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Comparison of nets and pump sampling gears to assess zooplankton vertical distribution in stratified lakes

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The efficiency of a cantilevered bridle net was tested in comparison with a Wisconsin net and a pumping system to sample zooplankton organisms in three water layers (epi-, meta- and hypolimnion) of three Canadian Shield lakes. Variations among samplers were compared to variations due to within-lake vertical distribution of zooplankters and among lake variations. For each lake and water layer, we also assessed the efficiency of the three methods according to the catches of zooplanktonic taxa. The highest percentages of variation were generally due to lake or water-layer effects; interaction between sampling gears and water layers was above 50% for most taxa, except cladoceran. Sampling methods explained more variation than the lake effect for some zooplankton taxa, indicating that using different sampling devices could potentially alter the among-lake variation interpretation of zooplankton abundance. The pumping system captured higher densities of animals per taxa than the cantilever and the Wisconsin nets. The cantilever net generally captured mobile taxa more efficiently (Polyarthra vulgaris, copepods, Daphnia sp., Diaphanosoma brachyurum and chaoborids) than the Wisconsin net and the pumping system, but its efficiency varied among water layers.

Keywords: *cantilever towed net; Wisconsin net; pumping system; zooplankton*

INTRODUCTION

Despite the development of new technologies such as the Optical Plankton Counter (OPC) (Sprules *et al.*, 1992; Stockwell and Sprules, 1995) and the remotely operated vehicle (ROV) (Bergstrom *et al.*, 1992; Schulze *et al.*, 1995), nets are still the most popular gear for collecting zooplankton (McQueen and Yan, 1993). Fancier gears, besides being expensive, do not provide any information on the species level. A large variety of nets and traps are currently used for determining the abundance of zooplankton, but their effectiveness varies with habitat and species (Wetzel and Likens, 1979). A few years ago, a new zooplankton-sampling device (cantilever vertical tow net) with an unobstructed mouth area was introduced by Filion *et al.* (Filion *et al.*, 1993). These authors alleged that catches of individuals per taxa were increased over those obtained with conventional centre-bridle plankton net, by decreasing avoidance behaviour by the zooplankton due to the outside position of the bridle. Although the cantilevered bridle net was found to be more efficient than a bridle net, this result does not imply that it is more efficient than other sampling gears or nets of different design. Thus, the cantilever should be compared to the Wisconsin net and pumping systems, which are widely used to sample zooplankton over the whole water column or epilimnetic waters [see (de Bernardi, 1984) for a review]. Integrated samples of limnetic water layers (epi-, meta- and hypolimnion) are an alternative to evaluate zooplankton vertical distribution in relation to abiotic and biotic conditions inherent in a lake (Masson *et al.*, in press). Thus, in order to assess zooplankton abundance in these three limnetic layers, we used a modified cantilever net (see *Method*).

The purpose of this study was to compare the efficiency of the cantilever net to that of a Wisconsin net, and a pumping system, to catch zooplankton in different water layers in three small lakes. First, we evaluated whether the

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sources of variation among sampling gears are smaller than both intra- (among replicates and three water layers) and inter-lake sources of variation in an attempt to estimate whether inter-lake comparisons based on studies using different devices are legitimate. Many studies have shown different efficiencies of sampling gears in one water body (Schindler, 1969; George and Owen, 1978; Lewis and Saunders, 1979; Filion *et al.*, 1993; Johannsson *et al.*, 1993). However, although few studies have related them to within-lake and/or inter-lake variations (Langeland and Rognerud, 1974; Knoechel and Campbell, 1992; McQueen and Yan, 1993), no study simultaneously assessed both of these variation sources. Second, for each lake and water layer, we investigated the efficiency of the three methods by comparing the catch-per-unit volume for several zooplankton groups or taxa.

