

Diet composition and prey selection of vendace *Coregonus albula* in the mesotrophic, temperate Lake Ostrowite (Northern Poland)

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Abstract

Lake Ostrowite is a mesotrophic lake in Northern Poland 280.7 ha in area and 43 m deep at its deepest point. To study vendace (*Coregonus albula* L.) diet in the lake, fish and zooplankton were sampled at two stations on 28-29 April, 15-16 May (fish only), 28-29 July and 15-16 August 2004. Fish were caught by gill netting, while zooplankton was collected from the whole water column by means of a Ruttner sampler ($5 \times 2 \text{ dm}^3$). In total 91 vendace specimens were analysed, of which 64.8% had non-empty alimentary tracts. In the April and May samples Copepoda were

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the most numerous prey, while Daphnidae dominated the diet in the July- and September-caught fish. Planktonic Chironomidae pupae were also an important dietary item in the April-caught fish. Cladocerans, especially from Daphnidae family, were positively selected by vendace whilst copepods were not. Large predatory cladocerans, *Leptodora kindtii*, and the non-indigenous *Bythotrephes longimanus* were consumed in substantial quantities by the July- and September-sampled fish, with the vendace feeding more intensively on the *L. kindtii* than on the *B. longimanus*.

INTRODUCTION

Lake Ostrowite is situated in northern Poland (53°48' N, 17°36' E) in the Bory Tucholskie National Park. It is a typical dimictic lake with low water dynamics (Błędzki & Kentzer 1988). Its trophic level is between mesotrophy and slight eutrophy, and it has never been reported as highly eutrophic (Gašiorowski & Szeroczyńska 2004). Fisheries data from Lake Ostrowite are available since the mid 1960s (Table 1, data from Bory Tucholskie National Park). Vendace (*Coregonus albula*), together with cyprinids and eel (*Anquilla anquilla*), have dominated the fish yield during that time. In 1966-1996 vendace constituted ca. 30% and in 2002-2005 ca. 40% of the total biomass of fish catches. Another coregonid species, whitefish (*Coregonus lavaretus*), was also fished, but in small amounts (usually, less than 1% of total catches). Total fish yields from the lake have reached up to 23 kg ha⁻¹ (mean 7 kg ha⁻¹ in 1966-96 and 5 kg ha⁻¹ in 2002-2005).

Table 1

Mean annual yield (kg) of particular fish species in Lake Ostrowite in 1966-1996 and 2002-2005 according to fisheries statistics (data from Bory Tucholskie National Park)

Family	Species	1966-1996		2002-2005	
		kg	%	kg	%
Anguillidae	<i>Anguilla anguilla</i>	375	24	165	11
Salmonidae	<i>Coregonus albula</i>	842	31	625	42
	<i>Coregonus lavaretus</i>	11	+	+	+
Cyprinidae	Cyprinidae n. det.	603	30		
	<i>Abramis brama</i>		n.d. ^{b)}	314	22
	<i>Rutilus rutilus</i>		n.d. ^{b)}	210	15
	<i>Tinca tinca</i>	28	2	83	6
Esocidae	<i>Esox lucius</i>	192	11	30	2
Percidae	<i>Perca fluviatilis</i>	31	2	28	2
Others ^{a)}		2	+	1	+
Mean total yield in kg/kg ha ⁻¹		20842/7.4		1455/5.2	

^{a)} bleak *Alburnus alburnus*, pikeperch *Sander lucioperca*, rudd *Scardinius erythrophthalmus*; ^{b)} no data available

Although vendace is a dominant, planktivorous fish, no data about the diet composition and food resources of this species in Lake Ostrowite have been published. To this end, concurrent vendace feeding and zooplankton structure and abundance in the lake were studied (zooplankton samples were taken close to the fishing sites, and at almost the same time as fish collections) at various times of the growing season in 2004. The aim of this study was to examine how the diet composition varied during the most intensive feeding period (April–September), and which prey taxa were selected by the vendace.

