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Evaluation of landscape connectivity between protected areas using pinch points

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Abstract: Protected areas, where the interaction of human and nature gain significant ecological, biological, cultural and scenic values and determining character over time, is also of vital importance in maintaining this interaction and protecting its integrity. The protected areas in Bursa, contribute to the landscape heterogeneity of the city and significantly support biological diversity. In this study, the protected areas in Bursa and the landscape connectivity between them and the effectiveness of protected areas related to land use in supporting landscape connectivity were evaluated. For this, the 2018 land use/land cover map was used and corridor connections were determined using the least-cost-path and Euclidean distance methods. The pinch points between these corridors were estimated using circuit theory. The pair of protected areas with the highest effective resistance (37.52) has been nature park and wildlife protection area. Least effective resistance value was calculated between seed stand and national park. The maximum value of the pinch points between all protected areas was calculated as 0.10. The pinch points between protected areas in the landscape represented the areas where movement between protected areas would be directed. Even a small loss of space at pinch points can compromise the connection between protected areas disproportionately. Therefore, determining the pinch points in the landscape has a very important place in planning studies.
Keywords: Pinch points, Landscape connectivity, Protected areas, Land cover/land use, Bursa

Korunan alanlar arasındaki peyzaj bağlantılılığının düğüm noktaları kullanılarak değerlendirilmesi

Özet: Zaman içerisinde insan ve doğa etkileşiminin önemli derecede ekolojik, biyolojik, kültürel ve görsel değerler ile belirleyici karakter kazandırdığı alanlar olan korunan alanlar, aynı zamanda bu etkileşimin sürdürülmesi ve bütünlüğünün korunması konusunda hayati önem taşımaktadır. Bursa sınırları içerisinde yer alan korunan alanlar, kentin peyzaj heterojenitesine katkıda bulunarak biyolojik çeşitliliği önemli derecede desteklemektedir. Bu çalışmada, Bursa kenti sınırları içerisinde yer alan korunan alanlar ile bunlar arasındaki peyzaj bağlantılılığı ve arazi kullanımlarıyla ilişkili korunan alanların peyzaj bağlantılılığını desteklemedeki etkinliği değerlendirilmiştir. Yöntem için 2018 yılı arazi örtüsü/arazi kullanımı haritasından yararlanılmış ve least-cost-path ile euclidean distance yöntemleri kullanılarak koridor bağlantıları belirlenmiştir. Bu koridorlar arasındaki düğüm noktaları (daralmalar/darboğazlar) devre teorisi kullanılarak tahmin edilmiştir. Düğüm noktalarının gectiği korunan alanlar arasındaki en etkin direnç 37.52 değeriyle tabiat parkı ve yaban hayatı koruma alanı arasında gerçekleşmiştir. En az etkinliğe sahip direnç değeri ise 0.01 ile tohum meşceresi ve milli park arasında hesaplanmıştır. Bursa peyzajında bulunan korunan alanlar arasındaki düğüm noktaları, korunan alanlar arasındaki hareketin yönlendirileceği alanları temsil etmiştir. Düğüm noktalarındaki küçük bir alan kaybı, bile orantısız bir şekilde korunan alanlar arasındaki bağlantıyı tehlikeye atabilir. Bu nedenle, peyzajdaki düğüm noktalarının belirlenmesi planlama çalışmalarında oldukça önemli bir yere sahiptir.
Anahtar kelimeler: Düğüm noktaları, Peyzaj bağlantılılığı, Korunan alanlar, Arazi örtüsü/arazi kullanımı, Bursa

1. Introduction

The contribution of protected areas in reducing global biodiversity loss is becoming clearer every day (Du et al., 2020; Ervin et al., 2010; Rudnick et al., 2012), however, these areas face many problems that have adverse effects on biodiversity, such as the fragmentation of natural ecosystems, habitat loss, especially climate change, due to urbanisation and increasing demands of natural resources (Castillo et al., 2020; Fletcher et al., 2018; Geldmann et al., 2019; Özcan and Aytaş, 2020; Sezen, 2017). A number of large species of (flora and fauna) existing within the boundaries of protected areas respond to these adverse effects either by isolating their habitats or by disappearing completely (DeFries et al., 2005; Zemanova et al., 2017). Therefore, the persistence of species and ecosystems depends not only on local actions but also on landscape management approaches. Since protected areas contain a natural or semi-natural habitat or a specific population, a well interconnected and well-managed system will contribute to the persistence of species and ecosystems (Gray et al., 2016; Haddad et al., 2015; Stewart et al., 2019; Watson et al., 2014).

In landscape ecology, connectivity (corridors) is used to describe the structural and functional continuity of a landscape in space and time (Forman and Godron, 1986). The habitat connection at the landscape level plays an important role in the viability of the population by facilitating movement, migration, dispersal and re-colonization by maintaining gene flow (Saura and Pascual-Hortal, 2007). The most important determinants of species survival and persistence are the spatial configuration and

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distribution of habitats on a landscape scale (Xun et al., 2014). The viability of populations can affect community dynamics, movement of individuals in landscapes and many related ecological processes. For example, species distributions and changes in response to climate changes not only depend on the movement capacity of the species, but also contribute to the landscape structure The loss of connectivity, coupled with the unprecedented pressure exerted by anthropogenic impact on the landscape since the Last Ice Age, is a growing central driver of the global biodiversity crisis. The key issue that needs to be addressed at this point is what connectivity means and how it will be measured. The best start for this is to examine the structural interconnectedness of the landscape, regardless of any biological or behavioural characteristics of the organisms that interact with it (Kindlmann and Burel, 2008; Tischendorf and Fahrig, 2000). The term "landscape connectivity" was used by Taylor et al. (1993) to describe the extent to which the landscape facilitates or inhibits movement between source patches. This term later evolved into the term "functional connectivity" Functional connectivity focuses on the landscape from the perspective of species and therefore the outcome of interactions between individuals and landscape structures according to their needs, perceptions, and responses (Fraser et al., 2018).

