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A comparative study of biodiversity between natural, urban and agriculture environments in the Gediz Delta, Turkey

Étude Comparative de la Biodiversité Entre les Habitats Naturels, Urbanisés et Agricoles du Delta du Gediz En Turquie

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Avant-propos
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Étude comparative de la biodiversité entre les habitats naturels, urbanisés et agricoles du Delta du Gediz en Turquie

Dilara Arslan

Résumé

La croissance économique, les pressions démographiques et le manque d'application des lois et des protections environnementales ont entraîné d'importants changements dans l'utilisation des sols et la destruction des habitats, menaçant les zones humides et leur biodiversité dans le monde entier. Les changements d'utilisation des terres ont été la force motrice la plus importante sur les changements de composition des espèces au cours du siècle dernier. Les zones humides méditerranéennes ont été transformées par les activités humaines et un tiers de leur surface a été perdu au cours des dernières décennies. Comprendre et quantifier les réponses des communautés aux changements d'utilisation des terres est essentiel pour créer une gestion de conservation durable afin de protéger les espèces et les écosystèmes. Le delta de Gediz est situé dans le bassin méditerranéen de la Turquie et offre l'opportunité de mieux comprendre comment l'agriculture et l'urbanisation affectent la biodiversité avec un bon potentiel de généralisation à d'autres zones humides du bassin méditerranéen. L'objectif principal de cette étude est de mieux comprendre comment la couverture terrestre affecte les processus d'assemblage des communautés d'oiseaux et de reptiles et quels sont les habitats du delta du Gediz qui nécessitent une attention particulière en matière de conservation. L'étude est divisée en 3 composantes : Premièrement, nous avons (a) évalué les changements de la biodiversité aviaire dans le delta de Gediz des années 1980-2019, et (b) comparé les communautés d'oiseaux et de reptiles dans des environnements naturels, agricoles et urbains. Enfin, nous (c) avons fait une analyse des menaces et identifié les actions de conservation possibles pour la gestion future afin de réduire les effets des menaces et améliorer la gestion durable du delta.

Mots clés : Zones humides, Delta du Gediz, Biodiversité, LULC, communauté, oiseau, reptile, Hmsc

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A comparative study of biodiversity between natural, urban and agriculture environments in the Gediz Delta, Turkey

Dilara Arslan

Abstract

Economic growth, demographic pressures, and lack of enforcement of environmental laws and protections have caused important levels of land-use changes and habitat destruction, threatening wetlands and their biodiversity around the world. Land-use changes have been the most important driving force on species composition changes in the last century. Mediterranean wetlands have been transformed by human activities over last the century and one-third of their surface area has been lost in the last decades. Understanding and quantifying the community-level responses to the land-use cover changes is essential for creating sustainable conservation management to protect species and ecosystems. The Gediz Delta is located in the Mediterranean basin of Turkey and offers the opportunity to understand better how agriculture and urbanization affect biodiversity with a good potential for generalization in other wetlands in the Mediterranean basin. This study's main objective is to better understand how land cover affects bird and reptile community assembly processes and which habitats in the Gediz Delta need special conservation attention. The study is divided into 3 components: First, we (a) evaluated the avian biodiversity changes in Gediz Delta from the 1980s-2019, and (b) compared bird and reptile communities in natural, agricultural, and urban environments. Finally, we (c) made a threat analysis and identified possible conservation actions for future management to reduce the effects of threats and improve the sustainable management of the delta.

Keywords: Wetlands, Gediz Delta, Biodiversity, LULC, community, bird, reptile, Hmsc

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Yaşar Kemal

CONTENTS

INTRODUCTION

Introduction

The transformation of the earth environment by humans began in the late-Pleistocene period through the hunting and gathering subsistence pattern and continued with the rise of agriculture since the early Holocene period (Barnosky *et al.* 2011, Braje and Erlandson 2013, Cummings 2014). Over the past 10,000 years, the world's wildlife in terms of fauna and flora has changed with the domestication of plants and animals, and the extinction of many different species (Ellis 2015). The range of human influences on earth is now so persuasive that many advocate that we have entered a new geological epoch, the Anthropocene epoch, starting with the Industrial Revolution (Lewis and Maslin 2015). The impact of human beings on the environment has never stopped growing and this situation is expected to continue (Ellis 2015, Stephens 2019). From the 1950s to 2000, the human population has tripled (from approximately 2.5 billion humans to over 7.5 billion) (Kaneda and Haub 2021). This is extremely important as the number of humans had only increased five times within the previous 10,000 years (Cohen 2003, Kaneda and Haub 2021). As a result of these increasing pressures, the planet faces a biotic crisis which has been called the sixth mass extinction, with approximately 1 % of the species currently extinct and 20–43% are threatened (commonly accepted estimate of 10 million species) since 1500s (Barnosky *et al.* 2011).

Increased anthropogenic pressures threaten many ecosystems around the world and half of the land surface has been transformed into anthropogenic landscapes such as agriculture or urban areas. This has reshaped the global biodiversity by widespread deforestation, soil erosion, and altered fire regimes, as well as species introductions, invasions, and extinctions (Vitousek *et al.* 1997, Hooke *et al.* 2012, Boivin *et al.* 2016, Stephens 2019). More than half of the habitable land on earth has been transformed into agricultural lands and 1% into urban and settlement areas (Ritchie and Roser 2013, Dudley and Alexander 2017).

1- Wetlands under pressure

Wetlands have been one of the most transformed ecosystems over the last century, with transformation occurring four times faster than in the 19th century. The available data shows that up to 87% of the global wetland resources have been lost since the 1700s (Davidson 2014, Ramsar Convention on Wetlands 2018). The remaining wetlands cover over 12.1 million km^2, about 6%, of the Earth's surface area (Ramsar Convention on Wetlands, 2018). Agricultural and urban development have been the main drivers of wetland loss over the last 200 years (Davidson 2014, Ramsar Convention on Wetlands 2018, Xu *et al.* 2019), with 35% of the existing wetlands lost between the 1970s and 2015 (Ramsar Convention on Wetlands, 2018). A quarter of wetland species are threatened with the risk of extinction and 81% of inland wetland species and 36% of coastal and marine species populations have declined since 1970 (Ramsar Convention on Wetlands 2018). However, many wetland species (such as colonial herons and lapwings) benefit from agricultural environments for foraging and breeding (Mathevet *et al.* 2002). On the other hand, intensification of agricultural practices, including increased use of pesticides and mineral fertilization, have negative impacts on wetland species in particular those subservient to agricultural areas (Gil-Tena *et al.* 2015, Katayama *et al.* 2015, Galewski and Devictor 2016, Mallet *et al.* 2022). In parallel, artificial wetlands (including canals, rice fields, salinas, fish farming ponds, excavation areas like gravel pits, wastewater treatment sites, and dam reservoirs and lakes) were expanded by 54% from 1975 to 2005 in the Mediterranean region (Mediterranean Wetland Observatory 2014a), which has had a favorable impact on certain wetland species (such as flamingos) (Galewski and Devictor 2016, Newbold *et al.* 2020).

Yet, artificial wetlands have not compensated for biodiversity loss as much as restored or natural wetlands (Sebastián-González and Green 2016). Restoring wetlands or increasing traditional agro-ecological farming practices are the conservation solutions that are the most often suggested to reduce threat impacts and protect wetland biodiversity (Sebastián-González and Green 2016, Galewski *et al.* 2021). In order to improve the impact of these actions, it is important to better understand and quantify community responses to land-use changes (Flynn *et al.* 2009, Oliver and Morecroft 2014, Borges *et al.* 2021).

2- Wetlands Protection Agreements

Since wetlands are critically important, providing ecosystem services, rich biological diversity and cultural-ecological value (Kingsford *et al.* 2016), the destruction and role of wetlands has been brought to a forefront internationally (Ramsar Convention Secretariat 2016). In this perspective, an international convention, the Wetlands of International Importance (RAMSAR), was signed in 1971. Today over 2,300 Ramsar Sites have been designated worldwide, covering almost 250 million hectares of wetlands (Ramsar Convention on Wetlands 2018). The Convention is the only international legal treaty primarily focused on wetlands and it aims to promote the conservation of the habitats, protect waterfowl and other migratory waterbirds and encourage the wise use of the wetlands by humans. The Convention provides a platform of 170 Contracting Parties, including Turkey (who signed in 1994), working together for wetland conservation worldwide (Ramsar Convention Secretariat 2016). Other international agreements were signed to protect habitats or animals (such as CITES (Convention on International Trade in Endangered Species), BERN (Bern Convention), the CBD (Convention on Biological Diversity) (Christoffersen 1997).

In Turkey, there exists additional national protection laws for wetlands which overlap with RAMSAR sites designation. In particular, Turkey developed a "Regulation for Protection of the Wetlands" in 2002 to protect its wetland areas. After this regulation was signed, the National Wetlands Commission (NWC) was established to plan the rational use, management, and conservation of the wetlands. Wetlands are one of the critical habitats of Turkish biodiversity and cover 1,2- 1,5 million hectares (Eken *et al.* 2006). Fourteen wetlands in Turkey were designated as Ramsar sites since 1994. However, 135 wetland sites are not designated yet as Ramsar sites even though they meet the required criteria of "Wetland of International Importance" according to Ramsar guidelines (Karadeniz *et al.* 2009, Popoff *et al.* 2021).

3- Wetlands in Turkey and Gediz Delta

Recent economic growth, demographic pressures, and lack of enforcement of environmental laws and protection continue to threaten the biodiversity and habitats of Turkey, causing significant levels of land-use changes and habitat destruction (Şekercioğlu *et al.* 2011). Wetlands are one of the key habitats of Turkish biodiversity. Over 1.3 million hectares of wetlands were damaged or destroyed due to agricultural activities, land reclamation, urbanization or to eliminate malaria outbreaks in the last 60 years in Turkey (Nivet and Frazier 2004). Similar to wetlands around the world, Turkish wetlands continue to be threatened by urbanization, land-use changes, illegal poaching, intensive pesticide use, heavy metal contamination, eutrophication, and hydrological modifications (Şekercioğlu *et al.* 2011). The most dramatic case is the disappearance of the Amik Lake during the 1960s and some other important wetlands, including Gavur, Emen, Suğla, Kestel, Söğütlü, Karagöl, Avlan lakes and Aynaz swamp (Korkmaz 2014). A current worrying case is observed in Burdur lake where dams built upstream and climate change, by decreasing water supply and precipitation regimes, have caused the lake surface area to shrink by half (Davraz *et al.* 2019).

The Gediz Delta is one of the most important habitats for biodiversity in Turkey (Fig. 1). It is the fourth-largest delta in Turkey and the biggest delta in west-Anatolia. Gediz Delta is also one of the most significant deltas in the Eastern Mediterranean (Eken *et al.* 2006). The approximate surface area of the Gediz Basin is 16,890 km², and the total area of the Gediz Delta is 40,000 hectares (Gediz Delta Management Plan 2007). The Gediz Delta wetland ecosystem is made up of a mosaic of ecosystems, consisting of freshwater-saltwater meadows that form 3 lagoons: Kırdeniz Lagoon (400 ha), Homa Lagoon (1824 ha), Çilazmak Lagoon (725 ha) (destroyed in 1979), and Çamaltı Saltwork, Ragıppaşa Dalyan (demolished at 2000s) and the northern Gediz Delta reedbeds (Gediz Delta Management Plan 2007, Tosunoğlu 2017) (Fig. 2). The lagoons are separated from the sea by narrow sandbars and islets which are very important for wetlands species. In the delta, there are rocky hills with 150-160 m altitude where the dry grasslands, arable land, and some woodlands habitats are located (Gediz Delta Management Plan 2007) (Figs. 1 and 2). The freshwater requirement in the Delta is met mainly from the Gediz River, rainfall, and channels and drainage water. The Gediz River forms the Delta, flowing across 401 km from its springs in Murat

Dağı, Kütayha to the Aegean Sea and the river passing across Uşak, Manisa and İzmir cities. Different side streams join the Gediz River along its route: Kurşunlu, Tabak, Sart, Gencer, Yeniköy, Karaçalı, Irlamaz and Keçilidere (Döndüren 2015). The average bed width of the Gediz River is estimated to be 100 m, its capacity is 300 m³ / sec, and its depth is 2 m (Durmuşkahya 2005). The water surface of basin potential is 1.95 m³ (Çetin *et al.* 2009).

The most important freshwater marshes are located in the northern part of the Delta (Fig. 1), vegetated with 500 ha reedbeds (mainly covered with *Phargmites sp*) and surrounded with some freshwater ponds (Büyük Pond, Uçak Pond and Angıt Pond) (Gediz Delta Management Plan 2007). Another freshwater marsh area is in Sazlı Lake (30 ha) covered by *Phragmites sp.*, which is northeast of Kozluca barriers (Gediz Delta Management Plan 2007). The northern part of the Delta consists of saltpans, pastures and meadows, agricultural areas, and small wooded areas. Since the delta is composed of a mosaic of salt and freshwater marshes, it hosts substantial biodiversity of plants and animals.

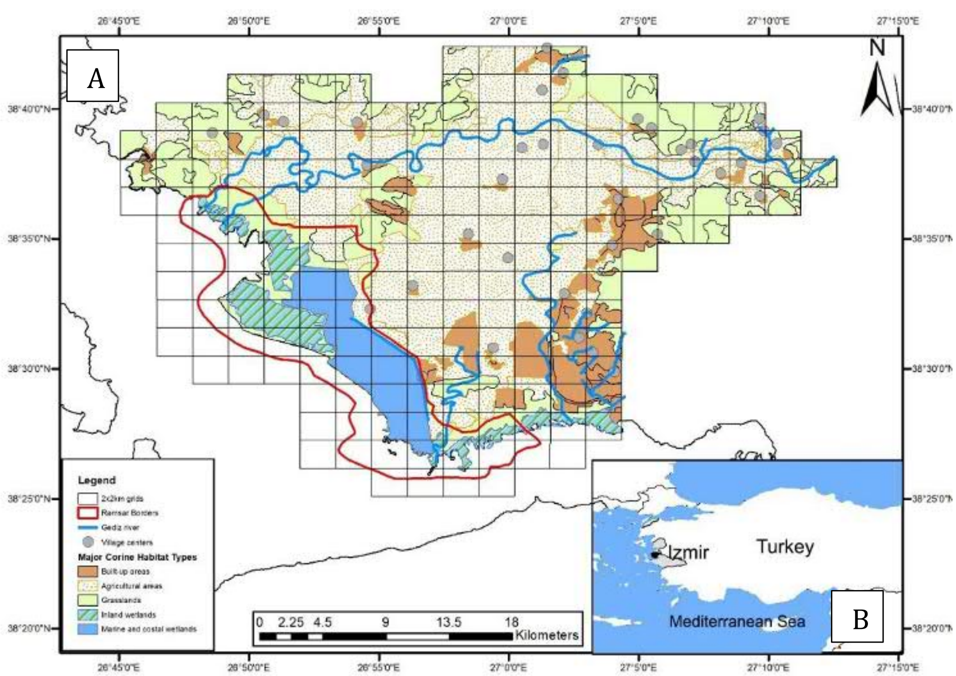

Figure 1: Location and primary ecosystems of the Gediz Delta (A) in Turkey (B)

A total of 299 bird species have been recorded wintering or migrating in the Delta. There are 115 breeding bird species, 14 freshwater fish species, 35 reptiles species and

8 mammal species identified in the Delta (Sıkı 1985, Eken 1997, Gediz Delta Management Plan 2007, Onmuş *et al.* 2009, Arslan *et al.* 2018, Arslan and Akyol 2020) (Gediz Delta Management Plan 2007; Arslan et al. 2018). Additionally, 308 plant species belonging to 60 families have been identified (Bolca *et al.* 2014).

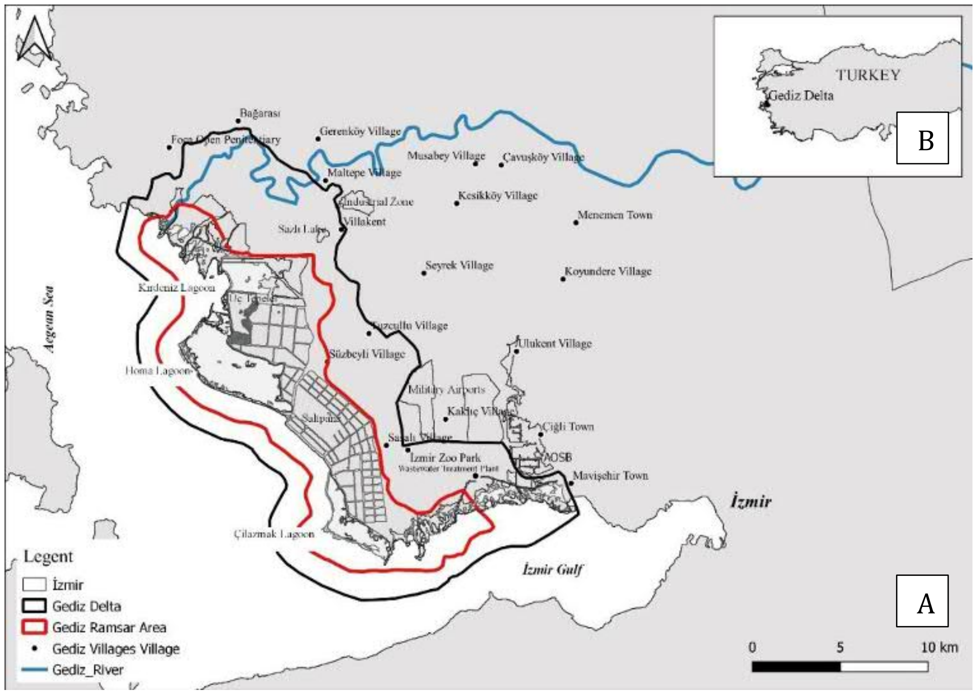

Figure 2: Locations area in the Gediz Delta (A) in Turkey (B)

A complex formation process shaped the Delta in terms of geological structure and palaeogeographical features, creating its current shape (Kayan and Öner 2016). The first formation of the Gediz Delta started with the Gediz River emptying directly into the Gulf of Izmir and accumulating alluviums through the Menemen Plato, which was opened 40-50 thousand years ago. The delta appears to have been evolving since the late Pliocene period (Erinç 1955, Gediz Delta Management Plan 2007, Kayan and Öner 2016). The delta formation progressed between the Karaburun peninsula and Foça hills during the last glacial period, under the conditions of increased humidity and relief energy compared to a level approximately 100 m lower than today's sea level (Aksu *et al.* 1987, Gediz Delta Management Plan 2007). Due to the flow of the Gediz River into an inland sea (Gulf of İzmir), its development was faster than other deltas in the eastern Mediterranean basin (Aksu *et al.* 1987). In the last glacial period of the Pleistocene, the entire Delta was flooded, the hills known as "üç tepeler" today were previously islands.

In 1886, the Gediz Delta started to change due to strong human influence (See Appendix 1, Fig. 3). The riverbeds were moved to reduce the threats of flooding. The river gave its final shape to the delta with the alluviums accumulated by flowing from the old river bed to the new one (Aksu *et al.* 1987). Pelikan and Karşıyaka beds were used by the Gediz River until 1886, the bed changed again in the 1800s, then, it was changed to the oldest bed of Maltepe, with a project prepared by the French (Aksu *et al.* 1987). A flood in the 1980s redirected the bed further south. As a result of replacing these riverbeds, the Gediz River formed an extensive delta in the form of an arc in the west of Karşıyaka and south of Foça, covering approximately 40,000 ha (Eken 1997).

Figure 3: The situation of Gediz Delta in the early 1900s. Some place name also in German and/or Latin. Image provided by: Library of Congress, Washington, DC (Kiepert 1908) (See Appendix 2)

The Delta is intertwined with the metropolis of İzmir. The geographic proximity to Izmir multiplies the threats in the Gediz Delta, various degrees of human impact can be observed in the different habitats of the Delta. Human influence continues mainly in the coastal areas of the delta. A wide variety of human activities have been observed on the shores and lagoons of the delta. Fisheries, urbanization, and salt production are the leading threats. Small-scale fisheries are active in the three lagoons of the delta; in the Homa lagoon, there are cooperative houses of small-scale fisheries and the research institute of Faculty of Water Products of Ege University (Tosunoğlu 2017). The other lagoon, Kırdeniz, is also used for fishing by small-scale fisheries. However, fish stocks have decreased compared with the stocks in the 1980s. Before the 1980s, there were more than 300 tons of fish stocks in Homa and Kırdeniz lagoons, but over the last 20 years, there have been less than 30 tons of fish (Tosunoğlu 2017). The decrease is suspectedly due to the insufficient freshwater sources and poor water circulation in the Delta (Tosunoğlu 2017). Urbanisation has also caused the loss of many important habitats, such as Çigli Marshes (140 ha) and Ragıppaşa Lagoon. Çiğli Marshes were shallow freshwater marshes located in the south of the delta, but have now completely disappeared with urbanization (Eken 1997). Ragıppaşa lagoon was also destroyed in 1980 and again in 2000, because it was suspected to prevent the flow of water in the Gulf of İzmir (Tosunoğlu 2017). On the other hand, the Çilazmak lagoon was destroyed by natural causes (a storm) (Tosunoğlu 2017). Climate change continues to affect the Homa lagoon morphology. The changes in the wind direction and precipitation have caused severe damage to the coastlines of the Homa lagoon. In 2012, this coastline was re-rehabilitated with the support of relevant public institutions (Tosunoğlu 2017). Salt production in the delta has continued in Çamaltı Saltwork since 1863. It is located between Homa and Çil Azmak Lagoons (von Gonzenbach 1859, Selous 1900, Tiraş 2011). The saltpans cover an area of 7,300 ha, making it the largest saltpan in Turkey. It is managed by a private corporation called Binbir Gıda Çamaltı Tuzla İşletmesi after the privatization from the government (Binbir Gıda Tuzla İşletmesi 2021). Before the privatization of the saltpans, the production capacity was increased to 400,000 tons, and today the production capacity is 600,000 tons (Binbir Gıda Tuzla İşletmesi 2021).

After the 2000s, industrial facilities used the plain, with an increase in settlements, population and agriculture, intensifying water demand (Bolca *et al.* 2014). Irregular and decreasing amounts of rain and pollution of the existing freshwater source from industrial wastes caused additional problems for water management (Gediz Delta Management Plan 2007, Sıkı 2020). It should also be noted here that the river is one of the most polluted rivers in Turkey due to industrial discharges and agricultural effluents in the region (Parlak *et al.* 2006, Kucuksezgin *et al.* 2008, Suzer *et al.* 2015). The high demand of the freshwater contributed to the partial drying of the three important freshwater marshes in the Delta (Eken 1997). In response, the Regional Directorate of

Waterworks (DSI) provided freshwater from the main evacuation channel to the delta when urgently needed in the arid times (Tapan *et al.* 2008). The inner part of the delta, known as Menemen Plain, has very fertile agricultural lands (Ernoul *et al.* 2012, Bolca *et al.* 2014). Various fruits, vegetables and field crops are grown in these agricultural lands (Gediz Delta Management Plan 2007). Field crops are mostly cotton, wheat, corn, tobacco, sesame, broad beans, beans, potatoes and onions. Vegetable products include tomatoes, spinach, watermelon, melon, parsley, eggplant, leeks and lettuce (Gediz Delta Management Plan 2007). Fruit products include peaches, strawberries, tangerines, plums, pomegranates, pears, apricots, walnuts and citrus In suitable habitats, olive cultivation activities continue (Gediz Delta Management Plan 2007). One of the important economic inputs is the livestock activities, especially in the Seyrek and Süzbeyli villages in the region. 89% of the households dealing with livestock have between 1 and 50 cattle in the region (Sönmez and Onmuş 2006). The south of the delta is an industrial development site : Atatürk Organized Industrial Zone (Avdan 2020). There is also a water treatment facility, which constitutes the most important project of Izmir Metropolitan Municipality and is named Mega Channel Project. 604,800 m^3/day of wastewater is disposed of at the facility, and the remaining mud from the wastewater is buried in the Gediz Delta flats (Izsu 2021). In addition, Çiğli Military airport is also in the southern part of the Delta. Thus, industry and other facilities started entering the plain from the south. There are other industrial facilities in the plain of Menemen and its immediate surroundings. The Menemen Free Leather Zone is in the Panaztepe location on the Maltepe road on the plain (Izbaş 2021).

One of the most important regulations to reduce the impacts of these developments was the declaration of the Gediz Delta as a Ramsar site in 1998, protecting over 20,400 ha of the Delta (Gediz Delta Management Plan 2007). This Ramsar site is located across the southern and western part of the Delta (Fig. 1 and 2) and covers the most important habitats including lagoons, salt marshes, salines, some local freshwater marshes, and the hills with some other types of habitats. The Delta was also listed in the "List of Areas of Special Conservation Interest ASCI" within the scope of the Bern Convention of 2000 (Gediz Delta Management Plan 2007). It has the highest protection status under national laws with 8,000 ha of the Delta being approved as a "wildlife protection area" covering three lagoons : Kırdeniz, Homa and Çilazmak, the saline and freshwater marshes (in 1982) and "Natural Protected (SIT) Area" in 1985 (Gediz Delta Management Plan 2007). The entire wetland area was declared as the First Degree Natural Protected Area by the Ministry of Culture in 1999, and the sea borders of the 1st Degree Natural Protected Area were designated in 2002. The Üçtepeler site in the Delta is the Archaeological Site of the ancient city of Leukai, which was established 2400 years ago. However, wildlife protection area regulation changed and was given a new status as Wetland Protection Regulation in 2007. In 2017, the protected area borders of the Gediz Delta were changed with the work carried out by the T.C. Ministry of Forestry and Water Affairs, General Directorate of Nature Conservation and National Parks (National Wetland Commission Decision, 2017, Fig. 1) The new regulation classified the delta protection areas into "strict protection zones", "wetland zones", "ecological impact zones", and "buffer zones". However, many of the problems discussed above impact the different areas and have a direct impact on biodiversity in the delta (Onmuş and Siki 2013).

4- Objectives of the Thesis:

According to Swingland (2001), biodiversity is defined as various living organisms on Earth and typically measures variation at the genetic, species, and ecosystem levels. Monitoring biodiversity in a given area is one of the most common indicators used to assess habitat health, ecosystem functions or services since the land-use change has been reported to have significant effects on species populations (Buckland *et al.* 2005, Attum *et al.* 2006, Barrett and Guyer 2008, Kampichler *et al.* 2012, Geijzendorffer and Roche 2013, Adams *et al.* 2014, Hevia *et al.* 2016, Fraixedas *et al.* 2019, Rocha-Ortega *et al.* 2019, Borges *et al.* 2021). However, many studies have focused on the adverse effects of land-use changes on a single taxonomic group, and the combined effect on several groups of organisms has not been well studied; yet this is important as changes in land use offer opportunities for some species (such as decreasing competition, or more foods) and negative consequences for others (Flynn *et al.* 2009, Hevia *et al.* 2016). The modification of wetland structure, composition and dynamics lead to changes in general biodiversity or distribution, numbers, or existence of wetland-dependent species groups such as birds and reptiles (Boylan and MacLean 1997, Gibbs 2000). For example, the Greater flamingo (*Phoenicopterus roseus*) population increases in some wetlands with artificial salt areas (BirdLife International 2019). Northern Lapwings mainly tends to be breeding on grassland areas; however, this habitat has been converted to intensive ricefields in many wetlands areas, which has caused a decline in the population of the species (Pierluissi 2010, Souchay and Schaub 2016). Reptile species are often specialized to a specific habitat type causing them to be more vulnerable to land use changes (Attum *et al.* 2006, Barrett and Guyer 2008). In addition, knowing how populations have changed over time is essential for assigning conservation status to priority species and potential threats to a particular area (Fewster *et al.* 2000, Şekercioğlu *et al.* 2004, Bonebrake *et al.* 2010)

Species communities come together through ecological filters (Chase 2007) created by certain abiotic and biotic relationships, species interactions within local communities, and dispersal between local communities in a kind of habitat (Mittelbach and Schemske 2015, Ovaskainen and Abrego 2020). With the change of one of these filters (such as temperature increase or habitat destruction), communities in that ecological area are reorganized; some species increase in number while others decrease in number (Adams *et al.* 2014). This interaction varies according to the ecological characteristics of each species. Then ecological communities are rearranged according to their similarities or differences according to species' responses to environmental parameters (Gardener 2014).

Comprehensive and standardized data such as species richness, community structure, composition, and population time-series data is used to assess changes of communities species in a habitat (Loh *et al.* 2005, Galewski and Devictor 2016). To implement an adaptive management approach and successful ecosystem management of an area, it is necessary to evaluate its past and present and know its current structure. However, there is still considerable uncertainty about how the responses of different taxonomic groups to land-use change vary and how they act together.

The objective of this study is to evaluate how communities are shaped by land-use changes in the Gediz Delta wetlands by considering two emblematic taxa with different ecological requirements. Understanding the changes in Gediz Delta could offers the opportunity to understand better how the threats could affect biodiversity in other deltas that have similar threats.

This study focused on two questions:

- How does land cover affect bird and reptile community assembly processes?

- Which habitats in the Gediz Delta need special conservation attention?

This thesis was organized into three chapters, each concentrating on a different hypothesis to contribute to the research questions. The thesis specifically looks at how changing wetland structure, composition and dynamics result in changes in the overall biodiversity or distribution and numbers or presence of wetland-dependent species groups (Boylan and MacLean 1997). Since wetlands have been greatly degraded and transformed over the last century (Davidson *et al.* 2018), we hypothesized that ***biodiversity in the Gediz Delta has significantly changed from the past to the present due to anthropological changes*** discussed in the first chapter.

We used only the avian species to test this hypothesis. Compared to other vertebrate groups, bird species have been well studied and documented abundantly in the last decades and bird populations are known as appropriate indicators for the environmental status of a particular ecosystem (Furness *et al.* 1993, Robledano *et al.* 2010). However, this step is often complicated by the fact that for several hundreds of years, only absence/presence data of animals is collected in some places and have been documented by natural observers or scientists (Pocock et al. 2015, Galewski and Devictor 2016). The situation of the Gediz birds was the same with other wetland historical data; there was a good knowledge of the composition of species but only a little information on species abundance (Galewski and Devictor 2016). An expert knowledge survey can be used to overcome this obstacle and to evaluate the status of a natural site where historical data is insufficient (Galewski and Devictor 2016, Fraixedas *et al.* 2019). An expert knowledge survey is an useful tool for assessing changes in communities (Fraixedas *et al.* 2019). Understanding what has changed in biodiversity from the past to the present in the Gediz Delta provides a good case to measure the effects of land-use changes for other wetlands in the Mediterranean basin that have comparable threats.

Here, we focused on avian biodiversity and its evolution to assess long-term and recent trends in the delta. We highlighted significant changes in the status and abundance of the bird community by analyzing expert knowledge surveys and previous data from the literature spanning more than a century (first ornithological reports from the delta were date from the end of the 19th century). Then relationships between change in diversity and land use were discussed.

In the second chapter, we addressed the hypothesis that ***land-cover also drives the diversity in bird and reptile communities according to the species traits***. In its simplest definition, species richness is the total number of species in a given area, and species evenness is the number of individuals of each species and their relative abundance in a community (Scott et al. 1987, Krebs 1999). Diversity is evaluated in a community using both aspects like the number of species (richness) and their relative abundance (evenness) (Macarthur 1965, Krebs 1999). Many indices (Shannon's diversity index, Fisher, Berger-Parker, Simpson index) have been developed to accurately assess species diversity and richness depending on the conservation targets (Whittaker 1972, Gotelli and Colwell 2011). Species diversity is used as an indicator in many studies (Heip *et al.* 1998), making it possible to compare and monitor ecological committees with a single value (Magurran 1988). Given the habitat characteristics, species occupy some niches according to the gradient of changes between various biotic and abiotic factors, and land use is one of the most important drivers effecting biodiversity (Whittaker 1972, Hevia *et al.* 2016). The dispersal ability is one of the important characteristics of species and determines how widely a species can colonize various parts (Hager 1998). In 1999, Lawton (1999) introduced a new approach to community ecology and emphasized the conceptual approach in the macroecological relationship between local species richness and the size of the regional pool of species. With this approach, the science of ecology has developed rapidly and nowadays it aims to describe and understand the spatiotemporal structure and dynamics of ecological communities. Ecological community is defined as “the assemblage of at least two potentially interacting species at a given time and location” by Ovaskainen and Abrego (2020). Here, we aimed to study how land-cover have impacted target communities at the delta scale based on the presence and abundance of two different taxonomic groups (birds, reptiles in three land cover types (agricultural, natural and urbanized landscapes).

The third chapter described and prioritized the threats in the Gediz Delta. This chapter looked into the hypothesis that ***wetland habitats must be given priority in conservation management for the Gediz Delta***. The needs and demands of an increasing human population are changing and transforming more and more natural areas day by day (Newbold *et al.* 2015). Therefore, effective conservation management needs to provide clear, systematic identification of strategies and threats (Margules and Pressey 2000). In the case study, we evaluated current threats using a multi-method threat ranking aproach. This multi-method approach is consisted with 3 steps: (1) identification the threats in scientific journals, newspaper articles and grey literature; (2) understanding the perceptions of threats by key stakeholders in-depth interviews to identify additional threats and (3) determine visual threats through intensive fieldwork. Each of the threats and opportunities was identified in the conceptual model (Margules and Pressey 2000) and we then evaluated the consequences on natural habitats using the Open Standard Methodology (Salafsky *et al.* 2008). By describing and prioritizing the threats, we aimed to develop conservation strategies that could promote the sustainable management of the delta in the future. This study showed that some threats are acknowledged by both scientific and local knowledge, but others are missing from one system or the other. Therefore, it is necessary to look at threats from many different perspectives (Researcher, Quantitative Data, Stakeholders) to determine which factors in the field (indirect or direct threats, opportunities or protection objectives) are the most important to identify appropriate strategies for the site. Prior to initiating the work, we prepared land-use land change maps (LULC) of Gediz Delta as a baseline (Appendix 1).

CHAPTER 1

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Using literature and expert knowledge to determine changes in a Turkish wetland bird community over the last 40 years

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Abstract

Anthropogenic pressures continue to threaten wetland ecosystems. Given that bird species have been studied and documented abundantly in the last decades and that birds are good indicators of ecosystem conditions, research on bird trends is useful for monitoring the ecological state of the wetlands over time. However, the monitoring data for birds in wetland sites is often disparate and not homogeneous over time and between species, which complicates the interpretation of trends. Here, we analyzed the historical trends of every bird species observed in the Gediz Delta. Gediz Delta is one of the fourteen Ramsar sites designated in Turkey, and like the others, it faces important threats with significant changes in land use and land cover. We conducted an expert knowledge survey for the period 1980-2019 and then combined the results with historical naturalist literature and online databases. We then estimated the abundance of species for the entire bird community and evaluated changes in the structure and composition by community commonness index. Our results suggest that land-cover and land-use changes in the Gediz Delta starting in the last century and intensified over the decades have shaped the local bird community with a decline in agricultural and grassland bird species. On the other hand, coastal wetland and marine birds have increased, most probably linked to the extension of saltpans and conservation measures as many of these species are of higher conservation concern. These trends demonstrate diverging impacts of land management on biodiversity. This approach can be replicated in other Ramsar and protected sites around the world, even where biodiversity intensive monitoring programs are lacking to identify conservation priorities and improve site conservation.

Additional keywords. Bird trends, Community Commonness Index, Indicator species, Agricultural practices, Saltpans

Introduction

Human activities threaten biodiversity at the global scale (Pievani 2014). Wetlands are one of the most impacted ecosystems, with three times higher losses than forest ecosystems (Ramsar Convention on Wetlands 2018). The available data indicates that as much as 87% of global wetlands have been lost since the 1700s, with a rate of destruction that has accelerated during the 20th century by four times as compared to the 19th century (Davidson 2014, Ramsar Convention on Wetlands 2018). The remaining 12.1 million km^2 of wetlands around the world continue to be threatened by urban sprawl, water abstraction, pollution, and agricultural intensification (Underwood *et al.* 2009, Darwall *et al.* 2014, Davidson 2014, Perennou *et al.* 2018). Destruction and degradation of wetlands contribute significantly to global biodiversity loss as wetlands compose a higher ratio of species per hectare compared to other ecosystems. In the Mediterranean basin, more than 30% of vertebrate species are dependent on wetlands which cover only 2-3% of the land surface of this region (Geijzendorffer *et al.* 2018). In order to reduce these threats and conserve wetlands and their associated biodiversity, the Ramsar Convention was established in 1971. There are now more than 170 countries that have adopted the Ramsar Convention. Additionally, various other international agreements have been signed to protect wetland species, including CITES (Convention on International Trade in Endangered Species), the CBD (Convention on Biological Diversity), and CMS (Convention on Migratory Species) (Christoffersen 1997).

Changes in wetlands due to human activities have modified the structure, composition and dynamics of species assemblages (Boylan and MacLean 1997, Gibbs 2000). At the site level, the detection of such biodiversity changes can help to prioritize management decisions or conservation actions, but it requires a good knowledge of the long-term evolution of the species communities (Bonebrake *et al.* 2010). To evaluate such long-term trends, it is necessary to have adequate information on both species abundance and richness (Loh *et al.* 2005, Teyssedre and Robert 2015). In many sites, there is a lack of systematic data, preventing sound comparisons between the present and the past (Pocock *et al.* 2015), but this may vary depending on the taxa considered. Fortunately, birds have received the attention of many pioneering naturalists and early academic ecologists, even in less developed countries, so comparing the bird community of a site, over different time scales, is often feasible and can provide insights into the changing condition at a site (Galewski and Devictor 2016).

Wetlands in Turkey follow the same global trends for global wetland loss around the world. Over 1,2 million ha^2 of wetlands in Turkey have been destroyed over the last 60 years (Nivet and Frazier 2004, Eken *et al.* 2006). The most dramatic cases are the Amik Lake in the 1960's and, more recently, the loss of other important wetlands, including Gavur, Emen, Suğla, Kestel, Söğütlü, Karagöl, Avlan lakes and the Aynaz swamps (Korkmaz 2014). The draining and drying of these wetlands have had direct negative effects on biodiversity with local extinctions documented. For instance, African Darter (*Anhinga rufa*) has not been seen in Turkey after Amik lake dried up (Ünal and Canli 2019). More recently, the Turkish breeding population of the globally endangered White-headed Duck (*Oxyura leucocephala*) dramatically decreased from 200-250 pairs to 82-125 pairs between 2001 and 2016 following the rapid drying of Central Anatolia lakes (Gürsoy-Ergen 2019, Özgencil and Uslu 2021).

In 1994, Turkey ratified the Ramsar Convention and designated its first five official Ramsar sites. Later in 2002, Turkey further elaborated its wetland conservation strategy with the "Regulation for Protection of the Wetlands". A National Wetlands Commission (NWC) was established to plan the country's rational use, management, and conservation of wetlands. In 2021, Turkey had designated 14 wetlands as Ramsar Sites, and 56 wetlands are protected by national laws (GDNCNP 2020).

One of the Ramsar sites in Turkey is the Gediz Delta (Fig. 1), located close to the city of Izmir on the Aegean Sea coast (TUIK 2020). İzmir has a population of approximately 5 million people and continues to increase (TUİK 2020), creating important demographic pressures on the surrounding area.

