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Seasonal variation of fish abundance and biomass in gillnet catches of an East Mediterranean lake: Lake Doirani

Dimitra C. Bobori* and Ioanna Salvarina

Laboratory of Ichthyology, School of Biology, Department of Zoology,
Aristotle University of Thessaloniki, PO Box 134, 541 24, Thessaloniki, Greece

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Abstract: *The seasonal variation of fish species composition and abundance in gillnet catches (14-90 mm knot-to-knot) from the Greek part of the transboundary Lake Doirani was studied during the period 2006-2007. A total of 8,419 specimens weighting 182.3 kg and belonging to 9 species were caught. Catch composition differed with season. Thus, Rhodeus meridionalis dominated in terms of NPUE the spring, Perca fluviatilis the summer and Alburnus macedonicus the autumn and winter catches. Cyprinids were generally the most abundant, with the cyprinids:percids biomass ratio ranging from 1.7 in summer to 14.8 in winter, supporting the eutrophic character of the lake. Richness and Shannon-Wiener diversity and evenness indices differed seasonally (ANOVA; $p < 0.05$). The abundance-biomass comparative (ABC) curves showed that fish communities were dominated by one or a few opportunistic species (e.g. Rhodeus meridionalis, Alburnus macedonicus), which while dominated in number did not dominate in biomass, being small bodied.*

Key words: *Abundance, Biomass, Freshwater fish, Gillnet catches, Lake Doirani*
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Introduction

The distribution of fish communities in lakes is known to fluctuate over space and time (Matthews, 1998). Research has so far been focused on understanding these patterns, with emphasis, among others, on the seasonal variation of fish abundance, biomass and ecological indices such as species richness and diversity (Fischer and Eckmann, 1997; Grant *et al*., 2004; Gray *et al*., 2009). Most of these studies are based on multi-mesh gillnet sampling, which is by far among the most applicable method for assessing fish community composition, species abundance and biomass in lakes (Moss *et al.,* 2003; Deceliere-Verges *et al.,* 2009). Yet, multiple gillnet catches are used widely in several European countries for assessing and monitoring fish communities (Appelberg, 2000; Mehner *et al.,* 2005; Lauridsen *et al.,* 2008) in the frame of the implementation of the Water Framework Directive (WFD) 2000/60/EC (European Commission, 2000).

Fish abundance and biomass are usually expressed as the catch-per-unit-of-fishing effort (CPUE) which can also be used for assessing the degree of exploitation of fishery resources (Degerman *et al.,* 1988; Ahmed and Hambrey, 2005). However, the reliability of CPUE for adequately expressing fish abundance and biomass is considered variable, since it strongly depends, among others, on the selectivity of gillnets as passive gears (Hamley, 1975). Thus, additional diversity indices (richness, evenness) or aggregate metrics (dominance or ABC curves), that emphasize the role of some important species in a community, are very common among ecologists for evaluating fisheries impacts (Rice, 2000).

The species composition of lake fish communities and the abundance or biomass of several species or functional groups have been used as descriptors for assessing the human pressures (Mehner *et al.,* 2005; Zambrano *et al.,* 2006) and for developing systems (Gassner *et al.,* 2003; Moss *et al.,* 2003; Freund and Petty, 2007) for the assessment of surface water ecological quality according to the WFD. Although the above have so far been studied in a number of European countries (Olin *et al.,* 2002; Mehner *et al.,* 2005; Diekmann *et al.,* 2005; Kubeeka *et al.,* 2009), similar data are not available for Greek lakes except Crivelli *et al.* (1997), although there is a vast demand for quantitative data concerning lake fish communities, towards the implementation of the WFD 2000/60/EC.

The objective of the present study was to address the lack of knowledge of gillnet quantitative data on fish communities in lake Doirani. Furthermore, we tested for seasonal changes in gillnet catch species composition and abundance and assessed the degree of disturbance of fish communities.

Materials and Methods

Study area: Lake Doirani (Fig. 1) is a transboundary lake, shared by the Former Yugoslavic Republic of Macedonia (FYROM) and Greece (East Mediterranean Sea). It is a tectonic, eutrophic (Temponeras *et al.,* 2000) lake (altitude: 148 m above sea level, drainage area: 276.3 km^2, surface area: 28 km^2, maximum depth: 5 m).

