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Census of selected riverbed breeding bird species on the Mura River between Ceršak (SLO) and Dekanovec (HR)

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IMPRESSUM

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Protecting and restoring ecological connectivity in the Mura-Drava-Danube river corridor through cross-sectoral cooperation

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Table of content

I. POVZETEK

V letih 2021 in 2022 so bili opravljeni terenski popisi izbranih gnezdilk struge reke Mure med Ceršakom (SLO) in Dekanovcem (HR) v skupni dolžini 92,8 km. Popisi so vključevali celotno matično strugo, v letu 2022 pa so bili popisani tudi vsi večji stranski rokavi in nekatere gramoznice na območju MDD TBR. Uporabljena metoda je večinoma ustrezala skupnim minimalnim standardom za popis ptic rečne struge na območju TBR MDD. Ciljne vrste popisov so bile mali deževnik *Charadrius dubius* (MD), mali martinec *Actitis hypoleucos* (MM), vodomec *Alcedo atthis* (VOD), breguljka *Riparia riparia* (BRE) in čebelar *Merops apiaster* (ČE). V popis je bil sistematično vključen tudi veliki žagar *Mergus merganser* (ŽAG), beležili pa smo tudi opazovanja nekaterih drugih vrst. Zbrani podatki so bili digitalizirani ter interpretirani skladno s posebnimi kriteriji. Za vse ciljne vrste so bile izdelane populacijske ocene, izračunani trendi in karte gnezditvenega pojavljanja na podlagi kernelske gostote. V sezonah 2021 in 2022 je bilo zbranih skupaj 321 oziroma 371 podatkov. Velikost populacije MD v strugi reke Mure je bila leta 2021 ocenjena na 51–60 parov z linearno gnezditveno gostoto 0,5–0,6 para/km, leta 2022 pa na 37–43 parov z gostoto 0,5–0,6 para/km. V obeh letih je bilo več kot dve tretjini vseh parov zabeleženih v popisnem odseku 8. Ocena za leto 2021 je največja zabeležena velikost populacije v strugi reke Mure od prvega celovitega popisa leta 2008. Z izjemo lokacije na zgornji Muri je bil MD v letih 2021 in 2022 razširjen le vzdolž spodnje polovice območja raziskave. Gnezdenje vrste v strugi reke Mure je odvisno izključno od razpoložljivosti ustreznih prodišč. MD je vsaj v enem letu zasedal 43,6 % vseh prodišč v strugi reke Mure. Trend populacije v obdobju 2008–2022 je bil ocenjen kot negotov. Spremembe številčnosti med leti je mogoče pojasniti z razpoložljivostjo primernih prodišč. Velikost populacije MM v strugi reke Mure je bila leta 2021 ocenjena na 35–41 parov z linearno gnezditveno gostoto 0,4 para/km, leta 2022 pa na 32–38 parov z gostoto 0,3–0,4 para/km. V obeh letih je bila več kot polovica vseh parov zabeležena v popisnem odseku 8. Ocene velikosti populacije so najvišje zabeležene v strugi reke Mure od prvega celovitega popisa leta 2008. Razširjenost vrste med Veržejem in Dekanovcem je bila precej zvezna, medtem ko je bila na zgornji Muri zabeležena na vsega 4–5 lokalitetah. Med letoma 2021 in 2022 se je razširjenost MM le malo spremenila. Večina parov (81 % leta 2021 in 89 % leta 2022) je gnezdila na prodiščih, ostali pa so gnezdili v stranskih rokavih, rečnih bregovih in umetnih strukturah s prodnato površino ali lesnimi naplavinami. MM je vsaj v enem letu zasedal 42,6 % vseh prodišč v strugi reke Mure. Po upadu v prejšnjem desetletju, se je populacija po letu 2016 občutno povečala, trend pa je bil ocenjen kot zmeren porast. Izolirana gnezdišča MD in MM na zgornji Muri so rezultat nedavno izvedenih projektov renaturacije. Površina prodišča določa verjetnost naselitve obeh vrst in pomembno vpliva na število gnezdečih parov, ki lahko na njem gnezdijo. Na nekaterih ključnih gnezdiščih so bile zabeležene škodljive dejavnosti človeka, kot so izkopavanje gramoza, terenska vožnja in dolgotrajna uporaba za namene rekreacije. Velikost populacije VOD v strugi reke Mure je bila leta 2021 ocenjena na 22–32 parov z linearno gnezditveno gostoto 0,2–0,3 para/km. Z vključitvijo dodatnih parov iz popisa različnih lokalitet zunaj glavne struge reke je bila skupna populacija območje reke Mure leta 2022 ocenjeno na 37–49 parov z

linearno gnezditveno gostoto 0,4–0,5 para/km. V obeh letih je bil največji delež parov zabeležen v popisnem odseku 8. Karta vseh zabeleženih lokacij kaže sliko razširjenosti vrste brez vrzeli, bistveno daljših od 2 km, vzdolž celotne struge nizvodno od cestnega mostu pri Veržeju, je pa nekaj takšnih vrzeli na zgornjem delu območja raziskave. Skupaj je bilo zbranih 58 podatkov o zasedenih/sveže izkopanih gnezdilnih rovih VOD na 31 lokacijah. Rezultati kažejo na pomen stranskih rokavov za vrsto na notranji Muri, kjer je matična struga v veliki meri utrjena in posledično brez naravnih bregov. Na spodnji Muri je bila večina gnezdilnih rovov izkopana v dolgih odsekih z naravnimi rečnimi bregovi. Mediana višine gnezdilnega rova VOD in gnezdilne stene nad vodno gladino reke je bila 1,1 m (razpon 0,5–3,0 m) oziroma 1,5 m (razpon 1,0–8,0 m). Gnezdeča populacija v strugi reke Mure si je po nizu izrazito slabih let v prvi polovici prejšnjega desetletja opomogla. Trend populacije VOD je bil ocenjen kot zmeren porast. Velikost populacije BRE v strugi reke Mure je bila leta 2021 ocenjena na 92–198 parov, leta 2022 pa na 113–257 parov. V obeh letih je bilo zabeleženih sedem kolonij, njihova velikost pa se je gibala od 1 do 115 gnezdilnih rovov (mediana = 14). Večina populacije je gnezdila v 2–3 kolonijah v gramoznici Križovec (HR), kjer je leta 2021 gnezdilo 819–2275 parov, leta 2022 pa 328–780 parov. Manjše kolonije so bile zabeležene še v 1–3 drugih gramoznicah na območju MDD TBR v Sloveniji. Sprememba številčnosti vrste v strugi med letoma 2021 in 2022 je bila na splošno zmerna (manj kot ena tretjina), vendar z velikimi razlikami na posameznih popisnih odsekih. Vse kolonije BRE v strugi so se nahajale na dolgih odsekih (večinoma nekaj sto metrov) naravnih rečnih bregov z navpičnimi površinami iz primerne aluvialne prsti, ki jih na zgornji in notranji Muri najdemo izključno na območjih nedavno izvedenih projektov renaturacije. Mediana višine gnezdilnega rova BRE in gnezdilne stene nad vodno gladino reke je bila 2,8 m (razpon 1,0–4,8 m) oziroma 3,4 m (razpon 1,5–5,2 m). Za gnezdečo populacijo BRE v strugi reke Mure so značilna nepredvidljiva in izrazita nihanja številčnosti. Posledično je bil trend populacije ocenjen kot negotov. V letih 2021 in 2022 je ČE gnezdil na eni sami lokaciji in sicer gramoznici Križovec (HR). Leta 2021 je bilo skupaj preštetih 88 aktivnih gnezdilnih rovov, leta 2022 pa 27. Velikost populacije ŽAG v strugi reke Mure je bila leta 2021 ocenjeno na 32–49 parov z linearno gnezditveno gostoto 0,3–0,5 para/km, leta 2022 pa na 29–41 parov z gostoto 0,3–0,4 para/km leta 2022. Registracije so bile dokaj enakomerno porazdeljene vzdolž celotne struge reke Mure med Ceršakom in Gibino, na spodnji Muri pa je bila vrsta redko zabeležena oziroma je ni bilo. Gnezdenje je bilo potrjeno z opazovanjem številnih zarodov. Popisi v letih 2021 in 2022 so potrdili mednarodni in nacionalni pomen območja reke Mure med Ceršakom (SLO) in Dekanovcem (HR) za ciljne vrste. Na osnovi podatkov o njihovem pojavljanju in linearnih gnezditvenih gostotah vzdolž struge reke Mure lahko sklepamo o stanju rečnih habitatov in naravnih procesov. Medtem ko je za spodnjo Muro med Križovcem in Dekanovcem s prevladujočim povsem naravnim rečnim tokom značilno zvezno pojavljanje ciljnih vrst v velikih gostotah, se na dolgih odsekih zgornje in notranje Mure pojavlja zelo malo značilnih vrst ptic naravnih rečnih habitatov. Takšne odseke je treba prednostno vključevati pri načrtovanju prihodnjih projektov renaturacije rek.

II. SUMMARY (in English)

In 2021 and 2022, field surveys of selected breeding bird species were carried out in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in a total length of 92.8 km. The surveys covered entire main river channel, while in 2022 all major side arms and some gravel pits in the territory of the MDD TBR were also surveyed. The field survey methods used mostly complied with common minimum standards for riverbed bird census in the TBR MDD area. Target species of the surveys were Little Ringed Plover *Charadrius dubius* (LRP), Common Sandpiper *Actitis hypoleucos* (CS), Common Kingfisher *Alcedo atthis* (KIN), Sand Martin *Riparia riparia* (SMA) and the Bee-eater *Merops apiaster* (BE). Common Merganser *Mergus merganser* (MER) was also systematically included in the census, and observations of some other species were recorded, too. The data collected were digitized and interpreted according to the special criteria. Population estimates, trends and breeding occurrence maps based on kernel density were produced for all target species. A total of 321 and 371 data on were collected in the 2021 and 2022 season, respectively. LRP population size in the Mura riverbed was estimated at 51–60 pairs with a linear breeding density of 0.5–0.6 pairs/km in 2021, and at 37–43 pairs with a density of 0.5–0.6 pairs/km in 2022. In both study years over two thirds of all pairs were recorded in the survey section 8. Estimate for 2021 is the highest population size recorded in the Mura riverbed since the first comprehensive census in 2008. With the exception of single location on the upper Mura, LRP was distributed only along the lower half of the study area in 2021 and 2022. The breeding of the species in Mura riverbed depends exclusively on the availability of suitable gravel bars. 43.6 % of all gravel bars mapped in the Mura riverbed were occupied by LRP in at least one of the study years. LRP population trend in the 2008–2022 period was estimated as uncertain. Variations in numbers detected over time can probably be explained availability of suitable gravel bars. CS population size in the Mura riverbed was estimated at 35–41 pairs with a linear breeding density of 0.4 pairs/km in 2021, and at 32–38 pairs with a density of 0.3–0.4 pairs/km in 2022. In both study years over half of all pairs were recorded in the survey section 8. Population size estimates are the highest recorded in the Mura riverbed since the first comprehensive census in 2008. Distribution of the species between Veržej and Dekanovec was fairly continuous, while it was recorded at only 4–5 sites on the upper Mura. Distribution of CS changed only slightly between 2021 and 2022. Most of the pairs (81 % in 2021 and 89 % in 2022) selected gravel bars for breeding, while others nested in side arms, river banks and artificial structures with shingle surface or woody debris. 42.6 % of all gravel bars were occupied by CS in at least one of the study years. After substantial decline in the previous decade, numbers recovered remarkably after 2016 and population trend was estimated as moderate increase. The isolated breeding locations of LRP and CS on upper Mura are result of recent river restoration projects. Gravel bar surface area determines occupancy probability of both species and has significant effect on the number of LRP and CS pairs nesting on it. Some of the key nesting locations were affected by anthropogenic activities, such as gravel excavation, off-road driving and prolonged recreational use. KIN population size in the Mura riverbed was estimated at 22–32 pairs with a linear breeding

density of 0.2–0.3 pairs/km in 2021. By including additional pairs from the survey of different localities outside the main river channel, the total 2022 population of the Mura River area was estimated 37–49 pairs with a linear breeding density of 0.4–0.5 pairs/km. In both study years the largest proportion of pairs was recorded in the survey section 8. Combined registrations from 2021 and 2022 riverbed surveys show distribution pattern without gaps significantly longer than 2 km along the entire riverbed downstream of Veržej road bridge, while a few exist on the upstream part of the study area. Overall, 58 data on occupied/freshly excavated nest holes were collected on 31 locations. Results indicate the importance of side arms for KIN on inner Mura, where the main river channel was largely regulated by rock ripraps and consequently no natural banks exists. On lower Mura, the majority of nest holes were excavated in long stretches of natural river banks. The median height of the nest hole and the nesting wall above the water level of the river was 1.1 m (range 0.5–3.0 m) and 1.5 m (range 1.0–8.0 m), respectively. Breeding population in the Mura riverbed recovered after a series of distinctly bad years during the first half of the previous decade. KIN population trend was estimated as moderate increase. SMA population size in the Mura riverbed was estimated at 92–198 pairs in 2021, and at 113–257 pairs in 2022. In both years, 7 colonies were registered, while colony size varied from 1 to 115 nesting burrows (median = 14). Majority of population was found in 2–3 colonies in the Križovec gravel pit (HR), where an estimated 819–2275 pairs nested in 2021 and 328–780 pairs in 2022. Smaller colonies were recorded in further 1–3 gravel pits in the territory of the MDD TBR in Slovenia. The population change in the riverbed between 2021 and 2022 was moderate overall (less than one third), but with big differences in separate survey sections. All SMA riverbed colonies were located in long stretches (mostly several hundred metres) of natural river banks with exposed steep surface of suitable alluvial soil, on the upper and inner Mura found exclusively in sections of recent river restoration projects. The median height of the nest burrow and the nesting wall above the water level of the river was 2.8 m (range 1.0–4.8 m) and 3.4 m (range 1.5–5.2 m), respectively. Breeding population in the Mura riverbed is characterized by unpredictable and highly fluctuating numbers. Consequently, SMA population trend was estimated as uncertain. In 2021 and 2022, BE nested at a single location, the Križovec gravel pit (HR). A total of 88 active nesting burrows were counted in 2021 and 27 in 2022. MER population size in the Mura riverbed was estimated at 32–49 pairs with a linear breeding density of 0.3–0.5 pairs/km in 2021, and at 29–41 pairs with a density of 0.3–0.4 pairs/km in 2022. Registrations were fairly evenly distributed along the entire Mura riverbed between Ceršak and Gibina, while the species was sparsely registered or absent on lower Mura. Breeding was confirmed with observations of numerous broods. Surveys in 2021 and 2022 confirmed international and national importance of the Mura River area between Ceršak (SLO) and Dekanovec (HR) for targeted species. Information on their occurrence and linear breeding densities along the Mura riverbed provide valuable clues about state of the riverine habitats and processes. While the lower Mura between Križovec and Dekanovec with predominant completely natural river flow is characterized by continuous occurrence of target species in high densities, long stretches of upper and inner Mura hold few characteristic bird species of pristine riverine habitats. Such sections should be considered a priority in planning future river restoration projects.

III. METHODS AND FIELD SURVEYS

A. - Study area

In both project years (2021, 2022), field surveys were carried out in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in a total length of 92.8 km. The surveys covered entire main river channel, including gravel bars, river islands, river banks with riparian vegetation, and other structures in the riverbed. Some of the larger side arms were also surveyed. For the purposes of data visualization and interpretation, the area is divided into eight survey sections, established for bird monitoring in previous years (Božič & Koce 2020). Survey sections are delineated by permanent structures such as bridges or boats (Figure 1). Sections and their corresponding lengths are as follows (in downstream direction):

(1)	state border at Ceršak–Trate/Mureck (bridge) (SLO-AU)	11,1 km
(2)	Trate/Mureck (bridge)–Gornja Radgona/Bad Radkersburg (bridge) (SLO-AU)	17,1 km
(3)	Gornja Radgona/Bad Radkersburg (bridge)–Radenci (bridge) (SLO-AU)	6,6 km
(4)	Radenci (bridge)–Veržej (road bridge) (SLO)	13,0 km
(5)	Veržej (road bridge)–Razkrižje (bridge) (SLO)	9,5 km
(6)	Razkrižje (bridge)–Gibina (bridge) (SLO)	3,3 km
(7)	Gibina (boat)–Mursko Središče (road bridge) (HR)	11,7 km
(8)	Mursko Središče (road bridge)–mouth of the Krka River (SLO-HR)	20,5 km

The term “upper Mura” is used for the river sections, mostly on the Slovene-Austrian border, between Ceršak and Radenci, “inner Mura” for the sections entirely on the Slovene territory between Radenci and Gibina, and “lower Mura” for the river sections bordering Croatia.

Apart from that, the following gravel pits located in the territory of the Mura-Drava-Danube TBR were included in the field surveys in both study years: Melinci (SLO), Krapje (SLO), Križovec (HR) and Dobrovnik (SLO) (Figure 1). Additional seven localities with gravel pits (SLO) were surveyed only in 2022. In 2022, all major side arms of the Mura River (17 localities, total length c. 40 km), most of which are located on Slovenian territory and not included in the regular survey of the riverbed, were also visited (Figure 2).

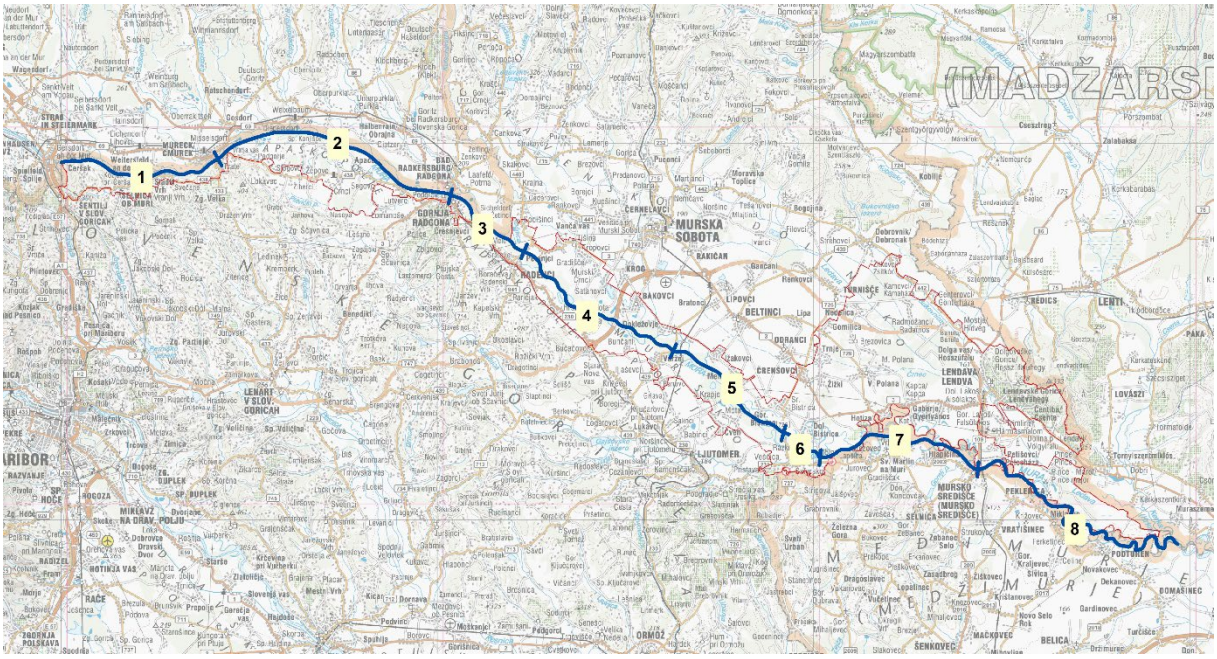

Figure 1: The Mura riverbed between Ceršak (SLO) and Dekanovec (HR), where census of selected breeding bird species was conducted in the 2021and 2022 seasons, with survey sections (1–8) depicted.

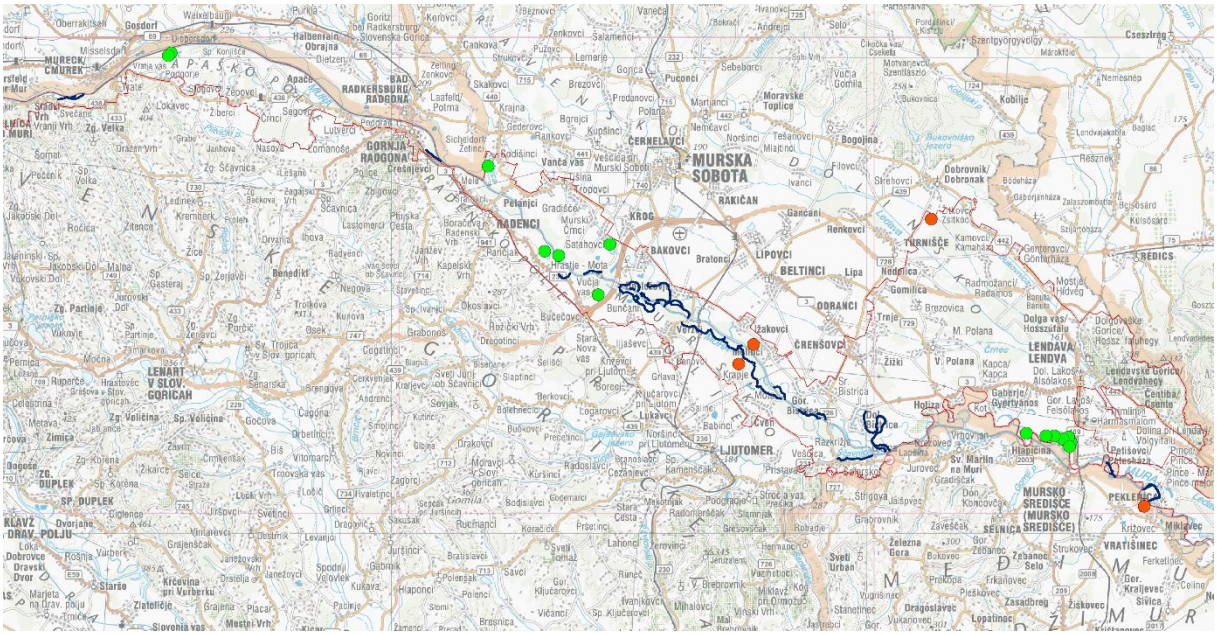

Figure 2: Side arms of the Mura River (blue lines) and gravel pits (red points – visited in 2021 and 2022, green points – visited only in 2022), surveyed separately in the study period.