Given its location on several migration pathways and its intersection between three continents, the Gediz Delta is extremely important for biodiversity (Yarar and Magnin 1997, Eken *et al.* 2006). In 1998, Gediz Delta was designated as a “wetland of international importance” by the Ramsar Convention due to its importance for breeding and migratory birds (Gediz Delta Management Plan 2007). In addition, Gediz Delta was included in the “List of Areas of Special Conservation Interest, ASCI” within the scope of Bern Convention of 2000. Despite these cumulated protection statuses, the Delta has been severely impacted by human activities for over a century and is still threatened today (Avdan 2020). Over the centuries, the riverbed course has been modified through the construction of dams and new channels, with the most important changes occurring during the 1880s, when the riverbed was redirected from the south to the north of the Delta (Erinç 1955, Aksu *et al.* 1987, 1990, Eken 1997, Gediz Delta Management Plan 2007). The Delta continues to be impacted by human activities, which creates new changes in habitats and species (Ernoul *et al.* 2012), with urbanization as the main driver of habitat transformation (Ernoul *et al.* 2012, Bolca *et al.* 2014, Avdan 2020).

Like many Ramsar sites around the world, the Gediz Delta has been studied sporadically over the years by both the scientific community and amateur birdwatchers, creating different origins and varieties bird data sets. Despite the availability of ornithological data for the Gediz Delta in scientific articles or databases, there are important temporal and species gaps that limit a comprehensive analysis of bird trends. For instance, the population counts mainly focused on certain species of waterbirds (Sıkı 1985, Eken 1997, Balkız 2006, Onmuş and Sıkı 2011), in particular, the Greater Flamingo (*Phoenicopterus roseus*) and shorebirds which all breed in the lagoon complex and the saltpans, but do not use the other ecosystems found in the Delta (e.g. farmland). Four inventories aimed at producing a bird atlas of the Gediz Delta have been carried out since the 1980s, providing good knowledge of the composition and distribution of the breeding species in all the ecosystems of the Delta, but with only a little information on species abundance (Sıkı 1985, Eken

1997, Onmuş 2008, Arslan and Akyol 2020). In order to fill these gaps, we interviewed ornithologists and reviewed ornithological literature to evaluate changes in bird populations over the last century. We then used the community commonness index to assess long-term changes in bird abundance and bird community structure.

The sporadic and heterogenic data available for birds in the Gediz Delta is similar to many other deltas in the Mediterranean basin, so this methodology could offer the opportunity to understand better how global change is affecting biodiversity with a high potential for generalization. Understanding and quantifying bird community changes over time can be useful to determine conservation and restoration priorities in many Ramsar sites around the world.

Material and Methodology

Study Site

Our study area encompasses the whole Gediz Delta, which extends over approximately 40,000 ha, constituting 20,400 ha of typical Mediterranean wetlands, including salt and freshwater marshes (5,000 ha), saltpans (3,300 ha) and four coastal lagoons (6,300 ha) (Gediz Delta Management Plan 2007; Fig. 1)). The eastern part of the delta is heavily cultivated with annual crops, and only artificial wetlands remain (saltpans and an artificial freshwater lake). Natural wetlands, such as seasonal brackish and oligohaline marshes, are concentrated in the northern and southern parts of the delta. The delta is mainly composed of flat areas at sea level and includes small hills up to 350 m above sea level in and around the wetlands. The site has a typical Mediterranean climate consisting of hot and dry summers and mild but windy winters with an annual average temperature of 17.8°C (min. daily average 13.48°C and max. 22.6°C). The average annual rainfall is 695.4 mm (Turkish State Meteorological Service 2020).

Expert knowledge Bird-Database

First, we constructed three independent databases for bird species observed in the delta over three periods (1) 1835-1980, (2) 1980-1999 and (3) 2000-2019. For each database, we distinguished between breeding and non-breeding populations. The first database included only presence and absence data of each species, because there were no abundance data prior to 1980 as the delta was not then visited systematically by ornithologists (Strickland 1836, von Gonzenbach 1859, Krüper 1869, Selous 1900, Ballance and Lee 1961, Sıkı 1985, 1988, Kumerloeve 1986). For the other two databases, we could estimate three parameters for each species. First, we assessed the presence or absence of the species. Second, we assessed the annual period of occurrence as follows: R: resident for species observed throughout the year; S: species only present in spring/summer; W: wintering; M: passage migrants for birds only observed during migration and not breeding or wintering in the Gediz Delta; V: vagrant species, not observed on an annual basis. Some species were assigned to several categories, for instance, resident and wintering if more northerly breeding populations join the resident population during winter months. Third, we asked ornithologist experts to evaluate relative abundance using 6 semi-quantitative classes: 0 (absent); 1 (1-9 individuals); 2 (10-99); 3 (100-9,999); 4 (1000-99,999); 5 (more than 10,000) and distinguishing again between breeding and non-breeding populations following a methodology developed for the Camargue wetlands in southern France (Galewski and Devictor 2016). As the abundance of many bird species varied over the course of the year, the experts gave the maximum abundance, i.e., the maximum observed on an average in a year for each period. Mid-winter waterbird counts since 1997, literature, and eBird records were used to validate the status of missing or undecided species information by the experts for 18 species (15 of them are vagrant). For the 2000-2019 database, we added the trend in abundance since the 1980-1999 period: (-1) “decrease” | (0) “stable” | (1) “increase”. Evaluation of the trend scores was made using the following assessment. We first checked breeding status (B= breeding or N= not breeding) and determined any changes from earlier periods. If the species stopped breeding, then the trend was set as decreasing (-1), and if a species started to breed in the site, then the trend was set as increasing (1). If there was no change in the breeding status, we ranked the population activity status (R, M, S, W, V) of each species in function of the relative length of time the bird spent in the field, and evaluated the population status changes across R> S=W> M> V. If there was a difference between *t* and *t* +1 time according to this order, we then scored the trend according to the change. For example, if in time *t* the species was a resident species, and at time t+1 the species was only recorded as wintering but not breeding any more, we set the population trend to decreasing. If there was no change in the occurrence status of the bird, we checked the population size score. If the score increased, we considered that the trend increased. If the score decreased, the trend was set to decreasing, or if no change occurred, the population was set to stable. Finally, we indicated the main habitat used by each species using six categories corresponding to the habitat classes: «Agricultural & Grassland», «Boreal & Temperate Forest», «Inland Wetlands», «Marine & Coastal», «Mediterranean Habitats» and « Generalist» (for bird species using more than one of these habitat types). The assignation of bird species to each habitat was done following the bird habitat classification provided in the second edition of the European Breeding Bird Atlas 2 (Keller *et al.* 2020), with the help of local bird experts for migratory or wintering populations. This was done separately for breeding and non-breeding seasons, as many bird species show different habitat preferences over the course of a year. To assess changes in conservation value of the Gediz Delta bird community, we also reported, for each species, the conservation priority status given by Birdlife through the Species of European Concern list (SPEC; BirdLife International 2017) and the threatened bird species list of the Annex I of the Birds Directive (ec.europa.eu).

A review of scientific literature and ornithological reports dealing with the Gediz Delta was carried out to collect relevant data (Sıkı 1985, 1988, Kumerloeve 1986, Sıkı and Öktem 1992, Eken 1997, Yarar and Magnin 1997, Kirwan *et al.* 1998, 2010, Sıkı *et al.* 1998, Yaman 2001, Gediz Delta Management Plan 2007, Onmuş 2008, Onmuş *et al.* 2009, Onmuş and Sıkı 2011, Gül 2014, Döndüren 2015, Ebird 2020, TRAKUŞ 2020). To assess data on population abundance, we also conducted interviews with ornithologists who have a solid knowledge of the delta's avifauna, especially in the protected area.

Interviews were conducted with Mehmet Sıkı (MS) (Prof. Dr., Ornithologist specialist in Gediz Delta), Güven Eken (GE) (Dr., ornithologist worked for Doğa Derneği) and Ömer Döndüren (ÖD) (Dr., ornithologist, and the curator of the Birds Paradise Reserve located in Gediz Delta). The experts were asked to correct and validate the databases as a final step.

Community Commonness Index (CCI)

For each bird community (defined as the species pool responding to a given criteria of habitat use or conservation status), we calculated the Community Commonness Index (CCI) to estimate the average abundance of the species of that community (Galewski and Devictor 2016). CCI uses the weighted mean of the abundance of a species to characterize the average abundance of a species in the overall bird community: CCI = $\sum a_i / \sum i$ (Galewski and Devictor 2016) with "a" the abundance (defined by five population size categories as described above) of a species "i". CCI scores compared the communities of both breeding and non-breeding birds in the delta. Then, CCI was calculated for species listed in SPEC and Annex I in the Bird Directive for the two time periods to compare trends in species in the function of their protection status (1980-1999 and 2000-2019) (supplemental material 1). Vagrant species were not included but are mentioned if their status has changed (such as if they started to occur more regularly) (Fig. 2). CCI was calculated for each period and each habitat (see above for the habitat categories). All analyses were carried out using R 3.6.3 software and the package "nlme" and "dplyr".

Results

Expert knowledge database

A) *Extinct and new species on the long-term*

Overall, bird trends show an increase in the number of bird species observed over the three-time periods. 299 species were recorded since 1835: 139 species between 1835-1979; 244 between 1980-2000: 288 from 2000 until 2019 (supplementary material 1). Approximately 22% of all species (66 of 299 species) were recorded as vagrant only. This is for instance the case of the Common Eider (*Somateria mollissima*) which usually spends winter at higher latitudes but was observed in the Gediz Delta for the first time in 2019 (Ebird 2020). Of the 36 species recorded for the first time between 2000 and 2019, only 8 now occur regularly: five are winter residents (Lesser flamingo (*Phoeniconaias minor*), Whooper swan (*Cygnus cygnus*), Greater Spotted Eagle (*Clanga clanga*), Bar-tailed Godwit (*Limosa lapponica*), Rook (*Corvus frugilegus*)), one is a non-breeding summer resident (Scopoli's Shearwater (*Calonectris diomedea)*), one is a passage migrant (Citrine Wagtail (*Motacilla citreola*)), and one is a resident all year round (Ring-necked Parakeet (*Psittacula krameri*)). The Ring-necked Parakeet is an invasive exotic species, well-established in Izmir and recorded in the south of the Gediz Delta, close to the city.

The historical records indicate the loss of four species: Black Francolin (*Francolinus francolinus*) (Strickland 1836), Black-bellied Sandgrouse (*Pterocles orientalis*) (Von Gonzenbach 1859), Egyptian Vulture (*Neophron percnopterus*) and Great Bustard (*Otis tarda*), (Von Gonzenbach 1859, Kroper 1869). The Black Francolin and Great Bustard were frequently observed in the İzmir Plains (Strickland, 1856) and they were likely present there as resident species. Evidence has shown that 3 Black Francolin eggs were taken near Izmir (Aegean) on 10/5/1899 (Kirwan *et al.* 2010), and a breeding population of Great Bustard at Marmara Lake (Manisa) in the Aegean region, within 100 km of the Gediz Delta (Karakaş and Akarsu 2009). The status of the Egyptian Vulture is less clear, but it was observed in an area suitable for breeding in Bornova, İzmir, in 1899 at a time where the species was much more common in the Mediterranean basin (Seloos 1900). The Black-bellied Sandgrouse was only noted in the İzmir list by Strickland (1856), and it could have been either resident or only wintering in the Delta. In addition, the White throated Kingfisher (*Halcyon smyrnensis*) was also a resident bird species in the Delta from 1720 (first time recorded by W. Sherard (1720) (Kirwan *et al.* 2010)) to 2000 but is now considered locally extinct. In our study, we considered this species to be vagrant as it was observed in the Delta for the last time in 2002 (Ebird 2020). Pied Kingfisher (*Ceryle rudis*) was recorded by Seloos (1900) and was observed one time in 1987 by Mehmet Sıkı (Kirwan *et al.* 2010), but its past status remains unclear.

B) Breeding Species.

95 bird species were recorded as breeders in the 1980-1999 time-period while 103 species were breeding in 2000-2019. In total, 115 species were recorded as breeding species in the 1980-2019 time-period in the Delta. Twelve species recorded as breeders in the Delta between 1980 and 1999 have not been breeding since 2000, including the Eurasian Spoonbill (*Platalea leucorodia*) and the Black-crowned Night Heron (*Nycticorax nycticorax*). On the other hand, 20 bird species started to breed in the Delta after 2000 (supplementary material 1). A majority of these new breeding species were «agricultural & grasslands» specialists. «Generalist» species ranked second in the number of breeders followed by «wetland» species. The habitat that hosted the least breeders are «boreal and temperate forests» species (Fig. 3).

C. Non-Breeding Species.

227 species were regularly observed as non-breeders in the Delta in the 1980-1999 period and 233 in the 2000-2019 period (supplementary material 1). 30 % of those species are resident; 50 % are summer non-breeding or wintering species; and 17 % are passage migrants in the Delta. There were 5 species regularly seen in 1980-1999 but which were not observed regularly in the 2000-2019 time-period: Greylag Goose (*Anser anser*), White-headed Duck (*Oxyura leucocephala*), Eurasian Eagle Owl (*Bubo bubo*), White-throated Kingfisher (*Halcyon smyrnensis*) and Rock Bunting (*Emberiza cia*). On the other hand, 11 new species started to be observed regularly in the 2000-2019 time-period: including the Mute Swan *(Cygnus olor),* Citrine Wagtail (*Motacilla citreola),* and Rook *(Corvus frugilegus)* (Fig. 2). «Generalist» species ranked first in the number of non-breeding species, followed by «agricultural & grasslands» and «wetland» species. The «boreal temperate forests» species had the least species number of breeders (Fig. 3).

D. Species trend.

According to the scoring evaluating the total of both breeding and non-breeding species, 27% of the species decreased in abundance between the two time periods, 40% were stable, and 33% increased. When assessing species trends in function of their main habitat type, we found that a majority of «agricultural & grasslands» birds have been declining (40.8 %), while 48.5 % of «marine & coastal» and 40.0 % of «inland wetlands» birds have been increasing (Fig. 4).

E. Changes in CCI index.

The CCI of breeding species has not changed between the two time periods (1980-1999 and 2000-2019) suggesting an overall stability in community abundance in breeding birds (Fig. 5). However, this trend varies between the two periods according to the habitat specialization of the bird community. There is an increase in the CCI of birds breeding in «marine & coastal» habitats (+ 64.7 %) and, to a lesser extent those breeding in the «mediterranean» habitats (+ 7.1 %) (Fig 5). On the contrary, breeding birds in «agricultural & grasslands» (-14 %) and «generalist» species (-9.7%) show a decreasing CCI value between the two time-periods. The CCI of «inland wetland» species is almost stable between the two time-periods (-1.2%). For non-breeding bird populations, there is almost no change in CCI between 1980-1999 and 2000-2019 (+0.3 %). When looking at CCI per habitat specialization, we observed limited variations over time compared to breeding bird populations. CCI of birds using «mediterranean» habitats or «generalist» were stable between the two time periods. CCI slightly decreased for the «agricultural & grassland» species (-7%), and «marine and coastal species» (-5.1%). On the other hand, there was a slight increase in the CCI of «inland wetlands» species (+7%), much more marked for « boreal & temperate forest » (+44%) even if the pool of species is very limited for this last category (10 species) (Fig. 5).

F- Conservation Status.

Among the 238 species observed regularly for at least one of the two time periods in the Gediz Delta. Most of the breeding species are not listed in Annex I (39 species listed out of 115 breeding species under the Annex I). The majority of non-breeding species have not been listed in both lists (91 species out of 238 listed SPEC, and 88 species out of 238 listed by Annex I) (Table 1). In the breeding bird community, species listed in Annex I has increased in CCI (27.17 %). The CCI index of the species not listed in Annex I (species that are targeted by conservation measures) decreased slightly (- 8.44 %) (Fig. 6). The non-breeding bird population species listed in Annex I slightly increased (2.22 %), and for the species not listed in Annex I, there is almost no change (0.18 %) (Fig. 6). The species listed in SPEC do not show much change in CCI for either non-breeding nor breeding species populations. The species not listed in the SPEC list (lower conservation value) slightly decreased in both breeding and non-breeding populations (Fig. 6).

Discussion

By combining historical records and expert knowledge, we have shown contradicting trends depending on bird communities and habitat preferences in the Gediz Delta over the last century. There were decreasing trends in breeding bird species that use «agricultural and grasslands» habitats while there were important increases in «marine & coastal» bird species. The observed changes in the breeding bird communities could be related with the land use and land cover changes that happened in the Delta. Previous studies have shown significant changes in the study area with some of the natural dry-lands and agricultural lands being converted to urban areas, and most of the natural wetlands having been converted to artificial wetlands, such as the brackish waters to saltpans (Ernoul *et al.* 2012, Bolca *et al.* 2014). Changes of the CCI index of the bird community over time are in the continuation of previous trends identified by Onmuş *et al.* (2008, Onmuş *et al.* 2011), with local avifauna responding to land-use changes in the Gediz Delta. Similar land use and land cover trends are found around the Mediterranean Basin (Mediterranean Wetland Observatory 2014) and greatly impact the biodiversity living in and around the wetlands (Galewski *et al.* 2011). On the other hand, the situation is slightly different for species that hold protection status. The CCI of breeding species listed by Annex I increased, indicating that the Delta does not hinder and even supports the progress of this group of species targeted by conservation policies.

Conversely, the breeding species not listed in Annex I decreased in abundance on average, suggesting that non-protected species have declined. For instance, this is the case of the Eurasian Skylark and the House Sparrow in Gediz Delta. This increase in Annex 1 list, confirms the efficiency of the protection status (Koschová *et al.* 2018) and suggests that similar regulation should be applied to other species with unfavorable conservation status. This result is similar to what can be observed in many other places in Europe where formerly common species, and thus not targeted by conservation efforts, have declined (Inger *et al.* 2015).

Bird communities can provide information about the changes in the biodiversity status of socio-ecosystems (Galewski and Devictor 2016). The average abundance of breeding bird species in coastal & marine areas increased in the Gediz Delta, during the same period, the saltpans in the Delta expanded (Ernoul *et al.* 2012, Bolca *et al.* 2014). This positive relationship can be attributed to the fact that breeding bird species associated with saline areas have increased at a very high rate, and this increase has tended to involve specialist species in the Delta. The land-use change from natural wetland areas to artificial, but protected wetlands has positively impacted specialist birds of coastal and marine habitats: the artificial wetlands (saltpans) area increased ~65% from 1963 to 2010 (Bolca *et al.* 2014). As in other wetlands around the world, this land-use change has led to an increase in the number of species specific to these habitats (Sripanomyom *et al.* 2011, Márquez-Ferrando *et al.* 2014), but these highly saline habitats are only beneficial to a very small number of species (Sebastián-González and Green 2016). Several management measures have enhanced these trends, such as the building of artificial islands for the reproduction of flamingos (Balkiz *et al.* 2009) with an increase in the breeding population size by more than 40-times between 1980 and 2019, or nesting platforms for other species such as gulls and terns. The expansion of saltpans seems to have also impacted positively non-breeding populations (more species have increased than decreased between the two time periods) even if the establishment of new species in very low numbers led to a small decrease of CCI in non-breeding «marine & coastal» species.

Despite almost no variation in CCI for specialist species breeding in inland wetland habitats, it is important to highlight that there was an increase in the total number of breeding species in this habitat with 6 new species and 3 extinct as breeders between the 2 time periods. These new breeders are mainly linked to reedbeds, such as Mute swan (*Cygnus cygnus*) and little bittern (*Ixobrychus minutus*). These new settled species preferences could be attributed to conservation efforts of the wetland habitats in the Delta (such as pumping freshwater into Gediz Delta). In contrast, some species were likely negatively affected by the variable water level in the reedbeds, such as Eurasian Spoonbill (*Platalea leucorodia*) and the Black-crowned Night Heron (*Nycticorax nycticorax*). It is important to note that the reedbeds in the Delta were almost completely dry in the early 2000s, and the administration of national park decided to pump water to protect the reeds and freshwater habitats (Ernoul *et al.* 2012, Bolca *et al.* 2014, Avdan 2020). Given that these habitats are very dependent on continual fresh water supplies, the sustainability of these habitats requires continued pumping. Therefore, the population size of inland wetland birds may have remained small due to the limited surface area that freshwater marshes represent in the delta (Sıkı 2020). Likewise, the extinction of Smyrna Kingfishers that build their nests in the soft bed of rivers is probably the consequence of the correction and containment of the Gediz River (land-use change) (Eken 1997).

Our study also highlights the possible impact of agricultural practices and intensification on certain species associated with agricultural & grasslands ecosystems. Here, we observed a decrease in breeding species numbers and their abundance index with several formerly common species that recently became scarcer (e.g. Calandra Lark, Greater Short-toed Lark, Corn Bunting, Spanish Sparrow) or even recently stopped breeding (Eurasian Skylark). This result is in the line of similar trends observed on bird populations after agricultural intensification (Gil-Tena *et al.* 2015, Katayama *et al.* 2015, Alderson and Sander 2021). One reason for the local decline of breeding birds in agricultural & grasslands is that the avifauna linked to semi-natural grassland environments have undergone a significant turnover over the past century, which could be linked to a change in the vegetative structure caused by reduced grazing pressure (Mérö *et al.* 2015) or conversion of grasslands into agricultural areas (Bolca *et al.* 2014). The use of ancient literature suggests that the cultivation of grasslands is one of the major drivers of change in the Gediz Delta bird community in the long-term. In the 19th and even until the middle of the 20th century, there was a marked presence of steppe species, some of which remain today (e.g. Calandra Lark), but others are virtually extinct (e.g. Eastern Imperial Eagle, Great Bustard, Black-bellied sandgrouse) (Strickland 1836, von Gonzenbach 1859, Selous 1900, Kirwan *et al.* 2010). This change could largely be attributed to the conversion of large pastoral areas into agricultural fields previous to 1980 (agricultural land increased 13 % between 1963-2010) (Bolca *et al.* 2014). Moreover, agriculture practices have evolved in the Delta, with drainage and reclamation methods to increase farming production (Efe 2007, Bolca *et al.* 2014). More recently, the urbanization pressure of the growing city of İzmir and the plantation of eucalyptus trees also may have reduced suitable breeding habitats for these species (Robledano *et al.* 2010, Avdan 2020). Hence, if before the 1990s, there were species linked to semi-natural grasslands such as the Stone Curlew (*Burhinus oedicnemus*), Calandra Lark (*Melanocorypha calandra*), Short-toed Lark (*Calandrella brachydactyla*), and Isabelline Wheathear (*Oenanthe isabellina*) in the southern part of the Delta, after the 2000s, these species no longer bred in that area and were replaced by birds nesting in wooded areas such as the Great tit (*Parus major*), Blue tit (*Cyanistes caeruleus*) and Golden oriole (*Oriolus oriolus*).

In the Gediz Delta, the «generalist» and «Mediterranean habitats» categories gather species with diverse ecological requirements. These inter-species differences might explain diverging trends with, for instance, an overall abundance increase in breeding species showing a strong attraction for highly anthropized habitats like urban areas (e.g. the «generalist» Eurasian Collared Dove or Hooded Crow and the «mediterranean habitats» Red-rumped Swallow) or like plantations of exotic trees (e.g. the «generalist» Great Tit or Common Chaffinch), whereas species more linked to semi-natural habitats seem to be declining (e.g. *Sylvia* spp, Western Rock Nuthatch). But, again, the expansion of urban settlements (Bolca *et al.* 2014, Ernoul *et al.* 2012, Avdan 2020) within and on the southern margin of the Delta might drive these opposite trends. On the other hand, the cumulative effects of both increasing plantations in recent periods and less observation or underreporting of small birds in the first period could also be a possible explanation for the increase in CCI of non-breeding boreal temperate forests birds.

The overall poorer trends of agricultural, grassland and semi-natural species in the Delta may seem less bad news than the good news of the increase in coastal wetland birds. The Delta is renowned for its waterbird populations, with breeding, wintering and migrating numbers exceeding the criteria of international importance for several species (e.g. Greater Flamingo, Dalmatian Pelican, Pygmy Cormorant, Pied Avocet, Little Stint). It is highly likely that the protection afforded to many coastal species both internationally (Bern Convention, Birds Directive) and locally through the designation of the coastal part of the Gediz Delta as a protected area has played a key role in improving the local conservation status of wetland birds. However, the majority of breeding and non-breeding species in the Delta whose conservation is currently considered to be of European concern are species associated with terrestrial habitats, particularly agricultural and grassland environments. Most often, these non-targeted species in conservation activities are farmland species (Chamberlain and Crick 1999, De Laet and Summers-Smith 2007, Galewski and Devictor 2016). Our results, therefore, argue in favor of extending biodiversity conservation measures to the Delta's terrestrial ecosystems, which have so far been largely forgotten by conservation policies. The same pattern has been observed in the Camargue, another large Mediterranean delta, where similar contrasted trends were found between birds breeding in wetlands (long-term increase) and farmland birds (long-term decline) (Galewski and Devictor, 2016).

The low number of bird species recorded in the early periods could be explained by the relatively low number of observers, since the Delta was not systematically studied by ornithologists until the 1980s (Özesmi and Per 2006). For this reason, there is certainly a lower number of bird species detected and recorded in the early periods due to lower observation pressures. Additionally, the experts' opinions might also be biased since their studies mainly concentrate on the reserve part of the Delta, which does not include all the ecosystems encountered in the Delta. It should be noted that most agricultural & grassland habitats are located outside the reserve, which could cause the number of birds to be underestimated and their trends less well estimated. We also acknowledge that there could be some limitations in preciseness concerning abundances because there could be bias based on observers' subjectivity. The use of historical reports and grey literature may have reduced these biases. Another limitation of this study is that we attempted to link changes in the bird community with bird habitat specialization, such as land use and land cover changes in the Gediz Delta. However, other drivers of community changes like climate change happen at a much larger geographical scale and also impacts Gediz bird populations. In this sense, it is certainly better to focus on changes in breeding populations than the non-breeding bird populations as they have stricter requirements for particular habitats and are more sensitive to habitat modifications (Greenwood 2003).

Our study has shown that using a combination of literature review, expert interviews, and freely accessible bird data can be used to understand bird trends and their link to habitat dynamics. The study highlights that major land use and land change have an impact on bird diversity; some transformations (such as the conversion of natural wetlands to artificial wetlands) may be more favorable for some marine and coastal birds. Other factors that are not visually apparent (changes in agricultural practices) could have negative repercussions. This method effectively evaluates how biodiversity is changing, allows for the assessment of the efficiency of protected areas, and prioritizes new conservation issues without being limited to the long-term monitoring results. This kind of information is important to promote the conservation of sensitive wetland habitats and could be generalized to many other sensitive ecosystems.

REFERENCES

Aksu, A.E., Konuk, T., Ulug, A., Duman, M., and PIPER, D.W., 1990. Quaternary tectonic and sedimentary history of Eastern Aegean Sea shelf area. Jeofizik, 4 (1), 3–35.

Aksu, A.E., Piper, D.J.W., and Konuk, T., 1987. Late Quaternary tectonic and sedimentary history of outer Izmir and Candarli bays, western Turkey. Marine Geology, 76, 89–104.

Alderson, J. and Sander, H.A., 2021. Combining historical accounts with contemporary bird survey data identifies changes in an avian community over a period of anthropogenic change. Ibis.

Arslan, Ş. and Akyol, A., 2020. Güney Gediz Deltası 2020 Yılı Üreyen Kuş Atlası Çalışması. İzmir, Turkey: Doğa Derneği.

Avdan, A.O., 2020. The making of consurbia: Conservation, urbanization, and socio-environmental change in Turkey's Gediz Delta. Thesis. Arts & Social Sciences: Department of Sociology and Anthropology.

Balkiz, O., Özesmi, U., Pradel, R., Germain, C., Siki, M., Amat, J.A., Rendón-Martos, M., Baccetti, N., Bechet, A., and others, 2009. An update of the greater flamingo Phoenicopterus roseus in Turkey. Special Publication 1 Proceedings of the IVth International Workshop on the Greater Flamingo in the Mediterranean region and northwest Africa. Bulletin of the IUCN-SSC/Wetlands International Flamingo Specialist Group

Balkız, Ö., 2006. Metapopulation dynamics of the greater flamingo in the Mediterranean (implications for conservation). PhD Thesis. Université de Montpellier 2 Sciences et Techniques du Languedoc, Montpellier.

Ballance, D.K. and Lee, S.L.B., 1961. Notes on autumn migration at the Bosphorus and in the Aegean. Ibis, 103 (2), 195–204.

BirdLife International, 2017. European birds of conservation concern: populations, trends and national responsibilities. Cambridge, UK: BirdLife International.

Bolca, M., Özen, F., and Güneş, A., 2014. Land use changes in Gediz Delta (Turkey) and their negative impacts on wetland habitats. Journal of Coastal Research, 30 (4), 756–764.

Bonebrake, T.C., Christensen, J., Boggs, C.L., and Ehrlich, P.R., 2010. Population decline assessment, historical baselines, and conservation: Inferring population declines. Conservation Letters, 3 (6), 371–378.

Boylan, K.D. and MacLean, D.R., 1997. Linking species loss with wetlands loss. National Wetlands Newsletter, 19 (6), 13–17.

Chamberlain, D.E. and Crick, H.Q.P., 1999. Population declines and reproductive performance of Skylarks Alauda arvensis in different regions and habitats of the United Kingdom. Ibis, 141 (1), 38–51.

Christoffersen, L.E., 1997. IUCN: A Bridge-Builder for Nature Conservation. Green Globe Yearbook, 59–70.

Darwall, W., Carrizo, S., Numa, C., Barrios, V., Freyhof, J., and Smith, K., 2014. Freshwater Key Biodiversity Areas in the Mediterranean Basin Hotspot: Informing species conservation and development planning in freshwater ecosystems. IUCN, Cambridge, 86.

Davidson, N.C., 2014. How much wetland has the world lost? Long-term and recent trends in global wetland area. Marine and Freshwater Research, 65 (10), 934–941.
De Laet, J. and Summers-Smith, J.D., 2007. The status of the urban house sparrow Passer domesticus in north-western Europe: a review. Journal of Ornithology, 148 (2), 275–278.
Döndüren, Ö., 2015. Gediz Nehri Havzası'nda Leylek (Ciconia ciconia L., 1758) Popülasyonunun Tespiti, Popülasyon Değişimlerinin ve Popülasyonu Etkileyen Etmenlerin Belirlenmesi İle Türün Göç Dinamikleri Üzerine Araştırmalar. Ege Üniversitesi, İzmir, Turkey.
Ebird, 2020. Ebird: An online database of bird distribution and abundance [web application]. Ebird, Cornell Lab of Ornithology, Ithaca, New York [online]. Available from: http://www.ebird.org [Accessed 12 Aug 2020].
Efe, R., 2007. Environmental change and wetland management: A case study in the Gediz Delta Ecosystem (Western Turkey). Presented at the International Conference of Global Changes and Problems-Theory and Practice, Sofia, Bulgaria: Sofia University 'St. Kliment Ohridski' Faculty of Geology and Geography, 16–22.
Eken, G., 1997. The breeding population of some species of waterbirds at Gediz Delta, Western Turkey. Zoology in the Middle East, 14 (1), 53–68.
Eken, G., Bozdoğan, M., İsfendiyaroğlu, S., Kılıç, D.T., and Lise, Y., 2006. Türkiye'nin önemli doğa alanları. Ankara, Turkey: Doğa Derneği.
Erinç, S., 1955. Gediz ve Büyük Menderes deltalarının morfolojisi [Morphology of Gediz and Great Menderes deltas]. Presented at the Dokuzuncu coğrafya meslek haftası tebliğler ve konferanslar, İstanbul: Türk Coğrafya Kur. Yay, 33–66.
Ernoul, L., Sandoz, A., and Fellague, A., 2012a. The evolution of two great Mediterranean Deltas: Remote sensing to visualize the evolution of habitats and land use in the Gediz and Rhone Deltas. Ocean & Coastal Management, 69, 111–117.
Ernoul, L., Sandoz, A., and Fellague, A., 2012b. The evolution of two great Mediterranean Deltas: Remote sensing to visualize the evolution of habitats and land use in the Gediz and Rhone Deltas. Ocean & coastal management, 69, 111–117.
Galewski, T., Collen, B., McRae, L., Loh, J., Grillas, P., Gauthier-Clerc, M., and Devictor, V., 2011. Long-term trends in the abundance of Mediterranean wetland vertebrates: from global recovery to localized declines. Biological Conservation, 144 (5), 1392–1399.
Galewski, T. and Devictor, V., 2016. When Common Birds Became Rare: Historical Records Shed Light on Long-Term Responses of Bird Communities to Global Change in the Largest Wetland of France. PLOS ONE, 11 (11), e0165542.
GDNCNP, 2020. Korunan Alanlar İstatistikleri, 2019 (Statistic for protected areas 2019).
Gediz Delta Management Plan, 2007. Gediz Deltası Sulak Alan Yönetim Planı, [Gediz Delta Management Plan]. İzmir, Turkey, T.C. Çevre ve Orman Bakanliği Doğa Koruma ve Milli Parklar Genel Müdürlüğü, Doğa Koruma Dairesi Başkanlığı, Sulak Alanlar Şubesi Müdürlüğü,.
Geijzendorffer, I., Chazée, L., Gaget, E., Galewski, T., Guelmami, A., Perennou, C., Davidson, N., and McInnes, R., 2018. Mediterranean wetlands outlook 2: Solutions for sustainable Mediterranean wetlands. Secretariat of the Ramsar Convention.
Gibbs, J.P., 2000. Wetland Loss and Biodiversity Conservation. Conservation Biology, 14 (1), 314–317.
Gil-Tena, A., De Cáceres, M., Ernoult, A., Butet, A., Brotons, L., and Burel, F., 2015. Agricultural landscape composition as a driver of farmland bird diversity in Brittany (NW France). Agriculture, Ecosystems & Environment, 205, 79–89.
von Gonzenbach, G., 1859. Excursionen an die Brüteplätze von Sterna, Larus und Glareola im Golf von Smyrna im Frühling 1859. Journal für Ornithologie, 7 (5), 393–398.

Greenwood, J.J., 2003. The monitoring of British breeding birds: a success story for conservation science? Science of the Total Environment, 310 (1–3), 221–230.

Gül, O., 2014. Gediz Deltası (İzmir) ve Büyük Menderes deltası (Aydın)'nda üreyen tepeli pelikan (Pelecanus crispus bruch, 1832) populasyon büyüklüğünün, değişiminin, göçlerinin, üreme ve beslenme biyolojilerinin araştırılması [Investigation of population size and trend, migration movements, breeding and feeding biology of dalmatian pelican (Pelecanus crispus bruch, 1832) populations breeding in Gediz Delta (İzmir) and Buyuk Menderes delta (Aydin)]. PhD Thesis. Ege Üniversitesi, İzmir, Turkey.

Gürsoy-Ergen, A., 2019. Hope for the White-headed Duck, Oxyura leucocephala (Aves: Anatidae) in Turkey despite a declining breeding population and abandonment of its traditional wintering area? Zoology in the Middle East, 65 (2), 116–127.

Inger, R., Gregory, R., Duffy, J.P., Stott, I., Voříšek, P., and Gaston, K.J., 2015. Common European birds are declining rapidly while less abundant species' numbers are rising. Ecology Letters, 18 (1), 28–36.

Katayama, N., Osawa, T., Amano, T., and Kusumoto, Y., 2015. Are both agricultural intensification and farmland abandonment threats to biodiversity? A test with bird communities in paddy-dominated landscapes. Agriculture, Ecosystems & Environment, 214, 21–30.

Keller, V.; Herrando, S.; Voríšek, P.; Franch, M.; Kipson, M.; Milanesi, P.; Martí, D.; Anton, M.; Klvanová, A.; Kalyakin, M.V.; Bauer, H.-G.; Foppen, R.P.B. (2020). European breeding bird atlas 2: Distribution, abundance and change. Lynx Edicions/European Bird Census Council (EBCC): Barcelona. ISBN 9788416728381. 967 pp.

Kirwan, G., Demirci, B., Welch, H., Boyla, K., Özen, M., Castell, P., and Marlow, T., 2010. The birds of Turkey. Bloomsbury Publishing.

Kirwan, G.M., Martins, R.P., Eken, G., and Davidson, P., 1998. Checklist of the Birds of Turkey: OSME Sandgrouse Supplement 1, 32p.

Korkmaz, H., 2014. Antakya-Kahramanmaraş Graben alaninda kurutulan sulak alanlarin (Amik gölü, Emen gölü ve Gâvur gölü batakliği) modellerinin oluşturulması. Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 5 (9), 19–37.

Koschová, M., Rivas-Salvador, J., and Reif, J., 2018. Continent-wide test of the efficiency of the European union's conservation legislation in delivering population benefits for bird species. Ecological Indicators, 85, 563–569.

Krüper, T., 1869. Beitrag zur Ornithologie Klein-Asiens. Journal für Ornithologie, 17 (1), 21–45.

Kumerloeve, H., 1986. Bibliographie der Säugetiere und Vögel der Türkei (rezente Fauna): unter Berücksichtigung der benachbarten Gebiete und mit Hinweisen auf weiterführendes Schrifttum [Bibliography of the mammals and birds of Turkey (recent fauna): considering the neighboring areas and with references to further literature]. Zoologisches Forschungsinstitut und Museum Alexander Koenig.

Loh, J., Green, R.E., Ricketts, T., Lamoreux, J., Jenkins, M., Kapos, V., and Randers, J., 2005. The Living Planet Index: using species population time series to track trends in biodiversity. Philosophical Transactions of the Royal Society B: Biological Sciences, 360 (1454), 289–295.

Márquez-Ferrando, R., Figuerola, J., Hooijmeijer, J.C.E.W., and Piersma, T., 2014. Recently created man-made habitats in Doñana provide alternative wintering space for the threatened Continental European black-tailed godwit population. Biological Conservation, 171, 127–135.

Mediterranean Wetland Observatory, 2014. Land cover: Spatial dynamics in Metierranean coastal wetlands from 1975 to 2005. France: Tour du Valat, Thematic collection No. 2.