When the studies conducted using graph theory and circuit theory methods, which are the most up-to-date methods for determining connectivity corridors in the landscape, are examined (D'Elia et al., 2020; Dickson et al., 2019; McRae, 2006; McRae and Beier, 2007; McRae et al., 2008; McRae and Kavanagh, 2011), it is seen that a target species is determined and regional corridor connections are created based on landscape resistance maps for this species. The regional landscape connectivity corridor study, which was carried out by preparing a landscape resistance map of a specific species in our country, was carried out by Özcan and Aytaş (2020) in the example of Cankiri, but no landscape resistance maps for a specific species were produced for other provinces. Therefore, in this study, landscape connectivity corridors between protected areas are not analysed for a specific species, but for all species that are likely to use landscape connectivity corridors between protected areas, making a general assessment.

In this study, after determining the landscape connectivity corridors between protected areas in the first step, the pinch points that are assumed to adversely affect the ecological flow between species/individuals along these connectivity corridors are determined in the second step. Pinch points are defined as places where corridors narrow, bottlenecks or congestion points (Jones, 2015; McRae, 2012; McRae et al., 2012) More precisely, pinch points represent habitat areas that are in relatively good condition and for which there are no comparable alternative routes. High values obtained as a result of the analysis indicate network connectivity that should be given more attention. If these links are broken or lost, a disconnection occurs between one or more core areas (used as protected area in this study), increasing the risk of death for the species. The areas where the pinch points are located are the most important areas that should definitely be protected from habitat degradation. In the Ottoman period, the city of Bursa, which was defines as "Green Bursa" by referring to the large and rich forests in the surrounding as well as the parks and gardens next to its urban texture, stands out with its natural and cultural landscape features. Protected areas in the city are an indicator of landscape heterogeneity. The purpose of this study is to evaluate the effectiveness of the protected areas located within the boundaries of Bursa in supporting landscape connectivity. In order to determine the landscape connectivity corridors between the protected areas, a landscape resistance map was created by using the 2018 land cover/land use data. The purpose of the resistance map is to determine the areas where the species will be challenged/faced with the risk of death and to determine the path to direct the species to the shortest and most risk-free corridor where they can reach the habitats that are vital importance to them. Corridor connections between the least risky or risk-free areas among these areas were determined using the least-cost-corridor method. By using the connectivity corridors between the protected areas, the pinch points that hinder the mobility (energy, matter, information, and gene flow, etc.) in the landscape have also been determined by circuit theory along these corridors.

As a result of the analysis made for this purpose, The pair of protected areas with the highest effective resistance (37.52) has been nature park and wildlife protection area. Least effective resistance value was calculated between seed stand and national park. The maximum value of the pinch points between all protected areas was calculated as 0.10. It can be interpreted that the higher the resistance value, the more difficult the ecological flow between areas will be. The pinch points between the protected areas in the Bursa landscape represented the areas where the movement between the protected areas would be directed. Among the protected areas, the area with the highest current ecological flow is the wetland and the national park. The pinch points between two areas have occurred at the locations of dams or regulators. This study will contribute to the literature on three subjects. These are; 1. Using up-to-date/new methods in determining landscape connectivity corridors, 2. Emphasizing and leading the way in the preparation of landscape resistance maps that will be used as a basis for the creation of regional wildlife corridors in our country, 3. Emphasizing the importance of restoring the function of the corridors in landscape planning by identifying the pinch points where ecological flow is hindered in the landscape connectivity corridors determined to be species-specific and producing strategies to improve these points.

2. Material and method

2.1. Material

Bursa province is located in the Marmara Region of Turkey at 40°11' north latitude and 29°03' east longitude. The protected areas within the boundaries of Bursa were chosen as the sample areas for the study. Gene conservation areas, honey forests, national parks, nature parks, nature protection areas, conservation forests, seed stands, wetland, wildlife protection areas and urban forests were evaluated within the scope of the study (Figure 1, Table 1).