MATERIALS AND METHODS

The most important morphometric features of Lake Ostrowite are its area 280.7 ha, volume ca. $30 \times 10^6 \text{ m}^3$, maximum depth 43 m, mean depth 10.8 m, maximum length 3900 m, and maximum width 1050 m (Jańczak 1997). The body of the lake is divided by the southern peninsula, with the western part being deeper and bigger and with a narrower littoral zone, than the eastern part (which has a maximum depth of only 25 m). Water transparency (Secchi disk visibility) fluctuates from 4 to 8 m. Submerged macrophytes (underwater meadows) are present down to a depth of 15 m and consist mainly of Charophyta, *Potamogeton* sp., and *Stratiotes* sp. (Luścińska & Wiśniewska 1999).

We sampled fish and zooplankton at two sites on the lake on 27–28 April, 15–16 May (fish only), 28–29 July and 15–16 September 2004. The study sites were located near the western shore of the lake, at depths of 25 m (site I) and 20 m (site II). Zooplankton was collected close to the fishing sites from the whole water column by means of a Ruttner sampler (5 replicates, 2 dm³ each) and sieved by a plankton net (mesh size 50 µm). The zooplankton at site I was sampled every 5 m of depth, and at site II every 4 m. The organisms were preserved immediately in 4% formalin for later analysis and counting. In the laboratory, each sample was diluted to a volume of 10 ml and several subsamples (depending on the plankton density) were analysed. Samples were identified and counted under a Nikon Alphaphot-2 YS2-H microscope. Zooplankton body length was measured to the nearest 0.01 mm. The biomass of particular zooplankters (wet weight, w.w.) was estimated on the basis of species-specific length/weight regressions (Bottrell et al. 1976, McCauley 1984).

Fish were collected with monofilament gill nets of 20 and 24 mm mesh-size (knot to knot). During each sampling the nets were left in the lake overnight. The fish were frozen shortly after capture. In the laboratory, total and standard lengths (to the nearest 1 mm) as well as wet body weight (to the nearest 1 g) were measured (Table 2). The stomachs were extracted by dissection and stored

Table 2

Mean, minimum, maximum, standard error (SE) for standard length (SL) and weight of vendace with nonempty stomach (n = number of specimens) from Lake Ostrowite in 2004

Date	Standard length (cm)			Weight (g)			n
	Mean	Min.-Max.	SE	Mean	Min.-Max.	SE	
27-28 April	18.8	16.8-20.0	1.0	81.2	65.4-101.1	11.8	11
12-13 May	18.1	17.4-19.6	0.6	74.2	67.1-86.6	6.1	9
28-29 July	16.7	15.2-18.3	0.9	62.2	49.6-79.4	8.6	23
15-16 Sept	16.5	15.5-18.2	0.8	60.1	47.7-83.0	9.1	16

in 4% formalin for later prey analysis. Of the 91 guts of vendace examined, 32 were empty (35.2%). Because it was often difficult to identify all the prey to species level due to digestion, they were grouped into seven taxonomic categories: Bosminidae n. det., *Bythotrephes longimanus*, Chironomidae larvae, Chironomidae pupae, Copepoda, Daphnidae n. det., and *Leptodora kindtii*. Dietary items were expressed as an index of relative importance (IRI) (Pinkas et al. 1972):

$$IRI = (N + W) \times F$$

where N is its the numerical abundance, expressed as the percentage contribution to the total number of prey taken, W is the contribution to the total wet weight of the stomach contents and F is the frequency of occurrence, expressed as the percentage of all stomachs (with empty stomachs excluded). In order to evaluate the percentage of total weight of dietary components (W) a few intact organisms selected at random from each category were measured and their wet weights determined from the published length–weight regressions (Bottrell et al. 1976, McCauley 1984), then summed for each prey group, and expressed as the percentage of the total wet weight of all prey items (overall food), according to Hyslop (1980). Diet selectivity was examined by comparing the share of a given zooplankton group in the biomass of the vendace stomach contents with its share in the biomass found in the environment (the whole water column of the lake). Due to the lack of the *B. longimanus* and *L. kindtii*, as well as chironomid larvae and pupae, in the zooplankton samples, only three prey categories (Bosminidae n. det., Daphnidae n. det., Copepoda n. det.) were considered in these analyses. Selection of prey items was estimated using Chesson's (1983) selectivity index:

$$\alpha_i = \frac{r_i / e_i}{\sum_{j=1}^k (r_j / e_j)}$$

where α_i is the selectivity for the prey item i for an individual vendace, r_i is the proportion of the prey item i in an individual vendace stomach, e_i is the proportion of prey item i in the environment and k is the number of prey categories. Values of α range from 0 to 1, corresponding to complete avoidance or full selection of prey, respectively. The results were averaged for each month. A value of α equal to $1/k$ indicates random feeding level. In our case $1/k = 0.33$ (three prey categories). Mean values of α_i were compared with $1/k$ using the Student's single means t -test.