Mérö, T.O., Lontay, L., and Lengyel, S., 2015. Habitat management varying in space and time: the effects of grazing and fire management on marshland birds. Journal of Ornithology, 156 (3), 579–590.
Nivet, C. and Frazier, S., 2004. A review of European wetland inventory information. Collaborative Report by Wetlands International and Institute for Inland Water Management and Wastewater Treatment, 262.
Onmuş, O., 2008. Gediz Deltası'nda üreyen su kuşu türlerinin yuvalama alanlarının izlenmesi ve bu kolonilerin yönetilmesi [Monitoring And Management Of Nest Sites Of Breeding Waterbirds At The Gediz Delta]. PhD Thesis. Doktora tezi, Ege Üniv. Fen Bil. Enst. İzmir.
Onmuş, O., Durusoy, R., and Eken, G., 2009. Distribution of breeding birds in the Gediz Delta, Western Turkey: (Aves). Zoology in the Middle East, 47 (1), 39–48.
Onmuş, O. and Sıkı, M., 2011. Shorebirds in the Gediz Delta (İzmir, Turkey): breeding and wintering abundances, distributions, and seasonal occurrences. Turkish Journal of Zoology, 35 (5), 615–629.
Onmuş, O., Sıkı, M., Sarıgül, G., and Crivelli, A.J., 2011. Status and development of the population of the globally threatened Dalmatian Pelican, Pelecanus crispus, in Turkey: (Aves: Pelecanidae). Zoology in the Middle East, 54 (1), 3–17.
Özgencil, İ.K. and Uslu, A., 2021. Update on the status of White-headed Duck Oxyura leucocephala and its breeding phenology in Central Anatolia, Turkey. Sandgrouse, 43.
Perennou, C., Guelmami, A., Paganini, M., Philipson, P., Poulin, B., Strauch, A., Tottrup, C., Truckenbrodt, J., and Geijzendorffer, I., 2018. Mapping Mediterranean Wetlands With Remote Sensing: A Good-Looking Map Is Not Always a Good Map. Advances in Ecological Research, 58, 243–277.
Pievani, T., 2014. The sixth mass extinction: Anthropocene and the human impact on biodiversity. Rendiconti Lincei, 25 (1), 85–93.
Pocock, M.J.O., Roy, H.E., Preston, C.D., and Roy, D.B., 2015. The Biological Records Centre: a pioneer of citizen science. Biological Journal of the Linnean Society, 115 (3), 475–493.
Ramsar Convention on Wetlands, 2018. Global Wetland Outlook: State of the World's Wetlands and their Services to People. Gland, Switzerland: Ramsar Convention Secretariat.
Robledano, F., Esteve, M.A., Farinós, P., Carreño, M.F., and Martínez-Fernández, J., 2010. Terrestrial birds as indicators of agricultural-induced changes and associated loss in conservation value of Mediterranean wetlands. Ecological Indicators, 10 (2), 274–286.
Sebastián-González, E. and Green, A.J., 2016. Reduction of avian diversity in created versus natural and restored wetlands. Ecography, 39 (12), 1176–1184.
Selous, F., 1900. XXIII.——A Fortnight's Egg-collecting in Asia Minor. Ibis, 42 (3), 405–424.
Sıkı, M., 1985. Çamaltı Tuzlası- Homa Dalyani Kuş türleri ve Bazı türlerin Biyolojileri üzerine araştırmalar [Çamaltı Saltworks- Homa Dalyani Studies on Bird Species and Biology of Some Species]. PhD Thesis. Ege Üniversitesi, İzmir, Turkey.
Sıkı, M., 1988. Çamaltı Tuzlası - Homa Dalyanı Kuş Türleri [Çamaltı Saltpan - Homa Dalyan Bird Species]. TÜBİTAK Doğa Türk Zooloji Dergisi, 13 (3), 272–283.
Sıkı, M., 2020. Gediz deltasi'ndaki İzmir kuş cennetini yaşatma mücadelesi (1982-2018). İzmir, Turkey: Kanguru Yayınları.
Sıkı, M. and Öktem, N., 1992. Çamaltı Tuzlası_Homa Dalyanı Kuş Türlerinin Revizyonu [Çamaltı Saltpan_Homa Dalyan Bird Species Revision]. Journal of Faculty of Science Ege Üniversity, 14 (1), 39–51.
Sıkı, M., Tok, C.V., Mermer, A., and Tosunoğlu, M., 1998. İzmir Kuşcenneti'nin Avifaunası ve Herpetofaunası [Avifauna and Herpetofauna of İzmir Bird Paradise]. Presented at the 14.Ulusal Biyoloji Kongresi, Samsun, 181–193.

Sripanomyom, S., Round, P.D., Savini, T., Trisurat, Y., and Gale, G.A., 2011. Traditional salt-pans hold major concentrations of overwintering shorebirds in Southeast Asia. Biological Conservation, 144 (1), 526–537.

Strickland, H.E., 1836. List of birds noticed or obtained by him in Asia Minor, in the winter of 1835 and spring of 1836. Proc Zool Soc London, 4, 97–102.

Teyssedre, A. and Robert, A., 2015. Biodiversity trends are as bad as expected. Biodiversity and Conservation, 24 (3), 705–706.

TRAKUŞ, 2020. Türkiye'nin Anonim Kuşları [TRAKUS Turkey's Birds Anonymous] [online]. [Accessed 2 Aug 2021].

TUIK, T.S.I., 2020. Address Based Population Registration System Results, 2019. Website.

Ünal, M. and Canli, M., 2019. Sulak Alanların Yok Edilmesinin Etkileri ve Amik Gölü Örneği [The Effects of Wetland Destruction and the Example of Lake Amik]. Doğanın Sesi, (4), 49–66.

Underwood, E.C., Viers, J.H., Klausmeyer, K.R., Cox, R.L., and Shaw, M.R., 2009. Threats and biodiversity in the mediterranean biome. Diversity and Distributions, 15 (2), 188–197.

Yaman, E., 2001. Gediz Deltasında kuluçkaya yatan kuş türlerinin tespiti ve bazı türlerin biyolojileri üzerine araştırmalar [The Determination of the bird species in Gediz Delta and investigation on biology of some birds]. Master. Ege Üniversitesi, İzmir, Turkey.

Yarar, M. and Magnin, G., 1997. Türkiye'nin Önemli Kuş Alanları (Important Bird Areas of Turkey)–Publications of Wildlife Protection Service.

Conflict of Interest

The authors whose names declare that there is no conflict of interest on any financial or non-financial (political, personal, professional) interests/relationships that may be interpreted to have influenced the manuscript.

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FIGURES and TABLES

Table 1: Percentage of habitat distributions of breeding and non-species in each conservation concern list (SPEC and Annex I lists) in the Gediz Delta, Turkey.

	N of Species	*SPEC List*	*Not Listed-SPEC List*	*Annex I List*	*Not Listed-Annex I List*
Breeding Species					
Agricultural & Grasslands	34	32.4	67.6	35.3	64.7
Boreal & Temperate Forests	2	50.0	50.0	50.0	50.0
Generalist	33	72.7	27.3	18.2	81.8
Inland Wetlands	24	66.7	33.3	41.7	58.3
Marine & Coastal	12	66.7	33.3	75.0	25.0
Mediterranean habitats	10	80.0	25.0	10.0	90.0
Total	**115**	**59.1**	**33.9**	**33.9**	**66.1**
Non-Breeding Species					
Agricultural & Grasslands	49	65.3	34.7	40.8	59.2
Boreal & Temperate Forests	10	20.0	80.0	40.0	60.0
Generalist	89	27.0	73.0	29.2	70.8
Inland Wetlands	45	40.0	60.0	40.0	60.0
Marine & Coastal	33	36.4	63.6	51.5	48.5
Mediterranean habitats	12	25.0	75.0	25.0	75.0
Total	**238**	**38.2**	**61.8**	**37.0**	**63.0**

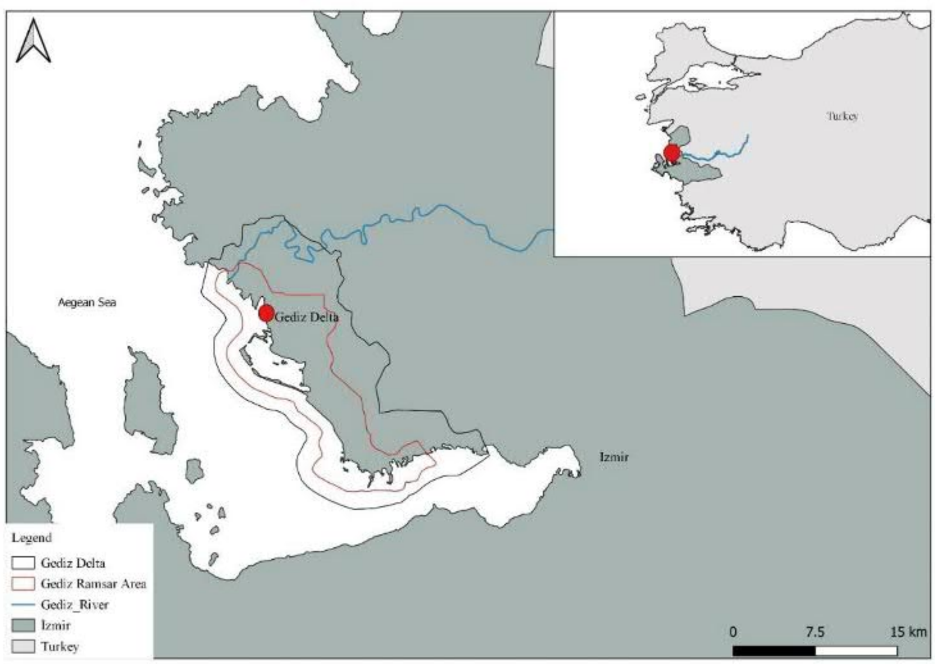

Figure 1: Location of the Gediz Delta in Turkey.

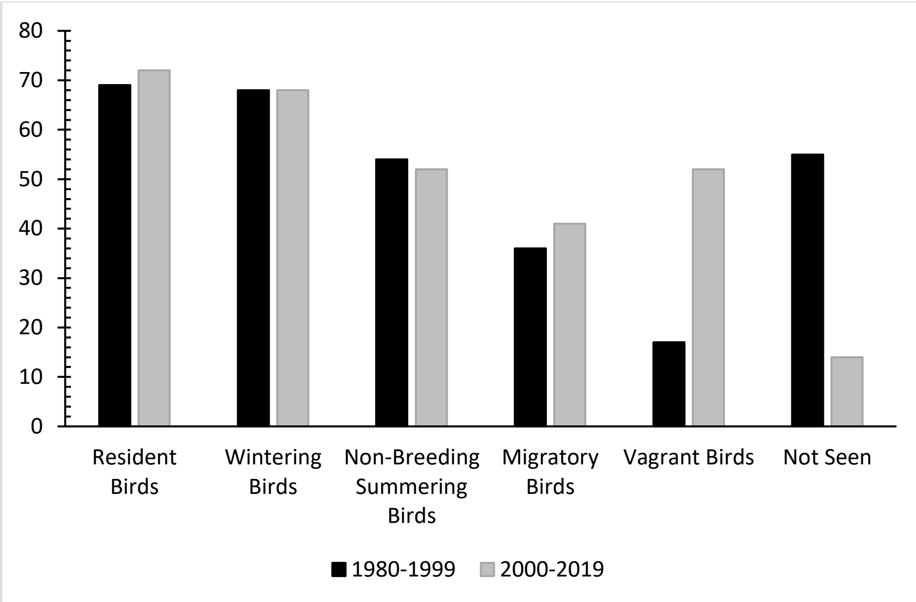

Figure 2: Number of species recorded in the Gediz Delta, Turkey in two different time-periods (1980-1999 and 2000-2019) (n=299) (x axis= number of species, y-axis = bird status).

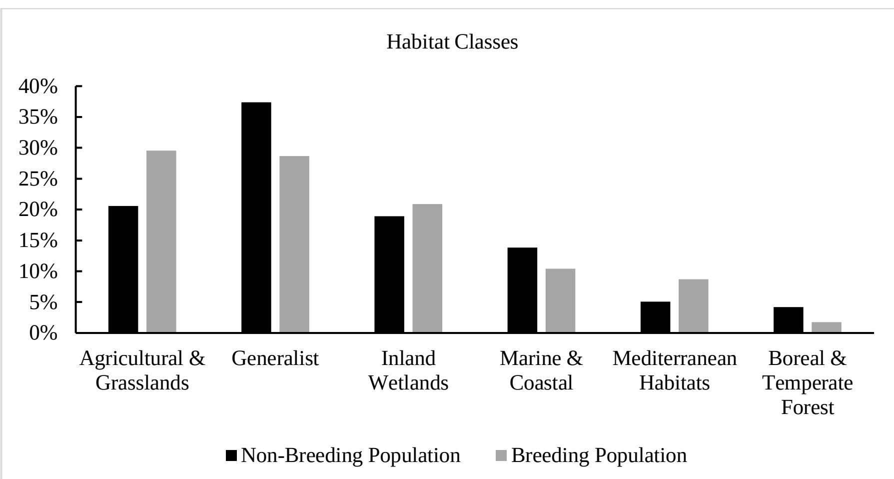

Figure 3: Percentage of variation of bird species depending on habitat classes in the regular observed species (n=238 species) and breeding species (n=115 species) in the Gediz Delta, Turkey. On the y axis, change for the percentage of habitats.

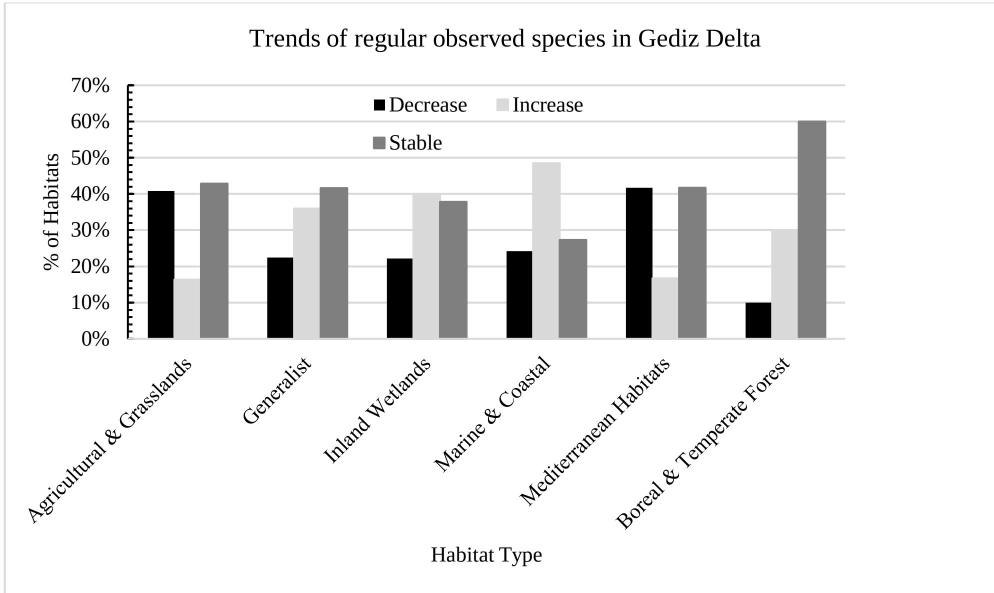

Figure 4: Trends classification for birds in each habitat class in the Gediz Delta, Turkey 1980 to 2019. On the y axis, change for percentage number of species (n=238).

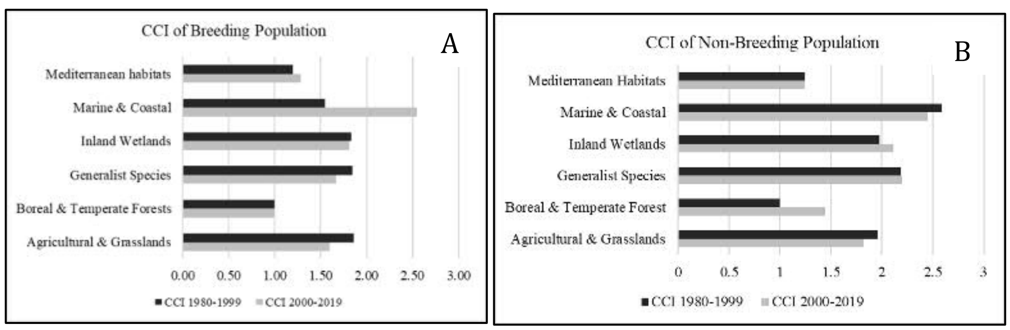

Figure 5: Change in the Community Commonness Index in each habitat: Community Commonness Index (CCI) of (A) breeding and (B) non-breeding birds over time in the Gediz Delta, Turkey from 1980-1999 to the 2000-2019 time-period. On the x-axis, change for the CCI scores of habitats.

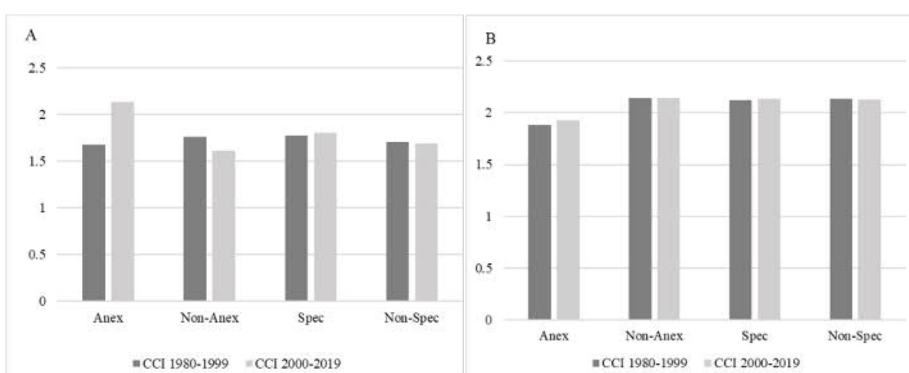

Figure 6: Change in the Community Index in Breeding Species (A) and non-breeding (B) in conservation concerns in the Gediz Delta, Turkey. On the y axis, change for the CCI scores of conservation groups.

Chapter 1 - Supplementary Material

Using literature and expert knowledge to determine changes in a Turkish wetland bird community over the last 40 years

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Table 1: Bird diversity in Gediz Delta

			Historical Records	1980-1999			2000-2019			
No	**LatinName**	**Englishname**	**Present Status**	**Present Status**	**Population Status**	**Breeding Status**	**Present Status**	**Population Status**	**Breeding Status**	**Final Present Status**
1	*Gavia stellata*	Red-throated Diver	-	+	V		-			Vagrant
2	*Gavia arctica*	Black-throated Diver	-	-			+	V		Vagrant
3	*Tachybaptus ruficollis*	Little Grebe	-	+	W	B	+	W	B	Present
4	*Podiceps cristatus*	Great Crested Grebe	+	+	W	N	+	W	B	Present
5	*Podiceps grisegena*	Red-necked Grebe	-	+	V		-			Vagrant
6	*Podiceps auritus*	*Horned Grebe*	-	-			+	V		Vagrant
7	*Podiceps nigricollis*	Black-necked Grebe	-	+	W	N	+	W	N	Present

8	*Calonectris diomedea*	Cory's Shearwater	-	-			+	S	N	Present
9	*Puffinus yelkouan*	Yelkouan Shearwater	-	+	R	N	+	R	N	Present
10	*Phalacrocorax carbo*	Cormorant	-	+	W	N	+	W	N	Present
11	*Phalacrocorax aristotelis*	Shag	-	+	W	N	+	R	N	Present
12	*Microcarbo pygmaeus*	Pygmy Cormorant	+	+	W	N	+	R	N	Present
13	*Pelecanus onocrotalus*	Great White Pelican	+	+	W	N	+	W	N	Present
14	*Pelecanus crispus*	Dalmatian Pelican	-	+	R	B	+	R	B	Present
15	*Botaurus stellaris*	Bittern	+	+	W	N	+	W	B	Present
16	*Ixobrychus minutus*	Little Bittern	-	+	S	N	+	S	B	Present
17	*Nycticorax nycticorax*	Night Heron	-	+	S	B	+	M	N	Present
18	*Ardeola ralloides*	Squacco Heron	-	+	S	N	+	S	N	Present
19	*Bubulcus ibis*	Cattle Egret	-	+	R	N	+	R	N	Present
20	*Egretta garzetta*	Little Egret	-	+	R	B	+	R	N	Present
21	*Ardea alba*	Great White Egret	+	+	R	N	+	R	N	Present
22	*Ardea cinerea*	Grey Heron	-	+	R	N	+	R	N	Present
23	*Ardea purpurea*	Purple Heron	-	+	S	B	+	S	B	Present
24	*Ciconia nigra*	Black Stork	-	+	W	N	+	W	N	Present
25	*Ciconia ciconia*	White Stork	+	+	S	B	+	S	B	Present
26	*Plegadis falcinellus*	Glossy Ibis	-	+	S	N	+	S	N	Present
27	*Platalea leucorodia*	Spoonbill	-	+	R	B	+	R	N	Present
28	*Phoenicopterus roseus*	Greater Flamingo	-	+	R	B	+	R	B	Present
29	*Phoeniconaias minor*	Lesser Flamingo	-	-			+	W	N	Present
30	*Cygnus olor*	Mute Swan	+	+	W	N	+	R	B	Present
31	*Cygnus columbianus*	Bewick's Swan	-	-			+	V		Vagrant
32	*Cygnus cygnus*	Whooper swan	-	-			+	W	N	Present
33	*Anser albifrons*	White-fronted Goose	-	+	W	N	+	W	N	Present
34	*Anser anser*	Greylag Goose	-	+	W	N	+	V		Vagrant
35	*Branta ruficollis*	Red-breasted Goose	-	+	W	N	+	W	N	Present
36	*Tadorna ferruginea*	Ruddy Shelduck	+	+	R	B	+	R	B	Present
37	*Tadorna tadorna*	Shelduck	+	+	W	B	+	R	B	Present

38	*Mareca penelope*	Wigeon	+	+	W	N	+	W	N	Present
39	*Mareca strepera*	Gadwall	-	+	W	N	+	W	N	Present
40	*Anas crecca*	Teal	+	+	W	N	+	W	N	Present
41	*Anas platyrhynchos*	Mallard	+	+	R	B	+	R	B	Present
42	*Anas acuta*	Pintail	-	+	W	N	+	W	N	Present
43	*Spatula querquedula*	Garganey	-	+	M	N	+	M	B	Present
44	*Spatula clypeata*	Shoveler	-	+	W	N	+	W	N	Present
45	*Netta rufina*	Red-crested Pochard	-	+	W	N	+	W	N	Present
46	*Aythya ferina*	Pochard	-	+	W	N	+	W	N	Present
47	*Aythya nyroca*	Ferruginous Duck	+	+	W	N	+	R	N	Present
48	*Aythya fuligula*	Tufted Duck	+	+	W	N	+	W	N	Present
49	*Aythya marila*	Scaup	-	-			+	V		Vagrant
50	*Somateria mollissima*	Common eider	-	-			+	V		Vagrant
51	*Melanitta nigra*	Common Scoter	-	-			+	V		Vagrant
52	*Bucephala clangula*	Goldeneye	+	+	V		+	V		Vagrant
53	*Mergellus albellus*	Smew	+	-			+	V		Vagrant
54	*Mergus serrator*	Red-breasted Merganser	-	+	W	N	+	W	N	Present
55	*Oxyura leucocephala*	White-headed Duck	-	+	W	N	+	V		Vagrant
56	*Pernis apivorus*	European Honey Buzzard	-	+	M	N	+	M	N	Present
57	*Milvus migrans*	Black Kite	+	-			+	V		Vagrant
58	*Haliaeetus albicilla*	White-tailed Eagle	-	-			+	V		Vagrant
59	*Neophron percnopterus*	Egyptian Vulture	+	-			-			Vagrant
60	*Gyps fulvus*	Griffon Vulture	+	-			+			Vagrant
61	*Circaetus gallicus*	Short-toed Eagle	+	+	S	N	+	S	N	Present
62	*Circus aeruginosus*	Marsh Harrier	-	+	R	N	+	W	B	Present
63	*Circus cyaneus*	Hen Harrier	+	+	W	N	+	W	N	Present
64	*Circus macrourus*	Pallid Harrier	-	+	M	N	+	M	N	Present
65	*Circus pygargus*	Montagu's Harrier	-	+	S	B	+	M	N	Present
66	*Accipiter gentilis*	Goshawk	+	+	V		+	V		Vagrant
67	*Accipiter nisus*	Sparrowhawk	+	+	W	N	+	W	N	Present
68	*Accipiter brevipes*	Levant Sparrowhawk	-	-			+	V		Vagrant

69	*Buteo buteo*	Common Buzzard	+	+	W	N	+	W	N	Present
70	*Buteo rufinus*	Long-legged Buzzard	+	+	R	N	+	R	B	Present
71	*Clanga pomarina*	Lesser Spotted Eagle	-	-			+	V		Vagrant
72	*Clanga clanga*	Greater Spotted Eagle	-	-			+	W	N	Present
73	*Aquila heliaca*	Imperial Eagle	+	-			+			Vagrant
74	*Aquila chrysaetos*	Golden Eagle	-	+	V		-			Vagrant
75	*Hieraaetus pennatus*	Booted Eagle	-	-			+	V		Vagrant
76	*Aquila fasciata*	Bonelli's Eagle	+	+	R	N	+	R	N	Present
77	*Pandion haliaetus*	Osprey	-	+	M	N	+	W	N	Present
78	*Falco naumanni*	Lesser Kestrel	+	+	S	B	+	S	B	Present
79	*Falco tinnunculus*	Kestrel	+	+	R	B	+	R	B	Present
80	*Falco vespertinus*	Red-footed Falcon	-	+	M	N	+	M	N	Present
81	*Falco columbarius*	Merlin	+	+	W	N	+	W	N	Present
82	*Falco subbuteo*	Hobby	-	+	W	N	+	W	N	Present
83	*Falco eleonorae*	Eleonora's Falcon	-	+	S	N	+	M	N	Present
84	*Falco biarmicus*	Lanner	-	+	V		-			Vagrant
85	*Falco peregrinus*	Peregrine Falcon	+	+	W	N	+	R	N	Present
86	*Alectoris chukar*	Chukar	+	+	R	B	+	R	B	Present
87	*Francolinus francolinus*	Black Francolin	+	-			-			Vagrant
88	*Coturnix coturnix*	Quail	+	+	S	B	+	R	B	Present
89	*Rallus aquaticus*	Water Rail	+	+	R	B	+	R	B	Present
90	*Porzana porzana*	Spotted Crake	-	+	M	N	+	M	N	Present
91	*Zapornia parva*	Little Crake	-	+	M	N	+	M	N	Present
92	*Crex crex*	Corncrake	+	+	M	N	+	M	N	Present
93	*Gallinula chloropus*	Moorhen	+	+	R	B	+	W	B	Present
94	*Fulica atra*	Coot	+	+	R	B	+	W	B	Present
95	*Grus grus*	Common Crane	-	+	M	N	+	M	N	Present
96	*Anthropoides virgo*	Demoiselle Crane	+	+	V		-			Vagrant
97	*Tetrax tetrax*	Little Bustard	+	+	V		+	V		Vagrant
98	*Otis tarda*	Great Bustard	+	-			-			Vagrant
99	*Haematopus ostralegus*	Oystercatcher	+	+	R	B	+	R	B	Present

100	*Himantopus himantopus*	Black-winged Stilt	-	+	S	B	+	S	B	Present
101	*Recurvirostra avosetta*	Avocet	+	+	R	B	+	R	B	Present
102	*Burhinus oedicnemus*	Stone Curlew	-	+	S	B	+	S	B	Present
103	*Glareola pratincola*	Collared Pratincole	+	+	S	B	+	S	B	Present
104	*Charadrius dubius*	Little Ringed Plover	-	+	S	N	+	S	N	Present
105	*Charadrius hiaticula*	Ringed Plover	-	+	W	N	+	W	N	Present
106	*Charadrius alexandrinus*	Kentish Plover	+	+	R	B	+	R	B	Present
107	*Charadrius leschenaultii*	Great Sand Plover	-	-			+	V		Vagrant
108	*Pluvialis apricaria*	Golden Plover	-	+	M	N	+	W	N	Present
109	*Pluvialis squatarola*	Grey Plover	-	+	R	N	+	R	N	Present
110	*Vanellus spinosus*	Spur-winged Plover	-	+	S	B	+	S	B	Present
111	*Vanellus vanellus*	Lapwing	+	+	W	N	+	W	N	Present
112	*Calidris canutus*	Knot	-	+	W	N	+	W	N	Present
113	*Calidris alba*	Sanderling	-	+	W	N	+	W	N	Present
114	*Calidris minuta*	Little Stint	-	+	R	N	+	R	N	Present
115	*Calidris temminckii*	Temminck's Stint	+	+	W	N	+	W	N	Present
116	*Calidris ferruginea*	Curlew Sandpiper	-	+	M	N	+	M	N	Present
117	*Calidris alpina*	Dunlin	+	+	W	N	+	W	N	Present
118	*Calidris falcinellus*	Broad-billed Sandpiper	-	-			+	V		Vagrant
119	*Calidris pugnax*	Ruff	-	+	M	N	+	M	N	Present
120	*Lymnocryptes minimus*	Jack Snipe	+	+	W	N	+	W	N	Present
121	*Gallinago gallinago*	Snipe	+	+	W	N	+	W	N	Present
122	*Scolopax rusticola*	Woodcock	+	+	V		+	W	N	Present
123	*Limosa limosa*	Black-tailed Godwit	-	+	R	N	+	R	N	Present
124	*Limosa lapponica*	Bar-tailed Godwit	-	-			+	W	N	Present
125	*Numenius phaeopus*	Whimbrel	+	-			+	V		Vagrant
126	*Numenius arquata*	Curlew	+	+	R	N	+	R	N	Present
127	*Tringa erythropus*	Spotted Redshank	-	+	W	N	+	W	N	Present
128	*Tringa totanus*	Redshank	+	+	R	B	+	R	B	Present
129	*Tringa stagnatilis*	Marsh Sandpiper	-	+	W	N	+	W	N	Present

130	*Tringa nebularia*	Greenshank	+	+	R	N	+	R	N	Present
131	*Tringa ochropus*	Green Sandpiper	+	+	W	N	+	W	N	Present
132	*Tringa glareola*	Wood Sandpiper	-	+	M	N	+	M	N	Present
133	*Xenus cinereus*	Terek Sandpiper	-	-			+	V		Vagrant
134	*Actitis hypoleucos*	Common Sandpiper	-	+	R	N	+	R	N	Present
135	*Arenaria interpres*	Turnstone	-	+	W	N	+	R	N	Present
136	*Phalaropus lobatus*	Red-necked Phalarope	-	+	V		+	M	N	Present
137	*Larus ichthyaetus*	Great Black-headed Gull	-	-			+	V		Vagrant
138	*Ichthyaetus melanocephalus*	Mediterranean Gull	+	+	S	B	+	S	B	Present
139	*Larus cachinnans*	Caspian Gull	-	-			+	V		Vagrant
140	*Hydrocoloeus minutus*	Little Gull	-	+	W	N	+	W	N	Present
141	*Chroicocephalus ridibundus*	Black-headed Gull	+	+	R	N	+	R	N	Present
142	*Chroicocephalus genei*	Slender-billed Gull	-	+	R	N	+	R	B	Present
143	*Ichthyaetus audouinii*	Audouin's Gull	-	-			+	V		Vagrant
144	*Larus canus*	Mew Gull	-	+	W	N	+	W	N	Present
145	*Larus fuscus*	Lesser Black-backed Gull	-	+	W	N	+	W	N	Present
146	*Larus armenicus*	Armenian Gull	-	+	W	N	+	W	N	Present
147	*Larus cachinnans*	Yelow-legged Gull	+	+	R	B	+	R	B	Present
148	*Rissa tridactyla*	Kittiwake	-	-			+	V		Vagrant
149	*Gelochelidon nilotica*	Gull-billed Tern	+	+	S	B	+	S	B	Present
150	*Hydroprogne caspia*	Caspian Tern	-	+	S	B	+	S	B	Present
151	*Thalasseus sandvicensis*	Sandwich Tern	-	+	R	B	+	R	B	Present
152	*Sterna hirundo*	Common Tern	+	+	S	B	+	S	B	Present
153	*Sternula albifrons*	Little Tern	+	+	S	B	+	S	B	Present
154	*Chlidonias hybrida*	Whiskered Tern	-	+	M	N	+	M	N	Present
155	*Chlidonias niger*	Black Tern	-	+	M	N	+	M	N	Present
156	*Chlidonias leucopterus*	White-winged Tern	-	+	M	N	+	M	N	Present
157	*Pterocles orientalis*	Black-bellied Sandgrouse	+	-			-			Vagrant
158	*Columba livia*	Rock Dove	-	+	R	B	+	R	B	Present

159	*Columba palumbus*	Woodpigeon	+	-			+	V		Vagrant
160	*Streptopelia decaocto*	Collared Dove	+	+	R	B	+	R	B	Present
161	*Streptopelia turtur*	Turtle Dove	+	+	S	N	+	S	B	Present
162	*Psittacula krameri*	Ring-necked Parakeet	-	-			+	R	N	Present
163	*Clamator glandarius*	Great Spotted Cuckoo	-	+	S	B	+	S	B	Present
164	*Cuculus canorus*	Cuckoo	+	+	S	B	+	S	B	Present
165	*Tyto alba*	Barn Owl	-	+	R	B	+	R	B	Present
166	*Otus scops*	Scops Owl	+	-			+	S	B	Present
167	*Bubo bubo*	Eagle Owl	+	+	R	B	+	V		Vagrant
168	*Athene noctua*	Little Owl	+	+	R	B	+	R	B	Present
169	*Asio otus*	Long-eared Owl	-	+	R	N	+	R	B	Present
170	*Asio flammeus*	Short-eared Owl	+	+	W	N	+	W	N	Present
171	*Caprimulgus europaeus*	Nightjar	-	+	S	B	+	S	B	Present
172	*Apus apus*	Swift	-	+	S	B	+	S	B	Present
173	*Apus pallidus*	Pallid Swift	-	+	M	B	+	M	N	Present
174	*Tachymarptis melba*	Alpine Swift	-	+	M	N	+	M	N	Present
175	*Halcyon smyrnensis*	White-throated Kingfisher	+	+	R	N	+	V		Vagrant
176	*Alcedo atthis*	Common Kingfisher	+	+	W	N	+	W	N	Present
177	*Ceryle rudis*	Pied Kingfisher	+	+	V		-			Vagrant
178	*Merops apiaster*	European Bee-eater	+	+	S	B	+	S	B	Present
179	*Coracias garrulus*	European Roller	+	+	M	B	+	M	N	Present
180	*Upupa epops*	Hoopoe	-	+	S	B	+	S	B	Present
181	*Jynx torquilla*	Wrayneck	+	+	M	N	+	M	N	Present
182	*Picus viridis*	Green Woodpecker	-	-			+	V		Vagrant
183	*Dendrocopos major*	Great-Spotted Woodpecker	+	-			+	V		Vagrant
184	*Dendrocopos syriacus*	Syrian Woodpecker	-	+	R	B	+	R	B	Present
185	*Melanocorypha calandra*	Calandra Lark	+	+	R	B	+	R	B	Present
186	*Calandrella brachydactyla*	Short-toed Lark	-	+	S	B	+	S	B	Present
187	*Galerida cristata*	Crested Lark	+	+	R	B	+	R	B	Present

188	*Lullula arborea*	Woodlark	+	+	W	N	+	W	N	Present
189	*Alauda arvensis*	Skylark	+	+	W	B	+	W	N	Present
190	*Riparia riparia*	Sand Martin	-	+	S	B	+	S	N	Present
191	*Ptyonoprogne rupestris*	Crag Martin	-	+	V		+	V		Vagrant
192	*Hirundo rustica*	Swallow	+	+	S	B	+	S	B	Present
193	*Cecropis daurica*	Red-rumped Swallow	-	+	S	B	+	S	B	Present
194	*Delichon urbicum*	House Martin	-	+	S	B	+	S	B	Present
195	*Anthus campestris*	Tawny Pipit	-	+	S	B	+	S	B	Present
196	*Anthus trivialis*	Tree Pipet	-	+	M	N	+	M	N	Present
197	*Anthus pratensis*	Meadow Pipit	+	+	W	N	+	W	N	Present
198	*Anthus cervinus*	Red-throated Pipit	-	+	M	N	+	M	N	Present
199	*Anthus spinoletta*	Water Pipit	-	+	W	N	+	W	N	Present
200	*Motacilla flava*	Yellow Wagtail	+	+	R	B	+	S	B	Present
201	*Motacilla citreola*	Citrine Wagtail	-	-			+	M	N	Present
202	*Motacilla cinerea*	Grey Wagtail	+	+	W	N	+	W	N	Present
203	*Motacilla alba*	Pied Wagtail	+	+	R	B	+	R	B	Present
204	*Troglodytes troglodytes*	Wren	+	+	W	N	+	W	N	Present
205	*Prunella modularis*	Dunnock	+	-			+	V		Vagrant
206	*Cercotrichas galactotes*	Rufous Bush-chat	+	+	S	B	+	S	B	Present
207	*Erithacus rubecula*	European Robin	-	+	W	N	+	W	N	Present
208	*Luscinia luscinia*	Thrush Nightingale	-	+	M	N	+	M	N	Present
209	*Luscinia megarhynchos*	Common Nightingale	-	+	S	B	+	S	B	Present
210	*Luscinia svecica*	Bluethroat	-	-			+	V		Vagrant
211	*Irania gutturalis*	White-throated Robin	-	-			+	V		Vagrant
212	*Phoenicurus ochruros*	Black Redstart	-	+	W	N	+	W	N	Present
213	*Phoenicurus phoenicurus*	Common Redstart	-	+	M	N	+	M	N	Present
214	*Saxicola rubetra*	Whinchat	+	+	M	N	+	M	N	Present
215	*Saxicola torquata*	Stonechat	-	+	W	B	+	R	B	Present
216	*Monticola saxatilis*	Common Rock Thrush	-	-			+	V		Vagrant
217	*Oenanthe isabellina*	Isabelline Wheathear	-	+	S	B	+	S	B	Present

218	*Oenanthe oenanthe*	Wheathear	-	+	S	B	+	S	B	Present
219	*Oenanthe hispanica*	Black-eared Wheathear	+	+	S	B	+	S	B	Present
220	*Oenanthe finschii*	Finsch's Wheathear	-	-			+	V		Vagrant
221	*Monticola solitarius*	Blue Rock Thrush	+	+	R	B	+	R	B	Present
222	*Turdus merula*	Blackbird	+	+	R	B	+	R	B	Present
223	*Turdus pilaris*	Fieldfare	+	+	W	N	+	W	N	Present
224	*Turdus philomelos*	Song Thrush	+	+	W	N	+	W	N	Present
225	*Turdus iliacus*	Redwing	+	+	V		+	V		Vagrant
226	*Turdus viscivorus*	Mistle Thrush	+	-			+	V		Vagrant
227	*Cettia cetti*	Cetti's Warbler	-	+	R	B	+	R	B	Present
228	*Cisticola juncidis*	Fan-tailed Warbler	+	+	R	B	+	R	B	Present
229	*Locustella fluviatilis*	River Warbler	+	-			+	V		Vagrant
230	*Locustella luscinioides*	Savi's Warbler	+	-			+	V		Vagrant
231	*Acrocephalus melanopogon*	Moustached Warbler	-	+	W	N	+	W	B	Present
232	*Acrocephalus schoenobaenus*	Sedge Warbler	-	+	M	N	+	M	N	Present
233	*Acrocephalus palustris*	Marsh Warbler	-	+	S	B	+	S	B	Present
234	*Acrocephalus scirpaceus*	Reed Warbler	-	+	S	B	+	S	B	Present
235	*Acrocephalus arundinaceus*	Great Reed Warbler	-	+	S	B	+	S	B	Present
236	*Iduna pallida*	Olivaceous Warbler	-	+	S	B	+	S	B	Present
237	*Hippolais olivetorum*	Olive-tree Warbler	+	-			+	V		Vagrant
238	*Hippolais icterina*	Icterine Warbler	-	+	V		+	V		Vagrant
239	*Sylvia cantillans*	Subalpine Warbler	-	-			+	V		Vagrant
240	*Sylvia melanocephala*	Sardinian Warbler	+	+	R	B	+	R	B	Present
241	*Sylvia rueppelli*	Rüppell's Warbler	-	-			+	V		Vagrant
242	*Sylvia crassirostris*	Eastern Orphean Warbler	+	+	S	B	+	M	N	Present
243	*Sylvia nisoria*	Barred Warbler	+	+	M	N	+	M	N	Present
244	*Sylvia curruca*	Lesser Whitethroat	+	+	S	B	+	S	B	Present
245	*Sylvia communis*	Whitethroat	+	+	S	B	+	S	B	Present
246	*Sylvia borin*	Garden Warbler	-	+	M	N	+	M	N	Present
247	*Sylvia atricapilla*	Blackcap	+	+	W	N	+	W	N	Present

