population parameters between fixed and random sample sites on a large Texas reservoir (10,481 ha; King et al. 1981) found few statistically relevant differences and the authors argued that fixed sampling sites may be acceptable due to ease of sampling and accessibility. Detection of changes in CPUE for species inhabiting Muddy Creek, Wyoming was enhanced by using fixed sites (Quist et al. 2006). Because SDGFP monitors individual fish populations to detect temporal changes in CPUE and size structure, the current method of using fixed sites likely provides an adequate experimental framework to achieve its management goals.

We found that choice of fixed or simple random sampling designs made no consistent difference, but we acknowledge that including an element of randomization reduces subjective bias and is considered more statistically defensible. Choice of random versus systematic sampling designs has been among the most intensely debated topics in field ecology, but it has been agreed that the removal of subjective biases and, if at all possible, inclusion of randomization is recommended (Krebs 1999). Incorporating randomization into a sampling design can be easily done and performed at the outset of a sampling program to identify sample sites, which can thereafter be fixed or be randomized during each sampling period (Bonar et al. 2009a). However, by converging on similar population metrics by two different sampling designs we conclude that sampling of fixed sites by SDGFP on small glacial lakes provides a reliable estimation of relative abundance, size structure, and assemblage structure.

Table 5. Combined number of samples required to detect a significant difference between fixed and random sample designs for commonly calculated indices. Effect sizes were calculated using empirical data. Tests were two-tailed with power (1-β) set at 0.90 and α = 0.05 for all analyses.

Index	Gear	Lake	Species	Effect size	Required N
CPUE	Fyke net	Bullhead	Black Bullhead	0.373	>100
			Black Crappie	0.000	>100
			Bluegill	0.500	>100
			Northern Pike	0.540	>100
			Yellow Perch	0.079	>100
		Cochrane	Black Crappie	0.559	>100
			Bluegill	0.261	>100
			Green Sunfish	0.475	>100
			Yellow Perch	0	>100
		Wall	Black Bullhead	0.582	>100
			Black Crappie	0.214	>100
	Gill net	Bullhead	Black Bullhead	0.876	58
			Northern Pike	0.162	>100
			Yellow Perch	0.844	62
		Cochrane	Walleye	0.356	>100
			Yellow Perch	0.755	76
		Wall	Black Bullhead	0.831	64
			Channel Catfish	1.090	38
PSD	Fyke net	Bullhead	Yellow Perch	0.250	>100
		Cochrane	Bluegill	0.171	>100
		Wall	Black Bullhead	0.381	73
	Gill net	Cochrane	Yellow Perch	0.026	>100
PSD-P	Fyke net	Cochrane	Bluegill	0.062	>100
		Wall	Black Bullhead	0.928	13
	Gill net	Cochrane	Yellow Perch	0.071	>100

MANAGEMENT IMPLICATIONS

Recently, SDGFP has pushed to standardize sampling gears and methods statewide. For approximately two decades SDGFP has conducted annual lake surveys in South Dakota lakes using a fixed sampling design with sample sites originally distributed throughout each lake in a systematic fashion. We found that sampling at current SDGFP fixed sites produced comparable estimates of fish population parameters to those obtained from completely randomized sites. We conclude that the current fixed site design used by SDGFP is reliable for monitoring temporal changes in fish populations within small (< 200 ha) South Dakota glacial lakes.

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Table 6. Number of gear deployments necessary to collect 125 fish with 90% confidence for common species collected in three eastern South Dakota lakes using fixed and random sampling designs.

Gear	Lake	Species	Fixed	Random
Fyke net	Bullhead	Black Bullhead	46	24
		Bluegill	49	21
		Northern Pike	61	100
		Yellow Perch	37	21
	Cochrane	Bluegill	7	9
		Yellow Perch	80	76
	Wall	Black Bullhead	4	4
Gill net	Bullhead	Northern Pike	22	23
		Yellow Perch	18	62
	Cochrane	Yellow Perch	2	3
	Wall	Black Bullhead	6	10
		Channel Catfish	9	13

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