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Bird diversity along a riparian corridor in a moderate urban landscape

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ABSTRACT

Civilization built around rivers directly affects riparian corridor structure and ecology. Degradation, pollution, and deterioration along riparian corridors in urban landscapes change species composition and biodiversity. Birds are one of the most vulnerable taxa to ecological changes. The main objective of our study was to spatially compare bird species richness, abundance, and community structure along the Asar River, an urban riparian corridor in Düzce, Turkey. We identified 63 bird species, comprising 6722 individuals, and classified them into one of three groups: generalist species (11 species), woodland species (40 species), and waterbird species (12 species). Bird species richness was positively related to vegetative cover and negatively to urbanization. Richness was low in the winter and was higher during spring and summer. Riparian Quality Index (RQI) scores (mean = 54.8 ± 33.7; max. = 97 and min. = 5) were relatively low for all sampling plots and was reduced by human activities (e.g., roads, farmland, settlement). The number of woodland bird species changed positively (r = 0.71) with RQI. The generalist bird species, adapted to urbanization, were more common around settlements and open areas. Human population and settlement around Asar River increased one-third and farmland and natural habitat decreased one-fifth during the last decade. The area has high potential for growth and increased urbanization, thus increasing the pressure on the natural areas. Activities that diminish the amount of tree cover in the riparian corridor should be avoided. Habitat restoration and rehabilitation will increase RQI values, which can be used as indicators for bird richness in urban landscapes and benefit avian diversity along the riparian corridor. The existing riparian corridor and any enhancements to the corridor will help conserve Düzce's biodiversity in the future.

1. Introduction

More than half of the human population is now located in towns and cities (Fuller and Gaston, 2009). The shift of human habitation from rural to urban has affected mainstream ecological studies (Pickett et al., 2011). With urbanization, it is increasingly important to examine the effects of development on the distribution and behavior of biota in urban ecosystems (Marzluff et al. 2001). Urban ecological studies, started in the early- to mid-1900s, but have increased substantially around the world in the last several decades (Pickett et al., 2011). Urbanization changes global land use, substantially modifying biodiversity patterns (Dallimer et al., 2012). Native species decrease with urbanization because of the scarcity of natural areas, increases in predators, parasites, or competition, or intolerance of human activity (Marzluff, 2001); hence, native species are replaced by a pool of a few species adapted to the urban environment (Blair, 1999; Rodrigues et al., 2018).

Although urbanization adversely affects natural areas, urban green space, such as parks, woodlands, riparian areas of streams, community gardens, and school gardens (Roy et al., 2012), provide important services to people (e.g., physical activity, rest, and promoting public health) and wildlife (e.g., cover, reproduction, feeding) (James et al., 2009; Wolch et al., 2014). Green spaces increase as cities grow yet decline as human population density increases (Fuller and Gaston, 2009). In most cities, grass areas are concentrated and it is important to increase the cover of trees and shrubs in these areas (Attwell, 2000). Planting of exotic tree or shrub species in urban habitat adversely affects the proportion of natural flora and fauna (Acar et al., 2007). Due to lower nest predation and higher food availability, native bird species prefer urban areas dominated by native, rather than exotic, vegetation (Donnelly and Marzluff, 2004; White et al., 2005).

Cities are usually built around rivers, due to the benefits they provide such as transport, food, and drinking water (Karr and Chu, 2000; Groffman et al., 2003). But, river and stream corridors are seriously

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affected by settlement (Rottenborn, 1999). In this case, urbanization brings new challenges to ecologists. Especially, degradation of the natural areas, pollution of the receiving water, and deterioration of the drainage system necessitates new ecological approaches (Walsh, 2000). Riparian zones have important roles, supporting biodiversity, balancing the temperature of the aquatic habitat, providing woody debris, and creating green spaces in urban areas (Dallimer et al., 2012). Riparian zones act as ecological corridors offsetting the effects of landscape fragmentation connecting otherwise isolated habitat patches (e.g., farmland, home gardens, parks) (Bryant, 2006). Riparian areas provide food and cover for bird species and serve as colonization and dispersal corridors whereby birds can spread from riparian corridors to adjacent green spaces (Litteral and Shochat, 2017). Width of riparian buffers positively affects bird species richness and abundance (Kinley and Newhouse, 1997; Hagar, 1999). Riparian corridors are of greater importance for unique bird species in the most depleted landscapes (Bennett et al., 2014). To assess the ecological status of riparian systems, various indices have been developed such as: Riparian Quality Index (RQI) (Gonzalez del Tánago and García de Jalón, 2011), Qualitat del Bosc de Ribera (i.e., Riparian Forest Quality Index (QBR)) (Munné et al., 2003), and Stream–Wetland–Riparian (SWR) index (Brooks et al., 2009). RQI and QBR are commonly used indicators of ecological condition in the Mediterranean. RQI performed better than QBR across multiple riparian types, but QBR is superior for riparian forests (Valero et al., 2015).

Birds are a diverse class that significantly respond to ecological changes (Canterbury et al., 2000) and urbanization (Gagné and Fahrig, 2011). Birds are considered a good indicator group because of specific habitat needs by individual species, diverse habitat needs across species, well-developed life-history information, their location in the higher levels of the food chain, numerous long-term monitoring programs, and their conspicuous nature and resonance with the public (Gregory et al., 2008; Veselka and Anderson 2013). In urban landscapes, increasing greenery, particularly woody vegetation, enhances native bird populations and diversity (Herrando et al., 2017). In cities, greater bird diversity improves human well-being, and provides synergy between urban management and public perceptions (Corney and Neave, 2019). Bird ecology studies in urban landscapes are fewer than in other areas (van Heezik and Seddon, 2017), especially in Turkey, but are necessary to understand how birds use the urban landscape. Pidgeon et al. (2014) proposed that the effects of urbanization on bird communities occur in two phases. First, houses are located in fertile, highly productive areas that are also biodiversity hotspots such as riparian corridors. This results in an immediate positive effect on diversity as new niches, food sources, edges, and cover types are created. Second, settlement increases and bird richness decreases with increasing housing density. The relative impacts of urban and natural habitat factors on ecosystems, and their extent, can be determined spatially along urban-rural gradients, where human influences can be directly measured (McDonnell and Pickett, 1990). In the current study, we demonstrate short-term temporal patterns of bird communities along an urban-exurban gradient. The objectives of our study were to evaluate avian species richness, abundance, and community structure in relation to riparian quality along the Asar River, an urban riparian corridor in Düzce, Turkey. We hypothesized that indigenous bird species richness and abundance would be positively related to quality of the riparian corridor along the urban stream system.

