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Commercial fish species of inland waters: A model for sustainability assessment and management

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HIGHLIGHTS

- We proposed ESHIPPO*fishing* model for commercial fish species conservation.
- The model estimates the degree of sustainability of commercial fish populations.
- The results indicate the lowest degree of sustainability for sterlet and huchen.
- The ESHIPPO*fishing* model is formulated to be applicable to any kind of river basin.

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ABSTRACT

The permanent increase in the exploitation of commercial fish species has led to the need for developing practical and effective tools for the sustainability assessment and management of the target fish populations. The aim of this study was to formulate an ESHIPPO*fishing* model which would provide a reliable assessment of commercial fish population sustainability and indicate the conservation priorities. The existing ESHIPPO model was modified by introducing a new Index of local sustainability of fish populations (ILSFP) which enables the selection of "keystone populations" and "keystone habitats/ecosystems" within the basin being investigated. We employed a self-organizing map (SOM) in order to visualize the spatial distribution of the keystone populations and keystone habitats/ecosystems for each fish species. Based on the ILSFP values, environmental specialization (ES) of a fish species and local environmental factors (HIPPO factors), the model estimates the degree of sustainability (DS) of commercial fish populations in the freshwater ecosystems of the western Balkan Peninsula. The results indicate a low degree of sustainability for the majority of commercial fish species of the Middle Danube Basin, especially *Acipenser ruthenus* and *Hucho hucho*. The ESHIPPO*fishing* model presents a cost effective conservation approach, formulated to be applicable to any kind of river basin. The application of the ESHIPPO*fishing* model provides a comprehensive insight into the viability of target fish populations, which would not only further improve the selection of conservation priorities, but also facilitate the management of aquatic ecosystems.

1. Introduction

The overexploitation of inland water biological resources leads to their depletion, which is more intensive than in terestrial ecosystems (Essl et al., 2013). Among aquatic biota, fish are the most endangered group, being exposed to illegal and/or uncontrolled fishing (Cooke and Cowx, 2006; Maitland et al., 2007; Sumaila et al., 2007; Mota et al., 2014). Previous studies indicate that intensive fishing strongly affects the life-history, behaviour, physiology, and morphology of exploited fish species (Laugen et al., 2014). This is especially true for commercial fish species, particularly in developing countries where the restriction of overexploitation is less efficient (Smederevac-Lalić et al., 2012). Poor management and conservation policies and practice for the aquatic ecosystems of Western Balkan countries have led to an increased risk of extinction for important commercial fish species. The absence of an appropriate bio-monitoring programme is the main obstacle to applying any of the commonly used methods for assessing the risk of extinction (IUCN (IUCN, 2013), Vortex system (Miller and Lacy, 2003), FISAT II (Gayanilo et al., 2005)). In addition, the status of endangered fish populations is rapidly getting worse, overtaking the published assessment results of the IUCN system (Rocha et al., 2013) which could also affect the utility of conservation programmes.

Generally, the majority of studies so far have been focused on models for assessing the sustainability and vulnerability of biological resources and biodiversity for marine ecosystems (Musick, 1999; Béné and Doyen, 2003; Cheung et al., 2005; Le Quesne and Jennings, 2012; Burrow et al., 2013), whereas only a few studies have applied such

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models to the ecosystems of inland waters (Giam et al., 2011; Meixler, 2011; Linke et al., 2012). One such model, which assesses the state of the biological resources in freshwater ecosystems, was proposed by Simić et al. (2007). They presented the ESHIPPO model with the aim of assessing the risk of extinction and conservation priority for endangered species of macroalgae, macroinvertebrates and fish at a regional level. The model consists of two main steps. The first step is to quantify the ecological specialization of taxa—ES (including the global evolutionary adaptive characteristics of taxa, such as: adaptation to habitat, nutrition, reproduction, life cycle, body size, endemism and level of fragmentation; Fisher and Owens, 2004). The second step is to calculate the values of global factors of biodiversity endangerment, given in the acronym HIPPO (including: Habitat alteration, Invasive species, Pollution, Population growth and Overexploitation; Brennan and Withgott, 2005). Finally, the sum of the values of the ES and HIPPO parameters reflects the level of the risk of extinction and the conservation priority for aquatic taxa in the investigated area.

The ESHIPPO method could indicate whether the target species needs to be a conservation priority. However, this index does not provide any information regarding sustainability of the target population (keystone-population) and habitats or entire ecosystems (keystone-habitats/ecosystems). Applied to commercial fish species, the keystone population and keystone habitats/ecosystems represent the basic units of fisheries management and of the sustainable use and conservation of fish resources. A similar model was presented by Chantepie et al. (2011) and Chester and Robson (2013), in which they introduced the concept of refuge in the management of freshwater biodiversity. Moreover, such information is crucial for the conservation management of inland waters, which has to be cost-effective because of financial and time constraints.

The aim of this study is to develop a new ESHIPPO*fishing* model which would enable more efficient assessment of the sustainability of commercial fish species populations. In accordance with this aim we wanted to extend the ESHIPPO model by defining the indicators for the assessment of the Index of local sustainability of fish populations (ILSFP). Finally, we aimed to define the ecological, spatial, temporal and functional bond between the keystone populations and keystone habitats/ecosystems of target fish species.