* **Corresponding author:** bobori@bio.auth.gr

The lake suffers from intensive water abstraction resulting in the reduction of its water volume, which in combination with the deterioration of its water quality (Pertsemli and Voutsa, 2007) has caused the reduction of its fisheries' production. Moreover, cyanobacterial water blooms during the hot period have been reported, contributing to further degradation of its water quality (Cook *et al.,* 2004).

Sampling: Fishes were sampled seasonally (two constantly days per season), from April 2006 to February 2007, by multi-mesh, monofilament gillnets, with different mesh sizes (14, 18, 22, 26, 30, 40, 45, 50, 65, 70, 75, 80 and 90 mm, knot-to-knot). Gillnets of 14-30 mm were experimental nets (2 m height, 100 m length) and were set close to the shore (Station1, depth < 3m). Nets of 40-90 mm mesh-sizes were of those used by local fishermen (2.2-4 m height, 100 m length) and were set in the deeper part of the lake (station 2, depth up to 5 m). Nets were set in late afternoon (18:00-20:00) and retrieved the following morning (6:00-8:00) in order to ensure a constant fishing effort. All fish caught were identified according to Kottelat and Freyhof (2007) and measured for total length (TL, cm±0.1) and total weight (W, g±0.1).

Statistical analysis: Catches were analyzed separately for each season, and the total number and weight of specimens per species were recorded. For each species CPUE was calculated as the number (NPUE) and the weight (BPUE) of the individuals of each species caught 100 m^{-2} gillnet area per night. The Shannon-Wiener diversity index H'; species richness, expressed by Margalef's D index; evenness, measured by Pielou's J index (Maguran, 1988); and the number of species caught per season were calculated and compared by one-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) procedure. The cyprinids:percids biomass ratio (Cyp/Per) was also calculated based on the BPUE values of all cyprinids and percids respectively. This index has so far been used to display the response of fish communities along an increased trophic gradient (Olin *et al.,* 2002), with cyprinids dominating the catches in mesotrophic to highly eutrophic lakes and percids dominating the fish biomass only in small oligo-mesotrophic and large meso-eurtophic lakes of higher complexity. Additionally, the abundance-biomass comparison (ABC) method (Warwick, 1986) was applied, which plots the K-dominance cumulative curves (cumulative ranked abundances plotted against species rank; Lambshead *et al.,* 1983) for species abundances and biomasses on the same graph, so disturbed communities might be evaluated (Clarke and Warwick, 2001). ABC curves were conducted for each sampling season separately based on species NPUE and BPUE values after log (x+1) transformation for reducing the influence of rare or abundant species. For each curve the W-value was calculated. W ranges from -1 to +1 and when the biomass curve lies above the abundance curve it receives positive values, indicating undisturbed communities, dominated by K-selected species. In contrast, negative W values (when the abundance curve lies above the biomass curve), implies disturbed communities, dominated by

Table - 1: Fish species caught in Lake Doirani during the sampling period (2006-2007), number (NPUE) and weight (BPUE) of the individuals caught 100 m^{-2} of net per night and their percentages (%) per season and overall

Season	Spring		Summer		Autumn		Winter		Total	
Species	NPUE	%	NPUE	%	NPUE	%	NPUE	%	NPUE	%
Alburnus macedonicus	1.45	10.05	5.21	37.36	20.62	65.12	1.90	81.81	29.18	46.78
Carassius gibelio	0.57	3.95	0.44	3.14	0.42	1.31	0.10	4.15	1.52	2.44
Cyprinus carpio	0.04	0.26	0.03	0.21	0.03	0.09	0.00	0.00	0.10	0.15
Pachychilon macedonicum	2.48	17.18	0.40	2.87	0.35	1.10	0.00	0.00	3.23	5.18
Perca fluviatilis	1.02	7.02	7.21	51.66	7.44	23.49	0.21	8.95	15.87	25.43
Rhodeus meridionalis	7.97	55.12	0.13	0.96	1.25	3.93	0.06	2.56	9.41	15.08
Rutilus rutilus	0.76	5.23	0.53	3.77	1.56	4.94	0.06	2.56	2.91	4.66
Scardinius erythrophthalmus	0.11	0.77	0.00	0.01	0.00	0.00	0.00	0.00	0.11	0.18
Squalius vardarensis	0.06	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.10
Total	14.40	23.16	13.95	22.38	31.66	50.74	2.32	3.72	62.32	
	BPUE	%	BPUE	%	BPUE	%	BPUE	%	BPUE	%
Alburnus macedonicus	22.92	8.00	92.01	28.24	350.10	51.45	30.30	50.22	495.34	36.61
Carassius gibelio	53.83	18.79	42.58	13.07	43.68	6.42	23.22	38.49	163.31	12.07
Cyprinus carpio	28.12	9.81	32.71	10.04	23.04	3.39	0.00	0.00	83.87	6.20
Pachychilon macedonicum	70.92	24.75	14.52	4.46	11.06	1.62	0.00	0.00	96.50	7.13
Perca fluviatilis	20.24	7.06	121.49	37.29	187.74	27.59	3.82	6.34	333.30	24.63
Rhodeus meridionalis	54.55	19.04	0.85	0.26	8.99	1.32	0.49	0.80	64.88	4.79
Rutilus rutilus	23.52	8.21	20.80	6.38	54.84	8.06	2.50	4.14	101.65	7.51
Scardinius erythrophthalmus	5.24	1.83	0.81	0.25	0.98	0.14	0.00	0.00	7.03	0.52
Squalius vardarensis	7.18	2.50	0.00	0.00	0.00	0.00	0.00	0.00	7.18	0.53
Total	279.36	21.18	325.77	24.08	680.41	50.29	60.33	4.46	1345.87	