2. Methods

2.1. Study area

Our study was conducted on the Asar River riparian corridor passing through Düzce, which is located in the Western Black Sea region in northern Turkey (Fig. 1). Asar River flows 35 km in an east to west direction and has a drainage area of 154 km^2. It flows into the Kucuk Melen River, which flows into the Black Sea (Demir et al., 2016). The current study occurred at 18 sampling plots along a 9500 m transect (altitude range 130–180 m a.s.l.) on the Asar River. The first sampling point was located at 40° 48′ 56.6″N, 31° 12‘ 13.7″ E and the transect continued to the west. Approximately 4000 m of the river passes through the densely urbanized study area. The downtown is equal distance to the start and end points of the transect. Asar River riparian corridor was categorized into 3 sections. Section I occurred upstream of the city and was located between the first sampling plot and the start of the city (Plots 1 – 5). Section II consisted of the portion that passes through the city (Plots 6 – 13) and Section III was located downstream of the city (Plots 14 – 18).

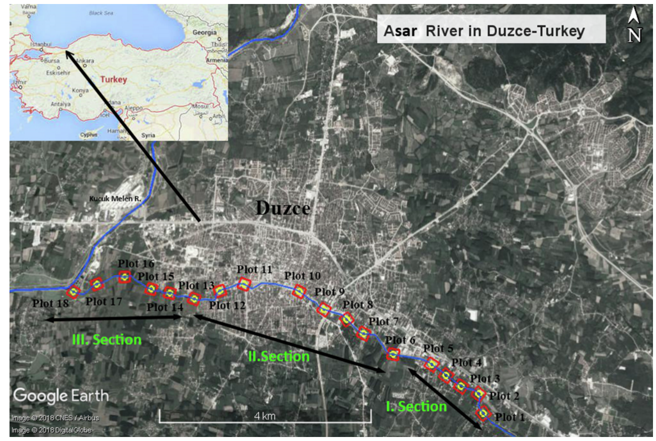

Fig. 1. Location of the 18 study plots on riparian areas on the Asar River in Düzce, Turkey (Red squares are sampling plots and yellow circles are sampling points established to observe birds). Asar River riparian corridor was structurally categorized into three sections; Section I (Upstream) Section II (City center) and Section III (Downstream). The map was produced from Google Earth.

The Asar River watershed population, which includes Düzce city, was around 80,000 people in 2000 but the population has since grown rapidly and now numbers 235,000 inhabitants. The population growth rate in the last decade is 31% (TUIK, 2018). Between 2008 and 2018, housing and industrial areas increased by 30% in Düzce city, with 10% growth within 100 m of Asar River. Düzce province is impacted by natural disasters such as earthquakes and floods, as well as human-induced threats (e.g., pollution) (Sözen, 2013). Mean annual precipitation is 834.4 mm and mean annual temperature is 13.2 °C in the study area.

2.2. Measurement of habitat variables

Birds and environmental variables were sampled along a gradient of human impacts along the riparian corridor. The 18 plots (200 × 200 m) were centered on the river, across lands comprised of municipalities, gardens, farmlands, homes, and orchards. Individual plots were located on both sides of the river, with the river bisecting the plots. We used four categories to describe the level of urbanization for each plot along an increasing settlement gradient: wildland, rural or exurban, suburban, and urban (Marzluff et al., 2001). We measured or visually estimated habitat variables relating to vegetation composition and urbanization. For each plot, the river body width (m) and riparian width (m) were measured, and tree and shrub cover, grass cover, farmland area, settlement area (i.e., housing, factories, stores, or other developments), and open area (i.e., bare ground without any vegetation but covered by impermeable surfaces (e.g., roads, pavement)) were estimated to the nearest 5% for the entire plot and riparian corridor. We also calculated Riparian Quality Index (RQI) for each plot (Gonzalez del Tánago and García de Jalón, 2011). For RQI, the riparian corridor was assessed by visual recognition of seven attributes; (i) dimension status, (ii) longitudinal continuity, (iii) structure of vegetation, (iv) natural regeneration, (v) bank conditions, (vi) lateral connectivity status of riparian and floodplain areas, and (vii) substratum and vertical connectivity status. The first three attributes were applied to each bank separately; the others were measured to integrate both sides. The maximum score of each criterion is 15, resulting in scores from 0 to 150. The RQI scores were placed into one of six categories: Very Good (150 – 130), Good (129 – 100), Moderate (99 – 70), Poor (69 – 40), Bad (39 – 10), or Very Bad (< 10).

2.3. Bird observations

We established 50-m radius bird point counts in the center of each of the 18 sampling sites, but due to flowing water we surveyed birds from the shore. At each sampling site, bird surveys were conducted regularly between the 15th and 20th of every month from March 2016 to February 2017 for a total of 216 bird point counts. Surveys were performed via single observer point count methodology (Bibby et al., 1992) within four hours of sunrise, under suitable weather conditions (no rain or fog, windless). Bird species detected by sight and sound were identified to species (Heinzel et al., 1995; Mullarney et al., 1999). Species were categorized as woodland birds, waterbirds, or generalist birds by the use of literature and field experience (Appendix A). Woodland birds favored forests, woodlands, and shrubs (Gregory et al., 2007), waterbirds lived on or around water (Kanaujia et al., 2015), and generalist bird species were adapted for different habitat types, and exploited urban areas (Tanalgo et al., 2015). Birds were also classified as migratory or resident (Appendix A). Resident species were observed in the study area throughout the year. Migratory birds occurred seasonally, especially in summer or winter.

2.4. Data analysis

Bird species richness and number of individuals for each species observed on each plot during the study period were recorded. Species richness and total bird abundance among sections (Fig. 1) and seasons (Winter: December, January, February; Spring: March, April, May; Summer: June, July, August; Autumn: September, October, November) were compared with two-way ANOVAs, followed by Tukey's Honest Significant Difference (HSD) test for multiple comparisons ($\alpha = 0.05$). We used Tukey's Ladder of Powers transformation to improve distribution of abundance data (Mangiafico, 2016).

We used Pearson correlation to relate each of eight environmental variables amongst each other and to species richness. Environmental variables included RQI values, water body width (W_width), riparian width (R_width), and percent tree and shrub cover (Tr_Sh), grassland cover (Grass), farmland area (Farm), settlement area (Sett), and open area (Ope). Species richness was partitioned as total bird (TSR), woodland bird (WoBR), waterbird (WBR), and generalist bird (GBR) species richness.

