Turk. J. Fish.& Aquat. Sci. 19(12), 1039-1048
http://doi.org/10.4194/1303-2712-v19_12_06

Turkish Journal of
FISHERIES and
AQUATIC SCIENCES

RESEARCH PAPER

Fish Community Structure in the Mediterranean Temperate Lake Volvi at Two Different Stages of Pumpkinseed Invasion: are Natives in Threat?

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Article History
Received 04 January 2018
Accepted 09 December 2018
First Online 10 December 2018

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Keywords
Introduced
Abundance
k-dominance curves
Invasiveness hazards
Lepomis gibbosus

Abstract

Lepomis gibbosus (L., 1758) (pumpkinseed) has been introduced in Greece accidentally and since then it has expanded its range and adapted successfully to several surface water bodies. Here, we provide baseline data on the status of fish community structure in the Mediterranean temperate Lake Volvi (Northern Greece) at the begging and three years after pumpkinseed's invasion. Additionally, we present some aspects on pumpkinseed's population characteristics to test the hypotheses of its invasion success and the potential impacts imposed to native fish populations. Fish sampling was conducted by benthic and pelagic, Nordic type, gillnets. A breeding population had become established in the lake within the three-years period studied. At the same time a decline in the abundance of some native fish species was observed. Pumpkinseed preferred the shallower habitats and exhibited trait similarity with the most native species, imposing thus a potential competed threat for local populations, especially for endemics that allocate the same habitats and compete for the same food resources with it. The efforts that should be implemented for the depreciation of species population and assessment of the general impacts of pumpkinseed invasion on natives are discussed.

Introduction

The invasiveness of alien species to aquatic ecosystems and the generated ecological impacts that propagated along the food chain have so far been documented in the literature (for a synopsis see Gallardo, Clavero, Sanchez, & Vila, 2016) at the individual, population, community and ecosystem level (Simon & Townsend, 2003). Invasive species may alter, among others, community structure (Meador, Brown, & Short, 2003), change the abundance of certain species with specific traits (Charles & Dukes, 2007), have negative effects on habitats (Essl *et al*., 2011; Bajer *et al*., 2016) and drive biodiversity loss (Katsanevakis *et al*., 2014; Gallardo *et al*., 2016). They consist an important pressure for several types of ecosystems, affect food-web properties and ecosystem services (Charles & Dukes, 2007; Katsanevakis *et al*., 2014), impact human health and cause economic loss. However, there are still gaps in our knowledge about the quantification and prioritization of these impacts and the recommended actions scientists and stakeholders should take for facilitating the risk assessment and management of alien species (Kumschick *et al*., 2014).

Lepomis gibbosus (Linnaeus, 1758) (pumpkinseed) is considered as one of the most successful fish invaders in the inland waters of Europe (Fox, Vila–Gispert, & Copp, 2007). The species, native to east-central North America (Tomeček, Kováč, & Katina, 2007), was introduced to Europe as an ornamental aquarium and pond fish in the late 1900's (Copp *et al*., 2005; Tomeček *et al*., 2007) and since then, it has been widely

Published by Central Fisheries Research Institute (SUMAE) Trabzon, Turkey in cooperation with Japan International Cooperation Agency (JICA), Japan

distributed to several aquatic ecosystems (Copp *et al*., 2005; Copp & Fox, 2007). Species successful invasiveness has so far been attributed to its remarkably great plasticity concerning its life history traits and phenotypes (Copp & Fox, 2007; Fox *et al*., 2007; Toměcek *et al*., 2007; Zięba, Fox, & Copp, 2010).

