

Assessment of Fish Stocks and Elemental Pollution in the Danube, Sava and Kolubara Rivers on the Territory of the City of Belgrade, Serbia

Katarina Jovičić^{1}, Mirjana Lenhardt², Željka Višnjić-Jeftić¹, Vesna Đikanović², Stefan Skorić¹, Marija Smederevac-Lalić¹, Milica Jaćimović¹, Zoran Gačić¹, Ivan Jarić¹, Aleksandar Hegediš¹*

¹ Institute for Multidisciplinary Research, University of Belgrade, Kneza Višeslava 1, 11000 Belgrade, Serbia;
E-mail: katarinaj@imsi.rs

² Institute for Biological Research, University of Belgrade, Despota Stefana 142, 11060 Belgrade, Serbia

Abstract: There is a lack of adequate estimates of the fish stocks in the Belgrade city area, Serbia, as well as of the current fishery pressure on fish diversity and of the contamination level of fish meat. These factors obstruct efforts to conduct valorisation of the current state and potential development of this resource. During 2012 and 2013, an assessment of the current state of the fish resources in Belgrade fishery waters was performed, in order to establish a good basis for the development of a monitoring system on the state of fish stocks and their exploitation. Fish were collected at ten localities in the Danube, Sava and Kolubara rivers. The fish stock composition and biomass were determined at each of the localities. The results indicate that the commercial fishery in the Danube and Sava rivers is characterised by seasonal variability regarding the amount and the composition of fish catch, while the ratio of high versus low quality fish remained relatively stable over time. In most of the analyzed fish, heavy metal concentrations remained below the prescribed maximum allowable concentrations (MAC). However, concentrations of mercury, cadmium and zinc exceeded MAC in the tissues of a number of individuals of Wels catfish, common carp, sterlet, pikeperch, European perch, ruffe, and sichel, which indicates that the meat of Danube fish species can be utilised in human diet only in limited quantities, and that it is necessary to establish permanent monitoring of heavy metal concentrations in this area. Based on the results, a system of indicators was defined and a monitoring system for the Belgrade fishery waters was proposed. Pikeperch and freshwater bream were selected as major species for fish meat quality monitoring, while the implementation of fishery monitoring program should comprise both economically important fish species and certain nonindigenous species.

Keywords: Fish stock, monitoring, fishery, heavy metals, Danube River, Sava River, Kolubara River

Introduction

The territory of the city of Belgrade comprises significant number of fishery waters with different hydrological and ecological characteristics, as well as diverse fish communities that inhabit them (PETROVIĆ 1998). However, there is a lack of adequate estimates of the fish stocks in this area and of the current fishery pressure on ichthyofaunistic diversity, which

obstructs efforts to conduct valorisation of the current state and potential development of this resource (SMEDEREVAC-LALIĆ 2013).

Heavy metals are considered to be among major pollutants in the Danube River in Serbia (TEODOROVIĆ 2009). However, there is a lack of information on the contamination level of fish meat by

*Corresponding author

heavy metals and numerous other pollutants in this region (SUBOTIĆ *et al.* 2013a). Fish tissue contamination monitoring has an important role as an early warning indicator regarding problems related to water and sediment quality, and it also enables detection of toxic chemicals in fish, which can produce adverse effects on consumers. Thus, such monitoring allows taking appropriate and timely measures to protect public health and the environment (LENHARDT *et al.* 2012).

The main aim of the present study was to assess the current state of the fish resources in Belgrade fishery waters and fish stocks' abundance and composition, as well as to evaluate heavy metals contamination and accumulation in fish tissues, in order to establish a basis for the development of a monitoring system on the state of the fish stocks and their exploitation, as well as on the state of the fish meat quality.

Material and Methods

The fish samples were collected between November 2012 and September 2013, at ten localities on the territory of the city of Belgrade (Fig. 1). Sampling in the Danube and Sava rivers was performed with the help of local commercial fishermen (gillnets, dimensions 20-30 m x 1-2 m, 40 mm mesh size, and drift nets, dimensions 100-150 m x 3 m, 40-60 mm mesh size), while the samples in the Kolubara River and other localities were collected by the use of gillnets (dimensions 30 m x 2 m, 20-60 mm mesh size) and electrofishing. Gillnets were left over night (*i.e.* for 15 hours), while drift nets were carried by water current for 800-1000 m. Electrofishing (Honda Elemax SHX 2000, 220 V / 6A DC 1.2 kW) was conducted by making 50 m long, 3 m wide transects along each bank of the river or channel. Fish stock composition and biomass were determined at each of the localities.