B. - Field survey methods

The field survey methods mostly complied with common minimum standards (ToR) for riverbed bird census in the TBR MDD area, developed by the Working group for birds of the lifelineMDD project, aided by bird experts. The only provision from the ToR that was not entirely taken into account is the implementation of the census at least 10 days after the cessation of high-flow events. The latter was not always possible due to administrative reasons related to crossing the Slovenian-Croatian border during the covid-19 pandemic and prolonged duration of large discharges.

According to the requirements of the contracting authority, target species of the surveys carried out in the study area were Little Ringed Plover *Charadrius dubius*, Common Sandpiper *Actitis hypoleucos*, Common Kingfisher *Alcedo atthis*, Sand Martin *Riparia riparia* and the Bee-eater *Merops apiaster* (Figure 3). Due to its nature conservation importance, Common Merganser *Mergus merganser* was also systematically included in the census of the riverbed breeding birds, and we also recorded random observations of Black Stork *Ciconia nigra*, White-tailed Eagle *Haliaeetus albicilla* and White-throated Dipper *Cinclus cinclus*.

Censuses were conducted twice at all survey sections of the riverbed, in both years the first time at the end of April (1st survey) and the second time in the first half of June (2nd survey). With the exception of the first survey in 2021, all censuses were carried out in three field days. In each field day, up to several sections were surveyed (field day 1 – sections 1, 2, 3 and 4; field day 2 – sections 5, 6 and 7; field day 3 – section 8).

Censuses were carried out using an inflatable boat with a crew of three or four people, of which at least two (mostly 3–4) were bird experts. The work was organized in such a way that both sides of the river in the direction of navigation and both river banks were systematically inspected in their entirety. An additional observer using inflatable kayak usually participated in the census of the lower Mura riverbed, which enabled the inspection of some of the more important river side arms.

The majority of gravel bars, with the exception of some smaller, overgrown and/or very low shingle areas (exposed only at very low water levels in the riverbed), were surveyed on foot during regular stops. Their surface was systematically checked by binoculars and/or spotting scope from suitable vantage point. Extensive gravel bars (>1 ha) were carefully walked by at least one bird expert. All potentially suitable steep natural banks were observed from slowly moving boat for Kingfisher and/or Sand Martin nest holes and the signs about their occupancy.

All registrations of census units (= individual, pair, group, nest hole/nesting burrow, sub-colony, adult/pair with young) of target bird species were accurately and unambiguously (with a sequential number) mapped on orthophotos printed in a scale of 1:5000 and recorded with all the required data in census forms. The minimum required information for each registration recorded (species, number of individuals) include (1) species, (2) number of individuals (occupied nest holes in colonial burrowing birds) and (3) behaviour, in particular any form suggesting breeding (i.e. warning calls or territorial,

display, distraction behaviour etc.). Additional information, e.g. distinction of individuals by sex, pairs formed (no. of pairs if clearly recognizable), nests found, adults attending chicks, direction of flight etc. was recorded when possible.

Figure 3: Target species of the Mura riverbed surveys in 2021 and 2022 (from top left to bottom right) – Little Ringed Plover *Charadrius dubius* (photo: T. Basle), Common Sandpiper *Actitis hypoleucos* (photo: J. Novak), Common Kingfisher *Alcedo atthis* (photo: L. Božič), Sand Martin *Riparia riparia* (photo: A. Ploj), Bee-eater *Merops apiaster* (photo: A. Ploj) and Common Merganser *Mergus merganser* (photo: L. Božič).

Gravel pits specified in the previous chapter were visited on foot due to the confirmed breeding of Sand Martin and Bee-eater (surveyed in both study years) or Kingfisher in the past (surveyed only in 2022). In 2022, all side arms of the Mura River considered potentially suitable for breeding of the Kingfisher were surveyed separately. Surveys were carried out in such a way that entire length of each side arm was walked, while special attention was given to the detection of possible nest holes. These sites were visited once or twice per season, based on judgement of the observers.

Details about surveys carried out in 2021 and 2022 seasons are given in Table 1.

In 2021, the following two parameters were assessed on the Kingfisher and Sand Martin nest-sites along the Mura riverbed:

- the height of the nesting wall from the water level of the river at the time of the census to the upper edge,
- the height of the nest hole/burrow from the water river level at the time of the census.

Where feasible, the parameters were estimated visually in the field, while for the other nest-sites estimates were made later on the basis of the photos taken during the census. Estimates of the specified parameters were not made for nest-sites without photos available.

Table 1: Information on field surveys of the Mura riverbed and other localities in the territory of the Mura-Drava-Danube TBR in the 2021 and 2022 seasons.

Date	Survey section/ Site	Hydrological conditions (where applicable)	Participants
Riverbed surveys 2021			
25 Apr 2021	Ceršak–Gibina	Small discharge, c. 100 m^3/s; similar as throughout the second half on the month.	Luka Božič, Monika Podgorelec, Željko Šalamun
29 Apr 2021	Gibina–Dekanovec	Small discharge, c. 100 m^3/s; similar as throughout the second half on the month.	Luka Božič, Monika Podgorelec, Željko Šalamun, Tadej Törnar
4 Jun 2021	Ceršak–Veržej	Medium discharge, c. 200 m^3/s; a few days after the period of large discharges in the last week of May (Qvk 469 m^3/s on 28 May 2021).	Luka Božič, Željko Šalamun, Tadej Törnar, Katja Berden

Date	Survey section/ Site	Hydrological conditions (where applicable)	Participants
10 Jun 2021	Veržej–Mursko Središće	Large discharge, c. 220 m^3/s; directly after the short-term discharge increase (Qvk 292 m^3/s on 7 Jun 2021).	Luka Božič, Aleksander Koren, Željko Šalamun, Katja Berden
9 Jun 2021	Mursko Središće–Dekanovec	Large discharge, c. 240 m^3/s; directly after the short-term discharge increase (Qvk 292 m^3/s on 7 Jun 2021).	Luka Božič, Aleksander Koren, Željko Šalamun, Tadej Törnar

Other surveys 2021

15 Jun 2021	Melinci gravel pit	-	Tadej Törnar, Katja Berden, Nevenka Mihevc
15 Jun 2021	Krapje gravel pit	-	Tadej Törnar, Katja Berden, Nevenka Mihevc
1 Jul 2021	Dobrovnik gravel pit	-	Luka Božič
9 Jun 2021	Križovec gravel pit	-	Luka Božič, Aleksander Koren, Željko Šalamun, Tadej Törnar

Riverbed surveys 2022

25 Apr 2022	Ceršak–Veržej	Small discharge, c. 120 m^3/s; similar as throughout the second half on the month.	Luka Božič, Monika Podgorelec, Željko Šalamun
26 Apr 2022	Veržej–Mursko Središće	Small discharge, c. 120 m^3/s; similar as throughout the second half on the month.	Luka Božič, Željko Šalamun, Tadej Törnar, Martina Vida
28 Apr 2022	Mursko Središće–Dekanovec	Medium discharge, c. 170 m^3/s; first day of the moderate discharge increase that lasted for the following 1,5 month (Qvk 249 m^3/s on 13 May 2022).	Luka Božič, Anja Cigan, Aleksander Koren, Monika Podgorelec, Željko Šalamun
6 Jun 2022	Ceršak–Veržej	Medium discharge, c. 170 m^3/s; similar as throughout the May and first week of June.	Luka Božič, Anja Cigan, Uroš Kur, Željko Šalamun

Date	Survey section/ Site	Hydrological conditions (where applicable)	Participants
7 Jun 2022	Veržej–Mursko Središće	Medium discharge, c. 190 m^3/s; similar as throughout the May and first week of June.	Luka Božič, Anja Cigan, Monika Podgorelec, Željko Šalamun
12 Jun 2022	Mursko Središće–Dekanovec	Medium discharge, c. 200 m^3/s; three days after the short-term discharge increase to 250 m^3/s on 8 Jun 2022).	Luka Božič, Anja Cigan, Željko Šalamun, Martina Vida

Other surveys 2022

14 Apr 2022 20 Apr 2022	Altergraba	-	Darko Lorenčič
14 May 2022	Lisjakova struga	-	Jasmina Filipič
20 Apr 2022 29 May 2022	Hrastika	-	Željko Šalamun
16 Apr 2022 08 May 2022	side arm at Bakovci	-	Matjaž Premzl
16 Apr 2022 08 May 2022	Stara Mura at Dokležovje	-	Monika Podgorelec
12 Apr 2022	Besnica	-	Luka Božič
16 Apr 2022 08 May 2022	Stara Mura (Veržej road–railway)	-	Monika Podgorelec
15 Apr 2022 11 May 2022	Stara Mura (Veržej railway–Zg. Krapje)	-	Željko Šalamun
12 Apr 2022 18 Apr 2022	Stara Mura (Zg. Krapje–Mota)	-	Jasmina Filipič
15 Apr 2022 20 May 2022	side arm Melinci–Tinekov brod	-	Tadej Törnar
18 Apr 2022 15 May 2022	side arm at Srednja Bistrica	-	Anja Cigan
18 Apr 2022 15 May 2022	Vučkova špica	-	Anja Cigan
12 Apr 2022 02 May 2022	Ščavnica River (Razkrižje–confluence with the Mura River)	-	Željko Šalamun, Jasmina Filipič
12 May 2022	Berek	-	Željko Šalamun, Anja Cigan, Martina Vida
16 Apr 2022 20 May 2022	Side arm at Dolnja Bistrica	-	Tadej Törnar
29 Apr 2022	side arm at Petišovci	-	Aleksander Koren, Larisa Koren

Date	Survey section/ Site	Hydrological conditions (where applicable)	Participants
11 Apr 2022	Side arm at Murska šuma (Benica)	-	Željko Šalamun, Martina Vida
11 Apr 2022	Zgornje Konjišče gravel pit	-	Robi Šiško
20 Apr 2022 29 May 2022	Murski Petrovci gravel pit	-	Željko Šalamun
20 Apr 2022 29 May 2022	Gradišče gravel pit	-	Željko Šalamun
20 Apr 2022 29 May 2022	Krog gravel pit	-	Željko Šalamun
20 Apr 2022 29 May 2022	Hrastje Mota gravel pit	-	Željko Šalamun
20 Apr 2022 29 May 2022	Vučja vas gravel pit	-	Željko Šalamun
15 Apr 2022 20 May 2022 1 Jul 2022	Melinci gravel pit	-	Tadej Törnar
15 Apr 2022 11 May 2022 1 Jul 2022	Zgornje Krapje gravel pit	-	Željko Šalamun
30 Jun 2022	Dobrovnik gravel pit	-	Luka Božič
11 Apr 2022	Petišovci gravel pit	-	Željko Šalamun, Martina Vida
12 Jun 2022	Križovec gravel pit	-	Luka Božič, Anja Cigan, Željko Šalamun, Martina Vida

C. - Data analysis and interpretation of results

The data collected were digitized and prepared in shapefile format with an attribute table as requested by the contracting authority. The content and form of the attribute table were determined at a meeting of bird experts and project partners and are uniform for all countries involved in the census of riverbed breeding bird species (Slovenia, Croatia, Serbia). The attribute table contains the following fields in the specified order: **Id, English species name, Scientific species name, GPS point** (in our case sequential number of the registration on orthophoto)**, Date, N_WGS84 (PHI), E_WGS84 (LAMBDA)**, River KM; Location – nearest settlement, **Number of individuals, Number of pairs, Breeding code**, Water conditions, Note, Photo, **Legit & det. / Expert name, Country, River**. Fields in bold are required.

The interpretation of the collected data (estimation of the population size) followed the criteria for a breeding pair/occupied territory, based on our previous experience and recommendations from abroad (Andretzke *et al.* 2005, Božič & Denac 2010, 2017). Special considerations for individual target species are as follows:

- Little Ringed Plover: Individuals registered were distinguished by sex whenever possible (usually possible in direct comparison of individuals; sexing of solitary birds sometimes difficult or unreliable) to facilitate the estimate of number of breeding pairs on separate gravel bars. Possible shifts of birds among different nesting locations in the period between the first and the second survey were taken into consideration when estimating the number of breeding pairs, especially in sections with numerous gravel bars in the immediate vicinity.

- Common Sandpiper: Behaviour and habitat at the location of registration were systematically recorded for all registered individuals to enable distinction of breeding birds from migrating individuals/flocks. Special importance was given to the intensively displaying individuals/pairs, or birds exhibiting territorial behaviour and/or giving alarm calls characteristic for parents attending chicks.

- Common Kingfisher: Kingfisher nest holes were defined as: (1) *occupied* (at the time of the census) in the case of observation of individual entering/exiting the nest hole, or the presence of excrement in the immediate vicinity or (2) *freshly excavated* (= assumed to be excavated in the season of observation) in the case of visible distinct footprints and fresh structure of the entrance part of the nesting tunnel, but without birds or excrements seen. For birds only observed while moving, the direction of flight was recorded (upstream/downstream, into/out of the side arm etc.). In general, registrations of individuals (without nest holes found) on locations ≥1,5 km apart were treated as separate pairs, while those ≤500 m apart were always regarded as belonging to the same pair.

- Sand Martin: The number of nesting burrows in large colonies of (>40 burrows) was determined by counting from a suitable stationary point, either on the same or the opposite river bank, or on the edge of the gravel pit. Only in small colonies number was estimated from the boat. In largest colonies with several hundred burrows or more, their number was determined from detailed set of photos, covering the entire area of nesting walls. The minimum number of breeding pairs was estimated using correction factors according to Kuhnen (1978), i.e. 0.5 for colonies with up to 50 burrows, 0.42 for colonies with 51–120 burrows, and 0.36 for colonies holding >120 burrows.

- Common Merganser: Population size was estimated on the basis of careful recording of the number of males and females on separate survey sections, taking into consideration the recorded movements of individuals (upstream/downstream) and females leading downy or partly feathered young.

Each data was assigned a breeding code according to EBCC (Keller *et al.* 2020, Slovenian version according to Mihelič *et al.* 2019); those actually used in this study are marked in bold:

0 **Species observed in breeding season outside possible nesting habitat**

1 **Species observed in breeding season in possible nesting habitat**

2 **Singing male(s) present (or breeding calls heard) in breeding season**

3 **Pair observed in suitable nesting habitat in breeding season**

4 Permanent territory presumed through registration of territorial behaviour (song, etc.) on at least two different days a week or more apart at the same place

5 **Courtship and display**

6 **Visiting probable nest site**

7 **Agitated behaviour or anxiety calls from adults**

8 Brood patch on adult examined in the hand

9 **Nest building or excavating nest-hole**

10 **Distraction-display or injury-feigning**

11 Used nest or eggshells found (occupied or laid within period of survey)

12 **Recently fledged young (nidicolous species) or downy young (nidifugous species)**

13 **Adults entering or leaving nest-site in circumstances indicating occupied nest (including high nests or nest holes the contents of which cannot be seen) or adult seen incubating**

14 **Adult carrying faecal sac or food for young**

15 **Nest containing eggs**

16 Nest with young seen or heard

For each recorded unmoving census unit of the target species with a breeding code ≥ 1, attribute table of the shapefile lists the type of structure the unit was using at the time of registration. The following types were distinguished: gravel/sand bar, shingle area exposed at low water level, side arm/channel, river bank, woody debris, rock in the riverbed, river island, outflow/inflow of the stream/side arm/channel, riprap, concrete breakwater/spillway and groyne. If a photograph of the structure concerned is included in the database submitted to the contracting authority, its serial number is indicated in the attribute table at corresponding census unit. For specimens that were observed exclusively in flight, the direction of flight (upstream, downstream) is indicated.

For graphical presentation of the breeding occurrence of target species, the kernel density tool in ArcGIS was used (Silverman 1986, ESRI 2009), based on all available point features (i.e. mapped registrations of presumably nesting individuals in both study years). In

kernel density, the value of smoothly curved surface fitted over each point is highest at the location of the point and diminishes with increasing distance from the point, reaching zero at the search radius distance (set at 750 m in our analysis) from the point (ESRI 2009). Population field value for the point was set to account for number of individuals underlying each point registration. For graphical presentation of numerical data box-and-whiskers diagrams, including data within 1.5 IQR, with median, minimum and maximum and outliers depicted are used.

D. - Trends

Trends were calculated using rtrim-package (Bogaart *et al.* 2018), which is a specially developed program for analysing ecological data with missing values, specifically time-series of counts using Poisson regression (Pannekoek & van Strien 2005). Rtrim-package was used in R (R Core Team 2013). The multiplicative overall slope (trend) represents the mean change over a period of time and was determined over the whole time period (2008–2022) for which the model was fitted. Plots of the overall slope, its 95% confidence band, the total population per time and their 95% confidence intervals were created. Based on values and confidence intervals (slope ± SE), trends are classified into one of the following categories: strong increase/decrease, moderate increase/decrease, and uncertain. As our dataset contained numerous zero counts, linear trend model with changepoints at all years with positive count data available, was used in the analysis (Pannekoek *et al.* 2005).

IV. RESULTS AND DISCUSSION

A. - General

During field surveys of the Mura riverbed between Ceršak (SLO) and Dekanovec (HR), a total of 321 and 371 data (census units) on the occurrence of four target species of birds and four other species of nature conservation importance were collected in the 2021 and 2022 season, respectively. Common Sandpiper was the most frequently recorded species, but a large part of the observations presumably comprises non-breeding individuals (without expressed nesting behaviour and/or outside suitable nesting habitat) that stopped in the study area on migration. Bee-eater was not recorded during the riverbed surveys. Details are given in table 2.

Datasets are stored in the following shp files, complement to this study: lifelineMDD_birds_2021, lifelineMDD_birds_2022, lifelineMDD_birds_2022_additional.

Table 2: Number of breeding data (census units) on four target breeding bird species and four other species of nature conservation collected during field surveys of the Mura riverbed and other locations (gravel pits, river side arms) in the territory of the Mura-Drava-Danube TBR in 2021 and 2022 (S1 – 1st survey, S2 – 2nd survey).

Species	2021			2022			Total overall
	S1	S2	Total	S1	S2	Total	
Little Ringed Plover	50	16	66	31	23	54	120
Common Sandpiper*	92	40	132	123	31	154	286
Common Kingfisher	18	37	55	29	44	73	128
Sand Martin	1	13	14	1	8	9	23
Bee-eater	0	0	0	0	0	0	0
Common Merganser	35	14	49	44	15	59	108
Black Stork	2	0	2	3	4	7	9
White-tailed Eagle	1	1	2	5	4	9	11
White-throated Dipper	1	0	1	3	3	6	7
Total	**200**	**121**	**321**	**239**	**132**	**371**	**692**

* If only breeding data are considered, the numbers are 43 and 35 in 2021, and 38 and 30 in 2022.

At gravel pits surveyed, eight data on the breeding of Sand Martin (4) and Bee-eater (4) were collected in each of the study years. In 2022 survey of the Mura river side arms, 20 data on occurrence of Kingfisher were obtained.

B. - Little Ringed Plover (*Charadrius dubius*)

Population size and dynamics

Little Ringed Plover population size in the Mura riverbed was estimated at 51–60 pairs with a linear breeding density of 0.5–0.6 pairs/km in 2021, and at 37–43 pairs with a density of 0.5–0.6 pairs/km in 2022. In both study years over two thirds of all pairs were recorded in the survey section 8, where linear density reached 1.9–2.1 and 1.3–1.4 pairs/km, respectively (Table 3).

Estimate for 2021 is the highest Little Ringed Plover population size recorded in the Mura riverbed since the first comprehensive census in 2008 (DOPPS *unpubl.*), while figures for 2022 are similar to the results from good years of the previous decade (Appendix 1).

Table 3: Number of individuals recorded, estimate of the number of breeding pairs and linear breeding density of Little Ringed Plover *Charadrius dubius* in survey sections of the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 and 2022.

Section	No. of individuals		Population size		Density (pair/km)	
	S1	S2	min	max	min	max
2021						
Section 1	0	0	0	0	0.0	0.0
Section 2	1	1	1	1	0.1	0.1
Section 3	0	0	0	0	0.0	0.0
Section 4	1	0	0	0	0.0	0.0
Section 5	18	3	9	11	0.9	1.2
Section 6	0	0	0	0	0.0	0.0
Section 7	7	4	3	4	0.3	0.3
Section 8	77	31	38	44	1.9	2.1
Total	**104**	**39**	**51**	**60**	**0.5**	**0.6**
2022						
Section 1	0	0	0	0	0.0	0.0
Section 2	2	0	1	2	0.1	0.1
Section 3	0	0	0	0	0.0	0.0
Section 4	0	0	0	0	0.0	0.0
Section 5	10	7	6	7	0.6	0.7
Section 6	0	0	0	0	0.0	0.0
Section 7	8	2	4	5	0.3	0.4
Section 8	39	46	26	29	1.3	1.4
Total	**59**	**55**	**37**	**43**	**0.4**	**0.5**

In both study years breeding pairs occurred in the same four survey sections. Population decrease between 2021 and 2022 was fairly consistent in the survey sections with majority of breeding pairs (Table 4).

Prior to 2014, the relative importance of last survey section for the species was lower (up to 50 % of the total population there). In 2008, the number of breeding pairs was the highest on survey section 5 of the inner Mura with linear breeding density of 1.6–1.8 pairs/km.

Table 4: Difference in estimated number of breeding pairs of Little Ringed Plover *Charadrius dubius* in survey sections of the Mura riverbed between 2021 and 2022.