L. gibbosus prefers to live in lakes and slow-moving streams but it tolerates a wide range of environmental conditions (Jordan, Backe, Wright, & Tovey 2009). It is an omnivorous species and tends to feed on the most abundant prey types (García- Berthou & Moreno-Amich, 2000a, Rezsu & Specziár, 2006). Sexual maturity occurs at the age of two to three years old and the maximum known age is twelve years (Cucherousset *et al*., 2009, Jordan *et al*., 2009). It is a nest-guardian species (Jordan *et al*., 2009). The maximum reported total length is 40.0 cm and the maximum reported weight 630 g (Froese & Pauly 2018). The introduction of *L. gibbosus* in Greece is attributed to coincidence, since fry and fingerlings were accidentally transported from Bulgaria (Economidis, Dimitriou, Pagoni, Michaloudi, & Natsis, 2000). Then, the species expanded its range and adapted successfully to several surface Greek aquatic ecosystems (Economidis *et al*., 2000; Economou *et al*., 2007), with still unknown potential impacts (Perdikaris *et al*., 2016) due mainly to the absence of relative ichthyological surveys. However, several studies have already documented the impacts of species invasion in European freshwaters (Copp, Fox, Przybylski, & Godinho, 2004). Recently *L. gibbosus* was ranked among the most highly risk invasive species in Greece, based on the risk identification tool, FISK (Fish Invasiveness Screening Kit; Perdikaris *et al*., 2016). However, the absence of quantitative data on the abundance and community structure of native fish prior and after pumpkinseed invasion in an ecosystem and on the relevance of species' trait preferences with natives as well as information on the rate of its range expansion, constitutes obstacles that do not allow firm estimates of invader impacts upon native populations (Nikolova *et al*., 2008) and habitats.

Several researchers have proposed different types of ecological metrics for assessing invasion impacts on native populations and ecosystems (Schmitz, Simberloff, Hofstetter, Haller, & Sutton, 1997; Parker *et al*., 1999). On a geographical scale, quantification of the distribution and abundance of an invader in introduced ranges is crucial for determining the impacts on native populations and ecosystems (Parker *et al*., 1999; Hierro, Maron, & Callaway, 2005). Here, we provide baseline data on the native fish community structure in the Mediterranean temperate Lake Volvi (Northern Greece), at two different stages of pumpkinseed's invasion. Specifically, we compared experimental catches from two different periods, in 2009, when the species was recorded for the first time as an invader in the lake and three years later, in 2012. Moreover, we present some aspects on its population characteristics to test the hypothesis of its invasion success and discuss the potential risks posed by the species invasion to local fish populations by comparing trait overlap with native species. These data will (a) add to the better understanding of species population dynamics, (b) quantify on a regional-scale the potential impacts of pumpkinseed invasion on local fish populations and (c) contribute in the development and implementation of future monitoring and management plans, focusing on the depreciation of *L. gibbosus* populations and the mitigation of invasion hazards posed by the species.

Materials and Methods

Study Area

Lake Volvi (surface area 68 km^2, maximum depth 21 m) is situated in Northern Greece (Figure 1), forms

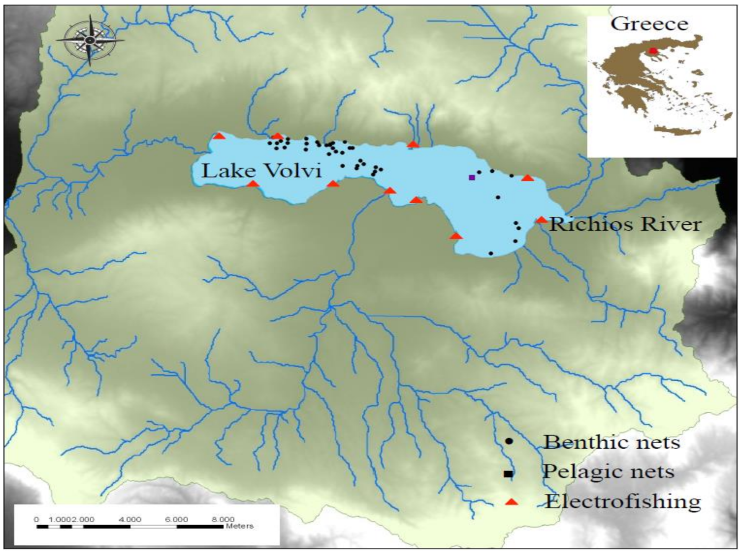

Figure 1. Sampling sites in Lake Volvi.

part of the National Park of the wetlands of Lakes Koronia-Volvi and Macedonian Temp and covered by the Ramsar Convention. The area is also protected under the Habitats Directive (92/43/EC; European Commission, 1992) and constitutes an Important Area for birds (94/24/EC; European Commission, 1994).