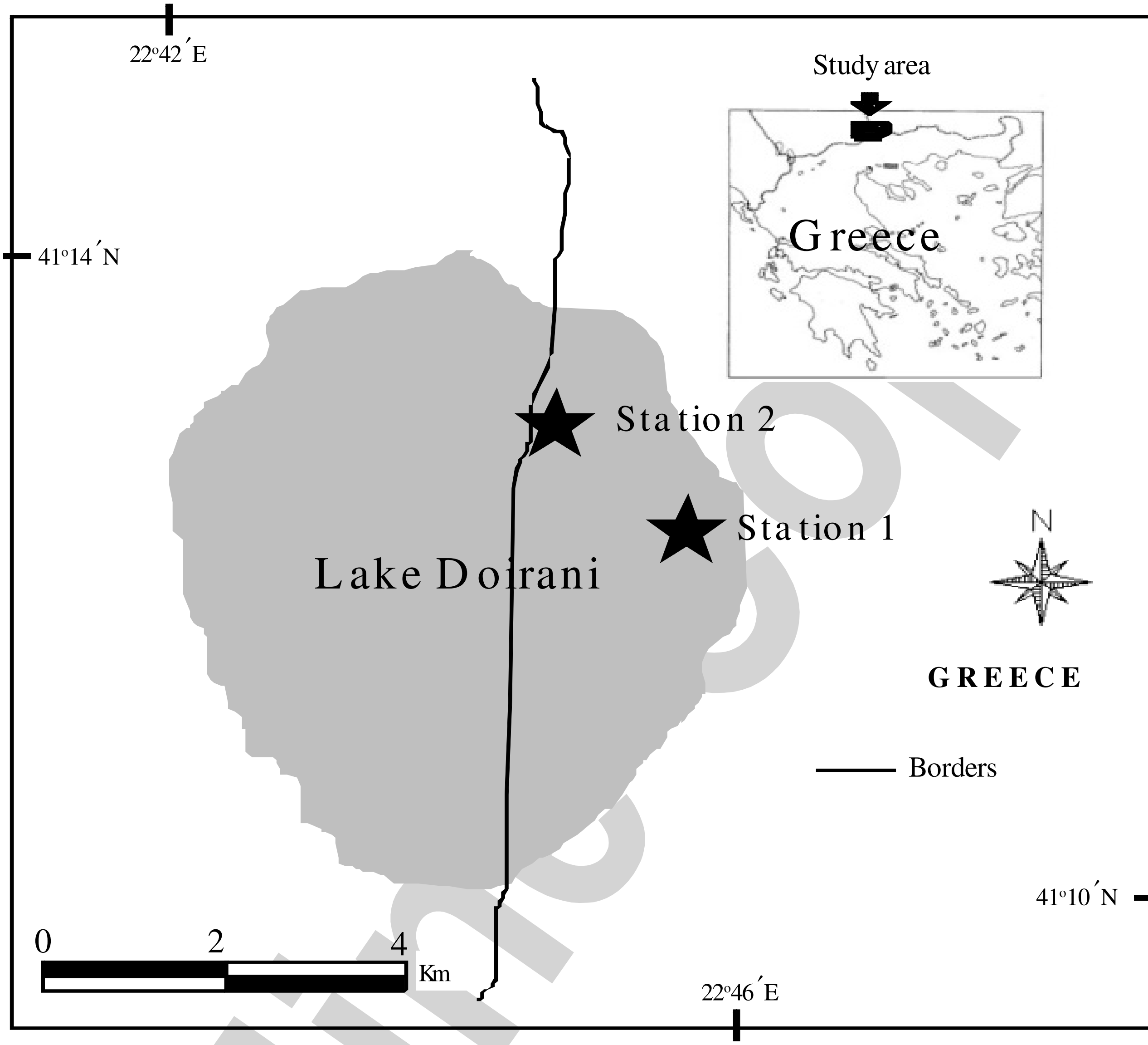

Fig. 1: The studied area of Lake Doirani with the sampling stations

r-selected species. Communities might be characterized as moderately stressed when the abundance and biomass curves are very close or intersect, represented by W values close to 0. All the above analyses were performed using Statgraphics plus 3.0 and PRIMER 6.0 (Clarke and Gorley, 2001).

Results and Discussion

Species composition and abundance: A total of 8,419 specimens, weighting 182.3 kg and belonging to 9 species (Table 1) and 2 families (Cyprinidae and Percidae) were caught. Eight out of the nine species recorded belonged to Cyprinidae, while Percidae family was represented by only one species, *Perca fluviatilis*. Three species (*Alburnus macedonicus, Pachychilon macedonicum* and *Squalius vardarensis*) are considered as endemic to Greece and the Balkan Peninsula, while one species (*Carassius gibelio*) is introduced. The most abundant species in the total annual catch, both in terms of number (NPUE) and weight (BPUE) was *Alburnus macedonicus* followed by *Perca fluviatilis* (Table 1). In general, total annual NPUE values varied widely, ranging between 0.1 individuals 100 m^{-2} per night for *Cyprinus carpio* to 29.18 individuals 100 m^{-2} per night for *Alburnus macedonicus* (Table 1). The later exhibited also the highest annual BPUE value (495.34 g 100 m^{-2} per night), while *Scardinius erythrophthalmus* the lowest one (7.03 g 100 m^{-2} per night).

Catch composition differed with season. More specifically, *Rhodeus meridionalis* made up in terms of NPUE the 55.12% of the spring catch though the same season *Pachychilon macedonicum* was the dominant species in terms of BPUE (24.75%). *Perca fluviatilis* dominated the summer catch (51.66 and 37.29% in terms

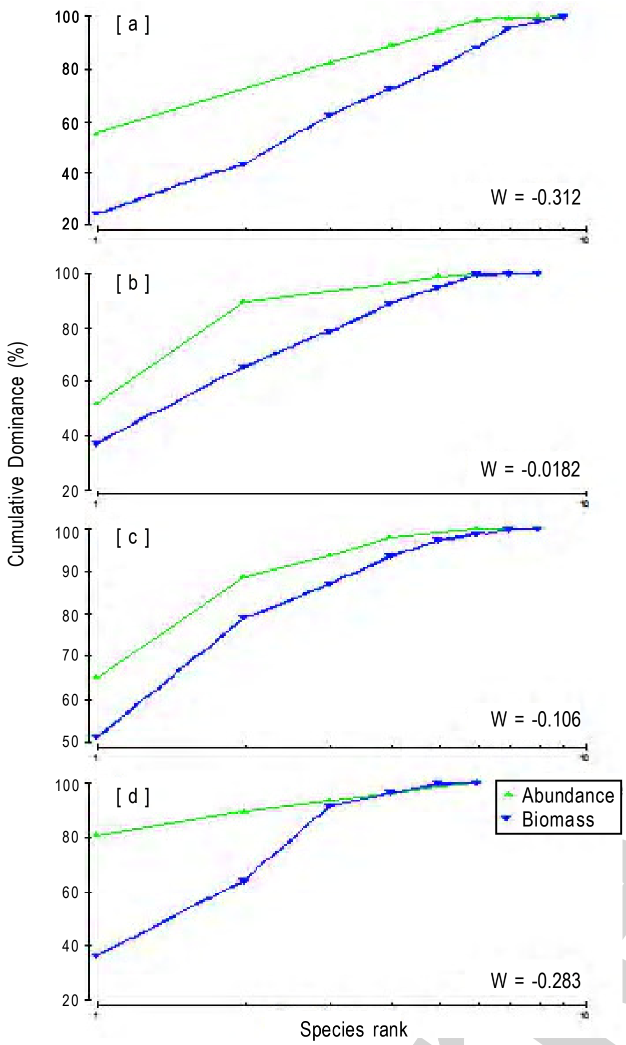

Fig. 2: K-dominance curves for species biomass (BPUE, g 100 m^{-2} of net per night) and abundance (NPUE, individuals 100 m^{-2} of net per night) by season (a: spring, b: summer, c: autumn, d: winter)