Section	DIF (No. of pairs)		DIFF (%)	
	min	max	min	max
Section 1	0	0	-	-
Section 2	0	+1	0.0	+100.0
Section 3	0	0	-	-
Section 4	0	0	-	-
Section 5	–4	–5	–40.0	–41.7
Section 6	0	0	-	-
Section 7	+1	+1	+25.0	+33.3
Section 8	–11	–14	–29.7	–32.6
Total	**–14**	**–17**	**–27.5**	**–28.3**

Distribution

With the exception of single location on the upper Mura, Little Ringed Plover was distributed only along the lower half of the study area in 2021 and 2022. There, two distinct areas of the species occurrence can be distinguished: (1) between Veržej and the SLO/HR border near Dolnja Bistrica on the inner Mura, (2) between Mursko Središće and Dekanovec on the lower Mura. Only at the population stronghold between Križovec and Dekanovec in the latter area was the distribution of Little Ringed Plover more or less continuous, while up to several kilometres long gaps existed elsewhere (Figure 4). Despite population decrease, distribution of the species remained practically unchanged between 2021 and 2022.

Moreover, the general distribution pattern of the species has not changed significantly compared to the previous comprehensive censuses of the species. The most obvious difference is the occasional registrations of Little Ringed Plover on the sections 3 and 6 during previous surveys, where it was absent in 2021 and 2022 (Appendix 2).

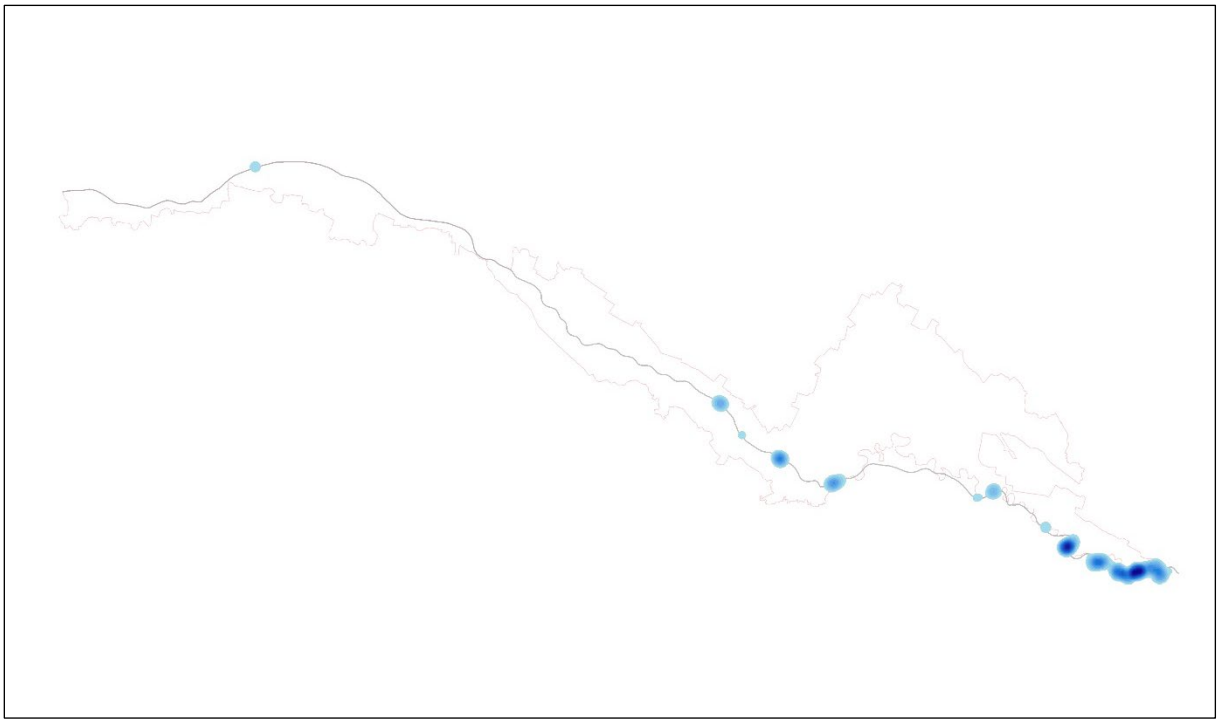

Figure 4: Density of Little Ringed Plover *Charadrius dubius* in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) after the kernel method, based on registrations of presumably nesting individuals during the 2021 and 2022 censuses (N = 119 registrations of 256 ind.). The darker the shade of blue colour, the greater the density in that area.

Habitat

Without a single exception, all Little Ringed Plover census units (120 in total) were registered on shingle deposits; 119 on gravel bars (either mid-channel bars or point bars) and only one on shingle area exposed at low water level in the riverbed, not suitable for nesting. Thus, the breeding of the species in Mura riverbed depends exclusively on the availability of suitable gravel bars.

Out of 94 gravel bars mapped in the Mura riverbed, 41 (43.6 % of all) were occupied by Little Ringed Plover breeding pairs in at least one of the study years: 36 (38.3 %) in 2021, 28 (29.8 %) in 2022 and 23 (24.5 %) in both years. On most gravel bars occupied 1–2 pairs nested, while more were recorded at only a few most suitable sites on lower Mura (Figure 5).

The isolated breeding locations on upper Mura are result of recent river restoration projects on the Austrian side, implemented along sections where otherwise no suitable habitat exists due to anthropogenic interventions in the past, especially riverbed channelization by construction of rock ripraps.

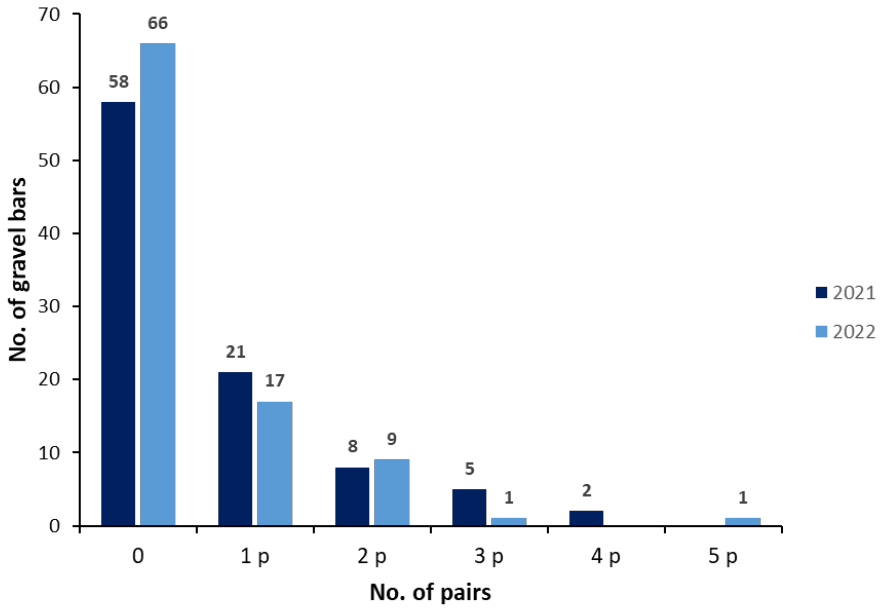

Figure 5: Number of gravel bars occupied by a given number of Little Ringed Plover *Charadrius dubius* breeding pairs in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 and 2022 (N = 94 gravel bars).

Trend

The apparently moderate long-term population increase was sporadically interrupted by individual years with substantially lower number of breeding pairs. The multiplicative overall trend of Little Ringed Plover in the 2008–2022 period was estimated as uncertain (multiplicative overall slope imputed ± SE 1.0199 ± 0.0181, $P < 0.01$) (Figure 6).

Variations in numbers detected over time can probably be explained by changes in surface area and proportions of the main habitats in the riverbed, especially availability of suitable gravel bars. Gravel bars are the result of erosion and sedimentation processes and are very dynamic systems characterized by a high proportion of deposits without or sparse vegetation cover. Their succession is, among others, related to the duration and frequency of flooding which tend to vary between years (Gilvear *et al.* 2008). Consequently, reduction in shingle area due to encroachment of woody vegetation result in a decline of breeding pairs, while the reverse triggered a population recovery (see Božič & Denac 2017).

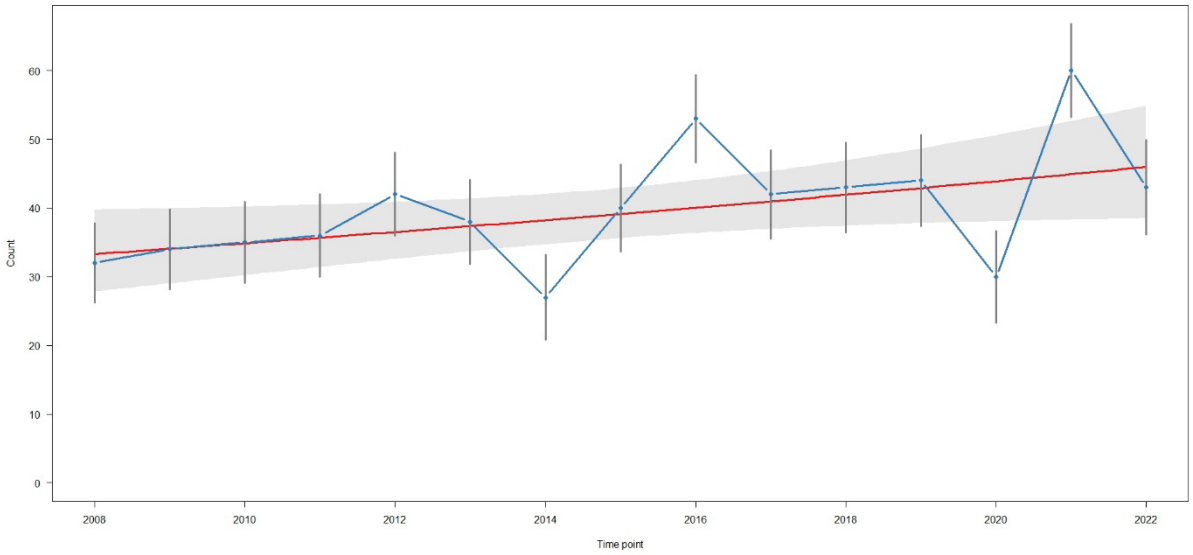

Figure 6: Multiplicative overall slope, its 95% confidence band, the total population (y axis) in individual years (x axis) and their 95% confidence intervals for Little Ringed Plover *Charadrius dubius* in the 2008–2022 period.

C. - Common Sandpiper (*Actitis hypoleucos*)

Population size and dynamics

Common Sandpiper population size in the Mura riverbed was estimated at 35–41 pairs with a linear breeding density of 0.4 pairs/km in 2021, and at 32–38 pairs with a density of 0.3–0.4 pairs/km in 2022. In both study years over half of all pairs were recorded in the survey section 8, where linear density reached 0.9–1.1 and 0.8–1.4 pairs/km, respectively (Table 5).

Population size estimates for both study years are the highest recorded in the Mura riverbed since the first comprehensive census in 2008 (DOPPS *unpubl.*). From the previous surveys only figures for 2016 are similar, while those obtained earlier are substantially lower (Appendix 3).

Table 5 (p. 22): Number of individuals recorded, estimate of the number of breeding pairs and linear breeding density of Common Sandpiper *Actitis hypoleucos* in survey sections of the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 and 2022.

Section	No. of individuals		Population size		Density (pair/km)	
	S1	S2	min	max	min	max
2021						
Section 1	8	5	3	3	0.3	0.3
Section 2	11	3	2	2	0.1	0.1
Section 3	14	3	2	2	0.3	0.3
Section 4	6	3	0	0	0.0	0.0
Section 5	11	8	3	4	0.3	0.4
Section 6	5	1	2	2	0.6	0.6
Section 7	38	12	4	5	0.3	0.4
Section 8	68	32	19	23	0.9	1.1
Total	**161**	**67**	**35**	**41**	**0.4**	**0.4**
2022						
Section 1	9	5	2	2	0.2	0.2
Section 2	9	2	1	1	0.1	0.1
Section 3	14	3	2	2	0.3	0.3
Section 4	8	0	0	0	0.0	0.0
Section 5	31	7	7	8	0.7	0.8
Section 6	11	0	0	0	0.0	0.0
Section 7	37	2	4	5	0.3	0.4
Section 8	80	32	16	20	0.8	1.0
Total	**199**	**51**	**32**	**38**	**0.3**	**0.4**

In 2021, breeding pairs were recorded in all survey sections with the exception of section 4 (seven sections occupied), while in 2022 the Common Sandpiper did not breed in section 6 as well (six sections occupied). The population change between 2021 and 2022 was small overall, as well as at the level of two survey sections with the most breeding pairs. A more than two-fold increase on section 5, to numbers similar to those in the pre-2012 period is remarkable (Table 6).

As with Little Ringed Plover, the number of breeding pairs in 2008 was highest on survey section 5, while the relative importance of last survey section for the species was lower (c. one third of the total population there).

Table 6: Difference in estimated number of breeding pairs of Common Sandpiper *Actitis hypoleucos* in survey sections of the Mura riverbed between 2021 and 2022.

Section	DIF (No. of pairs)		DIFF (%)	
	min	max	min	max
Section 1	−1	−1	−33.3	−33.3
Section 2	−1	−1	−50.0	−50.0
Section 3	0	0	0.0	0.0
Section 4	0	0	-	-
Section 5	+4	+4	+100.0	+133.3
Section 6	−2	−2	−100.0	−100.0
Section 7	0	0	0.0	0.0
Section 8	−1	−2	−5.9	−9.1
Total	**−1**	**−2**	**−3.0**	**−5.0**

Distribution

Common Sandpiper was somewhat more widely distributed than Little Ringed Plover in 2021 and 2022. Range along the lower half of the study area was very similar to the latter, but with shorter gaps (2–4 km), making distribution between Veržej and Dekanovec fairly continuous. On upper Mura breeding pairs were recorded at 4–5 sites, separated 4–12 km from the nearest neighbouring nesting location. However, this species was also completely absent from the upper part of the inner Mura (Figure 7). Distribution of Common Sandpiper changed only slightly between 2021 and 2022.

The general distribution pattern of the species has not changed significantly compared to the previous comprehensive censuses of the species. In the past, breeding pairs were occasionally registered also on the section 4, thus extending the distribution area a trifle upstream on the inner Mura, where it was absent in 2021 and 2022 (Appendix 4).

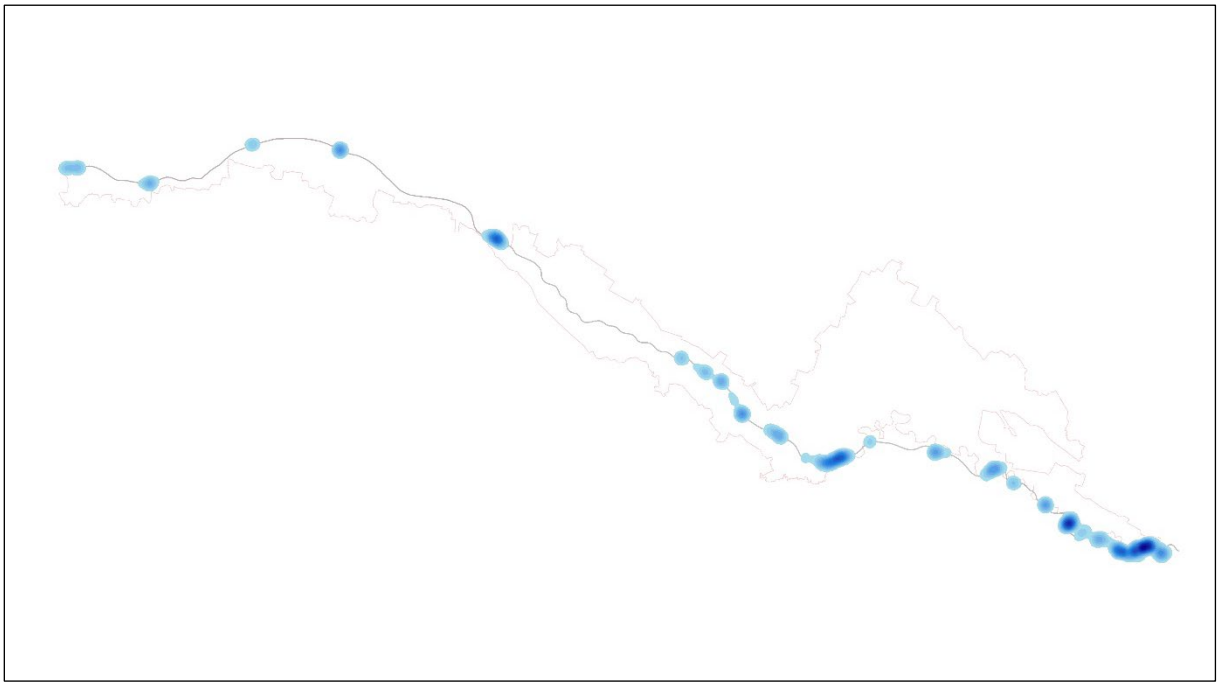

Figure 7: Density of Common Sandpiper *Actitis hypoleucos* in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) after the kernel method, based on registrations of presumably nesting individuals during the 2021 and 2022 censuses (N = 146 registrations of 251 ind.). The darker the shade of blue colour, the greater the density in that area.

Habitat

Most of the Common Sandpiper pairs (81 % in 2021 and 89 % in 2022) in the study area selected gravel bars for breeding (either mid-channel bars or point bars). Furthermore, small proportion of pairs nested in other types of riverine habitats such as side arms, river banks and artificial structures with shingle surface or woody debris (Figure 8). However, also for this species its breeding in the Mura riverbed can be considered as highly dependent on the availability of suitable gravel bars.

Out of 94 gravel bars mapped in the Mura riverbed, 40 (42.6 % of all) were occupied by Common Sandpiper breeding pairs in at least one of the study years, 29 (30.9 %) in one of them, either 2021 or 2022, and 18 (19.1 %) in both years. On most gravel bars occupied one pair nested, while two pairs on a single gravel bar were recorded at only four (2021) and five (2022) most suitable sites.

Isolated nesting in at least three locations on upper Mura occurred in areas where river restoration projects were carried out recently on the Austrian side of the riverbed.

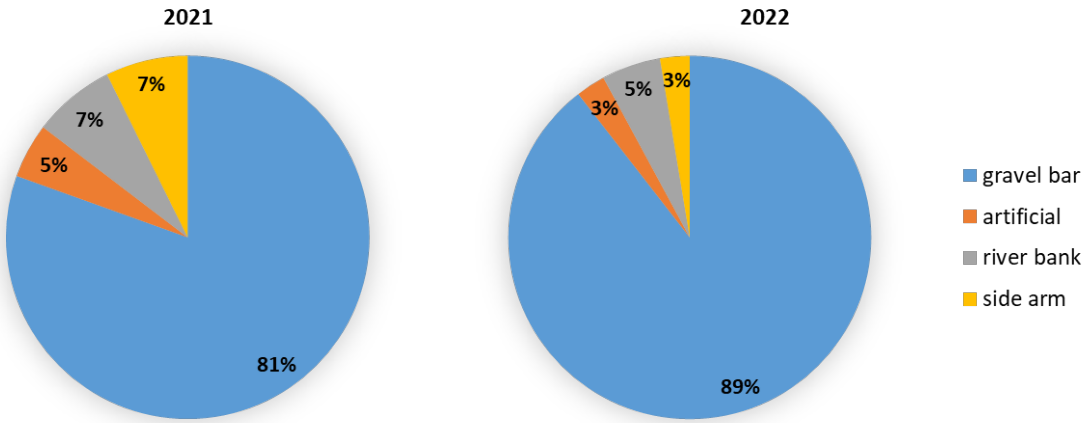

Figure 8: Types of habitat selected by Common Sandpiper *Actitis hypoleucos* breeding pairs in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 and 2022 (N = 41 pairs in 2021 and 38 pairs in 2022).

Trend

After moderate numbers recorded in the surveys in 2008 and 2010, the number of breeding pairs declined substantially in the first half of the previous decade, followed by remarkable recovery in 2016, characterized by more than doubling of population size, which then remained at a similar level in all subsequent surveys. The multiplicative overall trend of Common Sandpiper in the 2008–2022 period was estimated as moderate increase (multiplicative overall slope imputed ± SE 1.0461 ± 0.0167 $P < 0.01$) (Figure 9).

It seems that Common Sandpiper decline noted in first years after the start of regular surveys, was just a continuation of a long-term negative trend as the total breeding population estimate of the Important Bird Area (IBA) Mura in the late 1990s, although based on expert opinion rather than comprehensive census, was substantially higher (Bračko 2000). This is consistent with the decreasing European population trend in the past 13 years, more pronounced in the EU countries (BirdLife International 2021). Some evidence exists that depletion of the Common Sandpiper populations is at least partly due to declining adult survival rates, related to changing conditions in wintering and migratory stopover areas, i.e. factors largely operating outside its European breeding grounds (Pearce-Higgins *et al.* 2009). Population recovery recorded in the second half of the previous decade, and apparently continuing into the study period, corresponds to the similar population development on the Slovenian lowland part of the Drava River (DOPPS *unpubl.*).

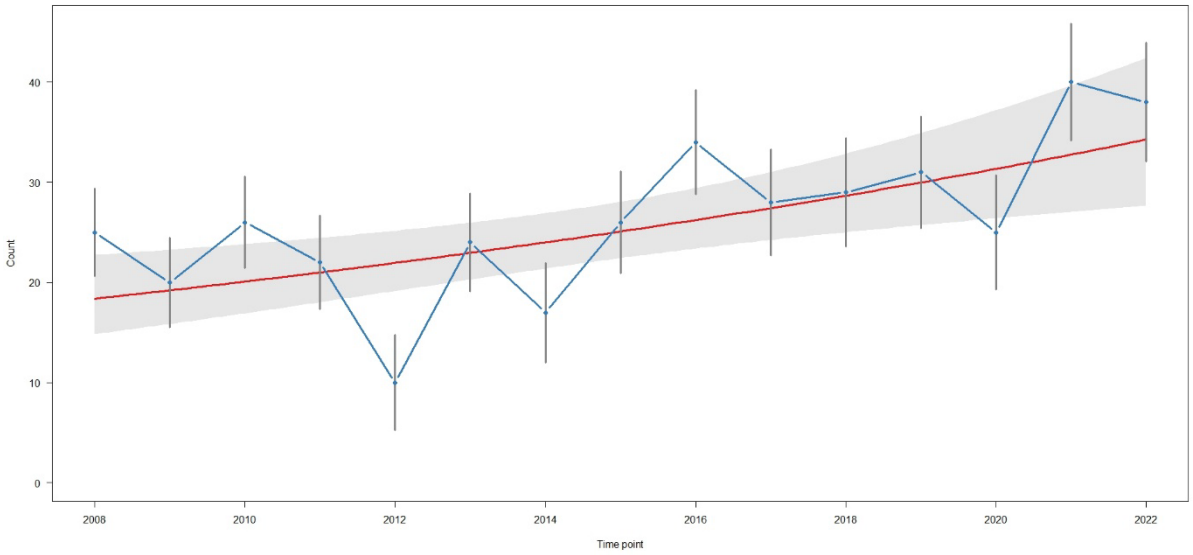

Figure 9: Multiplicative overall slope, its 95% confidence band, the total population (y axis) in individual years (x axis) and their 95% confidence intervals for Common Sandpiper *Actitis hypoleucos* in the 2008–2022 period.

