

Distribution, age and growth of the translocated invasive Northern pike (*Esox lucius*, L.) in the upper course of the Vrljika River in the Adriatic Basin

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Abstract

The objective of this paper is to determine the distribution, age and growth the Northern pike (*Esox lucius*) in the upper course of the Vrljika river. Samples were collected for two consecutive days in February 2020. In total, 38 individuals of *E. lucius* were analysed. The age of *E. lucius* in the upper course of the Vrljika River is divided into six age classes, and the oldest individual belongs to the 9+ age class. The total length of *E. lucius* ranges from 17.8 to 90.0 cm, while the relative population density is two individuals per 100 m. The upper course of the Vrljika River is habitat to two invasive, and three endemic fish species.

Key words: pike, age, growth, the Vrljika River, Adriatic Basin, invasive

Introduction

In Croatia, the Esocidae family is represented by one species, the Northern pike (*Esox lucius*). *E. lucius* lives in areas with a slow flow, preferring to keep to the thickets of aquatic vegetation (Lieberman et al., 2019), and primarily prefers shallow cool-waters which have productive and mesotrophic-eutrophic environments (Casselman et al., 1996). Habitats of *E. lucius* in Croatia are the middle and lower courses of rivers and lakes. *E. lucius* is a native species to the Republic of Croatia, but has been translocated from the Danube drainage to the Adriatic Basin. According to the current knowledge of distribution of *E. lucius* in the rivers and lakes of the Adriatic Basin, it has been confirmed in the rivers Gacka, Lika, Cetina and Neretva, in Vransko Lake near Biograd, Vransko Lake on the island of Cres, and in Ponikve Lake on the island of Krk (Čaleta et al., 2019), but also in the Krka and Vrljika Rivers, as well as Prološko Blato Lake and Šarana Lake near Knin. At most of these localities, the pike populations have been present for several decades and the impact on local ichthyofauna can be assessed (Marčić et al., 2016). Translocation represents the introduction of a species from one part of a political entity (country) where it is native to another part of the same country where it is not native (Copp et al., 2005). According to FISK v2 for Croatia and Slovenia, *E. lucius* was categorised as an invasive fish species with mean value of 18.5 FISK score and a moderately high risk in the criteria of native species translocated from the Danube to the Adriatic Basin (Piria et al., 2016).

Information on the reasons, origin, location, number, sex and age of the individuals or the approximate year or time of the translocation of *E. lucius* into the Vrljika River is not known.

Aquatic ecosystems in Croatia are divided into two geographic units, the Adriatic and the Danube Basin. One of the greatest values of the Croatian ichthyofauna is the biodiversity of endemic and steno endemic species of fish of the Adriatic Basin. With a large number of endemics, the Adriatic rivers of the Dalmatia region are among the most interesting ichthyological areas in Europe. Unfortunately, the specialised habitats of these endemic species are quickly changing in modern times under anthropogenic impacts (Ćaleta et al., 2015). Human activities usually shift the balance among fish species, causing the extirpation of many indigenous species and the dominance of a reduced set of often introduced fish species (Balirwa et al., 2003). The movement of fish species beyond their natural range is potentially one of the most ecologically damaging of human activities (Koehn, 2004). The translocation of native species can have impacts upon indigenous populations of native fish, the general ecosystem into which translocations occur, as well as subsequent social and economic impacts over time (Morgan et al., 2004). Previous papers on the age, growth and distribution of the Northern pike in the Vrljika River are unknown.

Materials and methods

Study area

The Vrljika River springs near Proložac in Imotsko polje, at the altitude of 273 m above sea level and belongs to the Adriatic Basin. The shorter portion of its course flows through Croatia, 18 km in length, and then it crosses to the territory of Bosnia and Herzegovina near Runović, where it is called the Matica River. The study area includes a transect of 2100 m in length in the upper course of the Vrljika River, from Zdilari, UTM coordinates (WGS84) 47°23'06"N, 17°10'05" E, to the location with coordinates 47°26'14"N, 17°10'36" E. The width of the water column ranged from 5 to 30 m, and the depth ranged from 40 to 190 cm. According to the national classification, the study area belongs to upper and middle courses of turbulent waters. Riparian vegetation is present for most part of the banks, in the faster parts of the river bed it is mostly microphytes, while the edges of the river bed have thick submerse vegetation. The monitoring area belongs to the NATURA 2000 ecological network, and has been an ichthyological nature reserve since 1971, where sports fishing is prohibited. The upper course of the Vrljika River is the habitat of endemic fish species Sofemouth trout (*Salmo obtusirostris*), Spotted minnow (*Delminichthys adspersus*), and Neretva roach (*Rutilus basak*) (personal data).

