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Comparison of Two Zooplankton Sampling Gears in Shallow, Homogeneous Lakes

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ABSTRACT We compared two zooplankton collection gears, Wisconsin nets and column samplers, to evaluate the effectiveness of each gear in quantifying inshore and offshore zooplankton density and size structure in shallow, homogeneous lakes. Zooplankton densities (within gear) did not differ ($P > 0.05$) between inshore and offshore sites in either study lake, with the exception of Wisconsin-netted *Cyclops* sp. in Lake Goldsmith. Wisconsin net samples produced a higher mean zooplankton density than column samplers for *Bosmina* sp., *Cyclops* sp., and *Daphnia* sp. in East Oakwood Lake and for *Cyclops* sp. (inshore), *Daphnia* sp., and *Diaptomus* sp. in Lake Goldsmith. Zooplankton densities had greater variability (coefficients of variation) in 4 of 5 taxa collected with the Wisconsin net in both study lakes. Zooplankton size structure did not differ ($P > 0.05$) between gears in either study lake, with the exception of *Diaptomus* sp. in East Oakwood Lake. Our results suggest that column samplers have higher precision than Wisconsin nets when sampling common zooplankton species in shallow, homogeneous lakes.

KEY WORDS column sampler, gear efficiency, Wisconsin net, zooplankton density, zooplankton sampling

Accuracy and precision are necessary sampling considerations for estimating zooplankton population parameters such as density and size structure. Depth, specialized habitats, species composition, time of day, and density are primary factors that can influence collection efficiency of a specific gear (Hartman and Herke 1987, Brinkman and Duffy 1996). Zooplankton sampling gears that entrap or filter organisms might exhibit sampling bias or selectivity due to design. Gear design or configuration can bias sampling in a number of different ways, such as escapement, net extrusion or clogging, size exclusion, and avoidance (Rabeni 1996). Configuration also can affect volume and depth capability of sampling gear (Clutter and Anraku 1968).

Intra-lake variation, such as depth, bottom type, habitat, and mixing, can affect precision of different sampling gears when estimating zooplankton density (Gannon 1980, Pace 1996). Spatial (e.g., inshore and offshore) density differences might occur because some gears sample only a prescribed part of the water column effectively (e.g., closing nets and traps) or because habitat preference varies among extant taxa (DeBates et al. 2003, Olson et al. 2004). Zooplankton sampling gears usually only effectively sample one portion or limited portions of the water column (Clutter and Anraku 1968). For instance, Masson et al. (2004) found greater spatial variations in zooplankton density collected among water layers than collected using different sampling gears.

During our study, a Wisconsin net and a column sampler were compared to assess the effectiveness of each gear type in evaluating inshore and offshore zooplankton density and size structure in shallow, homogeneous lakes. Both gears are commonly used to collect vertically integrated zooplankton samples. The Wisconsin net has been used widely to sample zooplankton over the entire water column (Masson et al. 2004), while the column sampler is limited to a few meters below the water surface (Applegate et al. 1968, Olson et al. 2004). Specifically, our objectives were to document differences in mean zooplankton density (n/L) between inshore and offshore sites, differences in mean zooplankton density between gears, and differences in zooplankton size structure between gears.

STUDY AREA

Our study area included two shallow, homogeneous lakes, East Oakwood Lake and Lake Goldsmith, located in Brookings County, South Dakota. East Oakwood Lake had a surface area of 405 ha with a mean depth of 1.6 m and a maximum depth of 3 m. Lake Goldsmith had a surface area of 117 ha with a mean depth of 2.0 m and a maximum depth of 3 m. These study lakes are representative of glacial lakes found within the Prairie Couteau region (Stukel 2003).

METHODS

We collected samples during September 2006 from 7 locations on East Oakwood Lake and 9 locations on Lake Goldsmith evenly distributed throughout each lake. We further divided each location into offshore (>50 m) and inshore (<50 m) strata and 3 replicate samples were collected at each site with each gear type. We used vertical column samplers (2 m length, 7.3-cm inside diameter or 1.5 m length, 6.3-cm inside diameter) to collect zooplankton at

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water depths of up to 2 m or 1.5 m. We filtered each sample with a Wisconsin net with 153-μm Nitex mesh attached to a 63-μm mesh bucket. We used a Wisconsin net, as configured above, to complete a vertical tow from the bottom of the sample lake to the surface. We simultaneously deployed gears from randomly selected positions from an anchored boat. We preserved samples using 10% Lugol's solution, pending analysis (Pennak 1989).

Table 1. Mean zooplankton density (*n*/L), coefficient of variation (CV), and paired *t*-test statistics resulting from taxa-specific comparisons between inshore and offshore habitats sampled concurrently with Wisconsin nets and column samplers in East Oakwood Lake and Lake Goldsmith, Brookings County, South Dakota, 2006.