We used canonical correspondence analysis (CCA) to understand which variables, and to what extent, they affected bird composition, based on the locations of sampling plots along environmental axes. CCA is a direct gradient analysis ordination technique and is a special representation of multivariate regression. Ordination of plot scores is based on CCA operations that perform a least-squares regression of sampling plot scores as dependent variables and environmental variables as independent variables. Results from the CCA produce eigenvalues that are used to describe how much variance is explained by each ordination axis, thus measuring the importance of each axis (Pennington et al., 2010). All analyses were made in R (version 3.5.1) (R-Development Core Team 2018). Boxplot graphics were created using ggplot2 package (Wickham, 2016), correlograms were made with corrplot package (Wei et al., 2017), and CCA was made with the vegan package (Oksanen et al., 2007).

3. Results

3.1. Habitat variables

In the general evaluation of sampling plots, different cover types (e.g., farmland, grassland, woodland, orchard, settlement, parks) were observed in different ratios. The building and impervious surface rate (e.g., pavement, road, and wall) is around 90% in the city center; the natural area is virtually non-existent. As you move away from the city, natural and semi-natural areas increase. In Section I, the riparian corridor is larger (mean = 45.6 m ± 4.6 (Standard deviation (SD)); min. = 35 m and max. = 65 m), splayed, and more tree-shrub covered, but the river is medium-width (mean = 8.8 m ± 0.8; min. = 6 m and max. = 11 m). Section II is a 30 m ± 0.0 wide riparian corridor where there is limited, separated, and irregular vegetative cover. In this 5 km long channelized river section, width is variable (mean = 12.7 m ± 6.7; min. = 7 m and max. = 26 m). The riparian corridor in Section III is partially narrow (mean = 18.2 m ± 3.1; min. = 8 m and max. = 30 m) and more tree covered. The shape of the river banks in Section III are vertical or very steep and the river width varies (mean = 11 m ± 2.9; min. = 4 m and max. = 26 m).

The RQIs scores (mean = 54.8 ± 33.7; max. = 97 and min. = 5) were relatively low for all sampling plots. In general, a lack of connection to upland or other wide large natural areas of Asar River riparian corridor caused low RQI values. Riparian corridor quality was reduced by human activities (e.g., roads, farmland, settlement) (Appendix B). RQI values varied among the riparian corridor sections ($F_{2;15} = 17.96$; $P < 0.001$). In the city outskirts (Section I and III), the RQI classification was Moderate except for plots 5 and 18, where low tree cover occurred, resulting in a Poor rating (62 and 52 respectively). It continued to decline towards the city (Section II). RQI in the city was most affected by vegetation and corridor structure. Due to the lack of adequate biological elements and the increase in human structures, the RQI decreased near the city center where the riparian area was classified as "Bad" or "Very Bad". RQIs were positively correlated with tree and shrub cover ($r = 0.65$). The RQI was negatively correlated with settlement ($r = -0.77$), impervious surfaces ($r = -0.73$), and water body width ($r = -0.60$). Farmland areas, and tree and shrub cover, decreased as settlement and open areas increased (Fig. 2).

3.2. Bird communities

We recorded a total of 6,722 individuals from 63 bird species, including 25 migratory (40%) and 38 resident (60%) species (Appendix A). All species were native and no exotic birds were observed. Bird species richness per plot ranged from 0 to 13 per count period (median = 5). The maximum total number of species (31) in a plot across all sampling dates was in the sampling plot where the Asar River intersected the Kucuk Melen River (Plot 18). The least number of species (10) were in the city center, and this plot also had the maximum number of individuals (2684), due to large flocks of Rock dove *Columba livia*. The most ubiquitous species of birds were Hooded crow *Corvus cornix* and Eurasian jackdaw *Corvus monedula* at 18 (100%) sampling plots, Barn swallow *Hirundo rustica* at 17 (94%) sampling plots, Common chaffinch *Fringilla coelebs* at 16 (89%) sampling plots, and House sparrow *Passer domesticus* and Eurasian magpie *Pica pica* at 15 (83%) sampling plots. Seventeen species were recorded from a single plot, and 14 of them were detected one time. The other three species were observed more than one time at the same plot.

Avian species richness varied significantly among seasons ($F_{3;204} = 20.66$; $P < 0.001$) and sections ($F_{2;204} = 8.37$; $P < 0.001$), but the interaction between season and section was not significant for bird species richness ($P = 0.50$). Species richness was lower in winter than other seasons and varied between Section II and III (Table 1 and Fig. 3a). Total species abundance differed significantly among seasons ($F_{3;204} = 3.47$; $P = 0.017$) and river sections ($F_{2;204} = 10.74$;