METHOD

Study lakes

Sampling was carried out in three lakes, representative of the Canadian Shield humic lakes. They are located at the Station de Biologie de l'Université de Montréal (46°N, 74°W), ~80 km north of Montréal (Québec, Canada). Lake Geai is a small fishless acidic bog lake (area, 0.99 ha; maximum depth, 7.5 m; pH 4.8). Within-lake distribution of zooplankton is highly influenced by both chemical and biological factors (Masson and Pinel-Alloul, 1998). Lake Cromwell, an oligo-mesotrophic, less acidic (pH 6.65), is the largest lake (9.29 ha) with a maximum depth of 10 m and is characterized by planktivorous fish. Macrozooplanktonic species distribution is regulated by physical and biological factors (Pinel-Alloul and Pont, 1991). Lake Croche, the deepest lake (11 m deep, 4.74 ha), has a pH close to 7. In contrast to the other lakes, it is characterized by the presence of piscivorous species and no study has been undertaken in this water body in relation to its zooplankton community.

Sampling devices

In order to sample zooplankton in the three water layers (epi-, meta- and hypolimnion) of the lakes, we slightly modified the cantilevering net (Filion *et al.*, 1993) by adding a second line close to the counterweight (Figure 1a). This way, a specific stratum can be sampled by tilting the net after sampling the water stratum. The sampling was carried out as follows: After having towed the net through a water layer, the second line attached to the counterweight was pulled up to close the net and then it was hauled back to the surface (Figure 1a–c). The cantilevering net has a 0.04 m^2 mouth area and 53 μm mesh size. As mentioned by Filion *et al.* (Filion *et al.*, 1993), its telemetered design allowed to ensure that no net clogging took place. A net of similar design regularly achieves >90% haul efficiency at a towing speed of 0.3 m s^{-1} (Filion *et al.*, 1993).

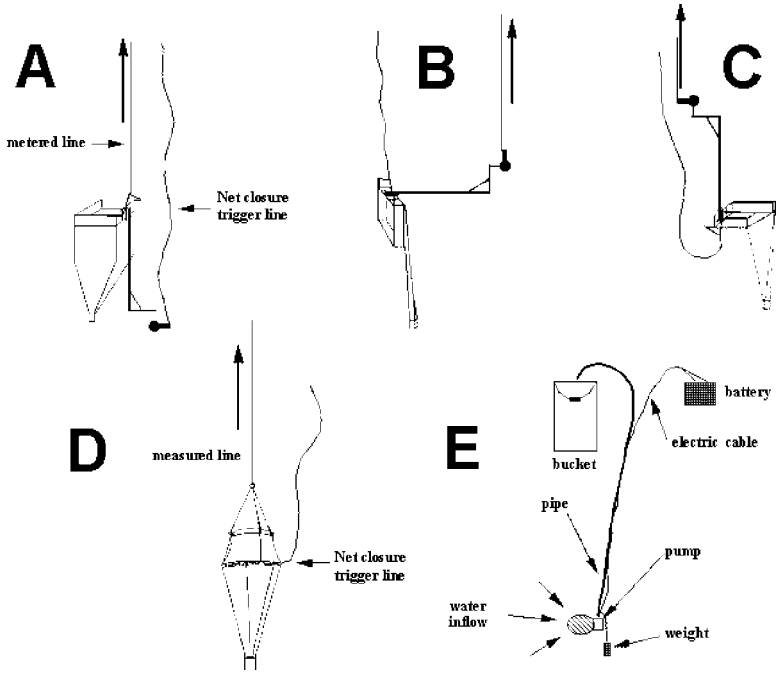

Fig. 1. Description of the samplers used in this study and modification of nets to sample limnetic water layers: **a**–**c**, cantilevering net; **d**, Wisconsin net; **e**, pumping system.

The Wisconsin net was also modified to sample zooplankton in water layers. A second line was added to the largest ring of the net, allowing to use it as a Hansen closing net [Figure 1d; (Gehringer and Aron, 1968)]. The Wisconsin net has a mesh size similar to that of the cantilevering net, but its mouth diameter was smaller (0.01 m^2). Sampling was carried out the same way as with the cantilevering tow net. In this study, we assumed a 100% filtration efficiency for the cantilever and Wisconsin nets, because we sampled shallow depths to prevent clogging.