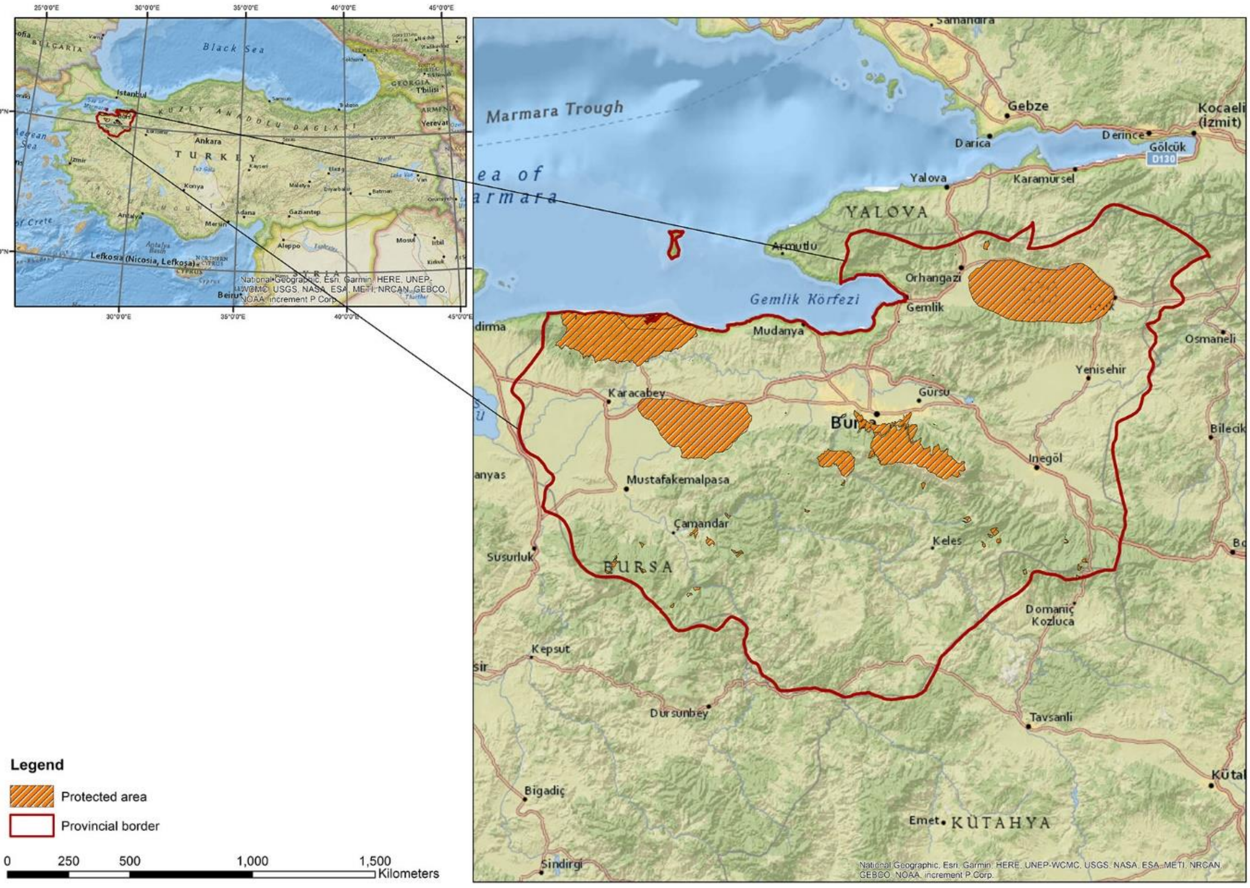

Figure 1. Geolocation of Bursa and protected areas

Table 1. Protected area statuses and descriptions that evaluated within the scope of the study

Statuses of protected areas	Name of protected area
Wildlife protection area	Karacabey Karadağı-Ovakorusu Wildlife Protection Area
Nature park	Delmece Yaylası Nature Park
Nature park	Eriklitepe Nature Park
Wetland	İznik Lake
Nature protection area	Kasalıç-Domaniç Nature Protection Area
Wetland	Kocaçay Delta
Nature park	Suuçtu Nature Park
Wetland	Uluabat Lake
National park	Uludağ National Park
Seed stand	-
Conservation forest	-
Gene protection area	-
Honey forest	-
City forest	-

As emphasized in the introduction of the study, protected areas are very valuable areas in terms of biological diversity. In the protected areas that are the subject of the study, both national and international protection statuses are given and information about the important species that are highlighted is shared below.

The methods used in the study will contribute to the conservation of the prominent species in the relevant protected areas.

Parnassius apollo graslini Oberthür, 1891, an endemic subspecies of *Parnassius apollo* (Apollo butterfly), one of the internationally endangered (International Union for Conservation Nature (IUCN)-Vulnerable-(VU)) butterfly species, spreads in ***Uludağ National Park***. In addition, the National Park is home to *Gypaetus barbatus* (Bearded vulture), one of the bird species that is likely to be endangered in the near future, as their numbers tend to decrease in the world. In the national park area, *Sus scrofa* (Wild boar), Ursudae, Wolf, Fox, Jackal, Martens, Leporids, Weasels, Snake, Frogs, Lacertids, Turtles, Vulture, *Aquila chrysaetos* (Mountain eagle), Picus, Owls, Eurasian collared-dove, Dunnock, Old World sparrows, and many crustacean, spider varieties and insect species survive. In addition, Uludağ is one of the 144 Important Plant Areas (IPA) in our country. Uludağ has been designated as an Important Bird Area (IBA) due to the breeding populations of the Bearded vulture and Golden eagle (ÇŞİM, 2019)

The most important resource value of ***Suuçtu Nature Park*** is Suuçtu Waterfall. Apart from the main waterfall, there are two more small waterfalls. The Nature Park and its surroundings are 1st degree protected area (ÇŞİM, 2019).

Uluabat Lake Wetland; is located on important bird migration routes from Europe to Asia. On the shores of the lake, there are bays covered with water lilies, wide reeds, cold waters and fresh water marshes. In the southwestern part of the lake, a large and wide delta was formed at the mouth of the Mustafakemalpaşa Stream and around it, due to the sedimentation of the sediment from the Mustafakemalpaşa Stream. Uluabat Lake; Due to its rich species diversity, being on an important bird migration route, and having a rich flora and fauna, it was declared a Wetland of International Importance on 15.04.1998 and was taken under protection by the Ramsar Convention. Uluabat Lake Wetland has species such as *Pelecanus crispus* (Crested pelican), *Hirudo medicinalis* (Medical leech), *Sagitaria sagittifolia* and *Stachys palustris*, which are in the "Vulnerable-VU" and "Near Threatened-NT" categories in the IUCN red list (ÇŞİM, 2019).