Sampling and Fish Processing

In the framework of the implementation of the directives 2000/60/EC (European Commission, 2000) and 92/43/EC (European Commission, 1992), two experimental fishing campaigns (November 2009 and September 2012) took place in Lake Volvi, using benthic and pelagic (Nordic type) gillnets. Sampling effort was estimated according to CEN (2005). Nets were set in the afternoon and lifted the next morning, ensuring a stable soak time of about 12 h. All specimens caught were identified to species level (Kottelat & Freyhof, 2007) and measured for total length (TL, cm) and weighed (W, g ± 0.1).

Data Analyses

Relative abundance was estimated as percentage of the total catches in terms of numbers and biomass. Catch per unit of effort (CPUE) was used to measure species abundance and expressed as the number of specimens of each species caught per 100 m^2 of gillnets (NPUE) and as the biomass (in g) per 100 m^2 of gillnets (BPUE) in total. Alterations in CPUE between 2009 and 2012 were assessed after converting in a ratio (Kornis, Sharma, & Vander Zanden, 2013): $+\frac{2012\ \mathrm{CPUE}}{2009\ \mathrm{CPUE}}$ in case of increased values or either by the negative form $-\frac{2009\ \mathrm{CPUE}}{2012\ \mathrm{CPUE}}$, indicating a decrease in CPUE. When a species was absent from the catches in one sampling period (i.e. 2009 or 2012), the ratio was not calculated. Differences in community structure between the two sampling periods (2009, 2012) were assessed by (a) calculating the Shannon's diversity index $H' = - S_i p_i(\log_e p_i)$ (Shannon & Weaver 1949), (b) estimating the Pielou's evenness index: $J' = H'/ \log S$, where H' is the Shannon diversity index and S is the total number of species, and (c) constructing the *k*-dominance curves (Lambshead, Platt, & Shaw, 1983) by plotting species cumulative relative abundance (or biomass) against log species rank (Clarke, 1990). Finally, in order to assess the potential risk of competitive success of *L. gibbosus* over the fish species present in the lake, we gathered the trait preferences (Blanck & Lamouroux, 2007; Kottelat & Freyhof, 2007; Froese & Pauly, 2018) of all species reported to be present in the system of Lake Volvi (including the inflowing streams that used as nesting and reproductive areas of several species). Thus, each of the 27 species (22 natives and 5 introduced) was attributed 15 different traits representing reproductive (7 traits), feeding preferences (6 traits) and habitat (2 traits) requirements. Consequently, a binary similarity matrix was built to determine how similar was *L. gibbosus* to native fish species in terms of all traits selected (Docherty, Ruppert, Rudolfsen, Hamann, & Poesch, 2017). High overlap was indicated with values close to 1 while values close to 0 were indicative of low overlap across traits. All statistical analyses were performed with SPSS and Primer v6 (Clarke & Gorley, 2005) software.