D. - Gravel bars in the studied area of the Mura riverbed

Based on the breeding habitat preferences of Little Ringed Plover and Common Sandpiper described in previous chapters, a clear link between availability of suitable gravel bars and number of breeding pairs on separate survey sections can be established, demonstrating dependence of the two indicator species of the riverine ecosystem on this type of habitat (Figure 10).

It must be emphasized that gravel bars were not classified further according to other important characteristics (i.e. the existence and proportions of their habitat types, relative height etc.), so some differences between the two species have likely remain undiscovered in this study. While preference of Little Ringed Plover for largely unvegetated or sparsely vegetated gravel bars is well known, habitat requirements of Common Sandpiper are more complex. Breeding habitat of the latter species is at least partly comprised of areas with denser herbaceous vegetation as well (cf. Frühauf & Dvorak 1996, Elas & Meissner 2014). Preference of Common Sandpiper for slightly more advanced succession stages also means that it is a later colonizer of newly deposited areas in river systems, as some time is needed before suitable habitats are progressively formed (Arlettaz *et al.* 2012).

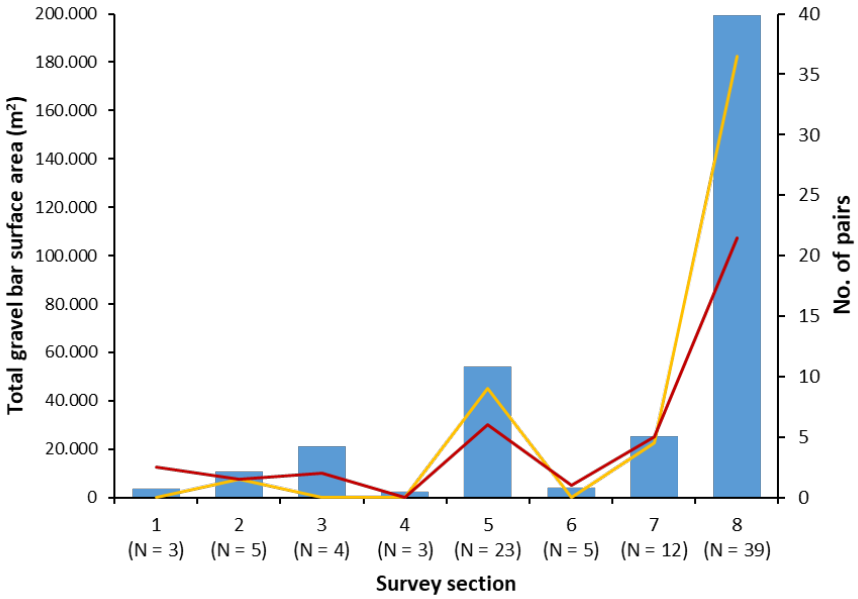

Figure 10: Total gravel bar surface area (blue bars) and number of Little Ringed Plover *Charadrius dubius* (yellow line) and Common Sandpiper *Actitis hypoleucos* (red line) breeding pairs in survey sections (1–8) of the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 and 2022 (N = No. of gravel bars).

However, among numerous gravel bars in the Mura riverbed, only some of them are suitable for breeding of Little Ringed Plover and Common Sandpiper. One important feature of gravel bars, related to the occurrence of indicator species is their surface area. It was demonstrated that both species mostly select larger gravel bars for breeding.

The surface area of gravel bars mapped in the Mura riverbed (N = 94) range from 142 to 21,652 m^2 (median = 1301 m^2). Median size of gravel bar occupied by breeding Little Ringed Plovers only either in 2021 or 2022, is 4210 m^2 and 4549 m^2, respectively, while median of those occupied in both study years is 4660 m^2 (N = 36, 28 and 23, range 308–21,652 m^2). The same figures for gravel bar occupied by breeding Common Sandpipers are: 2021 – 4438 m^2 (N = 29, range 392–18,701 m^2), 2022 – 4028 m^2 (N = 29, range 383–18,701 m^2) and both years – 5501 m^2 (N = 18, range 1007–18,701 m^2). Gravel bars occupied simultaneously by Little Ringed Plover and Common Sandpiper breeding pairs in the studied period are on average the largest, with median values as follows: 2021 – 5760 m^2 (N = 19, range 951–16,636 m^2), 2022 – 5760 m^2 (N = 15, range 383–16,636 m^2) and both years –7607 m^2 (N = 11, range 1221–16,636 m^2) (Figure 11).

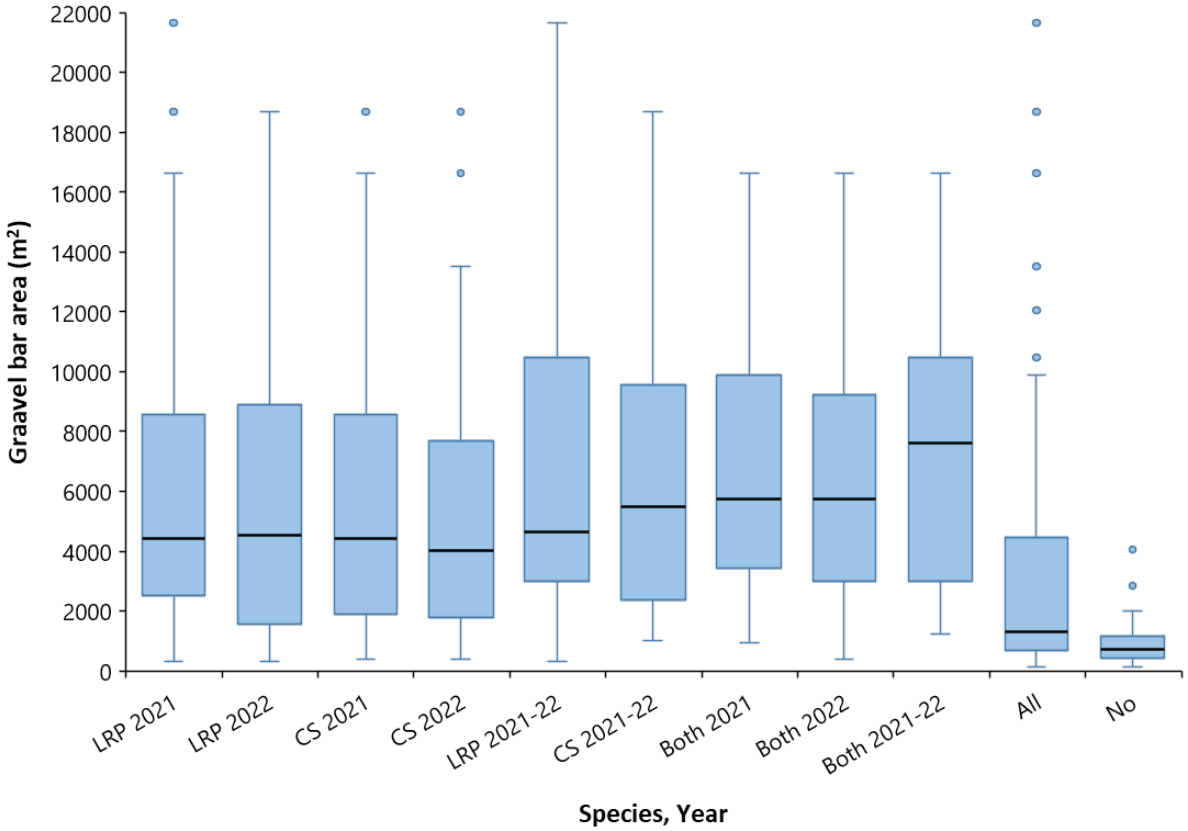

Figure 11: Surface area of gravel bars with different occupancy by Little Ringed Plover *Charadrius dubius* (LRP) or/and Common Sandpiper (CS) *Actitis hypoleucos* breeding pairs in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 and 2022 (All – all gravel bars, N = 94; No – gravel bars where neither of these two species was recorded in the period studied, N = 38).

Gravel bar size is not only important in terms of occupancy probability, but also has significant effect on the number of Little Ringed Plover and Common Sandpiper pairs nesting on it. The larger the surface area of the gravel bar, the more pairs can use it as a nest-site (Figure 12).

The following explanations for relationships described seem plausible: (1) only on the sufficiently large gravel bars enough space is available that several pairs of territorial species/two species with presumable high niche overlap can coexist; (2) probability for development of diverse mosaic of early successional stages interspersed with shingle areas, an optimal breeding habitat of both species is higher on large gravel bars.

A few examples of such extensive gravel bars in the study area are shown (Figure 13). The list of all gravel bars mapped with details on breeding pairs is given in Appendix 5.

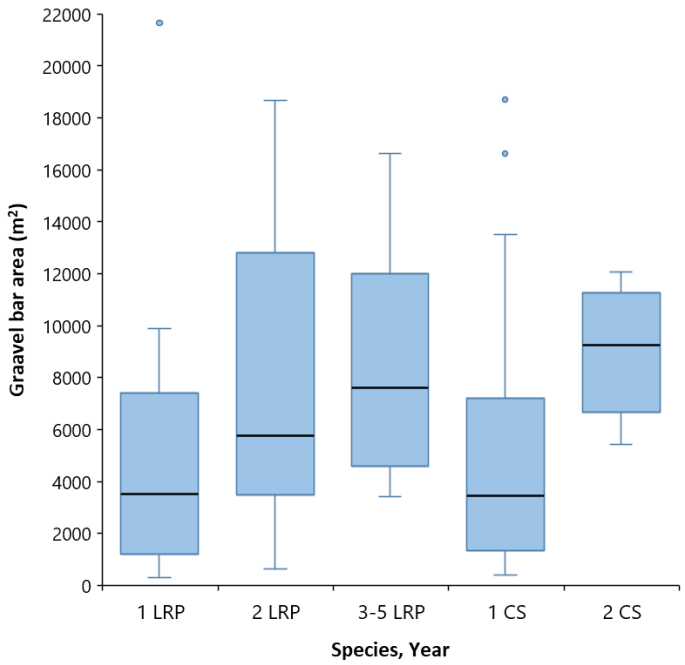

Figure 12: Surface area of gravel bars with different number of Little Ringed Plover *Charadrius dubius* (LRP) and Common Sandpiper (CS) *Actitis hypoleucos* breeding pairs in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 and 2022 (N = 122, data for both study years combined).

On some gravel bars in the Mura riverbed studied, traces of exploitative/leisure activities that clearly took place during or shortly before the breeding season of target species were encountered. The following activities were identified: gravel excavation, off-road driving and prolonged recreational use (i.e. picnic, fireplace, boat stop) (Figure 14).

These anthropogenic activities took place on at least 11 gravel bars (11.7% of all), seven in 2021, eight in 2022 and on four in both study years. Details are given in Appendix 5.

Some of the key nesting locations of Little Ringed Plover and Common Sandpiper in different survey sections were affected, including a large gravel bar on lower Mura severely degraded by combination of all three types of activities. Two pairs of Common Sandpiper nested there in 2021, but none were recorded in 2022. The species is known to be sensitive to human-related disturbances, caused by various forms of land use along river corridors (off-road driving, boating, camping, fishing, etc.), which are often listed among most important threats to local populations in some parts of Central Europe (Yalden 1992, Bezzel *et al.* 1995, Lengyel 1998, Schödl 2003, Bauer *et al.* 2005).

At the current level, the situation is not yet alarming, but all kinds of anthropogenic activities in the riverbed should be regulated appropriately in the future.

Figure 13: A few examples of extensive gravel bars in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) – optimal nesting habitat of several Little Ringed Plover *Charadrius dubius* and Common Sandpiper *Actitis hypoleucos* pairs.

Figure 14: Traces of anthropogenic activities, encountered on gravel bars during surveys in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR).

E. - Common Kingfisher (*Alcedo atthis*)

Population size and dynamics

Common Kingfisher population size in the Mura riverbed was estimated at 22–32 pairs with a linear breeding density of 0.2–0.3 pairs/km in 2021, and at 28–36 pairs with a density of 0.3–0.4 pairs/km in 2022. Compared to the previous two species, registrations were more evenly distributed along the study area. In both study years the largest proportion of pairs (over one third of the riverbed breeding population) was recorded in the survey section 8, where linear density reached 0.5–0.6 pairs/km. In 2022 however, the calculated linear densities were similar or even higher on survey sections 5 and 6, although these are substantially shorter (Table 7).

Estimates for 2022 are very similar to the so far highest Kingfisher population size, recorded in the Mura riverbed in 2020, while figures for 2021 are similar to the results of previous surveys in good years (Appendix 6).

Table 7: Number of individuals recorded, estimate of the number of breeding pairs and linear breeding density of Common Kingfisher *Alcedo atthis* in survey sections of the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 and 2022.

Section	No. of individuals		Population size		Density (pair/km)	
	S1	S2	min	max	min	max
2021						
Section 1	0	3	2	3	0.2	0.3
Section 2	1	5	3	5	0.2	0.3
Section 3	1	2	2	2	0.3	0.3
Section 4	2	0	1	2	0.1	0.2
Section 5	0	0	1	2	0.1	0.2
Section 6	1	0	1	1	0.3	0.3
Section 7	4	5	2	4	0.2	0.3
Section 8	3	16	10	13	0.5	0.6
Total	**12**	**31**	**22**	**32**	**0.2**	**0.3**
2022						
Section 1	2	6	3	3	0.3	0.3
Section 2	2	1	1	2	0.1	0.1
Section 3	1	1	1	2	0.2	0.3
Section 4	0	1	3	3	0.2	0.2
Section 5	4	5	4	5	0.4	0.5
Section 6	0	1	2	3	0.6	0.9
Section 7	3	8	4	5	0.3	0.4
Section 8	4	12	10	13	0.5	0.6
Total	**16**	**35**	**28**	**36**	**0.3**	**0.4**

In the study period, as well as in 2020, breeding pairs were recorded in all survey sections of the Mura riverbed. This was not the case in preceding surveys when also in good years one section was typically without Kingfisher registrations, most often the section 3. The population change between 2021 and 2022 was moderate overall, however there was no difference on the most important section. The main part of population increase from 2021 was due to changes on inner Mura, while only on upper Mura numbers decreased (Table 8). On the other hand, difference between 2020 and 2022 are negligible, also on the level of separate survey sections.

In all comprehensive riverbed surveys carried out to date, the number of breeding pairs was highest on section 8, while the relative importance of other survey section tended to vary between years.

Table 8: Difference in estimated number of breeding pairs of Common Kingfisher *Alcedo atthis* in survey sections of the Mura riverbed between 2021 and 2022.

Section	DIFF (No. of pairs)		DIFF (%)	
	min	max	min	max
Section 1	0	+1	0.0	+50.0
Section 2	–2	–3	–60.0	–66.7
Section 3	0	–1	0.0	–50.0
Section 4	+1	+2	+50.0	+200.0
Section 5	+3	+3	+150.0	+300.0
Section 6	+1	+2	+100.0	+200.0
Section 7	+1	+2	+25.0	+100.0
Section 8	0	0	0.0	0.0
Total	**+4**	**+6**	**+12.5**	**+27.3**

It should be emphasized that, unlike the previous two target species, the figures given above does not constitute estimates of the total number of breeding pairs in the area of the Mura River studied as the Kingfisher distribution is not entirely limited to the main river channel.

Additional survey of different localities outside the main river channel in 2022, resulted in 18 registrations of 19 individuals, all of them along the side arms (10 locations). Further two registrations (3 ind.) were obtained from random observations (Figure 15). Common Kingfisher population size on side arms surveyed in 2022 was estimated at 9–13 pairs (Table 9). The species was not recorded on any of the gravel pits surveyed.

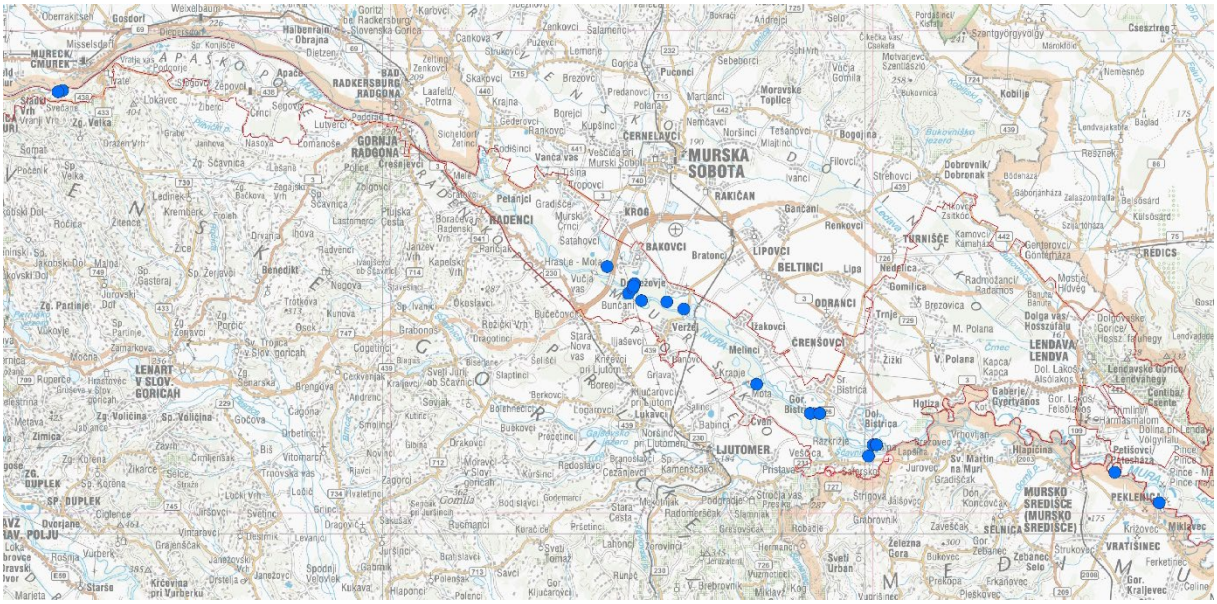

Figure 15: Locations of Common Kingfisher *Alcedo atthis* individuals, registered in additional survey of different localities outside the main river channel in 2022.

Table 9: Number of individuals recorded and estimate of the number of breeding pairs of Common Kingfisher *Alcedo atthis* on side arms of the Mura River surveyed in 2022, with the corresponding survey sections indicated. Only sites with the species registered are listed.

Site	Survey section	No. of individuals		Population size	
		S1	S2	min	max
Altergraba	1	1	1	1	1
side arm at Krog*	4	1	-	1	1
side arm at Bakovci	4	2	1	1	1
Stara Mura at Dokležovje	4	1	1	1	1
Besnica	4	2	-	1	2
Stara Mura (Zg. Krapje–Mota)	5	1	0	0	1
side arm at Srednja Bistrica	5	1	1	1	1
Vučkova špica	5	1	0	0	1
Ščavnica River (Razkrižje–Mura)	6	0	1	0	1
side arm at Dolnja Bistrica	6	2	1	1	1
side arm at Petišovci	8	2	-	1	1
side arm at Murska šuma (Benica)*	8	2	-	1	1
Total	**-**	**16**	**6**	**9**	**13**

By including these additional pairs, the total 2022 population of the Mura River area studied increases by one third, from 28–36 pairs to 37–49 pairs, and the overall linear breeding density rises to 0.4–0.5 pairs/km of the river. The increase is most evident on the inner Mura (Table 10).

Table 10: Total population size, difference in estimated number of breeding pairs (increase in %) and linear breeding density of Common Kingfisher *Alcedo atthis* in survey sections of the Mura River area studied in 2022, with results of the side arms survey taken into account.

Section	Population size		DIFF (%)		Density (pair/km)	
	min	max	min	max	min	max
Section 1	4	4	33.3	33.3	0.4	0.4
Section 2	1	2	0.0	0.0	0.1	0.1
Section 3	1	2	0.0	0.0	0.2	0.3
Section 4	7	8	133.3	166.7	0.5	0.6
Section 5	5	8	25.0	60.0	0.5	0.8
Section 6	3	5	50.0	66.7	0.9	1.5
Section 7	4	5	0.0	0.0	0.3	0.4
Section 8	12	15	20.0	15.4	0.6	0.7
Total	**37**	**49**	**32.1**	**36.1**	**0.4**	**0.5**

Distribution

Kingfisher occurred in low densities along the entire study area, with one somewhat longer (>7 km, sometimes >10 km) distribution gap at each upper and inner Mura in both years. Combined registrations from 2021 and 2022 riverbed surveys show distribution pattern without gaps significantly longer than 2 km along the entire riverbed downstream of Veržej road bridge, while a few exist on the upstream part of the study area. However, gaps on the inner Mura are largely obscured if the data from additional survey of side arms is included on the map (Figure 16). Overall distribution of Kingfisher changed only slightly between 2021 and 2022.

The general distribution pattern of the species has not changed significantly compared to the previous comprehensive censuses of the species. In some of the good years, distribution gap on the inner Mura was non-existent, while it was always evident on different sections (one or more) of the upper Mura (Appendix 7).

