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Effects of water retention time on zooplankton of shallow rheolimnic reservoirs

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Introduction

Zooplankton dynamics in highly rheolimnic reservoirs are structured by several factors, including water retention time (and its converse, flow rate) (BŁĘDZKI 1989, GIZINSKI et al. 1989, EJSMONT-KARABIN & WĘGLEŃSKA 1989, EJSMONT-KARABIN et al. 1993). Although many authors (e.g. THRELKELD 1983, DIRNBERGER & THRELKELD 1986, POŁTORAK 1992) have measured zooplankton abundance and distribution, less is known about responses of zooplankton community structure and trophic dynamics to changes in retention time. It is important to understand these responses because of the significant role that zooplankton, especially rotifers, have in nutrient cycling in reservoirs (EJSMONT-KARABIN et al. 1993). Here we illustrate how zooplankton community structure in three highly rheolimnic reservoirs varies as a function of reservoir retention time. We hypothesize that different measures of community structure are not equally dependent on retention time.

Materials and methods

We studied three highly rheolimnic reservoirs: Włocławek Dam Reservoir, Poland (WDR), and Upper Lake and Lower Lake, South Hadley, Massachusetts, USA (UL and LL, respectively). Physical characteristics of these reservoirs are presented in Table 1. All three reservoirs are hypertrophic. Concentrations of N and P often exceed 2 mg L^{-1} and 1 mg L^{-1}, respectively, and N:P ratios are often <5. More detailed information about WDR is presented in GIZIŃSKI et al. (1989). Zooplankton of WDR was sampled bimonthly from 1980–1988 and those of UL and LL biweekly from 1996–1998. Samples were taken using Patalas or Van Dorn water samplers and quantitative Wisconsin-type plankton nets (70-µm mesh size). Samples were concentrated through a 50-µm (WDR) or a 70-µm mesh plankton net (UL, LL), and preserved in 2% formaldehyde. Zooplankton was counted in a Sedgwick–Rafter cell using the subsample method (EDMONDSON & WINBERG 1971, BOTTRELL at al. 1976), and biomass was calculated according to DUMONT et al. (1975), BOTTRELL et al. (1976) and RUTTNER-KOLISKO (1977). Additional (non-fixed) zooplankton samples were taken to analyze species composition "in vivo", which is essential because rotifers are preserved poorly in fixed samples. Rotifera, Cladocera and Copepoda were identified using standard monographs and keys (BARTOŠ 1959, KUTIKOVA 1970, FLÖßNER 1972, SMIRNOV 1974, KIEFER 1978, KOSTE 1978), and unpublished keys by the senior author.

Water discharge rate at the Włocławek Dam was recorded by the Włocławek Power Plant. Stream flow measurements of Stony Brook were recorded by an automated gauging station installed in Stony

Table 1. Morphometric characteristic of the three reservoirs.

	Włocławek Reservoir	Upper Lake	Lower Lake
Surface area (ha)	7,500	5.08	2.39
Volume (m^3)	408,000,000	89,552	35,814
Length (km)	57	0.396	0.272
Mean depth (m)	5.5	1.76	1.49
Water discharge m^3 s^{-1}	1,048	0.29	0.29
Retention time: average (days)	4.5	4	1.5
range (days)	3.5–7.9	1–20	0.5–8

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Brook between Upper and Lower Lakes. Surface area and volume of UL and LL were derived from depth transect data. SYSTAT (version 5) and Minitab (version 11) were used for all statistical analyses.

Results

Water retention times of the three reservoirs are presented in Fig. 1. These data illustrate a trend towards increased retention time (because of reduced flow rates) in WDR between 1980 and 1988. The 2 years of data for UL and LL illustrate a decrease in retention time (increased water flow rate), related to local increases in rainfall.