RESULTS

Prey taxonomic structure and abundance in the lake

Eleven taxa of crustacean zooplankton were identified in Lake Ostrowite, including 6 cladoceran and 5 copepod taxa (Table 3). The highest number of taxa observed at any one time was in July. The mean number of crustacean zooplankton was 77 ind. dm^{-3} (cladocerans 9 ind. dm^{-3} and copepods

Table 3

Biomass (mg w.w. dm^{-3}) of crustacean zooplankton in the Ostrowite Lake (28 April, 28 July and 16 September 2004)

	28 April	28 July	16 September
<i>Bosmina longirostris</i>	0.043	0.019	0.009
<i>Ceriodaphnia pulchella</i>		0.001	
<i>Diaphanosoma brachyurum</i>		0.023	
<i>Daphnia cristata</i>		0.046	0.003
<i>Daphnia cucullata</i>	0.139	0.334	0.007
<i>Daphnia hyalina</i>		0.025	
Total Cladocera A	0.182	0.448	0.019
<i>Eudiaptomus gracilis</i>	0.699	0.052	0.069
<i>Eurytemora affinis</i>		0.007	
<i>Eurytemora lacustris</i>	0.013	0.006	
<i>Microcyclops</i> sp.		0.003	
<i>Thermocyclops oithonoides</i>	0.113	0.046	0.008
nauplii	0.32	0.037	0.011
copepodites	0.33	0.079	0.019
Total Copepoda B	1.475	0.23	0.107
Total Crustacea A+B	1.657	0.678	0.126

68 ind. dm^{-3}). The mean biomass of crustacean zooplankton was 0.820 mg w.w. dm^{-3} , of this cladocerans contributed 26%, viz. 0.216 mg w.w. dm^{-3} and copepods 74%, viz. 0.604 mg w.w. dm^{-3} . The highest biomass of cladocerans was observed in July, at 0.448 mg w.w. dm^{-3} and the lowest in September, at 0.019 mg w.w. dm^{-3} . The highest cladoceran contribution to the total biomass of crustacean zooplankton was also observed in July (over 66% of total crustacean biomass). During the entire study period *Daphnia cucullata* predominated in the cladoceran biomass. The highest biomass of copepods was recorded in April, viz. 1.475 mg w.w. dm^{-3} , and the lowest in September, viz. 0.107 mg w.w. dm^{-3} . *Eudiaptomus gracilis* comprised the dominant proportion of the copepod biomass.

Diet composition and food preference of vendace

The composition of the vendace diet showed a marked seasonal pattern. During the spring and summer of 2004, the vendace diet in Lake Ostrowite was dominated by zooplankton, including planktonic chironomid pupae, as indicated by both the *IRI* (Fig. 1) and percentage of total weight (%*W*) values of these dietary items (Table 4). Benthic organisms, such as chironomid larvae, did not exceed 0.3% *IRI* and 4.2% *W* in September. In April and May, copepods were the most important prey in terms of % *IRI* (79.2% and 55.7%, respectively). At the same time, the %*W* of copepods were 59.6% and 37.4%, respectively.

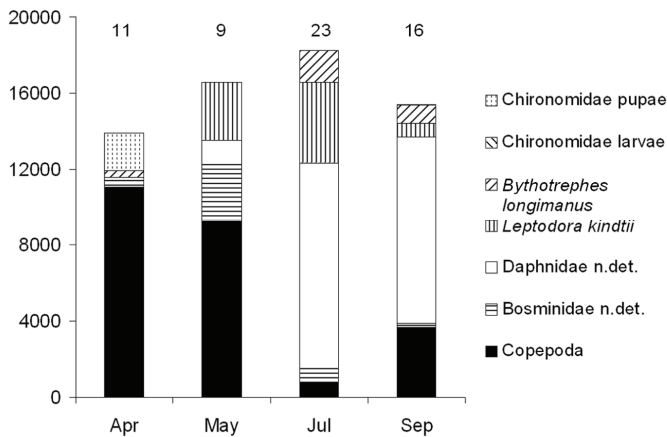


Fig. 1. Index of Relative Importance (*IRI*) of particular components in the diet of vendace in Lake Ostrowite (28-29 April, 15-16 May, 28-29 July, 15-16 September 2004). The number of nonempty stomachs examined on each sampling occasion is given above the relevant bar.