To determine the level of pollutant accumulation in fish from the studied area, the heavy metal and trace element concentrations in fish tissues were assessed during 2007-2010 in a number of specimens of the studied species (*i.e.* 6-30 specimens per species) on the territory of the city of Belgrade (JARIĆ *et al.* 2011, LENHARDT *et al.* 2012, SUNJOG *et al.* 2012, SUBOTIĆ *et al.* 2013b, RAŠKOVIĆ *et al.* 2014). Specimens were sacrificed with a quick blow to the head, measured for their total weight (g) and total

body length (cm), and subsequently dissected. The samples of gills, liver and the right dorsal muscle were removed, washed with distilled water and stored at -20°C prior to analysis. The sample preparation for the analysis was performed with the standard procedure (LENHARDT *et al.* 2012). The analysis was performed by inductively-coupled plasma optical spectrometry (ICP-OES) and included the assessment of concentrations of the following 18 elements: Al, As, B, Ba, Cd, Co, Cr, Cu, Fe, Hg, Li, Mn, Mo, Ni, Pb, Se, Sr and Zn. The concentrations in fish meat (*i.e.* muscle samples) were also recalculated to the wet tissue weight (ww) and compared with the maximum allowed concentrations (MAC) in fish meat for the utilization in human diet, as established by the European Union (EU) and the national legislation. According to the EU legislation (EUROPEAN COMMISSION REGULATION 2006), MAC for Cd, Hg and Pb are 0.05, 0.50 and 0.30 µg g⁻¹ ww, respectively. The national legislation prescribed MAC for As, Cd, Hg, Pb, Cu, Fe and Zn in fish meat at 2.0, 0.1, 0.5, 1.0, 30.0, 30.0 and 100.0 µg g⁻¹ ww, respectively (OFFICIAL GAZETTE OF RS 2011).

Results and Discussion

During the research, the following species were caught at the studied localities in the area of the city of Belgrade (Table 1): freshwater bream (*Abramis brama*), sterlet (*Acipenser ruthenus*), schneider (*Alburnoides bipunctatus*), bleak (*Alburnus alburnus*), black bullhead (*Ameiurus melas*), asp (*Aspius aspius*), zope (*Ballerus ballerus*), White-eye bream (*Ballerus sapa*), Danube barbel (*Barbus balcanicus*), barbel (*Barbus barbus*), white bream (*Blicca bjoerkna*), Prussian carp (*Carassius gibelio*), common nase (*Chondrostoma nasus*), grass carp (*Ctenopharyngodon idella*), common carp (*Cyprinus carpio*), northern pike (*Esox lucius*), ruffe (*Gymnocephalus cernua*), schraetzer (*Gymnocephalus schraetser*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), pumpkinseed (*Lepomis gibbosus*), ide (*Leuciscus idus*), burbot (*Lota lota*), monkey goby (*Neogobius fluviatilis*), perch (*Perca fluviatilis*), stone moroko (*Pseudorasbora parva*), bitterling (*Rhodeus amarus*), gudgeon (*Romanogobio vladykovi*), roach (*Rutilus rutilus*), cactus roach (*Rutilus virgo*), pikeperch (*Sander lucioperca*), Volga pikeperch (*Sander*



