GROWTH AND DIET OF INTRODUCED COREGONID FISH *COREGONUS PELED* (GMELIN) AND *COREGONUS LAVARETUS* (L.) IN TWO BELGIAN RESERVOIR LAKES

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Abstract. Introduced *Coregonus lavaretus* L. and *Coregonus peled* Gmelin populations in the Robertville and Bütgenbach Reservoir lakes (Belgium) were studied in order to assess their adaptation to their new habitat. We considered the evolution of abundance, biomass, size distribution structure, growth parameters and diet. Maximal temperature values are acceptable for *C. peled* but slightly too high for an optimal development of *C. lavaretus*. In order to remain in their acceptable range for dissolved oxygen, the coregonids must stay in surface water during stratification, although water temperature is largely above their optimum in these water layers. Length frequency diagrams established for *C. peled* in both lakes show only older cohorts, which indicate that there is no natural reproduction. Slope coefficients for *C. peled* in both lakes indicate an allometric growth ($b<3$), length increasing proportionally more rapidly than weight. *C. lavaretus* shows a broad diet spectrum with 14 categories whereas *C. peled* seems to have a more narrow diet spectrum. In our case *C. peled* shows an essentially zooplankton oriented diet in both lakes. In conclusion, the Bütgenbach and Robertville reservoir lakes seem to meet the habitat requirements of *C. lavaretus* and *C. peled* in terms of growth capacities and diet composition. On the other hand, the conditions necessary for the natural reproduction of these two species do not seem to be totally fulfilled, probably due to the trophic status and the fluctuations of the water level as consequence of reservoir operations.

Keywords: *abundance, biomass, size distribution structure, growth parameters, diet.*

Introduction

The genus *Coregonus* belongs to the class Actinopterygii, order Salmoniforms, family of Salmonidae and subfamily of Coregoninae [47]. The two species considered in this study are *Coregonus lavaretus* (L.) and *Coregonus peled* (Gmelin). *C. lavaretus* has a small low mouth with protruding upper jaw and a quite slender silvery body [27]. Maximum length reaches up to 130 cm with a mean value of 50 to 70 cm. Maximum mass is up to 10 kg for a mean value of 2 to 4 kg. Compared to *C. lavaretus*, *C. peled* has a broader body and a terminal mouth. Maximum length reaches 60 cm with a mean value of 30 to 40 cm, while maximum mass reaches 5 kg with a mean value up to 1 kg. According to [30] the natural distribution area of *C. lavaretus* in Europe covers the Baltic Sea, the North Sea and the Arctic Ocean up to the Kolyma River (Eastern Siberia). The species is still present in numerous lakes as a glacial relict (Poland, alpine lakes). This species has been stocked since 1880 [46] into many other places in Europe outside of its native range. The natural distribution of *C. peled* covers lakes and rivers of the Arctic Ocean basin from the Mézen River (Russia) to the Kolyma River. Since 1954 [17] this species has been widely introduced in North and Central European lakes. These two species have been introduced in 1978 [13] in the reservoir lakes of Robertville and Bütgenbach (Belgium) from strains originating from Bohemia (currently Czech Republic). From 1979 to 1995 the introduced fish were adults with a mean length of 30 cm. Only from 1991 on, the restocked species has been identified as mainly *C. lavaretus*. From 1996 on, restocking experiments with *C. lavaretus* larvae (2 cm) were conducted (*Table 1*).

Table 1. *Introduction of Coregonids in the Bütgenbach and Robertville reservoirs from 1978 to 1999 (TL = total length in cm, TB = total biomass in kg, Ab. = Abundance in number of individuals, IMW = individual mean weight in g)*

	Bütgenbach					**Robertville**				
Date	**TL (cm)**	**TB (kg)**	**Ab. (n)**	**I M W (g)**	**Species**	**TL (cm)**	**TB (kg)**	**Ab. (n)**	**I M W (g)**	**Species**
NOV - 78	5-6		50000		uknown	5-6		25000		uknown
NOV - 79	12-30	750			uknown	12-30	1250			uknown
NOV - 80					uknown					uknown
NOV - 81		675			uknown		675			uknown
NOV - 82		570			uknown		570			uknown
NOV - 83		437			uknown		437			uknown
NOV - 84		525			uknown		525			uknown
NOV - 85		500			uknown		500			uknown
NOV - 86		570			uknown		570			uknown
NOV - 87		850			uknown		850			uknown
NOV - 88		750			uknown		750			uknown
NOV - 89	19-29	750		177	uknown	19-29	750		177	uknown
NOV - 90	26-30	750		220	uknown	26-30	750		220	uknown
NOV - 91	26-35	750		200	99,7 % *C. lavaretus*	26-35	750		200	99,7 % *C. lavaretus*
NOV - 92	18-30	750		144	Mainly *C. lavaretus*	18-30	750		144	Mainly *C. lavaretus*
NOV - 93	12-22	600		49	Mainly *C. lavaretus*	12-22	900		49	Mainly *C. lavaretus*
NOV - 94	21-33	600			74% *C. lavaretus*	21-33	900			74% *C. lavaretus*
OCT- 95	12-42	600			99.7 % *C. lavaretus*	12-42	900			99.7 % *C. lavaretus*
FEB - 96	2		472000		*C. lavaretus* larva	2		1200000		*C. lavaretus* larva
NOV - 97	3.1 - 3.9				*C. lavaretus*	3.1 - 3.9				*C. lavaretus*
NOV - 98	1.2 - 1.6				*C. lavaretus*	1.2 - 1.6				*C. lavaretus*
JAN - 99	2.8 - 4.0				*C. peled*	2.8 - 4.0				*C. peled*

The aim of this study was to assess the adaptation of these two introduced species to their new environment. Different aspects were considered, starting with a survey of the evolution of abundance, biomass and size distribution structure of the coregonid populations from 1994 to 2000. Growth parameters were established for the 1996/1997 cohorts. Detailed dietary studies were conducted in 1996/1997 and in 1999/2000.

Materials and Methods

Study Area

Located in the eastern part of the province of Liège (Belgium), the man-made lakes of Robertville (50°27'N; 6°07'E) and Bütgenbach (50°25'N; 6°14'E) were respectively constructed in 1929 and 1932 on the upper reaches of the Warche River (*Fig. 1*). The Bütgenbach Reservoir is located 7 km upstream from the Robertville Reservoir. Owned by the S.A. Electrabel, their main function is the production of hydroelectric power. The fishing activities are managed by the "Ligue Royale de Propagande des Pêcheurs de l'Est".