It is an important area for the critical phases of the biological cycles of mammalian and bird species. *Lutra lutra* (Otter) is one of the species that lives around Uluabat Lake and is under international protection. In addition, many waterfowl use the area for resting, wintering and breeding. According to the Birds Breeding Survey in Lake Uluabat in 1998, around 5000 pairs of 85 species of national and international importance breed in the area. Uluabat Lake is one of the important areas where *Phalacrocorax pygmeus* (Small cormorant) breeds. There are regularly high numbers of waterfowl in the area. In addition, the lake is an important habitat in terms of reproduction and feeding of fish (ÇŞİM, 2019).

İznik Lake Wetland is a very rich region in terms of fauna and flora, as it hosts many different habitat types. Abolished Ministry of Forestry and Water Affairs II. Within the scope of the "İznik Lake Wetland Management Plan Project, İznik Lake Wetland Sub-Basin Biological Diversity Research Sub-Project" carried out by the Regional Directorate in 2012-2013, 24 reptile species belonging to 11 families in the area; 8 amphibian species belonging to 5 families; It was determined that 172 bird species belonging to 44 families and 37 mammal species belonging to 16 families were distributed. As a result; A total of 241 vertebrate species belonging to 76 families (excluding fish) were identified in and around Lake İznik Wetland (ÇŞİM, 2019).

Considering the number of vertebrate species in Turkey (excluding fish), it is concluded that approximately 1/3 of the vertebrate species in Turkey are encountered in and around Lake İznik. It is an important area in terms of finding endemic species, as 5 of the 19 fish species defined in the region are endemic and 1 of them is within the scope of Annex-III of the Bern Convention. It has been determined that there are a total of 172 bird species belonging to 16 orders and 44 bird families in the region. Of these bird species, 50 are waterfowl and 122 are terrestrial birds. Accordingly, the number of bird species identified in the region is approximately 37% (about 1/3) of the number of bird species (463 bird species) registered in the Turkish ornithofauna. From this point of view, it is concluded that the bird species diversity of the region is rich. The presence of *Phalacrocorax pygmeus* (Dwarf cormorant), *Aythya nyroca* (Pas-bass patka) and *Circus macrourus* (Steppe borer) species, which are in the category of species with European priority in conservation, makes the area an important bird area (ÇŞİM, 2019).

As a result of the floristic studies carried out in the İznik Lake Wetland, 497 species and subspecies taxa belonging to 88 families were identified. 11 of these taxa are endemic to our country and the endemism rate is 4.97%. Locally endemic *Rumex bithynicus* "Critical (CR)" detected from the area; *Verbascum bombyciferum* and *Lathyrus undulatus* "Vulnerable (VU)" which are regional endemics, *Verbascum lagurus* "Near Threatened (NT)" which are widely distributed endemics; others are in the "Least Concern (LC)" categories (ÇŞİM, 2019).

Kocaçay, which is formed by the merging of most of the Southern Marmara streams, especially the Susurluk River and Nilüfer Stream, meets the Sea of Marmara near Yeniköy, a district of Bursa's Karacabey district. Located at this meeting point and one of the 135 internationally important wetlands in our country, Kocaçay Delta has a unique richness in terms of the diversity of its natural habitats. The delta is home to different habitats with dune plants, marshes, floodplain forests and lakes. There are Dalyan, Poyraz and Arapçiftliği lakes in ***Kocaçay Delta Wetland***. The lakes are surrounded by reeds and floodplain forests of ash (*Fraxinus sp.*), alder (*Alnus glutinosa*) and willows (*Salix sp.*) covered with a one meter deep layer of water in most places. The delta is also home to aquatic plants such as water lilies, hyacinths, lake bulbs and hares. The delta is also a very important area for the life cycle of eels (*Anguilla anguilla*). Eels, which set off from the Gulf of Mexico during the breeding period, come to the shores of the Kocaçay Delta after crossing the Atlantic Ocean, Mediterranean, Aegean and Marmara Seas. They crawl over the sand dune between the lake and the sea, and after laying their eggs in the lakes in the region, they return to their habitat, the Gulf of Mexico. Kocaçay Delta is an important wetland because it is located on bird migration routes (ÇŞİM, 2019).

In Kocaçay Delta, 114 bird species belonging to 14 orders and 44 families have been identified. In the studies conducted in the delta, it was determined that 38 species are native (breeding in the delta), 22 species are summer migratory, 11 species are winter migrant, and 16 species are transit species. Since 27 species were observed once or twice in the field, their status could not be decided. 46 of 114 bird species are waterfowl and 12 of these waterfowl breed in the delta. According to the IUCN criteria, 110 of the 114 species identified in the delta are in the LC, 2 of them are in the VU, and 1 of them are in the NT category. Species in the VU danger class are *Pelecanus crispus* (Crested pelican) and *Aquila clanga* (Great shouting eagle). *Aythya nyroca* (Pasbaş patka) was evaluated as NT. Domain; It has gained the status of Important Bird Area (IBA) with the breeding populations of *Ciconia nigra* (Black stork), *Glareola pratincola* (Marsh swallow), *Charadrius alexandrinus* (Cut-necked rainbird) (ÇŞİM, 2019).

Karacabey Karadağı-Ovakorusu Wildlife Protection Area; Kocaçay Delta, which is one of the important wetlands of our country, is also located within the wildlife development area. The height differences, landforms and climate in the area have provided the formation of many different ecosystems. The target species of Karacabey Karadağı-Ovakorusu Wildlife Protection Area is *Phasianus colchicus* (Pheasant). Other values of the site that require protection and management are *Capreolus capreolus* (Roe deer), floodplain forests, Kocaçay Delta wetland, wildlife rehabilitation centre, bear shelter and coastal dune ecosystem that hosts endemic species (ÇŞİM, 2019).