Fig. 1. Sampling locations: 1) Danube River, Batajnica area (N 44° 55' 40.44", E 20° 19' 14.07"); 2) Danube River, central Belgrade area (N 44° 49' 50.55", E 20° 28' 25.32"); 3) Danube River, Grocka area (N 44° 55' 40.44", E 20° 19' 14.07"); 4) Sava River, Umka area (N 44° 40' 24.07", E 20° 17' 37.24"); 5) Sava River, Progar area (N 44° 42' 37.43", E 20° 09' 05.21"); 6) Kolubara River, Obrenovac area (N 44° 39' 39.55", E 20° 14' 44.39"); 7) Kolubara River, Veliki Crljani area (N 44° 30' 00.38", E 20° 15' 31.86"); 8) Borča irrigation canal (N 44° 52' 25.34", E 20° 26' 32.28"); 9) Sava Lake (N 44° 47' 02.28", E 20° 23' 25.64"); 10) Markovačko Lake (N 44° 23' 26.20", E 20° 39' 09.80")

volgensis), Rudd (*Scardinius erythrophthalmus*), Wels catfish (*Silurus glanis*), chub (*Squalius cephalus*), vimba bream (*Vimba vimba*), sichel (*Pelecus cultratus*) and zingel (*Zingel zingel*). Based both on their average biomass and abundance in the catch, relative contribution of each species is presented in Fig. 2.

Biomass estimation of the fish stocks in four major fishing areas in the Belgrade city area is presented in Table 2. Catch-per-unit-effort (CPUE) was estimated as an average catch of fish per night (*i.e.* 15 hours), and expressed as either kg/m of net length or kg/m² of net (mesh size 40 mm). CPUE was not estimated for electrofishing. As can be observed in Table 2, CPUE in winter was relatively similar among localities. The spring season was characterised by a substantially lower CPUE. The results indicated that the commercial fishery in the Danube and Sava rivers was characterised by seasonal variability regarding the amount and the composition of fish catch, while the ratio of high versus low quality fish remained relatively stable over time. The catch statistics for the studied area indicated an increasing catch of both commercial and recreational fishery and an increasing number of recreational fishermen, while the number of commercial fishermen experienced a rapid decrease over time (SMEDEREVAC-LALIĆ 2013). Although there is a number of possible explanations

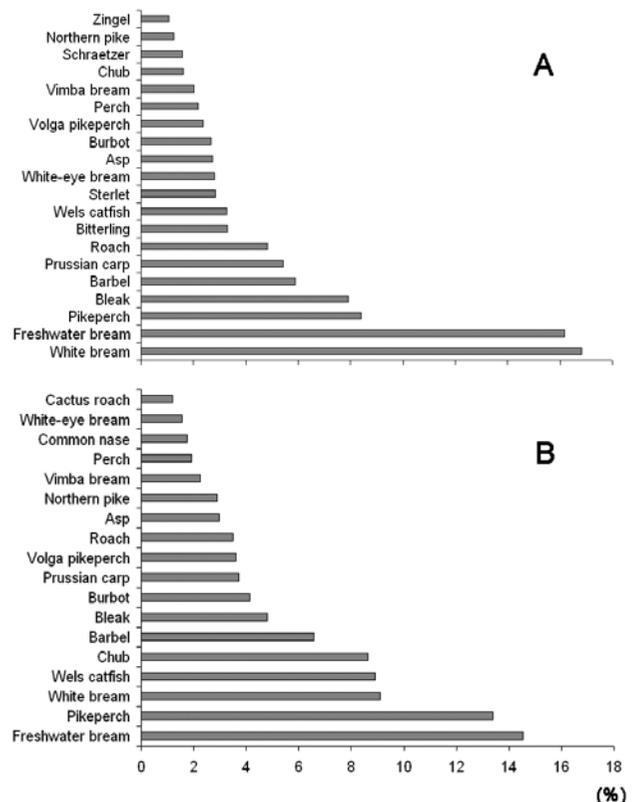


Fig. 2. Species composition of fish samples collected at the ten sampling locations by abundance (A) and by biomass (B) (relative contribution, %). Species with the abundance and biomass below 1% are not presented