248	*Phylloscopus bonelli*	Eastern Bonelli's Warbler	-	+	M	N	+	M	N	Present
249	*Phylloscopus sibilatrix*	Wood Warbler	-	+	M	N	+	M	N	Present
250	*Phylloscopus collybita*	Chiffchaff	+	+	M	N	+	M	B	Present
251	*Phylloscopus trochilus*	Willow Warbler	+	+	M	N	+	M	N	Present
252	*Regulus regulus*	Goldcrest	-	+	W	N	+	W	N	Present
253	*Regulus ignicapilla*	Firecrest	+	-			+	V		Vagrant
254	*Muscicapa striata*	Spotted Flycatcher	-	+	M	N	+	M	N	Present
255	*Ficedula parva*	Red-breasted Flycatcher	-	-			+	V		Vagrant
256	*Ficedula semitorquata*	Semi-collared Flycatcher	-	-			+	V		Vagrant
257	*Ficedula albicollis*	Collared Flycatcher	-	+	M	N	+	M	N	Present
258	*Ficedula hypoleuca*	Pied Flycatcher	-	+	M	N	+	M	N	Present
259	*Panurus biarmicus*	Bearded Tit	+	+	R	B	+	R	B	Present
260	*Aegithalos caudatus*	Long-tailed Tit	-	-			+	V		Vagrant
261	*Poecile lugubris*	Sombre Tit	-	+	R	N	+	R	N	Present
262	*Cyanistes caeruleus*	Blue Tit	+	+	R	N	+	R	B	Present
263	*Parus major*	Great Tit	+	+	R	B	+	R	B	Present
264	*Sitta neumayer*	Rock Nuthacth	+	+	R	B	+	R	B	Present
265	*Remiz pendulinus*	Penduline Tit	-	+	R	B	+	R	B	Present
266	*Lanius phoenicuroides*	Isabelline Shrike	-	-			+	V		Vagrant
267	*Lanius collurio*	Red-backed Shrike	+	+	S	B	+	S	B	Present
268	*Lanius minor*	Lesser Grey Shrike	+	+	S	B	+	S	N	Present
269	*Lanius senator*	Woodchat Shrike	+	+	S	B	+	S	B	Present
270	*Lanius nubicus*	Masked Shrike	+	+	S	B	+	S	B	Present
271	*Garrulus glandarius*	Jay	+	+	R	N	+	R	N	Present
272	*Pica pica*	Magpie	+	+	R	B	+	R	B	Present
273	*Corvus monedula*	Eurasian Jackdaw	+	+	R	B	+	R	B	Present
274	*Corvus frugilegus*	Rook	-	-			+	W	N	Present
275	*Corvus corone*	Carrion Crow	-	+	R	B	+	R	B	Present
276	*Corvus corax*	Common Raven	+	+	R	N	+	R	B	Present
277	*Oriolus oriolus*	Golden Oriole	+	+	S	N	+	S	B	Present
278	*Sturnus vulgaris*	Common Starling	+	+	R	N	+	R	B	Present

279	*Pastor roseus*	Rosy Starling	-	+	M	N	+	M	N	Present
280	*Passer hispaniolensis*	Spanish Sparrow	+	+	S	B	+	S	B	Present
281	*Passer montanus*	Tree Sparrow	-	+	R	N	+	R	B	Present
282	*Passer domesticus*	House Sparrow	+	+	R	B	+	R	B	Present
283	*Fringilla coelebs*	Chaffinch	+	+	R	N	+	R	B	Present
284	*Fringilla montifringilla*	Brambling	+	+	V		+	V		Vagrant
285	*Serinus serinus*	European Serin	+	+	W	N	+	W	N	Present
286	*Carduelis chloris*	Greenfinch	-	+	R	N	+	R	B	Present
287	*Carduelis carduelis*	Goldfinch	+	+	R	B	+	R	B	Present
288	*Carduelis spinus*	Siskin	-	+	W	N	+	W	N	Present
289	*Linaria cannabina*	Linnet	-	+	W	N	+	W	N	Present
290	*Coccothraustes coccothraustes*	Hawfinch	-	+	V		+	V		Vagrant
291	*Emberiza citrinella*	Yellowhammer	-	+	V		+	V		Vagrant
292	*Emberiza cirlus*	Cirl Bunting	+	+	R	B	+	R	B	Present
293	*Emberiza cia*	Rock Bunting	+	+	W	N	-	V		Vagrant
294	*Emberiza cineracea*	Cinereus Bunting	+	-			+	V		Vagrant
295	*Emberiza hortulana*	Ortolan	+	+	M	N	+	M	N	Present
296	*Emberiza caesia*	Cretzschmar's Bunting	+	+	S	B	+	S	B	Present
297	*Emberiza schoeniclus*	Reed Bunting	+	+	W	N	+	W	N	Present
298	*Emberiza melanocephala*	Black_headed Bunting	+	+	S	B	+	S	B	Present
299	*Emberiza calandra*	Common corn Bunting	+	+	R	B	+	R	B	Present
		COUNT	139	244	0	95	288	0	104	

CHAPTER 2

Contrasting effects of agriculture and urbanization on birds and reptiles communities in a Mediterranean delta (Gediz Delta, Turkey)

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Abstract: Understanding and quantifying the relationships between different community responses to habitat change is essential for developing sustainable conservation measures. Wetlands have been some of the most destroyed ecosystems over the last century, with important land use changes due to growing human demands. Gediz Delta is a large wetland on the Aegean coast of Turkey that has been greatly impacted with important losses of natural areas due to agricultural activities and urbanization. Here, we compared bird and reptile communities in three different land-use categories ("Natural" landscapes, "Agricultural" landscapes and "Urban" landscapes) in the Gediz Delta, in order to assess the impact of landscape type on the community structure for each taxon. Totally, 143 bird species and 14 reptile species were recorded over 30 grids covering the three land-use categories in the Gediz delta between 2019-2021. We used generalized linear models to estimate the effect of landscape on community richness and performed joint species distribution modeling to identify how species traits affected composition changes across landscape types. Our results show that community assembly processes in different taxa are impacted in different dimensions (positively and negatively) depending on

habitat type. Natural landscapes were important habitats for bird species specialist of «Agricultural & Grassland» and «Marine & Coastal» habitats, and reptile species specialist of «Mediterranean Habitats». Agricultural landscapes were positively related the occurrences for some «inland wetland» birds and some «inland wetlands» reptile species. Urban landscapes demonstrated positive impacts on some «Marine & Coastal» bird species and «Generalist» bird species. Besides, natural landscapes were negatively related with the occurrence of some «Inland Wetlands» birds and «Inland Wetlands» reptile species. Therefore, to sustain high biodiversity at a landscape scale, it is important to promote land management in agricultural and urban landscapes which include a mosaic of habitats and preserving natural landscapes.
Key words: Joint species distribution modelling, agriculture effects, urbanization effects, birds, reptile, Wetlands conversion, community assembly, community structure

Introduction

Biodiversity has been in a sharp decline throughout the worldwide over the last century with the conversion of natural areas to accommodate for human needs (Mittermeier *et al.* 2011, Le Viol *et al.* 2012, Keil *et al.* 2015). The 2020 Living Planet Report indicated a decline of approximately 68% of vertebrate species between 1970 and 2016 due to overexploitation and/or agricultural activity (Almond *et al.* 2020). Land use and land cover changes have been the most important driving forces on species composition changes in the last century (Galewski and Devictor 2016). Communities have been reshaped by land use/land cover changes with winners (species that have benefited or increased due to the changes) and losers (species that have declined or become extinct) (Devictor *et al.* 2007, Le Viol *et al.* 2012, Morelli *et al.* 2016). For instance, three-quarters of the European farmland bird species have declined as a response to reductions in the quantity or quality of food resources and reduced nesting success caused by accelerated agricultural intensification (Butler *et al.* 2010). A reverse situation was observed for some species such as flamingos or wader species that benefited from artificial wetlands (such as saltpans or rice fields) as alternative foraging habitats (Tourenq *et al.* 2001, Tryjanowski *et al.* 2015, Mao *et al.* 2019)**.**

Wetlands are important habitats for biodiversity, and many species depend on them to complete their life cycle (Spampinato *et al.* 2019). Among the natural ecosystems, wetlands are the most converted terrestrial habitats worldwide, with most of the destruction caused as a result of the creation of new agricultural lands or urbanization due to increasing human populations (Davidson 2014). As a result, 71% of wetland areas have been lost since the beginning of the 20th century (Dixon *et al.* 2016). Mediterranean wetland surface area declined by 45-51% since 1970, with associated loss of high ecological, economic and social values for the region (Daoud-Bouattour *et al.* 2011, Geijzendorffer *et al.* 2018). The changes in wetland structure composition and dynamics shape the biodiversity of wetland species (Boylan and MacLean 1997, Gibbs 2000). According to the IUCN Red list, 40 assessed species associated with Mediterranean wetlands are threatened with extinction and their abundances have decreased by 46 % since 1990 (Geijzendorffer *et al.* 2019).

Despite the evidence of important land use/land cover change in wetlands, there is little documentation of how agricultural and urban extension affect wetland biodiversity (Johnson *et al.* 2013, Galewski and Devictor 2016, Davidson *et al.* 2018, Mao *et al.* 2019), and in particular outside European countries (García-Navas and Thuiller 2020, Morgado *et al.* 2020). At the landscape scale, increased habitat heterogeneity in agricultural and urban areas may diversify the environmental conditions. This can result in a positive effect on generalist species (Le Viol *et al.* 2012) and even in an increase in species richness (Sebastián-González and Green 2016, Morgado *et al.* 2020) but also in the loss of specialized species (Le Viol *et al.* 2012). Species occupy habitats according to their specialization and the degree of habitat variation between various biotic and abiotic factors (Ovaskainen *et al.* 2017). The community assembly process has a causal connection to land-use change and differs between habitats and species communities (Kampichler *et al.* 2012, Newbold *et al.* 2020, Tikhonov *et al.* 2020). Given that land-use change is one of the most critical drivers affecting biodiversity (Whittaker 1972, Hevia *et al.* 2016), it is imperative to identify the dynamics of ecological communities and species interaction at different levels for better management and conservation prioritization.

Gediz Delta is one of the Mediterranean wetlands where urbanization and agriculture extension threats are intensely felt (Ernoul *et al.* 2012). This delta is located north of İzmir, a metropolis with a human population of more than 4 million people (TUIK 2020). The Delta is composed of a mosaic of salt and freshwater marshes and hosts a significant biodiversity (TUIK 2020, RIS 2021) made up of over 400 plant species, 299 birds species, and 35 reptiles and amphibians species (Gediz Delta Management Plan 2007, Onmuş *et al.* 2009, Arslan *et al.* 2018). The ecosystems in the Delta have been converted over the last century to accommodate the growth of the city (Bolca *et al.* 2014, Ernoul *et al.* 2014, Avdan 2020). The most considerable transformation was the translocation of the Gediz riverbed 50 km to the north through a system of dikes and canals at the beginning of the 19^{th} century to reduce flooding risks from the İzmir Bay (Avdan 2020). Then swamps were drained to combat malaria in the following years (Avdan 2020) and the margins of the delta were urbanized since the beginning of the 2000s (Bolca *et al.* 2014, Ernoul *et al.* 2012). Despite these changes, some species have positive population trends in the Gediz delta (such as Greater flamingos *Phoenicopterus roseus*), which may be explained by specific conservation efforts (Balkız 2006, Onmuş and Siki 2013). Nevertheless other species (such as Spur-thiged tortoise *Testudo graeca* or farmland bird species) did not benefit from these conservation efforts (Onmuş and Siki 2013, Arslan *et al.* 2021).

The Gediz Delta offers the opportunity to better understand how agriculture and urbanization affect biodiversity in the Mediterranean region, where many delta face similar threats (Geijzendorffer *et al.* 2018). In this study, we investigated how land cover affect birds and reptiles community assembly processes in the Gediz Delta. We tested the following hypotheses: (1) landscape types (natural, urban and agricultural) affect overall community indexes and species compositions of two taxa, birds and reptiles; and (2) the habitat specialization of species contributes to explain the observed changes in species assemblage and occurrence patterns across landscape types.

Methodology

1. Study area and sampling design

Gediz Delta (38˚ 30'N, 26˚ 55'E) is located in the eastern Mediterranean Basin (İzmir, Turkey) on the coast of the Aegean Sea (Fig. 1). It comprises a mosaic of freshwater and saltwater ecosystems made up of shrub forests, salt meadows, reed beds, marshes, lagoons, Salinas, beaches, farmlands, and urban landscapes (Gediz Delta Management Plan 2007). The study area (ca. 80,000 ha) is located between the present and past tributaries of the Gediz River and includes the immediate surroundings (Fig. 1). Land cover data were obtained by the analysis of 2019 satellite images (see Appendix of the Thesis) and habitats were classified according to ESA/DUE GlobWetland-II project combining CORINE Land Cover (CLC) classes with the Ramsar habitat definitions (Mediterranean Wetland Observatory 2014). Three landscape types (natural, agricultural, and urban) were defined by the most common observed habitat type within the same grid (Table S1). The landscapes are located from the coast to the inner parts of the delta. Urban and agricultural landscapes include areas that were previously natural wetlands (Fig 1).

The study site was divided into 200 2x2 km UTM grids. We selected 30 sampling grids randomly with a total of 10 sampling grids per landscape type. Natural landscape grids are composed of an average of 95% natural habitats including wetlands, grasslands, and scrublands. Agricultural landscapes grids are composed of an average 90% intensive farmlands habitats. Urban landscapes grids care composed of an average of 56% human settlements (Table S1). The natural landscape grids are located on the coastline in the protected zone of the delta and 6 of them included saltpans (out of 10 grids). The agricultural grids are in the inner part of the delta and the main crops include wheat, cotton, and some vegetables (tomatoes, cucumbers, etc.). The 6 urban grids are located on the periphery of the delta and 4 of them are located in the villages. 4 out of 6 urban grids in the periphery were formed by the transformation of a coastal lagoon, and still include some remnant coastal wetlands habitats. The villages are also surrounded by agricultural landscapes. All sampling sites shared a similar elevation (between 0-10 m) and the presence at least one water body (e.g., temporary ponds, ditches, channels).

2. Biodiversity monitoring

The taxa counts were carried out from early April to early June in 2019 (n=15 grids) and 2021 (15 new grids). Each grid was sampled twice within a year for both birds and reptiles. The bird monitoring was done following a point sampling framework, at 5-point counts per grid. The bird counts (conducted by DA) were made in a single grid/day from sunrise until afternoon. At each point, birds were identified and counted for 15 min within a 500 m-radius circle, recording all individual birds or flocks of each species seen or heard. Birds flying and located more than 50 m from the cell were excluded from the analyses.

We summed the abundances of species observed or heard at the same point and date and used the maximum abundance between April and June counts. Reptiles were surveyed by walking along 3 transects of 200 m long, randomly set up within each of the 30 grids. Reptiles were denombred by walking and checking under rocks or flat surface debris (like garbage in urban zones). The transects were walked slowly, with approximately 10 minutes allocated to each transect. The presence of all species that were seen or captured were recorded. We considered a reptile species present at a transect location when it has been observed at least once in April or June. We did not recorded reptile abundance because some species had low detectability and cryptic behaviors which could affect abundance estimations (Ward *et al.* 2017). The data resulted in 150 point-counts for birds (presence/absence and abundance), and 90 transects for reptiles (presence/absence) in 30 cells.

3. Species characteristics

We investigated community structures using both species functional traits and phylogeny. A species habitat specialization matrix was created for the species of each taxon based on species traits**.** In order to assign a habitat type to a bird species, we relied on the habitat classification provided by the bird and reptile experts of this study following criteria used in the second edition of the European Breeding Bird Atlas 2 (Keller *et al.* 2020). Reptile species were first classified by following the habitat description of Baran and Atatür (1998) and Yaşar *et al.* (2021) as references. We came up with six habitat specialization categories for birds: «Agricultural & Grassland», «Boreal & Temperate Forest», «Inland Wetlands», «Marine & Coastal», «Mediterranean Habitats» and «Generalist» (Table S2). We came up with two habitat specialization categories for reptiles: «Inland Wetlands», and «Mediterranean Habitats» (Table S3). Phylogenetic trees were obtained from Vertlife for birds and reptiles (https://vertlife.org/data/, accessed on 20.12.2021) (Jetz *et al.* 2012, Tonini *et al.* 2016) (Fig S1; Fig S2). Phylogenetic trees were used to assess the residual variation in species occurrence due to phylogenetic relationships.

Statistical Analyses

We used two approaches to evaluate bird and reptile communities in the Gediz Delta. We first (approach 1) estimated the effect of the landscape on biodiversity metrics and then (approach 2) evaluated community assembly in bird and reptile across the three landscape types.

To assess the relationship between biodiversity metrics [species richness, abundances, community commonness indexes (CCI), and Shannon Indexes] and landscapes types [agricultural, natural, urban], we built generalized linear mixed model with the 'lme4' package (Bates *et al.* 2015) **(Approach 1)**. Shannon index was used to compare the species evenness in each community (Hill 1973). Community commonness index was used to measure community responses to land cover by comparing the average abundances of the species in the community (Galewski and Devictor 2016). We used the mixed-effects models to deal with pseudo-replication in our sampling scheme (Zuur *et al.* 2009), with 'grid' as a random factor as several points and transects were set inside each grid. We used a Poisson error distribution for species richness and abundance models, and log transformed CCI and Shannon indexes to model them with a Gaussian error distribution. We assessed the effect of land cover on the biodiversity parameters, using a model selection framework. Models were contrasted using Akaike's information criterion corrected for small samples (AICc) (Burnham and Anderson 2002). The chi-squared test ($\chi 2$ tests) was used to interpret the significance of the fixed effects based on the AIC criterion (by drop1 function in "*lme4*" package).

We then performed a joint species distribution modelling to estimate the species occurrences pattern in the community assembly of each taxon (Ovaskainen *et al.* 2017, Ovaskainen and Abrego 2020) **(Approach 2)**. We fitted Hierarchical Modelling of Species Communities (HMSC) models with the R-package *Hmsc* (Ovaskainen *et al.* 2017, Tikhonov *et al.* 2020). HMSC is a joint species distribution model (Warton *et al.* 2015), using both species habitat specialization matrix as functional traits and phylogeny to assess species relationships to environmental variables (Abrego *et al.* 2017, Ovaskainen *et al.*, 2017). We performed one model for reptiles using presence/absence and two models for birds using alternatively species presence-absence and species abundance conditional on presence (Abundance COP) as response variables and the landscape types as explanatory variables. We included sampling locations as a spatially structured random effect to account for spatial autocorrelation among sampling sites (sampling points of birds or middle points of the reptile transects). It should be noted that the credible intervals of 50 bird species could not be calculated by R^2 and were thus excluded from the dataset for the Abundance COP model. We used a binomial error distribution to model species presence-absence, and a Gaussian error distribution for the log(Abundance COP), assuming the default distribution of priors (Ovaskainen and Abrego 2020). We sampled the posterior distribution with four Markov Chain Monte Carlo (MCMC) chains, and each presence-absence model ran for 37,500 iterations, of which the first 12,500 were removed as burn-in, and each abundance COP model ran for 150,000 iterations, of which the first 50,000 were removed as burn-in. We examined MCMC convergence by examining the model parameters' potential scale reduction factors (Gelman and Rubin 1992). The model fit was evaluated using Tjur R2 and AUC for presence-absence models and R^2 for abundance models (Ovaskainen and Abrego, 2020). The statistical program used for all the statistical analyses was R version 4.2.1 in the R environment.

Results

1. Species occurrence pattern in three habitats

1.1. Bird Species

A total of 143 bird species from 45 families were recorded across the Gediz Delta (Table S2). The most abundant bird species were flamingos (*Phoenicopterus roseus*), Yellow-legged gulls (*Larus michahellis*) and Barn swallows *(Hirundo rustica)* and the most frequent bird species were Eurasian magpies (*Pica pica*), Barn swallows (*Hirundo rustica*) and Crested larks (*Galerida cristata*). About 39.2% (56 species) of bird species were only observed in natural landscapes, 6.2% (9) in agricultural landscapes, and 5.5% (8) in urban landscapes (Fig 2). Generalist species accounted for 40.6% of the observed species, while 22.5% were specialists of Agricultural & Grasslands habitats, 20.4% specialists of Inland Wetlands, 13.3% specialists of Marine & Coastal habitats, 2.8% specialists of Mediterranean habitats and 0.7% specialists of Boreal & Temperate Forests habitats (Table S2).

1.2. Reptile Species:

A total of 14 reptiles species were recorded across the Gediz Delta (Fig S3). The most the most frequent reptile species were Snake-eyed lizards *(Ophisops elegans),* western Caspian turtle (*Mauremys rivulata*) and Mediterranean Spur-thighed tortoise (*Testudo graeca*). Three reptile species were only observed in natural sites and one only in agricultural grids (Fig 2). Nine species were evaluated as specialist of Mediterranean habitats and five as specialists of inland wetlands (Table S3).

2. Community structure patterns in three habitats

2.1. Bird Community

From the mixed effect models (Approach 1), natural landscape accommodates more avian richness, abundance, community commonness indexes yet lower Shannon indexes than the other two landscapes (Fig. 3). Landscape type affected species richness ($\chi2$=13.30, p= 0.0009), with natural grids accommodating more species (12.6 species ± 0.5 (SE)) than agricultural grids (9.7 ± 0.4) and urban ones (9.7 ± 0.4). Landscape type also impacted abundance ($\chi2$=24.50, p<0.00001), with natural landscapes accommodating almost 6 times more birds (355.02 ± 79.3) than agricultural grids (55.72 ± 14.2) and 6 times more birds than urban landscapes (67.2 ± 8.2). Landscape type also impacted CCI index ($\chi2$=15.50, p= 0.0004), with natural grids hosting 5 times more birds (27.93 ± 6.19) than agricultural grids (5.48 ± 1.1) and 3 times than urban grids (7.29 ± 0.9). We also found significant effect of landscape type on the Shannon Index ($\chi2$=7.40, p= 0.02) for birds, natural landscapes have lower Shannon (1.45 ± 0.09) than two other landscape (1.70 ± 0.05 in Agricultural landscape and 1.71 ± 0.05 urban landscape).

The joint species distribution models were fitted to 143 species for presence-absence models and 93 species for the COP models. The presence/absence model showed a moderate explanatory power as measured by AUC (mean= 0.83, SD= 0.13; range=0.2752:1.00, Fig. S3) and a low predictive power (AUC = 0.52 ± 0.24) predictive power. Habitat specialization explained most of the model variation (mean=80.8, SD:0.18) (Fig. S4). The abundance COP model had a low explanatory power, measured by the mean R^2 (mean 0.69, 0.33 SD; range=0.006–1, Fig. S3) and a very low predictive power of -0.21(0.4). Consequently, the results of the Abundance COP model were not further discussed due to the low R^2 value for both explanatory power and predictive power.

The Eurasian magpie (*Pica pica*) was significantly more common than the other species (Fig 5, Table S2). We identified a significant effect (95% credible interval) of at least one land cover on 88 species (62.5 %), three land covers on 23 species (26.2 %) and two land cover on 65 species (73.8 %). Only 2 of these 88 species [Common Reedwarbler (*Acrocephalus scirpaceus*), Common kestrel, (*Falco tinnunculus*)] were estimated to be more present only in agricultural landscapes than natural and urban landscapes.

The contrast between agricultural and natural landscapes was significant for 70 species (48.9 %) (Fig 5). These 70 species consisted of 10 «Agricultural & Grassland» species, 32 «Generalist» species, 9 «Inland wetlands» species, and 9 «Marine & Coastal» species. Among them, the majority of the species (56 species, 80.0 %) were more likely to occur in natural landscapes than in agricultural landscapes. Species with higher occurrence probability in natural landscapes were mostly «Generalist» species (42.8 %), and «Marine & Coastal» species (33.9 %), while consisting of some species from «Agricultural & Grassland» (8.93 %) and «Inland wetlands» (14.2 %) species. These species also are mainly waterbirds (46 out of 56 species). The species with a higher occurrence probability in agricultural than in natural landscapes (14 species, 20.0 %) consisted mainly of «Generalist» species (57.1 %) and to a lower extent of «Agricultural & Grassland» (35.7 %), and «Inland wetlands» species (7.14 %).

The contrast between agricultural and urban habitats was significant for 41 species (28.6%). These 41 species consist of 16 «Agricultural & Grassland» species, 11 «Generalist» species, 12 «Inland wetlands» species and 2 «Marine & Coastal » species. Among them, the majority of the species (27 species, 65.85%) showed a significant decline in their predicted occurrence probabilities in urban landscapes compared to agricultural landscapes (Fig 5). Species with higher occurrence probability in urban landscapes (14 species, 34.15 %), mainly consisted of «Generalist» species (71.4 %), and «Marine & Coastal» species (14.2 %), with only a few «Agricultural & Grassland» (7.14 %) and «Inland wetlands» (7.14 %) species. The species with a higher occurrence probability inside agricultural than urban landscapes (27 species, 65.85%) consisted mainly of «Agricultural & Grassland» (51.8 %), «Inland wetlands» (44.4 %) and «Generalist» species (3.7 %).

Overall, «Marine & Coastal» specialist species responded positively to natural and urban landscapes compared to agricultural landscapes (Fig. 6). Conversely, «Generalist» species had a more positive response to urban landscapes than to agricultural landscapes (Fig. 6). The «Agricultural & Grassland» species (intercept in Fig. 6) were positively affected by natural landscape but presented negative response to both urban landscapes and agricultural landscapes (Fig 6). No significant effect was detected for «Boreal

& Temperate Forest», «Inland Wetlands» and «Mediterranean Habitats» species.

The species responses to environmental covariates showed a moderate phylogenetic signal in the presence-absence model ($\Pr(\rho > 0) = 1$; $E(\rho) = 0.32$), which means some missing traits are not phylogenetically structured.

Reptiles Community:

From the mixed effect models (Approach 1), landscape type affected reptile species richness ($\chi 2$=8.68, p= 0.01), with natural landscape (1.47 species ± 0.2 (SE) and agricultural landscapes (1.43 ± 0.2) accommodating approximately equal richness but two times more than urban ones (0.6 ± 0.17) (Fig 4).

The joint species distribution models were fitted to those 14 reptile species for presence-absence models. The presence/absence models showed a high explanatory power as measured by AUC (mean= 0,91; 0.05 SD; range=0.83:1.00, Fig. S3) but a low predictive power of 0.57 (0.19). Habitat classification explained 80.6% (SD=0.05) of the model variation (Fig. S5).

Occurrence probability was relatively low for 92.8% of the species (n=13). The contrast between agricultural and natural landscapes was significant for 5 species (35.7 %) (Fig 7). Two of them [Snake-eyed lizards (*Ophisops elegans*) and Rough-tail agama (*Stellagama stellio*)] had a higher occurrence probability in natural landscapes and 3 species [Western Caspian turtle, (*Mauremys rivulata*), Grass snake (*Natrix natrix*), Dice snake (*Natrix tessellata*)] had a lower occurrence probability inside natural habitats compared to agricultural habitats (Fig. 7).

The contrast between agricultural and urban landscapes was significant for 5 species (35.7 %) (Fig 7). All these 5 species [(Western Caspian turtle, (*Mauremys rivulata*), European pond turtle (*Emys orbicularis*), Grass snake (*Natrix natrix*), Dice snake (*Natrix tessellata*) and Blotched snake (*Elaphe sauromates*)] had a higher occurrence probability in agricultural than in urban landscapes (Fig. 6).

Overall, the occurrence probability of the «Mediterranean habitat» reptile species was higher in natural than agricultural habitats (Fig. 8). The «Inland wetland» reptile species occurrence probability was lower inside urban than in agricultural habitats. Considering a 90% credible interval, the occurrence probability of the «Inland wetland species» was lower in natural than in agricultural habitats and the occurrence probability of the «Mediterranean habitat» species was also higher urban than agricultural habitats. The species responses to environmental covariates showed a low phylogenetic signal in the presence-absence model ($\Pr(\rho > 0) = 0.16; E(\rho) = 0.43$) that means missing traits are not phylogenetically structured.

Discussion:

Our results shows that birds and reptile communities are affected by changes in land cover, especially urbanization and agricultural extension in different dimensions (positive or negative). We showed that natural landscapes have a positive effect on the occurrences of «Marine & Coastal» bird species, «Agricultural & Grassland» bird species, and on «Mediterranean habitats» reptile species. In turn, urban landscapes had a positive effect on the occurrences of «Marine & Coastal» bird species and «Generalist » bird species. In agricultural landscapes, we found that only some «inland wetland» bird and «inland wetland» reptile species occurrence was higher than in urban landscapes. Hence, natural, and urban landscapes appear to have more similar bird community composition than agricultural landscapes. The similarity of natural and urban landscapes may be due to the fact that cities still contain some natural habitats (Table S1). However, our results show that natural landscapes accommodate more avian richness, abundance, community commonness indexes yet lower Shannon indexes than the other two landscapes. Since the natural areas of the Gediz Delta are mainly composed of saltwater habitats and surrounded by farmlands and settlements, the apparent difference in species composition and indexes of birds communities could be associated with these stark differences in habitats in the delta (Bolca et al. 2014, see Appendix of the Thesis). For instance, the increased Salinas surface areas have created favorable conditions for specific- coastal bird species (Sripanomyom *et al.* 2011, Márquez-Ferrando *et al.* 2014). On the other hand, reptiles' biodiversity variable (richness) is similar between natural and agricultural landscapes, and higher than in urban landscapes. One possible explanation of that similar richness is that freshwater channels used for irrigation offer alternative habitats of good quality for some reptiles in agricultural landscapes and these remnant habitats are key to reptile persistence (Schutz and Driscoll 2008). Another possible explanation is that reptilian diversity has decreased even in natural landscape due to increased human activity and close proximity to human settlements (Johnson *et al.* 2013, Castro-Expósito *et al.* 2021).

The lower occurrence probability of «Agricultural & Grassland» bird species in agricultural landscapes compared to natural landscapes could be explained by the fact that the crops (which are mainly cotton) found in the agricultural landscapes are not very suitable for these birds. However, it is important to note that despite these intensive agricultural activities, agricultural landscapes still provide more adequate habitats for «Agricultural & Grassland» bird species compared to urban landscapes. Previous studies also indicated that «Agricultural & Grassland» bird species decreased or even disappeared in the Gediz Delta because of the decrease in freshwater marshes, and grasslands habitats (Bolca *et al.* 2014, Ernoul *et al.* 2012, Onmuş and Siki 2013, See Chapter 1). These bird species need short vegetation in marshes or meadows to breed or feed (Keller *et al.* 2020), and destruction of such habitats is likely to have a negative impact on these species. A similar pattern of negative impacts of intensification and urbanization has also been observed in the Mediterranean Basin (Galewski and Devictor 2016, Palacín and Alonso 2018, Morgado *et al.* 2020, Mallet *et al.* 2022) and Europe (Butler *et al.* 2010). On the other hand, we also estimated that some «Inland Wetlands» bird species are more common in natural and some in agricultural landscapes in delta. For instance, small passerines such as reed warblers (*Acrocephalus scirpaceus* or *A. arundinaceus*) are more widespread in agricultural landscapes and some duck species are common in natural landscapes such as (*Anas querquedula*, or *Tadorna ferruginea*). This could be in part due to the fact that limited freshwater supplies in the Delta have increased the importance of freshwater in channels and reedbeds located on the edges of agricultural landscapes as also found in the Camargue delta (Mallet *et al.* 2022); these habitats are not present in most urban landscapes of the delta (Bolca *et al.* 2014, Ernoul *et al.* 2012). Additionally, the prevalence of «Inland Wetlands» species in natural lands could also be attributed to conservation efforts in the Delta (such as pumping freshwater into Gediz Delta (Bolca *et al.* 2014, Sıkı 2020).

In natural landscapes, we observed that the occurrence probability of the majority of «Agricultural & Grassland» and «Marine & Coastal» bird species is higher than in agricultural landscapes. These results are also consistent with previous studies on bird diversity trends in the Gediz Delta, showing similar patterns of increased abundance of the coastal-marine species with possible collinearity with increasing Saline surfaces (see Chapter 1), such as flamingo species (Balkız 2006). In Chapter 1, we found that «Agricultural & Grassland» bird populations decreased due to the destruction of semi-natural habitats including grassland habitats. Therefore, we consider that the probability of finding these species was higher in natural landscapes given this is the only landscape category that provides these suitable habitats (Galewski and Devictor 2016, Keller *et al.* 2020). In addition, some of «Generalist» waterbirds showed a tendency to be more presence inside natural than agricultural habitats. The increase in the presence of these species in natural areas of the Delta may indicate that the urbanization effect has increased in the natural part of the delta. Previous research has shown that «Generalist» bird species become more common in wetlands affected by urbanization (Galewski and Devictor 2016, Mao *et al.* 2019).

In urban landscapes we found that «Marine & Coastal» and «Generalist» bird species have higher occurrence probability than agricultural landscapes. The «Marine & Coastal» species in urban habitats could benefit from the remnant wetlands (such as salt marshes or lagoons), which significantly impacts certain adaptable bird species (Vallejo *et al.* 2009, Newbold *et al.* 2020). The proximity of urban landscapes to natural coastal areas in the Gediz Delta could also explain the occurrence of «Marine & Coastal» species (Winfree *et al.* 2005). On the other hand, urban landscapes generally host «Generalist» bird species that can nest in highly anthropized habitats like plantations of exotic trees or roofs of the human settlements (Chace and Walsh 2006, Devictor *et al.* 2007, Johnson *et al.* 2013). Given the presence of trees planted in parks and urban areas, these «Generalist» species (such as *Parus major*) are less likely to be found in natural and agricultural landscapes compared to urban landscapes (Bolca *et al.* 2014, See Thesis Appendix 1) .

For reptiles, we also observed that the occurrence probability of some «Inland wetland» species was higher inside agricultural than in urban landscape and natural landscape. Freshwater habitats are very limited in the delta and are very dependent on continuous freshwater supplies; the sustainability of these habitats requires continued pumping though the channels (Bolca *et al.* 2014, Ernoul *et al.* 2012, Avdan 2020, See Thesis Appendix 1). Hence, the limited freshwater habitats in natural areas may have adversely affected the existence of «Inland wetland» reptile species. Similar to bird species, the remnant habitats could sustain some reptile species (Schutz and Driscoll 2008). The presence of freshwater in channels could also be beneficial to «Inland wetlands» reptile species [such as Western Caspian turtle, (*Mauremys rivulata*), Grass snake (*Natrix natrix*), or Dice snake (*Natrix tessellata*)]. Contrary to prior research showing that remnant wetlands in urban landscapes have a positive impact on some aquatic reptile species (Barrett and Guyer 2008), our study in the Gediz Delta does not show this impact in urban landscapes.

In this study, we demonstrated that «Mediterranean Habitats» reptile species occurrence probability of at least two species [snake-eyed lizards (*Ophisops elegans*), and Rough-tail agama (*Stellagama stellio*)] were higher in natural than agricultural habitats. A possible explanation is that the remnant-scrubs found in natural landscape delta may have increased the probability of the general occurrence of the Mediterranean reptile species as it did for «Agricultural & Grassland» bird species (Garden *et al.* 2007). However, it should be noted that we did not sample the scrub hills of the delta while they are known to have a very rich reptile diversity (Arslan et al. 2018). Similar to previous studies (Garden *et al.* 2007, Moreno-Rueda and Pizarro 2007, Barrett and Guyer 2008), the difference of richness between the results of our 2018 study and this one (2021) may also result from the importance of scrub hills habitats for these specialized species (Arslan *et al.* 2018).

Birds and reptiles are recognized as bioindicators in the ecosystem because of their specific ecological requirements (trophic levels, dispersal ability and degree of habitat specialization); however, birds have received more attention due to their higher detectability in various habitats (Hager 1998, Weller 1999, Ewers and Didham 2006, Barrett and Guyer 2008, Mistry *et al.* 2008, Robledano *et al.* 2010, Galewski and Devictor 2016, Castro-Expósito *et al.* 2021). Therefore, birds may be better indicators in places such as the Gediz Delta, which are home to many habitat specialist species but where habitat destruction and fragmentation is common. Conversely, limited reptile observations with low detectability and high ecological requirements may be less efficient indicators in places like the Gediz Delta (Hager 1998, Ward *et al.* 2017). Previous studies on reptiles have shown that species richness was high in native Mediterranean type scrub areas in the hills of the Delta and the diversity did not vary in the rest of the Delta (Arslan *et al.* 2018). The second limitation of the study is that the sampling grids included some remnant natural habitats such as lagoons or marshes, which may positively impact the presence of specialized species in these grids (Schutz and Driscoll 2008, Vallejo *et al.* 2009, Boissinot *et al.* 2019, Goertzen and Suhling 2019, Mallet *et al.* 2022). Further studies should investigate the impact of remnant-habitat types to determine the effects of urbanization and agricultural activities.

Our study shows that the community assembly processes in different taxa are impacted by land cover in different dimensions, both positively and negatively. We observed that the frequency of coexistence of bird and reptile species specialized in the same habitats was similar in natural and urban landscapes in the delta. In this study, the similarity between urban landscapes and natural landscapes is mainly associated with fragmented habitats found in cities and settlements. For instance, the urban grids sampled in this study consists of 15.6 % natural landscapes on average in the Delta (Table S1). On the contrary, we have demonstrated that agricultural areas have negative effects for many species in both taxa. Therefore, in future studies, it is highly recommended to work on the impacts of remnant habitats on different taxa. To maintain high biodiversity, we must pay more attention to holistic land management in agricultural and urban landscapes to integrating a mosaic of habitat types by preserving natural patches (Garden *et al.* 2007, Tryjanowski *et al.* 2015, Mallet *et al.* 2022). The restoration of agro-ecological infrastructures in the Gediz farmland habitats could be a potential action that could promote farmland and inland wetland species. For instance, inside an intensive agricultural context, an open channels surrounded by reeds can significantly support and promote biodiversity in farmlands (Mallet *et al.* 2022). The remaining natural habitats in urban landscapes have proven to be much more suitable for birds than agriculture or urban areas (Vallejo *et al.* 2009) and should be conserved.

Supplementary Material

Attached end of the thesis.

Conflict of Interest

The authors whose names declare that there is no conflict of interest on any financial or non-financial (political, personal, professional) interests/relationships that may be interpreted to have influenced the manuscript.

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REFERENCES

Abrego, N., Norberg, A., and Ovaskainen, O., 2017. Measuring and predicting the influence of traits on the assembly processes of wood-inhabiting fungi. Journal of Ecology, 105 (4), 1070–1081.

Almond, R.E., Grooten, M., and Peterson, T., 2020. Living Planet Report 2020-Bending the curve of biodiversity loss. World Wildlife Fund.

Arslan, D., Oliver, A., Yaşar, Ç., Ismail, İ.B., Döndüren, Ö., Ernoul, L., Beck, N., and Çiçek, K., 2018. Distribution and current status of herpetofauna in the Gediz Delta (Western Anatolia, Turkey). Herpetology notes, 11, 1–15.

Arslan, D., Olivier, A., Ernoul, L., Béchet, A., and Çiçek, K., 2021. Demography, distribution, and threat assessment of the Spur-thighed Tortoise (Testudo graeca) in the Gediz Delta, Turkey (Reptilia: Testudines). Zoology in the Middle East, 67 (3), 216–227.

Avdan, A.O., 2020. The making of consurbia: Conservation, urbanization, and socio-environmental change in Turkey's Gediz Delta. Thesis. Arts & Social Sciences: Department of Sociology and Anthropology.

Balkız, Ö., 2006. Metapopulation dynamics of the greater flamingo in the Mediterranean (implications for conservation). PhD Thesis. Université de Montpellier 2 Sciences et Techniques du Languedoc, Montpellier.

Barrett, K. and Guyer, C., 2008. Differential responses of amphibians and reptiles in riparian and stream habitats to land use disturbances in western Georgia, USA. Biological Conservation, 141 (9), 2290–2300.

Bates, D., Mächler, M., Bolker, B., and Walker, S., 2015. Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67, 1–48.

Boissinot, A., Besnard, A., and Lourdais, O., 2019. Amphibian diversity in farmlands: Combined influences of breeding-site and landscape attributes in western France. Agriculture, Ecosystems & Environment, 269, 51–61.