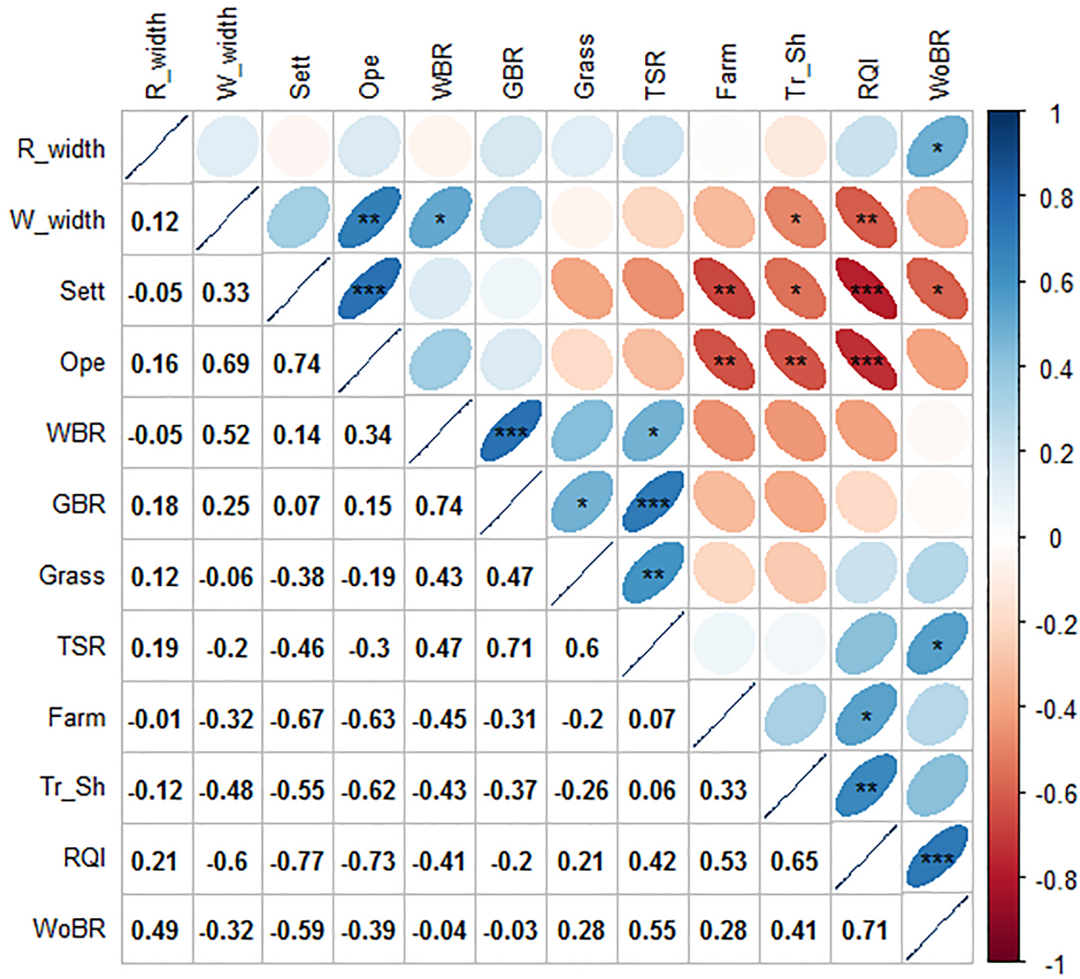

Fig. 2. Correlation matrix between the variables (habitat variables and bird species richness) for 18 sampling plots. The numbers show correlation coefficients. The flatness and color of the ellipse indicate the magnitude and direction of the correlation. The significance values are shown with asterisk (*p < 0.05, **p < 0.01, ***p < 0.001). (RQI: Riparian Quality Index; W_width: Water body width; R_width: Riparian corridor width; Tr_Sh: Tree-shrub cover; Grass: Grassland cover; Farm: Farmland areas; Sett: Settlement areas; Ope: Open areas; TSR: Total bird species richness; WBR: Waterbird species richness; WoBR: Woodland bird species richness; GBR: Generalist bird species richness).

$P < 0.001$), but the interaction between season and section was not significant ($P = 0.868$) (Table 1). The source of variation of abundance for seasons was different between summer and winter. Also, the high population levels of a few predominant species in Section II caused this section to be different from Section I and III (Fig. 3b).

A total of 11 generalist species (mean = 7.8 ± 1.8) were seen on plots. Generalist species abundance was correlated ($r = 0.60$) to grassland area. Although these species composed 17% of all species observed, they constituted 83% of the individuals. Generalist species richness and abundance increased with urban landscape. On the contrary, woodland bird richness and abundance decreased towards the city center (Fig. 4). They were positively related to RQI ($r = 0.71$) and riparian corridor width ($r = 0.49$), and negatively correlated with settlement ($r = -0.59$) (Fig. 2). Waterbird richness was correlated to larger and shallower water surface ($r = 0.52$), including the wider river near the city center, but the number of individuals were quite low.

Habitat variables explained about 59% of variance in bird community composition ($P = 0.001$). The first axis (CCA1) accounted for 33% of the total variance, and the second axis (CCA2) accounted for 18%. Areas of intense urbanization were grouped separately from semi-natural areas according to CCA1. Sampling plots were clustered into two main groups: urban (right side) and suburban (left side), based on bird communities (Fig. 5a). Increasing coverage of trees and shrubs, and agricultural areas were related to RQI. However, the increase in riparian corridor width and grassland did not provide a significant contribution to CCA1, but it was a distinguishing feature for CCA2. The number of woodland bird species changed positively with tree-shrub density, the amount of farm area, and RQI. Rock dove, House sparrow, and Hooded crow, which are generalist bird species adapted to urbanization, were more common around settlements and open areas. Regulating the water from the settlement area by channelization caused the water surface to be wide, slow, shallow, and lack vegetation, providing suitable habitat for some waterbirds such as Common kingfisher *Alcedo atthis*, Grey heron *Ardea cinerea*, Little egret *Egretta garzetta*, and Black stork *Ciconia nigra* (Fig. 5b).

4. Discussion

Urbanization along the Asar River adversely affected riparian vegetative cover and native bird species, especially woodland birds. In the city center, the number of bird species dropped to 10 and most of them are generalist species. The most important reason for this is the deterioration of riparian quality due to lack of vegetation, structured channeling, and high human settlement. Our results show that Düzce's Asar River has a riparian bird abundance and species gradient similar to those of other urban riparian corridors (Smith and Schaefer, 1992; Rottenborn, 1999; Hennings and Edge, 2003; Pennington et al., 2008; Pennington and Blair, 2011; Dallimer et al., 2012). We found the

Table 1
Two-way ANOVA results comparing species richness and total bird abundance among seasons and sections in Asar River, Düzce, Turkey. Tukey HSD multiple comparisons of means 95% family-wise confidence level.

Effect	df	F	P
Species richness			
Season	3	20,656	< 0,001
Spring-Autumn			0,136
Summer-Autumn			0,002
Winter-Autumn			0,001
Summer-Spring			0,446
Winter-Spring			< 0,001
Winter-Summer			< 0,001
Section	2	8,368	< 0,001
Section I-Section II			0,171
Section I-Section III			0,102
Section II-Section III			< 0,001
Season:Section	6	0,894	0,500
Bird abundance			
Season	3	3,474	0,017
Spring-Autumn			0,983
Summer-Autumn			0,391
Winter-Autumn			0,371
Summer-Spring			0,212
Winter-Spring			0,592
Winter-Summer			0,009
Section	2	10,740	< 0,001
Section I-Section II			< 0,001
Section I-Section III			0,759
Section II-Section III			0,002
Season:Section	6	0,415	0,868

highest abundance of bird species in urban areas. Several studies reported that bird abundance in urban sites was higher than or similar to other land uses (Clergeau et al., 2006; Luther et al., 2008). Generalist bird species are highly adapted to human-impacted landscapes resulting in high abundance as in our study.

The general effect of urbanization on bird species and the relationship between tree cover and bird communities has been well explained (Ferenc et al., 2014; Canedoli et al., 2018; Rodrigues et al., 2018). Even species preferring open habitat select some tree cover (Droz et al., 2019). Not only trees, but shrub density also increases avian richness in riparian areas (Kinley and Newhouse, 1997). The restoration of riparian woody vegetation is a priority management concern in human-dominated environments (Bennett et al., 2014). Woody vegetation is important to riparian bird vitality, but woody vegetation is most likely to exist only if other stream functions and biophysical processes (e.g., bank stability) are maintained (George and Zack, 2001). Bird and other vertebrate communities often improve at restored riparian areas (Bateman et al., 2015). However, restoration of vegetative structure and composition may not be enough for woodland birds and waterbirds to exist in riparian areas due to high levels of human activity (Miller et al., 2003). Habitat restoration may be more useful for common species rather than rare species (Young et al., 2013). Our study did not aim to determine an optimum riparian width required for bird communities, but results indicated that broader riparian corridors with more trees and shrubs, and therefore greater structural diversity, better maintained native bird diversity along the gradient of urban to rural landscapes.