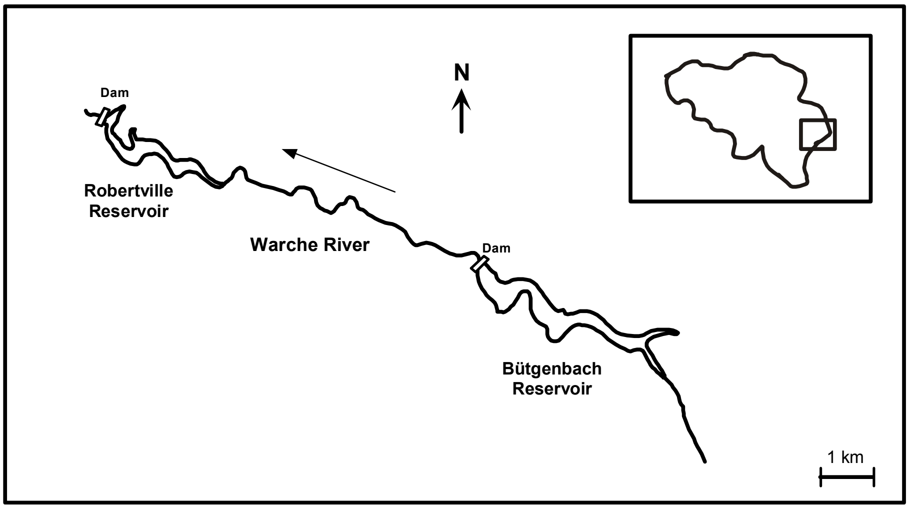

***Figure 1.** Map of the study area: The Reservoir Lakes of Robertville and Bütgenbach (Belgium)*

Both reservoirs are known to display a tendency to eutrophication [26, 25]). The morphometric and hydrologic data concerning both lakes can be found in *Table 2*.

***Table 2.** Morphometric and hydrological features of Bütgenbach and Robertville reservoirs [25]*

Features	**Bütgenbach**	**Robertville**
Altitude (m)	550	490
Length (km)	3,4	3,5
Mean width (m)	280	150
Mean surface area (ha)	120	63
Volume (10^6 m³)	23	7,7
Maximum depth (m)	11	47
Mean depth (m)	9,6	12,2
Mean yearly depth fluctuation (m)	6	3

Sampling methods

Physicochemical variables (pH, temperature, dissolved oxygen and conductivity at 20 °C) were directly measured in the field, on water samples collected with a Van Doorn bottle (in 1996) from April to November up to 20 m depth in Bütgenbach, and 40 m in Robertville. Samples of 500 ml were collected for nutrients (PO_4^-, P_{total}, NH_4^+, NO_2^-, NO_3^-) and Chlorophylle ***a*** analysis. During the 1999/2000 campaign, the physicochemical parameters were measured with a Hydrolab multiparameter probe every 2,5 m up to 10 m in Robertville and up to 15 m in Bütgenbach. During the 1999/2000 campaign, water samples were collected on a weekly basis from July to November 1999 and from March to July 2000 for phytoplankton and zooplankton analysis. Phytoplankton was filtered on Whatman GF/C 0,22 µm filters from a volume of 500 ml water collected using a Van Doorn bottle at the same depths as mentioned before. These extracts were analysed for pigment composition by HPLC in the lab. The zooplankton was sampled at the same depth with a 10 l Schindler trap equipped with a 65 µm filter. Samples were fixed with a 4 % formaldehyde solution for microscopical identification. Fish were sampled from spring to autumn, between 1994 and 2000 by, surface and bottom horizontal gill netting in both lakes. One gill net set is composed of 8 nets with mesh sizes ranging from 10 to 80 mm with a step of 10 mm. Each panel has a length of 50 m for a height of 1.5 m. The panels are attached together to form a set of 400 m for a surface of 600 m² (*Fig.2*).

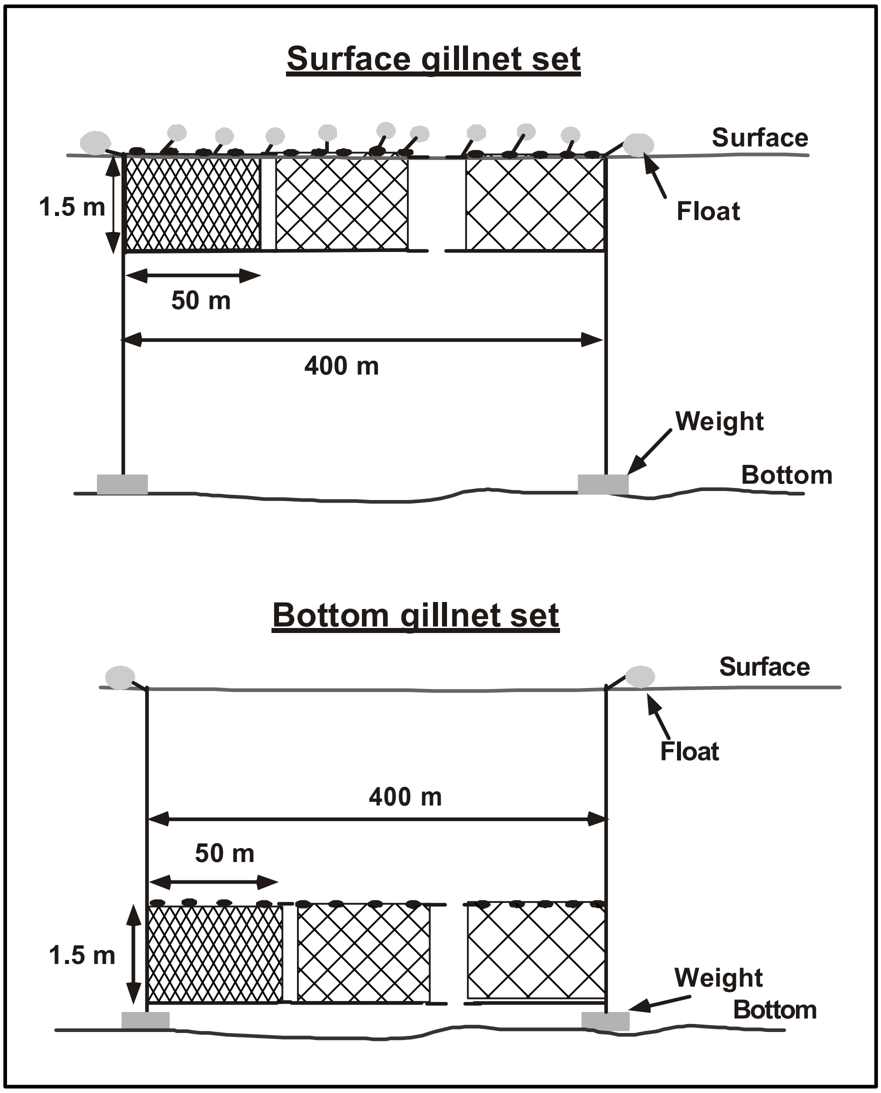

Figure 2. *Horizontal gill netting device used for fish sampling [24]*

Fish were weighted to the nearest 1 g, total length (L_T) was measured to the nearest 1 mm. Scales for age determination and growth parameter calculations were pulled from the upper flank region above the lateral line, behind the dorsal fin. In 1996/1997 and in 1999/2000, stomach contents were also removed for diet analysis. For zooplankton identification the determination keys of [16, 1, 33] were used.

