



The *Alburnus* benthopelagic fish species of the Western Balkan Peninsula: An assessment of their sustainable use



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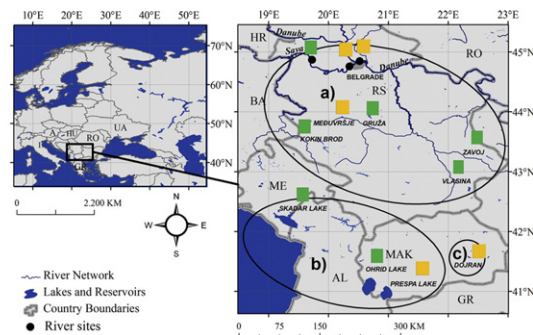
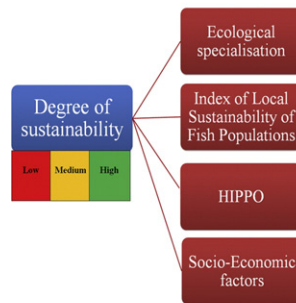
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HIGHLIGHTS

- We assessed the sustainability of bleak populations over the Western Balkan Peninsula.
- Bleak populations were highly sustainable in the continental basin.
- The sustainability of bleak populations in the Mediterranean basin varied.
- Socio-economic factors were significant for Mediterranean bleak populations.
- The Danube Basin bleak populations are safe for utilization in the human diet.

GRAPHICAL ABSTRACT



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SUMMARY

In this study, we aimed to assess the population status of bleak (*Alburnus* spp.) over the Western Balkan Peninsula in terms of its sustainable use. A second objective was to determine key factors important for fishery management planning. Two different basins, continental (the Danube Basin and the Sava River sub-basin) and marine (the Adriatic and the Aegean Sea Basins) were examined. A sustainability assessment and factor analysis were conducted using the adjusted ESHIPPOfishing model, extended with additional socio-economic sub-elements, and the categorical principal components analysis (CATPCA), respectively. The results of the assessment revealed the bleak populations in the Danube Basin and the Sava River sub-basin to be highly sustainable. The population characteristics with abiotic and biotic factors were responsible for this status, while the influence of socio-economic factors was insignificant. The sustainability status of the bleak populations of the Mediterranean basin varied, with the populations from Ohrid and Skadar Lakes showing a high and those from Prespa and Dojran Lakes a medium status. Socio-economic factors with traditional fishing were the most important for the Mediterranean bleak populations.

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1. Introduction

Inland fisheries, including both commercial and recreational fisheries, are able to generate the economy, employment and nutrition in all

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parts of the World (FAO, 2009; Welcomme et al., 2010). However, environmental, socio-economic and political conditions vary greatly in different countries, thereby influencing the development of inland fisheries to different extents (Cowx, 2015). Strong inequality in these conditions across Europe has caused a significant decrease in commercial fishing in Western European countries, while it is still the main source of employment in local communities from post-socialist countries. Because of the important role of commercial fishing, shifts in fisheries legislation, administration and access to water can have a great impact on the population sustainability of commercial fish species. In addition, fishing waters are permanently exposed to anthropogenic pressure through, for example, hydromorphological degradation and organic pollution (Cowx, 2015). This leads to the alteration of freshwater ecosystems, especially in industrialized countries, which could also affect the sustainable status of commercial fish populations, and be harmful for inland fisheries as well (Arlinghaus et al., 2002). Because of this highly complex situation, managing inland fisheries demands an ecosystem approach (FAO, 2003) which takes into account information regarding the biotic, abiotic and human components of ecosystems. The same applies to assessing the sustainability status of commercial fish populations, in which not only biological and ecological factors, but also social and economic factors have to be taken in consideration.

The genus *Alburnus* (bleak) is represented with four species in the western part of the Balkan Peninsula (Kottelat and Freyhof, 2007). Within the genus *Alburnus*, the species *Alburnus alburnus* (Linnaeus, 1758) shows the widest distributional pattern including the Danube, Sava and Velika Morava Rivers (the Black Sea drainage basin). Beside *A. alburnus*, the species *Alburnus scoranza* (Heckel and Kner, 1858) is distributed within the Drim Basin including the large natural lakes Ohrid and Skadar (the Adriatic Sea Basin). Finally, the last two species, *Alburnus belvica* (Karaman, 1924) and *Alburnus macedonicus* (Karaman, 1928), are endemic to Prespa Lake (the Adriatic Sea Basin) and Dojran Lake (the Aegean Sea Basin), respectively. Although these populations have been isolated to some extent, they have been totally isolated from the *Alburnus* population in the aquatic systems of the Middle Danube Basin. Such a distributional pattern has brought about a high number of endemic species and fish communities with a low number of top carnivore species such as catfish, zander and pike, which are ordinary species for the aquatic systems of the Danube Basin. The absence of carnivores could be one of the favorable conditions which have enabled the abundant population of 'peaceful' fish species to be formed.