The pump system used a JABSCO submersible pump with a 10 m pipe of 30 mm diameter mouth area (Figure 1e). The pipe was lowered to the lower limit of each water layer and was slowly (0.3 m s^{-1}) hauled back to the upper limit. Before collecting animals from the outflowing stream, we purged the hose of zooplankton inadvertently collected from shallower depths as the pump was lowered, as suggested by de Bernardi (de Bernardi, 1984). A maximum of 20 L (Table I) of water was collected in a bucket (25 L) and filtered through a Nitex net of 53 μm mesh size.

Zooplankton sampling and analyses

At three stations in each lake, near the deepest site, zooplankton was sampled for each water layer (epi-, meta- and hypolimnion) with the three devices (Table I). All zooplankton samples were collected between 1000 and 1700 h during the last week of May 1993. Thermal stratification was apparent in each lake. After sampling, the organisms were immediately narcotized by adding carbonated water and preserved in 4% sugar–formaldehyde solution. The analysed volume (AV) of the subsamples depended on the density of the zooplankton, which greatly varied between samples. Subsamples from 5 to 30 mL were taken from homogenized volume of each concentrated sample using a pipette with an enlarged opening. About 500 individuals on average per subsample were identified under ×25–50 magnification and counted using an acrylic counting wheel.

Statistical methods

To evaluate whether the variation among sampling gears was smaller than both intra- and inter-lake variations, we analysed the data using a three-factor analysis of variance [ANOVA; (Zar, 1984)]. The lakes, water layers and samplers were the independent factors, and taxa abundance was the dependent variables. Total zooplankton density, taxa number and the more abundant taxa were chosen for the ANOVA. All taxa abundance were $\log(x + 1)$ transformed to normalize the data and reduce heteroscedasticity. To test the null hypothesis that estimates of taxa abundance in the three water layers of the three lakes were not affected by the type of sampling gear employed, we first evaluated the mean densities of the most important zooplankton taxa and groups. Later, Kruskal–Wallis one-way ANOVA (applied by lake and by water layer) was performed to identify significant differences between the mean total densities of all zooplankters captured by the three methods, followed by Mann–Whitney tests. Finally, to evaluate the effect of sampling gear on the number of taxa sampled, we also used Kruskal–Wallis one-way ANOVA and Mann–Whitney tests to detect significant

Table I: Sampling depths and volume filtered by the three sampling devices in each limnetic water layer for the three lakes

Strata and depth (m)	Station	Lake Geai			Lake Croche			Lake Cromwell		
		Cantilevering net (L)	Wisconsin net (L)	Pumping system (L)	Cantilevering net (L)	Wisconsin net (L)	Pumping system (L)	Cantilevering net (L)	Wisconsin net (L)	Pumping system (L)
Epilimnion										
Geai: 0–1.5	1	60	20	2.0	120	39.82	5.5	120	39.82	6.5
Croche: 0–3	2	60	20	5.5	120	39.82	11	120	39.82	7.0
Cromwell: 0–3	3	60	20	6.0	120	39.82	12	120	39.82	7.0
Metalimnion										
Geai: 1.5–2.5	1	40	13.27	4.0	40	13.27	7.5	80	26.55	8.0
Croche: 3–4	2	40	13.27	6.0	40	13.27	8.5	80	26.55	8.0
Cromwell: 3–5	3	40	13.27	6.0	40	13.27	15.5	80	26.55	8.0
Hypolimnion										
Geai: 2.5–5	1	100	33.18	6.5	220	73	15.5	120	39.82	10.5
Croche: 4–9.5	2	100	33.18	6.5	220	73	18	120	39.82	10
Cromwell: 5–8	3	100	33.18	7.5	200	73	19	120	39.82	10

differences in the mean number of taxa in each lake and water layer.