In urban areas, we found that RQI was positively associated with bird diversity. Previous studies have not evaluated bird diversity or composition in relation to RQI values. However, aquatic fauna richness also increases with higher RQI values (Navarro-Llácer et al., 2010). We suggested that RQI values can be a useful indicator for bird species richness. Woodland birds in the forested portion of the riparian corridor improved avian diversity and provided habitat for unique bird species in an urban landscape (e.g., woodpeckers, tits, warblers, Common nightingale *Luscinia megarhynchos*, Eurasian golden oriole *Oriolus oriolus*, and Goldcrest *Regulus regulus*). RQI provides a tool for rapid assessment and characterization of riparian quality. One of the most important factors in the RQI are the vegetative characteristics. Comparison of RQI values temporally can facilitate evaluation of possible changes in the riparian landscape due to urbanization (Gonzalez del Tánago and García de Jalón, 2011).

In the current study and our previous studies (Keten et al., 2012; Keten et al., 2016), a total of 183 species, most of which are residents, were identified in Düzce province. All of them are native. Two exotic parakeet species have been identified from 22 provinces in Turkey (Akyıldırım and Arslan, 2013; Çalışkan, 2018), but they have not been observed in Düzce. Bird species in Düzce live in different habitats such as coniferous and deciduous forests, and wetlands. It is important that we found at least one-third of these species in Düzce city and nearby areas. In addition, the riparian corridor on Asar River passing through Düzce city constituted habitats for short-distance migrant birds such as European robin *Erithacus rubecula*, Common buzzard *Buteo buteo*, Grey wagtail *Motacilla cinerea*, Eurasian siskin *Cardueluis spinus*, and Great tit *Parus major*. In moderately urbanized areas, green space networks provide potential habitat for some bird species which are threatened because of habitat degradation (Droz et al., 2019). The increase in summer migratory species causes seasonal differences. Bird species richness increases during summer and decreases during winter in the region (Keten et al., 2010; Keten et al., 2012).

Generalist species increased in the areas near the city and their numbers prevailed over other species. Rock dove and house sparrow which constituted about 60% of the total number of individuals along the Asar River riparian corridor were positively associated with concrete structure abundance. Indeed, rock dove, starling and house sparrow are often the most common species in cities in the northern hemisphere (Lancaster and Rees, 1979; Blair, 1996; Fernandez-Juricic, 2001). Generalists occur typically at higher rates in urban areas than in nearby natural or rural habitats (Pickett et al., 2011), likely due to their propensity for anthropogenic food sources that enhance colonization and survival rates (Fidino and Magle, 2017). In fact, these species with superior dispersal abilities, high reproductive rates, higher survival rates, and short flight distances, select for urban habitats (Møller, 2009). Thus, in urban areas of intermediate disturbance, species richness and generalist species abundance is often higher than at lower or higher levels of urbanization (Marzluff 2005; Litteral and Shochat, 2017). Some of them are identified as synurbic birds which are colonizers directly into a strongly urbanized habitat (Tomiałojć, 2017).

The temporal effects of urbanization on woodland bird communities can be observed in riparian corridors (Pidgeon et al., 2014). Changes in avian species composition can be predicted if human settlement increases in riparian areas over time. Woodland bird richness and number of individuals decreased, and urbanization increased toward the city center. With the development of cities over time, the speed of withdrawal of woodland birds from their geographic range can be estimated. Nevertheless, there are some unknowns in understanding the effects of urbanization in a short-duration study. Long-term studies can provide a better understanding of relationships between avian diversity and urbanization (Fidino and Magle, 2017). Our study provides a solid baseline so the study can be repeated every 10 years to improve our understanding of urban bird dynamics in the region as the community continues to grow.

Düzce is a moderately-sized urban area, but, in the near future, it could become a metropolis. The population and settlement rate of Düzce have increased by one-third over the last decade, and this development trend is continuing. In contrast, cultivated and natural areas have declined about 20%. The new residential and industrial areas are usually developed from agricultural or natural areas (Sözen, 2013). Asar River's narrow riparian corridor is comprised of remnant habitats surrounded by farms, gardens, or settlements. Each subsequent human intervention will affect the sensitive landscape. Agricultural activities also can negatively impact riparian condition (Chua et al., 2019). But, riparian vegetation can offset some of the negative attributes of