	East Oakwood Lake							
	Wisconsin net				Column sampler			
	Inshore		Offshore		Inshore		Offshore	
Taxon	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Bosmina	27.7	871.1	47.3	1424.1	12.0	377.6	18.0	686.5
Cyclops	106.1	3227.9	137.3	5844.0	43.2	698.0	47.2	682.2
Daphnia	14.9	479.9	4.6	94.4	4.5	77.5	4.3	171.2
Diaphanasoma	14.9	377.9	20.2	321.3	12.4	487.3	9.1	103.4
Diaptomus	13.5	397.8	11.4	340.8	16.4	1379.9	6.2	183.4
	Lake Goldsmith							
	Wisconsin net				Column sampler			
	Inshore		Offshore		Inshore		Offshore	
Taxon	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Bosmina	1.6	349.8	2.0	427.2	0.1	18.1	1.0	239.8
Cyclops	18.0*	394.6	8.8*	166.8	3.6	89.3	7.7	332.7
Daphnia	21.2	372.4	18.1	816.4	14.8	474.1	11.0	465.7
Diaphanasoma	3.7	134.2	4.0	933.6	1.1	132.7	6.6	710.6
Diaptomus	31.4	872.4	18.3	355.5	14.2	537.6	7.6	194.4

* Indicated a significant relationship ($P < 0.05$).

We filtered samples through a 153-μm Nitex mesh into Erlenmeyer flasks and rinsed the samples to remove the Lugol's solution. We standardized the volume of the sample to 50 mL, using distilled water. Samples containing more than 200 zooplankton/50 mL were sub-sampled using a Hansen-Stemple pipette to measure 3 separate, 1 mL aliquots from the total sample; otherwise we conducted total sample counts. To minimize potential sampling biases, we mixed and subsequently recorded the first 20 lengths (mm) for each genus. We assumed that because the solution was mixed prior to counting, samples were random and representative of the size structure within the mixed solution.

We selected the 5 most abundant taxa (*Bosmina* sp., *Cyclops* sp., *Daphnia* sp., *Diaphanasoma* sp. and *Diaptomus* sp.) to compare taxa-specific densities between inshore and offshore strata and between sampling gears. Other taxa were not present in large enough numbers to conduct robust comparisons. Additionally, we selected the 3 most abundant taxa in both lakes (*Cyclops* sp., *Daphnia* sp. and *Diaptomus* sp.) to conduct a size structure comparison between gears. We used paired *t*-tests to compare differences in mean taxa-specific zooplankton density between paired inshore and offshore sites, and mean taxa-specific zooplankton density between gear types. We used the coefficient of variation (CV = standard deviation/ mean * 100) to calculate precision of the sampling gear type. We used two-sample Kolmogorov-Smirnov (*D*) tests to compare differences in zooplankton size structure between gears within each lake; we set significance at $\alpha = 0.05$ for all analyses.

Table 2. Mean zooplankton density (*n*/L), coefficient of variation (CV), and paired *t*-test statistics resulting from comparisons between zooplankton sampling gears on East Oakwood Lake and Lake Goldsmith, Brookings County, South Dakota, 2006.

East Oakwood Lake				
	Column sampler		Wisconsin net	
Taxon	Mean	CV	Mean	CV
*Bosmina**	15.4	507.8	38.3	1161.8
Cyclops *	43.4	682.1	115.6	4595.8
*Daphnia**	4.2	116.2	11.0	514.7
Diaphanasoma	10.2	320.0	16.7	360.6
Diaptomus	10.6	1119.0	11.9	459.0
Lake Goldsmith				
	Column sampler		Wisconsin net	
Taxon	Mean	CV	Mean	CV
Bosmina	0.6	215.5	1.8	371.6
*Cyclops (inshore)**	3.6	89.3	18.0	394.6
Cyclops (offshore)	7.7	166.8	8.8	322.7
*Daphnia**	12.9	457.6	19.7	549.4
Diaphanasoma	3.8	695.3	3.9	517.1
*Diaptomus**	10.9	446.9	24.9	734.3

* Indicated a significant relationship ($P < 0.05$). The mean taxa-specific zooplankton density between paired inshore and offshore sites for *Cyclops* sp. in Goldsmith had to be analyzed separately because the inshore/offshore comparison was significant.