Additionally, substantial amounts of chironomid pupae were consumed in April (14.1% *IRI*, 28.2% *W*). The abundance of cladocerans (Bosminidae n. det., Daphnidae n. det.) in the diet increased in July (63.5% *IRI*, 30.1% *W*) and remained high in September (65.6% *IRI*, 36.9% *W*). The predatory cladocerans, *Leptodora kindtii* and *Bythotrephes longimanus*, were found in vendace stomachs, although they were completely absent from the plankton samples taken from the water column close to the fishing sites. In successive months, *L. kindtii* constituted up to 23.3% *IRI* and 43.6% *W*, while *B. longimanus* played a less important role in the diet (9.2% *IRI* and 23.7% *W*).

Table 4

Percentage of the total weight of the particular components in the diet of vendace in Lake Ostrowite (28-29 April, 15-16 May, 28-29 July, 15-16 September 2004)

	27-28 April	12-13 May	28-29 July	15-16 Sept	Mean
Cladocera:					
Bosminidae n. det.	3.1	11.2	2.3	2.0	4.6
Daphnidae n. det.	-	7.8	30.1	36.9	18.7
<i>Bythotrephes longimanus</i>	9.1	-	23.7	23.5	14.1
<i>Leptodora kindtii</i>	-	43.6	42.3	14.9	25.2
Total Cladocera	12.2	62.6	98.4	77.2	62.6
Copepoda	59.6	37.4	1.6	18.6	29.3
Chironomidae:					
larvae	28.2	-	-	-	1.0
pupae	-	-	-	4.2	7.0
Total Chironomidae	28.2	-	-	4.2	8.0
Total number of stomachs	13	17	31	30	
Number of nonempty stomachs	11	9	23	16	

In April and May vendace selected positively ($\alpha > 1/k$) for cladocerans, especially from the Daphnidae. These were also strongly positively selected in September ($\alpha = 0.82$, *t*-test vs. 0.33, $t = 6.85$, $df = 22$, $P < 0.001$), but in July the selection was close to positive, although not significant ($\alpha = 0.44$, $t = 1.96$, $df = 15$, $P = 0.06$). Bosminidae were preferred by vendace in July ($\alpha = 0.51$, $t = 6.85$, $df = 22$, $P < 0.005$), whilst in September they were negatively selected ($\alpha = 0.04$, $t = -22.84$, $df = 15$, $P < 0.001$). In April-collected samples the results of the *t*-test do not allow rejection of the null-hypothesis that selection of vendace for bosminids ($\alpha = 0.49$,

$t=1.54$, $df=8$, $P<0.12$) and copepods ($\alpha=0.51$, $t=1.72$, $df=8$, $P<0.12$) was neutral (random feeding). Daphnidae were absent from the stomach contents of vendace in April. In July and September the vendace showed a negative preference for copepods ($\alpha=0.04$, $t=-45.72$, $df=22$, $P<0.001$ and ($\alpha=0.14$, $t=1.54$, $df=8$, $P<0.16$, respectively).

DISCUSSION

Planktivorous vendace, being a visual predator, rely on the optical characteristics of the environment and prey conspicuousness for effective feeding (Lazzaro 1987). Due to morphological (size, shape, pigmentation) and behavioural (mobility) traits, various planktonic crustacean taxa are more or less susceptible to fish predation. Large and non-evasive cladocerans, especially *Daphnia* sp., are usually the preferred food items of *Coregonus* sp. (Hamrin 1983, Viljanen 1983, Schultz et al. 2003). Smaller cladocerans, such as *Bosmina* sp., are taken in large numbers when they are abundant in the environment and the larger cladocerans are scarce (e. g. Mookerji et al. 1998). Copepods, because of their evasive behaviour, are not so easy for fish to catch. However, a substantial proportion of copepods in the diet of coregonids during low feeding periods, especially in winter, has been reported (Szypuła 1970, Mookerji et al. 1998). Cyclopoid copepods were seen to be consumed in greater quantities than calanoids, which in most cases were negatively selected, by *Coregonus* sp. (Enz et al. 2001, Schultz et al. 2003).