The number of recorded zooplankton species was high (UL, LL) to very high (WDR). Observed zooplankton density was high in all three reservoirs and especially high in UL and LL (Table 2). Measures of zooplankton community structure were significantly associated with retention rate in UL and LL, but not in WDR; low sample size (n = 9) in WDR reduced the power of the analysis of WDR data. In UL and LL, 53–68% of total zooplankton biomass was attributable to variability in retention time (Table 3). Slightly more variation in total copepod biomass than cladoceran biomass was explainable by retention time in those two lakes (59–67% and 31–59%, respectively; Table 3). The relative percentage of biomass in each of the three groups that can be explained by retention ranged from 30% to 50% in all three lakes (Table 3). Species richness is less well related to retention time (17–31%; Table 3). Although biomass of both herbivores and carnivores is significantly associated with retention time in UL and LL, the ratio of carnivore biomass to herbivore biomass is not significantly associated with retention time (Table 3).

Discussion

Zooplankton of shallow and rheolimnic reservoirs are highly variable in time, which was well documented on an annual basis in WDR (Giziński et al. 1989). This variability could explain the relatively high number of species found in reservoirs relative to lakes (Błędzki et al. 1992). The high biomass of zooplankton in such reservoirs is related to high production rates and differences between the lotic and limnetic parts of reservoirs (Błędzki 1989, Ejsmont-Karabin & Węgleńska 1989).

Threlkeld (1983) found a lack of congruence between physical–chemical and zooplankton-based data in a riverine reservoir. He also found that spatial variability in zooplankton communities was usually greater than temporal variability, and that spatial effects were predominately transient. Our data (Fig. 2, Table 3) suggest that variability in zooplankton abundance and community is significantly dependent on water retention time. The data from WDR and UL also suggest that a retention time of 6 days represents a threshold. At this retention time in both WDR and UL, Cladocera comprised the

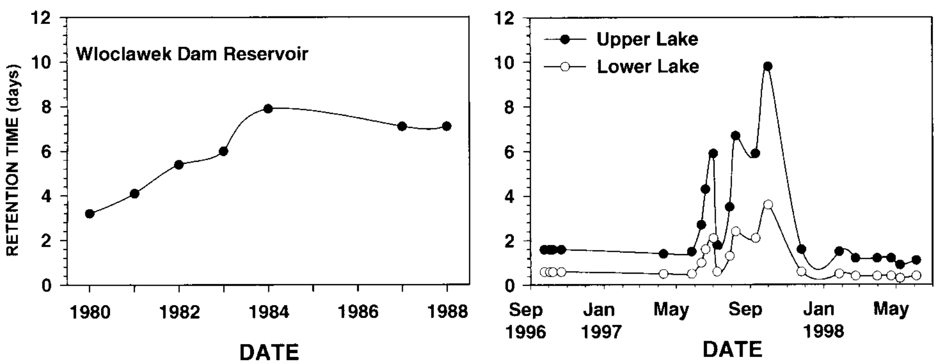

Fig. 1. Water retention time in the three reservoirs.

Table 2. Number and mean density of zooplankton in WDR, UL, and LL.

	Rotifera	Cladocera	Copepoda	Zooplankton total
		Number of species		
WDR	103	23	20	146
UL	28	21	6	55
LL	22	15	6	43
		Density (mg Dry Weight/L ± SD)		
WDR	0.379 ± 0.56	0.322 ± 0.59	0.156 ± 0.24	0.856 ± 1.29
UL	0.307 ± 0.613	0.798 ± 0.807	1.619 ± 1.715	2.724 ± 2.668
LL	0.434 ± 0.859	0.873 ± 1.632	0.818 ± 0.940	2.125 ± 2.554

Table 3. Coefficient of determination (r^2) from regressions (Fig. 2) of zooplankton parameters on water retention time.