Table 1. Fish species recorded in the studied localities

| | Danube River | Sava River | Kolubara River | Other (localities 8-10)* |
|------------------|---------------------|-------------------|-----------------------|---------------------------------|
| Freshwater bream | + | + | | + |
| Sterlet | + | + | | |
| Schneider | | | + | |
| Bleak | | | + | + |
| Black bullhead | + | | + | + |
| Asp | + | + | | + |
| Zope | + | | | |
| White-eye bream | + | + | + | |
| Danube barbel | | | + | |
| Barbel | + | + | + | |
| White bream | + | + | + | + |
| Prussian carp | + | + | + | + |
| Common nase | + | + | + | |
| Grass carp | | | | + |
| Common carp | + | | + | + |
| Northern pike | + | + | + | + |
| Ruffe | + | | + | + |
| Schraetzer | + | + | + | |
| Silver carp | + | | | + |
| Bighead carp | | | | + |
| Pumpkinseed | | | + | + |
| Ide | + | + | | |
| Burbot | + | | | |
| Monkey goby | | | + | + |
| Perch | + | + | + | + |
| Stone moroko | | | + | + |
| Bitterling | | | + | + |
| Gudgeon | | | + | |
| Roach | + | + | + | + |
| Cactus roach | | + | | |
| Pikeperch | + | + | | + |
| Volga pikeperch | + | + | + | |
| Rudd | | | | + |
| Wels catfish | + | | + | + |
| Chub | | | + | |
| Vimba bream | + | + | + | |
| Sichel | + | | | |
| Zingel | + | | | |

See the text and Fig. 1 for the exact position of the sampling locations

for such opposite trends, such as increasing fishing effort, increased fish stock abundance or catch statistics keeping procedures, there is a lack of data that would provide clear insight in this issue. Consequently, continuous monitoring programs will be necessary to improve knowledge and provide sound data on fishery and the state of fish stocks in this region.

The elemental concentrations in each of the analysed fish tissues are presented in Tables 3 and 4. The elemental analyses indicated that the fish liver was the centre of accumulation of the majority of heavy metals and trace elements. Such results were in accordance with previous findings (JARIĆ *et al.* 2011, LENHARDT *et al.* 2012, SUBOTIĆ *et al.* 2013a).

Table 2. Estimation of fish stocks in four major fishing areas in the Belgrade city area, calculated as catch-per-unit-effort (CPUE) in two seasons. Sampling was not performed in spring in the central Belgrade area and Grocka area. ¹ Drift nets; ² Gillnets

| Locality | CPUE (kg/m of net length) | | CPUE (kg/m ² of net) | |
|--|---------------------------|--------|---------------------------------|--------|
| | Spring | Winter | Spring | Winter |
| Danube River, Batajnica area ¹ | 0.031 | 0.163 | 0.010 | 0.108 |
| Danube River, central Belgrade area ² | / | 0.191 | / | 0.106 |
| Danube River, Grocka area ¹ | / | 0.113 | / | 0.072 |
| Sava River, Umka area ² | 0.068 | 0.134 | 0.045 | 0.089 |
| Mean | 0.050 | 0.150 | 0.028 | 0.094 |

Table 3. Concentrations of Al, As, B, Ba, Cd, Co, Cr, and Cu in muscle, gill, liver, and gonads of fish from the territory of the city of Belgrade. Data represents average values (means \pm standard deviation, minimum and maximum values in parentheses) among analysed fish species (barbel, burbot, common carp, freshwater bream, pikeperch, silver carp, sterlet, wels catfish, and white bream). Concentrations are expressed as $\mu\text{g g}^{-1}$ dry weight. * An element above detection level in a single species

| | Muscle | Gill | Liver | Gonads |
|----|-----------------------------------|------------------------------------|------------------------------------|--------------------------------|
| Al | 12.09 \pm 12.13 (4.87-33.71) | 36.67 \pm 25.24 (9.63-85.80) | 21.83 \pm 21.30 (3.86-54.78) | 7.14* |
| As | 0.79 \pm 0.66 (0.17-2.2) | 0.74 \pm 0.10 (0-2.71) | 0.76 \pm 0.71 (0.12-2.419) | 0.56 \pm 0.74 (0.11-1.41) |
| B | 0.22 \pm 0.36 (0.06-1.04) | 12.41 \pm 18.11 (0.17-48.43) | 0.69 \pm 0.49 (0.13-1.37) | ND |
| Ba | 1.514 \pm 1.1 (0.66-3.631) | 9.27 \pm 6.18 (0.93-17.75) | 0.77 \pm 1.35 (0.05-3.93) | ND |
| Cd | 0.02 \pm 0.04 (0-0.08) | 0.05 \pm 0.06 (0.01-0.15) | 0.54 \pm 1.03 (0.01-2.83) | ND |
| Co | ND | 0.03 \pm 0.05 (0-0.1) | 0.01 \pm 0.02 (0-0.04) | ND |
| Cr | 0.04 \pm 0.03 (0.01-0.08) | 0.05 \pm 0.04 (0.01-0.11) | 0.02 \pm 0.02 (0-0.04) | ND |
| Cu | 2.60 \pm 2.70 (0.75-7.85) | 25.72 \pm 54.93 (1.01-160.11) | 42.74 \pm 53.29 (6.18-188-78) | 1.16* |