Fishing samplings

Samples were collected for two consecutive days in February 2020., with a Hans-Grassl IG600 electrofishing device, with a maximum power of 650 W of direct current and 1200 W of pulsating electric current, and with an EL64II electrofishing device with a maximum power of 7,5 kW of direct current. The samples were collected over the entire length of the transect, in such a way that the IG600 electrofishing device was used for the shallower edges of the river by walking along the river bed, while the EL64II was used from an inflatable boat for the deeper parts of the course and the middle of the river bed. Samples were taken throughout the channel width at all sampling locations. After collecting the samples, the species were determined according to the Kottelat and Freyhof (2007) determination key. All individuals were transported to a laboratory for further analysis. Three to five scales were taken from the body of each individual just under the dorsal fin. The scales were placed in an alcohol solution, then cleaned and dried. The age of the fish was determined by reading the annuli on scales through a binocular Motic ZS-171. The total length of each individual was measured with an ichthyometer with a 1 mm precision.

Results

In total, 38 pike individuals were collected and analysed from the upper course of the Vrljika River. The distribution of *E. lucius* in the upper course of the Vrljika River begins 230 m downstream from the first sampling location, with UTM coordinates (WGS84) 47°23'06"N, 17°10'05"E, on the edges of the river bed with thick submersed vegetation, and continues until the end of the transect. Almost half of all the samples caught, 18 individuals, were caught in the first half of the transect with the length of 400 m, from the location with coordinates 43°26'52"N, 17°10'33"E to the location with coordinates 43°26'41"N, 17°10'30"E. Eight individuals were caught in the second half of the transect along the length of only 130 m, from the location with coordinates 43°26'22"N, 17°10'29"E to the location with coordinates 47°26'14"N, 17°10'29"E. Relative population density of *E. lucius* in the upper stream of the Vrljika River is two individuals per 100 m, and the population has an uneven spatial layout (Figure 1).



Figure 1. Map of the upper course of the Vrljika river with sampling locations

The age of *E. lucius* in the upper stream of the Vrljika River is divided into six age classes: 0+, 1+, 2+, 4+, 5+ and 9+. Most individuals belonged to the 0+ and 1+ age classes with an almost even share, while the 4+ and 9+ classes were represented by only one individual. Age classes 3+, 6+, 7+ and 8+ were not found in this research. (Figure 2a).

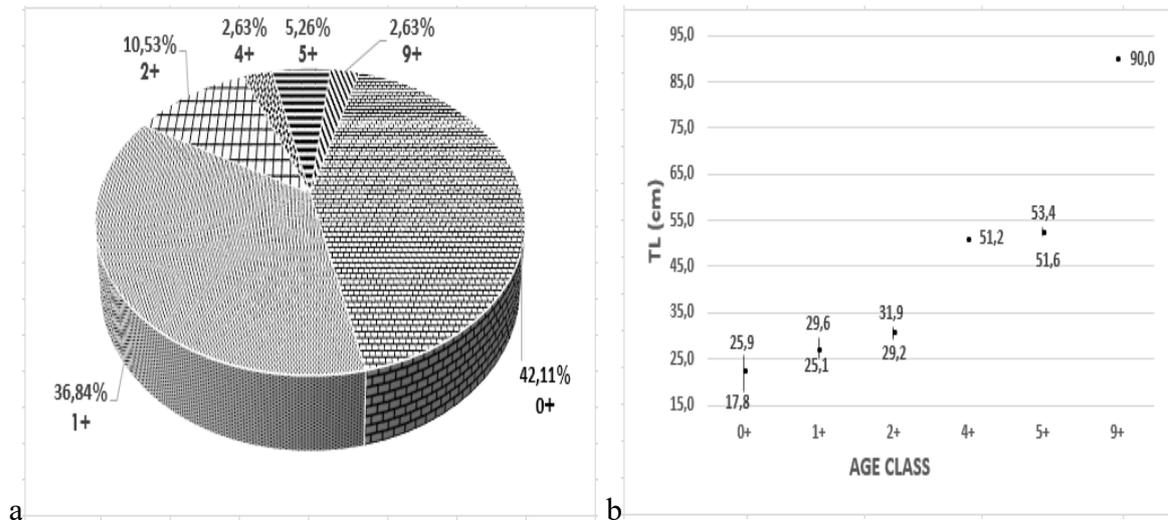


Figure 2. Relative abundance by age classes of *E. Lucius* in the upper course of the Vrljika River a), Total length of *E. Lucius* aged from 0+ to 9+ caught in the upper course of the Vrljika River b) (The vertical bar represents the range, point represents the mean TL)

The average total body length of the entire sample is 29.3 cm, ranging from 17.8 to 90 cm \pm 12.7 cm SD (Figure 2b). The available data shows positive correlation between total length and age class ($R^2=0,83$).