	Rotifera	Cladocera	Copepoda	Zooplankton total
Dry mass				
WDR	0.11	0.13	0.07	0.13
UL	0.09	0.59**	0.67**	0.68**
LL	0.13	0.31**	0.59**	0.53**
% of biomass				
WDR	0.49	0.31	0.31	
UL	0.37**	0.27**	0.40**	
LL	0.14	0.51**	0.53**	
Species number				
WDR	0.01	0.27	0.37	0.16
UL	0.21	0.04	0.32**	0.17*
LL	0.26	0.18*	0.34**	0.31**
Trophic structure		Herbivores	Carnivores	Carn./Herb.
WDR		0.14	0.12	0.13
UL		0.55**	0.64**	0.09
LL		0.42**	0.33**	0.09

*P < 0.05; **P < 0.01.

highest percent of total zooplankton biomass, while its relative importance declined at both lower and higher retention times (Fig. 2). The mechanism behind this threshold merits greater study and its relationship to water chemistry and other data will be presented elsewhere. Because cladocerans remove dissolved P from water through herbivorous grazing activity and transformation of smaller particles into larger ones (faster sedimentation) (EJSMONT-KARABIN et al. 1993), our data suggest that a 6-day retention time could result in maximal depletion of P. We hypothesize that under such conditions, zooplankton community composition could ameliorate declines in water quality.

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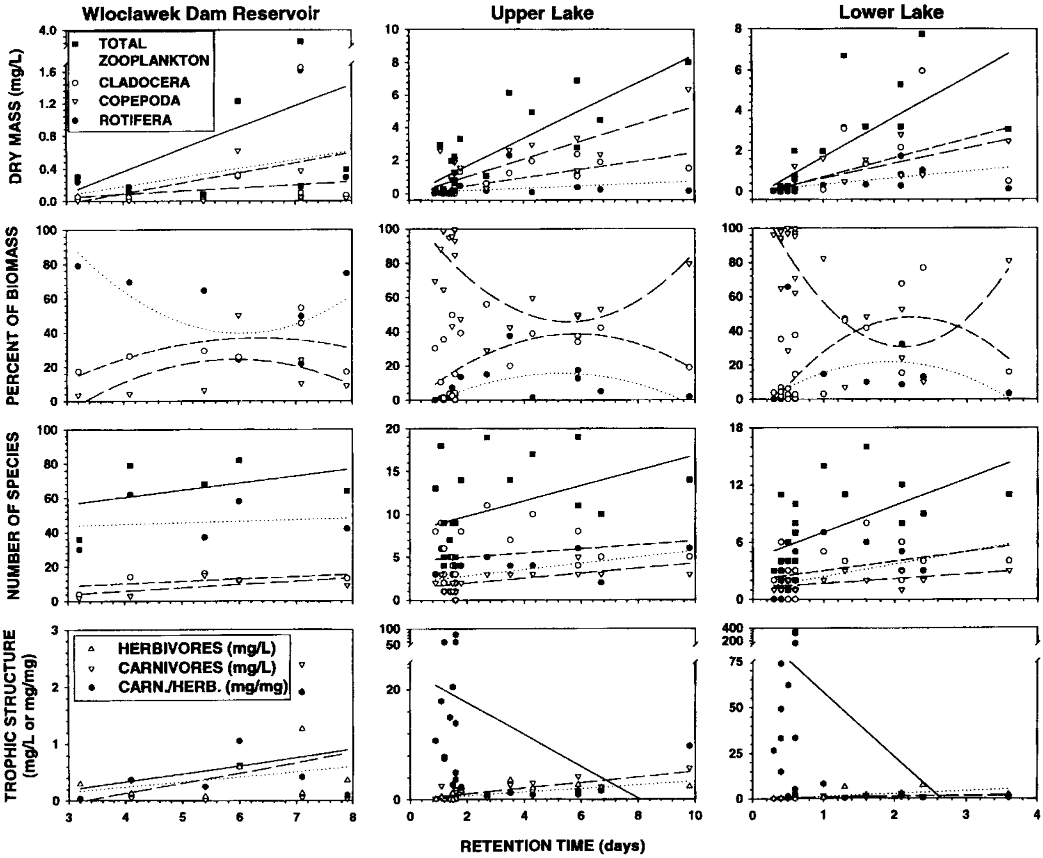

Fig. 2. Relationships between water retention time and zooplankton parameters. Lines are best-fit linear or quadratic regressions.

oke College) provided the depth transect data used to calculate area and volume of UL and LL.

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