Bolca, M., Özen, F., and Güneş, A., 2014. Land use changes in Gediz Delta (Turkey) and their negative impacts on wetland habitats. Journal of Coastal Research, 30 (4), 756–764.

Boylan, K.D. and MacLean, D.R., 1997. Linking species loss with wetlands loss. National Wetlands Newsletter, 19 (6), 13–17.

Burnham, K.P. and Anderson, D.R., 2002. A practical information-theoretic approach. Model selection and multimodel inference, 2.

Butler, S.J., Boccaccio, L., Gregory, R.D., Vorisek, P., and Norris, K., 2010. Quantifying the impact of land-use change to European farmland bird populations. Agriculture, Ecosystems & Environment, 137 (3), 348–357.

Castro-Expósito, A. de, García-Muñoz, E., and Guerrero, F., 2021. Reptile diversity in a Mediterranean wetlands landscape (Alto Guadalquivir region, southeastern Spain): are they affected by human impacts? Acta Herpetologica, 16 (1), 27–36.

Chace, J.F. and Walsh, J.J., 2006. Urban effects on native avifauna: a review. Landscape and Urban Planning, 74 (1), 46–69.

Daoud-Bouattour, A., Muller, S.D., Jamaa, H.F.-B., Saad-Limam, S.B., Rhazi, L., Soulié-Märsche, I., Rouissi, M., Touati, B., Jilani, I.B.H., Gammar, A.M., and Ghrabi-Gammar, Z., 2011. Conservation of Mediterranean wetlands: Interest of historical approach. Comptes Rendus Biologies, 334 (10), 742–756.

Davidson, N.C., 2014. How much wetland has the world lost? Long-term and recent trends in global wetland area. Marine and Freshwater Research, 65 (10), 934–941.

Davidson, N.C., Fluet-Chouinard, E., and Finlayson, C.M., 2018. Global extent and distribution of wetlands: trends and issues. Marine and Freshwater Research, 69 (4), 620–627.

Devictor, V., Julliard, R., Couvet, D., Lee, A., and Jiguet, F., 2007. Functional homogenization effect of urbanization on bird communities. Conservation Biology, 21 (3), 741–751.

Dixon, M.J.R., Loh, J., Davidson, N.C., Beltrame, C., Freeman, R., and Walpole, M., 2016. Tracking global change in ecosystem area: The Wetland Extent Trends index. Biological Conservation, 193, 27–35.

Ernoul, L., Sandoz, A., and Fellague, A., 2012. The evolution of two great Mediterranean Deltas: Remote sensing to visualize the evolution of habitats and land use in the Gediz and Rhone Deltas. Ocean & coastal management, 69, 111–117.

Ewers, R.M. and Didham, R.K., 2006. Confounding factors in the detection of species responses to habitat fragmentation. Biological Reviews, 81 (1), 117–142.

Galewski, T. and Devictor, V., 2016. When Common Birds Became Rare: Historical Records Shed Light on Long-Term Responses of Bird Communities to Global Change in the Largest Wetland of France. PLOS ONE, 11 (11), e0165542.

García-Navas, V. and Thuiller, W., 2020. Farmland bird assemblages exhibit higher functional and phylogenetic diversity than forest assemblages in France. Journal of Biogeography, 47 (11), 2392–2404.

Garden, J.G., Mcalpine, C.A., Possingham, H.P., and Jones, D.N., 2007. Habitat structure is more important than vegetation composition for local-level management of native terrestrial reptile and small mammal species living in urban remnants: A case study from Brisbane, Australia. Austral Ecology, 32 (6), 669–685.

Gediz Delta Management Plan, 2007. Gediz Deltası Sulak Alan Yönetim Planı, [Gediz Delta Management Plan]. İzmir, Turkey, T.C. Çevre ve Orman Bakanliği Doğa Koruma ve Milli Parklar Genel Müdürlüğü, Doğa Koruma Dairesi Başkanlığı, Sulak Alanlar Şubesi Müdürlüğü,.

Geijzendorffer, I., Chazée, L., Gaget, E., Galewski, T., Guelmami, A., Perennou, C., Davidson, N., and McInnes, R., 2018. Mediterranean wetlands outlook 2: Solutions for sustainable Mediterranean wetlands. Secretariat of the Ramsar Convention.

Geijzendorffer, I.R., Beltrame, C., Chazee, L., Gaget, E., Galewski, T., Guelmami, A., Perennou, C., Popoff, N., Guerra, C.A., Leberger, R., Jalbert, J., and Grillas, P., 2019. A More Effective Ramsar Convention for the Conservation of Mediterranean Wetlands. Frontiers in Ecology and Evolution, 7, 21.

Gelman, A. and Rubin, D.B., 1992. Inference from Iterative Simulation Using Multiple Sequences. Statistical Science, 7 (4), 457–472.

Gibbs, J.P., 2000. Wetland Loss and Biodiversity Conservation. Conservation Biology, 14 (1), 314–317.

Goertzen, D. and Suhling, F., 2019. Urbanization versus other land use: Diverging effects on dragonfly communities in Germany. Diversity and Distributions, 25 (1), 38–47.

Guelmami, A., Unpublished work. Gediz Delta Land Use and Land Cover Changes.

Hager, H.A., 1998. Area-sensitivity of reptiles and amphibians: Are there indicator species for habitat fragmentation? Écoscience, 5 (2), 139–147.

Hevia, V., Carmona, C.P., Azcárate, F.M., Torralba, M., Alcorlo, P., Ariño, R., Lozano, J., Castro-Cobo, S., and González, J.A., 2016. Effects of land use on taxonomic and functional diversity: a cross-taxon analysis in a Mediterranean landscape. Oecologia, 181 (4), 959–970.

Hill, M.O., 1973. Diversity and Evenness: A Unifying Notation and Its Consequences. Ecology, 54 (2), 427–432.

Jetz, W., Thomas, G.H., Joy, J.B., Hartmann, K., and Mooers, A.O., 2012. The global diversity of birds in space and time. Nature, 491 (7424), 444–448.

Johnson, P.T.J., Hoverman, J.T., McKenzie, V.J., Blaustein, A.R., and Richgels, K.L.D., 2013. Urbanization and wetland communities: applying metacommunity theory to understand the local and landscape effects. Journal of Applied Ecology, 50 (1), 34–42.

Kampichler, C., Van Turnhout, C.A., Devictor, V., and Van Der Jeugd, H.P., 2012. Large-scale changes in community composition: determining land use and climate change signals. PloS one, 7 (4), e35272.

Keil, P., Storch, D., and Jetz, W., 2015. On the decline of biodiversity due to area loss. Nature Communications, 6 (1), 8837.

Keller, V.; Herrando, S.; Voríšek, P.; Franch, M.; Kipson, M.; Milanesi, P.; Martí, D.; Anton, M.; Klvanová, A.; Kalyakin, M.V.; Bauer, H.-G.; Foppen, R.P.B. (2020). European breeding bird atlas 2: Distribution, abundance and change. Lynx Edicions/European Bird Census Council (EBCC): Barcelona. ISBN 9788416728381. 967 pp.

Le Viol, I., Jiguet, F., Brotons, L., Herrando, S., Lindström, \AAke, Pearce-Higgins, J.W., Reif, J., Van Turnhout, C., and Devictor, V., 2012. More and more generalists: two decades of changes in the European avifauna. Biology letters, 8 (5), 780–782.

Mallet, P., Béchet, A., Galewski, T., Mesléard, F., Hilaire, S., Lefebvre, G., Poulin, B., and Sirami, C., 2022. Different components of landscape complexity are necessary to preserve multiple taxonomic groups in intensively-managed rice paddy landscapes. Agriculture, Ecosystems & Environment, 328, 107864.

Mao, Q., Liao, C., Wu, Z., Guan, W., Yang, W., Tang, Y., and Wu, G., 2019. Effects of Land Cover Pattern Along Urban-Rural Gradient on Bird Diversity in Wetlands. Diversity, 11 (6), 86.

Márquez-Ferrando, R., Figuerola, J., Hooijmeijer, J.C., and Piersma, T., 2014. Recently created man-made habitats in Doñana provide alternative wintering space for the threatened Continental European black-tailed godwit population. Biological Conservation, 171, 127–135.

Mediterranean Wetland Observatory, 2014. Land cover: Spatial dynamics in Metierranean coastal wetlands from 1975 to 2005.Thematic collection 2. France: Tour du Valat.

Mistry, J., Berardi, A., and Simpson, M., 2008. Birds as indicators of wetland status and change in the North Rupununi, Guyana. Biodiversity and Conservation, 17 (10), 2383.

Mittermeier, R.A., Turner, W.R., Larsen, F.W., Brooks, T.M., and Gascon, C., 2011. Global Biodiversity Conservation: The Critical Role of Hotspots. In: F.E. Zachos and J.C. Habel, eds. Biodiversity Hotspots: Distribution and Protection of Conservation Priority Areas. Berlin, Heidelberg: Springer, 3–22.

Morelli, F., Benedetti, Y., Ibáñez-Álamo, J.D., Jokimäki, J., Mänd, R., Tryjanowski, P., and Møller, A.P., 2016. Evidence of evolutionary homogenization of bird communities in urban environments across Europe. Global Ecology and Biogeography, 25 (11), 1284–1293.

Moreno-Rueda, G. and Pizarro, M., 2007. The relative influence of climate, environmental heterogeneity, and human population on the distribution of vertebrate species richness in south-eastern Spain. Acta Oecologica, 32 (1), 50–58.

Morgado, R., Santana, J., Porto, M., Sánchez-Oliver, J.S., Reino, L., Herrera, J.M., Rego, F., Beja, P., and Moreira, F., 2020. A Mediterranean silent spring? The effects of olive farming intensification on breeding bird communities. Agriculture, Ecosystems & Environment, 288, 106694.

Newbold, T., Bentley, L.F., Hill, S.L., Edgar, M.J., Horton, M., Su, G., Şekercioğlu, Ç.H., Collen, B., and Purvis, A., 2020. Global effects of land use on biodiversity differ among functional groups. Functional Ecology, 34 (3), 684–693.

Onmuş, O., Durusoy, R., and Eken, G., 2009. Distribution of breeding birds in the Gediz Delta, Western Turkey: (Aves). Zoology in the Middle East, 47 (1), 39–48.

Onmuş, O. and Siki, M., 2013. Impacts of anthropogenic activities and habitat degradation on breeding waterbirds. Turkish Journal of Zoology, 37 (3), 249–261.

Ovaskainen, O. and Abrego, N., 2020. Joint Species Distribution Modelling: With Applications in R. Cambridge: Cambridge University Press.

Ovaskainen, O., Tikhonov, G., Norberg, A., Guillaume Blanchet, F., Duan, L., Dunson, D., Roslin, T., and Abrego, N., 2017. How to make more out of community data? A conceptual framework and its implementation as models and software. Ecology letters, 20 (5), 561–576.

Palacín, C. and Alonso, J.C., 2018. Failure of EU Biodiversity Strategy in Mediterranean farmland protected areas. Journal for Nature Conservation, 42, 62–66.

RIS, R.S.I.S., 2021. Information Sheet on Ramsar Wetlands (RIS) – 2006-2008 version. https://rsis.ramsar.org/.

Robledano, F., Esteve, M.A., Farinós, P., Carreño, M.F., and Martínez-Fernández, J., 2010. Terrestrial birds as indicators of agricultural-induced changes and associated loss in conservation value of Mediterranean wetlands. Ecological Indicators, 10 (2), 274–286.

Schutz, A.J. and Driscoll, D.A., 2008. Common reptiles unaffected by connectivity or condition in a fragmented farming landscape. Austral Ecology, 33 (5), 641–652.

Sebastián-González, E. and Green, A.J., 2016. Reduction of avian diversity in created versus natural and restored wetlands. Ecography, 39 (12), 1176–1184.

Sıkı, M., 2020. Gediz deltasi'ndaki İzmir kuş cennetini yaşatma mücadelesi (1982-2018). İzmir, Turkey: Kanguru Yayınları.

Spampinato, G., Sciandrello, S., del Galdo, G., Puglisi, M., Tomaselli, V., Cannavò, S., and Musarella, C.M., 2019. Contribution to the knowledge of Mediterranean wetland biodiversity: Plant communities of the Aquila Lake (Calabria, Southern Italy). Plant Sociol, 56, 53–68.

Sripanomyom, S., Round, P.D., Savini, T., Trisurat, Y., and Gale, G.A., 2011. Traditional salt-pans hold major concentrations of overwintering shorebirds in Southeast Asia. Biological Conservation, 144 (1), 526–537.

Tikhonov, G., Opedal, Ø.H., Abrego, N., Lehikoinen, A., de Jonge, M.M.J., Oksanen, J., and Ovaskainen, O., 2020. Joint species distribution modelling with the r-package Hmsc. Methods in Ecology and Evolution, 11 (3), 442–447.

Tonini, J.F.R., Beard, K.H., Ferreira, R.B., Jetz, W., and Pyron, R.A., 2016. Fully-sampled phylogenies of squamates reveal evolutionary patterns in threat status. Biological Conservation, 204, 23–31.

Tourenq, C., Bennetts, R.E., Kowalski, H., Vialet, E., Lucchesi, J.-L., Kayser, Y., and Isenmann, P., 2001. Are ricefields a good alternative to natural marshes for waterbird communities in the Camargue, southern France? Biological Conservation, 100 (3), 335–343.

Tryjanowski, P., Skórka, P., Sparks, T.H., Biaduń, W., Brauze, T., Hetmański, T., Martyka, R., Indykiewicz, P., Myczko, Ł., Kunysz, P., Kawa, P., Czyż, S., Czechowski, P., Polakowski, M., Zduniak, P., Jerzak, L., Janiszewski, T., Goławski, A., Duduś, L., Nowakowski, J.J., Wuczyński, A., and Wysocki, D., 2015. Urban and rural habitats differ in number and type of bird feeders and in bird species consuming supplementary food. Environmental Science and Pollution Research, 22 (19), 15097–15103.

TUIK, T.S.I., 2020. Address Based Population Registration System Results, 2019. Website.

Vallejo, B.M., Aloy, A.B., and Ong, P.S., 2009. The distribution, abundance and diversity of birds in Manila's last greenspaces. Landscape and Urban Planning, 89 (3), 75–85.

Ward, R.J., Griffiths, R.A., Wilkinson, J.W., and Cornish, N., 2017. Optimising monitoring efforts for secretive snakes: a comparison of occupancy and N-mixture models for assessment of population status. Scientific Reports, 7 (1), 18074.

Warton, D.I., Blanchet, F.G., O'Hara, R.B., Ovaskainen, O., Taskinen, S., Walker, S.C., and Hui, F.K.C., 2015. So Many Variables: Joint Modeling in Community Ecology. Trends in Ecology & Evolution, 30 (12), 766–779.

Weller, M.W., 1999. Wetland birds: habitat resources and conservation implications. Cambridge University Press.

Whittaker, R.H., 1972. Evolution and Measurement of Species Diversity. TAXON, 21 (2–3), 213–251.

Winfree, R., Dushoff, J., Crone, E.E., Schultz, C.B., Budny, R.V., Williams, N.M., and Kremen, C., 2005. Testing Simple Indices of Habitat Proximity. The American Naturalist, 165 (6), 707–717.

Zuur, A.F., Ieno, E.N., Walker, N.J., Saveliev, A.A., and Smith, G.M., 2009. Mixed effects models and extensions in ecology with R. Springer.

TABLES AND FIGURES

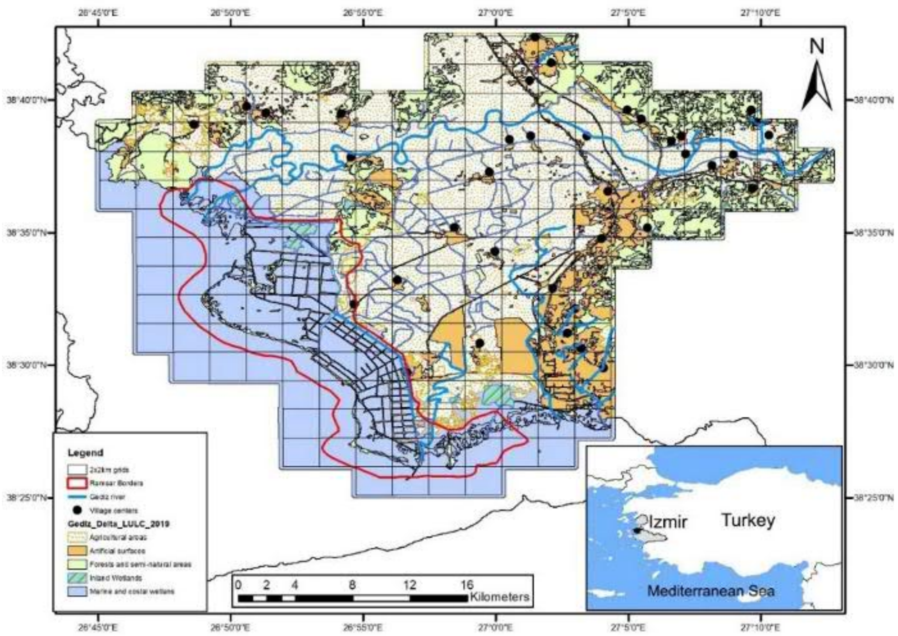
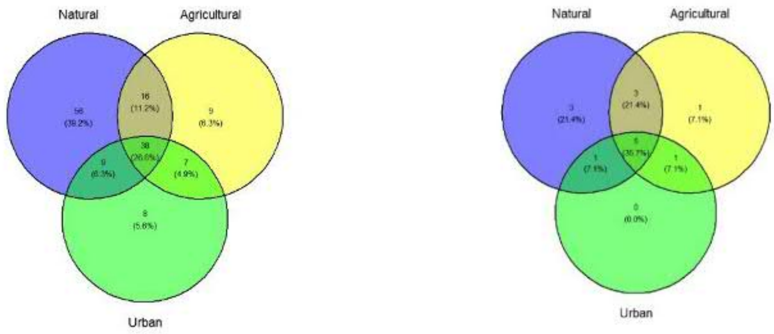


Figure 1: Location and principal ecosystems of the Gediz Delta in Turkey (adapted from Thesis Appendix 1).



Birds Reptiles

Figure 2: A Venn diagram displaying the distribution of shared species numbers in each taxon between the three habitat types in the Gediz Delta (N_{bird}=143 species, $N_{reptiles}$=14 species).

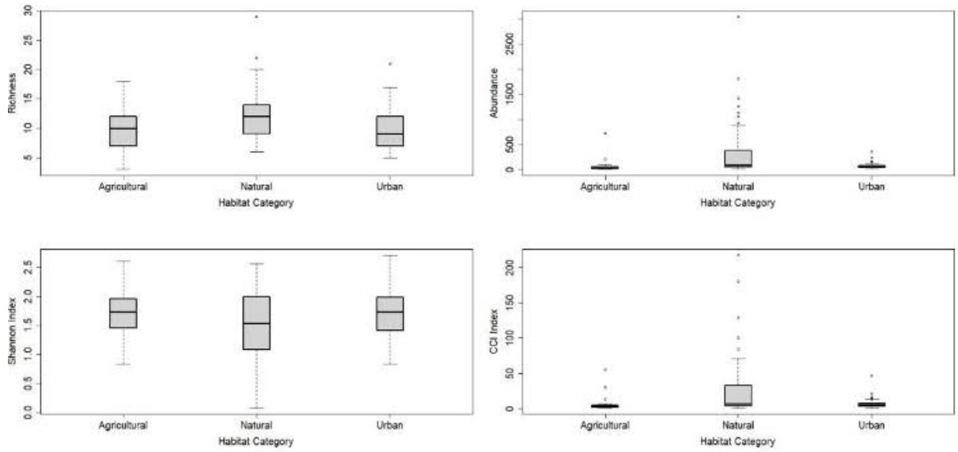


Figure 3: Biodiversity variables in birds: Richness, Abundances, Shannon Index and Community Commonness Index (CCI) in Agricultural, Natural and Urban habitat categories in the Gediz Delta.

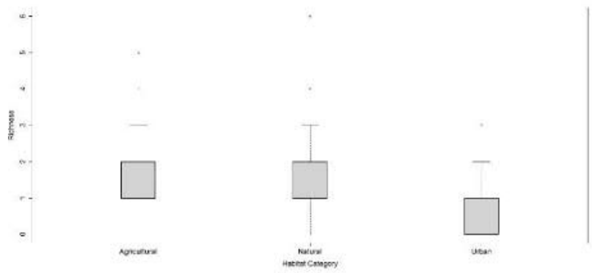


Figure 4: Biodiversity variables in reptile: Richness in Agricultural, Natural and Urban habitat categories in the Gediz Delta.

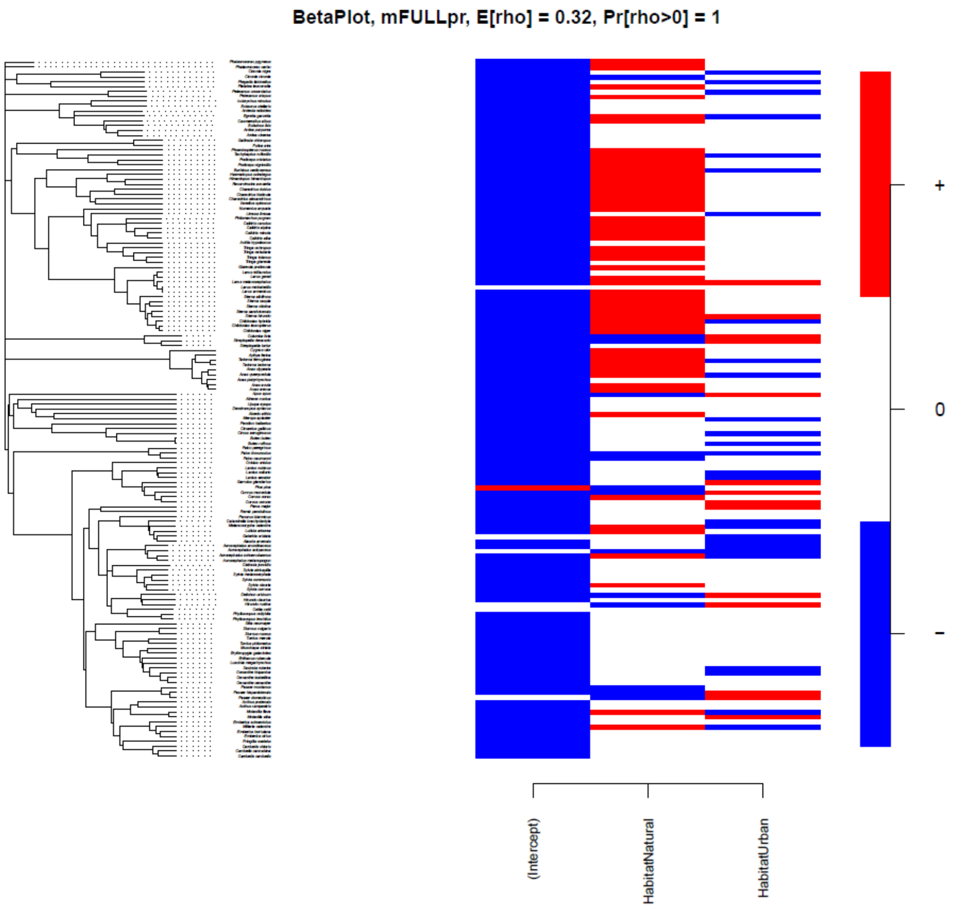


Figure 5: Heat map of estimated species species responses (standardised regression coefficients) to three landscape categories (Intercept (Agricultural), Natural, Urban). The blue color indicates a negative response of the species prevalence in each landscape while a red color indicates a positive response, with at least 0.95 posterior probability. The responses that did not gain strong statistical support are shown by white. The species are ordered according to their phylogeny as illustrated by the phylogenetic tree shown in the panels at Y axis.

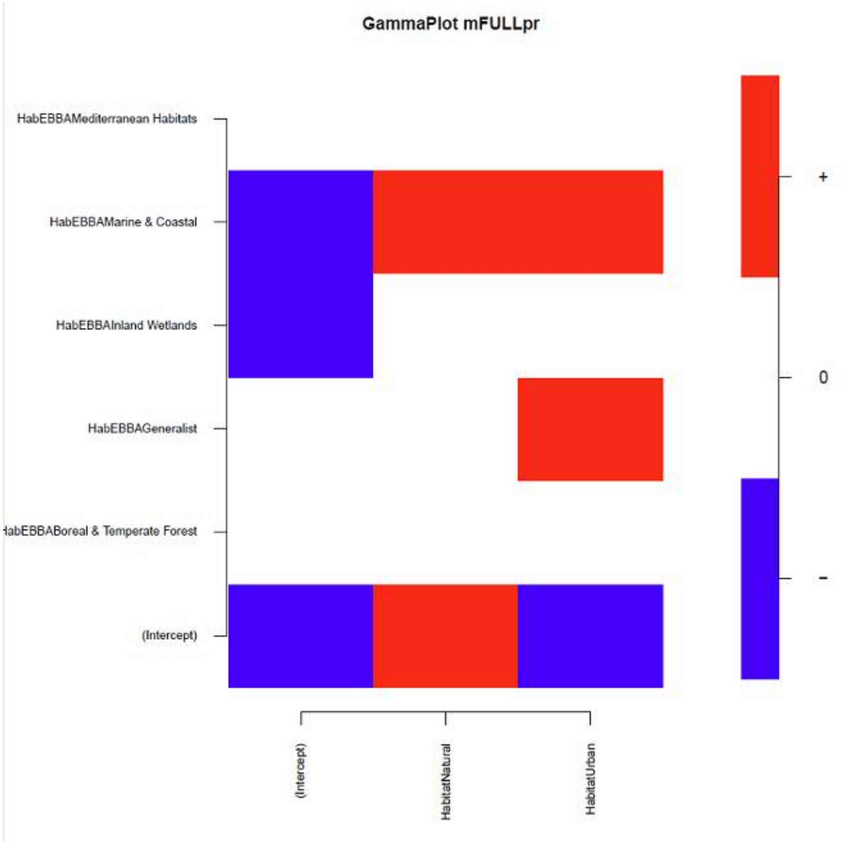


Figure 6. Heatmap of estimated gamma parameters linking bird species traits to landscape types. Y axis shows the species habitat specialization. The blue color indicates a negative response of the community prevalence in a given landscape while a red color indicates a positive response, with at least 0.95 posterior probability. The responses that did not gain strong statistical support are shown by white. The species are ordered according to their phylogeny as illustrated by the phylogenetic tree shown in the panels at Y axis.

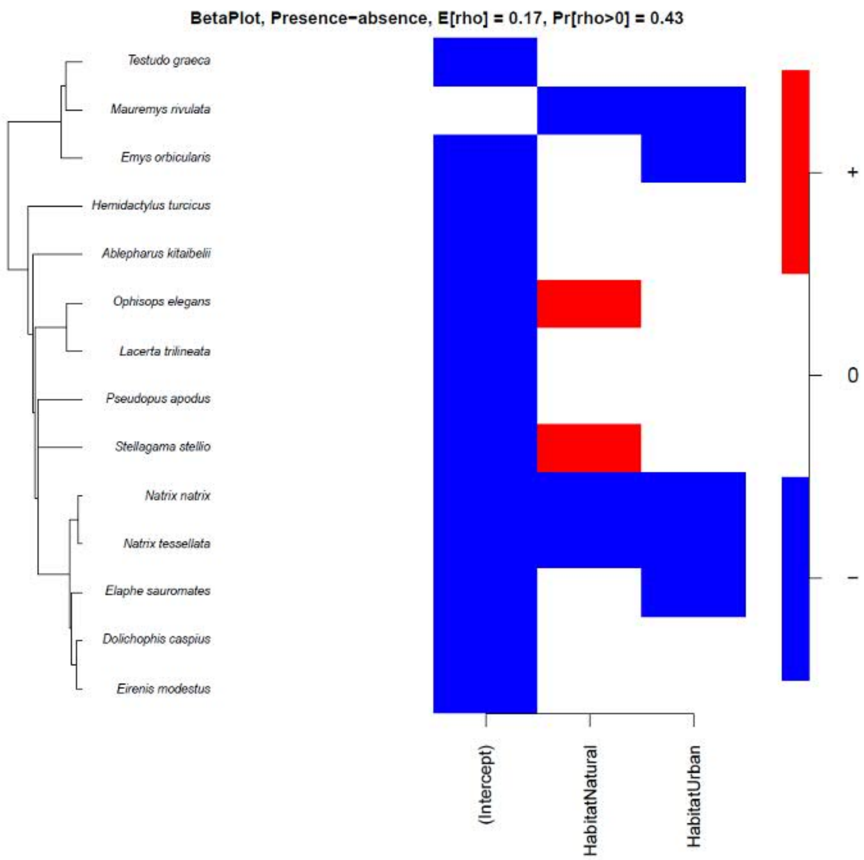


Figure 7: Heat map of estimated 14 reptiles species responses (standardized regression coefficients) to three landscape categories (Intercept (Agricultural), Natural, Urban). The blue color indicates a negative response of the species prevalence in each landscape while a red color indicates a positive response, with at least 0.95 posterior probability. The responses that did not gain strong statistical support are shown by white. The species are ordered according to their phylogeny as illustrated by the phylogenetic tree shown in the panels at Y axis.

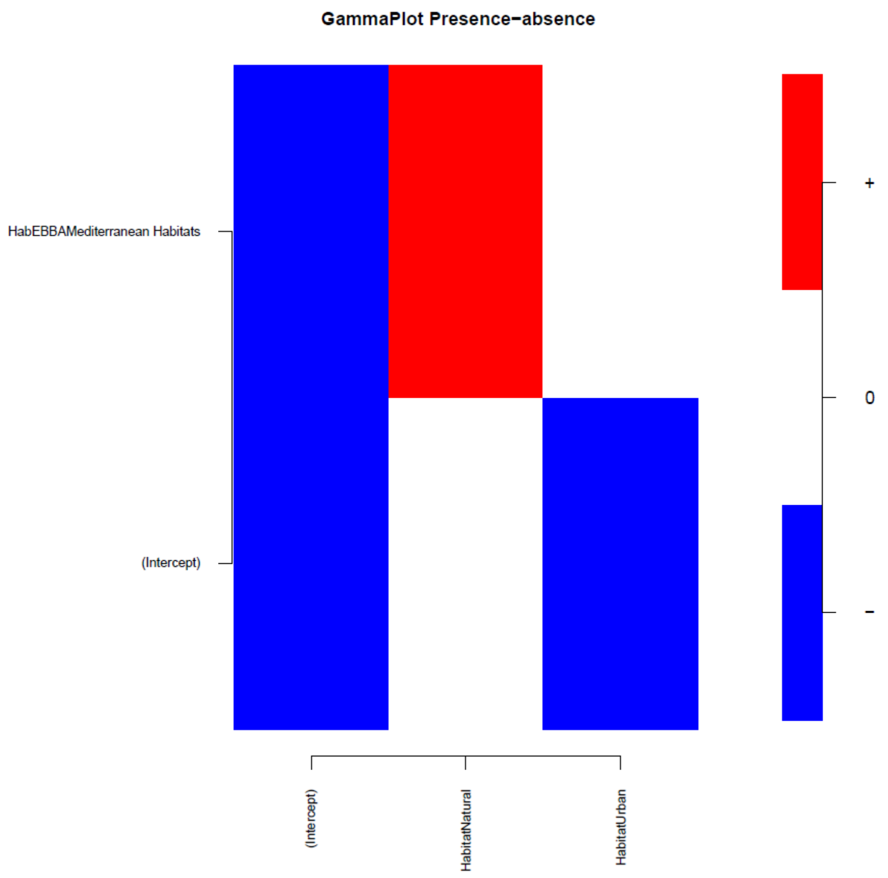


Figure 8. Heatmap of estimated gamma parameters linking species traits to species niches. The blue color indicates a negative response of the community prevalence in a given landscape while a red color indicates a positive response, with at least 0.95 posterior probability. The responses that did not gain strong statistical support are shown by white. The species are ordered according to their phylogeny as illustrated by the phylogenetic tree shown in the panels at Y axis.

Chapter 2 - Supplementary Material

Contrasting effects of agriculture and urbanization on birds and reptiles communities in a Mediterranean delta (Gediz Delta, Turkey)

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Table S1: Percentage of each landscapes category in each grid to characterize natural (10 grids), agricultural (10 grids) and urban (10 grids) sampled for birds and reptiles in Gediz Delta, İzmir.

Sampling Grid	Habitat	Agricultural Landscape Rate	Natural Landscape Rate	Urban Landscape Rate
A01	Agricultural	95.36	2.64	1.99
A02	Agricultural	82.88	8.72	9.18
A03	Agricultural	88.14	4.58	7.27
A04	Agricultural	91.82	6.96	1.21
A05	Agricultural	90.43	3.59	5.97
A06	Agricultural	88.97	7.61	3.4
A07	Agricultural	86.50	11.58	1.91
A08	Agricultural	91.68	4.60	3.71
A09	Agricultural	92.45	7.54	0
A10	Agricultural	94.85	4.05	1.09
N01	Natural	0	91.63	8.36
N02	Natural	0	96.32	3.67

N03	Natural	0.39	99.64	0
N04	Natural	0	99.62	0.38
N05	Natural	1.03	98.97	0
N06	Natural	0	90.71	9.29
N07	Natural	0	94.54	5.46
N08	Natural	0	89.26	10.73
N09	Natural	0	100	0
N10	Natural	7.28	88.59	4.12
U01	Urban	0	14.49	85.51
U02	Urban	11.83	44.09	44.08
U03	Urban	75.58	7.04	17.38
U04	Urban	48.82	0.06	51.12
U05	Urban	49.08	7.26	43.65
U06	Urban	0	13.68	86.31
U07	Urban	0	4.28	95.72
U08	Urban	25.76	50.59	23.64
U09	Urban	5.47	6.96	87.55
U10	Urban	58.90	8.29	32.79

Table S2. Frequency of occurrence (%) of bird species recorded along 150-point counts in 10 sampling grids in each agricultural, natural, and urban landscapes at the Gediz Delta (Turkey). Species are ordered by decreasing total frequency of occurrence.