Apart from *E. lucius*, three individuals of an invasive species Pumpkinseed, *Lepomis gibbosus*, were caught in the upper course of the Vrljika River and transported to the laboratory for further analysis, as well as endemic species *S. obtusirostris*, *D. adspersus*, and *R. basak*, which were returned to river instantly.

Discussion

E. lucius individuals in the upper course of the Vrljika River were caught in two types of habitat; in edging, slower and shallower parts of the course next to rapids and waterfalls, or in relatively bigger, deeper areas of the slower course of the river. Regardless of these two types of habitat, all individuals were caught in parts of the course with thick aquatic vegetation. It has been found that if a greater number of individuals was caught in a smaller surface area of the transect, the individuals were similar in size. On the other hand, bigger individuals were caught in bigger surface areas without the presence of other individuals. This kind of distribution of population density and the size of individuals is most likely connected with the cannibalism of this species. The cannibalism of *E. lucius* has been described in many previous papers (Mann, 1982., Kipling, 1983., Elvira et al., 1996). In Scotland, large pike preyed on smaller pike (Munro, 1957), in River Frome cannibalism on pike aged between six months and two years accounted for most of their natural mortality (Mann, 1982). The pike actually prefer prey fish that are smaller than predicted from optimal foraging models based on energy and time budgets (Hart et al., 1984). The absence of the 3+, 6+, 7+ and 8+ age classes can be caused by unfavourable biotic conditions, no spawning or poor spawning in particular years, but also by inter-cohort cannibalism in which older fish eat younger age classes, which can have a strong density-dependent impact on year class strength. In lakes where one or only a few species occur, cannibalism may be the major population regulatory mechanism (Helfman et al., 2009).

When comparing the total length and age classes of the *E. lucius* analysed in this paper with the results of caught in the Danube Basin, (Habeković et al., 1998), the *E. lucius* from this paper have a significantly smaller total length in all age classes when compared with *E. lucius* from the Danube Basin. *E. lucius* from the Danube Basin from age classes 1+ and 5+ have a total length ranging from 30.0 to 37.5 cm and 66.0 to 71.00 cm, while the total length of the individuals from this paper belonging to the same age classes ranges from 25.1 to 29.6 and 51.6 to 53.4 cm. The reason for this can be seen in the qualitatively and quantitatively larger range of ichthyocenosis in the Danube Basin, which enables a larger choice of food, its availability and an easier access to food. The results from this paper concerning total length in regard to age classes are very similar to those of *E. lucius* from the Rubikiai Lake in Lithuania (Žiliukiene et al., 2012).

Conclusion

According to the oldest age class in this paper, one can conclude that the *E. lucius* has been present in the Vrljika River for at least ten years. Six different age classes show that the *E. lucius* spawns in the Vrljika River in the years of favourable biotic and abiotic conditions. *E. lucius* from the upper course of the Vrljika River have a smaller total length in regard to age than the *E. lucius* from the Danube Basin. Apart from middle and lower courses of rivers of the Danube Basin, the *E. lucius* also inhabits the upper course by the very spring of the Vrljika River. The upper course of the Vrljika River is habitat to invasive species *E. lucius* and *L. gibbosus*, but also three endemic fish species *S. obtusirostris*, *D. adspersus* and *R. basak*.

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Rasprostranjenost, dob i rast translocirane invazivne vrste štuke (*Esox Lucius*, L.) u gornjem toku rijeke Vrljike u Jadranskom slivu.

Sažetak

Cilj ovog rada je utvrditi rasprostranjenost, dob i rast štuke (*Esox lucius*) u gornjem toku rijeke Vrljike. Uzorci su prikupljeni dva dana zaredom u veljači 2020. godine, analizirano je ukupno 38 jedinki *E. lucius*. Dob *E. lucius* u gornjem toku rijeke Vrljike je raspodijeljena u šest dobnih razreda, a najstarija jedinka pripada 9+ dobnom razredu. Raspon ukupne dužine tijela *E. lucius* je između 17,8 i 90,0 cm, dok je relativna gustoća populacije dvije jedinke na 100 m. Gornji tok rijeke Vrljike stanište je dvije invazivne i tri endemske vrste riba.

Ključne riječi: štuka, dob, rast, rijeka Vrljika, jadranski sliv, invazivna