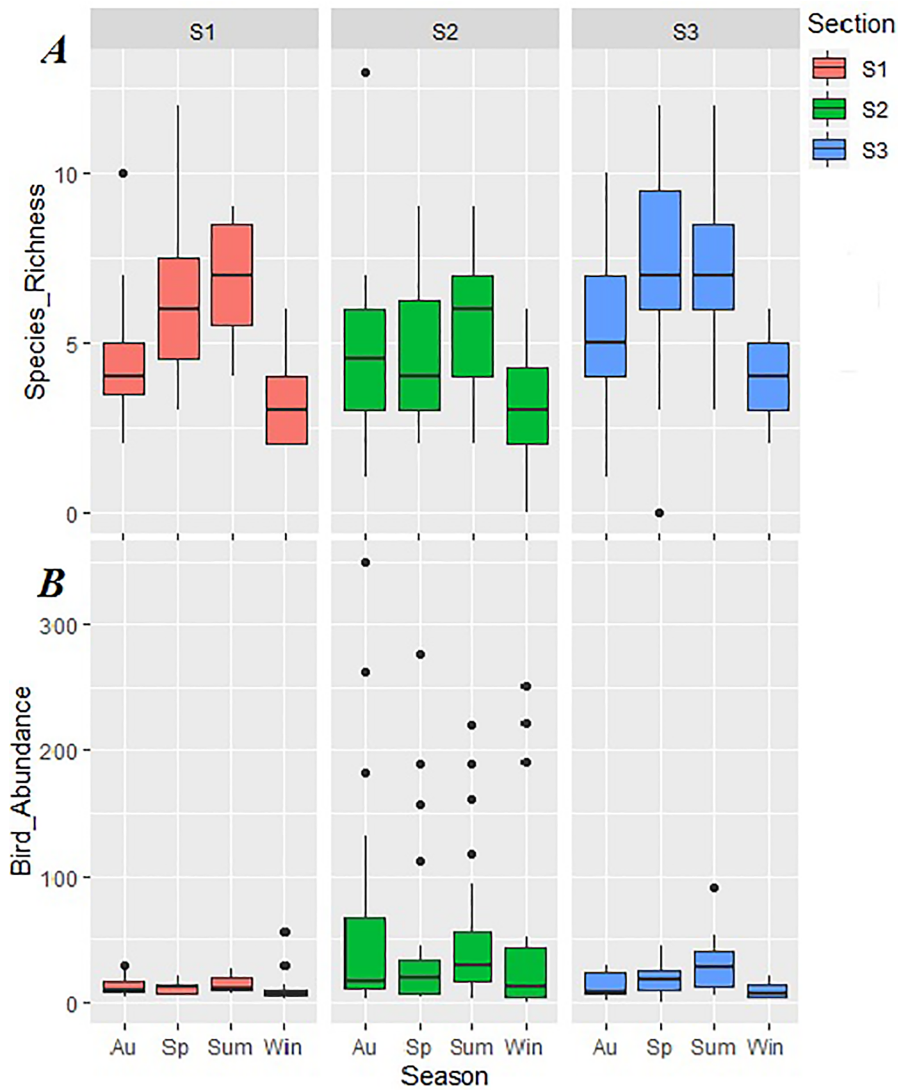

Fig. 3. Box plot graph of total species richness (A) and total bird abundance (B) by season and section during all sampling. Species richness was lower in winter than other seasons. Species abundance was higher in Section II (City center) caused by higher populations of Rock dove, Hooded crow, Eurasian jackdaw, and House sparrow than in the other sections. Seasons: Au, Autumn; Sp, Spring; Sum, Summer; Win, Winter; and Sections: S1, Section I; S2, Section II; S3, Section III.

surrounding land use and provide greater opportunity for movement of woodland species between riparian and other nearby habitats (Bennett et al., 2014). Undeveloped shorelines in urban ecosystems support waterbird species that are sensitive to human disturbance (Donaldson et al., 2007). The riparian corridor in the heart of Düzce will help to conserve biodiversity in the future.

5. Conclusion

Bird species richness declined to 10 species as impervious surface decreased and increased up to 31 species as vegetative cover increased. The RQI values were directly influenced by vegetation ($r = 0.65$). We found that RQI scores can be used as indicators for bird richness in urban landscapes. In riparian systems, the RQI is a helpful tool for rapid assessment of environmental conditions and the index can be used in the design of restoration strategies by controlling riparian components affected by human activities (Gonzalez del Tánago and García de Jalón, 2011). To maintain RQI scores, activities that reduce the amount of tree cover in urban environs should be avoided. Native trees and shrubs should be planted in the riparian corridor where vegetation is sparse. Thus, RQI values can be raised with habitat restoration and rehabilitation with native vegetation. For RQI, it is quite difficult to change other structural forms along the riparian corridor. In the current situation, even if the RQI value is at least increased to the “Poor” level (RQI score, 69–40) from the “Very Bad” (RQI score < 10) level, it is possible to increase bird species in the urban landscape. These improvements will not adversely affect the generalist and waterbird species, but will enable woodland species to live in the area.

In areas where human population is expanding, settlement and industry increase the pressure on natural areas. Continued pressure on riparian zones in the near future will increase and can lead to a drop in riparian corridor quality. In balancing protection and use, it is important that the natural landscape structure is not fragmented along the riparian zone. For this reason, necessary measures should be taken to avoid degradation, thus reducing future declines in biodiversity. The quality of riparian corridors close to cities should be monitored periodically to assess land use changes, biodiversity, and impacts of anthropogenic disturbance and natural disasters, especially flooding; urban planners should incorporate these changes into city plans (regional, development, and master plans) as necessary. Green spaces (e.g., riparian corridors, gardens, parks) are an important part of the mosaic of urban landscapes. Ecological connections using roadside

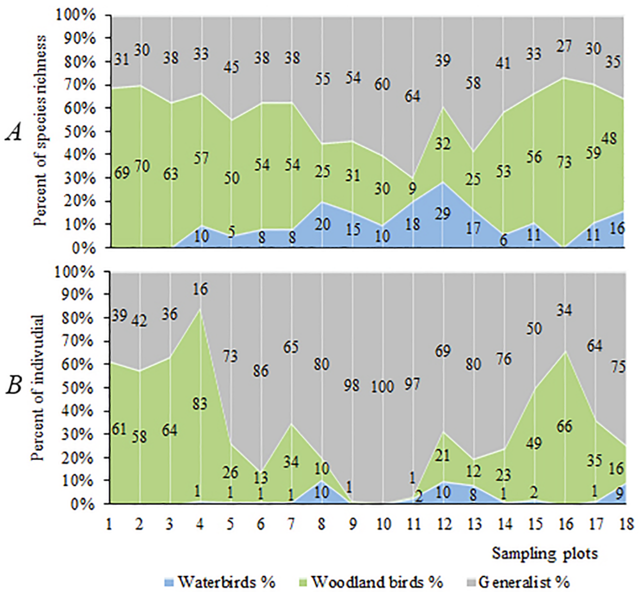

Fig. 4. Proportional rate of change of species richness (A) and avian abundance (B) categorized as waterbirds, woodland birds, and generalist birds in the 18 sampling plots displayed in Fig. 1. Generalist species richness and abundance increased, and woodland bird richness and abundance decreased towards the city center.

plantings of native nectar and fruit producing plants and natural landscape designs, such as green walls, green roofs, and rain gardens, between existing green spaces in the city center and the riparian corridor should be established to promote biological diversity in the urban landscape.