Species	Habitat Specialization Category	Agricultural (50 points)	Natural (50 points)	Urban (50 points)	Total (150 points)
Pica pica	Generalist	0.66	0.36	0.66	0.56
Hirundo rustica	Generalist	0.56	0.36	0.72	0.55
Galerida cristata	Agricultural & Grasslands	0.64	0.80	0.18	0.54
Passer domesticus	Generalist	0.40	0.16	0.92	0.49
Cettia cetti	Inland Wetlands	0.62	0.38	0.24	0.41
Larus michahellis	Generalist	0.40	0.46	0.28	0.38
Motacilla flava	Agricultural & Grasslands	0.42	0.64	0.04	0.37
Streptopelia decaocto	Generalist	0.22	0.04	0.78	0.35
Acrocephalus scirpaceus	Inland Wetlands	0.56	0.22	0.20	0.33
Delichon urbicum	Generalist	0.26	0.10	0.60	0.32
Apus apus	Generalist	0.24	0.10	0.46	0.27
Miliaria calandra	Agricultural & Grasslands	0.20	0.54	0.04	0.26
Acrocephalus arundinaceus	Inland Wetlands	0.48	0.22	0.06	0.25
Corvus corone	Generalist	0.08	0.06	0.62	0.25
Corvus monedula	Generalist	0.04	0.00	0.60	0.21
Phoenicopterus roseus	Marine & Coastal	0.00	0.60	0.02	0.21
Alauda arvensis	Agricultural & Grasslands	0.32	0.22	0.00	0.18
Columba livia	Generalist	0.14	0.04	0.34	0.17
Egretta garzetta	Generalist	0.06	0.44	0.00	0.17
Carduelis carduelis	Generalist	0.14	0.10	0.22	0.15

Gallinula chloropus	Inland Wetlands	0.24	0.08	0.08	0.13
Parus major	Generalist	0.04	0.02	0.34	0.13
Passer hispaniolensis	Agricultural & Grasslands	0.06	0.04	0.26	0.12
Phylloscopus collybita	Generalist	0.20	0.10	0.04	0.11
Hirundo daurica	Generalist	0.10	0.06	0.16	0.11
Sylvia curruca	Generalist	0.12	0.10	0.10	0.11
Tadorna tadorna	Marine & Coastal	0.00	0.32	0.00	0.11
Melanocorypha calandra	Agricultural & Grasslands	0.04	0.26	0.00	0.10
Passer montanus	Agricultural & Grasslands	0.12	0.00	0.18	0.10
Saxicola rubetra	Agricultural & Grasslands	0.16	0.08	0.06	0.10
Sterna hirundo	Marine & Coastal	0.02	0.20	0.08	0.10
Vanellus spinosus	Generalist	0.02	0.20	0.08	0.10
Cisticola juncidis	Inland Wetlands	0.18	0.04	0.06	0.09
Merops apiaster	Agricultural & Grasslands	0.14	0.12	0.02	0.09
Motacilla alba	Generalist	0.02	0.08	0.18	0.09
Turdus merula	Generalist	0.06	0.10	0.12	0.09
Tringa totanus	Marine & Coastal	0.00	0.22	0.04	0.09
Falco tinnunculus	Agricultural & Grasslands	0.20	0.04	0.00	0.08
Pelecanus crispus	Generalist	0.02	0.22	0.00	0.08
Phalacrocorax pygmeus	Generalist	0.02	0.22	0.00	0.08
Calidris minuta	Marine & Coastal	0.00	0.22	0.00	0.07
Sylvia melanocephala	Mediterranean Habitats	0.04	0.14	0.04	0.07
Anas platyrhynchos	Inland Wetlands	0.02	0.10	0.06	0.06
Lanius collurio	Agricultural & Grasslands	0.10	0.08	0.00	0.06
Remiz pendulinus	Inland Wetlands	0.12	0.02	0.04	0.06
Sylvia communis	Agricultural & Grasslands	0.08	0.04	0.06	0.06
Anthus campestris	Agricultural & Grasslands	0.06	0.08	0.02	0.05
Sylvia atricapilla	Generalist	0.02	0.08	0.06	0.05
Burhinus oedicnemus	Agricultural & Grasslands	0.00	0.14	0.00	0.05
Ciconia ciconia	Agricultural & Grasslands	0.08	0.00	0.06	0.05
Oenanthe oenanthe	Generalist	0.02	0.08	0.04	0.05
Podiceps cristatus	Generalist	0.00	0.14	0.00	0.05
Anthus pratensis	Agricultural & Grasslands	0.06	0.04	0.02	0.04
Circus aeruginosus	Inland Wetlands	0.06	0.06	0.00	0.04
Falco naumanni	Agricultural & Grasslands	0.10	0.00	0.02	0.04
Haematopus ostralegus	Marine & Coastal	0.00	0.12	0.00	0.04
Himantopus himantopus	Generalist	0.00	0.10	0.02	0.04
Upupa epops	Agricultural & Grasslands	0.04	0.02	0.06	0.04
Buteo rufinus	Agricultural & Grasslands	0.06	0.04	0.00	0.03
Calidris alpina	Marine & Coastal	0.00	0.10	0.00	0.03
Charadrius hiaticula	Marine & Coastal	0.00	0.10	0.00	0.03
Lanius senator	Agricultural & Grasslands	0.10	0.00	0.00	0.03
Phalacrocorax carbo	Generalist	0.00	0.10	0.00	0.03
Sterna albifrons	Marine & Coastal	0.00	0.10	0.00	0.03
Acrocephalus schoenobaenus	Inland Wetlands	0.00	0.08	0.00	0.03
Anas querquedula	Inland Wetlands	0.00	0.08	0.00	0.03
Ardea cinerea	Generalist	0.04	0.04	0.00	0.03

Buteo buteo	Generalist	0.06	0.02	0.00	0.03
Chlidonias hybrida	Inland Wetlands	0.00	0.08	0.00	0.03
Chlidonias leucopterus	Generalist	0.00	0.08	0.00	0.03
Dendrocopos syriacus	Generalist	0.06	0.00	0.02	0.03
Fringilla coelebs	Generalist	0.00	0.04	0.04	0.03
Glareola pratincola	Generalist	0.02	0.06	0.00	0.03
Lullula arborea	Generalist	0.02	0.06	0.00	0.03
Sterna sandvicensis	Marine & Coastal	0.00	0.08	0.00	0.03
Tachybaptus ruficollis	Inland Wetlands	0.00	0.08	0.00	0.03
Anas clypeata	Generalist	0.00	0.06	0.00	0.02
Athene noctua	Agricultural & Grasslands	0.00	0.04	0.02	0.02
Calidris alba	Marine & Coastal	0.00	0.06	0.00	0.02
Calidris canutus	Marine & Coastal	0.00	0.06	0.00	0.02
Casmerodius albus	Generalist	0.00	0.06	0.00	0.02
Ciconia nigra	Inland Wetlands	0.04	0.02	0.00	0.02
Corvus corax	Generalist	0.00	0.06	0.00	0.02
Cygnus olor	Generalist	0.00	0.06	0.00	0.02
Emberiza hortulana	Agricultural & Grasslands	0.04	0.02	0.00	0.02
Garrulus glandarius	Boreal & Temperate Forest	0.00	0.00	0.06	0.02
Larus genei	Marine & Coastal	0.00	0.06	0.00	0.02
Muscicapa striata	Generalist	0.00	0.04	0.02	0.02
Numenius arquata	Marine & Coastal	0.00	0.06	0.00	0.02
Tadorna ferruginea	Inland Wetlands	0.00	0.06	0.00	0.02
Tringa nebularia	Generalist	0.00	0.04	0.02	0.02
Anas crecca	Generalist	0.00	0.04	0.00	0.01
Ardea purpurea	Inland Wetlands	0.00	0.00	0.04	0.01
Calandrella brachydactyla	Agricultural & Grasslands	0.00	0.04	0.00	0.01
Carduelis chloris	Generalist	0.02	0.00	0.02	0.01
Charadrius alexandrinus	Marine & Coastal	0.00	0.04	0.00	0.01
Charadrius dubius	Inland Wetlands	0.00	0.04	0.00	0.01
Chlidonias niger	Generalist	0.00	0.04	0.00	0.01
Circaetus gallicus	Mediterranean Habitats	0.04	0.00	0.00	0.01
Ixobrychus minutus	Inland Wetlands	0.00	0.00	0.04	0.01
Larus armenicus	Generalist	0.00	0.04	0.00	0.01
Larus melanocephalus	Marine & Coastal	0.00	0.02	0.02	0.01
Larus ridibundus	Generalist	0.00	0.02	0.02	0.01
Oenanthe hispanica	Agricultural & Grasslands	0.00	0.04	0.00	0.01
Oenanthe isabellina	Agricultural & Grasslands	0.04	0.00	0.00	0.01
Philomachus pugnax	Generalist	0.00	0.04	0.00	0.01
Platalea leucorodia	Marine & Coastal	0.00	0.04	0.00	0.01
Plegadis falcinellus	Inland Wetlands	0.00	0.04	0.00	0.01
Recurvirostra avosetta	Marine & Coastal	0.00	0.04	0.00	0.01
Sterna caspia	Marine & Coastal	0.00	0.04	0.00	0.01
Streptopelia turtur	Agricultural & Grasslands	0.00	0.04	0.00	0.01
Sturnus roseus	Agricultural & Grasslands	0.00	0.00	0.04	0.01
Sturnus vulgaris	Agricultural & Grasslands	0.02	0.00	0.02	0.01
Tringa glareola	Inland Wetlands	0.02	0.02	0.00	0.01

Tringa ochropus	Inland Wetlands	0.00	0.04	0.00	0.01
Acrocephalus melanopogon	Inland Wetlands	0.02	0.00	0.00	0.01
Actitis hypoleucos	Generalist	0.02	0.00	0.00	0.01
Alcedo atthis	Generalist	0.00	0.02	0.00	0.01
Anas acuta	Generalist	0.00	0.02	0.00	0.01
Ardeola ralloides	Inland Wetlands	0.00	0.02	0.00	0.01
Aythya ferina	Inland Wetlands	0.00	0.02	0.00	0.01
Botaurus stellaris	Inland Wetlands	0.02	0.00	0.00	0.01
Bubulcus ibis	Agricultural & Grasslands	0.00	0.00	0.02	0.01
Carduelis cannabina	Agricultural & Grasslands	0.00	0.02	0.00	0.01
Emberiza cirlus	Agricultural & Grasslands	0.00	0.02	0.00	0.01
Emberiza schoeniclus	Inland Wetlands	0.02	0.00	0.00	0.01
Erithacus rubecula	Generalist	0.02	0.00	0.00	0.01
Erythropygia galactotes	Mediterranean Habitats	0.02	0.00	0.00	0.01
Falco peregrinus	Generalist	0.00	0.02	0.00	0.01
Fulica atra	Inland Wetlands	0.00	0.02	0.00	0.01
Lanius nubicus	Agricultural & Grasslands	0.00	0.02	0.00	0.01
Limosa limosa	Inland Wetlands	0.00	0.02	0.00	0.01
Luscinia megarhynchos	Generalist	0.00	0.02	0.00	0.01
Oriolus oriolus	Generalist	0.00	0.00	0.02	0.01
Pandion haliaetus	Generalist	0.00	0.02	0.00	0.01
Panurus biarmicus	Inland Wetlands	0.00	0.02	0.00	0.01
Pelecanus onocrotalus	Inland Wetlands	0.00	0.02	0.00	0.01
Phylloscopus trochilus	Generalist	0.00	0.00	0.02	0.01
Podiceps nigricollis	Generalist	0.00	0.02	0.00	0.01
Sitta neumayer	Mediterranean Habitats	0.00	0.02	0.00	0.01
Sterna nilotica	Generalist	0.00	0.02	0.00	0.01
Sylvia nisoria	Generalist	0.00	0.02	0.00	0.01
Turdus philomelos	Generalist	0.00	0.00	0.02	0.01

Table S3. Frequency of occurrence (%) of reptile species recorded along 90-transect counts in 10 sampling grids in each agricultural, natural, and urban landscapes at the Gediz Delta (Turkey). Species are ordered by decreasing total frequency of occurrence.

Species	Habitat Specialization Category	Agricultural (30 Transect)	Natural (30 Transect)	Urban (30 Transect)	Total (90 transects)
Ophisops elegans	Mediterrean Species	26.7	66.7	33.3	42.2
Mauremys rivulata	Inland Wetland Species	43.3	3.3	13.3	20.0
Testudo graeca	Mediterrean Species	6.7	20.0	6.7	11.1
Dolichophis caspius	Mediterrean Species	6.7	16.7	3.3	8.9
Ablepharus kitaibelii	Mediterrean Species	3.3	6.7	13.3	7.8
Natrix natrix	Inland Wetland Species	13.3	3.3	6.7	7.8
Emys orbicularis	Inland Wetland Species	13.3	3.3	3.3	6.7
Natrix tesellata	Inland Wetland Species	13.3	3.3	3.3	6.7
Lacerta trilinata	Mediterrean Species	6.7	0.0	6.7	4.4
Stellagama stellio	Mediterrean Species	0.0	10.0	3.3	4.4

Elaphe sauromates	Inland Wetland Species	0.0	6.7	3.3	3.3
Hemidactylus turcicus	Mediterrean Species	0.0	3.3	6.7	3.3
Eirenis modestus	Mediterrean Species	3.3	0.0	3.3	2.2
Pseudopus apodus	Mediterrean Species	0.0	3.3	3.3	2.2

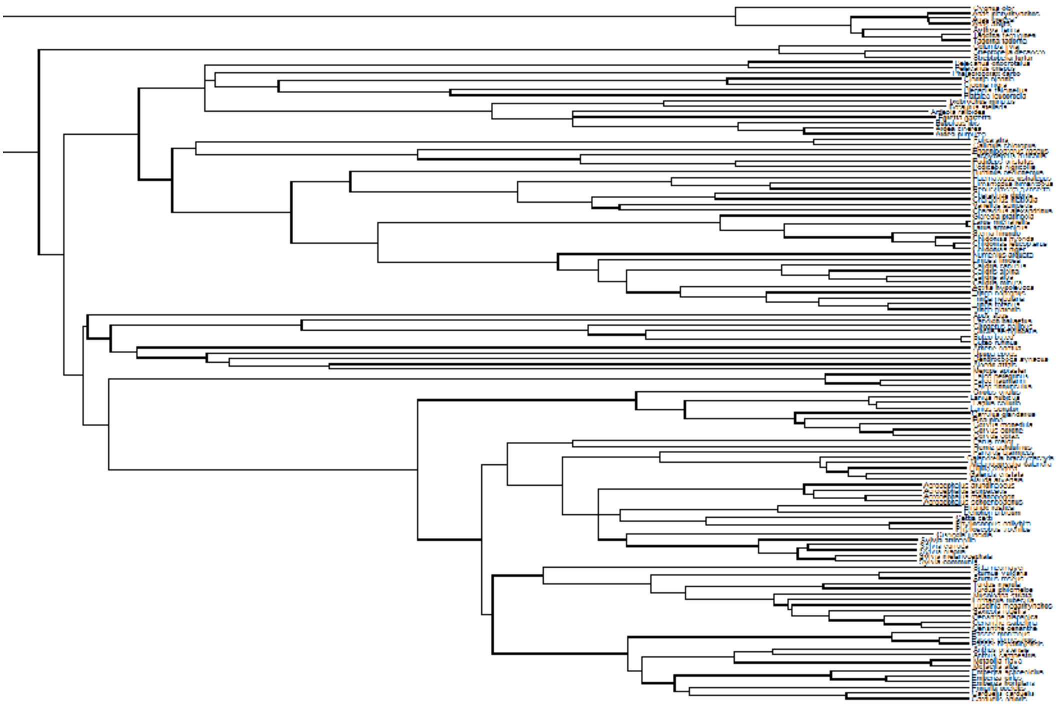

Fig. S1. Phylogenetic tree extracted from Vertlife for birds (https://vertlife.org/data/, accessed on 20.12.2021) (Jetz *et al.* 2012) from which the phylogenetic was derived for birds models (see main text for details).

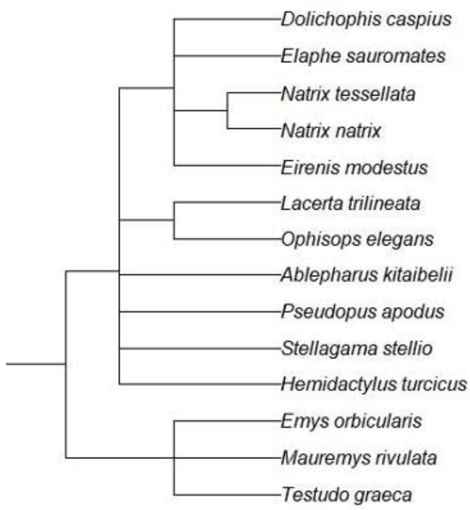

Fig. S2. Phylogenetic tree extracted from Vertlife for reptiles (https://vertlife.org/data/, accessed on 20.12.2021) (Tonini *et al.* 2016) from which the phylogenetic was derived for reptile model (see main text for details).

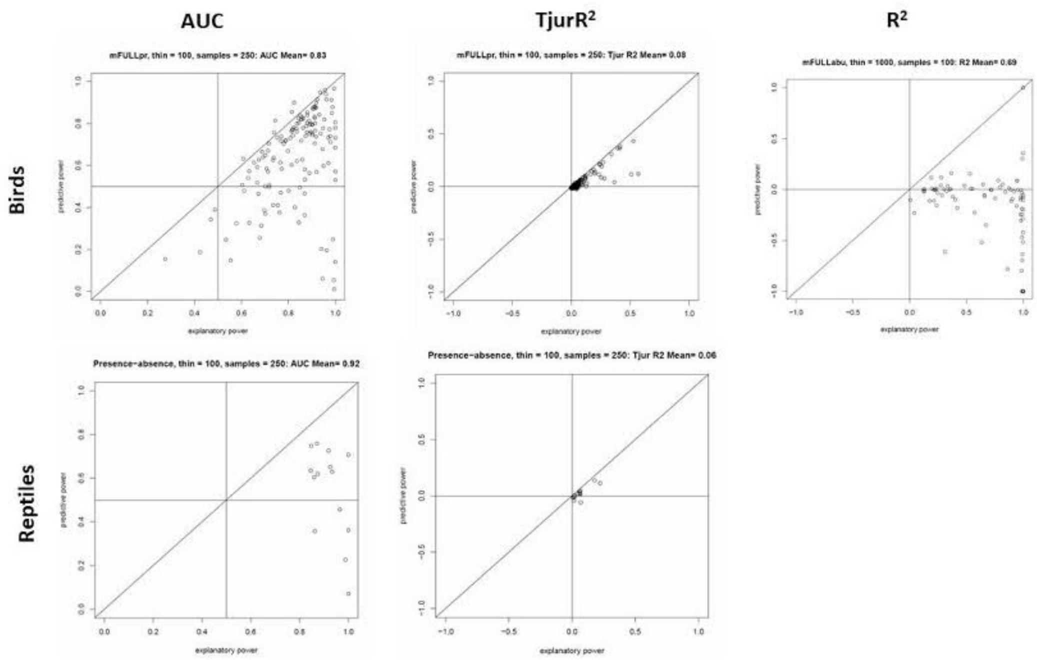

Fig. S3: Model fit tables based on explanatory power and predictive power of presence-absence models and abundance COPs models in two taxons. Present-absence models evaluated both variations in Tjur's Coefficient of Discrimination (Tjur R^2) and Area under the ROC (Receiver Operating Characteristic) curve (AUC) and Abundance COP models evaluated by Coefficient of Determination (R^2).

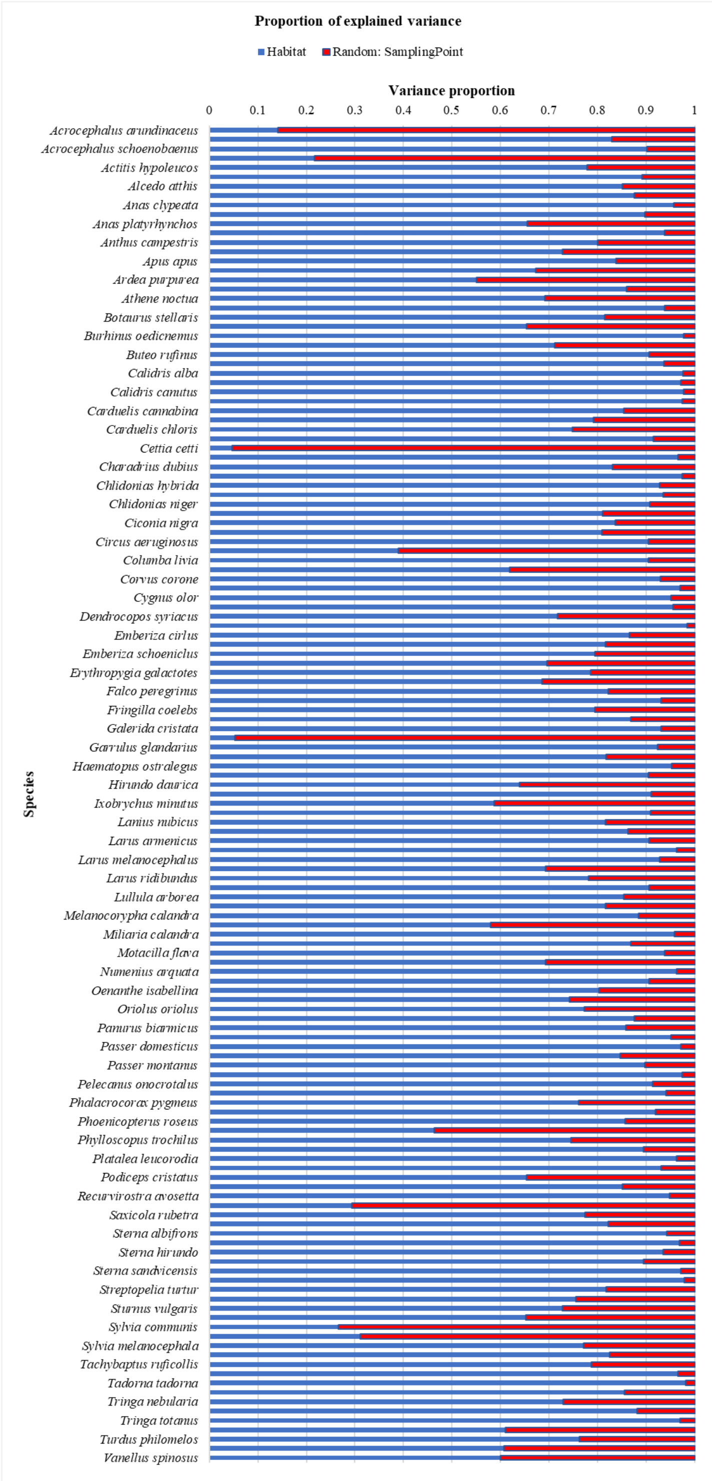

Fig. S4: Explained variance partitioning for each of 143 species of birds in species occurrence attributed to fixed effect to habitat category (blue) and random effects to Sampling Point (red). Species are ordered according to alphabetic order. The mean proportion of habitat category is 80.8 and random effects (sampling point) is 19.2.

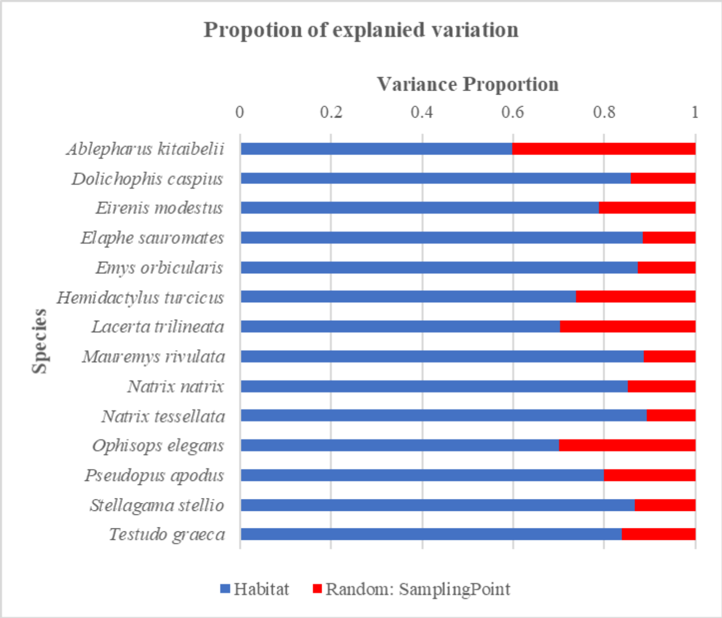

Fig. S5: Explained variance partitioning for each of 14 species of reptiles in species occurrence attributed to fixed effect to habitat category (blue) and random effects to Sampling Point (red). Species are ordered according to alphabetic order. The mean proportion of habitat category is 80.6 and random effects (sampling point) is 19.4.

CHAPTER 3

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Threat Ranking to Improve Conservation Planning: An Example from the Gediz Delta, Turkey

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Abstract: Mediterranean wetlands are among the most threatened natural areas. The needs and demands of an increasing human population are modifying land use and converting natural habitats into artificial areas. In order to combat these trends, effective conservation planning needs to provide clear, systematic identification of threats to find sustainable conservation strategies. In this case study,we evaluated current threats in the Gediz Delta (Turkey) using a multi-method approach. First, we did a comprehensive literature review and stakeholder interviews to identify existing threats. We then did a complete survey of the Delta through intensive fieldwork. The threats were coded and ranked using the conservation standards. We used the threat ranking and field survey to map the most vulnerable areas of the Delta. The most commonly observed threats in the field were pollution and agriculture and aquaculture activities. According to the threat ranking, the most important threats are climate change and residential and commercial development. The habitats that are most at risk are agricultural grassland habitats. The results indicate a need to extend conservation actions in the inner part of the Delta. In addition, the multi-method threat ranking approach could serve as a model to improve conservation planning in other sites worldwide.

Keywords: conservation planning; Gediz Delta; perceptions; threat ranking; wetlands

1. Introduction

The needs and demands of the increasing human population are inciting the conversion of natural lands into agricultural and urbanized areas, with significant consequences on biodiversity and human well-being [1]. Holistically protecting natural ecosystems is essential to avoid a biodiversity crisis [2]. Previous research conducted between 1997 and 2011 showed that freshwater wetlands provided the world with USD 2.7 trillion a year worth of ecosystem services [3]. However, the available data show that up to 87% of global wetland resources have been lost since the 1700s [4,5]. Unfortunately, this situation holds true in the Mediterranean basin, with wetlands being the most destroyed ecosystem in the region [4,5]. Wetlands cover 2–3% of the Mediterranean basin surface, providing critical habitats for many plant species, and breeding and feeding grounds for many animal species [6]. Wetlands host 30% of vertebrate species, more than 40% of the endemic and 36% of threatened species in the Mediterranean basin [6,7]. There has been a decline of 28% of the vertebrate population in freshwater habitats in the Mediterranean region [7].The loss of these habitats and species means a significant loss of human well-being and biodiversity [3]. Most of these losses are due to the drainage of wetlands for residential, industrial, and agricultural activities, with a high impact on coastal Delta areas [5]. Climate change is predicted to be the primary driver that will change and destroy wetlands in the future [6,8]. Therefore, understanding the source of threats on wetlands is essential for sustainable conservation planning [5]. Conservation scientists need to identify current and potential threats in order to design effective future interventions [9]. The Conservation Standards is a framework for adaptive planning and management, based on an improved methodology that highlights objectives and goals for conservation management processes [10]. In this methodology, the International Union for Conservation of Nature (IUCN) and the Conservation Measures Partnership (CMP) designated a set of standardized classifications of direct threats to support the identification of problems and solutions in conservation management [11]. Previous research identified the main threats to wetlands as pollution (54%), biological resources use (53%), natural system modification (53%), and agriculture and aquaculture (42%); however, the presence and impacts of these threats are different from one wetland toanother according to the regulation in the country and human activity [12]. Therefore, each wetland should be evaluated according to the local socio-ecological context while applying a global standard.

Gediz Delta is composed of a mosaic of salt and freshwater marshes (5000 ha), saltpans (3300 ha), and four lagoons (Homa 1824 ha; Çilazmak 725 ha; Kırdeniz 450 ha; and Tas¸ 500 ha) (Figure 1). The Delta is recognized for its international importance for breedingand wintering waterbirds [13]. In addition, the Delta plays a vital role in maintaining the biogeographic diversity in the region. It is an important waterbird breeding site in the Mediterranean basin and hosts 80,000 wetland birds annually [13]. Furthermore, there are 20 species of fish, 35 species of amphibians and reptiles, 300 species of birds, and more than ten species of mammals and dozens of invertebrates inhabiting the Delta [13–15]. Apart from its biological importance, the Delta also provides important economic and aesthetic values [16]. Despite all these features, the Delta has faced significant land-use changes inthe last 100 years, which has greatly impacted its biodiversity [17–20].

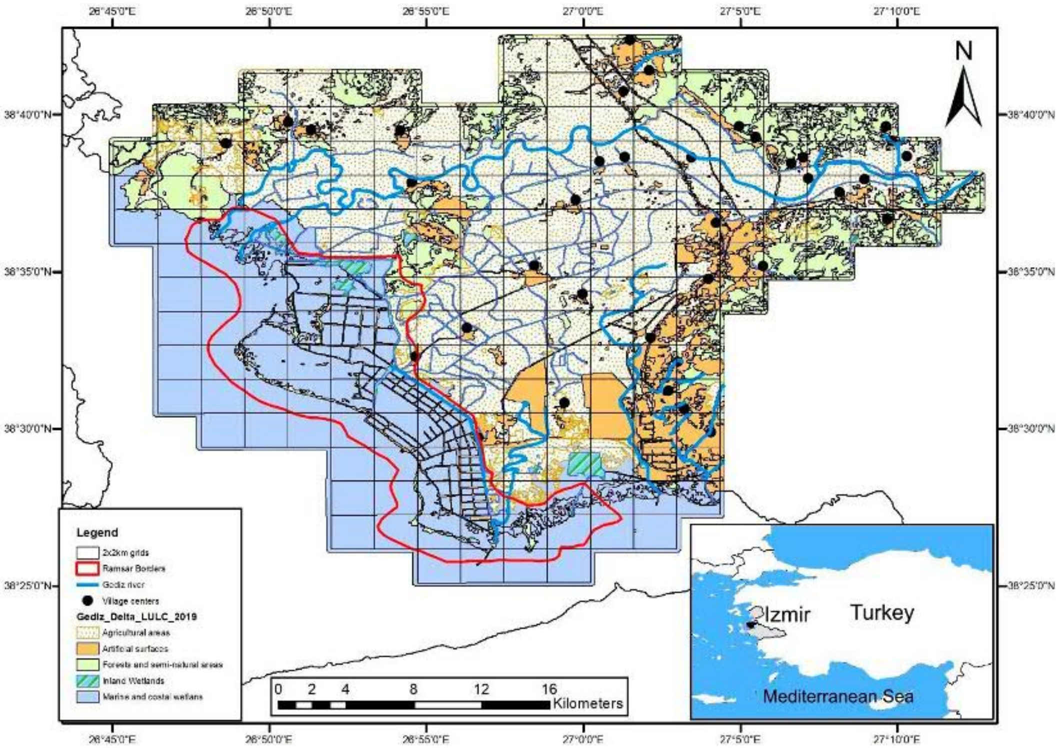

Figure 1. Location and principal ecosystems of the Gediz Delta in Turkey (adapted from Guelmami, 2021 unpublished data).

The Gediz Delta is located close to the city of Izmir, a metropole with a population of over 4 million people [21]. The geographic proximity to Izmir accentuates the threats and human pressures. The Delta sustains many ecosystem services for local livelihoods such as agriculture, fishing, and salt production and hosts two organized industrial zones. Despite these ecosystem services, the wetlands have been considered a threat to the local population, causing significant structural changes over the centuries [18]. This research aimed to understand the current threats in the Delta in order to improve conservation planning (e.g., suggesting concrete conservation actions to prevent further degradation or to improve the current state of the wetlands). The work was developed in 3 steps: (1) using a literature review, we gathered the threats identified in scientific journals, newspaper articles and grey literature; (2) we applied in-depth interviews to identify additional threats and gather the perceptions of threats by key stakeholders; and (3) we identified the visual threats through intensive fieldwork over 200 grids in the Delta. The information collected was coded using the IUCN threats classification system [9,22] and then ranked using the Conservation Standards methodology [11]. The threats were mapped to identify the most vulnerable zones in the Delta and provide recommendations for conservation planning. This study can be replicated in other wetlands to identify threats and improve management on a larger scale.

2. Materials and Methods

2.1. Study Site

Gediz Delta (38°30′ N, 26°55′ E) is located in the Mediterranean basin on the coast of the Aegean Sea (Figure 1). It is composed of a mosaic of freshwater and saltwater ecosystems made up of shrub forests, salt meadows, reed beds, marshes, lagoons and rivers, Salinas, and beaches [23]. The Gediz River was thought to be a flooding danger forIzmir and its course was changed 50 km to the north at the beginning of the century througha system of dykes and canals. The swamps were also drained to combat malaria [18] and, since the beginning of the 2000s, the border of the Delta was urbanized to create new residential land [17,24]. In this study, we consider the Gediz Delta to include the area between the old and new riverbeds of the Gediz River and the lower Gediz Basin.

2.2. *Threats Assessments*

The threats assessment was conducted using a three-step approach based on a literature review, in-depth interviews with stakeholders, and field visits. The information gathered using these approaches were coded using the IUCN classification system and then ranked using the Conservation Standards designed by the Conservation Measures Partnership (CMP) [11].

2. 2. 1. Literature Review

We began our research with a literature review of both scientific journals and news articles to identify existing threats to the Delta from 1980 to 2020. Firstly, we searched the threats by Google news using the combination of the following keywords: "Gediz Deltası", "İzmir Kuş Cenneti", "Gediz Delta", "UNESCO", "Ramsar", "Izmir", and "Flamingo". Then, we searched in scientific and academic reports in Google scholar and the national thesis database (https://tez.yok.gov.tr/UlusalTezMerkezi/, accessed 11 November 2021). The search included published articles, PhD theses, management plans, and books. Only the documents containing threats specific to the Gediz Delta were used. Each threat detected in the news and literature review were classified using the IUCN threat classifications and ranked by frequency of times each threat was identified.

2.2.2. In-Depth Interviews

Stakeholders from both governmental and non-governmental organizations were chosen using a targeted sampling technique [25]. We first identified key actors from the management plans of the Delta (2007 and 2019) and based on our previous experience working in the area (Table 1). A semi-structured interview with open-ended questions was administered with those stakeholders. We structured the interviews using a conceptual chain to identify the threats by determining their direct and indirect causes [25]. The open ended-questions allowed for deeper expression of environmental problems with their different dimensions, perspectives and nuances [26], where the participants expressed their ideas without being guided by previously established responses [25]. The interviews consisted of 2 questions: (1) "What are the critical threats on biodiversity in the Delta? Please identify each threat and score them according to their importance"; and (2) "What kind of solutions should be implemented to protect nature? Please identify each solution". Before starting the interviews, the study was introduced, and participation consent was established. Interviews were conducted in Turkish, and each interview lasted between 30 and 40 min in total. The interviews were conducted from August 2019 to June 2020. The responses were first written in Turkish and then translated to English. The English translations were put into an excel spreadsheet and coded according to the IUCN threats classification. The different threat classes were then ranked according to their frequency given in the interviews. We used a $\chi 2$ test to assess the similarities and differences of threats identified by governmental and non-governmental stakeholders. The threats identified through the literature review and interviews were analyzed by clustering with "tm" and "wordcloud" packages in R [27,28].

Table 1. List of stakeholders in the Gediz Delta participating in the semi-structure interviews about environmental threats in the Delta.

Governmental	N	Non-Governmental	N
National Park Regional Directorate	4	National NGOs	2
State Hydraulic Works	2	Local NGOs	4
Ministry of Agriculture and Forestry	1	Headmen	7
Ministry of Urban and Environment Planning	1	Company	1
İzmir Municipality	3	Farmer	1
Karşıyaka Municipality	1	Student Club	1
Menemen Municipality	1		
Çiğli Municipality	1		

2.2.3. Field Visits

The fieldwork was conducted from January–June 2021. The fieldwork was designed using the maps and grids developed during the literature review (Figure 1). The field (ca. 80,000 ha) was divided into approximately 200 2 2 km UTM grids covering the old and new riverbeds of the Gediz River. The grids were visited with a team of 2 people by car using a transect methodology through each grid. Each transect took approximately 30 min, and the car was travelling at 30 km/h. During the transect, observations were made to determine the presence/absence of the previously identified threats per grid. Then, a simple heat map created with Argics 10.2, was used for estimations building representation of hotspots for increased threats according to their rate in the grid. In addition, threats that were seen but not previously identified in the literature were added to the database. Existing threats that were identified in the literature or interviews but were not visually identifiable were not localized in the maps (such as sea levels increase and other threats); nor were no-longer existing threats (such as cancelled construction projects).

2.3. Threat Ranking

Threat ranking with the conservation standards uses criteria-based ranking of threats to provide an objective analysis to determine the importance of each threat. This ranking allows for the identification of critical threats, which are the threats that are the most problematic. First, the threats and conservations suggestions were coded based on the IUCN threats classification system [9,22] and then ranked using the Conservation Standards methodology [11]. We linked the threats to the habitats that they impact (Inland wetlands, Marine and Coastal wetlands, Agricultural and Grassland habitats, and Mediterranean habitats). The habitat classification is based on the unpublished data of Guelmami [19], 2021, in the hierarchical order given following the bird habitat classification provided in the second edition of the European Breeding Bird Atlas 2 [20,29]. Using the conservation standards threat classification [11], threats were then ranked for each habitat according to four classes: “Very High (71–100%)”, “High (31–70%)”, “Medium (11–30%)”, and “Low (1–10%)” using three criteria: (a) scope (the proportion of the total area affected based on fieldwork observations and literature reviews), (b) severity (based on overall declines caused by the threat according to expert knowledge, importance scores from interviews or literature sources), and (c) irreversibility (based on how long it takes to restore or reverse according to expert knowledge and literature) [11]. The Conservation Standards for the Practice of Conservation and its software platform Miradi were used to rank the threats [30].

3. Results

3.1. Threats Assessments

3.1.1. Literature Review

A total of 547 news articles were found in Google news; 285 of 547 articles concerned the Gediz Delta; of the 285 news articles, 82 identified threats in the Gediz Delta. A total of 24 scientific publications were evaluated for the specific threats in the Delta [17,24,31–45]. These publications included 17 scientific articles, 4 PhD theses [46–49]; 2 reports [23,50] and one book [51]. A total of 106 sources (scientific and popular journals) were examined, mentioning 233 threats (some of the threats were mentioned multiple times). The threats were coded into 11 classes. The most cited threats were: “residential & commercial development” (20.17%) and “pollution” (19.31%) followed by “transportation & service corridors” (18.45%) and “climate change” (13.73%). The “human intrusions & disturbance” and “energy production & mining” threat categories were also mentioned in the literature review (Figures 2 and 3).

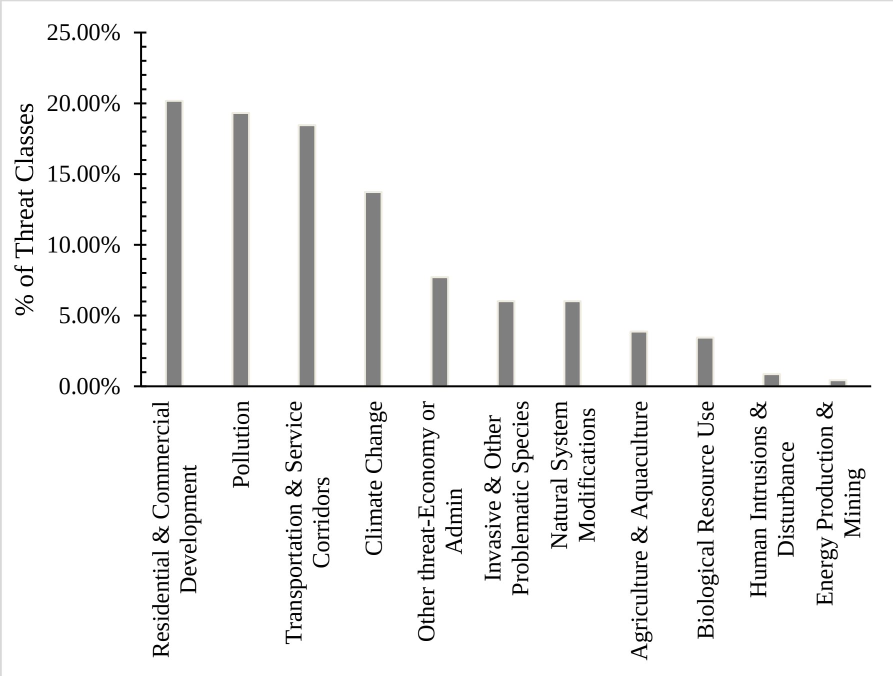

Figure 2. Classification of the major threats in the Gediz Delta based on the IUCN threats classification system using asystematic literature review (n = 233 sources).

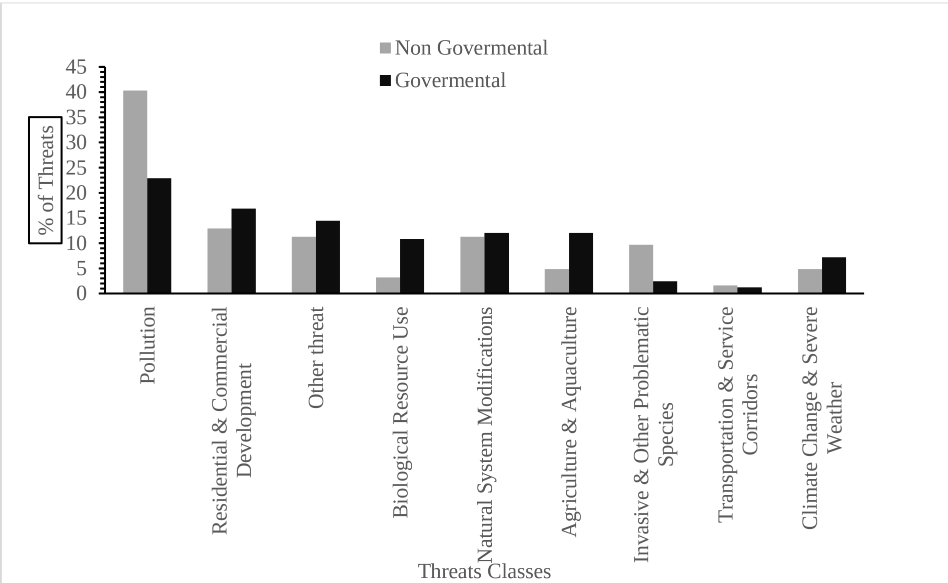

Figure 3. Frequency of direct threats identified by governmental and non-governmental stakeholders in the Gediz Delta based on the IUCN threat classification system (30 ind).

3.1.2. In-Depth Interviews

To assess the local perspectives, a total of 30 (6 Female, 24 Male) stakeholders from 24 different socio-professional and local groups were interviewed. The stakeholders were from both governmental and non-governmental organizations (14 and 16 people, respectively) (Table 1). A total of 152 threats were identified in the interviews. The threats were coded using the IUCN threats classification system. A total of nine distinct threat categories were identified. The most frequently cited threat in the interviews was "pollution", whereas "urbanization" was most cited in the literature review. Other common threats included "residential & commercial development" (16.45%) followed by "agriculture & aquaculture" (11.84%), and "natural system modification" (11.18%). Pollution was less identified by government stakeholders (21.84%) compared to non-governmental

≤

stakeholders (40%). Likewise, "invasive & other problematic species" are less pronounced by the governmental stakeholders (Figure 3). There are significant differences in the responses between governmental and non-governmental stakeholders (x^2 = 6.82, df = 1, p 0.0008). The most common conservation recommendations included "conservation designation & planning" (21.14%), followed by "awareness raising" (14.63%) and "land/water management activities" (15.45%) (Table 2).

3.1.3. Field Visits

A total of 200 grids were visited, and 19 threats grouped into 9 classes were identified. Certain threats such as "human intrusions & disturbance" and "other threats" could not be visually observed in the field visits. The most common threats in the grids were "invasive non-native/alien plants & animals" (observed in 77% of grids), "annual & perennial non-timber crops" (observed in 70% of grids), and "garbage & solid waste" (observed in 67% of grids). The least common threat in the grids is "mining & quarrying" (1%). According to the heat map, the threats are mostly located in the inner part of the Delta, in agricultural & grassland habitats (Figures 1 and 4).

Table 2. Suggested conservation actions for the Gediz Delta and their frequency as identified by stakeholders (classified according to the Conservation Standards Methodology).