RESULTS AND DISCUSSION

Sources of variation

Spatial variation either between water layers or among lakes explained most of the variance for all groups of zooplankton (Table II). The total taxa number, the abundance of some rotifers (*Kellicottia* spp. and *Keratella taurocephala*), all cladocerans (except *Diaphanosoma brachyurum*), all cyclopoid copepods and chaoborids diptera showed more variations in abundance between lakes. On the other hand, the total density of zooplankton, some rotifers (all individuals, *Ascomorpha* sp., *Conochilus* sp., *Keratella cochlearis* and *Polyarthra vulgaris*) and all calanoid copepods and nauplii were more variable between water layers. Thus, spatial variations among lakes or water layers were stronger than variations induced by the sampling devices employed to collect zooplankton in the three lakes. However, sampling methods explained more variation than the lake effect for total zooplankton density, total rotifers, total copepods and nauplii. Therefore, the use of different sampling devices could potentially alter the interpretation of inter-lake variation in zooplankton abundance (Gannon, 1980; Pace, 1986).

According to our results, interaction between lake-sampling methods is particularly important for cladoceran species, whereas interaction between water-layer-sampling methods was important for all the other groups (Table II). Changes in zooplankton-sampling methodologies could result in quantifiable differences in zooplankton

Table II: Percentages of variance ascribed to independent factors (lake, water layer and method) showing significant differences in the density of organism groups, according to the three-factor analysis of variance

Dependent variable	Main effect			Interaction		
	Lake	Layer	Method	Lake–layer	Lake–method	Layer–method
Total density	4.38***	**70.80***	24.82***	28.61	Not significant	**69.37***
All rotifers	0.05***	**71.77***	23.06***	32.38**	Not significant	**65.87***
Ascormorpha sp.	27.79**	**38.17***	34.05**	Not significant	Not significant	Not significant
Conochilus sp.	0.08***	**79.63***	12.24***	21.43*	Not significant	**74.93***
Kellicottia bostoniensis	**82.75***	10.54**	6.71*	28.96***	Not significant	**67.20***
Kellicottia longispina	**52.56***	17.60***	29.83***	**89.10***	Not significant	Not significant
Keratella cochlearis	Not significant	**76.39***	22.66***	**54.76***	Not significant	41.34**
Keratella taurocephala	**54.44***	33.74***	11.83***	Not significant	**45.87***	Not significant
Polyarthra vulgaris	34.88***	**50.55***	28.83***	31.74**	Not significant	**65.70***
All cladocerans	**68.40***	14.63***	16.96***	41.37*	**43.96***	Not significant
Bosmina longirostris	**66.48***	16.13***	17.38***	**45.36****	41.41**	Not significant
Cladocera immature	**48.38***	33.05*	Not significant	Not significant	**72.92***	Not significant
Daphnia sp.	**68.62***	15.63*	15.76*	**69.71***	Not significant	Not significant
Diaphanosoma brachyurum[a]	Not significant	Not significant	**72.40****	Not significant	Not significant	Not significant
Holopedium gibberum	**78.62***	Not significant	15.80*	Not significant	**53.02****	Not significant
All copepods	0.05***	**68.22***	26.84***	Not significant	Not significant	**81.54***
All calanoids	29.69**	**63.90***	Not significant	Not significant	Not significant	**58.24***
Stage copepodite C1–C3	37.07**	**49.59***	13.24***	Not significant	Not significant	Not significant
Stage copepodite C4–C5	14.76**	**75.66***	9.61**	**52.49***	Not significant	Not significant
All cyclopoids	**60.73****	24.50*	Not significant	Not significant	Not significant	**86.23***
Stage copepodite C1–C3	**50.57***	15.82*	33.61**	Not significant	Not significant	**89.45***
Stage copepodite C4–C5	**70.58***	Not significant	Not significant	Not significant	Not significant	**95.59***
Nauplii	Not significant	**77.29***	22.46***	30.07*	Not significant	**63.07***
Chaoborids[a]	**78.98***	Not significant	15.92***	Not significant	13.17**	**80.24***

The highest level of variance explained are in bold, for main effect and interaction between factors.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.
[a]Not observed in Lake Cromwell during the study.

densities and lead to erroneous conclusions. Thus, the sources of error would be especially serious in studies of many lakes where community structure and lake trophy vary considerably, as observed by Pace (Pace, 1986).