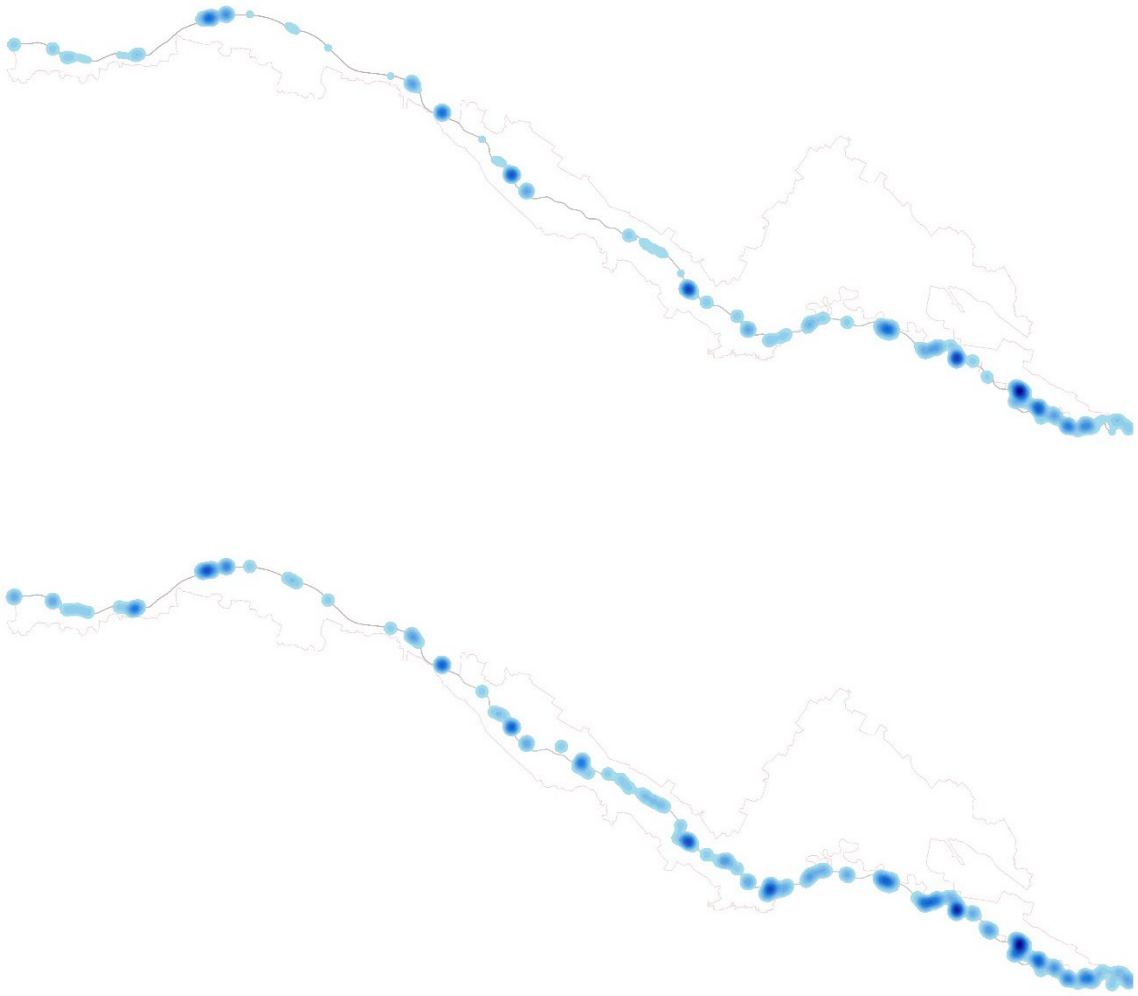

Figure 16: Density of Common Kingfisher *Alcedo atthis* in the area of the Mura River between Ceršak (SLO) and Dekanovec (HR) after the kernel method, based on registrations of presumably nesting individuals – (1) only data from riverbed surveys in 2021 and 2022 censuses used (N = 128 registrations) (above), and (2) data from additional survey of side arms in 2022 included (N = 148 registrations) (below). The darker the shade of blue colour, the greater the density in that area.

Habitat

In general, Kingfisher inhabits flowing or still water bodies, rich in fish of suitable size and with overhanging bank vegetation that provides hunting perches. For nesting, it requires vertical walls, located over or near water, comprised of fine-grained, usually sandy material, in which it excavates a 50–90 cm long nesting tunnel. Kingfisher most often breeds along rivers and large streams with at least partly preserved natural banks and is regarded a characteristic indicator species of natural river dynamics and alluvial riverine habitats (Hagemeier & Blair 1997, Bauer *et al.* 2005, Woodall 2020).

In the study period, 58 data on occupied/freshly excavated Kingfisher nest holes were collected (27 in 2021 and 31 in 2022) on 31 locations (nest-sites) along the Mura riverbed, including side arms surveyed (Figure 17). Fifteen nest-sites (48.4%) were active in both study years. According to the survey sections, nest-sites are distributed as follows: Section 1 – 1, Section 2 – 2, Section 3 – 2, Section 4 – 3, Section 5 – 2, Section 6 – 2, Section 7 – 2 and Section 8 – 17. Thus, more than half of all nesting locations (54,8 %) were encountered on the Section 8, while the remaining was divided in small percentages (3,2–9,7 %) among the other survey sections (Figure 18).

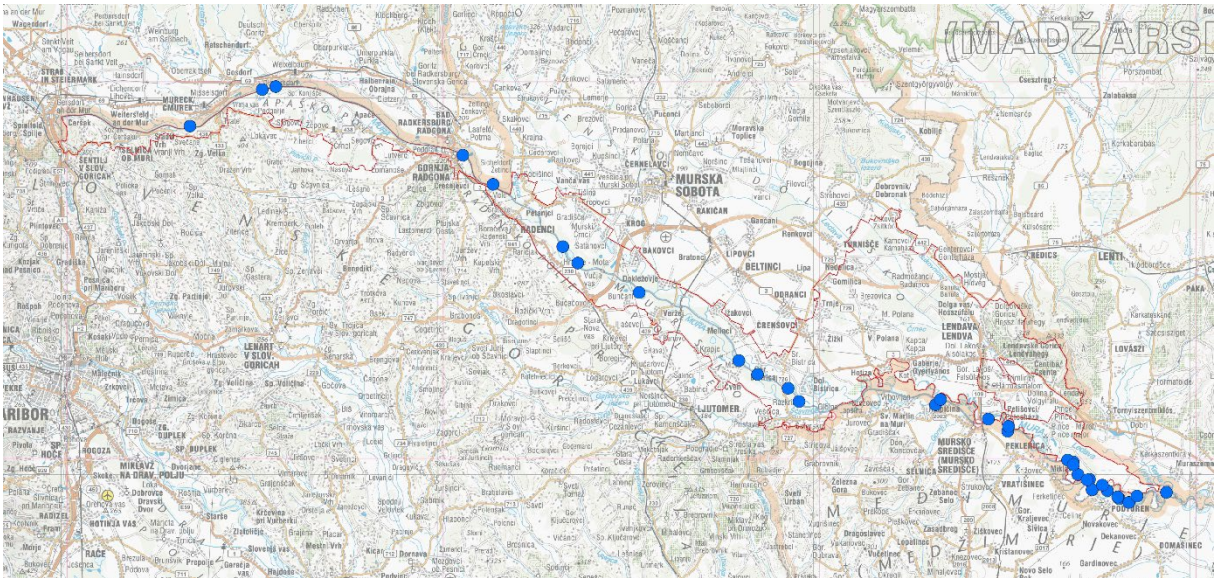

Figure 17: Nesting locations (nest-sites) of Common Kingfisher *Alcedo atthis*, encountered in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR), including side arms surveyed (N = 31, data for both study years combined)

On lower Mura, the majority of Kingfisher nest holes were excavated in long stretches of natural river banks (often several hundred metres), while on the inner Mura most were found in rather short areas of river bank with an exposed steep surface of suitable alluvial soil (a few tens of meters at most). On the upper and inner Mura, nest-sites in long stretches of natural river banks existed only in areas where recent river restoration

projects, focused on removal of dysfunctional/unnecessary rock ripraps were carried out (Figure 18 and 20).

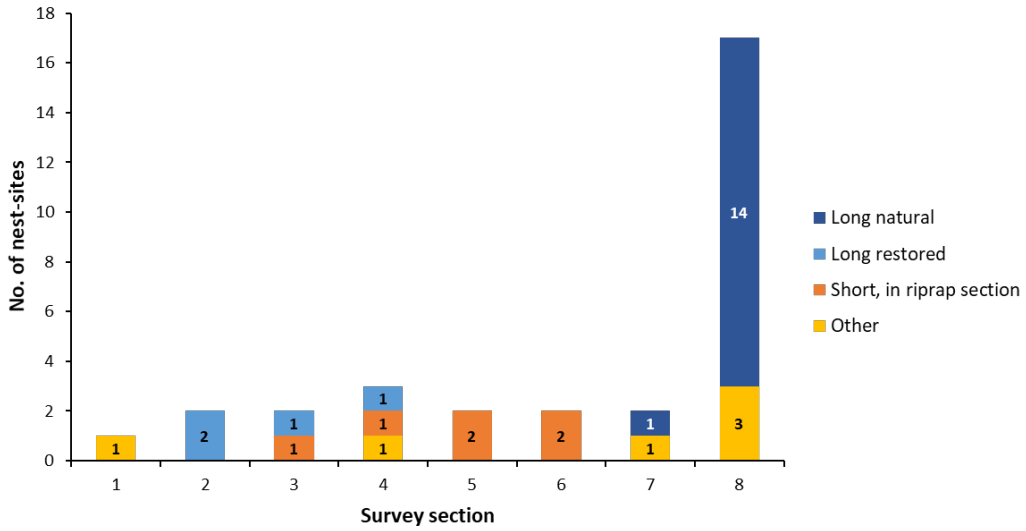

Figure 18: Number of Common Kingfisher *Alcedo atthis* nest-sites encountered in survey sections (1–8) of the Mura riverbed between Ceršak (SLO) and Dekanovec (HR), presented according to the type of river bank (N = 31, data for both study years combined).

Kingfisher nest-sites were located in the following places in the riverbed: (1) outer (concave) banks of the main river channel, (2) inner (convex) or straight banks of the main river channel, (3) side arms and (4) river island (Figure 19 and 20).

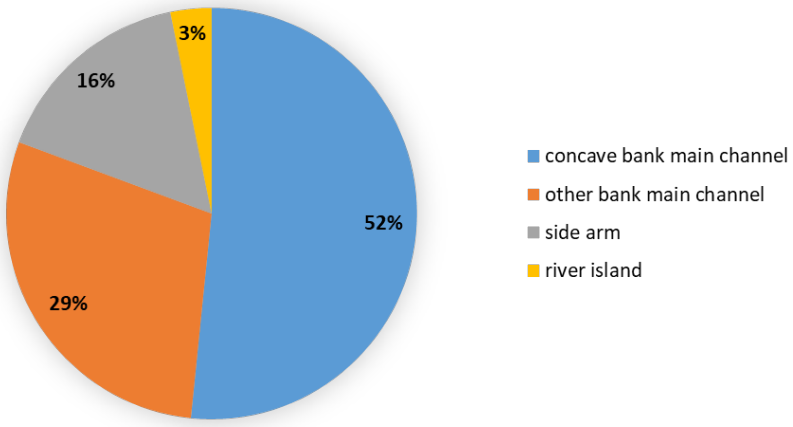

Figure 19: Locations of Common Kingfisher *Alcedo atthis* nest-sites in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) (N = 31, data for both study years combined).

Figure 20: Kingfisher *Alcedo atthis* nest-sites in the Mura riverbed; long natural outer bank of the main river channel on lower Mura (top left), restored sections on upper (top right) and inner Mura (middle left), short natural river bank in section largely regulated by rock ripraps on inner Mura (middle right), Besnica side arm (bottom left) and river island at Podturen HR (bottom right).

Although few nest holes were found there, results of the 2022 census indicate the importance of river side arms for Kingfisher, especially in sections where the main river channel was largely regulated by rock ripraps and consequently no natural banks exists (e.g. inner Mura). In contrast to the sections with long stretches of natural river banks, side arms are presumably the main nest-site type of the species in such sections.

Lack of suitable nest sites is presumably a limiting factor for the Kingfisher population on large parts of the upper and inner Mura, as reported for several rivers with altered flow regime elsewhere (Čech 2006, Schmidt & Zuna-Kratky 2009). Otherwise, long-term, up to several decades long, use of preferred nest sites is typical of the species (Čech 2006, Weggler *et al.* 2015), a phenomenon that also applies to some locations of the study area.

Estimates of Kingfisher nest-site parameters were assessed at 22 locations. The median height of the nest hole and the nesting wall above the water level of the river was 1.1 m (range 0.5–3.0 m) and 1.5 m (range 1.0–8.0 m), respectively (Figure 21). Characteristics of nest sites in our study confirm the preference of Kingfisher for nesting close to the bank top (Isotti & Consiglio 1998, Hartwig 2005, Straka & Grim 2007).

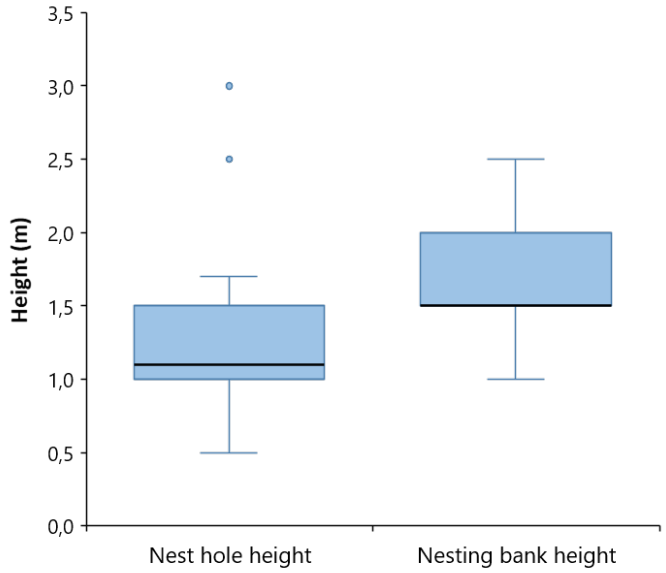

Figure 21: Height of Common Kingfisher *Alcedo atthis* nest holes and the nesting walls above the water level at the time of the census in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 (N = 22 nest-sites).

Trend

Breeding population in the Mura riverbed recovered after a series of distinctly bad years during the first half of the previous decade (2010–2014), and remained at a fairly similar level in all subsequent surveys. The multiplicative overall trend of Common Kingfisher in

the 2008–2022 period was estimated as moderate increase (multiplicative overall slope imputed ± SE 1.0692 ± 0.0133, $P < 0.01$) (Figure 22).

Kingfisher is known to be susceptible to harsh winter conditions that can decimate its numbers, mainly through high mortality of adults caused by starvation due to prevented fishing on frozen waters (Morgan & Glue 1977, Hagemeier & Blair 1997, Sackl 1997, Čech 2006, Schmidt & Zuna-Kratky 2009). Therefore, the prolonged period of the exceptionally severe winter temperatures in February 2012 (Cegnar 2012) could be the cause for the population low-point in the breeding season of that year and in the subsequent survey.

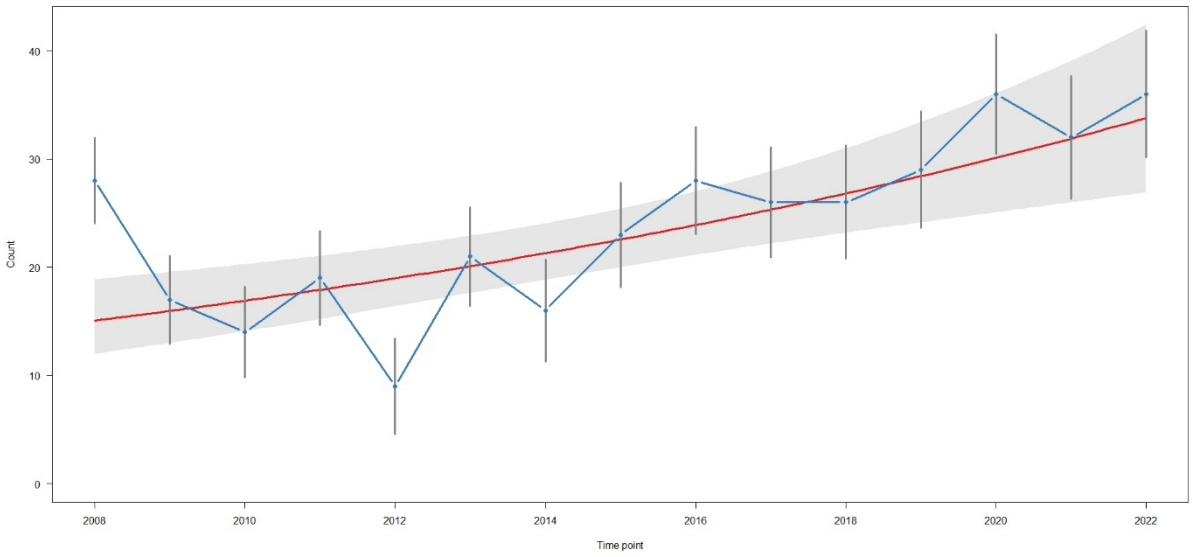

Figure 22: Multiplicative overall slope, its 95% confidence band, the total population (y axis) in individual years (x axis) and their 95% confidence intervals for Common Kingfisher *Alcedo atthis* in the 2008–2022 period.

F. - Sand Martin (*Riparia riparia*)

Population size and dynamics

Sand Martin population size in the Mura riverbed was estimated at 92–198 pairs (7 colonies) with a linear breeding density of 1.0–2.1 pairs/km in 2021, and at 113–257 pairs (7 colonies) with a density of 1.2–2.8 pairs/km in 2022. Colony size varied from 1 to 115 nesting burrows (median = 14). The bulk of Sand Martin population in the Mura River area in both study years (90 % in 2021 and 60 % in 2022) nested in 2–3 colonies in the Križovec gravel pit (HR), situated 200–300 m from the Section 8 of the Mura riverbed. There, an estimated 819–2275 pairs nested in 2021 (560 + 1285 + 430 burrows counted) and 328–780 pairs in 2022 (130 + 650 burrows counted). Smaller colonies were recorded

in further 1–3 gravel pits in the territory of the Mura-Drava-Danube TBR in Slovenia (Table 11).

Table 11: Number of colonies and estimate of the number of breeding pairs of Sand Martin *Riparia riparia* in separate survey sections/localities in the territory of the Mura-Drava-Danube TBR studied in 2021 and 2022. For the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) also linear breeding density is given.

Section	No. of colonies	Population size		Density (pair/km)	
		min	max	min	max
2021					
Section 1	0	0	0	0.0	0.0
Section 2	1	37	89	2.2	5.2
Section 3	1	23	46	3.5	7.0
Section 4	0	0	0	0.0	0.0
Section 5	0	0	0	0.0	0.0
Section 6	0	0	0	0.0	0.0
Section 7	2	8	16	0.7	1.4
Section 8	3	24	47	1.2	2.3
Total	**7**	**92**	**198**	**1.0**	**2.1**
Melinci (SLO)	1	11	11	-	-
Krapje (SLO)	0	0	0	-	-
Križovec (HR)	3	819	2275	-	-
Dobrovnik (SLO)	0	0	0	-	-
Total overall	**11**	**922**	**2484**	**-**	**-**
2022					
Section 1	0	0	0	0.0	0.0
Section 2	0	0	0	0.0	0.0
Section 3	1	4	7	0.6	1.1
Section 4	1	39	93	3.0	7.2
Section 5	0	0	0	0.0	0.0
Section 6	0	0	0	0.0	0.0
Section 7	0	0	0	0.0	0.0
Section 8	5	70	157	3.4	7.7
Total	**7**	**113**	**257**	**1.2**	**2.8**
Melinci (SLO)	1	10	20	-	-
Krapje (SLO)	1	40	95	-	-
Križovec (HR)	2	328	780	-	-
Dobrovnik (SLO)	1	50	120	-	-
Total overall	**12**	**541**	**1272**	**-**	**-**

In both years, colonies were recorded in half or less of the Mura riverbed survey sections, same as during all previous comprehensive riverbed surveys. The population change in the riverbed between 2021 and 2022 was moderate overall (less than one third), but with big differences in separate survey sections, ranging from cessation of nesting in two sections, to tripling of the population size in section 8 (Table 12). Only in the latter more than one colony nested in both study years.

Sand Martin riverbed population in both study years was substantially lower as in 2020, but higher as in all surveys of the previous decade (Appendix 7). However, the overall breeding population size in the study area in 2021 was close to the highest known values, typical of the 1990s (Bračko 2000). The number of active colonies in the riverbed in 2021 and 2022 ranks among the highest to date as only 1–3 were registered in all previous surveys, except 2008 and 2020 (8 and 7 colonies, respectively) (DOPPS *unpubl.*). However, compared to those years, colonies were substantially smaller on average in the study period (Figure 23).

Table 12: Difference in estimated number of breeding pairs of Sand Martin *Riparia riparia* in survey sections of the Mura riverbed between 2021 and 2022.

Section	DIFF (No. of pairs)		DIFF (%)	
	min	max	min	max
Section 1	0	0		
Section 2	–37	–89	–100.0	–100.0
Section 3	–19	–39	–82.6	–84.8
Section 4	39	93		
Section 5	0	0		
Section 6	0	0		
Section 7	–8	–16	–100.0	–100.0
Section 8	+46	+110	191.7	234.0
Total	**+21**	**+59**	**+22.8**	**+29.8**

Among possible causes for the lower number of Sand Martin breeding pairs in the Mura riverbed in the study period compared to the best years, especially in 2021, can be found in the unfavourable hydrological conditions during the formation of colonies in the second half of May and the beginning of June, and the availability of an optimal nesting site (Križovec gravel pit) with presumably most suitable size and structure of sand particles (Berndt *et al.* 1994) in the immediate vicinity.