Our results from Lake Ostrowite are in agreement with previously published findings. Vendace were collected four times between April and September, i.e. during the period of their most intensive feeding (Mookerji et al. 1998). Substantial seasonal changes in the diet composition were reflective of changes in prey availability in the environment. In April, due to the scarcity of cladocerans and the concurrent highest abundances of copepods, the vendace food consisted mainly of the latter. Chironomid pupae were also taken in substantial numbers, probably because of their periodically increased abundance in water caused by their gregarious emergence from sediments to become adults. In May chironomid pupae disappeared from the diet, whereas copepods, together with *Leptodora kindtii* and bosminids, were eaten in the greatest amounts. In July and September samples cladocerans from the Daphnidae family, as well as large cladoceran predators *L. kindtii* and *Bythotrephes longimanus*, were eaten in the greatest quantities. The biomass of copepods was distinctly lower in the summer than in the spring. However, these evasive crustaceans were not positively selected by the vendace.

Surprisingly *Leptodora kindtii* and *Bythotrephes longimanus* were fairly abundant in the stomach contents of vendace, but completely absent in our

plankton samples taken from the lake. A similar situation was observed by Hamrin (1983) in Lake Bolmen (Sweden), and by Schultz et al. (2003) in Lake Stechlin (Germany). Schultz et al. (2003) state that there may be a technical problem in quantifying large predatory crustaceans with a common plankton net, because of their ability to escape; a Ruttner sampler probably also suffers this disadvantage. A Ruttner sampler is generally efficient for small, non-evasive plankters (De Bernardi 1984), although there are reports that show its efficiency of catching crustaceans is comparable to other samplers (Paggi et al. 2001), and they have been used to study zooplankton communities in lakes (Rodriguez et al. 2001, Jankowski 2004, Jankowski et al. 2005, Nöges et al. 2005, Paturej & Goździewicz 2005, Paturej 2006). Nevertheless, in the future other methods should be applied in order to quantify the abundance of large crustacean plankters in the lake, such as vertical plankton hauls using a special net (Boudreau & Yan 2004).

The spiny water flea, *Bythotrephes longimanus* is an invasive species, expanding its range in Eurasia and established in North America (Grigorovich et al. 1998, Branstrator et al. 2006, Drake et al. 2006), where it can be an important element of food webs in lake pelagic zones (Palmer et al. 2001). Although it has a wide ecological range, it is most prolific in deeper lakes of low trophicity (Palmer et al. 2001), such as Lake Ostrowite. *B. longimanus* is a common prey, often preferred by various fish species, such as whitefish *Coregonus* sp. (Mookerji et al. 1998, Enz et al. 2001, Mayr 2001, Palmer et al. 2001), arctic charr *Salvelinus alpinus* (Winfield et al. 2002, Saksgård & Hesthagen 2004) and brown trout *Salmo trutta* (Haugen & Rygg 1996, Saksgård & Hesthagen *loc. cit.*). *B. longimanus* is usually preferred and predominates in fish diets over *L. kindtii*. Mookerji et al. (1998) found that in Lake Lucerne *B. longimanus* was positively selected by whitefish *Coregonus* sp., whilst *L. kindtii*, was never found in the stomach samples. Both predatory cladocerans were very rare in the lake. Enz et al. (2001) and Palmer et al. (2001) also observed that *Bythotrephes* was consumed in higher amounts than *Leptodora* by whitefish. Palmer et al. (*loc. cit.*) found that *B. longimanus* generally lived at greater depths than *L. kindtii*, reaching a mean depth of 30 m in summer in the part of the lake in which shoals of whitefish were concentrated. It is noteworthy that *Bythotrephes* is protected from fish predation by its long caudal spine, whereas *Leptodora* is protected by its transparency (Branstrator 2005).