Results

Population Establishment and Abundance

Experimental catches in both sampling periods (Table 1) indicated that, after three years of the first record of *L. gibbosus* in Lake Volvi, the species increased its population. Both juveniles and adults caught gave evidence that a breeding population had become established in the lake, with fish size ranging from 44 to 160 mm TL (Figure 2a), mostly caught with 24 and 29 mm mesh size nets (Figure 2b). Pumpkinseed increased its numerical abundance and biomass by almost 45 and over 400 folds respectively, based on the total gillnet catches (Table 1). Several native fish species also increased their CPUE values from 2009 to 2012, i.e. *Perca fluviatilis* L., 1758, *Vimba melanops* (Heckel, 1837), *Abramis brama* (Linnaeus, 1758), while others, i.e. *Alburnus* sp*., Rhodeus amarus* (Bloch, 1782), *Alosa macedonica* (Vinciguerra, 1921), demonstrated the opposite trend. However, fish communities seemed to exhibit almost the same characteristics in both periods (H'_{2009}=1.534, H'_{2012}=1.493 and J'_{2009}= 0.6397, J'_{2012}= 0.6227). Even the number of species caught was the same (11 species including one hybrid and two introduced species, Table 1), differences were observed in the species recorded, since *Scardinius erythrophthalmus* (Linnaeus, 1758) and the Hybrid were present only in 2009 catches while *Cyprinus carpio* (Linnaeus, 1758) and *Esox lucius* Linnaeus, 1758 only in 2012. Moreover, disparities in species dominance were also observed (Table 1), as *Rhodeus amarus* (Bloch, 1782) was numerically the most abundant species in 2009 while *Rutilus rutilus* (Linnaeus, 1758) dominated the catches in 2012. The k-dominance curves calculated from species abundances and biomass extracted from 2009 and 2012 catches (Figure 3) exhibited little overlap in species composition and cross. Moreover, they reached their maximum values quickly as indicated from the plots based on species abundance (Figure 3a) and biomass (Figure 3b). Generally, cyprinids dominated the catches in both sampling campaigns, while the rest of the families were represented by only one species (Table 1).

Table 1. Numerical abundance (NPUE: number of specimens per 100 m^2 of gillnets) and biomass (BPUE: g per 100 m^2 of gillnets) and relative numerical (% abun) and biomass (% biom) contribution of each species caught with benthic and pelagic gillnets in Lake Volvi, during 2009 and 2012 surveys. *=Introduced species

Family/species	2009				2012			
	NPUE	BPUE	%abun	%biom	NPUE	BPUE	%abun	%biom
Centrarchidae								
*Lepomis gibbosus**	0.09	0.34	0.08	0.02	4.01	148.12	3.16	5.03
Clupeidae								
Alosa macedonica	8.06	133.70	7.34	9.96	7.10	125.20	5.60	4.25
Cyprinidae								
Abramis brama	0.35	3.17	0.32	0.24	0.61	31.73	0.48	1.08
Alburnus sp.	17.86	137.36	16.26	10.23	9.89	67.24	7.80	2.28
*Carassius gibelio**	0.26	24.88	0.24	1.85	0.57	28.72	0.45	0.98
Cyprinus carpio					0.09	25.76	0.07	0.87
Rhodeus amarus	35.51	76.44	32.33	5.69	20.22	50.37	15.95	1.71
Rutilus rutilus	32.85	656.57	29.91	48.92	62.18	1596.03	49.04	54.19
S. erythrophthalmus	0.13	7.69	0.12	0.57				
Vimba melanops	0.04	3.78	0.04	0.28	0.44	12.74	0.34	0.43
Hybrid	0.04	0.45	0.04	0.03				
Esocidae								
Esox lucius					0.09	36.51	0.07	1.24
Percidae								
Perca fluviatilis	14.64	297.88	13.33	22.19	21.61	822.59	17.04	27.93