RESULTS

Mean zooplankton density did not differ ($P > 0.05$) between paired inshore and offshore sites, with the exception of *Cyclops* sp. (t_8 = 2.41, P = 0.04) in Lake Goldsmith (Table 1). Mean zooplankton densities differed ($P < 0.05$) between sampling gears in both study lakes (Table 2). For instance, Wisconsin nets sampled higher mean densities of *Bosmina* sp. ($\bar{x}$ = 38.3, CV = 1161.8 n/L), *Cyclops* sp. ($\bar{x}$ = 115.6, CV = 4595.8 n/L), and *Daphnia* sp. ($\bar{x}$ = 11.0, CV = 514.7 n/L) in East Oakwood Lake and higher mean densities of inshore *Cyclops* sp. ($\bar{x}$ = 18.0, CV = 394.6 n/L), *Daphnia* sp. ($\bar{x}$ = 19.7, CV = 549.4 n/L) and *Diaptomus* sp. ($\bar{x}$ = 24.9, CV = 734.3 n/L) in Lake Goldsmith than column samplers (Table 2). We documented no differences ($P \geq 0.09$) in *Diaphanasoma* between gear types in either study lake. Bosmina and offshore Cyclops densities were similar ($P \geq 0.23$) between gear types in Lake Goldsmith. Similarly, Diaptomus density did not differ (P = 0.80) between gear types in East Oakwood Lake (Table 2). Zooplankton size structure did not differ ($P \geq 0.09$) for the 3 species between gear types in either study lake, except for *Diaptomus* sp. in East Oakwood, which was greater (D_{188} = 0.26, P = 0.01) when sampled with Wisconsin nets (Table 3).

DISCUSSION

Wisconsin nets sampled higher mean densities of some common zooplankton taxa than column samplers. In addition, Wisconsin nets sampled mean zooplankton density at a lower level of precision than column samplers. Differences in mean zooplankton density and precision between the two sampling gears evaluated during our study illustrate the need to choose the correct sampling gear for achieving study-specific objectives (Rabeni 1996). Our results suggest column samplers are more effective for sampling zooplankton in shallow, homogeneous lakes because the gear samples at a consistent depth and presumably reduces operator sampling vulnerability when compared to Wisconsin nets.

Within gear type, mean zooplankton density did not differ ($P > 0.09$) between paired inshore and offshore sites with the exception of *Cyclops* sp. in Lake Goldsmith, suggesting lake size and distance between inshore and offshore habitats may not affect zooplankton density in shallow, homogeneous lakes. Zooplankton density did not differ between paired inshore and offshore sites possibly because Prairie Couteau lakes commonly have low shoreline development, consistent shallow depths, uniform mixing from wind and wave action and homogeneous substrate (Stukel 2003).

Wisconsin nets exhibited a higher mean density CV than column samplers, inferring lower precision. Variations in precision could be attributed to operator error, mesh size escapement, and even active avoidance of the gear as *Diaptomus* sp. can actively swim backwards away from a perceived threat (Lochhead 1961). In a similar study, Karjalaien et al. (1996) found column samplers to be more reliable at sampling smaller organisms while plankton nets were more effective at sampling large, rare, or active organisms.

Table 3. Mean zooplankton size structure (mm), coefficient of variation (CV), and Kolmorgorov-Smirnov test statistics from comparison of taxa-specific size structure between gears on East Oakwood Lake and Lake Goldsmith, Brookings County, South Dakota, 2006.

East Oakwood Lake				
	Column sampler		Wisconsin net	
Taxon	Mean	CV	Mean	CV
Cyclops	0.6	42.0	0.6	50.4
Daphnia	1.0	32.0	1.0	22.8
*Diaptomus**	0.7	35.1	0.9	26.0
Lake Goldsmith				
	Column sampler		Wisconsin net	
Taxon	Mean	CV	Mean	CV
Cyclops	0.6	36.0	0.6	42.1
Daphnia	1.3	34.5	1.2	30.3
Diaptomus	0.7	37.8	0.7	43.5

* Indicated a significant relationship ($P < 0.05$).

Zooplankton size structure of the two lakes did not differ ($P > 0.09$) between the two sampling gears evaluated in this study, with the exception of *Diaptomus* sp. in East Oakwood. There are a few potential explanations as to why size structure did not differ between gears. First, both gears might effectively sample available zooplankton size structure. Second, samples from both gears were filtered though the same size mesh, therefore including or excluding the same size zooplankton. Third, larger zooplankton might have avoided both gears equally.

MANAGEMENT IMPLICATIONS

Our findings suggest that column samplers may be more effective for sampling zooplankton in shallow, homogeneous lakes. Managers and researchers should consider using either column samplers or a combination of these gear types when sampling zooplankton in shallow, homogeneous lakes. Future work should include a more robust comparison of these two gear types to determine their usefulness in different habitats and their sampling efficiency of various zooplankton taxa. Future studies should be conducted over a longer time scale to incorporate seasonal variations in the zooplankton species composition, in habitats with varying degrees of vegetation and different bottom types. Additionally, incorporating larger sample sizes to include a greater number of species for comparison and investigating potential factors (i.e., operator error, mesh size escapement, and active avoidance of gear by zooplankton) contributing to low precision of zooplankton density estimates is warranted.

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