2.2. Method

Data on protected areas within the boundaries of Bursa was obtained from the data portal of the Ministry of Agriculture and Forestry. In order to determine the pinch points between protected areas, core area data was produced (Rempel, 2015) and landscape connectivity corridors between these core areas were determined. The methods used in determining landscape connectivity corridors are least-cost-path (LCP) and Euclidean distance (ED) (McRae and Kavanagh, 2011). Using circuit theory (Cushman and Landguth, 2010; Cushman et al., 2006; D'Elia et al., 2020; Dyer et al., 2010; Hanks and Hooten, 2013; Lookingbill et al., 2010; McRae, 2006; McRae and Beier, 2007; McRae et al., 2008; Owen-Smith et al., 2010; Rayfield et al., 2011; Saura and Rubio, 2010; Urban et al., 2009) the severity of the connection was measured to keep the overall network between the corridors connected. In this study, Circuitscape v4.0.5 programme was used for the easy application of circuit theory (McRae et al., 2014). The Pinchpoint Mapper programme was also run to identify critical habitat pinch points (bottlenecks) (McRae, 2012) All of the maps are visualised in ArcGIS 10. Pinchpoint Mapper uses Circuitscape programme to connection with maps produced by Linkage Mapper and generates maps that identify pinch points in least-cost-path/corridors. In order to better understand the connections between protected areas, tables were created with the descriptive statistical method with the IBM SPSS 27 programme.

3. Results and discussion

3.1. Results

3.1.1. Landscape connectivity corridors between protected areas

Core area is a term used to describe either a centre or interior of a patch (Forman, 1995) and structurally shows properties different from the interior area of the patch. Before determining the pinch points between the protected areas in the Bursa landscape, the core area indices of these areas were analysed (Figure 2).

Accordingly, wildlife protection area and wetland areas appeared with the highest core area index value (96%). These areas are followed by national parks (93%) and protection forest (84%), respectively. Nature protection area (54%), gene protection areas (62%) and seed stands (63%) index values are relatively close to each other. Urban forest is 28%, honey forest is 31%. The area with the lowest index value is the nature park (11%). Ecologically, core areas are vital for species that should be far from their surroundings (Covich, 1976; Forman, 1995; Koeppl et al., 1975). The edge effect plays an important role in determining the core areas in a landscape. Because as the edge effect increases, the habitat in the core area allows more diversity (Başkent and Jordan, 2011; Gustafson and Crow, 1994; Laurance and Yensen, 1991). The areas with the greatest edge effect and therefore the diversity have been wildlife protection areas, wetlands, national parks and conservation forests. It is possible to interpret that the species living in the patch with a large core area index can survive without being affected by the environment (Forman, 1995; Forman and Godron, 1986)

The landscape scale connectivity addresses and facilitates the movement of a large number of plant and animal species among the patches of large, unspoiled natural terrain, while wildlife corridors address the requirements for the movement of particular animals or species within the landscape. Considering their importance in species and population health, identification and conservation of the landscape connectivity and wildlife corridors becomes even more important (Castillo et al., 2020; Jalkanen et al., 2020). From this point of view, effective resistance values among the protected areas in Bursa landscape should be interpreted (Figure 3-4-5).

According to the chart above, the effective resistance between the seed stand and the national park is in the lowest class with a value of 0.01. The ratio of cost-weighted distance to effective resistance between these two protected areas was calculated as 930.105. The cost-weighted distance and effective resistance ratio between the protected area pair, nature park, wildlife protection area and wetland trio where the effective resistance is high is 1491.44. In the graph, at the point where the cost-weighted distance is the highest (2363.39), there are gene protection area, wetland and wildlife protection area. The effective resistance between these areas was calculated as 11.32. When analysing cost-weighted distance, it is wrong to think that the shortest way will always be the most effortless way (McRae and Kavanagh, 2011; 2017). Because in the shortest distance, factors such as slope, topography, climate will make the shortest distance the most troublesome. Therefore, when determining corridors between protected areas, more than one factor is evident in the analysis. These may be factors such as excess energy to travel, lack of nutrients, risk of death for tours that will use corridors between protected areas.

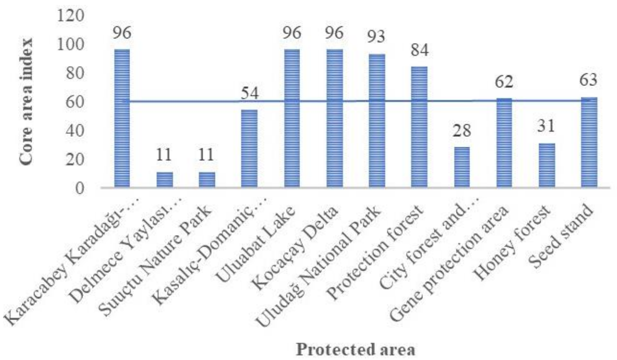

Figure 2. Relationship between core area indexes and protected areas

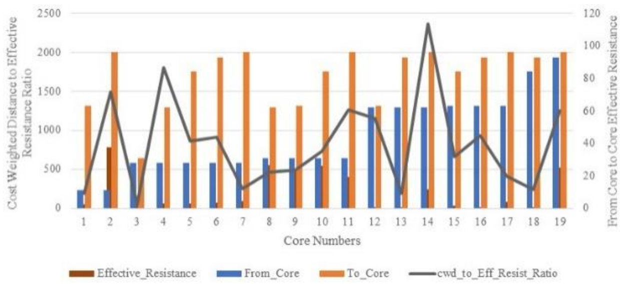

Figure 3. Trends and changings between effective resistance values in Amper (A) and protected areas