Zooplankton estimates and water sampled volumes

Despite the fact that the pump allowed higher catches of zooplankton abundance in the three water layers of most lakes (Figure 2), there was generally no significant difference between samplers, except for the metalimnion in the lakes Geai and Cromwell and the hypolimnion in the lake Croche. Assuming that higher zooplankton abundances indicated higher gear efficiency, the pump system was, in most cases (86/127), the best device to catch a maximum of individuals in each water layer for the most taxa (Table III). The Wisconsin net was the worst sampler, catching fewer individuals (Table III), whereas the performance of the cantilever net was intermediate. The density of individuals sampled by the pumping system could vary from 10 to 100 times the density of individuals captured by the nets, especially in the meta- and hypolimnetic waters.

In a comparative study, Johannsson *et al.* (Johannsson *et al.*,1993) observed that their pump system sampled more efficiently some species than the nets; however, their sample volumes were similar for each device (540 versus 563 L). In our study, the pumping system filtered a maximum of 20 L (10 L on average) in each water layer, while the nets filtered water volumes ranging from 13.27 to 220 L (Table I). It is difficult to explain the differences observed between samplers since we did not filter the same water volumes by the sampling devices. Johannsson *et al.* (Johannsson *et al.*, 1993)

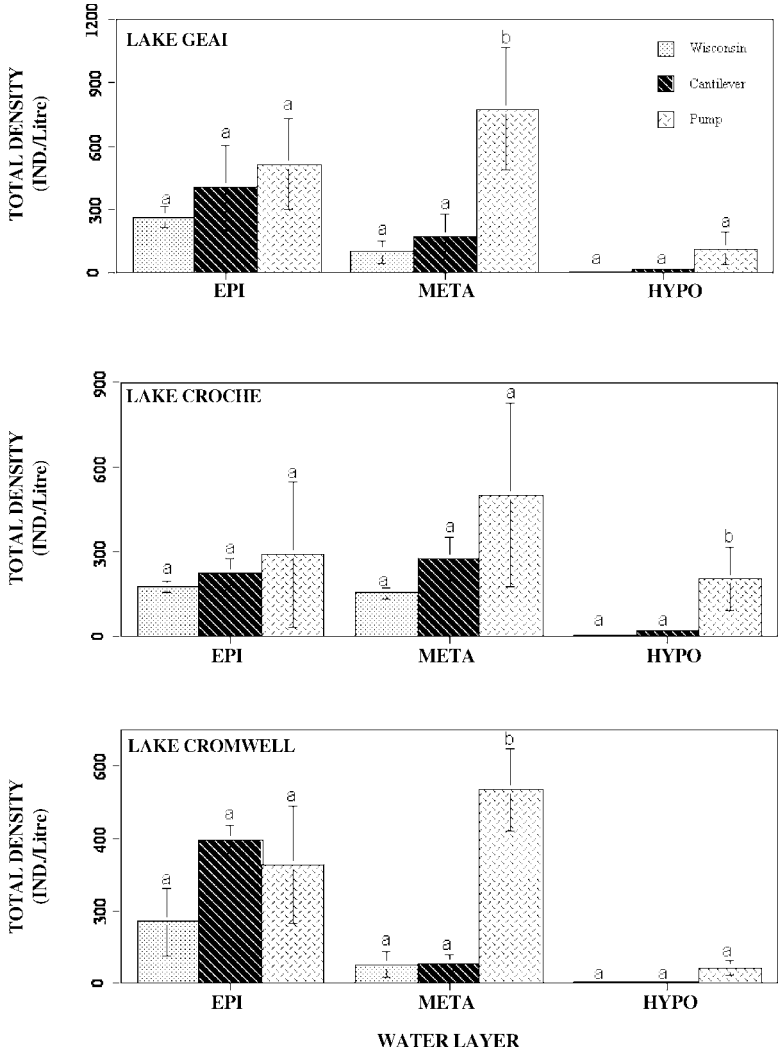

Fig. 2. Mean total densities with their standard deviation of all zooplankters sampled in each water layer in the three lakes by each sampling device. **a**, no significant difference between samples; **b**, significant difference ($P < 0.05$).