Data Analysis

Length–weight relationships [21] were studied

$$W_t = a * L_t^b$$

where W_t = total weight in g, L_t = total length in mm, a, b = constants.
Constant b allows us to establish the allometric condition factor [34],

$$C = \frac{L_t}{W_t^b} * 10^5$$

Growth performances between the two lakes were compared by homogeneity slope tests [10] after linear transformation of the length-weight relationship:

$$LogW_t = Loga + b * LogL_t . \qquad \text{(Eq.1)}$$

The growth model of [5] was used on the 1996/1997 cohort data

$$L_t = L_\infty * \left[1 - e^{-k*(t-t_0)}\right] \qquad \text{(Eq.2)}$$

where L_t= total length in mm, L_∞ = the maximum theoretical length in mm, K = Growth coefficient indicating the rate by which the length tend to L_∞, t_0 is the theoretical age of the fish at length 0.

Stomach contents were analysed in four ways. First by Occurrence Index [19],

$$I_0 = \frac{N_a}{N_t} * 100 \qquad \text{(Eq.3)}$$

where N_a = number of stomachs where the item is present, N_t= total number of non-empty stomachs. Secondly by Abundance Index [19]

$$I_a = \frac{N_x}{N_{xt}} * 100 \qquad \text{(Eq.4)}$$

where Nx = number of individuals belonging to the food category x, N_{xt} = total number of individuals in the different food categories x. Thirdly by Biomass Index

$$I_b = \frac{B_x}{B_{xt}} * 100 \qquad \text{(Eq.5)}$$

where B_x = biomass in µg of the individuals belonging to the food category x and B_{xt} = total biomass of the individuals in the different food categories x. Dry weight conversion equations were used for the phytoplankton [39]and the zooplankton [42].
Fourthly by Selectivity Index [9]

$$\alpha = \frac{\frac{r_a}{p_a}}{\sum_{i=1}^{n} \frac{r_i}{p_i}} \qquad \text{(Eq.6)}$$

where n = number of prey categories in the sample, r_a = abundance of the prey category a in the stomach content, p_a= abundance of prey category a in the field (m^3), r_i = abundance of the i^{st} prey category in the stomach content, p_i = abundance of the i^{st} prey category in the field (m^3).

Results

Physicochemical features

The minimum and maximal values of the physicochemical parameters measured during the 1996 campaign from April to November are shown in *Table 3*. The thermal stratification period in Bütgenbach extends from April to September with a maximal surface value of 20.4 °C in August. The hypolimnion is anoxic from June to September. In August anoxic conditions are already visibled at 7 m depth near the dam and Chlorophyl ***a*** values rise up to 140 µg/l in the first two meters from the surface. In Robertville, the thermal stratification period extends from May to September with a maximal value of 19.5 °C in August.

Table 3. *Physico-chemical features of the Bütgenbach and Robertville Reservoirs during the 1996 sampling campaigns from April to November (in bold mean values, in standard respectively minimum and maximum values)*

	Bütgenbach	**Robertville**
Temperature (°C)	1.9 - **12.8** - 20.4	2.2 - **10.4** - 19.5
Transparency (m)	0.8 - **1.7** - 1.9	0.7 - **2.6** - 4.6
Conductivity (µS/cm)	102 - **129** - 204	109 - **129** - 158
Dissolved Oxygen (mg/l)	0 - **10.7** - 14.6	0 - **6.7** - 19.4
Chlorophylle a (µg/l)	5.1- **35.9** - 140	1.4 - **13.4** - 45.5
PO_4^- (µg/l)	<5 - **[?]** - 48	<5 - **[?]** - 41
NH_4^- (µg/l)	<3 - **[?]** - 909	<3 - **[?]** - 259
NO_2^- (µg/)	1 - **22** - 60	4 - **30** - 72
NO_3^- (µg/l)	1280 - **2160** - 4015	680 - **2496** - 4970
N (µg/l)	1323 - **2346** - 3590	788 - **2455** - 5700

The hypolimnion is anoxic from late May until mid-October. Anoxic conditions are also encountered at less than 10 m depth near the dam in August. Chlorophyl ***a*** values are lower than in Bütgenbach, with a maximum value of 45.5 µg/l in August.

The physicochemical parameters measured during the 1999-2000 campaign are shown in *Table 4*.

Table 4. *Physico-chemical features of the Bütgenbach and Robertville Reservoirs during the 1999/2000 sampling campaigns (from July 99 to October 99 and from March 00 – June 00).*

	Bütgenbach				**Robertville**			
	1999		**2000**		**1999**		**2000**	
	Min value	**Max value**	**Min value**	**Max value**	**Min value**	**Max value**	**Min value**	**Max value**
Temperature (°C)	7	22	5	22	12	22	6	22
Conductivity (µS/cm)	105	125	95	105	114	129	101	117
Dissolved Oxygen (mg/l)	0	14	0	12	0	13	0	13
Dissolved Oxygen (%)	0	150	0	120	0	141	0	137
pH	6.2	9.2	5.7	9.8	6.4	9	6.9	9.4

Temperatures in surface waters are higher than 20 °C during summer in both lakes. A thermal stratification is also observed in both lakes from July to September. Mixing takes place in October. Dissolved oxygen concentrations drop below 4 mg/l at a depth of 7 m in the Bütgenbach reservoir during summer. Anoxic conditions are the rule under 8 m depth. These phenomena are observed in Robertville as well, but at a depth of 10 m.

Abundance and Biomass

In terms of abundance and biomass *C. peled* largely dominates *C. lavaretus* in both lakes although restocking mainly concerns the later species (*Table 5*).

Absolute and relative contributions of both species are higher in Robertville than in Bütgenbach. From 1999 on, there were no more captures of *C. lavaretus*.

Table 5. Coregonus lavaretus *and* Coregonus peled *gillnetting results for the Bütgenbach and Robertville Reservoirs from June 1994 to August 1999 (Ab. (n) = Abundance in number of captured individuals, Rel. Ab. (%) = Relative abundance with regards to the total abundance of all fish species captured, Biom (kg) = Biomass in kg, Biom. Rel (%) = Relative biomass).*