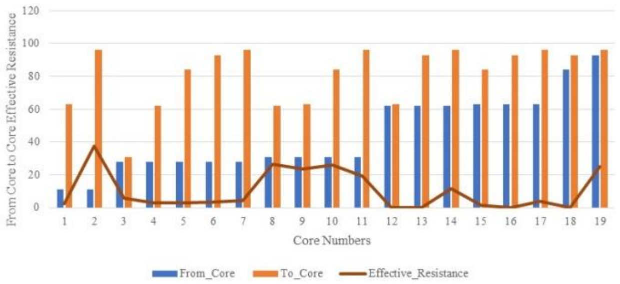

Figure 4. Trends and changings between effective resistance values in Amper (A) and protected areas

In circuit theory, the high value of effective resistance between two points indicates that the current between those points is forced (Kuphaldt, 2006; McRae and Beier, 2007). Therefore, the corridor between the nature park, wetland and wildlife protection area envisages a connection where species and habitats will be extremely difficult. By the same logic, the corridor connection between seed stand and national park is quite free and comfortable for species and habitats. The lower the resistance, the more comfortable the ecological flow will be. The flows of matter, energy, and information occurring in the landscape may be due to physical factors (wind, water flows, etc.), either from all directions or following a circumferential slope.

Another conclusion to be drawn is that the cost-weighted-distance and Euclidean distance values and their ratios to each other are in parallel with the effective resistance values. The cost-weighted-distance (10) and Euclidean distance values (10) of the protected area pair with low effective resistance values and their ratios to each other (1) are also low. In the analysis, the protected area most connected to other protected areas was the city forest. The most connected protected areas have been wetlands and wildlife protection areas. The purple-coloured areas seen on the map represent areas with high corridor potential, and the light-yellow lines around them represent the corridors between these areas. When we evaluate the possible corridor connections between protected areas in terms of descriptive statistics with effective resistance values, it is seen that there are a total of nineteen protected areas and the lowest core area index among these areas is 11% and the highest is 93%. The average percentage of core areas belonging to protected areas is 44.11. When we look at the effective resistance values, it is seen that the lowest resistance is 0.01, the highest resistance is 37.52, and the average is 10.33. Also table of descriptive statistics values can be seen in Table 2.

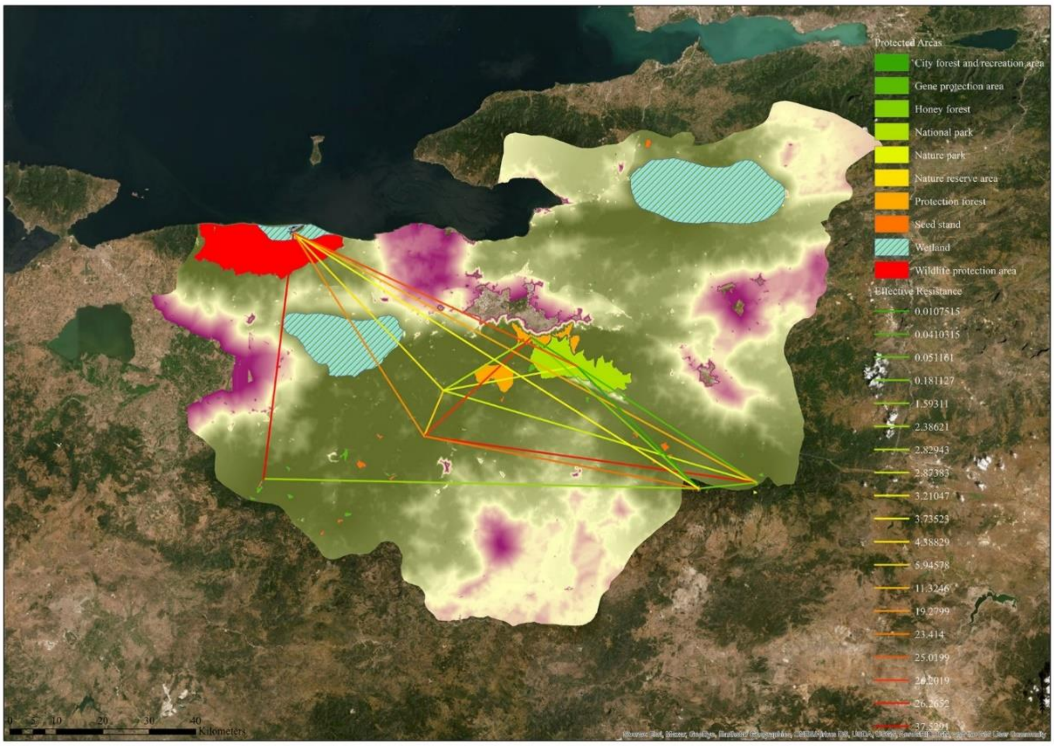

Figure 5. Effective resistance values of protected areas

Table 2. Results of descriptive statistics protected area core index and effective resistance

Descriptive statistics					
	N	Minimum	Maximum	Mean	Std. deviation
From_core	19	11	93	44.11	23.793
To_core	19	31	96	81.26	18.478
Efective_resistance	19	.0107	37.52	10.33	11.86
Valid N (listwise)	19				