2. Materials and methods

2.1. ESHIPPOfishing: assumptions and rationale

The model was tested in the fishing waters of the Middle Danube Basin (Sommerwerk et al., 2009) in the territories of the Western Balkan countries (70% in the territory of Serbia) (Fig. 1). In order to evaluate the degree of sustainability of commercial fish populations the most important species are included in the model: sterlet *Acipenser ruthenus* Linnaeus 1758, huchen *Hucho hucho* (Linnaeus 1758), grayling *Thymallus thymallus* (Linnaeus 1758), brown trout *Salmo trutta* Linnaeus 1758, pike-perch *Sander lucioperca* (Linnaeus 1758), catfish *Silurus glanis* Linnaeus 1758, pike *Esox lucius* Linnaeus 1758, carp *Cyprinus carpio* Linnaeus 1758, bream *Abramis brama* (Linnaeus 1758), barbel *Barbus barbus* (Linnaeus 1758), nase *Chondrostoma nasus* (Linnaeus 1758), chub *Squalius cephalus* (Linnaeus 1758) and Prussian carp *Carassius gibelio* (Bloch 1782). In this study, the term commercial fish species applies not only to species harvested for profit purposes, but also to species significant for recreational fishing.

In order to obtain the results of this study, a robust and heterogeneous data set was used and processed in two phases.

2.1.1. Phase 1—working database

Two databases were constructed using data from the professional and scientific papers on fishing and fish resources in the Middle Danube

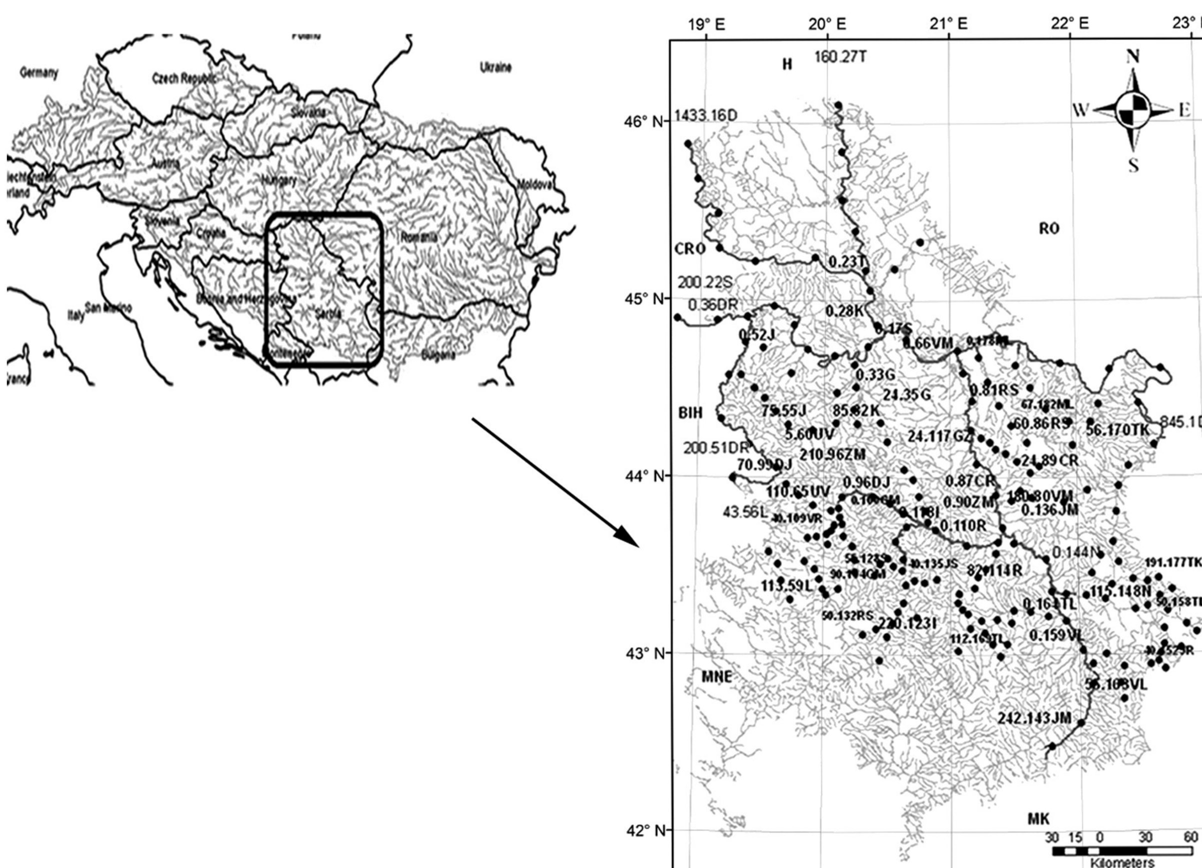

Fig. 1. Sites under investigation of commercial fish species over the Middle Danube Basin.