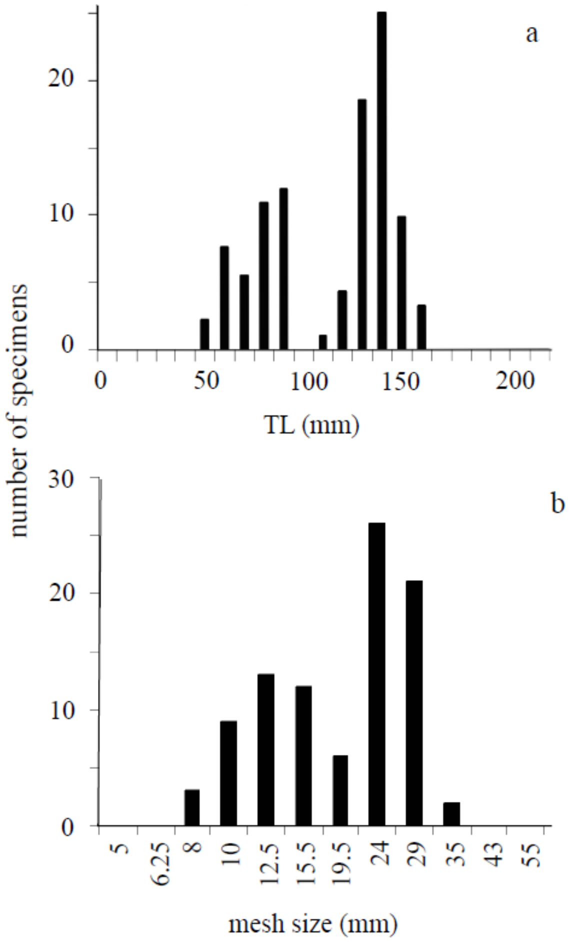

Figure 2. (a) Length-frequency distribution of *Lepomis gibbosus* and (b) number of specimens caught by different mesh sizes of benthic gillnets, Lake Volvi, 2012.

Depth Distribution

Numerical distribution and biomass of all species caught differed among the sampling periods and depth zones (Table 2) with the most specimens been caught in the shallower depth zones (0-2.9 and 3-5.9 m). The same pattern, both in numerical abundance and biomass was evident for *L. gibbosus* for 2012, when most specimens were caught (Table 2).

Potential Risk of Competitive Success

L. gibbosus was found to be competed with the most native cyprinids (*Alburnus* sp., *A. macedonica, Leuciscus aspius* (Linnaeus, 1758), *Pachychilon macedonicum* (Steindachner, 1892), *Petroleuciscus borysthenicus* (Kessler, 1859), *Squalius orpheus* Kottelat & Economidis, 2006 and *V. melanops*), the blenny *Salaria fluviatilis* (Asso, 1801) and the introduced *Gambusia holbrooki* Girard, 1859 (r = 0.583, P<0.05; Table 3), imposing thus a potential threat for these species. Specifically, *L. gibbosus* had similarities with lithophilic species that prefer stony substrate to reproduce, sharing with them the same habitat preferences. Concerning the diet preferences, similarities were recorded mostly with the invertivorous species (Table 3).

Discussion

Lepomis gibbosus is a relatively new invader in the catchment, where it was recorded for the first time in 1999, at Mpogdanas Stream, which inflows in the close Lake Koronia (Kokkinakis, Sinis, & Kriaris, 2000). Then the species extended its distribution in several streams in the catchment (Romanidis-Kyriakidis, Ntislidou, & Bobori, 2013). However, its presence was not confirmed in Lake Volvi, even in commercial catches, since 2009, when two specimens were caught during our sampling efforts, affirming for the first time the species invasion and range expansion in the lake. The following years the species was only sporadically appeared in commercial catches. Since the fish movement between the two lakes (Volvi and Koronia) is not feasible, it is assumed that the species reached Lake Volvi accidentally, probably through illegal transportation and stocking of *P. fluviatilis* specimens from other lakes (Doirani, Kastorias) that are occasionally conducted by local fishermen, as an easy practise reported in several other countries as well (Copp *et al*., 2005; Villeneuve, Copp,