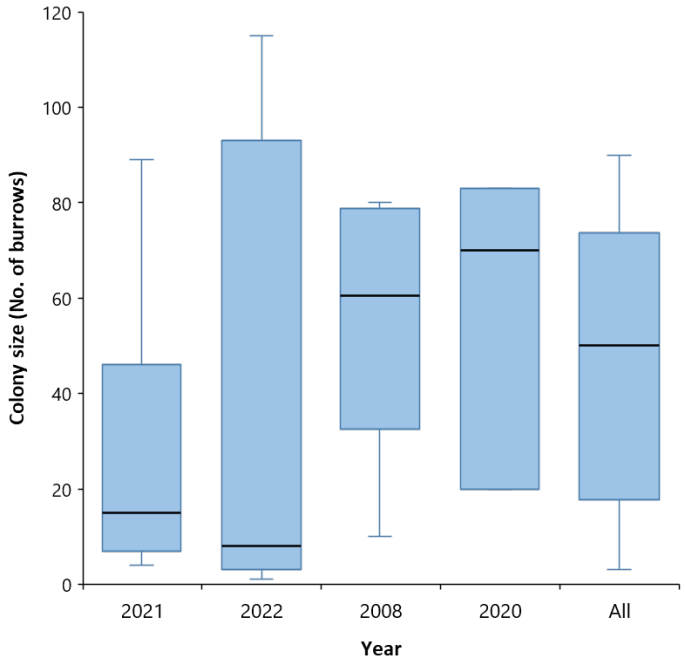

Figure 23: Size of Sand Martin *Riparia riparia* colonies in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in the study years, in 2008 and 2020 (years with >3 colonies in previous surveys), and in all years since the first comprehensive census (N = 122, data for both study years combined)

Distribution

In 2021 and 2022, colonies were registered on 15 locations. Out of 11 in the riverbed, two were located on the upper Mura, one on the inner Mura, and the rest (8 locations) on the lower Mura. Individual colonies were separated from their nearest neighbours by 8–17 km on upper and inner Mura. On the lower Mura distances among colonies ranged from 250 m to 7 km, but most locations were more than 2 km apart (Figure 24).

The general distribution pattern of the species, with few active nesting locations on upper and inner Mura, and a scattered, but regular occurrence on lower Mura, has not changed significantly compared to the previous comprehensive censuses of the species.

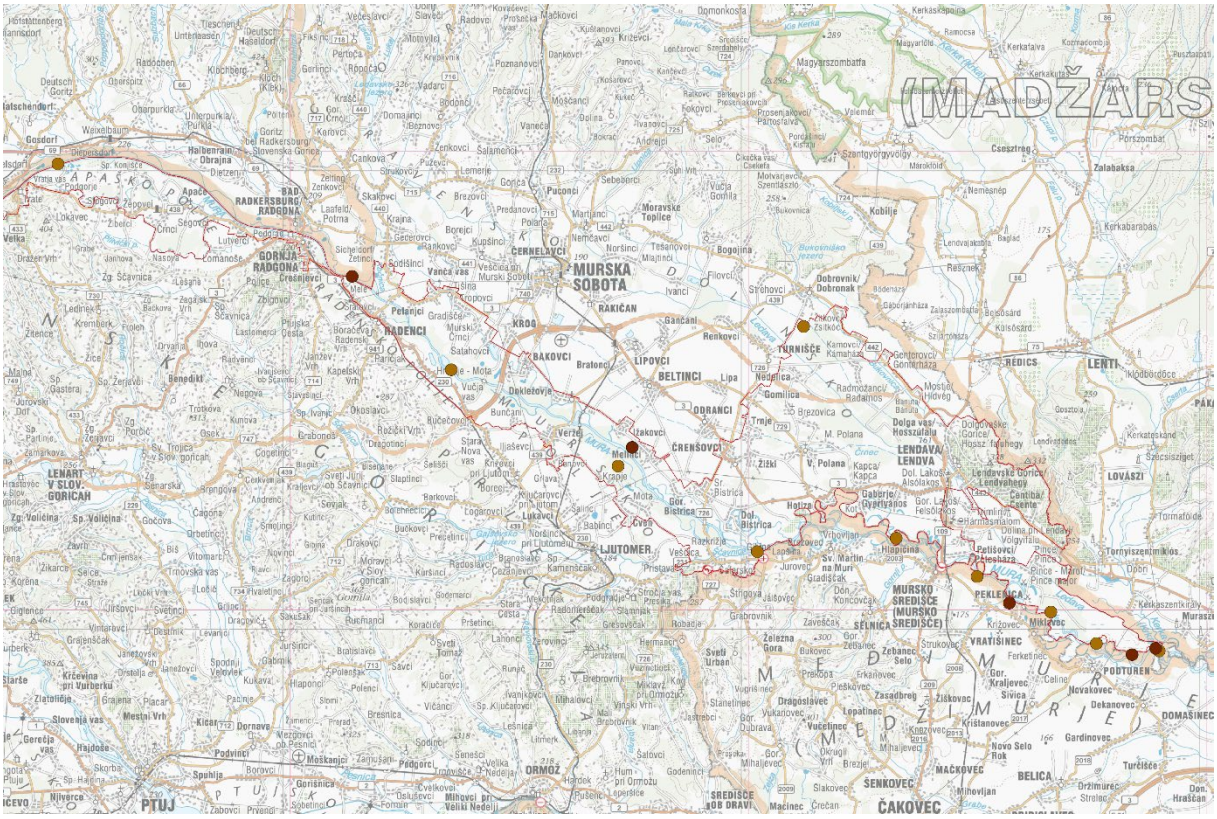

Figure 24: Nesting locations (active colonies) of Sand Martin *Riparia riparia*, encountered in the territory of the Mura-Drava-Danube TBR studied in 2021 and 2022 (N = 15); locations occupied in both study years are depicted in dark brown.

Habitat

All Sand Martin riverbed colonies were located in long stretches (mostly several hundred metres) of natural river banks with exposed steep surface of suitable alluvial soil. On the upper and inner Mura, such locations are found exclusively in sections where recent river restoration projects, focused on removal of dysfunctional/unnecessary rock ripraps were carried out (Figure 25). Thus, the preservation of the species on large part of the Mura riverbed is dependent entirely on implementation of conservation measures.

Figure 25: Examples of Sand Martin *Riparia riparia* nesting locations in long stretches of natural river banks in the Mura riverbed; lower Mura at Novakovec HR (top), restored section on Austrian side of the river at Mele (middle), restored section at Hrastje - Mota SLO (bottom left) and colony detail of the same location as above (bottom right).

Estimates of Sand Martin nest-site parameters were assessed at 18 places on four nesting locations – either entire individual colonies (2 locations) or different sectors within the same nesting wall (2 locations). The median height of the nest burrow and the nesting wall above the water level of the river was 2.8 m (range 1.0–4.8 m) and 3.4 m (range 1.5–5.2 m), respectively (Figure 26).

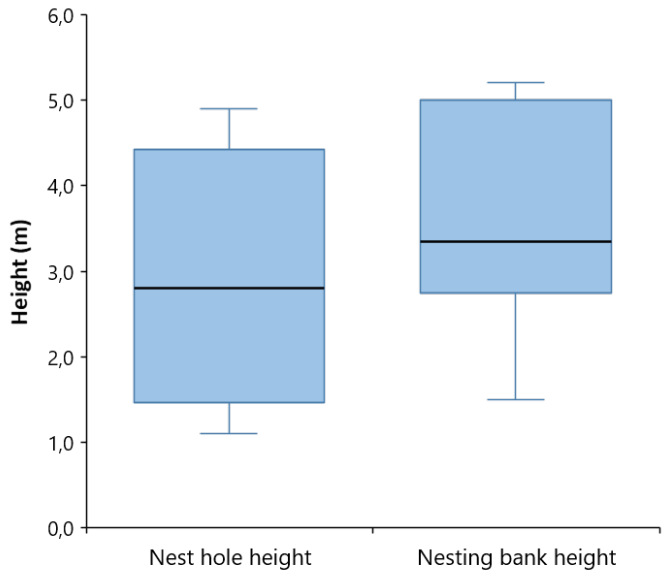

Figure 26: Height of Sand Martin *Riparia riparia* nest burrows and the nesting walls above the water level at the time of the census in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 (N = 18 sectors of the nesting walls).

Our results corroborate the findings from abroad that Sand Martins mostly select high (rarely < 1.5 m) and open banks for nesting, with a low percentage of vegetative cover, enabling an unobstructed access to the nest (Bauer *et al.* 2005, Hagemeier & Blair 1997).

In a recently established (excavations in different parts begun between 2016 and 2019), but during our visits non-operational Križovec gravel pit, all burrows were located in several meters high, freshly excavated and only slightly overgrown vertical walls comprised of sandy material (Figure 28 and 29). Small to medium-sized colonies were encountered in different types of nesting walls in three further operating gravel pits (Figure 29).

Trend

Breeding population in the Mura riverbed is characterized by unpredictable and highly fluctuating numbers, making ascertainment of population trend difficult. The multiplicative overall trend of Sand Martin in the 2008–2022 period was estimated as uncertain (multiplicative overall slope imputed ± SE 1.0754 ± 0.0692, $P < 0.01$) (Figure 27).

Together with factors discussed above, the marked Sand Martin population fluctuations can be explained by conditions on wintering grounds. The survival of adult birds is significantly affected by droughts in the Sub-Saharan Africa, resulting in several-fold decrease of breeding populations in a short period of time (Szép 1993, Hagemeier & Blair 1997).

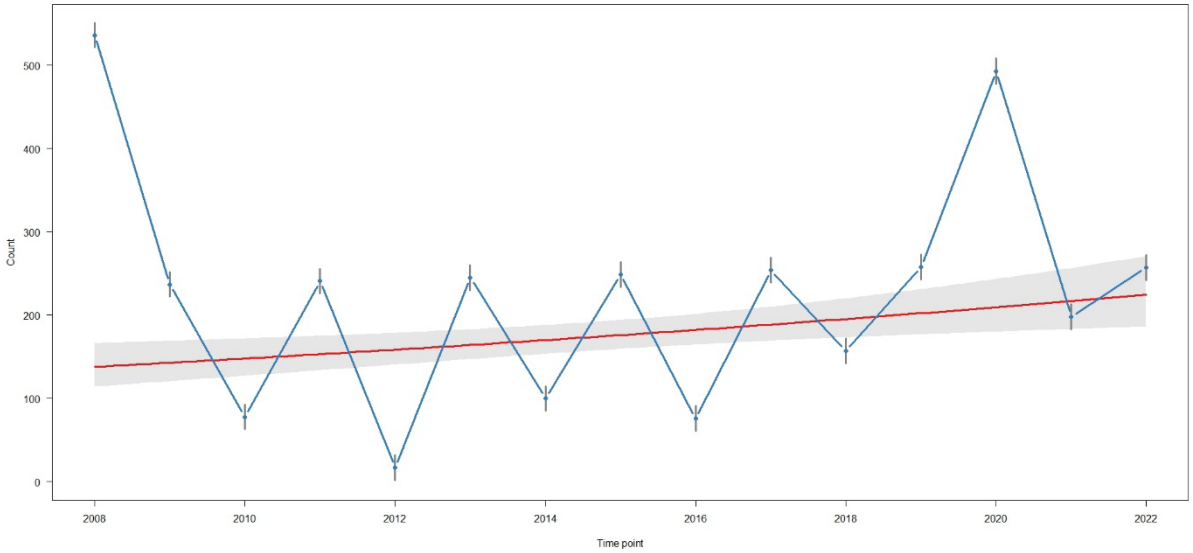

Figure 27: Multiplicative overall slope, its 95% confidence band, the total population (y axis) in individual years (x axis) and their 95% confidence intervals for Sand Martin *Riparia riparia* in the 2008–2022 period.

G. - Bee-eater (*Merops apiaster*)

In 2021 and 2022, Bee-eater nested in the territory of the Mura-Drava-Danube TBR studied at a single location – the Križovec gravel pit (HR). A total of 88 active nesting burrows in four colonies were counted in 2021 (12 + 13 + 59 + 4 burrows) and 27 (5 + 4 + 10 + 8 burrows) in two colonies in 2022. The majority of Bee-eater nesting burrows were located in other nesting walls, or at least different sectors of the same nesting wall as Sand Martin colonies (Figure 28 and 29). Numbers from 2021 are presumably the highest ever recorded in the study area (Bračko 2000, DOPPS *unpubl.*). Bee-eater was not recorded at two further locations (Melinci gravel pit and Mura riverbed at Pince-Marof), where breeding was occasionally confirmed in the past.

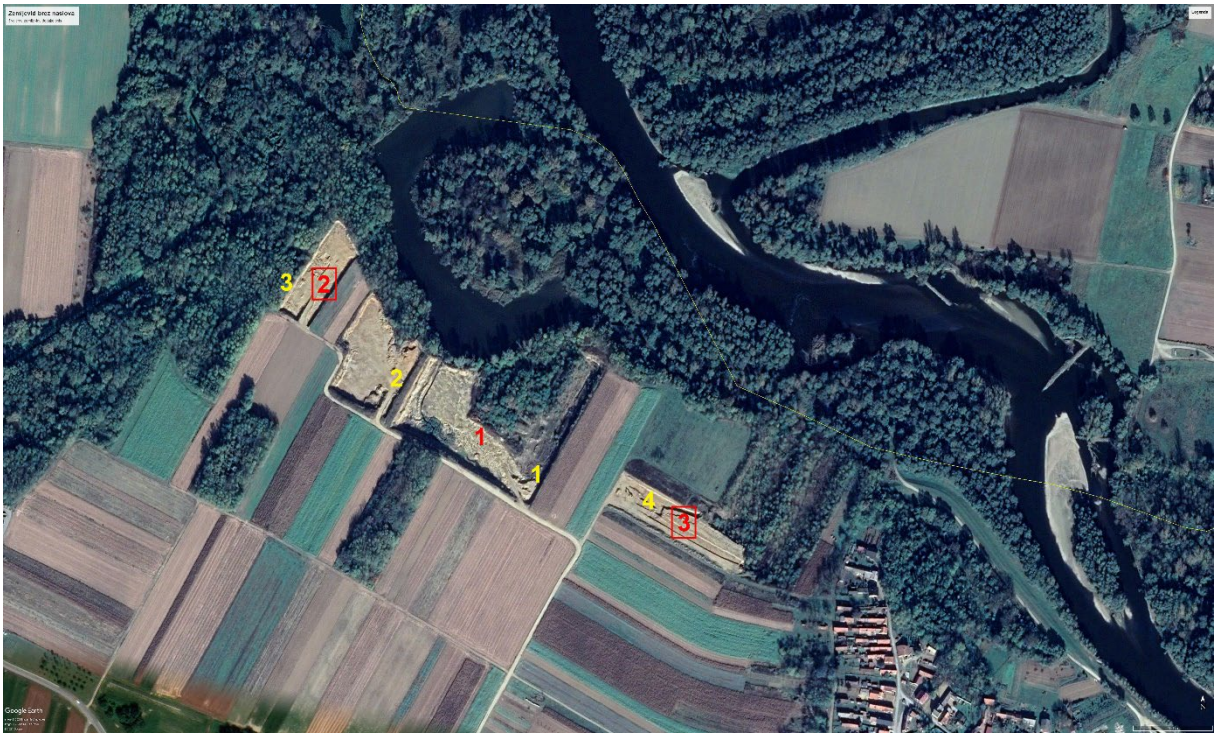

Figure 28: Locations of Sand Martin *Riparia riparia* (red) and Bee-eater *Merops apiaster* (yellow) colonies in the Križovec gravel pit (HR) in 2021 and 2022. Numbers of locations occupied in both study years are framed.

Figure 29 (pp. 50–51): Nest-sites of the target species in the Križovec gravel pit (HR); the central nesting wall of Sand Martin *Riparia riparia* with highest number of pairs in 2021 (p. 50 top, red 1) and the same location in 2022, with a progressing encroachment of woody plants clearly visible (p. 50 middle), a detail of this wall in 2021 with the highest density of burrows (p. 50, bottom left); detail of nesting wall with nest burrows of Bee-eater *Merops apiaster* on location yellow 2 (p. 50, bottom right), detail of the Sand Martin nesting wall in the easternmost part of the gravel pit (red 3 in the previous picture) in 2021 (p. 51, top left) and in 2022 (p. 51, top right), detail of the Sand Martin nesting wall in the westernmost part of the gravel pit (red 2 in the previous picture) in 2021 (p. 51, middle left) and in 2022 (p. 51, middle right). In both years, the highest number of Bee-eater pairs nested in the wall on eastern side of the central part (p. 50 top, yellow 1). In Dobrovnik gravel pit (SLO), Sand Martin colony nested in 2022 – a view of the nesting wall (p. 51, bottom left) and a detail with nest burrows visible (bottom right).


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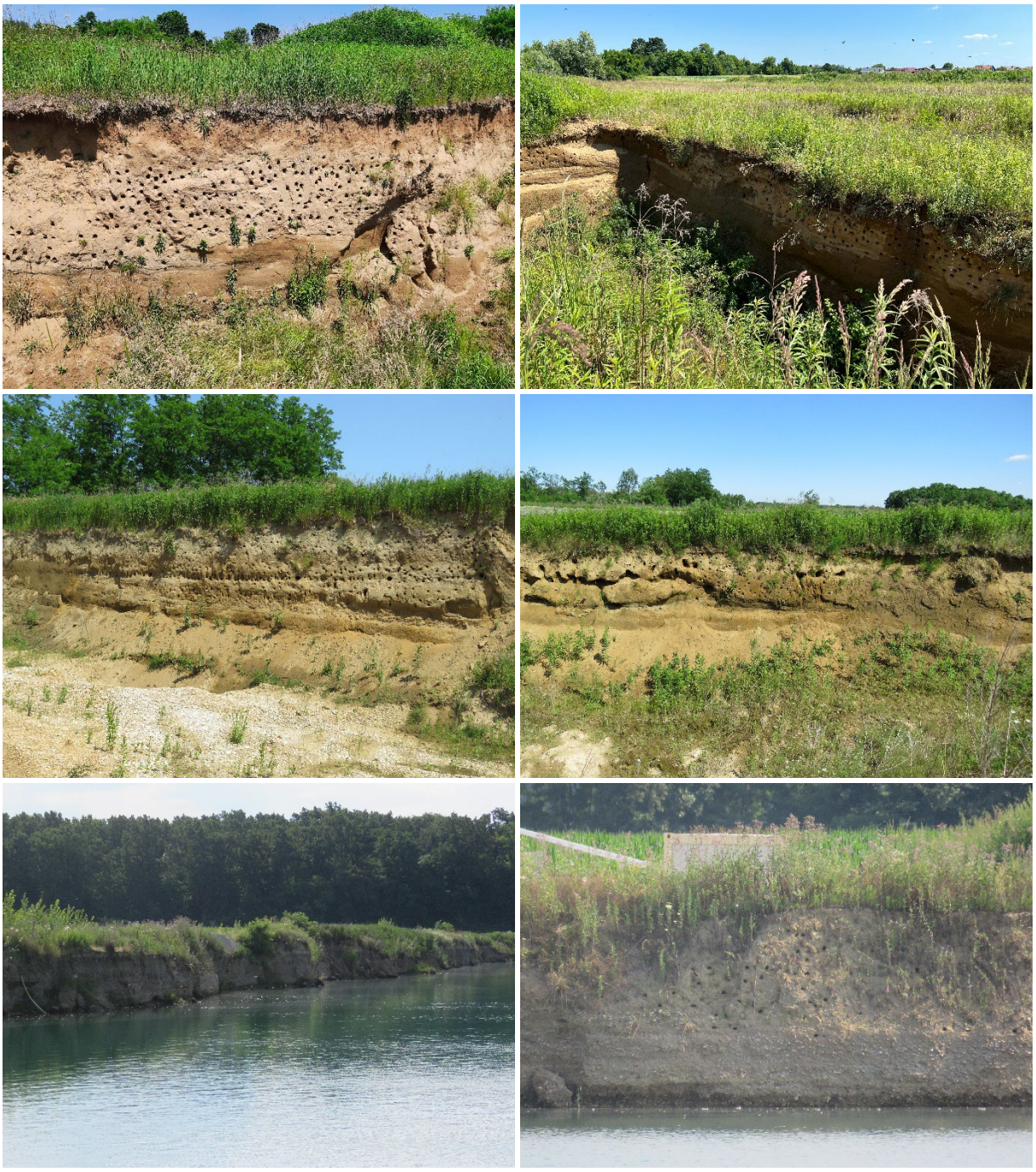


H. - Common Merganser (*Mergus merganser*)

Common Merganser population size in the Mura riverbed was estimated at 32–49 pairs with a linear breeding density of 0.3–0.5 pairs/km in 2021, and at 29–41 pairs with a density of 0.3–0.4 pairs/km in 2022 (Table 13). Registrations were fairly evenly

distributed on the upper and the inner Mura in 2021. In 2022 distribution was essentially the same, but with somewhat higher linear density in the two uppermost survey sections. The species was also recorded on Besnica side arm on the inner Mura (one pair in 2022). Combined registrations from 2021 and 2022 riverbed surveys show continuous distribution pattern with few obvious gaps along the entire Mura riverbed between Ceršak and Gibina (Figure 30). Breeding was confirmed with observations of broods; 11 in 2021 (9 on the upper and 2 on the lower Mura) and 14 in 2022 (12 on the upper and 2 on the lower Mura). On lower Mura, the species was sparsely registered only in the survey section 7, while breeding was not confirmed.

Table 13: Number of individuals recorded, estimate of the number of breeding pairs and linear breeding density of Common Merganser *Mergus merganser* in survey sections of the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 and 2022.