The gills, due to their direct exposure to the pollutants present in the water, also represent an important indicator of water quality. Although the fish muscle represents a tissue that is characterised by minimum accumulation levels, the heavy metal accumulation monitoring in muscles is important due to the use of fish muscles in human diet. In most of the analysed fish, the heavy metal concentrations remained below the prescribed MAC. However, the concentrations of mercury, cadmium and zinc exceeded MAC in a number of samples, which indicated that the meat of fish from the Danube River can be utilised in human diet only in limited quantities, and that it is necessary to establish permanent monitoring of heavy metal concentrations in this area. Moreover, it will be important to focus future

research efforts on defining appropriate quantities of fish meat to be used in human diet (*i.e.* kg of fish meat per week).

Because of their presence at the studied localities, pikeperch and freshwater bream have the best potential to be used as major species for fish meat quality monitoring, although the implementation of fishery monitoring programs should comprise both economically important fish species (*e.g.* Wels catfish, pikeperch, common carp, pike, freshwater bream, and barbel) and certain exotic species, such as Prussian carp. The future programs for monitoring fish stocks and pollution should also comprise simultaneous use of a number of different methods and indicators, such as the analysis of heavy metal concentrations, monitoring of histopathological

Table 4. Concentrations of Fe, Hg, Mn, Mo, Ni, Se, Sr and Zn in muscle, gill, liver, and gonads of fish from the territory of the city of Belgrade. Data represents average values (means ± standard deviation, minimum and maximum values in parentheses) among analysed fish species (barbel, burbot, common carp, freshwater bream, pikeperch, silver carp, sterlet, wels catfish, and white bream). Concentrations are expressed as µg g⁻¹ dry weight. * An element above detection level in a single species

| | Muscle | Gill | Liver | Gonads |
|----|------------------------------|------------------------------------|-----------------------------------|----------------------------------|
| Fe | 12.26 ± 7.43 (1.31-27.06) | 176.51 ± 109.33 (54.93-379.439) | 244.26 ± 159.73 (36.97-511.72) | 34.23 ± 8.67 (26.04-43.31) |
| Hg | 1.37 ± 0.52 (0.73-2.15) | 1.04 ± 0.56 (0-1.52) | 1.48 ± 0.44 (0.63-1.9) | ND |
| Mn | 0.73 ± 0.40 (0.12-1.47) | 17.79 ± 19.04 (3.16-69.42) | 8.04 ± 22.05 (0.49-78.00) | 10.10 ± 0.53 (9.73-10.47) |
| Mo | 1.57 ± 3.78 (0-10.13) | 0.19 ± 0.25 (0.01-0.8) | 0.35 ± 0.40 (0.03-1.52) | 0.09 ± 0.03 (0.07-0.11) |
| Ni | 9.11* | 0.59 ± 0.33 (0.33-0.96) | 5.10 ± 8.47 (0.03-14.88) | ND |
| Se | 0.44 ± 0.88 (0-2.017) | 0.83 ± 0.71 (0.21-2.06) | 1.31 ± 1.82 (0.15-4.53) | ND |
| Sr | 2.37 ± 1.82 (0.08-6.44) | 66.87 ± 41.42 (7.86-166.71) | 0.27 ± 0.17 (0.04-0.72) | 0.72 ± 0.87 (0.07-1.96) |
| Zn | 24.15 ± 15.91 (7.91-5901) | 273.96 ± 548.65 (40.11-1773.76) | 129.80 ± 162.01 (18.78-582.79) | 141.38 ± 94.06 (71.69-272.48) |

changes in fish tissues, genotoxicity monitoring (e.g. by the use of the Comet assay and micronucleus test), molecular analyses, application of body indices, and analysis of endoparasite infestation.

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