Table III: Average density estimates (individual L^{-1}) for the most important taxonomic groups collected using the three methods for the three limnetic layers of the three lakes

Taxonomic group	Epilimnion			Metalimnion			Hypolimnion		
	Wisconsin	Cantilever	Pump	Wisconsin	Cantilever	Pump	Wisconsin	Cantilever	Pump
Geai									
Total individuals	265.00	404.62	**515.78**	99.53	175.23	**776.28**	12.99	17.09	**115.90**
Total rotifers	227.90	359.65	**451.97**	86.99	155.79	**719.49**	38.85	15.74	**89.09**
Conochilus sp.	101.30	**160.68**	79.71	23.92	46.33	**310.08**	1.75	3.89	**8.13**
Kellicottia longispina	0.00	0.00	**2.87**	0.25	0.07	**2.60**	0.00	0.00	**4.89**
Keratella cochlearis	44.36	53.71	**212.29**	22.92	42.23	**182.17**	3.87	5.67	**24.98**
Keratella taurocephala	24.99	23.35	**103.50**	10.13	20.32	**78.28**	1.56	2.55	**13.64**
Polyarthra vulgaris	55.88	**118.70**	48.55	26.37	42.33	**135.60**	4.09	3.22	**33.03**
Total nauplii	25.38	27.34	**32.52**	9.25	14.88	**45.13**	0.87	0.92	**16.89**
Total calanoids	0.00	**0.59**	0.00	**0.25**	0.00	0.00	0.00	**0.02**	0.00
Total cyclopoids	**0.94**	0.67	0.00	0.00	0.21	**0.36**	0.00	0.00	0.00
Total cladocerans	0.00	1.18	**2.31**	**0.29**	**0.29**	0.00	0.02	**0.03**	0.00
Daphnia sp.	0.00	0.05	**1.43**	0.00	**0.07**	0.00	0.00	0.00	0.00
Diaphanosoma brachyurum	0.00	0.52	**0.87**	0.20	**0.22**	0.00	**0.04**	0.00	0.00
Holopedium gibberum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.03**	0.00
Total chaoborids	0.08	**0.43**	0.00	0.18	**0.63**	0.11	0.45	0.01	**1.30**
Croche									
Total individuals	176.10	223.74	**293.46**	154.07	276.00	**502.11**	9.54	20.80	**204.88**
Total rotifers	122.03	153.43	**176.93**	127.09	210.21	**429.13**	6.68	12.96	**152.70**
Conochilus sp.	52.46	**97.70**	86.85	44.55	62.16	**150.32**	1.24	2.17	**24.01**
K. longispina	7.46	6.46	**29.37**	7.05	**14.47**	12.89	0.47	1.05	**9.89**
K. cochlearis	**32.28**	30.59	31.26	39.32	79.33	**187.54**	1.36	2.49	**47.97**
K. taurocephala	1.58	2.42	**8.12**	0.86	**1.53**	1.20	0.02	**0.11**	0.10
P. vulgaris	**24.87**	13.65	17.96	34.24	50.69	**55.48**	3.37	6.39	**65.13**
Total nauplii	18.02	26.36	**56.88**	5.82	18.46	**26.47**	0.46	1.21	**6.66**
Total calanoids	0.83	**1.57**	0.51	0.24	0.09	**0.44**	0.04	0.00	**0.10**
Total cyclopoids	1.45	**1.46**	0.16	0.31	1.99	**2.28**	0.02	0.15	**2.68**
Total cladocerans	5.72	5.22	**7.29**	6.05	6.35	**8.28**	0.92	2.97	**13.04**
Bosmina longirostris	3.31	3.20	**4.18**	2.44	4.84	**5.28**	0.09	0.41	**6.57**
Daphnia sp.	**0.37**	0.05	0.33	0.24	0.25	**0.65**	0.43	1.33	**4.34**
D. brachyurum	0.10	**0.90**	0.00	0.00	**1.25**	0.00	0.11	**0.24**	0.00
H. gibberum	0.19	**0.90**	0.81	**2.40**	0.00	2.35	0.02	0.08	**1.56**
Total chaoborids	0.00	0.00	**0.03**	0.00	0.00	0.00	0.00	0.00	0.00
Cromwell									
Total individuals	170.22	**395.89**	328.79	52.65	55.96	**533.18**	7.37	6.01	**43.03**
Total rotifers	132.91	**306.06**	251.32	44.82	44.13	**453.30**	6.00	3.83	**31.51**
Conochilus sp.	20.46	91.23	**103.16**	9.18	10.12	**86.08**	0.43	0.62	**1.90**
K. longispina	2.53	**18.87**	10.17	0.93	0.61	**18.90**	0.07	0.09	**0.78**
K. cochlearis	77.61	**144.96**	103.13	25.27	17.30	**278.83**	3.78	1.76	**7.75**
K. taurocephala	3.50	7.72	**11.58**	0.83	0.20	**16.79**	0.14	**0.21**	0.11
P. vulgaris	14.46	**32.10**	8.26	3.54	5.40	**23.15**	0.63	0.22	**3.38**
Total nauplii	27.59	**62.98**	56.10	5.28	4.90	**63.33**	0.92	0.96	**3.33**
Total calanoids	0.32	**0.76**	0.18	0.04	0.21	**0.39**	0.00	0.00	**0.11**
Total cyclopoids	0.63	**1.48**	0.00	0.29	**0.71**	0.47	0.00	0.12	**0.91**
Total cladocerans	1.73	5.65	**8.67**	0.57	1.13	**7.52**	0.07	0.16	**1.91**
B. longirostris	1.31	4.91	**6.80**	0.53	1.13	**6.35**	0.07	0.10	**1.24**
Daphnia sp.	0.12	**0.25**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H. gibberum	**0.18**	0.15	0.00	0.00	0.00	**0.25**	0.00	0.00	0.00
Total chaoborids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Highest densities are in bold.