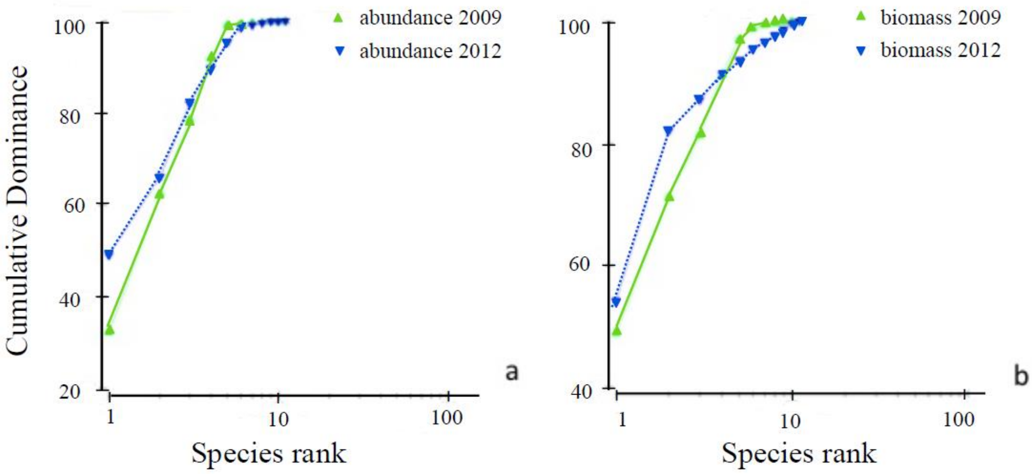

Figure 3. *k*-dominance curves calculated from species abundances (a) and biomass (b) extracted from 2009 and 2012 catches in Lake Volvi.

Table 2. Total benthic catch distribution (%) per depth zone in Lake Volvi (in parenthesis *Lepomis gibbosus* catch distribution). NPUE: specimens per 100 m^2 gillnet, BPUE: g per 100 m^2 gillnet.

Depth zone (m)	NPUE (%)	BPUE (%)	NPUE (%)	BPUE (%)
	2009		2012	
0-2.9	41.56(0)	28.51(0)	30.89(29.35)	33.88(20.94)
3-5.9	28.80 (0)	35.75 (0)	35.42 (51.09)	40.19 (58.34)
6-11.9	21.56 (75.00)	25.18 (79.66)	28.83 (18.48)	22.18 (18.96)
12-21	8.08 (25.00)	10.56 (20.34)	4.86 (1.09)	3.75 (1.76)

Fox, & Stakėnas, 2005; Uzunova *et al.*, 2008) for enhancing some commercially important fish populations.

Diversity indices, have so far been traditionally used for assessing diversity variability (Heino, Mykrä, Hämäläinen, Aroviita, & Muotka, 2007). Here, we calculated two commonly used community indices, based on species number and species relative abundances. The extracted results demonstrated the relevance of fish communities in both periods studied. Moreover, the *k*-dominance curves calculated from species abundances for 2009 and 2012 revealed little overlap and cross, indicating that differences in diversity cannot unambiguously be assessed. Besides, different diversity indices biased towards species richness or evenness, ranking thus species in different ways (Warwick, Clarke, & Somerfield, 2008). Indeed, the calculated values of Pielou's evenness index for both sampling periods gave evidence of the presence of dominant species. Specifically, *R. amarus* and *R. rutilus* were the most abundant species that dominated numerically the catches in 2009 (32.33% and 29.91% respectively) while *R. rutilus* was exclusively the dominant species in 2012, accounting for half of the numerical catch at this period (49.04%). Generally, *k*-dominance curves of the cumulative relative abundances and biomass of species plotted against log species rank for 2009 and 2012, reached their maximum value (of 100) quickly, thus indicating low evenness and richness components of diversity (Warwick *et al*., 2008).

The abundance of *L. gibbosus* was greater in the shallow depth zones, where local fish species were also numerous. Higher abundances of pumpkinseed in the littoral lake areas are also reported by Garcia-Berthou, Moreno-Amich & Coden (2000) and Uzunova, Georgieva, Pavlova, Studenkov, and Popov (2012), depicting species preference for the shallower depth zones, although it can also inhabit deeper areas (García -Berthou & Moreno-Amich, 2000b). However, higher depths (>6 m) in Lake Volvi contributed less to the numerical abundance and biomass of pumpkinseed in 2012 while in the first sampling all specimens were caught at depths 6-19.9 m. Nonetheless, since the number of specimens caught in 2009 was very limited, it is perilous to make assumptions about the distributional

Table 3. Reproductive, feeding and habitat preferences of the fish species present in Lake Volvi and the inflowing rivers. Species similarity to *Lepomis gibbosus* is denoted with # (r=0.583, P<0.05). *=Introduced species.