	BÜTGENBACH							
	C. lavaretus				***C. peled***			
	Ab. (n)	**Rel. Ab. (%)**	**Biom (kg)**	**Rel. Biom. (%)**	**Ab. (n)**	**Rel. Ab. (%)**	**Biom (kg)**	**Rel. Biom. (%)**
June 1994	13	1,59	1	0,50	248	30,28	139	69,85
October 1994	0	0,00	0	0,00	85	7,21	62	46,97
May 1995	4	0,60	1	0,91	83	12,48	54	49,09
September 1995	2	0,25	0	0,00	32	4,06	22	25,58
October 1995	4	0,58	1	0,62	151	21,82	110	68,32
June 1996	14	1,25	5	2,81	125	11,12	98	55,06
September 1996	0	0,00	0	0,00	66	18,80	59	64,13
September 1997	2	0,21	3	1,66	83	8,60	69	44,14
October 1998	0	0,00	0	0,00	31	8,49	33	40,53
August 1999	0	0,00	0	0,00	4	0,59	3	14,35
Total	**39**	**0,5**	**11**	**0,9**	**908**	**11,9**	**648**	**53,2**
	ROBERTVILLE							
	C. lavaretus				***C. peled***			
	Ab. (n)	**Rel. Ab. (%)**	**Biom (kg)**	**Rel. Biom. (%)**	**Ab. (n)**	**Rel. Ab. (%)**	**Biom (kg)**	**Rel. Biom. (%)**
June 1994	1	0,07	0	0,00	365	25,10	301	79,84
October 1994	7	1,19	2	2,33	47	7,97	42	48,84
May 1995	35	4,33	8	4,42	159	19,65	114	62,98
September 1995	0	0,00	0	0,00	66	11,54	54	52,94
October 1995	0	0,00	0	0,00	152	19,84	124	70,45
June 1996	24	4,69	9	7,83	77	15,04	69	60,00
September 1996	5	1,65	1	0,93	72	23,76	78	72,90
September 1997	16	2,35	7	5,19	70	10,28	74	54,81
October 1998	2	0,65	1	1,39	22	7,10	27	52,22
August 1999	0	0,00	0	0,00	7	3,20	7	15,46
Total	**90**	**1,4**	**28**	**2,0**	**1037**	**16,7**	**890**	**64,6**

Growth

Length frequency diagrams have been established for *C. peled* (*Fig. 3*), but not for *C. lavaretus* because of its low abundance in both reservoirs. *C. lavaretus* total length ranges from 250 to 425 mm in Bütgenbach and from 240 to 458 mm in Robertville. Concerning *C. peled* there is globally one cohort in both lakes ranging from 350 to 530 mm. Until 1995, there were few individuals with a size below 350 mm. After restocking with *C. peled* has been stopped in 1996 these size classes were not captured anymore. Some larger individuals with a size over 540 mm have been captured only until 1996.

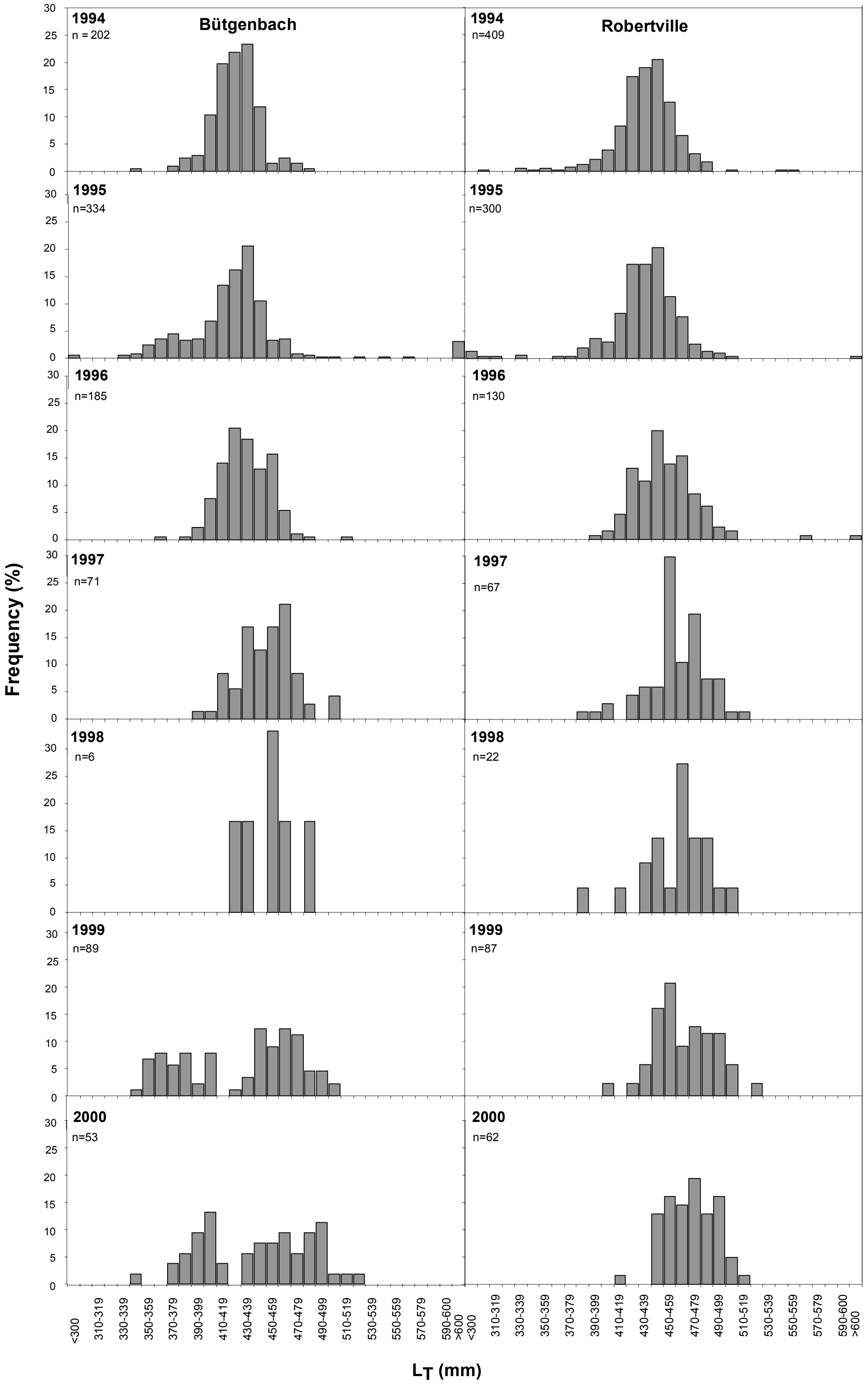

Figure 3. *Length frequency distributions of* C. peled *in Bütgenbach (left column) and Robertville (right column) reservoirs from 1994 to 2000.*

Length-weight relationships for *C. peled* have been compared for the two reservoirs (*Fig. 4*).