Section	No. of individuals		Population size		Density (pair/km)	
	S1	S2	min	max	min	max
2021						
Section 1	10 M, 2 F	4 F	4	10	0,4	0,9
Section 2	9 M, 11 F	9 F	9	11	0,5	0,6
Section 3	5 M, 6 F	8 F	5	8	0,8	1,2
Section 4	8 M, 5 F	3 F, 3 juv	5	8	0,4	0,6
Section 5	7 M, 8 F	2 F	7	8	0,7	0,8
Section 6	2 M, 4 F, 2	0	2	4	0,6	1,2
Section 7	1 F	0	0	0	0,0	0,0
Section 8	0	0	0	0	0,0	0,0
Total	**41 M, 37 F, 2**	**26 F, 3 juv**	**32**	**49**	**0,3**	**0,5**
2022						
Section 1	5 M, 9 F	2 juv, 2 F/juv	5	9	0,5	0,8
Section 2	12 M, 10 F	2 F, 3 juv	10	12	0,6	0,7
Section 3	1 M, 1 F	1 F, 4 juv	1	2	0,2	0,3
Section 4	7 M, 5 F	1 F	5	7	0,4	0,5
Section 5	7 M, 4 F	1 M, 4 F	4	7	0,4	0,7
Section 6	2 M, 2 F	0	2	2	0,6	0,6
Section 7	2 M, 2 F	0	2	2	0,2	0,2
Section 8	0	0	0	0	0,0	0,0
Total	**36 M, 33 F**	**1M, 8F, 2 juv**	**29**	**41**	**0,3**	**0,4**

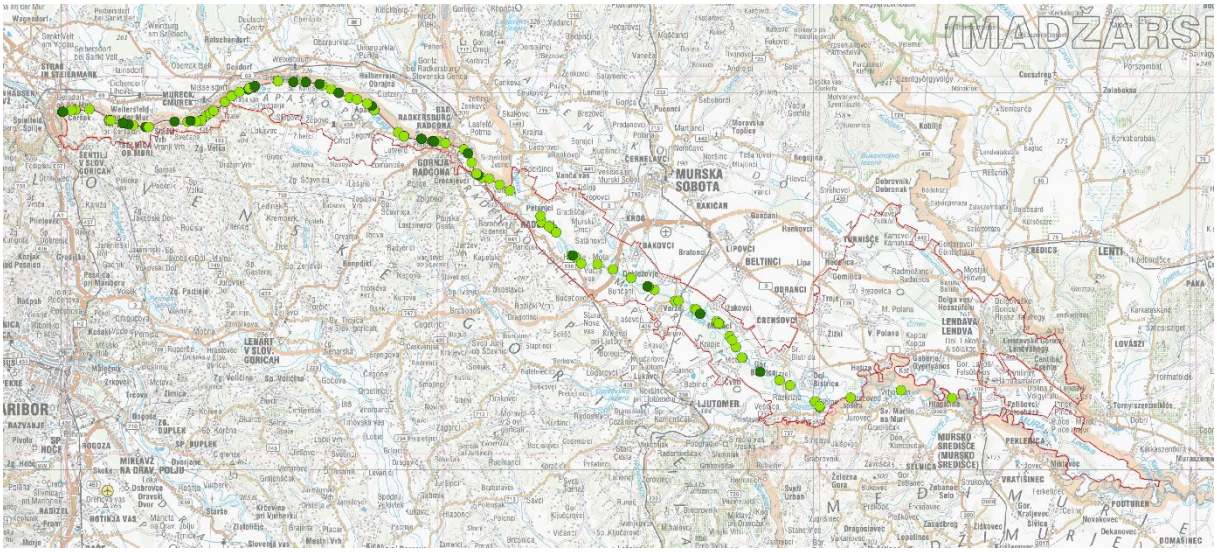


Figure 30: Registrations of Common Merganser *Mergus merganser* in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 and 2022 (N = 106); dark green dots depict locations of broods observed.

It should be noted that Common Merganser data interpretation is difficult without species-specific, targeted censuses due to its high mobility, no apparent territorial behaviour, communal courtship that often includes several males and females, aggregations of nesting females and early departure of males from the breeding area (Andretzke et al. 2005, Pearce *et al.* 2020). The estimates based on surveys in 2021 and 2022 represent a significant increase of the breeding population in the Mura riverbed studies compared to previous years (Mihelič *et al.* 2019), where only 2–3 pairs were recorded in 2006 when breeding was first confirmed (Božič 2007). The population increase recorded is probably related to the expansion of the European population in recent decades (Keller *et al.* 2020).

I. - Other species

During riverbed surveys in 2021 and 2022, several interesting records of other bird species associated with riverine habitats were collected (Figure 31).

White-tailed Eagle registrations on the upper and inner Mura in 2022 indicate occurrence of new individuals/pairs during the breeding season, in addition to previously known nesting locations on lower Mura (Gibina and Murska šuma area). Although the pair observed at Bunčani was apparently not nesting in this season, it is possible it will settle here in the future. Currently, two pairs nest along the Mura riverbed studied on regular basis (Mihelič *et al.* 2019).

Surveys carried out during the study period confirmed breeding of White-throated Dipper in uppermost survey section in small numbers (1 pair in 2021 and 2–3 pairs in 2022). This easternmost area of breeding occurrence in Slovenia, on the outskirts of the Pannonian basin, at the same time constitute the only breeding nesting locations in the entire territory of Mura-Drava-Danube Transboundary Biosphere Reserve.

Breeding of Common Goldeneye *Bucephala clangula* has never been recorded in Slovenia (Mihelič *et al.* 2019), nor does the species breed anywhere within boundaries of the MDD Biosphere Reserve. In the first survey of 2022, a single male was registered in the main Mura river channel – a highly unusual place and time of occurrence for this species in the study area. Moreover, its behaviour indicated it might be a territory-holding individual.

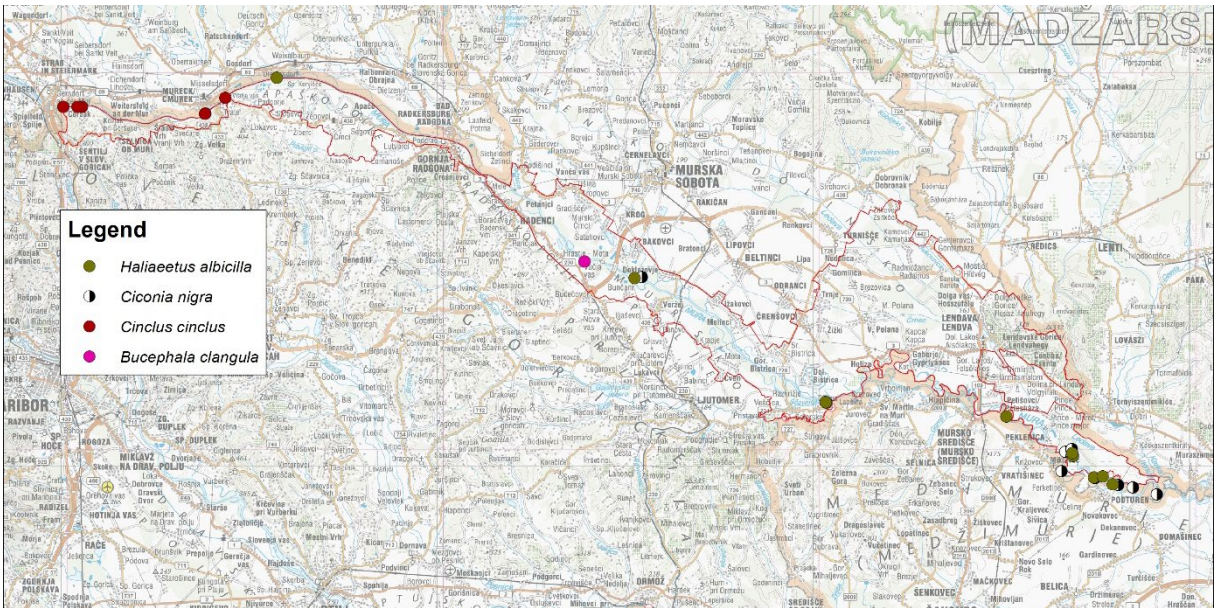


Figure 31: Interesting records of other bird species in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 and 2022.

J. - Importance and natural potential of the area studied

Surveys in 2021 and 2022 confirmed international and national importance of the Mura River area between Ceršak (SLO) and Dekanovec (HR) for targeted species. The area surveyed ranks among the most important areas for riverbed breeding bird species of conservation concern in Slovenia (Denac *et al.* 2011), mostly together with lowland part of the Drava River. As for 2021 and 2022, breeding populations of all four target species on Mura were the highest in the country, constituting c. 14–20% of the total national population of Little Ringed Plover, c. 25–27% of Common Sandpiper, c. 14% of Common Kingfisher (in 2022) and up to c. 40% population of Sand Martin. According to the last published estimate for Common Merganser (Mihelič *et al.* 2019), the Mura riverbed

population would comprise 36–41% of the Slovene breeding population, but actual figures are probably somewhat lower as population has undoubtedly increased since then.

All four target species are considered as indicators of natural river dynamics and morphology (e.g. van Vessem *et al.* 1997, Arlettaz *et al.* 2012, Schmidt *et al.* 2015). Thus, information on their occurrence and linear breeding densities along the Mura riverbed provide valuable clues about state of the riverine habitats and processes.

Linear densities of Little Ringed Plover breeding pairs on best survey section(-s) were higher than recorded on most comparable sections of the Central European rivers, where these only rarely exceed 1 pair/km, mostly on wide, natural or restored stretches of large rivers (see Božič & Denac 2010, Arlettaz *et al.* 2012, Schmidt 2016). Similarly, is a linear density of c. 1 pair/km of Common Sandpiper, recorded only in one survey section on the lower Mura, a value characteristic of high-quality sections on a diverse array of rivers, from alpine to lowlands (see Božič & Denac 2010, Frühauf & Dvorak 1996, Arlettaz *et al.* 2012). Within or close to the territory of the Mura-Drava-Danube TBR, similar linear densities of both species as in the most downstream section of Mura riverbed were only reported for a few sections of the Drava River between 236 and 180 rkm (mostly in Hungary) and 319–305 rkm in Slovenia (Fenyősi 2005, Božič & Denac 2010, 2017). Such a high densities of breeding pairs only occur in river sections with numerous extensive and sparsely vegetated gravel bars, most of which are occupied by several pairs of either or both species. However, exceptional densities along vast natural river corridors can surpass these values for both species by several-fold (e.g. Reich 1994, Elas & Meissner 2014).

The Kingfisher densities of well below 1 pair/km on most survey sections in the Mura riverbed are more typical of the rivers in Central Europe (see Božič & Denac 2010). These low values recorded reflect the current prevailing situation along the riverbed studied, with the main river channel largely regulated by rock ripraps and are presumably not consistent with the great natural potential of the river. Under optimal conditions, the expected Kingfisher densities would be c. 1 pair/km of the riverbed as found on some of the large natural rivers (Westermann & Westermann 1998, Griesser 2022). Sand Martin numbers in the Mura riverbed are also substantially lower as recorded on downstream sections of the Drava River in Croatia or natural stretches of other major rivers in the region, such as Sava or Tisa (Szep *et al.* 2003, Reeder *et al.* 2006, Mikuska & Grlica 2013). However, such situation is typical for rivers with altered flow regime (e.g. Schmidt *et al.* 2015).

Contrasting linear breeding densities of the target species in the individual survey sections along the Mura River studied imply different state of the riverine habitats and processes on separate parts of the river channel. This pattern can be ascertained on the map with densities of all four species registered in the riverbed combined (Figure 32). The lower Mura between Križovec and Dekanovec with predominant completely natural river flow clearly stands out, while long stretches of upper and inner Mura obviously hold few characteristic bird species of pristine riverine habitats. Such sections should be

considered a priority in planning future river restoration projects. These should focus primarily on large-scale removal of rock ripraps and other types of lateral embankments.

A considerable amount of best-practice examples from various Central European countries demonstrates a positive effect of such measures on target species, including a substantial recovery of once depleted breeding populations to the levels at estimated carrying capacity of the river ecosystem in a short time (Metzner 2002, Petutschnig 2004, Arlettaz *et al.* 2012, Uhl & Weissmair 2012, Griesser 2022).

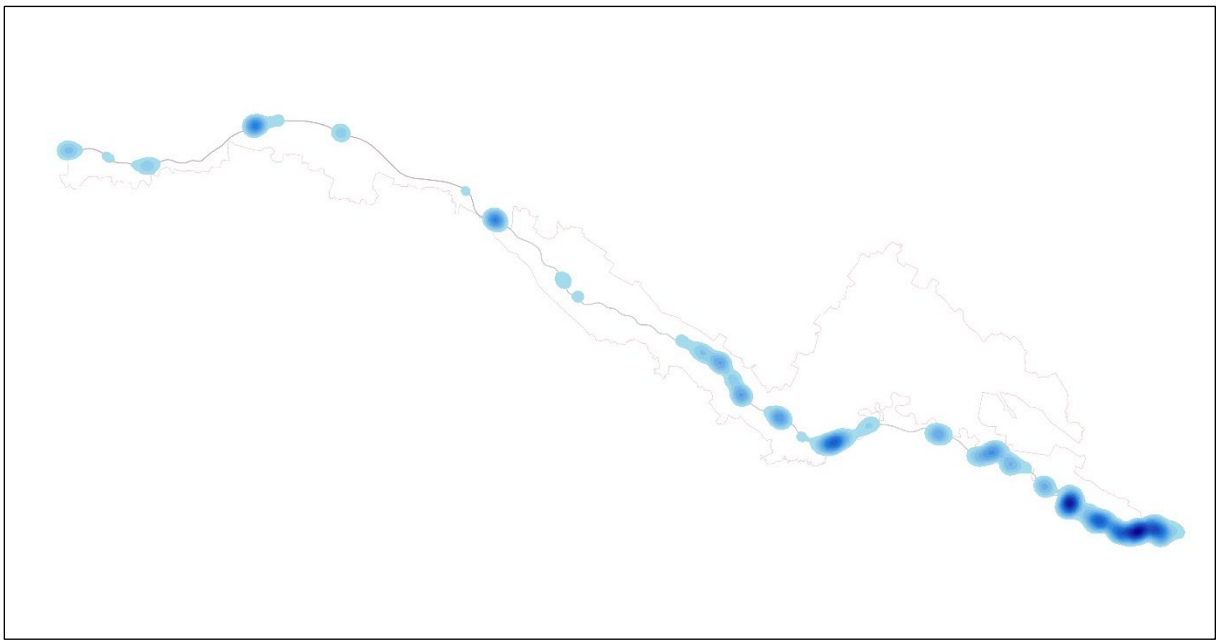


Figure 32: Density of the four target bird species (Little Ringed Plover *Charadrius dubius*, Common Sandpiper *Actitis hypoleucos*, Common Kingfisher *Alcedo atthis*, Sand Martin *Riparia riparia*in) registered in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) after the kernel method, based on registrations of presumably nesting individuals during the 2021 and 2022 censuses (N = 416 registrations of 1166 ind.). The darker the shade of blue colour, the greater the density in that area.

V. REFERENCES

Andretzke H., Schikore T., Schröder K. (2005): Artsteckbriefe. pp. 135–695 In: Südbeck P., Andretzke H., Fischer S., Gedeon K., Schikore T., Schröder K., Sudfeldt C. (eds.): Methodenstandards zur Erfassung der Brutvögel Deutschlands. – Radolfzell.

Arlettaz R., Lugon A., Sierro A., Werner P., Kery M., Oggier P. A. (2011): River bed restoration boosts habitat mosaics and the demography of two rare non-aquatic vertebrates. – Biological Conservation 144 (8): 2126–2132.

Bauer H.-G., Bezzel E., Fiedler W. (eds.) (2005): Das Kompendium der Vögel Mitteleuropas. – AULA Verlag, Wiebelsheim.

Berndt, R. K., Hein, K. & Gall, T. (1994): Stabile Brutbestände der Uferschwalbe *Riparia riparia* in Schleswig-Holstein zwischen 1979 und 1991. – Vogelwelt 115: 29-37.

Bezzel E., Fünfstück H.-J., Kirchner J. (1995): Der Flußuferläufer *Actitis hypoleucos* im Werdenfelser Land 1966 bis 1994: Lebensraum, Durchzug, Brutbestand und Schutzprobleme. – Garmischer Vogelkundliche Berichte 24: 47–60.

BirdLife International (2021): Common Sandpiper *Actitis hypoleucos*. – The IUCN Red List of Threatened Species 2021: e.T22693264A166252539. [https://dx.doi.org/10.2305/IUCN.UK.2021-3.RLTS.T22693264A166252539.en].

Bogaart P., van der Loo M., Pannekoek J. (2018): rtrim: Trends and Indices for Monitoring Data. Version 2.0.6. – 24 Aug 2018. [https://cran.r-project.org/web/packages/rtrim/index.html].

Božič L. (2007): Analiza živega sveta na območju Mure med Šentiljem in Veržejem. Segment: Ptiči (Aves). Zaključno poročilo. Naročnik: Vodnogospodarski biro Maribor d.d. – DOPPS, Ljubljana.

Božič L., Denac D. (2010): Številčnost in razširjenost izbranih gnezdilk struge reke Drave med Mariborom in Središčem ob Dravi (SV Slovenija) v letih 2006 in 2009 ter vzroki za zmanjšanje njihovih populacij. – Acrocephalus 31 (144): 27–45.

Božič L., Denac D. (2017): Population dynamics of five riverbed breeding bird species on the lower Drava River, NE Slovenia. – Acrocephalus 38 (174/175): 85–126.

Božič L., Koce U. (2020): Vodomec *Alcedo atthis*. str. 10–21. V: Denac K., Božič L., Kmecl P., Mihelič T., Denac D., Bordjan D., Koce U.: Monitoring populacij izbranih ciljnih vrst ptic na območjih Natura 2000 v letu 2020 in sinteza monitoringa 2019–2020. Poročilo. Naročnik: Ministrstvo za kmetijstvo, gozdarstvo in prehrano. – DOPPS, Ljubljana.

Bračko F. (2000): Reka Mura. str. 161–171 V: Polak S. (ur.): Mednarodno pomembna območja za ptice v Sloveniji. Important Bird Areas (IBA) in Slovenia. Monografija DOPPS št. 1. – DOPPS, Ljubljana.

Cegnar T. (2012): Podnebne razmere v februarju 2012. Naše okolje. Bilten Agencije RS za okolje 19 (2): 3–22.

Čech P. (2006): Reprodukční biologie ledňáčka říčního (*Alcedo atthis*) a možnosti jeho ochrany v současných podmínkách České republiky. – Sylvia 42: 49–65.

Elas M., Meissner W. (2014): Number and distribution of breeding Common Sandpiper *Actitis hypoleucos* in the Middle Vistula, Poland. Poster. – International Wader Study Group Annual Conference, Haapsalu, Estonia, 26–29 September 2014.

ESRI (2009): ArcGIS, ver. 9.3. – ESRI, Redlands.

Fenyősi L. (2005): Studies of avian communities along river Drava between 2000–2004 (Aves). – Natura Somogyiensis 7: 119–141.

Frühauf J., Dvorak M. (1996): Der Flussuferläufer *(Actitis hypoleucos)* in Österreich: Brutbestand 1994/95, Habitat und Gefahrdung. – BirdLife Österreich: Wien.

Griesser M. (2022): 30-jähriges Monitoring und Artenförderung des Eisvogels *Alcedo atthis* an der zürcherischen Thur. – Ornithologischer Beobachter 119 (3): 246–256.

Gilvear D., Francis R., Willby N., Gurnell A. (2008): Gravel bars: a key habitat of gravel-bed rivers for vegetation. pp. 677–700. In: Habersack H., Piegay H., Rinaldi M. (eds.): Gravel-bed rivers VI: From process understanding to river restoration. – Elsevier, Amsterdam.

Hagemeier W. J. M., Blair M. J. (eds.) (1997): The EBCC Atlas of European Breeding Birds. Their Distribution and Abundance. – T & A D Poyser, London.

Hartwig S. (2005): Analyse zum Nisthabitat des Eisvogels (*Alcedo atthis*) in der Region Oberes Elbtal, Osterzgebirge. – Mitteilungen des Vereins Sächsischer Ornithologen 9: 507–525.

Isotti R., Consiglio C. (1998): Characteristics of kingfisher's, *Alcedo atthis*, nesting site. – Rivista Italiana di Ornitologia 68 (1): 57–62.

Keller V., Herrando S., Voříšek P., Franch M., Kipson M., Milanesi P., Martí D., Anton M., Klvaňová A., Kalyakin M. V., Bauer H.-G., Foppen R. P. B. (2020). European Breeding Bird Atlas 2: Distribution, Abundance and Change. – European Bird Census Council & Lynx Edicions, Barcelona.

Kuhnen K. (1978): Zur Methodik der Erfassung von Uferschwalben (*Riparia riparia*)-Populationen. – Vogelwelt 99: 161–176.

Lengyel S. (1998): Distribution and status of the Common Sandpiper (*Actitis hypoleucos*) and Little Ringed Plover (*Charadrius dubius*) along two rivers in North-Eastern Hungary. – Aquila 103/104: 47–57.

Metzner J. (2002): Die Bestandsentwicklung des Flussuferläufers *Actitis hypoleucos* am Obermain nach Renaturierung und Einwirkungen von Hochwasserprozessen – Ornithologischer Anzeiger 41 (1): 41–49.

Mihelič T., Kmecl P., Denac K., Koce U., Vrezec A., Denac D. (eds.) (2019): Atlas ptic Slovenije. Popis gnezdilk 2002–2017. – DOPPS, Ljubljana.

Mikuska T., Grlica D. I. (2013): Istraživanje bregunice (*Riparia riparia*), kulika sljepčića (*Charadrius dubius*) na rijeci Savi od Zagreba do Stare Gradiške. Konačno izvješće. – Hrvatsko društvo za zaštitu ptica i prirode, Osijek.

Morgan R., Glue D. (1977): Breeding, Mortality and Movements of Kingfishers. – Bird Study 24 (1): 15–24.

Pannekoek J., Van Strien A. J. (2005): TRIM 3 Manual (Trends & Indices for Monitoring Data). – Statistics Netherlands, Voorburg.

Pannekoek J., Van Strien A. J., Gmelig Meyling A. W. (2005): TRIM 3.51. – Statistics Netherlands. [http://www.ebcc.info/trim.html].

Pearce-Higgins J. W., Yalden D. W., Dougall T. W., Beale C. M. (2009): Does climate change explain the decline of a trans-Saharan Afro-Palaearctic migrant? – Oecologia 159 (3): 649–659.