Species	Reproductive habitat	Feeding preferences	Habitat
Abramis brama	PHLI	INV	BENT
Alburnus sp. Volvi#	PHLI	PLAN	WCOL
Alburnus volviticus#	LITH	INV/PISC	WCOL
Alosa macedonica#	LITH	PLAN/PISC	WCOL
Anguilla anguilla	PEL	INV/PISC	WCOL
*Carassius gibelio**	PHYT	OMNI	BENT
Cobitis strumicae	PHYT	INV	BENT
Cyprinus carpio	PHYT	OMNI	BENT
Esox lucius	PHYT	PISC	WCOL
Gambusia holbrooki#*	OVIP	INV	WCOL
*Hypophthalmicthys molitrix**	PEL	PLAN	WCOL
Knipowitschia caucasica	PHLI	INV	BENT
*Lepomis gibbosus**	LITH	INV	WCOL
Leuciscus aspius#	LITH	PISC	WCOL
Pachychilon macedonicum#	PHLI	INV	WCOL
Perca fluviatilis	PHLI	INV/PISC	WCOL
Petroleuciscus borysthenicus#	PSAM	INV	WCOL
*Pseudorasbora parva**	PHLI	OMNI	WCOL
Rhodeus amarus	0STR	OMNI	WCOL
Rutilus rutilus	PHLI	OMNI	WCOL
Salaria fluviatilis#	LITH	INV	BENT
Scardinius erythrophthalmus	PHYT	OMNI	WCOL
Silurus aristotelis	PHYT	PISC	WCOL
Silurus glanis	PHYT	PISC	WCOL
Squalius orpheus#	LITH	OMNI	WCOL
Tinca tinca	PHYT	OMNI	BENT
Vimba melanops#	LITH	INV	BENT

Reproductive habitat: PHLI=phytolithophil, LITH=lithophil, PHYT=phytophil, PEL=pelagophil, PSAM=psammophil, OVIP=oviparous, OSTR=ostracophil,
Feeding preferences: INV=invertivorous, OMNI=omnivorous, PLAN=planktivorous, INV/PISC=invertivorous/piscivorous, PLAN/PISC=planktivorous/piscivorous, PISC=piscivorous, Habitat: BENT=benthic, WCOL=water column

patterns of pumpkinseed the first year of its invasion in Lake Volvi.

From the length range of specimens caught and considering the available age estimations for the species in Greek reservoirs (Kerkini: Neophytou & Giapis, 1994; Tavropos: Bobori, Tsikliras, & Economidis, 2006) and lakes (Vegoritis: Keramidas, 2013) we may assume that the population of *L. gibbosus* in Lake Volvi in 2012 was consisted by young-of-the-year to ages up to 9 years, depicting a self-sustainable population and providing evidence of large sized specimens introduction in the lake, possibly through the illegal transportations mentioned previously.