CRediT authorship contribution statement

Akif Keten: Conceptualization, Methodology, Data curation, Formal analysis, Writing - original draft. **Engin Eroglu:** Project administration, Funding acquisition, Conceptualization. **Sertac Kaya:** Resources. **James T. Anderson:** Writing - reviewing and editing, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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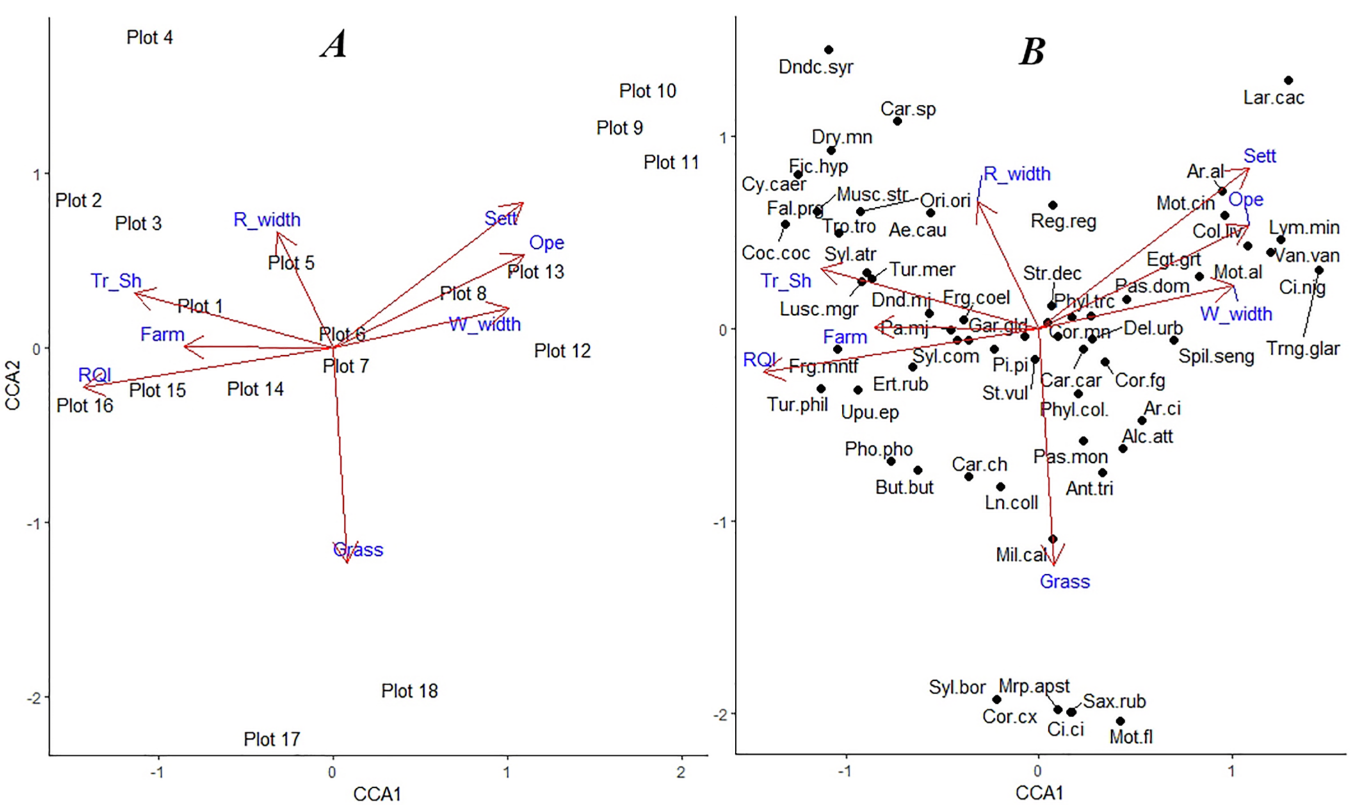

Fig. 5. The result of ordination diagram presenting the first two axes of the Canonical Correspondence Analysis (CCA) (percent of explained variability: CCA1 = 33%, CCA2 = 18%) based on the distribution of species abundance in 18 sample plots in the urban area of Duzce, Turkey, and its correlation with eight variables (arrows). For graph A, codes correspond to the sampling plots, and for graph B, codes represent bird species. The first axis shows urbanization (negatives values on right = more urbanized regions; positive values on left = less urbanized regions). All axes were significant ($P < 0.001$). The abbreviations in Appendix A and B were used for bird species name and habitat variables.

Appendix A

A total of 63 bird species surveyed with 216 detections from 18 sampling plots between March 2016 and February 2017 in Asar River in Düzce, Turkey used in analyses. Species are separated three categories as woodland birds, waterbirds and generalist birds (Gregory et al., 2007; Kanaujia et al., 2015; Tanalgo et al., 2015). For migratory status, R = Resident or short-distance migrant, M = Migrant.