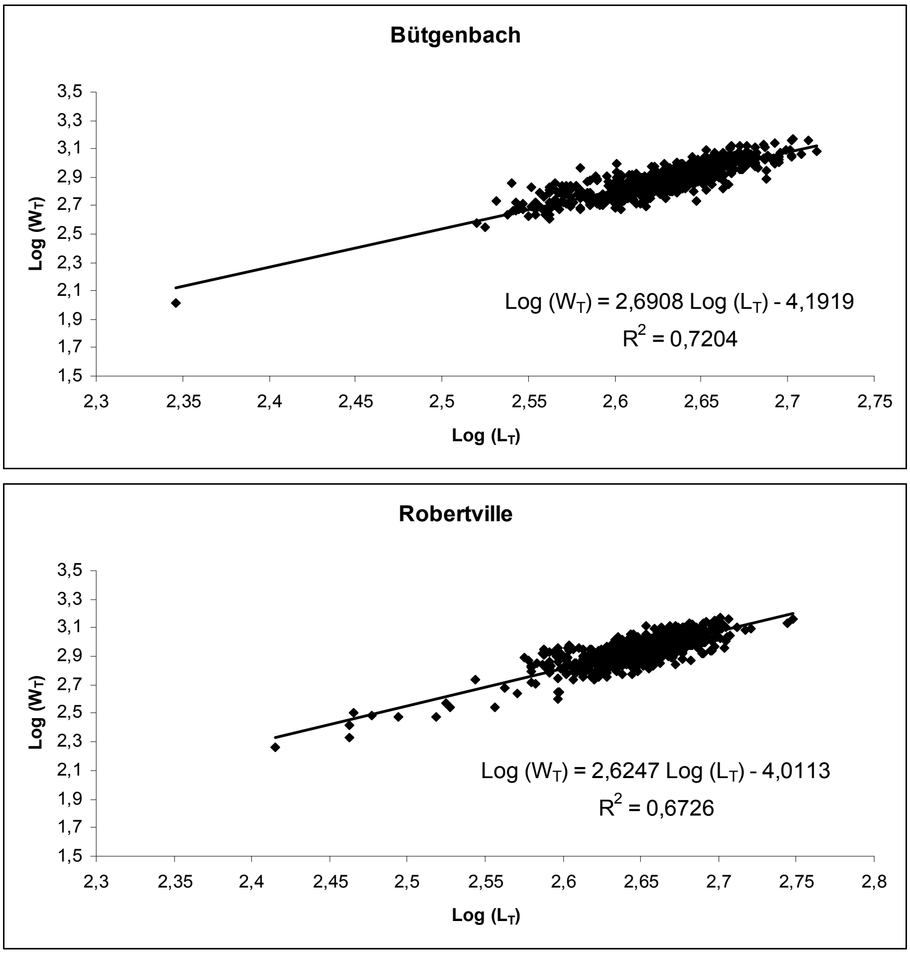

Figure 4. *Logarithmic Length- Weight relationship for* C. peled *in the Bütgenbach (A) and Robertville (B) reservoirs (L_T = total length in mm, W_T = total weight in g)*

After linear logarithmic tranformation, the following relationships (Eq.1) are obtained for Bütgenbach:

$$LogW_t = 2.69 * LogL_t - 4.19, \ r^2 = 0.72$$

and for Robertville:

$$LogW_t = 2.62 * LogL_t - 4.01, \ r^2 = 0.67.$$

The slopes of these two equations do not differ significantly (modified t-Student homogeneity of slope tests, t = 0.8, d.f. = 1805, p= 0.85). Mean allometric growth condition factors equal 0.94 for Bütgenbach and 1.09 for Robertville. Both factors do not differ significantly (Student's t test: t = -1.34, n = 1809, p= 0.18).

Von Bertalanffy's growth models (Eq.2) were estimated for the 1996 captures [26]. In Robertville the model equation for *C. peled* is

$$L_t = 569 * \left[1 - e^{-0.39*(t+0.36)}\right]$$

and for *C. lavaretus*

$$L_t = 508 * \left[1 - e^{-0.25*(t-0.20)}\right]$$

In Bütgenbach the model equation for C. peled is

$$L_t = 796 * \left[1 - e^{0.19*(t-0.30)}\right]$$

The abundance of C. lavaretus was too low in Bütgenbach to use the growth model.

Diet Analysis

Diet analyses were conducted on the fish captured in 1996 and 1997 by [7] in Robertville reservoir. *C. lavaretus* has a broad diet spectrum with 14 categories (*Fig. 5 A, B, C*). There were benthic organisms (chironomids, gammaridae and molluscs) as well as zooplankton (*Daphnia* and cyclopoid copepods) or surface insects. Gravel and plant debris were frequently found in stomachs. *Microcystis* colonies were found in all stomachs in November and March but with an abundance index below 10 %. Chironomid larvae are the dominant prey items in terms of abundance during the three periods. Cyclopoid copepods are important prey items in November, while Gammaridae are important in November and December. In December and March, pollen is well represented in term of abundance. *C. peled* eggs are found in the stomachs of *C. lavaretus* in December. *C. peled* has a narrower diet spectrum with only 6 categories (*Fig. 5 D, E, F*). Zooplankton constitutes the main prey category during the three periods. Cyclopoid copepods have an abundance index higher than 80 %. *Daphnia* are less consumed, especially in March. *Microcystis* colonies have an occurrence between 10 and 20 % in November and December and of more than 80 % in March.

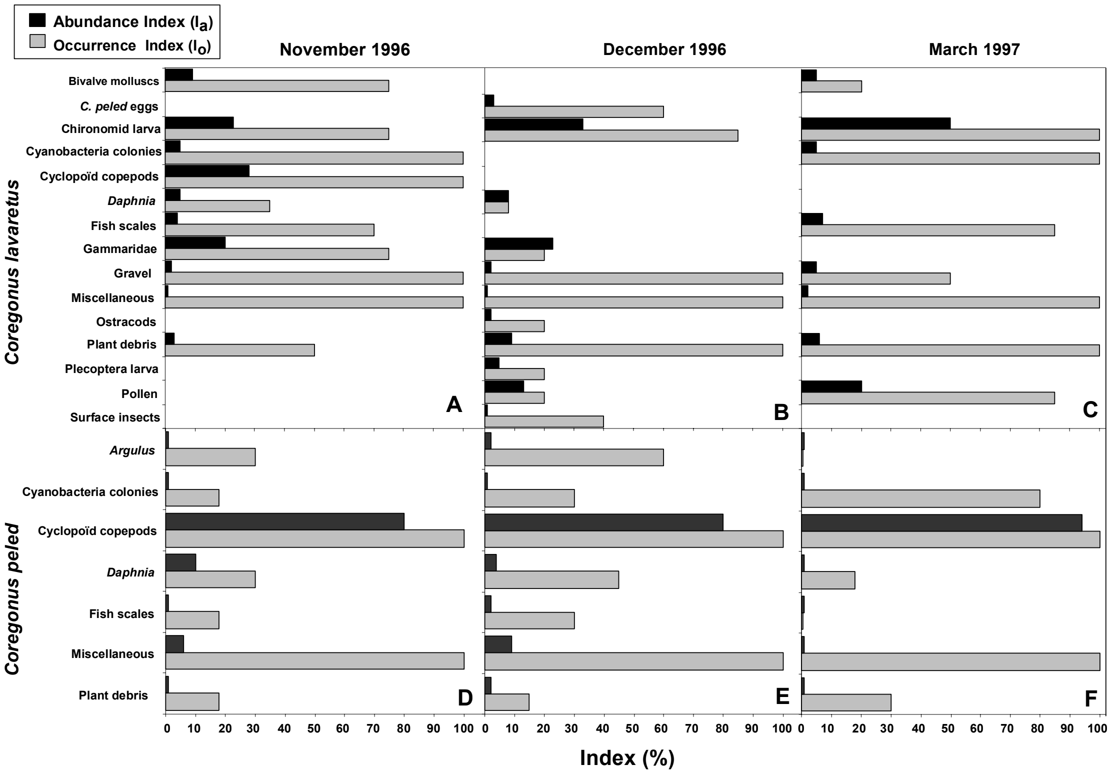

Figure 5. *Occurrence (Eq.3) and Abundance(Eq.4) Indexes (%) for* C. lavaretus *(A, B, C) and* C. peled *(D, E, F) in the Robertville Reservoir in 1996 and 1997 [7].*