L. gibbosus multiplied several times its abundance in the three-years period studied. The increment of an invader's abundance in an area has been used as a measure of its increasing impact to native communities (Anable, McClaran, & Ruyle, 1992), since any biomass (or space, or energy) controlled by the invader constitute resources no longer available to competitors or prey (Parker *et al*., 1999). However, since pumpkinseed invasion is relatively recent in Lake Volvi and its impacts on local fish communities and habitats cannot yet be fully evident, it triggers an alarm for the stability of the ecosystem, as invaders have been shown to alter food-web structure (Britton, Davies, & Brazier, 2010). The extent to which these ecological hazards are expressed is partially depended on the population density of the invader, accepting the common assumption of a positive relationship between invasion impact and density of the invader (Jackson, Ruiz Navarro, & Britton, 2015). Moreover, Parker *et al*. (1999) argue that the total impact of an invader includes three fundamental dimensions: the area occupied, abundance, and the impact per-individual. Nevertheless, even a great deal of recent progress has been made on the relationship between invader density and the caused ecological impacts, in several cases there are divergence interpretations. Benkwitt (2015) supports that the effects of invasive species scale non-linearly with increasing invader density while experimental studies of Kornis, Carlson, Lehrer-Brey, and Vander Zanden (2014) reveal that the ecological effects of the invader are reduced at high densities. Consequently, and given the short time period covered by observations in Lake Volvi, it is hard to make confident assumptions on how *L. gibbosus* will affect local fish populations. One hypothesis could be that the steady increase in pumpkinseed abundance observed would cause a steady decline in some local populations of native species that allocate the same habitats and compete for the same food resources with pumpkinseed. Generally, since our comparisons between the two invasion stages are very limited, it is yet difficult to make safe assumptions on the impacts of the new invader on native fish populations, since most species in Lake Volvi are commercially exploited and it is not easy to differentiate the impacts caused by fishing activities or the invasion. Nevertheless, we may assume that they highlight the importance of considering pumpkinseed density for future managing of invasion impacts (Gherardi & Lazzara, 2006). *L. gibbosus* so far consists a very small component of the lake's fish community. A potential increase of species abundance could be expected due to the very low populations (Bobori & Psaltopoulou, 2012) of its effective predators, such as *E. lucius* and *Silurus glanis* L., 1758 (Scott & Crossman, 1973; Guti, Andrikowics, & Biro, 1991; Tomeček *et al*., 2007). *P. fluviatilis* is also referred as an efficient predator of pumpkinseed (Spătaru, 1967), whereas no correlation of *L. gibbosus* with piscivorous total abundance in several water bodies, is referred by Uzunova *et al*. (2012). The same authors note an antagonistic relationship at sites where pumpkinseed coexists with piscivorous fish, resulting in lower mean length and mean age (Uzunova *et al*., 2012).

In general, *L. gibbosus,* is considered responsible for severe impacts on the biodiversity of several water bodies where it has been introduced (Casal, 2006; Dextrase & Mandrak, 2006). Actually, pumpkinseed is an opportunistic omnivorous feeder (García-Berthou & Moreno-Amich, 2000a; Almeida, Almodóvar, Nicola, & Elvira, 2009), which demonstrates many diet shifts along its life, depending on food availability (Mittelbach, Osenberg, & Wainwright, 1992). However, studies about species diet in European water bodies failed to reveal highly predation upon native fish species. On the contrary, it was found to prey upon eggs of another exotic species *Pseudorasbora parva* (García- Berthou & Moreno-Amich, 2000a). Moreover, minor dietary overlap is reported between *L. gibbosus* and natives i.e. *Gymnocephalus cernua* (Linnaeus, 1758), *P. fluviatilis* and *S. erythrophthalmus* (Rezsu & Specziár, 2006; Nikolova *et al*., 2008) and exotic species i.e. *P. parva* (Wolfram-Wais, Wolfram, Auer, Mikschi, & Hain, 1999). Studies concerning species' life-history traits and its diet overlap with natives as well as the identification of the environmental drivers that favor its survival could enlighten the interactions with local fish fauna and help in the accurate assessment of the potential risks posed by its invasion. So far, a negative relation between pumpkinseed and predator density is referred, indicating that predator-induced mortality may be key in determining pumpkinseed invasiveness (van Kleef & Jongejans, 2014). Under this view, and considering the rigorous protection status of Lake Volvi, it is required specific monitoring and management plans to be implemented focusing initially on the depreciation of species population and secondly on the assessment of the general impacts of pumpkinseed invasion on biodiversity. Thus, the enhancement of native piscivorous populations such as *E. lucius*, may be effective for preventing pumpkinseed domination and reduce damage to local biodiversity (van Kleef & Jongejans, 2014). Moreover, the invasion impacts could be early assessed through monitoring surveys and the driving human and environmental forces could be revealed, setting the basis for launching management measures. Finally, it is fundamental need the public education on the consequences of introducing exotic species or translocation of non-native ones.

Acknowledgments

This research was partially co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program “Education and Lifelong Learning” of the National Strategic Reference Framework (NSRF) – Research Funding Program: Heracleitus II. Investing in knowledge society through the European Social Fund. We would like to thank the PhD candidate Chrysoula Ntislidou and the staff of the Management Body of Lakes Koronia-Volvi for helping in field work and providing the permissions for fish sampling.

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