Conservation Action Classification	Description	Government Stakeholders	Non-Governmental Stakeholders	Average of Interviews	Examples
Conservation Designation & Planning	Conservation Planning Easements & Resource Rights Land/Water Use Zoning & Designation Protected Area Designation &/or Acquisition Site Infrastructure	29.31%	13.85%	21.14%	• increase the capacity of the water treatment facilities, • lobby to include the Gediz River into the river boundaries law, • enforce nature and urban planning, • improve intersectoral planning tools
Land / Water Management	Ecosystem & Natural Process (Re)Creation Site/Area Stewardship	10.34%	20.00%	15.45%	• wetland restoration, • intersectoral water resource planning • reinforce dyke management • lobby for regular freshwater supply to the delta
Awareness Raising	Outreach & Communications	13.79%	15.38%	14.63%	• agro-ecological farmer training, • awareness raising campaigns about the Delta's values
Institutional Development	External Organizational Development & Support Financing Conservation Internal Organizational Management & Administration	17.24%	6.15%	11.38%	• Increase the number of staff for law enforcement (NGO or Government), • fundraising nature protection activities (such as new water treatment facilities)
Livelihood, Economic & Moral Incentives	Linked Enterprises & Alternative Livelihoods Market-Based Incentives	8.62%	12.31%	10.57%	• eco-branding and improved marketing of traditional products
Law Enforcement & Prosecution	Detection & Arrest	6.90%	7.69%	7.32%	• control illegal industrial waste • removal of illegal livestock yards and fishing houses
Legal & Policy Frameworks	Laws, Regulations & Codes Policies & Guidelines	5.17%	6.15%	5.69%	• create legislation for organic farming, • lobby for stronger regulation,
Research & Monitoring	Basic Research & Status Monitoring	5.17%	6.15%	5.69%	• independent pollution testing and enforcement,

					• research and monitoring to identify problem species
External capacity building	Alliance & Partnership Development	0.00%	9.23%	4.88%	• collaboration between all stakeholders
Species Management	Species Stewardship	3.45%	3.08%	3.25%	• move dog shelter to new location, • population control hunting, • removal of feral animals, • improved management of the animal shelter, • capture and sterilization campaigns

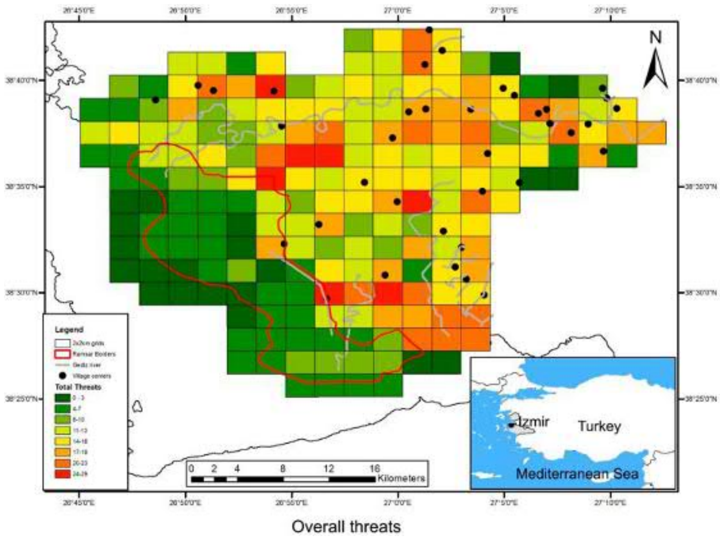

Figure 4. Global threat heat map of the Gediz Delta with green representing the lowest threat rankings and red representing highest threat rankings.

3.2. Threat Ranking

Overall, 11 threat classes were recorded (Table 3) and evaluated for four key habitats in the Delta. The habitats that were ranked as “very highly threatened” were Inland wetlands, Marine and Coastal Habitats, and Agricultural and Grassland Habitats. Mediterranean habitats are ranked as highly threatened. “Residential and commercial development” and “climate change” are the highest ranked threats and have the potential to impact all habitats in the Delta, followed by “transportation/service corridors” and “pollution”. The category of “residential & commercial development” includes (1) “commercial & industrial areas”, (2) “housing & urban areas”, and (3) “tourism & recreation areas” in the Delta.The “climate change” threat includes “droughts” and “habitat shifting & alteration” across the Delta. The “transportation services and corridors” threats are mainly evaluated as an existing threat with utility services (such as electric poles) and flight paths (on the southern coast; there is a military airport). The third direct threat in the Delta is pollution from (1) “agricultural & forestry effluents”, (2) “garbage & solid waste”, (3) “household sewage & urban wastewater”, and (4) “industrial & military effluents”. The category of “other threats” (such as management problems) and “human intrusions” were evaluated as directly affecting only inland and coastal marine habitats with low impact. “Energy production & mining” threats were indicated for Mediterranean habitats (Table 3). The threat ranking combined with the heat maps shows that the most threatened habitats are in the inner part of the Delta (agricultural & grassland habitats) (Figure 4 and Appendix A). The inner parts of the Delta are mainly threatened by “pollution” and “residential and commercial development” (Table 3), whereas the marine and coastal areas are threatenedby “climate change”.

Threats \ Targets	Inland wetlands	Marine Coastal	Agricultural Grassland	Mediterrean Habitats	Summary Threat Rating
Residential & Commercial Development	Very High	Very High	Very High	Very High	Very High
Climate Change	Very High	Very High	Medium	Medium	Very High
Transportation & Service Corridors	High	Very High	Medium	Medium	High
Pollution	High	High	Very High	Low	High
Invasive & Other Problematic Species	Medium	Medium	Medium	Medium	Medium
Agriculture & Aquaculture	Medium	Low	Medium	Medium	Medium
Natural System Modifications	High	Medium	Medium	Low	Medium
Biological Resource Use	Medium	Low	Low	Low	Low
Other threat-Economy or Admin	Low	Low			Low
Human Intrusions & Disturbance	Low	Low			Low
Energy Production & Mining				Low	Low
Summary	Very High	Very High	Very High	High	Very High

Table 3. Threat impacts ranking of key habitats of the Gediz Delta using the Conservation Standards Methodology. Threat impacts have been categorized as Low (Dark Green), Medium (Light Green), High (Yellow), Very High (Red), and not existing (White).

4. Discussion

A systematic analysis of the threats in the Gediz Delta using a multi-method approach allowed us to identify a wide panorama of threats that are both perceived and observed. Similar to other studies concerning the threats to wetlands around the world [6,12], "residential & commercial development" and "climate change" are ranked as very high direct threats contributing to habitat destruction. The main driver of "residential & commercialdevelopment" is urbanization; this threat was only minimally evoked in the stakeholder interviews, yet it was quite important in the literature review and field survey (the built-up area increased by 85% over 40 years [24]). The reason that urbanization is less mentioned in the interviews could in part be due to the fact that the construction occurred outside the protected area, and these areas are not seen as a threat to the natural areas. Most of the urbanization also occurred before the 2000s [24], which could make this threat be seen as a past threat rather than a current threat. Despite this fact, it is important to highlight that the literature review continues to show the ongoing construction proposals for the Delta,indicating a continued threat [18].

Climate change was ranked as a very high threat, affecting all habitats in the Delta. The direct impacts of climate change could only be partially observed (sea-level increases and droughts), yet the projected scenarios for the region indicate serious risks in the future [8,41]. Climate change was not commonly evoked by the stakeholders (less than 10%) nor in the literature (13.73%); however, the reoccurring droughts between 1988 and 1997 caused severe drying of the wetland and grassland habitats. The climate change projections forecast more severe droughts in time, which will adversely affect the populations of many species living in the Delta [24]. Additionally, the current data indicates that climate change is impacting and will continue to impact the marine and coastal wetlands, especially lagoons [41,52,53]. In order to reduce the effects of these threats, some restoration work was carried out in the Delta. First, in 1999, freshwater was pumped to prevent inland marshes from drying up [24,51] and second, the flamingo breeding islands that were destroyed by waves were restored in the salinas [52]. These restoration activities are only short-term solutions and are necessary to repeat over time. In order to protect these valuable habitats, new and alternative solutions must be found using a more global approach [8,54]. However, short- term solutions are critical for the sustainability of these habitats in the Delta, especially for inland wetlands that are directly dependent on continual freshwater sources. In order to maintain these resources, continued lobbying for regular freshwater input into the Delta is highly recommended. This implies a collaboration between the environmental and agricultural sectors to ensure a sustainable balance of water use [54].

The “transportation service and corridors” threat in the Delta is often associated with the threat of “residential & commercial development” in both the literature and stakeholder interviews. According to the threat heat map, the two threats were concentrated in the inner part and on the periphery of the Delta; however, the coastal parts of the Delta have been threatened with projects that did not materialize. These planned, or announced but cancelled projects include building a container port, public beaches, an amusementpark (Disneyland), a new fairground project, a mega-bridge construction project and a skyscraper project in Mavişehir (on the Delta shoreline) [51,55]. The fact that the Delta is located next to the city of İzmir causes an increase in demand for urban development in the region [18,49]. This threat can be seen around the Mediterranean basin with increasing human population pressures causing the transformation of 45–51% of natural wetlands into agricultural and urban zones since 1970 [6,54]. The protection status of Gediz Delta has had a significant impact, preventing many construction projects on the coastline [51,56]; however, it has been shown that legislation alone is not sufficient [54]. To reduce the threats of “transportation services and corridors” and “urbanization”, it is imperative to increase social awareness about the protection and sustainable management of Mediterranean wetlands and to improve intersectoral planning and collaboration [57].

The “pollution” threat is most prominent in the stakeholder interviews. The perception of this threat could be as it is often more visible than other threats (illegal dumps) in the Delta, and its impact is felt directly by the local population. “Pollution” was directly observed in more than 60% of the grids. All three sources of information (literature review, stakeholder interviews, and field visits) have identified the Gediz River as a primary source of pollution in the Delta, and it has been cited as one of the most heavily polluted rivers in Turkey due to agricultural drainage water, industrial wastewater and domestic wastewater [34,37,40]. This pollution is enhanced by 400 leather factories in Uşak and 57 leather, oil, and soap factories in Manisa [58]. The change in farming practices, with extensive vegetable and fruit production being replaced with intensive cotton and vegetable farming, has contributed to increased pollution [36]. One participant in the interview commented that “the river’s water was directly drinkable by locals forty years ago, but after the 2000s, the increased pollution in the river has had adverse effects in agriculture productivity and quality”. There have also been reports in the press about mass fish deaths along the river [59,60]. In addition to water pollution, the threat of garbage and solid waste problems, such as plastics, domestic waste, and rubbles, reduces the quality of the Delta’s habitats. Garbage and solid waste problems were found in 67% of the grids. Pollution is an important variable that threatens not only the Gediz Delta, but also 54% of the world’s wetlands [12]. The EU Water Framework Directive (2000/60/EC) policies have positively reduced pollution and nutrient concentrations in surface water in European countries [54]. In this perspective, we highly recommend that the Gediz River be included into the river boundaries law in Turkey; this will create the necessary legislation to enforce water quality in the Delta. Secondly, it is necessary to increase the capacity of water treatment facilities to reduce overflow and direct discharges into the river. Another management recommendation is to promote organic and sustainable farming practices to reduce pesticides and other agricultural inputs from entering into the water supply [61].

The threats in the Delta that were ranked as medium include “invasive and other problematic species”, “agriculture and aquaculture”, and “natural system modifications”. All these threats were identified in the literature review, interviews, and field observations, yet the frequency and importance given to the threats varied significantly depending on the method used. “Invasive and other problematic species” in the Delta include eucalyptus trees, feral horses, dogs and cats, and wild boars. These problematic species were observed in 77% of the grids. The feral cats and dogs prey on many wild bird and animal species [62,63], impacting the biodiversity. An example of this impact can be seen in the Delta when feral dogs attacked the flamingo nests repeatedly from 2006–2011, breaking thousands of eggs (3600 eggs in 2011 and 2189 eggs in 2010) [51]. Feral dog collection campaigns and barbed wire fencing were used to tackle these problems, and we recommend that these strategies be maintained to control the feral dog population in the future. On the other hand, feral horses are categorized as a threat, yet they also hold an ecological role for maintaining the habitats open in the absence of other wild grazing animals [50,64]. This indicates that population size should be controlled through management practices, but eradication should not be promoted as this could have even greater consequences on the biodiversity of the Delta. Another example of the "invasive and problematic species" threat are the eucalyptus tree plantations and their impact in terms of water demands [18]. The trees were initially planted in the Gediz Delta in the 1970s to open residential and recreational areas, based on the idea that the trees would help dry the marshes that were considered a source of malaria [18]. It should be noted here that these trees are no longer planted today, and they are gradually being removed and replaced by native tree species overtime [50].

The "agriculture and aquaculture" threat mainly focused on agricultural intensification (for both agricultural crops and livestock farming) [23,32,36,45,47,50,51]. This threat was observed in 70% of the grids. Despite this intense scope, the threat was evaluated as having a medium impact as the potential for irreversibility. In order to reduce this threat, two conservation activities are recommended: (1) agro-ecological farmer training and (2) branding and improved marketing of traditional products. Promoting this kind of activity could bring mutual benefits for both biodiversity and landowners [65].

The "natural system modification" threat category was also evaluated as "medium" severity in the threat ranking; however, it is a high threat for inland wetlands due to riverbed infrastructure and increased channels that reduce freshwater sources in the Delta [24]. In addition, the threat was commonly expressed by stakeholders with inefficient freshwater circulation in the channels and salt pans and negative impacts of the dams on the river and the water regime. Despite this concern from the stakeholders, there was no evidence in the literature showing impacts of channelization, saltpan extension, or dams in the water circulation of the Delta. To better understand this discrepancy, we recommend implementing an improved water monitoring schemes to apprehend the water circulation in the Delta and create a management system to use the existing water more effectively. These data could provide the necessary information to put in place a restoration project in part of the abandoned Salinas, improving water circulation and the development of dunes and temporal coastal wetlands in the Delta [66].

The threats that were ranked as low include "biological resource use", "other threat-economy or administration", "human intrusions & disturbance", and "energy production & mining". The literature review identified various "biological resource use" threats including poaching, improper reed management, overfishing, and grazing activities [47,50,53,67]. These threats were often associated with lack of regulation or limited policy control due to insufficient staff. Although the "biological resource use" threat is not commonly cited in the Delta, and it was evaluated with a low impact severity, it should be noted that this threat is one of the four most common threats in wetlands worldwide [7,12]. Thus, this study might have underestimated the threat severity due to limited literature and low attention given by the stakeholders. To reduce the impacts of this threat, we recommend further research and monitoring studies be implemented to identify impacts of the threat both on biodiversity and ecosystem services. Based on this information, it can be determined if there is a need to develop new laws or regulations and/or enforce staff (NGOs or Government) to ensure the implementation of existing laws.

The threats "human intrusions & disturbance" and "energy production & mining" were not identified by the stakeholders and were only vaguely mentioned in the literature. There were some articles that mentioned concern about noise disturbances from military airports [46,47]; however, this threat was not evaluated, as it could not be precisely localized in the grids. "Energy production and mining" was observed with two indirect threats: "mining and quarrying" and "renewable energy". This threat was observed with solar energy farming, but the other references from the literature were unrealized projects [68]. These planned projects could pose eventual threats in the Delta in the future and attention should be given to avoid the impact that they could have on the biodiversity.

The overall threat analysis ranked "coastal and marine", "inland wetlands", and "agricultural & grassland" habitats as highly threatened in the Delta. On the contrary, the heat maps do not show this ranking, as some of the important threats were not visible during the field visits such as planned but unrealized projects and sea level rise. Given that the Delta is protected by national laws, some construction projects proposed for coastal and marine habitats were abandoned [51], yet despite this protection other projects have caused serious loss to inland wetlands in last decades [17,24,51,69] with irreversible loss to some critical habitats (such as the Çiğli marshes) [24]. It is expected that many of the exitings threats will continue due to the geographical proximity of the Delta to the city of İzmir, with increasing urbanization pressures [18,46] and climate change projections. This highlights the need to conserve habitats in the protected areas and to target the conservation activities that will reduce the threats affecting these habitats.

Unfortunately, the agricultural and grassland habitats are often outside of the highly protected areas, yet in our study these are the habitats that are the most threatened. It has been shown that agricultural and grassland habitats surrounding wetland ecosystems have an important role in conserving wetlands as they provide feeding and breeding habitats for many species [70,71]. Therefore, it is essential that conservation activities include all of the Delta's terrestrial ecosystems, especially those largely forgotten in conservation policies [20,71].

The use of different methods and perspectives to identify threats in the Gediz Delta allowed us to pinpoint the critical threats in the Delta. This multi-method approach is useful to better understand where conservation efforts could and should be undertaken. The threats mentioned in this study are common to many wetland ecosystems around the world [12]. However, it is important that they be evaluated in each specific context. Taking into account different perspectives (stakeholders' perceptions, media, and scientific research) can contribute to the success level of the conservation strategies [72–74].

5. Conclusions

This study identified both the perceived and observed threats impacting the habitats, and its biodiversity in the Gediz Delta using a multi-method approach involving local and scientific knowledge systems. The threat ranking could have had some bias, given that it was based on expert evaluation, but this bias was reduced with the inclusion of literature and survey results. The difference in results from each collection method shows the importance of using a multi-method approach to understand the dimensions of the threats fully. This methodology can be applied in other wetlands to prioritize the threats and understand the cumulative effects on both habitats and species. The threat analysis in the Gediz Delta shows the importance of enlarging conservation activities outside of the strictly protected. This analysis also provides the grounds to identify the most appropriate conservation strategies that could be applied to the site in order to have the most impact.

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Data Availability Statement: Raw data were generated at the Tour du Valat. Derived data supporting the findings of this study are available from the corresponding author on request.

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Conflicts of Interest: The authors declare that there are no conflicts of interest on any financial or non-financial (political, personal, professional) interests/relationships that may be interpreted to have influenced the manuscript.

Appendix A

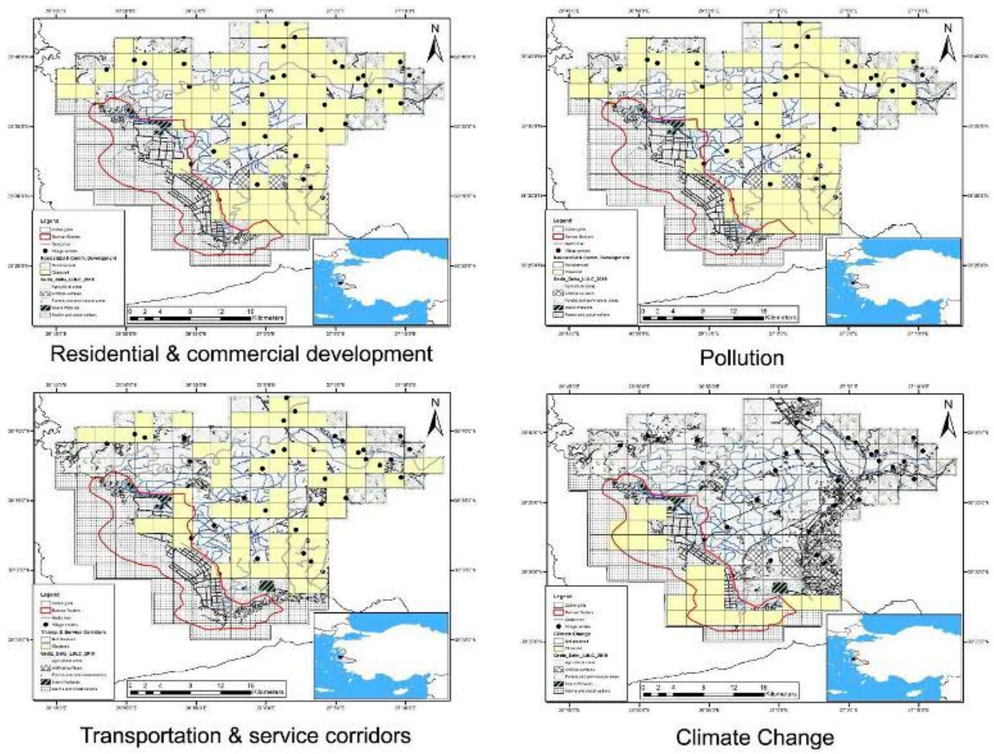

Figure A1. The maps show the grids where the four major the threats were identified through the field survey. Yellow colour represents where the threat was observed.

References

(1) Hoekstra, J. M.; Boucher, T. M.; Ricketts, T. H.; Roberts, C. Confronting a Biome Crisis: Global Disparities of Habitat Loss and Protection. Ecology Letters 2005, 8 (1), 23–29. https://doi.org/10.1111/j.1461-0248.2004.00686.x.

(2) Dudley, N. Guidelines for Applying Protected Area Management Categories; Iucn, 2008.

(3) Ramsar Convention Secretariat. The Fourth Strategic Plan 2016-2024. Ramsar Handbooks for Wise Use of Wetlands; 5th edition, Vol. 2.; Ramsar Convention Secretariat: Gland, Switzerland, 2016; p 56.

(4) Davidson, N. C. How Much Wetland Has the World Lost? Long-Term and Recent Trends in Global Wetland Area. Mar. Freshwater Res. 2014, 65 (10), 934–941. https://doi.org/10.1071/MF14173.

(5) Gardner, R. C.; Finlayson, C. Global Wetland Outlook: State of the World's Wetlands and Their Services to People; SSRN Scholarly Paper ID 3261606; Social Science Research Network: Rochester, NY, 2018.

(6) Geijzendorffer, I.; Chazée, L.; Gaget, E.; Galewski, T.; Guelmami, A.; Perennou, C.; Davidson, N.; McInnes, R. Mediterranean Wetlands Outlook 2: Solutions for Sustainable Mediterranean Wetlands; Secretariat of the Ramsar Convention, 2018.

(7) Galewski, T.; Segura, L.; Biquet, J.; Saccon, E.; Boutry, N. Living Mediterranean Report – Monitoring Species Trends to Secure One of the Major Biodiversity Hotspots; Tour du Valat: Arles (FRA), 2021; p 20.

(8) Giosan, L.; Syvitski, J.; Constantinescu, S.; Day, J. Climate Change: Protect the World's Deltas. Nature 2014, 516 (7529), 31–33. https://doi.org/10.1038/516031a.

(9) Salafsky, N.; Salzer, D.; Stattersfield, A. J.; Hilton-Taylor, C.; Neugarten, R.; Butchart, S. H.; Collen, B. E. N.; Cox, N.; Master, L. L.; O'CONNOR, S. A Standard Lexicon for Biodiversity Conservation: Unified Classifications of Threats and Actions. Conservation Biology 2008, 22 (4), 897–911.

(10) Redford, K. H.; Hulvey, K. B.; Williamson, M. A.; Schwartz, M. W. Assessment of the Conservation Measures Partnership's Effort to Improve Conservation Outcomes through Adaptive Management. Conservation Biology 2018, 32 (4), 926–937. https://doi.org/10.1111/cobi.13077.

(11) CMP, C. M. P. About Conservation Standards (CS). The Open Standards for the Practice of Conservation, 2021.

(12) Xu, T.; Weng, B.; Yan, D.; Wang, K.; Li, X.; Bi, W.; Li, M.; Cheng, X.; Liu, Y. Wetlands of International Importance: Status, Threats, and Future Protection. Int J Environ Res Public Health 2019, 16 (10). https://doi.org/10.3390/ijerph16101818.

(13) RIS, R. S. I. S. Information Sheet on Ramsar Wetlands (RIS) – 2006-2008 Version; https://rsis.ramsar.org/, 2021.

(14) Onmuş, O.; Durusoy, R.; Eken, G. Distribution of Breeding Birds in the Gediz Delta, Western Turkey: (Aves). Zoology in the Middle East 2009, 47 (1), 39–48.

(15) Arslan, D.; Oliver, A.; Yaşar, Ç.; Ismail, İ. B.; Döndüren, Ö.; Ernoul, L.; Beck, N.; Çiçek, K. Distribution and Current Status of Herpetofauna in the Gediz Delta (Western Anatolia, Turkey). Herpetology Notes 2018, 1–15.

(16) Ernoul, L.; Wardell-Johnson, A. Adapting International Conservation Strategies to Local Context: Perceptions of Biodiversity Values and Management Responsibility in Two Mediterranean Deltas. International Journal of Biodiversity Science, Ecosystem Services & Management 2014, 1–13. https://doi.org/10.1080/21513732.2014.980849.

(17) Ernoul, L.; Sandoz, A.; Fellague, A. The Evolution of Two Great Mediterranean Deltas: Remote Sensing to Visualize the Evolution of Habitats and Land Use in the Gediz and Rhone Deltas. Ocean & coastal management 2012, 69, 111–117.

(18) Avdan, A. O. The Making of Consurbia: Conservation, Urbanization, and Socio-Environmental Change in Turkey's Gediz Delta. Thesis, Arts & Social Sciences: Department of Sociology and Anthropology, 2020.

(19) Guelmami, A. Gediz Delta Land Use and Land Cover Changes, Unpublished work.

(20) Arslan, D.; Ernoul, L.; Béchet, A.; Döndüren, Ö.; Siki, M.; Galewski, T. Using Literature and Expert Knowledge to Determine Changes in a Turkish Wetland Bird Community over the Last 40 Years, Unpublished work.

(21) TUIK, T. S. I. Address Based Population Registration System Results, 2019; Website, 2020.

(22) IUCN. Threats Classification Scheme (Version 3.2) https://www.iucnredlist.org/resources/threat-classification-scheme (accessed 2021 -10 -19).

(23) Gediz Delta Management Plan. Gediz Deltası Sulak Alan Yönetim Planı, [Gediz Delta Management Plan]; T.C. Çevre ve Orman Bakanliği Doğa Koruma ve Milli Parklar Genel Müdürlüğü, Doğa Koruma Dairesi Başkanlığı, Sulak Alanlar Şubesi Müdürlüğü,; İzmir, Turkey, 2007.
(24) Bolca, M.; Özen, F.; Güneş, A. Land Use Changes in Gediz Delta (Turkey) and Their Negative Impacts on Wetland Habitats. Journal of Coastal Research 2014, 30 (4), 756–764.
(25) Babbie, E. R. The Practice of Social Research, 11th ed.; Thomson Higher Education, 2007.
(26) Roca, E.; Villares, M. Public Perceptions of Managed Realignment Strategies: The Case Study of the Ebro Delta in the Mediterranean Basin. Ocean & Coastal Management 2012, 60, 38–47.
(27) Meyer, D.; Hornik, K.; Feinerer, I. Text Mining Infrastructure in R. Journal of statistical software 2008, 25 (5), 1–54.
(28) Fellows, I.; Fellows, M. I.; Rcpp, L.; Rcpp, L. Package 'Wordcloud.' R Package, Maintainer Ian and Rcpp, Linking To and Rcpp.[(accessed on 4 February 2021)] 2018.
(29) Keller, V.; Herrando, S.; Voríšek, P.; Franch, M.; Kipson, M.; Milanesi, P.; Martí, D.; Anton, M.; Klvanová, A.; Kalyakin, M. V. European Breeding Bird Atlas 2: Distribution, Abundance and Change; 2020.
(30) Schwartz, M. W.; Deiner, K.; Forrester, T.; Grof-Tisza, P.; Muir, M. J.; Santos, M. J.; Souza, L. E.; Wilkerson, M. L.; Zylberberg, M. Perspectives on the Open Standards for the Practice of Conservation. Biological Conservation 2012, 155, 169–177. https://doi.org/10.1016/j.biocon.2012.06.014.
(31) Delibacak, S.; Okur, B. Infiltration rate and heavy metal contents in common soils of the Gediz delta. Ege Üniversitesi Ziraat Fakültesi Dergisi 2000, 37 (1), 9–16.
(32) Murray-Rust, D. H.; Svendsen, M. Performance of Locally Managed Irrigation in Turkey: Gediz Case Study. Irrigation and Drainage Systems 2001, 15 (4), 373–388. https://doi.org/10.1023/A:1014408826933.
(33) Kaplan, A.; Güler, G. G.; Küçükerba, E. V.; Kurucu, Y.; Ölgen, M. K.; Türkyilmaz, B.; Siki, M.; Akgün, A. Kıyı Sulak Alan Sistemi Bağlamında Gediz Deltasının İşlevleri ve Üzerindeki Baskılar Yönüyle Değerlendirilmesi. 2005, 14, 17.
(34) Parlak, H.; Çakır, A.; Boyacıoğlu, M.; Arslan, Ö. Ç. Heavy Metal Deposition in Sediments from the Delta of the Gediz River (Western Turkey): A Preliminary Study. E. Ü. Su Ürünleri Dergisi 2006, 23 (4), 445–448.
(35) Dora, E. Ç.; Sunlu, U.; Ergen, Z. Heavy Metal Concentrations In Hediste Diversicolor (Polychaeta) And Sediments From Homa Lagoon (Izmir Bay-Turkey). Rapp. Comm. int. Mer Médit 2007, 38, 1.
(36) Efe, R. Environmental Change and Wetland Management: A Case Study in the Gediz Delta Ecosystem (Western Turkey); Sofia University "St. Kliment Ohridski" Faculty of Geology and Geography: Sofia, Bulgaria, 2007; Vol. 5th, pp 16–22.
(37) Aydin, S.; Kucuksezgin, F. Distribution and Chemical Speciation of Heavy Metals in the Surficial Sediments of the Bakırçay and Gediz Rivers, Eastern Aegean. Environ Earth Sci 2012, 65 (3), 789–803. https://doi.org/10.1007/s12665-011-1124-7.
(38) Kaplan, A. How Effective Could 'Landscape Management' Tool Address Mitigation of Cultural and Natural Threats on Coastal Wetlands System? In National Security and Human Health Implications of Climate Change; Fernando, H. J. S., Klaić, Z., McCulley, J. L., Eds.; NATO Science for Peace and Security Series C: Environmental Security; Springer Netherlands: Dordrecht, 2012; pp 307–316. https://doi.org/10.1007/978-94-007-2430-3_27.
(39) Onmuş, O.; Siki, M. Impacts of Anthropogenic Activities and Habitat Degradation on Breeding Waterbirds. Turkish Journal of Zoology 2013, 37 (3), 249–261.
(40) Suzer, E. U.; Kontaş, A.; Yılmaz, E. C. Assessment of heavy metal pollution of surface sediments from lagoon areas of Gediz Delta (Izmir Bay). Journal of Fisheries and Aquatic Sciences (Su Ürünleri Dergisi) 2015, 32 (2), 79–87.
(41) Tulger, G.; Bilgiç, E.; Gündüz, O. Deniz Seviyesi Yükselmesi Durumunda Gediz Deltasinin Su Altinda Kalma Analizi; Harran Üniversitesi, Şanlıurfa, 2015.
(42) Akyol, D.; Sönmez, İ. Ö. Wetlands under the Pressure of Urbanization: The Gediz Delta Case-Science, Ecology and Engineering Research in the Globalizing World; ST Kliment Ohridski University Press, 2018.
(43) Alevkayali, Ç.; Tağil, Ş. Ortak Malların Trajedisi Üzerine Teoriler: Gediz Deltası'nda Arazi Kullanımı-Arazi Örtüsü Değişimi. Süleyman Demirel Üniversitesi Fen-Edebiyat Fakültesi Sosyal Bilimler Dergisi 2018, No. 43, 120–142.
(44) Ünal, M.; Canli, M. Sulak Alanların Yok Edilmesinin Etkileri ve Amik Gölü Örneği [The

Effects of Wetland Destruction and the Example of Lake Amik]. Doğanın Sesi 2019, No. 4, 49–66.
(45) Arslan, D.; Olivier, A.; Ernoul, L.; Béchet, A.; Çiçek, K. Demography, Distribution, and Threat Assessment of the Spur-Thighed Tortoise (*Testudo graeca*) in the Gediz Delta, Turkey (Reptilia: Testudines). Zoology in the Middle East 2021, 67 (3), 1–12. https://doi.org/10.1080/09397140.2021.1933764.
(46) Sevinç, N. Wetland conservation within the framework of city planning. Master, Izmir Institute of Technology (Turkey), 2000.
(47) Onmuş, O. Gediz Deltası'nda Üreyen Su Kuşu Türlerinin Yuvalama Alanlarının Izlenmesi ve Bu Kolonilerin Yönetilmesi [Monitoring and Management Of Nest Sites Of Breeding Waterbirds At The Gediz Delta]. PhD Thesis, Doktora tezi, Ege Üniv. Fen Bil. Enst. İzmir, 2008.
(48) Gül, O. Gediz Deltası (İzmir) ve Büyük Menderes Deltası (Aydın)'nda Üreyen Tepeli Pelikan (Pelecanus Crispus Bruch, 1832) Populasyon Büyüklüğünün, Değişiminin, Göçlerinin, Üreme ve Beslenme Biyolojilerinin Araştırılması [Investigation of Population Size and Trend, Migration Movements, Breeding and Feeding Biology of Dalmatian Pelican (Pelecanus Crispus Bruch, 1832) Populations Breeding in Gediz Delta (İzmir) and Buyuk Menderes Delta (Aydin)]. PhD Thesis, Ege Üniversitesi, İzmir, Turkey, 2014.
(49) Yılmaz, Y. Ş. Planlamada Ekolojik Duyarli Alanlarin Belirlenmesi: Gediz Deltasi Sulak Alani Örneği [Defining Ecologically Sensitive Areas In Planning: Case Of Gediz Delta Wetland]. Master, Karadeniz Teknik Üniversitesi Fen Bilimleri Enstitüsü, Şehir Ve Bölge Planlama Anabilim Dali, 2016.
(50) Gediz Delta Management Plan. Gediz Deltası Sulak Alan Yönetim Planı, [Gediz Delta Management Plan]; T.C. Çevre ve Orman Bakanliği Doğa Koruma ve Milli Parklar Genel Müdürlüğü, Doğa Koruma Dairesi Başkanlığı, Sulak Alanlar Şubesi Müdürlüğü,; İzmir, Turkey, 2020.
(51) Sıkı, M. Gediz deltasi'ndaki İzmir kuş cennetini yaşatma mücadelesi (1982-2018); Kanguru Yayınları: İzmir, Turkey, 2020.
(52) Balkız, Ö.; Onmuş, O.; Sıkı, M.; Döndürenc, Ö.; Gül, O.; Arnaud, A.; Germain, C.; İsfendiyaroğlu, S.; Özbek, M.; Çağlayan, E.; Araç, N.; Parmak, B.; Özesmi, U.; Béchet, A. Turkey as a Crossroad for Greater Flamingos Phoenicopterus Roseus: Evidence from Population Trends and Ring-Resightings (Aves: Phoenicopteridae). Zoology in the Middle East 2015, 61 (3), 201–214. https://doi.org/10.1080/09397140.2015.1058452.
(53) Tosunoğlu, Z. İzmir'in Kıyı Dalyanları (Coastal Dalyans of Izmir). In İzmir Balıkçılığı; İzmir Büyükşehir Belediyesi: İzmir, Turkey, 2017; p 304.
(54) Geijzendorffer, I. R.; Beltrame, C.; Chazee, L.; Gaget, E.; Galewski, T.; Guelmami, A.; Perennou, C.; Popoff, N.; Guerra, C. A.; Leberger, R.; Jalbert, J.; Grillas, P. A More Effective Ramsar Convention for the Conservation of Mediterranean Wetlands. Frontiers in Ecology and Evolution 2019, 7, 21. https://doi.org/10.3389/fevo.2019.00021.
(55) BirdLife International. Important Bird Areas factsheet: Gediz Delta. http://datazone.birdlife.org/site/factsheet/gediz-delta-iba-turkey/text (accessed 2021 -08 -27).
(56) "'İzmir Körfez Geçişi Projesi İptal Kararı İzmir Halkına Armağandır'" https://www.sivilsayfalar.org/2019/01/02/izmir-korfez-gecisi-projesi-iptal-karari-izmir-halkina-armagandir/ (accessed 2021 -11 -03).
(57) Pickaver, A.; Ferreira, M.; Veiga, J.; Steign, R.; Czerniak, P.; Heinichen, B.; Volckaert, A. A European Inititiative to Support ICZM, 2009.
(58) Merkezi, H. Gediz Havzası ölmesin, öldürülmesin. Özgür Denizli. https://ozgurdenizli.com/gediz-havzasi-olmesin-oldurulmesin/ (accessed 2021-11-17)
(59) Gediz Nehri'nde Balık Ölümleri Devam Ediyor http://www.yapi.com.tr/haberler/gediz-nehrinde-balik-olumleri-devam-ediyor_175332.html (accessed 2021 -11 -03).
(60) Birliği, Ekoloji. Gediz Nehri'nda balık ölümleri devam ediyor! https://ekolojibirligi.org/gediz-yataginda-oksijensizlikten-binlerce-balik-oldu/ (accessed 2021 -11 -03).
(61) Muneret, L.; Mitchell, M.; Seufert, V.; Aviron, S.; Djoudi, E. A.; Pétillon, J.; Plantegenest, M.; Thiéry, D.; Rusch, A. Evidence That Organic Farming Promotes Pest Control. Nat Sustain 2018, 1 (7), 361–368. https://doi.org/10.1038/s41893-018-0102-4.
(62) Dauphiné, N.; Cooper, R. J. Impacts of Free-Ranging Domestic Cats (Felis Catus) on Birds in the United States: A Review of Recent Research with Conservation and Management Recommendations. In Proceedings of the fourth international partners in flight conference:

tundra to tropics; 2009; Vol. 205.
(63) Morgan, S. A.; Hansen, C. M.; Ross, J. G.; Hickling, G. J.; Ogilvie, S. C.; Paterson, A. M.; Morgan, S. A.; Hansen, C. M.; Ross, J. G.; Hickling, G. J.; Ogilvie, S. C.; Paterson, A. M. Urban Cat (Felis Catus) Movement and Predation Activity Associated with a Wetland Reserve in New Zealand. Wildl. Res. 2009, 36 (7), 574–580. https://doi.org/10.1071/WR09023.
(64) Biró, M.; Molnár, Z.; Öllerer, K.; Lengyel, A.; Ulicsni, V.; Szabados, K.; Kiš, A.; Perić, R.; Demeter, L.; Babai, D. Conservation and Herding Co-Benefit from Traditional Extensive Wetland Grazing. Agriculture, Ecosystems & Environment 2020, 300, 106983. https://doi.org/10.1016/j.agee.2020.106983.
(65) Lillo, A.; Matteau, J.-P.; Kokulan, V.; Benalcazar, P. The Contribution of Wetlands Towards a Sustainable Agriculture in Canada; SSRN Scholarly Paper ID 3484143; Social Science Research Network: Rochester, NY, 2019. https://doi.org/10.2139/ssrn.3484143.
(66) De Wit, R.; Vincent, A.; Foulc, L.; Klesczewski, M.; Scher, O.; Loste, C.; Thibault, M.; Poulin, B.; Ernoul, L.; Boutron, O. Seventy-Year Chronology of Salinas in Southern France: Coastal Surfaces Managed for Salt Production and Conservation Issues for Abandoned Sites. Journal for Nature Conservation 2019, 49, 95–107. https://doi.org/10.1016/j.jnc.2019.03.003.
(67) Gediz'de Söğüt Tartışması https://www.haberler.com/gediz-de-sogut-tartismasi-6923286-haberi/ (accessed 2021 -11 -10).
(68) Menemen'e bağlı Çaltı'daki taş ocağı projesi iptal edildi – Evrensel https://www.evrensel.net/haber/350900/menemene-bagli-caltidaki-tas-ocagi-projesi-iptal-edildi (accessed 2021 -11 -10).
(69) Eken, G. The Breeding Population of Some Species of Waterbirds at Gediz Delta, Western Turkey. Zoology in the Middle East 1997, 14 (1), 53–68. https://doi.org/10.1080/09397140.1997.10637704.
(70) Mathevet, R.; Tourenq, C.; Mesléard, F. Agricultural Policies, Land-Use and Waterbird Conservation: The Case Study of a Major Mediterranean Wetland, the Camargue. Cybergeo : European Journal of Geography 2002. https://doi.org/10.4000/cybergeo.3755.
(71) Galewski, T.; Devictor, V. When Common Birds Became Rare: Historical Records Shed Light on Long-Term Responses of Bird Communities to Global Change in the Largest Wetland of France. PloS ONE 2016, 11 (11), e0165542. https://doi.org/10.1371/journal.pone.0165542.
(72) Laurentiu Rozylowicz, Andreea Nita, Steluta Manolache, Cristiana M. Ciocanea, Viorel D. Popescu. Recipe for success: A network perspective of partnership in nature conservation, Journal for Nature Conservation, Volume 38, 2017, Pages 21-29, ISSN 1617-1381, https://doi.org/10.1016/j.jnc.2017.05.005.
(73) Manolache S, Nita A, Ciocanea CM, Popescu VD, Rozylowicz L. Power, influence and structure in Natura 2000 governance networks. A comparative analysis of two protected areas in Romania. J Environ Manage. 2018 Apr 15;212:54-64. doi: 10.1016/j.jenvman.2018.01.076. Epub 2018 Feb 8. PMID: 29428654.
(74) Bodin, Ö., A. Sandström, B. Crona. Collaborative networks for effective ecosystem-based management: A set of working hypotheses. Policy Studies Journal. 2016. doi: 10.1111/psj.12146

GENERAL DISCUSSION AND CONCLUSION

General Discussion

This thesis focuses on two research questions: How does land cover affect bird and reptile community assembly processes? and Which habitats in the Gediz Delta need special conservation attention? This thesis was organized into three chapters, each concentrating on a different hypothesis respond to the research questions. The thesis specifically looks at how changing wetland structure, composition and dynamics result in changes in the overall biodiversity or distribution and numbers or presence of wetland-dependent species groups (Boylan and MacLean 1997). Since wetlands have been greatly degraded and transformed over the last century (Davidson *et al.* 2018), we hypothesized that biodiversity in the Gediz Delta has significantly changed from the past to the present due to anthropological changes discussed in the first chapter. In the second chapter, we addressed the hypothesis that land-cover also drives the diversity in bird and reptile communities according to the species traits. The third chapter described and prioritized the threats in the Gediz Delta. This chapter looked into the hypothesis that wetland habitats should take priority in conservation management for the Gediz Delta. Understanding the changes in Gediz Delta offers the opportunity to better understand how the threats could affect biodiversity in other deltas with similar threats (Geijzendorffer *et al.* 2018, Galewski *et al.* 2021).