The diet analyses in 1999 and 2000 [23, 40] only concern *C. peled* in both lakes, as no *C. lavaretus* has been captured during this period. In the summer of 1999 in Bütgenbach, the main food items of *C. peled* were *Bosmina*, *Daphnia*, the cyclopoid and calanoid copepods, cladoceran and copepod eggs (*Fig. 6 A*). For each of these categories the Occurrence Index was higher than 90 %. Other food categories such as nauplii*, Argulus coregoni*, Hydracarina and *Ceriodaphnia* were only occasionally present with Occurrence Indexes below 10 %. In terms of abundance, the best-represented prey item was *Bosmina coregoni* (O.F. Müller 1785) for the same period (I_a= 37%). Copepod eggs have an I_a of approximately 30 % followed by *Daphnia* and cyclopoid copepods with an I_a of more or less 15 % each. Considering only the main zooplankton preys, *Bosmina* represents more or less 58 % of the ingested biomass (*Fig. 7 A*). *Daphnia* represents approximately 22 %, and the cyclopoid copepods 10 % in terms of biomass. As shown by the selectivity indexes (*Fig. 8 A*) the preferred preys for this period in Bütgenbach are *Bosmina coregoni* and *Daphnia*. During the summer of 1999 in Robertville the main and the secondary prey items were the same as in Bütgenbach *(Fig. 6 D*), but their abundances differed. Cyclopoid copepods are dominant (I_a= 45 %), followed by copepod eggs (I_a= 35 %) and *Bosmina* (I_a = 15 %). Among zooplankton preys (*Fig. 7 B*) cyclopoid copepods are dominant in biomass (I_b> 60 %), followed by *Bosmina* (I_b = 33 %). *Bosmina* is largely selected in this lake (*Fig. 8 B*).

In the autumn of 1999 in Bütgenbach, the main food items were *Daphnia*, *Bosmina*, *Microcystis* colonies, calanoid and cyclopoid copepods, *Diaphanosoma*, cladoceran and copepod eggs, and *Volvox* (*Fig. 6 B*). Each of these categories had an Occurrence Index higher than 70 %. The other categories are only occasionally present. The zooplankton preys are the most abundant, with *Bosmina coregoni* representing more or less 65 %. *Daphnia* is predominant in biomass (I_b= 50 %), followed by *Microcystis* colonies (I_b = 18 %), *Diaphanosoma* (I_b = 12 %) and cyclopoid copepods (I_b = 8 %) (*Fig. 7 A*). The preferred prey items are respectively *Ceriodaphnia*, *Bosmina* and *Diaphanosoma* (*Fig. 8 A*).

In the autumn of 1999 the main food items in Robertville are again the same as in Bütgenbach (*Fig. 6 E*), but the secondary prey items are less diversified. *Bosmina* is the only well represented category (I_a>55 %). The other categories have an I_a below 12 % such as *Microcystis* colonies and *Diaphanosoma*. *Microcystis* colonies and *Volvox* represent the bulk of biomass, with an I_b of 83 % and respectively 12 % (*Fig. 7 B*). The preferred prey items are *Diaphanosoma* and *Bosmina* (*Fig. 8 B*).

In the spring 2000 for the Bütgenbach Reservoir the main prey categories are *Bosmina*, cyclopoid copepods and cladoceran and copepod eggs with an I_o higher than 95 % (*Fig. 6 C). Daphnia* has an occurrence of 55 %. The secondary prey items are *Keratella cochlearis*, Hydracarina and *Ceriodaphia*, *Microcystis* colonies and fish scales (I_o between 6 % and 12 %). *Bosmina coregoni* is the most abundant prey item with an I_a of 51 %, followed by cyclopoid copepods (I_a= 20 %) and copepod eggs (I_a= 15 %). *Bosmina coregoni* dominates biomass with an I_b of 70 %, followed by cyclopoid copepods (I_b=12 %) and *Daphnia* (I_b = 8 %) (*Fig. 7 A*). In early spring the preferred prey item are cyclopoid copepods, while in late spring the preferred items are *Bosmina* and calanoid copepods (*Fig. 8 A*).

In the spring of 2000 in the Robertville Reservoir, the main prey categories are the same as in Bütgenbach for the same period. *Microcystis* colonies are more frequent than in Bütgenbach with an I_o of 22 % (*Fig. 6 F*). Except for *Keratella cochlearis* and

Ceriodaphnia, the secondary categories are similar as in Bütgenbach. Copepod eggs are the most abundant (I_a = 56 %) followed by the cyclopoid copepods and *Bosmina* with an I_a of more or less 15 % each. *Bosmina* has a Biomass Index higher than 50 %, followed by cyclopoid copepods (I_b= 26 %) and *Daphnia* (I_b= 12 %) (*Fig. 7 B*). In early spring the preferred prey items are *Daphnia* and cyclopoid copepods, while in late spring the only preferred items are cyclopoid copepods (*Fig. 8 B*).