3.1.2. Pinch points between protected areas

Pinch points (also known as bottle necks) are areas where wildlife movement is directed into connections. The pinch point modelling methods are based on current flow models in electrical circuit theory. Where the current is very strong indicated restrictions where connections are most susceptible to breakout (McRae et al., 2008). The map produced identifies the regions where a small loss of land could seriously compromise the landscape connection. The protected area pair with the highest current flow in the Bursa landscape has been wetland and national park. In the sample area, the highest value of the pinch points is calculated as 0.10 and the lowest value as 0 (zero) (Figure 6). The value between wetland and national park is lower than 0.10. The higher the value, the more difficult the species and habitat mobility at those points will be (Jones, 2015). Other components that will contribute to the assessment of pinch points may be topographic features and land uses (Jones, 2015). The topographical features in the places where the pinch points between the wetland and the national park coincide do not appear to be overly limiting values. When evaluated in terms of land uses, it has been determined that the mentioned bottlenecks are mostly located on forest areas. Therefore, it is inevitable that there will be another situation that causes these pinch points to occur. Considering the dam structures within the provincial boundaries, it is seen that these structures are mostly located near the points where the pinch points occur. It can be concluded that the dam structures cause pinch points by disrupting the existing ecological flow between the wetland and the national park (Figure 7). The same interpretation can be made for the wildlife protection area in the northwest and the wetland in the northeast. The points where the dam structures built on the outer boundaries of these two protection areas were found as bottlenecks.