Bird Species	Abbreviation	Migratory status	No. of plots	No. of detections	No. of individuals	% of total individuals
Woodland birds	WoBR					
Aegithalos caudatus, Long-tailed tit	Ae.cau	R	2	2	7	0.10
Anthus trivialis, Tree pipit	Ant.tri	M	2	2	3	0.04
Buteo buteo, Common buzzard	But.but	R	5	9	9	0.13
Carduelis carduelis, European goldfinch	Car.car	R	4	7	37	0.55
Carduelis chloris, European greenfinch	Car.ch	R	4	4	7	0.10
Cardueluis spinus, Eurasian siskin	Car.sp	M	4	7	119	1.77
Coccothraustes coccothraustes, Hawfinch	Coc.coc	M	1	2	3	0.04
Corvus corax, Common raven	Cor.cx	R	1	1	1	0.01
Cyanistes caeruleus, Eurasian blue tit	Cy.caer	M	2	4	6	0.09
Dendrocopos major, Great spotted Woodpecker	Dnd.mj	R	2	2	2	0.03
Dendrocopos syriacus, Syrian woodpecker	Dndc.syr	R	1	1	1	0.01
Dryobates minor, Lesser spotted woodpecker	Dry.mn	R	1	1	1	0.01
Erithacus rubecula, European robin	Ert.rub	R	11	25	44	0.65
Falco peregrinus, Peregrine falcon	Fal.prg	M	1	1	1	0.01
Ficedula hypoleuca, European pied flycatcher	Fic.hyp	M	1	1	1	0.01
Fringilla coelebs, Common chaffinch	Frg.coel	R	16	103	194	2.89
Fringilla montifringilla, Brambling	Frg.mntf	M	1	1	18	0.27
Garrulus glandarius, Eurasian jay	Gar.gld	R	9	13	25	0.37
Lanius collurio, Red-backed shrike	Ln.coll	M	6	10	16	0.24
Luscinia megarhynchos, Common nightingale	Lusc.mgr	M	11	27	66	0.98
Merops apiaster, Bee-eater	Mrp.apst	M	2	3	6	0.09
Miliaria calandra, Corn bunting	Mil.cal	M	5	14	41	0.61
Motacilla alba, White wagtail	Mot.al	R	6	12	41	0.61
Motacilla cinerea, Grey wagtail	Mot.cin	R	8	16	23	0.34
Muscicapa striata, Spotted flycatcher	Musc.str	M	2	2	3	0.04
Oriolus oriolus, Eurasian golden oriole	Ori.ori	M	7	16	27	0.40
Parus major, Great tit	Pa.mj	R	14	79	147	2.19
Passer montanus, Eurasian tree sparrow	Pas.mon	R	5	8	19	0.28
Phoenicurus phoenicurus, Common redstart	Pho.pho	M	2	2	2	0.03
Phylloscopus collybita, Common chiffchaff	Phyl.col.	R	4	6	18	0.27
Phylloscopus trochilus, Willow warbler	Phyl.trc	M	1	1	1	0.01
Regulus regulus, Goldcrest	Reg.reg	R	1	1	2	0.03
Saxicola rubetra, Whinchat	Sax.rub	R	2	2	10	0.15
Sylvia atricapilla, Blackcap	Syl.atr	M	8	14	28	0.42
Sylvia borin, Garden warbler	Syl.bor	M	1	1	2	0.03
Sylvia communis, Common whitethroat	Syl.com	M	11	24	31	0.46
Troglodytes troglodytes, Eurasian wren	Tro.tro	R	7	13	14	0.21
Turdus merula, Common blackbird	Tur.mer	R	10	26	30	0.45
Turdus philomelos, Song thrush	Tur.phil	R	1	1	2	0.03
Upupa epops, Common hoopoe	Upu.ep	M	2	2	3	0.04
Waterbirds	WBR					
Alcedo atthis, Common kingfisher	Alc.att	R	5	5	5	0.07
Ardea alba, Great egret	Ar.al	R	1	1	1	0.01
Ardea cinerea, Grey heron	Ar.ci	R	8	25	42	0.62
Ciconia ciconia, White stork	Ci.ci	M	2	3	3	0.04
Ciconia nigra, Black stork	Ci.nig	M	1	4	4	0.06
Egretta garzetta, Little egret	Egt.grt	R	12	41	56	0.83
Larus cachinnans, Caspian Gull	Lar.cac	R	1	1	1	0.01
Lymnocryptes minimus, Jack snipe	Lym.min	R	2	2	3	0.04
Motacilla flava, Western yellow wagtail	Mot.fl	R	1	3	6	0.09
Nycticorax nycticorax, Black-crowned Night-heron	Nyc.nyc	R	3	3	3	0.04
Tringa glareola, Wood sandpiper	Trng.glar	M	1	1	1	0.01
Vanellus vanellus, Lapwing	Van.van	R	1	1	2	0.03
Generalist birds	GB					
Columba livia, Rock dove	Col.liv	R	11	44	3628	53.97
Corvus cornix, Hooded crow	Cor.cr	R	18	156	547	8.14
Corvus frugilegus, Rook	Cor.fg	M	9	14	119	1.77
Corvus monedula, Eurasian jackdaw	Cor.mn	R	18	62	316	4.70
Delichon urbicum, Northern house martin	Del.urb	M	12	24	139	2.07
Hirundo rustica, Barn swallow	Hir.rus	M	17	47	212	3.15
Passer domesticus, House sparrow	Pas.dom	R	15	75	333	4.95
Pica pica, Eurasian magpie	Pi.pi	R	15	85	129	1.92
Spilopelia senegalensis, Laughing dove	Spil.seng	R	5	5	8	0.12
Streptopelia decaocto, Collared dove	Str.dec	R	11	26	52	0.77
Sturnus vulgaris, Common starling	St.vul	R	12	21	101	1.50
Total			18	216	6722	100

Appendix B

Habitat variables that were recorded for each plot (200 m × 200 m) and riparian corridor in the sampling plots. According to Marzluff et al. (2001), gradients of urbanization were described; R: Rural/exurban, SU: Suburban, U: Urban. Also the values obtained for the calculation of the Riparian Quality Index (RQI) for each sampling plots. Riparian status; M: Moderate (70–99), P: Poor (40–69), B: Bad (10–39), VB: Very Bad (< 10).

Habitat variables	Abbreviation	Side	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Plot 11	Plot 12	Plot 13	Plot 14	Plot 15	Plot 16	Plot 17	Plot 18
Sampling plot																				
Gradient of urbanization			SU	SU	SU	SU	U	SU	SU	U	U	U	U	U	U	SU	SU	R	R	SU
Tree-shrub cover (%)	Tr_Sh		40	30	35	30	10	15	15	30	5	5	5	5	10	30	50	70	10	5
Grassland (%)	Grass		15	5	20	20	25	5	10	15	5	0	5	20	10	15	10	5	50	75
Farmland (%)	F.land		30	45	40	20	5	60	30	0	5	0	0	0	50	40	30	25	35	0
Settlement (%)	Sett.		10	15	5	15	40	15	30	40	55	75	50	40	8	10	5	0	0	5
Openness (%)	Ope		5	5	5	15	20	5	20	10	25	20	40	30	15	5	5	3	5	10
Riparian area (%)	Rip		15	12	14	22	13	10	10	10	10	3	10	10	9	5	4	3	6	10
Riparian corridor																				
Riparian corridor width (m)	R_width		45	35	43	65	40	30	30	30	30	10	30	30	26	15	12	8	18	30
Water body width (m)	W_width		10	6	9	11	8	7	7	16	10	10	26	26	25	6	6	4	10	9
Tree cover (%)			60	90	85	90	95	80	65	0	0	10	0	0	0	80	80	90	20	10
Shrub cover (%)			30	30	15	20	50	10	20	5	10	0	0	5	5	50	50	10	30	20
Grass cover (%)			20	25	20	25	20	30	70	35	25	5	10	40	20	45	40	0	35	20
Riparian Quality Index																				
Dimensions of land with riparian vegetation		Left	3	2	2	1	2	2	2	1	0	0	0	0	1	2	3	3	3	2
		Right	3	3	3	1	2	2	1	0	0	0	0	1	1	3	3	3	5	2
Longitudinal continuity, coverage and distribution pattern of riparian corridors		Left	9	9	8	7	5	6	3	2	1	1	0	2	2	7	8	5	4	3
		Right	10	10	12	12	6	4	3	2	1	1	0	2	2	8	9	5	4	3
Composition and structure of riparian vegetation status		Left	10	10	9	9	8	7	3	2	1	0	1	2	2	10	11	8	10	7
		Right	11	11	12	10	8	7	3	2	1	0	1	2	2	12	12	8	10	7
Age diversity and natural regeneration of woody species			13	13	13	14	10	8	7	3	0	1	0	4	3	12	15	14	9	6
Bank conditions			11	12	12	10	7	3	3	3	1	0	1	3	3	12	12	10	12	9
Floods and lateral connectivity			13	13	12	10	7	3	3	3	2	2	2	3	3	7	9	9	12	6
Substratum and vertical connectivity			14	13	13	11	7	8	4	3	1	0	2	2	2	11	10	9	14	7
Riparian Quality Index Score	RQI		97	96	96	85	62	50	32	21	8	5	7	21	21	84	92	74	83	52
Riparian status			M	M	M	M	P	P	B	B	VB	VB	VB	B	B	M	M	M	M	P

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