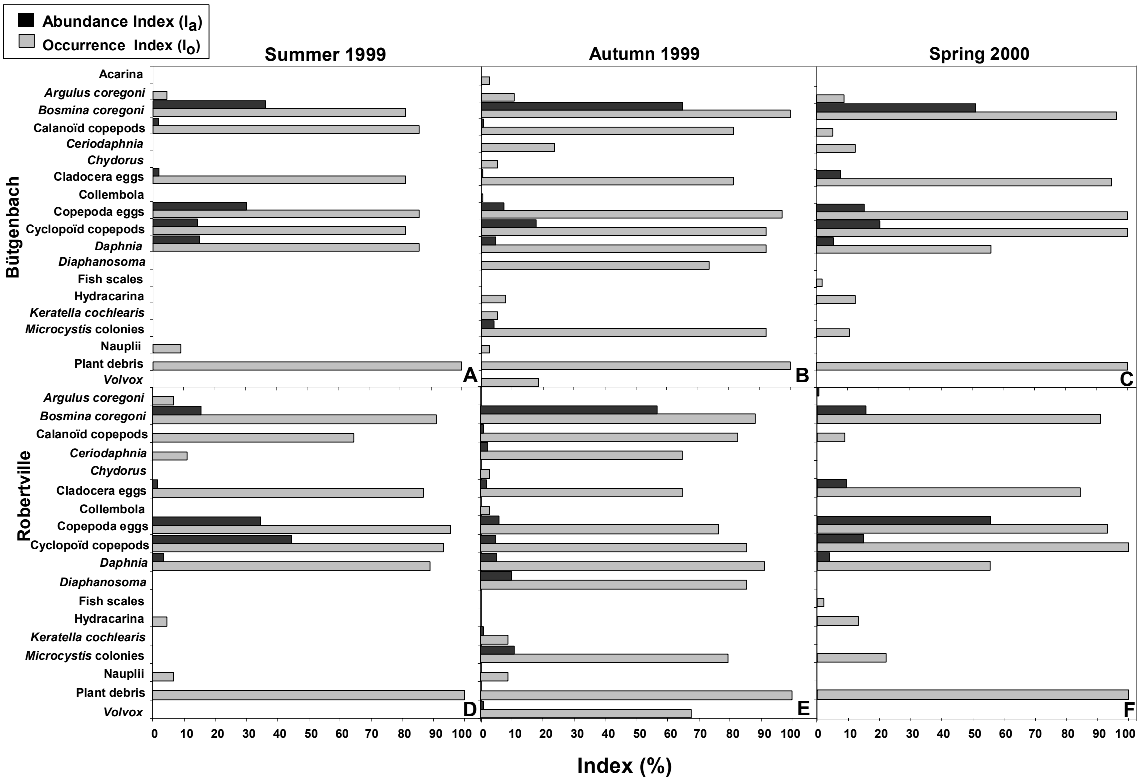

Figure 6. Occurrence(Eq.3) and Abundance (Eq.4) Indexes (%) for C. peled *in the Bütgenbach (A, B, C) and Robertville (D, E, F) Reservoirs in 1999 and 2000 [22, 39]*

Discussion

Fish habitat in lakes is strongly constrained by water temperature and available dissolved oxygen [11]. Coregonids need oligothrophic to mesotrophic waters, cool and well oxygenated. Lethal temperature for *C. lavaretus* is more or less 22°C with an optimum of less than 15°C [8]. According to [30] *C. peled* is more tolerant dealing with temperatures ranging from 0 to 28°C, but on the other hand [44] recommends water temperatures below 25°C. During our investigation periods the temperatures were relatively cool in both lakes except during the summer where surface water temperatures are likely to rise above 20°C. These values are acceptable for *C. peled* but slightly too high for an optimal development of *C. lavaretus*. Threshold values for dissolved oxygen are 4 mg/l and oxygen saturation in hatching areas must be above 70 % [8] for both species. During thermal stratification periods the hypolimnion is anoxic in both lakes as well in 1996 as in 1999/2000. Threshold values are already reached at 7 m depth in Bütgenbach and around 10 m in Robertville.

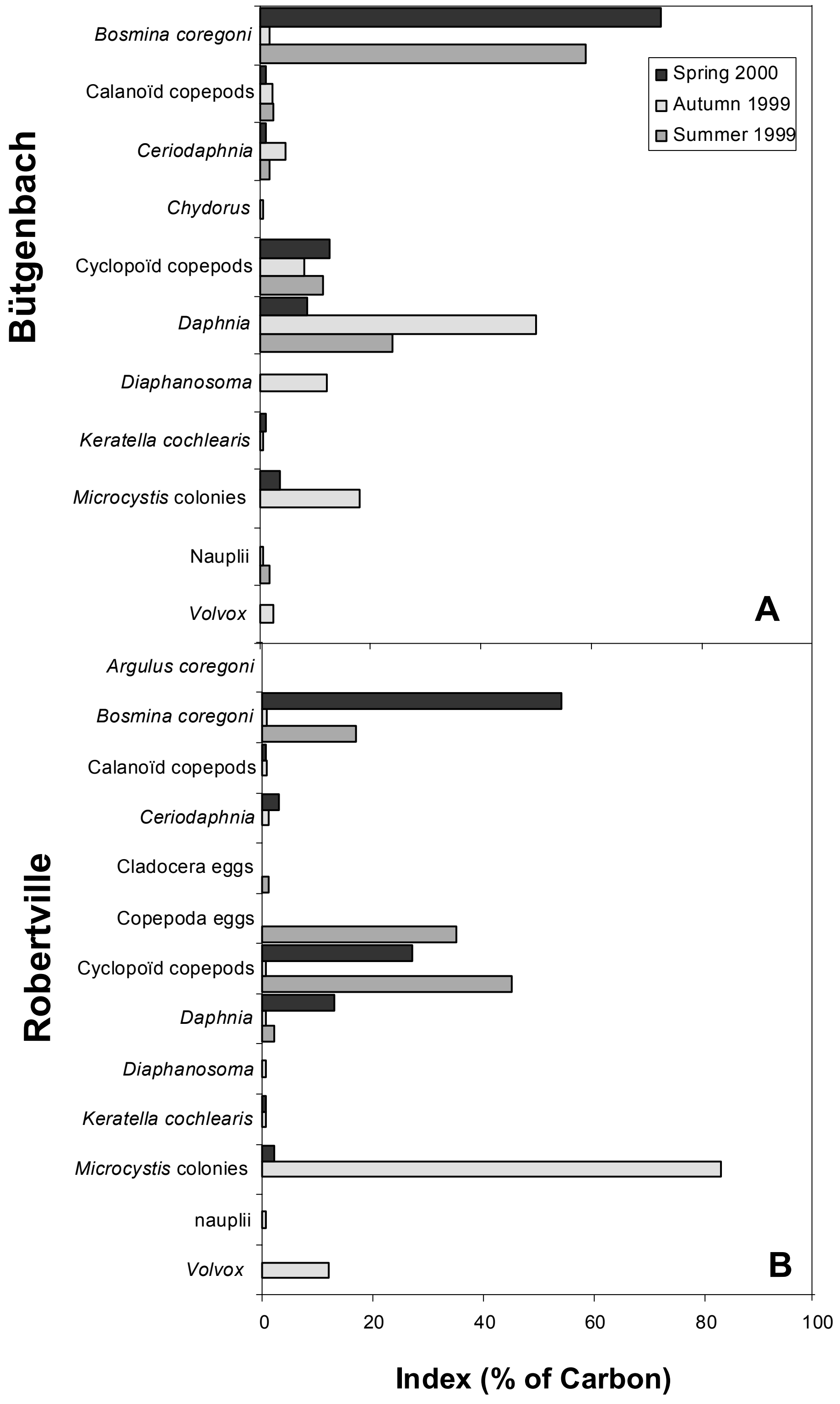

***Figure 7.** Biomass (Eq.5) Index (% of Carbon) calculated for main categories of prey items in the diet of* C. peled *in the Bütgenbach (A) and Robertville (B) Reservoirs in 1999 and 2000 [22, 39].*