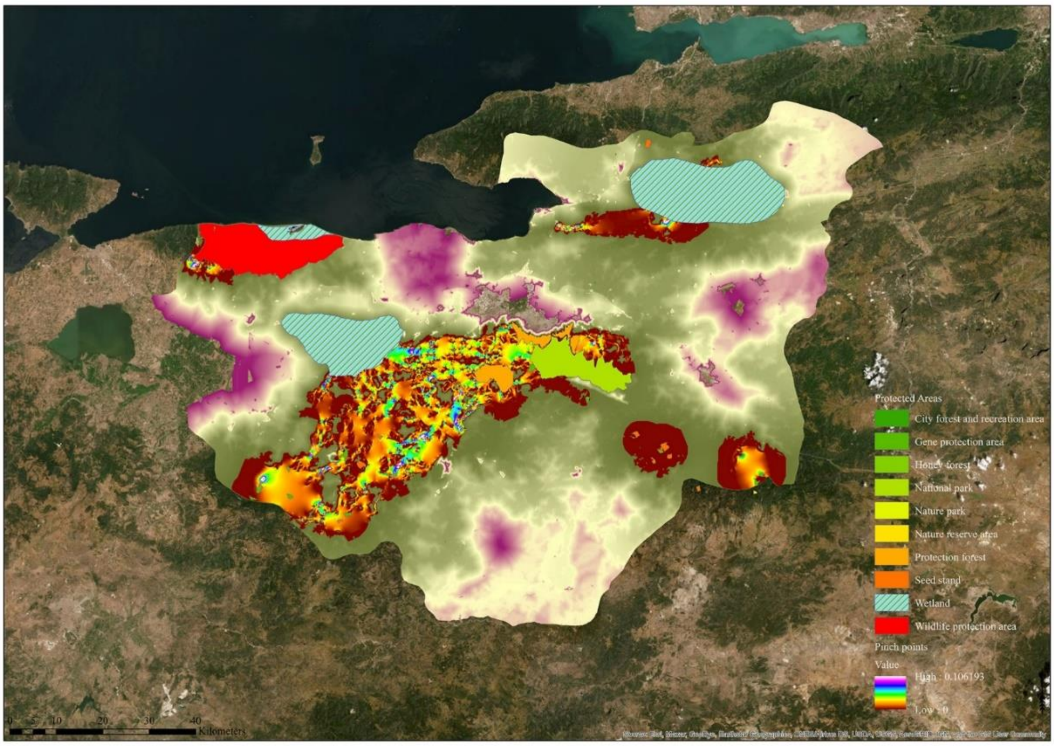

Figure 6. Pinch points between protected areas

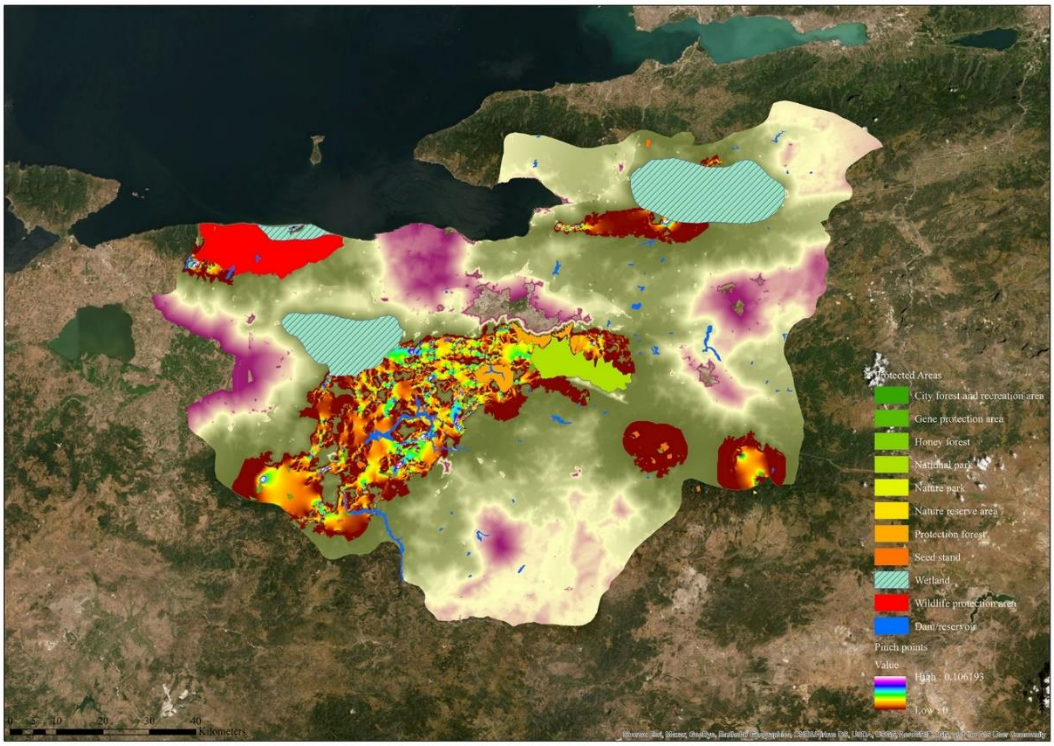

Figure 7. Dams, reservoirs, streams and rivers related to pinch points

3.2. Discussion

3.2.1. Determination of connectivity corridors for multiple species

Bursa is the fifth most economically developed city in Turkey. Bursa's economy is based on agriculture and agriculture-based industry, trade and tourism. It is also rich in minerals (ÇŞİM, 2019). Although agriculture, industry, trade and tourism provide economic gains for developing and developing societies, increasing population and urbanization dynamics have begun to threaten protected areas as well. At this point, the involvement of landscape architects, the only professional discipline capable of ecological planning, in the planning and design of landscape connection corridors in ecologically important areas, together with other professional disciplines, will prevent irreversible degradation in the landscape.

Wildlife corridors are of vital importance for the continuity of species and habitats. In the studies carried out to date, we see that a target type has been studied in the determination of landscape connection corridors/wildlife corridors. For example, Carroll et al. (2012) identifies corridors for the Gray wolf population using circuit theory and graph theory, while D'Elia et al. (2020), created landscape link maps for the California vulture. While these samples can be easily reproduced in Europe in our country, Özcan and Aytaş (2020), exemplified the ecological connection for *Capreolus capreolus* (Roe) in the Çankırı province example. Liu et al. (2018), defined the only types used in connection studies as "flag types". For other types, he used the definition of "umbrella tour". However, in recent years, a multi-species approach has begun to develop in the planning of connectivity corridors for wildlife (Khosravi et al., 2018; Marrotte et al., 2017). In this study, the determination of the landscape connection corridors between the protected areas within the borders of Bursa province was not based on a single species, but on the species using the protected areas as habitats. Planning of connecting corridors for multiple species allows to increase continuity between habitats, providing long-term connectivity and protection

3.2.2. Landscape resistance maps

A resistance surface is one of the most important inputs for linkage analysis and represents the difficulty a tour experiences as it moves across the landscape. (Zeller et al., 2012). The easiest data that can be used to create a resistance surface is land cover/land use. In this study, the Coordination of Information on the Environment (CORINE) 2018 data was used while creating the resistance surface. With a simple logic, land cover/land use data and slope data are combined to form surfaces that restrict the movement of the tours. Even though resistance maps, which are indispensable for landscape connection corridors, can be obtained very easily in studies conducted in Europe, there is a great deficiency in this regard in our country. Because landscape resistance surfaces should be created by working with a wildlife expert and related disciplines. Landscape resistance maps to be produced with this detail and attention will also affect the quality of wildlife connection corridors to be made at all scales.

4. Conclusions

In this study, the connection between the landscape and protected areas in the Bursa city and the pinch point (bottlenecks) that prevent the flow in these connections are analysed.

According to the analysis results;

- Wildlife protection area and wetland have the highest core area index (96%), but there is no corridor between these two areas. The absence of landscape corridors that enable food, material, etc. Flows between the areas means that it can be concluded that the species and habitats that survive in these areas are isolated. Identification and conservation of the landscape connectivity and wildlife corridors becomes even more important, given their importance to species and population health.
- Effective resistance values also play an important role in the interpretation of landscape connectivity. The high effective resistance value between the two areas indicates that the ecological flow between these areas is difficult. Among the protected areas, the highest effective resistance value (492.564) is seen between nature park and wetland. Therefore, the corridor between the nature park and the wetland envisages a connection where species and habitats will be extremely difficult. The areas with low effective value have been seed stands and national park. The corridor connection between these two areas is very free and comfortable for species and habitats. Cost-weighted-distance and Euclidean distance values also showed parallels with effective resistance values between protected areas. Resistance values of the protected area pair with greater distance between each other are also high.
- Current ecological flow in the Bursa landscape has been realised mostly between the wetland and the national park. It has been concluded that the higher the pinch values between the areas, the more difficult the species and habitat mobility at those points will be. On the other hand, the pinch value between these two areas is less than 0.10. Although this value is not very high, it can be concluded that the congestion in these bottlenecks can be solved by ecological interventions.
- Most of the pinch points occurred over the forest area. When evaluated from an ecological perspective, it can be though that such a negative effect will not be in question among forest areas. However, it is obvious that dams or power plants built on streams, and streams passing through forest areas will disrupt the connection of the corridors formed by the rivers. Water storage structure, which are among the protected areas where the current ecological flow continuous, can be considered among the results that affect the connectivity between species (fishes, birds, etc.) and restrict movement with other habitats.

The connection depends on the spatial structure of the landscape and the permeability of the different components that make up it. The connection between the two core areas will mainly depend on three aspects of the landscape: the permeability of the mosaic, the presence of ecological corridors, and the presence of stepping stones. Ecological corridors (streams and rivers) and stepping stones are structures that facilitate the connection of their area. It is seen that stepping stones are needed in order to establish ecological connections with other protected areas in the Bursa landscape and to maintain the flow at existing pinch points. Thus, it can be clearly stated that it will be easier for isolated habitats and species to connect with each other and with other structures.

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