An opposing pattern of *B. longimanus* and *L. kindtii* importance in the fish diet was found in our study. Vendace in Lake Ostrowite fed more intensively on *L. kindtii* than *B. longimanus*. This may result from the considerably lower abundances of *B. longimanus* in the environment compared to *L. kindtii*, making feeding on the latter species more efficient. Mookerji et al. (1998) observed in Lake Lucerne that although *L. kindtii* resembled *B. longimanus* in size and

abundance in the lake, it did not face any predation from whitefish, while *B. longimanus* was one of the most numerous and frequent items in the diet of whitefish. The authors postulate that this preference results from the better visibility, and therefore better availability to a visual predator (whitefish), of the pigmented *B. longimanus* compared to the transparent *L. kindtii*. The results presented here may show the effect of vendace adapting to eating *L. kindtii* in Lake Ostrowite compared with whitefish and/or penetrating shallower, more transparent water layers. Further studies on the preferences of vendace for *L. kindtii* or *B. longimanus* would further explain details of the observed phenomenon.

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REFERENCES

- Błędzki L.A. & Kentzer A., 1988, *Hydrobiological characteristic of selected lakes from Tuchola Pinewoods*. [in:] *Environmental Protection of Tuchola Pinewoods*. Proceedings of 1st Scientific Conference, 20-27, (in Polish).
- Bottrell H.H., Duncan A., Gliwicz Z.M., Grygierek E., Herzig E. et al., 1976, *A review of some problems in zooplankton production studies*, Norw. J. Zool., 24: 419-456.
- Boudreau S.A. & Yan N.D., 2004, *Auditing the accuracy of a volunteer-based surveillance program for an aquatic invader Bythotrephes*, Environ. Monit. Assess., 91: 17-26.
- Branstrator D.K., 2005, *Contrasting life histories of the predatory cladocerans Leptodora kindtii and Bythotrephes longimanus*, J. Plankton Res., 27(6): 569-585.
- Branstrator D.K., Brown M.E., Shannon L.J., Thabes M., Heimgartner K., 2006, *Range expansion of Bythotrephes longimanus in North America: evaluating habitat characteristics in the spread of an exotic zooplankton*, Biol. Invasions, 8:1367-1379.
- Chesson J., 1983, *The estimation and analysis of preference and its relationship to foraging models*. Ecology, 64: 1297-1304.
- De Bernardi R., 1984, *Methods for the estimating of zooplankton abundance*. [in:] *A manual on methods for the assessment of secondary productivity in fresh waters*, (eds.) Downing, J.A. & Rigler F.H., IBP Hand Book 17, Blackwell Science Ltd., Oxford, UK, pp. 228-265.
- Drake J.M., Drury K.L.S., Lodge D.M., Blukacz A., Yan N.D. & Dwyer G., 2006, *Demographic stochasticity, environmental variability, and windows of invasion risk for Bythotrephes longimanus in North America*, Biol Invasions, 8: 843-861.
- Enz C.A., Bürgi H.R., Stössel F. & Müller R., 2001, *Food preference of adult whitefish in eutrophic Lake Hallwil (Switzerland), and the question of cannibalism*, Arch. Hydrobiol., 152: 81-98.