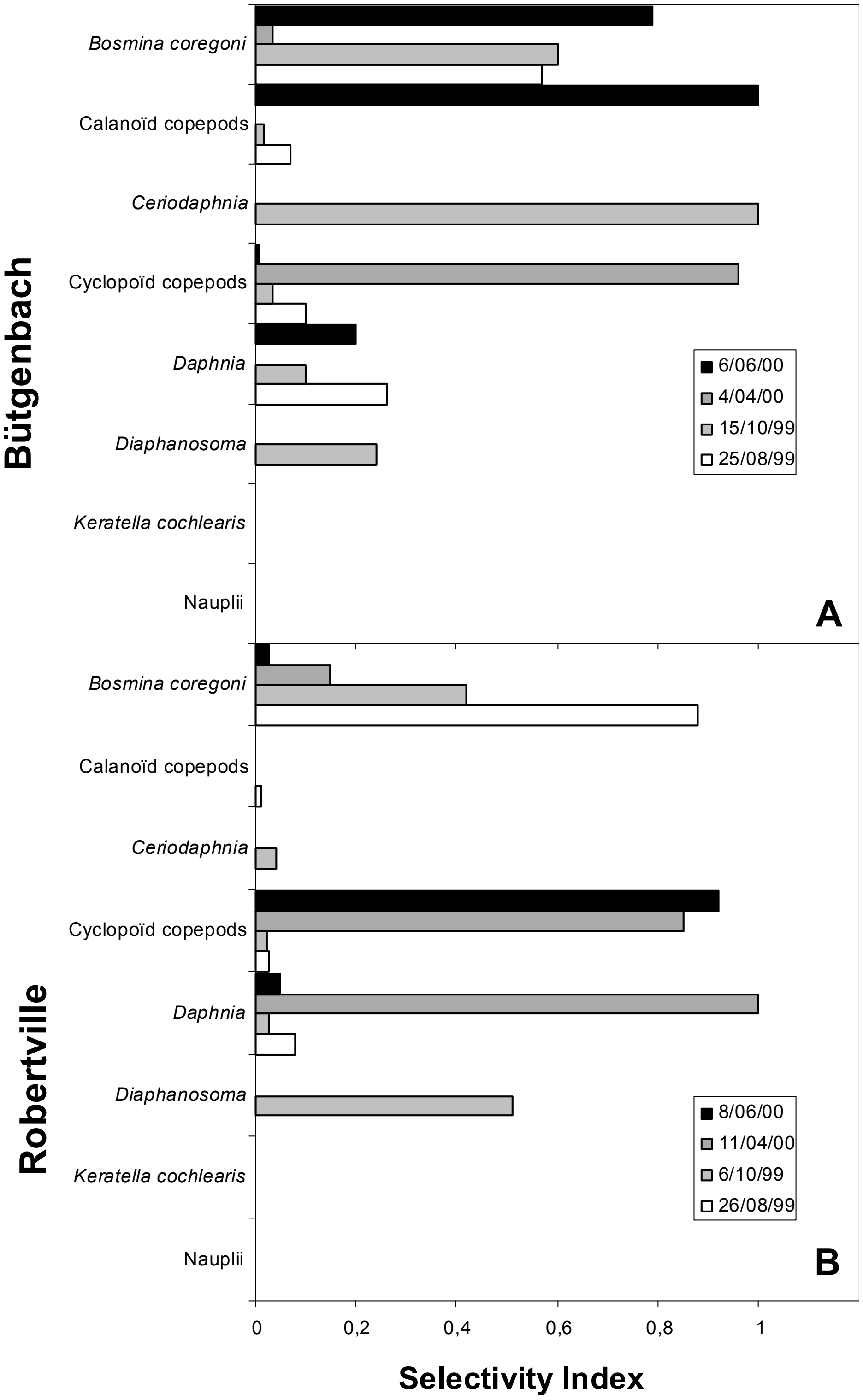

Figure 8. *Chesson's Selectivity (Eq.6) Index calculated for main categories of zooplanktonic prey items in the diet of* C. peled *in the Bütgenbach (A) and Robertville (B) Reservoirs in 1999 and 2000 [22, 39]*

In order to remain in their acceptable range for dissolved oxygen, the coregonids must stay in surface water during stratification, although water temperature is largely above their optimum in these water layers. Our results also show that the Robertville reservoir is less eutrophicated than the Bütgenbach reservoir according to their Chlorophylle *a* values.

Length frequency diagrams established for *C. peled* in both lakes show only older cohorts, which indicates that there is no natural reproduction. Indeed [47 in 13] showed for the Mazurian Lakes that eutrophication, predation and bad weather conditions are responsible for losses higher than 95 % during embryonic phase of vendace (*C. albula* L.) and *C. lavaretus*. In the most eutrophicated lakes there is no hatching and the coregonids populations have to be maintained by restocking.

Slope coefficients for *C. peled* in both lakes indicate an allometric growth (b<3), length increasing proportionally more rapidly than weight. For *C. peled* in the Robertville Reservoir L_∞ equals 56.9 cm, while in the Bütgenbach reservoir L_∞ equals 79.6 cm. These values are a bit higher than those reported in Siberian (51.8 cm), Polish (42.7 cm) and Mongolian (45.1 cm) lakes by [44], but still within the range of the maximum length cited by [30]. Infinite length of *C. lavaretus* is 50.8 cm in the Robertville Reservoir. Values reported in the literature vary between 36.8 and 94.7 cm [45, 35].

For *C. lavaretus*, the results from 1996/1997 in Robertville show a broad diet spectrum with 14 categories. This is in agreement with the findings of several authors [13, 41, 20, 3, 6]. On the other hand *C. lavaretus* was also reported as exclusively zooplanktivorous [29, 43, 44, 2]. Some authors describe a diet composed of zooplankton and adult and larval insects [36, 28, 31, 32]. According to these results adults of *C. lavaretus* can adapt their diet as exclusively zooplanktivorous, benthic or mixed in relation to the prey availability in their habitat. Consumption of fish eggs by Coregonids and especially *C. lavaretus* is frequently cited [41, 31, 18]. [37] and [31] considered cannibalism on their own eggs as a common trait of *C. lavaretus,* such as in Loch Lomond where coregonid eggs constitute the major food item in the stomach contents of the fishes captured in January.

C. peled seems to have a more narrow diet spectrum. General diet characteristics are similar in both lakes, but a seasonal variation in main prey categories could be noticed. In winter in Robertville main prey are cyclopoid copepods. In spring and summer copepods and cladocerans are more balanced. In autumn, cladocerans become dominant with *Bosmina coregoni.* We have no data for the winter period in Bütgenbach, but for the three other periods the tendencies are the same, except for the relative contribution of *Bosmina*, who is higher especially in spring and summer. *C. peled* is an omnivorous species, which can adapt largely to the food availability [44, 39]. In our case *C. peled* shows an essentially zooplankton oriented diet in both lakes with cladoceran and copepod species being the same as those frequently reported [22, 15, 24].

Cyanobacterial colonies are found in stomach contents in both species for both lakes, essentially in autumn, but their abundance does generally not exceed 10 %. The presence of cyanobacteria was reported by only a few authors [4, 44].

In conclusion, the Bütgenbach and Robertville reservoir lakes seem to meet the habitat requirements of *C. lavaretus* and *C. peled* in terms of growth capacities and diet composition. On the other hand, the conditions necessary for the natural reproduction of these two species do not seem to be totally fulfilled, probably due to the trophic status of the reservoirs and the fluctuations of the water level as consequence of reservoir operations. Meanwhile coregonid populations are sustained by restocking. *In situ* cage-rearing of *C. lavaretus* juveniles to enhance restocking procedures is presently tested in the Robertville reservoir.

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