Bleak is a small but commercially valuable consumable fish, with different commercial potential across the Balkan Peninsula (Vladau et al., 2008; Official Bulletin of the Republic of Macedonia, 2011a,b,c). More precisely, great inequality in the exploitation of *Alburnus* has been shown by relevant surveys of fish catches in the lotic and lentic systems of the Western Balkan Peninsula. The percentage of bleak in the annual fish catch of the Sava and Middle Danube Rivers is insignificant (less than 1%), which is not the case with the lentic systems of the Adriatic and the Aegean Sea Basins, where bleak is one of the most exploited fish species (e.g. 40–70% of the total fish catch of Skadar Lake) (Mrdak, 2009). Due to the high level of exploitation in this region, bleak is also important in the fish processing industry.

This pattern of inequality in the exploitation rate of *Alburnus* is related to variations in the extent of aquatic ecosystem degradation, as well as differences in fisheries legislation, administration and tradition (Stanković, 1957; Mrdak et al., 2001; Official Bulletin of the Republic of Macedonia, 2011a,b,c; Simić and Simić, 2014b,d). For example, the artificial lentic systems of the Middle Danube Basin were constructed with the main purpose of creating a drinking water supply, and having a freshwater supply for the surrounding industries, municipal area, and agricultural lands, as well as for flood control. Since recreation, tourism and fishing are not primary activities in the man-made lakes of the Middle Danube Basin, such a prioritization of activities is also defined by law, which is the main obstacle to commercial fisheries. This is not the case in the natural lakes of the Adriatic and the Aegean Sea Basins,

where fishing for recreational or commercial purposes is legal (Spirkovski and Bojadzieski, 2013). It is obvious that region-specific socio-economic conditions with differences in bureaucracy and laws could also affect the viability of bleak populations and should be taken in account in the assessment of population sustainability.

The biological and ecological traits of *Alburnus* populations in both areas are strongly sensitive to man-caused factors, especially hydrological alterations (damming). For example, positive population growth and colonization have been recorded for the species *A. alburnus*. This has been a consequence of forming large artificial lentic systems within the Danube Basin (Simonović, 2001). Similar changes in the fish community structure were recorded in the aquatic ecosystems of the Iberian Peninsula, where Almeida et al. (2014) stressed that the bleak population could be harmful for the Mediterranean fish fauna. Furthermore, the endemic *Alburnus* species in the Adriatic and the Aegean Sea Basin react in the same way, colonizing newly formed artificial aquatic systems. The Mediterranean bleak species were also introduced into the lentic systems of the Danube Basin (Simić et al., 2012). The species *A. scoranza* was introduced to Vlasina Reservoir together with Ohrid trout (*Salmo ohridanus* Steindachner 1892; Janković and Raspopović, 1960). However, only scarce information about these processes is available, with no studies examining any further consequences regarding biodiversity reduction and *Alburnus* species hybridization. Finally, poor statistics related to fishing data and sporadic surveys inordinately conducted in the Western Balkan Peninsula provide insufficient information about bleak diversity and their population structure and dynamic (Stein et al., 1975; Knežević, 1981; Radusinović, 1983; Janković, 1994; Rakaj and Floko, 1995; Mrdak et al., 2001; Simić et al., 2012; MEPP, 2014; Almeida et al., 2014).

Having all this in mind, we wanted to examine here how different abiotic, biotic and socio-economic conditions influence the sustainability status of bleak populations across the Western Balkan Peninsula using the ESHIPPofishing model (Simić et al., 2014). For this purpose, socio-economic factors were included in the ESHIPPofishing model. Furthermore, the objective was to reveal key factors important for the degree of sustainability and the fisheries management planning of wild *Alburnus* populations.

2. Material and methods

2.1. Study area and sampling

The study was conducted over the three drainage areas in the Western Balkan Peninsula: the Black, the Adriatic and the Aegean Sea Basins (Fig. 1).

The Black Sea Basin, i.e. the Danube Basin with the sub-basin of the Sava River, occupies the largest part of the territory of Serbia, about 81,700 km², or 92.46% (Gavrilović and Dukić, 2002).

The Adriatic Sea Basin covers an area of 4732 km², or 5.36% of the territory of Serbia and approximately 6560 km² in Montenegro. A small western area of the Republic of Macedonia also belongs to this basin (Gavrilović and Dukić, 2002). The Aegean Basin, the smallest of those investigated, covers an area of 2650 km², of which 3% is on the territory of Serbia, and the rest belongs to the territory of Macedonia.

According to Illies (1978) and revised by Paunović et al. (2012), the investigated area includes the ecoregions 5, 6, 7 and 11. The climate of the investigated area of the Balkan Peninsula ranges from moderate continental with high temperatures during the summer and mountainous with high snowfall in the winter to the Mediterranean climate in the coastal region.

The research included the Lower Sava River (upstream and downstream) and the Pannonian Plain Danube (Tubić et al., 2013), as well as lentic systems belonging to the Sava River sub-basin (Kokin Brod, Medjuvršje and Gruža reservoirs) and the Danube River Basin (Zavoj and Vlasina reservoirs) (Fig. 1). All these lentic systems, situated on the territory of Serbia, are artificial, the highest and the largest being

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