- Gąsiorowki M. & Szeroczyńska K., 2004, *Abrupt changes in Bosmina (Cladocera, Crustacea) assemblages during the history of the Ostrowite Lake (northern Poland)*, Hydrobiologia, 526: 137-144.
- Grigorovich I.A., Pashkova V., Gromova Y.F. & van Overdijk C.D.A., 1998, *Bythotrephes longimanus in the Commonwealth of Independent States: variability, distribution and ecology*, Hydrobiologia, 379: 183-198.
- Hamrin S.F., 1983, *The food preference of vendace (Coregonus albula) in South Swedish forest lakes including the predation effect on zooplankton populations*, Hydrobiologia, 101: 121-128.
- Haugen T.O. & Rygg T., 1996, *Food- and habitat-segregation in sympatric grayling and brown trout*, J. Fish Biol., 49: 301-318.
- Hyslop E.J., 1980, *Stomach content analysis-a review of methods and their application*, J. Fish Biol., 17: 411-429.
- Jankowski T., 2004, *Predation of freshwater jellyfish on Bosmina: the consequences for population dynamics, body size, and morphology*, Hydrobiologia, 530/531: 521-528.
- Jankowski T., Strauss T., Ratte H.T., 2005, *Trophic interactions of the freshwater jellyfish Craspedacusta sowerbii*, J. Plankton Res., 27(8): 811-823.
- Jańczak J. (ed.), 1997, *The Atlas of Polish Lakes*, 2. Bogucki Wydawnictwo Naukowe, Poznań, pp. 233, (in Polish).
- Lazzaro X., 1987, *A review of planktivorous fishes: their evolution, feeding behaviours, selectivities and impacts*, Hydrobiologia, 146: 97-167.
- Luścińska M. & Wiśniewska M., 1999, *Algal community in Ostrowite Lake*, AUNC Limnol. Pap., 20: 55-67.
- Mayr C., 2001, *The Influence of Population Density on Growth of Whitefish (Coregonus lavaretus L.) in Four Prealpine Lakes*, Limnologica, 31: 53-60.
- McCauley E., 1984, *The estimation of the abundance and biomass of zooplankton in samples*. [in:] *A manual on methods for the assessment of secondary productivity in fresh waters*, (eds.) Downing J.A. & Rigler F.H., IBP Hand Book 17, Blackwell Science Ltd., Oxford, UK, pp. 228-265.
- Mookerji N., Heller C., Meng H.J., Bürgi H.R. & Müller R., 1998, *Diel and seasonal patterns of food intake and prey selection by Coregonus sp. in re-oligotrophicated Lake Lucerne, Switzerland*, J. Fish Biol., 52: 443-457.
- Nõges P., Tuvikene L., Feldmann T., Tõnno I., Künnap H. et al., 2005, *The role of charophytes in increasing water transparency: a case study of two shallow lakes in Estonia*, Hydrobiologia, 506-509: 567-573.
- Paggi J.C., Mendoza R.O., Debonis C.J. & Jos de Paggi S.B., 2001, *A simple and inexpensive trap-tube sampler for zooplankton collection in shallow waters*, Hydrobiologia, 464: 45-49.
- Palmer A., Stich H.B. & Maier G., 2001, *Distribution patterns and predation risk of the coexisting cladocerans Bythotrephes longimanus and Leptodora kindtii in a large lake – Lake Constance*, Hydrobiologia, 442: 301-307.
- Paturej E., 2006, *Assessment of the trophic state of the coastal Lake Gardno based on community structure and zooplankton-related indices*, EJPAU, 9(2), #17.
- Paturej E., & Goździejewska A., 2005, *Zooplankton-based assessment of the trophic state of three coastal lakes – Lebsko, Gardno, and Jamno*, Bulletin of the Sea Fisheries Institute, 3(166): 7-26.
- Pinkas L., Oliphant M.S., Iverson I.L.K., 1972, *Food habits of albacore, bluefin tuna and bonito in California*, Calif. Fish. Bull., 152: 101-105.
- Rodriguez A., Avila-Perez P., Velazquez-Olvera I.A., 2001, *Effects on the zooplankton community of pollutant disposal into the Jose Antonio Alzate dam, Mexico*, Int. J. Environ. Pollut., 15(5): 497-504.

- Saksgård R. & Hesthagen T., 2004, *A 14-year study of habitat use and diet of brown trout (Salmo trutta) and Arctic charr (Salvelinus alpinus) in Lake Atnsjøen, a subalpine Norwegian lake*, Hydrobiologia, 521: 187–199.
- Schultz M., Kasprzak K., Anwand K. & Mehner T., 2003, *Diet composition and food preference of vendace (Coregonus albula (L.)) in response to seasonal zooplankton succession in Lake Stechlin*, Arch. Hydrobiol. Spec. Issues Advanc. Limnol., 58: 215-226.
- Szypuła J., 1970, *Feeding habits of Coregonus albula in Legnickie and Wądzyńskie Lakes*, Roczn. Nauk Roln., 92-H-3: 61-70.
- Viljanen M., 1983, *Food and food selection of cisco (Coregonus albula L.) in a dysoligotrophic lake*, Hydrobiologia, 121: 129-138.
- Winfield I.J., Bean C.W. & Diane P., Hewitt, D.P., 2002, *The relationship between spatial distribution and diet of Arctic charr, alvelinus alpinus, in Loch Ness, U.K.* Environ. Biol. Fish., 64: 63–73.