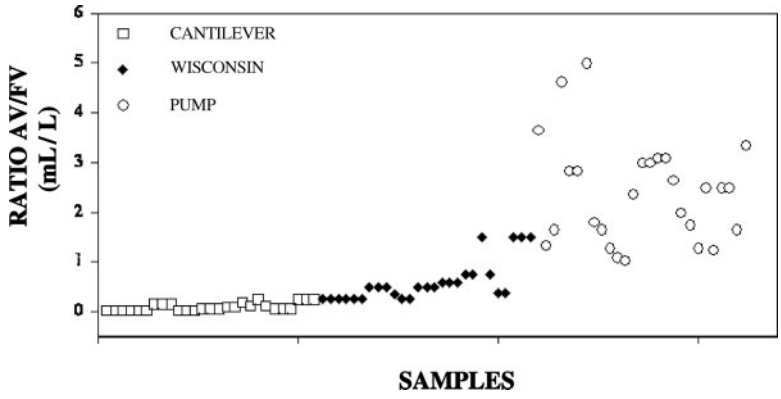

Fig. 3. Ratios of analysed volume in laboratory (AV) to filtered water volume on the field (FV) for all samples collected in the three lakes.

indicated that a larger volume of water needed to be sampled in order to accurately estimate taxa abundance. These discrepancies have to be considered when one has to compare the performance of sampling devices. Spatial heterogeneity could be at the origin of these differences, because many studies have demonstrated microscale distribution of zooplankton in relation to different biotic and abiotic factors (Pinel-Alloul and Pont, 1991; Pascual *et al.*, 1995; Masson and Pinel-Alloul, 1998; Masson *et al.*, 2001, in press; Maar *et al.*, 2003). The pumping system showed the highest coefficient of variation for the density of many taxa compared to the nets (data not included).