Pearce, J., M. L. Mallory, and K. Metz (2020). Common Merganser (*Mergus merganser*), version 1.0. In Birds of the World (S. M. Billerman, Editor). – Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.commer.01

Petutschnig W. (2004): Der Flussuferläufer (*Actitis hypoleucos* L.) in Kärnten. – Kärntner Naturschutzberichte 9: 5–13.

Reeder D., Mohl A., Schneider-Jacoby M., Stumberger B. (2006): 11. The protection of the Drava-Mura wetlands. pp. 110–120. In: Terry A., Ullrich K. & Riecken U. (eds.): The green belt of Europe: from vision to reality. – IUCN, Gland.

Reich M. (1994): Kies- und schotterreiche Wildflußlandschaften – primäre Lebensräume des Flußregenpfeifers (*Charadrius dubius*). – Vogel und Umwelt 8 (1/2): 43–52.

Sackl P. (1997): Eisvogel *Alcedo atthis*. pp. 182–183. In: Sackl P., Samwald O. (eds.): Atlas der Brutvögel der Steiermark. – BirdLife Österreich-Landesgruppe Steiermark & Steiermärkisches Landesmuseum Joanneum, Graz.

Schmidt M. (2016): Ergebnisse der Erhebung der Kiesbrüterbestände (Flussregenpfeifer *Charadrius dubius* & Flussuferläufer *Actitis hypoleucos*) im Nationalpark Donau-Auen im Jahr 2015. Kurzbericht. – BirdLife Österreich, Wien.

Schmidt M., Zuna-Kratky T. (2009): Bestandsentwicklungen und limitierende Faktoren für ausgewählte flussgebundene Vogelarten in den March-Thaya-Auen (Flussuferläufer, Flussregenpfeifer und Eisvogel). – BirdLife Österreich, Wien.

Schmidt M., Bandacu D., Bogdea L., Bozhinova S., Costea G., Gáborik A., Grlica I. D., Hima V., Kiss G., Koev V., Kovarik A., Melišková M., Milenkovic- Srbulovic M., Parrag T., Petrova V., Raluca A., Rožac V., Šakić R., Schneider T., Surovec P., Tatai S., Tóth B., Tucakov M., Vasić I., Frank G. (2015): Riparian bird species (Little Ringed Plover, Sand Martin) as indicators for river dynamics and morphology. pp. 72–79 In: Liška I., Wagner F., Sengl M., Deutsch K., Slobodník J. (eds.): Joint Danube Survey 3. A Comprehensive Analysis of Danube Water Quality. – ICPDR – International Commission for the Protection of the Danube River, Vienna.

Schödl M. (2003): Brutzeitraum und Daten zu Schlüpfen und Flüggewerden des Flussuferläufers *Actitis hypoleucos* an Ammer und Oberer Isar. – Ornithologische Anzeiger 42: 51–56.

Silverman B. W. (1986): Density Estimation for Statistics and Data Analysis. – Chapman and Hall, New York.

Straka O., Grim T. (2007): Nest site selection in the Kingfisher (*Alcedo atthis*). – Sylvia 43: 109–122.

Szép T. (1993): Changes of the Sand Martin (*Riparia riparia*) population in Eastern Hungary: the role of the adult survival and migration between colonies in 1986–1993. – Ornis Hungarica 3 (2): 56–66.

Szép T., Szabó D. Z., Vallner J. (2003): Integrated population monitoring of Sand Martin *Riparia riparia* – an opportunity to monitor the effects of environmental disasters along the River Tisza. – Ornis Hungarica 12/13: 169–182.

Uhl H., Weißmair W. (2012): Artenschutzprojekt Flussuferläufer (*Actitis hypoleucos*) in Oberösterreich 2010 mit Anmerkungen zum Flussregenpfeifer (*Charadrius dubius*). – Vogelkundliche Nachrichten aus Oberösterreich, Naturschutz aktuell 20 (1/2): 93–122.

Van Vessem J., Hecker N., Tucker G. M. (1997): Inland wetlands. pp. 125–158. In: Tucker G. M., Evans M. I. (eds.): Habitats for birds in Europe: a conservation strategy for the wider environment. BirdLife Conservation Series No. 6. – BirdLife International, Cambridge.

Weggler M., Schwarzenbach Y., Widmer M. (2015): Stabiler Lokalbestand und langjährig benutzte Brutplätze beim Eisvogel *Alcedo atthis* am Hochrhein. – Ornithologischer Beobachter 112 (4): 251–258.

Westermann K., Westermann S. (1998): Der Brutbestand des Eisvogels (*Alcedo atthis*) in den Jahren 1990 bis 1996 in der südbadischen Rheinniederung. – Naturschutz Südlicher Oberrhein 2: 261–269.

Woodall P. F. (2020): Common Kingfisher (Alcedo atthis), version 1.0. In: Birds of the World (del Hoyo J., Elliott A., Sargatal J., Christie D. A., de Juana E. (eds.). – Cornell Lab of Ornithology, Ithaca, NY, USA. [https://doi.org/10.2173/bow.comkin1.01]

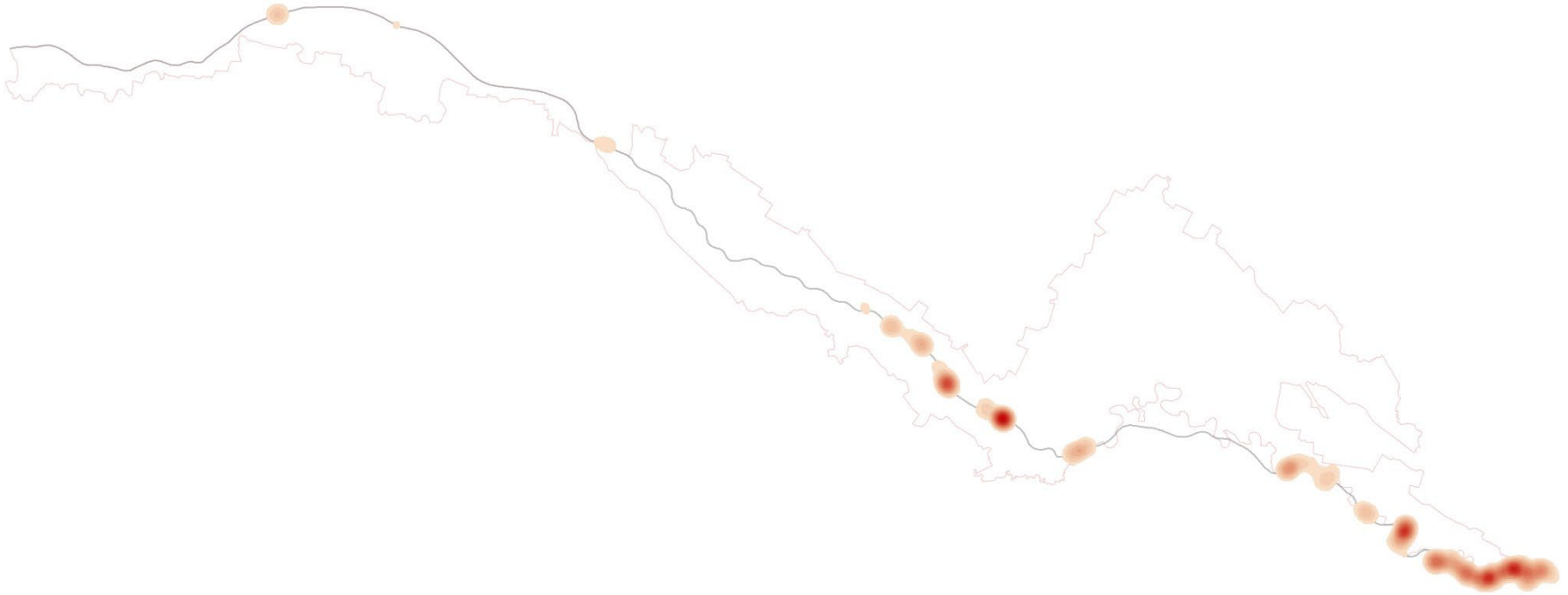
Yalden D. W. (1992): The influence of recreational disturbance on common sandpipers *Actitis hypoleucos* breeding by an upland reservoir, in England. – Biological Conservation 61 (1): 41–49.

VI. APPENDIX

Appendix 1: Number of Little Ringed Plover *Charadrius dubius* breeding pairs in survey sections of the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in all comprehensive surveys carried out to date (- not surveyed, x – the species was not censused).

Section	2006		2008		2010		2012		2014		2016		2018		2020		2021		2022	
	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Section 1	0	0	0	0	0	0	0	0	0	0	0	0	x	x	0	0	0	0	0	0
Section 2	0	0	3	3	2	2	1	1	0	0	1	1	x	x	1	2	1	1	1	2
Section 3	0	0	0	0	0	0	2	2	0	1	0	0	x	x	1	1	0	0	0	0
Section 4	0	0	0	0	0	0	0	0	0	0	0	0	x	x	0	0	0	0	0	0
Section 5	12	13	15	17	10	12	11	11	1	1	7	8	x	x	2	2	9	11	6	7
Section 6	0	0	0	0	0	0	0	0	0	0	0	0	x	x	1	1	0	0	0	0
Section 7	-	-	0	0	3	3	2	2	1	2	1	1	x	x	5	5	3	4	4	5
Section 8	-	-	12	12	16	18	20	26	22	23	36	43	x	x	16	19	38	44	26	29
Total	**-**	**-**	**30**	**32**	**31**	**35**	**36**	**42**	**24**	**27**	**45**	**53**	**x**	**x**	**26**	**30**	**51**	**60**	**37**	**43**

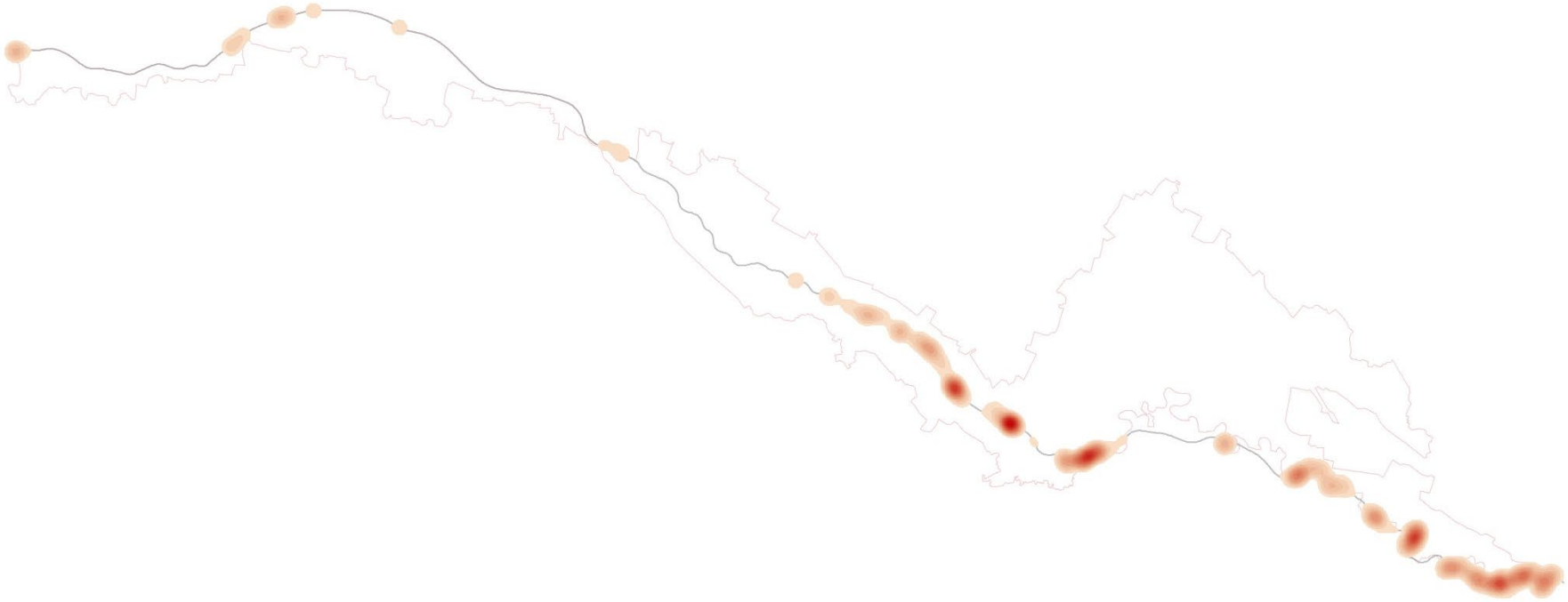
Appendix 2: Density of Little Ringed Plover *Charadrius dubius* in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) after the kernel method, based on data of presumably nesting individuals collected in the 2006–2020 period (N = 320 registrations of 574 ind.). The darker the shade of red colour, the greater the density in that area.



Appendix 3: Number of Common Sandpiper *Actitis hypoleucos* breeding pairs in survey sections of the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in all comprehensive surveys carried out to date (- not surveyed, x – the species was not censused).

Section	2006		2008		2010		2012		2014		2016		2018		2020		2021		2022	
	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Section 1	3	3	2	2	0	0	0	0	0	1	2	2	x	x	-	-	3	3	2	2
Section 2	1	1	2	2	2	2	1	1	1	2	1	1	x	x	-	-	2	2	1	1
Section 3	1	1	0	0	1	1	0	0	0	1	0	0	x	x	0	0	2	2	2	2
Section 4	2	2	0	0	1	1	0	0	0	0	2	2	x	x	0	0	0	0	0	0
Section 5	6	6	11	11	5	6	0	0	3	3	3	4	x	x	3	3	3	4	7	8
Section 6	0	0	0	0	0	0	0	0	0	0	1	1	x	x	1	1	2	2	0	0
Section 7	-	-	1	1	2	2	2	2	1	2	3	3	x	x	4	5	4	5	4	5
Section 8	-	-	9	9	9	14	5	7	6	8	19	21	x	x	9	12	19	23	16	20
Total	**-**	**-**	**25**	**25**	**20**	**26**	**8**	**10**	**11**	**17**	**31**	**34**	**x**	**x**	**-**	**-**	**35**	**41**	**32**	**38**

Appendix 4: Density of Common Sandpiper *Actitis hypoleucos* in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) after the kernel method, based on data of presumably nesting individuals collected in the 2006–2020 period (N = 263 registrations of 354 ind.). The darker the shade of red colour, the greater the density in that area.



Appendix 5 (pp. 60–64): Basic data on gravel bars mapped in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) in 2021 and 2022, with number of Little Ringed Plover *Charadrius dubius* (LRP) and Common Sandpiper *Actitis hypoleucos* (CS) breeding pairs, and anthropogenic activities encountered (E – gravel excavation, D – off-road driving, R – prolonged recreational use) given, X – other types of riverine habitats.

Gravel bar			2021					2022				
Section	ID	Surface area (m^2)	LRP		CS		Human	LRP		CS		Human
			min	max	min	max		min	max	min	max	
1	1	923										
1	2	2127								1	1	
1	3	428								0	0	
1	X	-			3	3				1	1	
2	4	507										
2	5	4438	1	1	1	1		1	2	0	0	
2	6	4062	0	0	0	0						
2	7	1462			1	1				1	1	
2	8	187										
2	X	-			0	0				0	0	
3	9	691										
3	10	1244										
3	11	18701			1	1	D, R			2	2	D, R
3	12	668			1	1						
3	X	-			0	0				0	0	
4	13	1034										
4	14	454										
4	15	957										
4	X	-	0	0	0	0				0	0	
5	16	821										

Gravel bar			2021					2022				
Section	ID	Surface area (m^2)	LRP		CS		Human	LRP		CS		Human
			min	max	min	max		min	max	min	max	
5	17	1092	1	1						1	1	
5	18	835										
5	19	1737								0	0	
5	20	1406										
5	21	383						0	1	0	1	
5	22	344										
5	23	1007			0	1				1	1	
5	24	3981	2	2								
5	25	2342	1	1	1	1		1	1	1	1	R
5	26	1287						1	1			
5	27	2833			0	0						
5	28	4497	0	1								
5	29	1214			0	0		1	1			
5	30	1013	1	1				1	1			
5	31	5241			1	1				1	1	
5	32	1667										
5	33	158										
5	34	7136								1	1	
5	35	2668	1	2	0	0				1	1	
5	36	7909	1	1			R	1	1			R
5	37	3963	2	2	1	1		1	1	0	0	
5	38	584								1	1	
5	X	-			0	0				0	0	
6	39	355								0	0	

Gravel bar			2021					2022				
Section	ID	Surface area (m^2)	LRP		CS		Human	LRP		CS		Human
			min	max	min	max		min	max	min	max	
6	40	1161					R					
6	41	441			1	1						
6	42	1150										
6	43	739										
6	X	-			1	1				0	0	
7	44	739						0	0			
7	45	3588	1	1	0	0		1	1	1	1	
7	46	7875	0	0	1	1		1	1	1	1	
7	47	3446	1	1	1	1		1	1	1	1	
7	48	4028			0	0				0	1	
7	49	1182	1	1				1	1	0	0	
7	50	195			0	0						
7	51	176										
7	52	712										
7	53	2737			1	1						
7	54	332										
7	55	308	0	1				0	1			
7	X	-			1	2				1	1	
8	56	798										
8	57	142										
8	58	7247	0	1	1	1						
8	59	5760	3	3	1	1		2	2	2	2	
8	60	1314										
8	61	4463								1	1	

Gravel bar			2021					2022				
Section	ID	Surface area (m^2)	LRP		CS		Human	LRP		CS		Human
			min	max	min	max		min	max	min	max	
8	62	685										
8	63	2016										
8	64	2356			0	1				1	1	
8	65	553								0	0	
8	66	761										
8	67	472								0	0	
8	68	1221	1	1	1	1		1	1	1	1	
8	69	695										
8	70	21652	0	1				1	1			
8	71	1010								1	1	
8	72	649	1	2								
8	73	9240	1	1	1	2	P	1	1	1	1	P
8	74	5421						1	1	1	2	
8	75	3416	3	3	1	1		3	3	0	0	
8	76	639										
8	77	3689	0	1								
8	78	9133	1	1	0	0						
8	79	18685	2	2	0	0		2	2			
8	80	3000	2	2	1	1		2	2	1	1	D, R
8	81	4660	2	2				0	1	0	0	
8	82	9883	1	1	0	1						
8	83	13525	4	4	1	1		2	2	1	1	R
8	84	192										
8	85	16636	3	3	1	1		2	2	1	1	

Gravel bar			2021					2022				
Section	ID	Surface area (m^2)	LRP		CS		Human	LRP		CS		Human
			min	max	min	max		min	max	min	max	
8	86	7607	3	3	1	2		5	5	1	2	R
8	87	392			1	1						
8	88	10469	3	4	2	2	D	1	2	2	2	
8	89	4491	1	1	1	1	D			0	1	
8	90	12061	2	2	2	2	E, D, R	2	2			E, D, R
8	91	7745	3	3	1	1		1	2	1	1	
8	92	951	1	1	1	1						
8	93	2669	1	1								
8	94	2996	0	1								
8	X	-			2	2				1	2	
Total		**320459**	**51**	**60**	**35**	**41**	**-**	**37**	**43**	**32**	**38**	**-**

Appendix 6: Number of Common Kingfisher *Alcedo atthis* breeding pairs in survey sections of the Mura River area between Ceršak (SLO) and Dekanovec (HR) in all comprehensive surveys carried out to date – only the main river channel (top table) and with results of the survey of localities outside the main river channel (side arms, gravel pits) taken into account (bottom table) (- not surveyed).

Section	2006		2008		2010		2012		2014		2016		2018		2020		2021		2022	
	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Section 1	3	3	3	4	3	4	1	1	1	1	3	4	3	5	3	3	2	3	3	3
Section 2	2	2	1	1	1	1	1	1	2	2	2	3	1	1	2	2	3	5	1	2
Section 3	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	2	2	2	1	2
Section 4	3	3	3	4	1	1	1	1	1	1	4	5	2	3	4	4	1	2	3	3
Section 5	1	1	4	4	1	1	1	1	1	1	0	0	2	2	2	3	1	2	4	5
Section 6	0	0	1	1	0	0	0	0	1	2	1	1	1	1	2	3	1	1	2	3
Section 7	-	-	1	2	2	3	2	2	3	4	3	5	2	3	4	5	2	4	4	5
Section 8	-	-	8	12	3	4	3	3	4	5	8	9	10	11	12	14	10	13	10	13
Total	**10**	**10**	**21**	**28**	**11**	**14**	**9**	**9**	**13**	**16**	**22**	**28**	**21**	**26**	**30**	**36**	**22**	**32**	**28**	**36**

Section 1	3	3	-	-	-	-	-	-	3	3	3	4	-	-	-	-	-	-	4	4
Section 2	3	5	-	-	-	-	-	-	2	2	2	3	-	-	-	-	-	-	1	2
Section 3	1	1	-	-	-	-	-	-			1	1	-	-	-	-	-	-	1	2
Section 4	7	11	-	-	-	-	-	-	5	6	5	7	-	-	-	-	-	-	7	8
Section 5	3	5	-	-	-	-	-	-	3	3	4	4	-	-	-	-	-	-	5	8
Section 6	1	3	-	-	-	-	-	-	1	2	1	2	-	-	-	-	-	-	3	5
Section 7	-	-	-	-	-	-	-	-	3	4	3	5	-	-	-	-	-	-	4	5
Section 8	-	-	-	-	-	-	-	-	4	5	8	9	-	-	-	-	-	-	12	15
Total	**18**	**28**	**-**	**-**	**-**	**-**	**-**	**-**	**21**	**25**	**27**	**35**	**-**	**-**	**-**	**-**	**-**	**-**	**37**	**49**

Appendix 7: Density of Common Kingfisher *Alcedo atthis* in the Mura riverbed between Ceršak (SLO) and Dekanovec (HR) after the kernel method, based on data of presumably nesting individuals collected in the 2006–2020 period (N = 473 registrations of 500 ind.). The darker the shade of red colour, the greater the density in that area.