of NPUE and BPUE respectively) while *Alburnus macedonicus* contributed more than 50% in autumn and winter catches (Table 1). Almost 51% of NPUE and BPUE of the total annual catch was caught in autumn whilst, winter catches contributed the least (Table 1). The number of species and individuals caught did not differ significantly among seasons (ANOVA; F = 2.36, p>0.05 and F = 0.61, p>0.05 respectively), although Fisher's LSD test revealed significant differences between the number of the species caught in spring and winter (p<0.05). However, *D, H'* and *J* indices differed seasonally (ANOVA; for all cases F=3.07, p<0.05), with all indices exhibit their lowest values during winter. Moreover, BPUE values exhibited significant seasonal differences (ANOVA, F = 3.544, p<0.05), with the lowest value being recorded in winter (Fischer's LSD test, p<0.05). Contrary, NPUE values did not differ among seasons (ANOVA, F = 1.29, p>0.05).

Several abiotic (water temperature, water fluctuation, dissolved oxygen, transparency) and biotic (predation, food availability, maturation state) parameters (Craig *et al.,* 1986; Fischer and Eckmann, 1997; Matthews, 1998; Linløkken and Haugen, 2006) as well as operational (mesh sizes, net length, set time) factors (Jensen, 1986; Minns and Hurley, 1988) are well known to drive this temporal variability suggesting that certain species become more or less catchable by gillnets in the course of the year (Grant *et al.,* 2004; Olin *et al.,* 2009). For example, the search and capture rates of *Perca fluviatilis* increases with the increase of temperature (Persson, 1986). This could explain the observed increase of NPUE and BPUE from spring to autumn. The same seems to be true also for *Alburnus macedonicus.* Moreover, some other abiotic factors like water transparency, which makes the gillnets more easily detectable by fish and thus affecting their catchability (Neumann and Willis, 1995), could account for the low NPUE and BPUE values observed during winter. Furthermore, seasonal trends in NPUE and BPUE may be due to differences in fish distribution, activity and habitat use related also to fish size and sex (Phiri and Shirakihara, 1999; Grant *et al.,* 2004).

The Cyp: Per biomass ratio calculated during this study ranged from 1.7 in summer to 14.8 in winter, while the overall Cyp: Per ratio (*i.e.* based on the total annual catches) was 3.1, supporting the eutrophic character of the lake (Temponeras *et al.,* 2000), even though some other factors such as species richness and lake size may also affect this ratio (Olin *et al.,* 2002).

Abundance-biomass comparison (ABC) curves: The ABC curves are given in Fig. 2. For all seasons the abundance curves lay above the biomass dominance curves along their entire length indicating that fish communities were dominated by one or a few opportunistic species (*e.g. Rhodeus meridionalis, Alburnus macedonicus*) which whilst they dominated in numbers, did not dominate in biomass, since they are small bodied. *W* took negative values in all seasons, corresponding to disturbed or moderately disturbed conditions (Clarke and Gorley, 2001).

In conclusion, Doirani is one of about 20 transboundary European lakes (Noges *et al.,* 2008), several of which, including the studied lake, are important as recourse for recreation and fisheries *e.g.* lake Constance: (Fischer and Eckmann, 1997); lake Peipsi (Kosk, 2001). For this lake category, integrated transboundary lake catchment management is widely accepted and supported in aquatic and landscape ecology (Boon, 2005), requiring adequate information for the implementation of management measures. Thus, the quantitative data collected during this research could be useful: (a) as a "reference point" for comparing fish community structure and species abundance, (b) to formulate actions and measures for species protection and (c) to enforce the sustainable transboundary fisheries management of the lake. However, since gillnet CPUE is not always linearly related to fish density (Linløkken and Haugen, 2006), such estimations based on gillnetting should only cautiously and roughly been used for describing fish abundances (Olin *et al*., 2009), supplemented (if available) with time series data of CPUE (Stergiou *et al.,* 1997). Nonetheless, gillnet catches under certain conditions could serve for estimating and monitoring changes in fish abundance (Olin *et al*., 2009) as they are also proposed by the Water Framework Directive 2000/60/EC.

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