Furthermore, because the abundance of organisms was generally very high in the cantilever concentrated samples, smaller subsample volumes were analysed in laboratory (5 mL compared to 20–30 mL for the pump samples). The pump concentrated samples presented the lowest densities of individuals due to the lower filtered volume (FV) on the field. As suggested by Karjalainen *et al.* (Karjalainen *et al.*, 1996), higher subsample volumes should be analysed in pump samples to obtain reliable estimates. Ratios (AV:FV) established between AV in laboratory (AV = 5–30 mL) and FV of lake water (FV = 2–220 L) were higher for the pump than for the other devices (Figure 3). These ratios could be 100-fold superior for the pump compared to the nets. As for zooplankter densities, the AV:FV ratios were comparable between nets but were very divergent from the pump. These discrepancies (different water filtered and AV; AV:FV ratio) could potentially lead to an overestimation of the zooplankton densities evaluated by different gears.

Sampling efficiency of rapid swimming species

The best approach for determining the effects of different sampling methods would be a taxon-by-taxon analysis (Brinton and Townsend, 1981). The efficiency of samplers should be based on their capacity to catch animals with swimming abilities (copepods and cladocerans) and not address the rheotactic organisms (rotifers), for which the pumping system outperforms (Waite and O'Grady, 1980; Johannsson *et al.*, 1993; this study). The rotifer *P. vulgaris*, recognized as a rapid swimmer, is a species expected to avoid nets. Its density was greater in the epilimnetic waters of Lakes Geai and Cromwell, when sampled with the cantilever net, and higher in Lake Croche using the Wisconsin net (Table III). Johannsson *et al.* (Johannsson *et al.*, 1993) also observed a better performance of the pump over the nets for capturing this species. *Daphnia* sp., *D. brachyurum* and adult copepods usually display the strongest avoidance reactions (Schindler, 1969; Waite and O'Grady, 1980). Density estimates of these organisms in the epilimnetic waters were higher with the cantilever net than with the Wisconsin net and the pump for the three lakes (Table III). As observed with the rotifer *P. vulgaris*, the pump outperformed the nets in the meta- and hypolimnion of the three lakes.

Rahkola *et al.* (Rahkola *et al.*, 1994) observed that the density of some cladocera taxa (*Daphnia galeata*, *Bosmina coregoni* and all cladocera) was higher in the pump samples than in the net samples. In the present study, the performance of the gears was highly variable according to the lake, water layer and the cladocera taxa (Table III). *Daphnia* spp. were more abundant in the epilimnion of Lake Geai and in the meta- and hypolimnion of Lake Croche when sampling with the pump. On the other hand, their densities were highest in the metalimnion of Lake Geai and in the epilimnion of Lake Cromwell when using the cantilever net (Table III). Furthermore, the density of *D. brachyurum* in all water layers of Lake Croche and in the metalimnion of Lake Geai was higher in the cantilever samples.

CONCLUSION

This study showed stronger spatial variations among lakes or water layers than variations induced by the sampling devices. Where spatial and among-lake variation were smaller, it would be even more important to decrease sampling

variation by using a single type of sampling device. The use of several devices to study zooplankton community could alter the interpretation of inter-lake variation, since variance due to methods can be greater than variability among lakes for some zooplankton taxa. The pumping system allowed us to catch more zooplankton by taxa than did the nets in these three lakes. The cantilever net showed a better efficiency to catch swimming organisms than Wisconsin and pump, but its efficiency varied among water layers. The use of these three sampling gears did not have any effect on zooplankton taxa numbers. Because of the importance of a good replication, while studying a large set of lakes, especially deepest lakes, the pumping system is not suitable. On the other hand, the cantilevering net samples more rapidly and with less effort than the pump. We therefore recommend the cantilever net to collect pelagic zooplankton samples in lakes of various depths for vertically integrated water layers.

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