1-Main outcomes

Since wetlands are among the most altered habitats (Davidson *et al.* 2018), we hypothesized that biodiversity significantly changed from the past to the present due to anthropological changes. Given the availability of bird data in the Gediz Delta, we tested this hypothesis using only bird species. We observed a significant shift in bird species in the Gediz Delta over the past century. Using an extensive database of recorded bird observations, scientific literature, and expert interviews, we showed a significant increase in community commonness index (CCI) of «Marine & Coastal» breeding specialist species and a decrease in «Agricultural & Grassland» breeding specialist bird species in the delta. Additionally, we observed a decrease in «Generalist» breeding species while there were significant increases in «Mediterranean Habitats» breeding species over the last century (see Chapter 1 for more details). These trends correlate positively with the conversion of extensive pastures to agricultural land, marine wetlands to salt pans, and inland wetlands to urbanized areas (Bolca *et al.* 2014, Ernoul *et al.* 2012, See Thesis Appendix 1). The observed changes in the breeding bird communities may have resulted from the land use and land cover changes in the delta. Similar land use and land cover changes have shown impacts on species trends around the Mediterranean basin (Galewski *et al.* 2011, 2021b, Geijzendorffer *et al.* 2018, Perennou *et al.* 2020), and most of the biodiversity living in wetlands was adversely affected by land use land cover changes (Chace and Walsh 2006, Devictor *et al.* 2007, Galewski *et al.* 2011, Gil-Tena *et al.* 2015). These results confirm our hypothesis that changing wetland structure, composition, and dynamics result in changes in the overall biodiversity or distribution and the presence of wetland-dependent species groups.

Furthermore, our study found 299 bird species recorded between 1835-2019, and 66 out of 299 species were recorded as a vagrant in delta. In total, 115 species were recorded as breeding species in the 1980-2019 period in the delta. The use of historic documents and grey literature suggests that the bird communities in the delta were very different in the 19th and even until the middle of the 20th century. This difference corresponds to significant landscape modifications (such as riverbed changes) that occurred before the 1980s. For example, some steppe species locally extinct (e.g., Eastern Imperial Eagle, Great Bustard, Black-bellied sandgrouse) (See Chapter 1 for more details). This study comforts previous research showing that agricultural intensification and urbanization of pastoral areas are major drivers of landscape change with direct impacts on bird diversity (Butler *et al.* 2010, Galewski and Devictor 2016). The impact of these land-use changes could be directly observed with the extinction of Smyrna Kingfishers that previously built their nests in the soft riverbed and no could use these habitats with the containment and dyking of the Gediz River.

In the second chapter, we explored the hypothesis that land-cover also drives the diversity in bird and reptile communities according to the species traits. The study demonstrated diverging impacts of the land cover on the species occurrences in the Gediz Delta. We observed that the birds and reptiles were colonizing certain regions in the delta according to their habitat specializations. We estimated that the natural landscape in the delta mainly consisted of the «Marine & Coastal» birds species, «Agricultural & Grassland» birds species and «Mediterranean Habitats» specialist reptile species. We also showed that some «Inland Wetlands» specialized bird and reptiles species higher occurrences in agricultural landscapes in the delta. Urban landscapes provided habitats for «Marine & Coastal» birds, «Generalist» birds and some «Mediterranean Habitats» reptile species. Therefore, this study emphasized that bird and reptile community assembly processes are impacted by land cover in different dimensions; however, the impact is dependent on habitat type and specific species traits.

Here, we observed that the occurrence probability of «Marine & Coastal» bird species increases in the delta's natural and urban landscapes (See Chapter 2 for details). This positive impact is also in collinearity with our first chapter results indicating that the landscape of the Delta consists of coastal wetlands and saltpans in the protected area, which has probably impacted the occurrence of «Marine & Coastal» bird species in the delta, as other wetlands (Sripanomyom *et al.* 2011, Kleijn *et al.* 2014, Márquez-Ferrando *et al.* 2014). On the other hand, urban landscapes were expanded by converting coastal habitats in the delta, but some of the coastal habitats still boarder these urbanized areas (See Thesis Appendix 1). These remnant coastal habitats in urban landscape structure could benefit some «Marine & Coastal» bird species (Vallejo *et al.* 2009, Morelli *et al.* 2016), providing an alternative foraging habitat with easy food availability (Tourenq *et al.* 2001, Tryjanowski *et al.* 2015, Mao *et al.* 2019). Therefore, the positive occurrences of «Marine & Coastal» bird species could decline if these periphery habitats are not maintained.

We also estimated that some «Inland Wetlands» bird species are more common in natural and in agricultural landscapes in delta (See Chapter 2). For instance, small passerines such as reed warblers (*Acrocephalus scirpaceus* or *A. arundinaceus*) are more widespread in agricultural landscapes and some duck species are common in natural landscapes such as (*Anas_querquedula*, or *Tadorna_ferruginea*). In parallel, there was an increase in both total richness and community index in non-breeding «Inland Wetlands» bird species populations highlighted in chapter one. Both outcomes may be due to the possible relation with artificially transported freshwater to the delta by passing through canals in the farmlands, creating suitable habitats for this group in agricultural areas (Mallet *et al.,* 2022). Additionally, the abundance of certain species in natural lands could also be attributed to conservation efforts in the Delta (such as pumping freshwater into Gediz Delta (See Chapter 1 and 2 for more details). The observed changes in species of «Inland Wetlands» specialist bird species provide a new clue on the driving force of land cover on biodiversity for the hypotheses.

Furthermore, in the second chapter, we also emphasized that «Agricultural

& Grassland» bird species are more likely to be found in natural landscapes than in agricultural and urban landscapes. This could be linked to a change in the vegetative structure caused by reduced grazing pressure (Mérö *et al.* 2015) or conversion of grasslands into intensive agricultural areas (Bolca *et al.* 2014, García-Navas and Thuiller 2020). This result confirms previous studies that highlight the negative impact of agricultural intensification, such as the expansion of monocrops cultivation or the reduction or disappearance of green infrastructure (fences, tree lines, etc.) (Fewster *et al.* 2000, Donald *et al.* 2006, Gil-Tena *et al.* 2015, Katayama *et al.* 2015, García-Navas and Thuiller 2020). On the other hand, despite the negative effects of agricultural activities, «Agricultural & Grassland» bird species are more likely to occur in agricultural areas than in urban landscapes (See Chapter 2). This result indicates that agricultural areas may still harbor some «Agricultural & Grassland» bird species, probably because the natural habitat fragments are still part of these landscapes, such as semi-natural areas in the field margins (Mallet *et al.* 2022).

Another meaningful change was observed in «Generalist» bird species in the delta. The «Generalist» bird species were frequently observed in highly anthropized habitats such as exotic parks for urban areas (e.g. the «Generalist» Great Tit or Common Chaffinch) (Keller *et al.* 2020). Similarly, we observed the occurrence probability of «Generalist» species increased in urban landscapes, and some «Generalist» waterfowl may be more common in natural landscapes (see Chapter 2 for more details), which provides additional evidence for hypothesis two. We also observed in Chapter 1 that while the «Generalist» breeding species have decreased in community commonness index (CCI) with a slight increase in the number of species, there is a small increase in the CCI of the non-breeding population. The increase in the number of «Generalist» species and their prevalence in natural areas may be caused by the increasing urbanization effect in natural areas, as previously shown by Galewski and Devictor and Mao et al. (2016, 2019). On the other hand, although there was a general increase in the breeding community in «Mediterranean Habitats», we also observed that the community commonness index (CCI) of some species is in decline, especially species more linked to semi-natural habitats (See Chapter 1 for more details). There was an increase in CCI of non-breeding boreal temperate forests birds; this could be related to increasing plantations in recent periods and less observation or underreporting of small birds in the early periods.

Similar to previous studies (Arslan *et al.* 2018), reptile richness in the Gediz Delta was observed mostly in natural and agricultural landscapes. However, we determined that this richness differs between natural and agricultural landscapes according to the specialization of the species. The reptile community changes also provide evidence for the driving force of land use on biodiversity. Here, we observed that the occurrence probability of «Inland Wetlands» reptile species increased in agricultural landscapes in the delta. On the other hand, we observed that the occurrence probability of «Mediterranean Habitats» specialist reptile species increased in natural landscapes in the delta. Some «Mediterranean Habitats» specialist reptile species increased in urban landscapes (see chapter 2 for details). Like birds species, the remnant habitats also significantly impacts reptile diversity (Garden *et al.* 2007). Therefore, the remnant habitats in agricultural landscapes (such presence of freshwater in channels) could sustain many reptile species (Schutz and Driscoll 2008), for instance, «Inland Wetlands» reptile species. Similarly, the presence of «Mediterranean Habitats» specialist reptile species in natural and urban landscapes could also be explained by the remnant scrubs found in the natural and urban landscape.

We observed that there are similarities in the same habitats in terms of species compositions. This indicates that the diversity and abundance of bird and reptile species vary from one habitat to another, and this variation is linked to specific species traits. These findings parallel previous studies that highlighted that landscape is the driving force impacting bird and reptiles community assemblies (Boylan and MacLean 1997, Schutz and Driscoll 2008, Flynn *et al.* 2009, Vallejo *et al.* 2009, Butler *et al.* 2010, Wanger *et al.* 2010, Galewski and Devictor 2016, Hevia *et al.* 2016, Geijzendorffer *et al.* 2018, Nopper *et al.* 2018, García-Navas and Thuiller 2020, Newbold *et al.* 2020, Morgado *et al.* 2021, Mallet *et al.* 2022). Therefore, this study emphasized that the bird and reptile biodiversity in the Gediz Delta is shaped by the effect of the landscape.

Wetlands habitats (such as marine & coastal wetlands) are considered to be some of the most threatened ecosystems worldwide (Finlayson *et al.* 1999, Davidson *et al.* 2018, Geijzendorffer *et al.* 2018), therefore we were hypothesized that priority should be given to protect these lands in order to conserve the biodiversity in the Gediz Delta. To test this hypothesis, we evaluated and ranked the threats on habitats in the delta using a multi-method threat ranking approach. Here, we showed that the main threats in the delta are "residential & commercial development", "climate change", "residential & commercial development", and "pollution". These threats could potentially affect many natural habitats such as «Coastal & Marine wetlands» and «Inland Wetlands», but current protections laws and public awareness have ensured the protection of this area (See chapter 3 for details). However, we observed that unprotected «Agricultural & Grassland» habitats, which are critical for many bird and reptile species, are threatened with more intense human pressure by intensive farming practices and urbanization (See Thesis Appendix 1). The «Agricultural & Grassland» habitats are often outside of the highly protected area, so contrary to the hypothesis, these areas need urgent conservation attention in the Gediz Delta (See Chapter 3). Therefore, the results indicate a need to extend conservation actions in the inner part of the delta to sustain different components of landscapes to protect the biodiversity.

"Residential & commercial development" is ranked as a very high direct threat contributing to habitat destruction in all-natural habitats in the delta. This is aggravated by the fact that the "transportation service and corridors" threat is also often associated with the threat of "residential & commercial development" in both the literature and stakeholder interviews. These two threats were concentrated in the inner part and on the periphery of the Delta; however, the coastal parts of the Delta have been threatened with several projects that did not materialize (See Chapter 3). Urbanization is also expected to be one of the most important future threats in the for the Gediz Delta, which already caused lost many freshwater and lagoon habitats, especially in the south of the delta (Hepcan *et al.* 2009, Avdan 2020). In conclusion, the destruction of meadows and pastures by urbanization and intensive agricultural practices could negatively affect the biodiversity of these habitats, especially «Agricultural & Grassland» bird species (Besnard and Secondi 2014). To reduce the adverse impact of urbanization and intensive farming practices, we highly recommended improving intersectoral planning and collaboration for the management of the Delta. Then increasing social awareness at both public and governmental levels is recommended to reduce the public's demands for development projects in the Delta such as bridges, etc, and efficient to manage agri-environmental.

On the other hand, "climate change" is ranked as a very high direct threat in terms of its adverse scope, severity and irreversibility on marine and inland wetlands in the Delta. Its effects on the wetland seen through severe droughts and habitats shifting and alteration (Sıkı 2020). Reoccurring droughts between 1988 and 1997 caused severe drying of the «Inland Wetlands» and «Agricultural & Grassland» habitats (Bolca *et al.* 2014, Ernoul *et al.* 2012). This study observed that these habitats are essential for protecting some reptile and bird species. In addition, the coastal lagoons in the delta have been eroded by waves and are expected to be affected by sea-level rise (Tulger *et al.* 2015). To restore these habitats, freshwater was pumped continuously to the area and the damaged flamingo island and dykes were restored (Balkız 2006, Bolca *et al.* 2014, Sıkı 2020). Despite these efforts, there has been a net decline in some habitats including reedbeds (Sıkı 2020). These short-term efforts are critical to the sustainability of these habitats and their biodiversity in the delta, but long-term planning is necessary to ensure sustainable freshwater flow over time.

The "pollution" threat is most prominent in the stakeholder interviews and literature. Pollution sources were observed in the area in from of (1) "agricultural & forestry effluents", (2) "garbage & solid waste", (3) "household sewage & urban wastewater", and (4) "industrial & military effluents". The most common sources of pollution are "agricultural & forestry effluents" and "industrial & military effluents". All three sources of information (literature review, stakeholder interviews and field visits) have identified the Gediz River as a primary source of pollution in the delta. The Gediz River has been cited as one of the most heavily polluted rivers in Turkey due to agricultural drainage water, industrial wastewater and domestic wastewater (Parlak *et al.* 2006, Efe 2007, Aydin and Kucuksezgin 2012, Suzer *et al.* 2015). On the other hand, agricultural pollution was stated as an important threat by many participants during the interviews. Despite the fact that the adverse impact of the agricultural pollutants is well documented (McLaughlin and Mineau 1995, Isenring 2010, Morgado *et al.* 2021), the extent of this effect is not known within the Gediz Delta.

The overall threat ranking indicated that «Marine & Coastal», «Inland Wetlands», and «Agricultural & Grassland» habitats are the most threatened habitats in the Gediz Delta. However, «Agricultural & Grassland» habitats need priority in conservation management for the Gediz Delta since they face major threats from pollution, construction, and intensive farming practices and do not have any conservation status. Conservation activities have been carried out to protect the «Inland Wetlands» habitats remaining in the delta, but their sustainability depends on the continuity of these conservation activities (such as pumping freshwater in to reedbeds). Despite the protection of the natural wetlands in the delta, the delta is still under a high level of threat due to the fact that the delta is located near the İzmir city, which causes the accentuation of existing threats (Sevinç 2000, Avdan 2020) (See Chapter 3 for more details).

This study has negated our hypothesis and suggests that conservation activities should not only focus on fragile wetland habitats, but should be oriented towards all-natural terrestrial and freshwater habitats in the inner parts of the delta, creating a mosaic of habitats which is beneficial for biodiversity (Galewski and Devictor 2016). Overall, the results highlight that multi-level studies with a systematic biodiversity and social monitoring approach could allow scientists to estimate the impacts of the land-use changes on different components of biodiversity and benefit conservation planning on a local landscape.

2- Suggestions for Bird Communities

Bird populations have been proven to be appropriate indicators for the environmental status of a particular ecosystem (Furness *et al.* 1993, Butler *et al.* 2010). This study shows the importance of land use on bird diversity in the Gediz Delta. Moreover, considering the results of the first and second sections, it is important to highlight that the remnant habitats can have driving effects on biodiversity. Residual habitats have possible positive effects on the occurrence pattern of some species in agricultural or urban landscapes (McLaughlin and Mineau 1995, Vallejo *et al.* 2009, Tryjanowski *et al.* 2015, Morgado *et al.* 2021). This suggests that protecting natural patches in agricultural and urban landscapes could be help protect species living in these limited habitats in the delta.

National and international laws have been successful in protecting some of the coastal and marine habitats in the Gediz Delta, however, there were considerable losses in «Inland Wetlands» before the applications of these laws (such Çiğli Marshes). The largest remaining freshwater marshes are located in the protected area, in the northern part of the Delta, surrounded by 500 hectares of reed vegetation (mostly covered with *Phargimites* sp) (Gediz Delta Management Plan 2007). It is important to note that the reedbeds of the delta were almost completely dry in the early 2000s and were naturally restored when the National Park decided to freshwater into the Reserve to protect the reeds and freshwater habitats (Ernoul *et al.* 2012, Bolca *et al.* 2014, Avdan 2020). This protection measure helped stabilize the marsh habitat and the populations of «Inland Wetlands» breeding birds and even contributed to the increase in breeding bird species in general by creating suitable habitats for some species including swans (See Chapter 1). In addition, we also observed that the freshwater water supply in these natural landscapes could also positively affect the existence of some ducks species (See Chapter 2). However, it should be noted here that these habitats are very dependent on continual fresh water supplies, and the sustainability of these habitats requires continued pumping. The other inland wetland habitats in the Delta are Sazlı Lake (30 ha) covered by *Phragmites* sp. and channels covered by concrete or *Phragmites* sp. (Gediz Delta Management Plan 2007). These freshwater habitats especially covered with *Phragmites* sp. could benefit a higher occurrence probability of «Inland Wetlands» species inside agricultural landscapes (See Chapter 2).

On the other hand, special urgent protection of «Agricultural & Grassland» is required to prevent the extinction of «Agricultural & Grassland» bird species in the delta. Previous studies have also indicated that «Agricultural & Grassland» bird species decreased or even disappeared in the Gediz Delta because of the decrease in freshwater marshes and grasslands habitats (Bolca et al. 2014, Ernoul et al. 2012, Onmuş and Siki 2013). This is similar to many other places in Europe where formerly common species were not included in conservation measures and have declined (Inger et al. 2015). Therefore, land and water management should be implemented or developed to reduce the threats' adverse impact not only for species of conservation concern, but for common species and habitats as well. This management should especially consider natural landscape patches in agricultural and urban landscapes to effectively conserve regional biodiversity in terms of the rich taxonomic elements they contain (Vallejo *et al.* 2009, Newbold *et al.* 2020). Some of the management activities could include promoting agro-ecological practices to reduce the adverse impact of intensive agricultural activities (Lillo *et al.* 2019) and ensuring long-term monitoring to determine the remnant natural habitats' impacts on biodiversity.

3- Suggestions for Reptile Communities:

Reptiles are also accepted as good indicators due to their sensitivity to environmental conditions; however, it is difficult to observe them due to their cryptic life (Crnobrnja-Isailovic 2007) and the fact that they have lower densities, richness and dispersal capacity than birds (Crnobrnja-Isailovic 2007, Moreno-Rueda and Pizarro 2007). Given these factors, we may have observed only half of the existing species compared to the 2018 study (Arslan *et al.* 2018). On the other hand, the scrub hills of the delta, which we did not sample in this study, have a very rich reptile diversity and provide natural habitat in the Delta (Arslan *et al.* 2018). Similar to previous studies (Garden *et al.* 2007, Moreno-Rueda and Pizarro 2007, Barrett and Guyer 2008), the decrease in richness between 2018 and 2021 may also highlight importance of habitats for these specialized species, since scrub hills were not sampled in this study. Besides, this particular habitat is also threatened by urbanization (see chapter 3 and other studies (Onmuş and Siki 2013, Arslan *et al.* 2018)). Threats to this habitat could have an impact on the threatened species *Testudo graeca,* listed VU by IUCN, as they prefer open shrub habitats to complete their life cycle (Anadón *et al.* 2006, Arslan *et al.,* 2018). Moreover, It should be noted that reptile species have a low recovery capacity; therefore, land-use change on a local scale could cause a significant reduction in the richness of reptiles and cause local extinction (Moreno-Rueda and Pizarro 2007, Cordier *et al.* 2021). Therefore, in order to protect these species in the delta, conservation activities should concentrate on all-natural terrestrial and freshwater habitats in the inner parts of the delta. Special attention should be given to freshwater habitats either in channels or small natural habitats (such ponds or Sazlıgöl) in the inner part of Delta to ensure the existence of aquatic reptiles (Arslan *et al.* 2018). This is essential for the threatened species *Emys orbicularis,* listed near threatened (NT) by IUCN, which requires permanent freshwater ponds for breeding and feeding (Ficetola *et al.* 2004).

4- Limitations of the study

In this thesis, we have shown that land-cover changes impact biodiversity to a large extent in Gediz Delta; however, we acknowledge some limitations to our study. In chapter we used expert knowledge to calculate the abundance of birds species, which could have some biases linked to observers' subjectivity. The use of historical reports and gray literature may have reduced these biases. Another limitation of this study is in the second chapter where we attempted to link changes in the reptile and bird community to main landscape types. Variations within each grid (such as remaining habitats, environmental heterogeneity) may have caused some bias for community responses throughout our study. In order to compensate for this eventual bias, we recommend that future studies look at the effects of these residual habitats on biodiversity. Similarly, in our study, it was frequently mentioned in the interviews that pollution may have an impact on biodiversity, but there is not enough information in literature about the extent of this threat. Therefore, we also recommend that future studies look at the effects of pollution in the Gediz Delta on biodiversity, especially for fish and amphibian species.

Conclusion

This thesis examined land-cover impact from three different perspectives on biodiversity in the Gediz Delta, an important wetland in the Mediterranean Basin. Using expert knowledge surveys and multi-taxon field observations, we demonstrated that land use is a driving factor for biodiversity in the Gediz Delta. This is of upmost importance as our multi-method threat ranking showed that "residential & commercial development" and "climate change" are very severe threats in the delta. If these threats are not managed properly, they can contribute to the further destruction of habitats with negative effects on the biodiversity. Even we could not estimate all dimensions of the land use, such as remnant habitats, environmental heterogeneity is regarded as one of the most important components to sustain high biodiversity (Stein *et al.* 2014). Therefore, it is highly recommended to work on the impacts of remnant habitats on different taxa in future studies, with long term monitoring studies. To maintain high biodiversity, more attention must be given to holistic land management, integrating a mosaic of habitat types (Garden *et al.* 2007, Tryjanowski *et al.* 2015, Mallet *et al.*, 2022).

APPENDIX 1

Using Satellite Time Series to Monitor Land Use and Land Cover Changes 1984-2019 within a Ramsar site (the Gediz Delta, Turkey)

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Summary:

Mapping land use/land cover (LULC) changes of ecosystems is essential for planning and management activities for conserving a particular habitat. In this study, Gediz Delta LULC was investigated between 1984-2019 using Remote sensing and Geographic Information Systems (GIS) and the maps were built upon the Horizon-2020 SWOS processing methodology and algorithms. Gediz Delta, a Ramsar area, is located close to the city of Izmir, Turkey. Here, we evaluated land-use changes in the Gediz Delta and aimed to showed wider changes for the delta. The results indicate that land cover changes have occurred in urbanized areas (+ 147. 14 %), natural wetlands (-33.24 %), natural dry lands (- 27.04 %), artificial wetlands (+ 35. 05 %), sea (+11.15 %) and no major changes were observed in agricultural areas (- 2. 16 %) between 1984-2019. It was seen that the LULC changes mostly occurred in natural wetlands and natural dry lands between 1984-2010. However, while no major land use change was observed in the Ramsar region between 2010-2019, it was observed that urbanization increased again outside the Ramsar area. This study provides important information to managing the land resource to conserve the delta in the future.

Methodology:

The study area: Gediz Delta (38˚ 30'N, 26˚ 55'E) is one of the most important wetlands in the Mediterranean basin and is located on the Aegean Sea coast in the west of Turkey (Figure 1). Gediz Delta extends over approximately 40,000 ha, covering the provinces of Uşak, Manisa and Izmir, starting from the Gediz River in the province of Kütahya and formed by aggregations of the alluvial materials carried by the Gediz River, and flowing into the Aegean Sea just north of Izmir (Arslan et al., 2018). Gediz Delta has a typical Mediterranean delta ecosystem, composed of a mosaic of salt and freshwater marshes (5000 ha), saltpans (3300 ha), four lagoons (Homa 1824 ha; Çilazmak 725 ha; Kırdeniz 450 ha; Taş 500 ha) (Gediz Delta Management Plan 2007), the Gediz River, and agricultural and dry hilly habitats (Arslan *et al.* 2018). We used satellite images from 1984-2019 to determine land use /land cover changes in and around the protected area of the delta. The flat area between the old and new branches of the Gediz River were chosen to analyze general land use/land cover changes in the non-protected area (Figure 1). The areas within the borders of the Ramsar site (as protected area areas) were extracted to evaluated how the LULC of the protected area changed.

Land Use / Land Cover Change (LULC) in the Delta: Within the studied area, Land Use/Land Cover (LULC) maps were produced using Landsat TM, Landsat ETM and Sentinel-2 time series satellite images covering 1984, 1990, 2000, 2010 and 2019 annual time periods (supplement material 1). Based on these maps, it was then possible to analyze the long-term LULC dynamics observed over the entire studied time range (1984-2019) and to derive the status and trend statistics corresponding to each habitat class.

We used a mapping approach built upon the Horizon-2020 SWOS processing methodology and algorithms (Weise *et al.* 2020). It includes object and rule-based classification algorithms and integrates a hybrid LULC nomenclature that was developed during the ESA/DUE GlobWetland-II project combining CORINE Land Cover (CLC) classes with the Ramsar habitat definitions (Mediterranean Wetland Observatory 2014). Thus, the produced LULC maps capture the status of wetland ecosystems, regarding their main types, spatial extent, and human pressures they face (e.g. agriculture expansion and urban sprawl). Then, we grouped those habitats in 6 classes "Built up Areas", "Agricultural areas", "Natural Dry lands", "Natural wetlands", "Artificial Wetlands", and "Sea" (supplement material 1). Each habitat classes area was calculated using the ArcGIS Calculator for inside and outside of the Ramsar zone in 1984, 1990, 2000, 2010 and 2019. We then determined for each habitat type how much land was converted and transformed this into other as a percentage.

Results:

The LULC classification results for the Gediz Delta are summarized for the years 1984 and 2019 in Table 1. LULC classes were aggregated into six categories (Table 1) and the variation of these categories was assessed. In 1984, the delta surface area in general had 21.18 % natural dry-lands and 13.34 % natural wetlands as natural ecosystems (Figure 2). The natural dry land, which includes bush and scrub habitats, is mainly located outside the Ramsar site. The natural wetlands, which is includes inland wetlands (water courses, inland marches, lakes, wet forests, reedbeds) and coastal wetlands (lagoons, salt marches, intertidal flats, shores etc.) is mainly located inside the Ramsar site. However, by 2019, the presence of these natural areas decreased in the area, leaving 8.90 % natural wetlands and 15.45 % natural dry lands in the Delta since 1984. The existing surface in 1984 of natural habitats was reduced by 27.04% of natural drylands and 33.24% of natural wetlands until 2019 (Figure 3). Most of the conversion of those natural habitats was into built-up areas. There has been an increase in anthropogenic pressures in the Delta from 1984 to 2019. The main changes can be attributed to the conversion of natural drylands (17.00%) and agricultural areas (8.44%) in 1984 into built-up areas in 2019. the total percentage of conversion in the Delta involved 147 % of the built-up increase (Figure 3). The LULC change maps also highlighted that one of the other main observed transformations between 1984 and 2019 was the rapid progression of sea and marine waters at the detriment of coastal brackish wetland habitats (lagoons), especially in the southern part of the delta. According to our classification, artificial wetlands increased by approximately 35% in the delta while the sea increase in 11%. The increase in artificial wetlands (mainly through converting managed salinas) and seas was achieved with the loss of natural wetlands by 13.29% and 13.59%, respectively, during the same time laps (Figure 4).

Tables and Figures:

Table 1: Coverage area (ha) of land use from 1984 to 2019 in the Ramsar site and study area in the Gediz Delta.

LULC SupClas	*Borders*	*Area 1984 (ha)*	*Area 1990 (ha)*	*Area 2000 (ha)*	*Area 2010 (ha)*	*Area 2019 (ha)*
Built-up areas	*Gediz Delta*	4253.2	5319.7	7067.6	8318.6	10511.5
	Ramsar Area	645.2	684.5	690.6	698.8	756.4
Agriculture	*Gediz Delta*	32637.9	33031.9	32789.2	32683.1	31931.5
	Ramsar Area	562.2	583.0	571.3	604.0	610.3
Natural dry lands	*Gediz Delta*	17619.9	16425.8	15083.9	14162.1	12854.2
	Ramsar Area	374.0	356.9	365.7	373.9	362.5
Natural wetlands	*Gediz Delta*	11101.7	10300.7	9323.6	7666.8	7410.6
	Ramsar Area	8029.6	7387.1	6493.9	5525.3	5434.3
Artificial wetlands	*Gediz Delta*	3951.8	4462.9	4809.2	5260.3	5337.0
	Ramsar Area	2328.5	2898.7	3322.5	3630.6	3620.5
Sea	*Gediz Delta*	13628.7	13652.2	14119.8	15102.3	15148.4
	Ramsar Area	3338.8	3368.2	3834.3	4445.8	4494.3

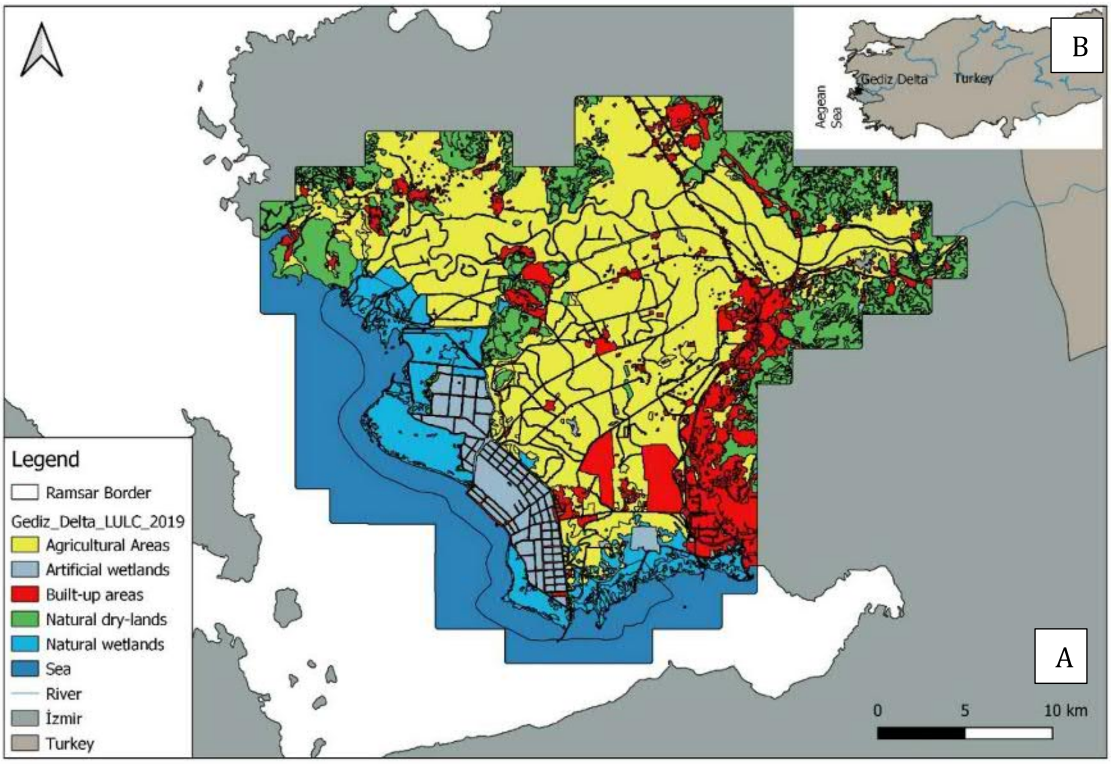


Figure 1: Location of the the Gediz Delta (A) with 2019 LULC maps in Turkey(B).

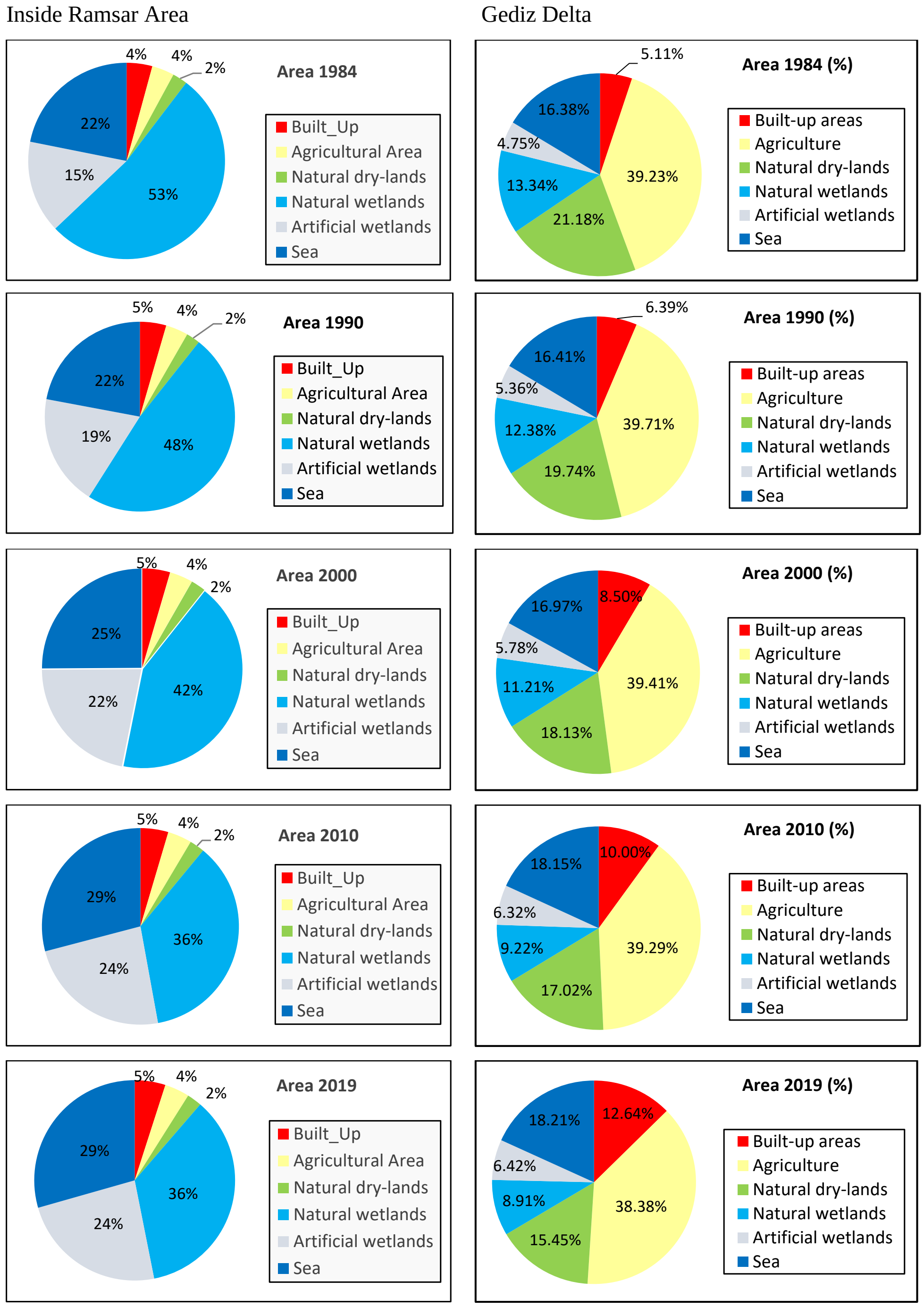


Figure 2: Land use change inside the Ramsar site and the Gediz Delta, Turkey from 1984 to 2019 and classified into 6 categories: Built up Area, Agricultural Area, Natural dry lands, Natural wetlands, Artificial wetlands and Sea.

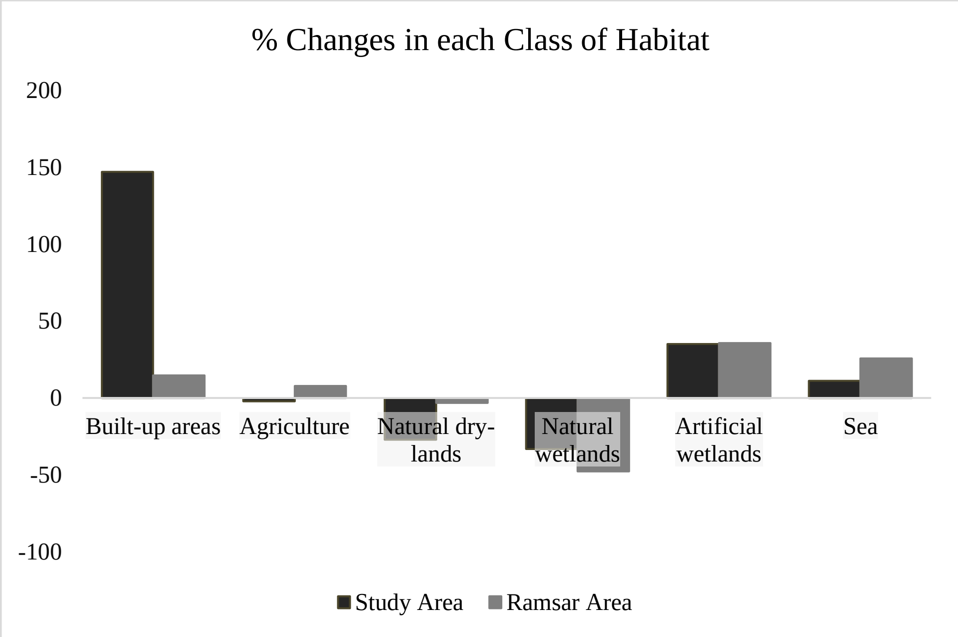
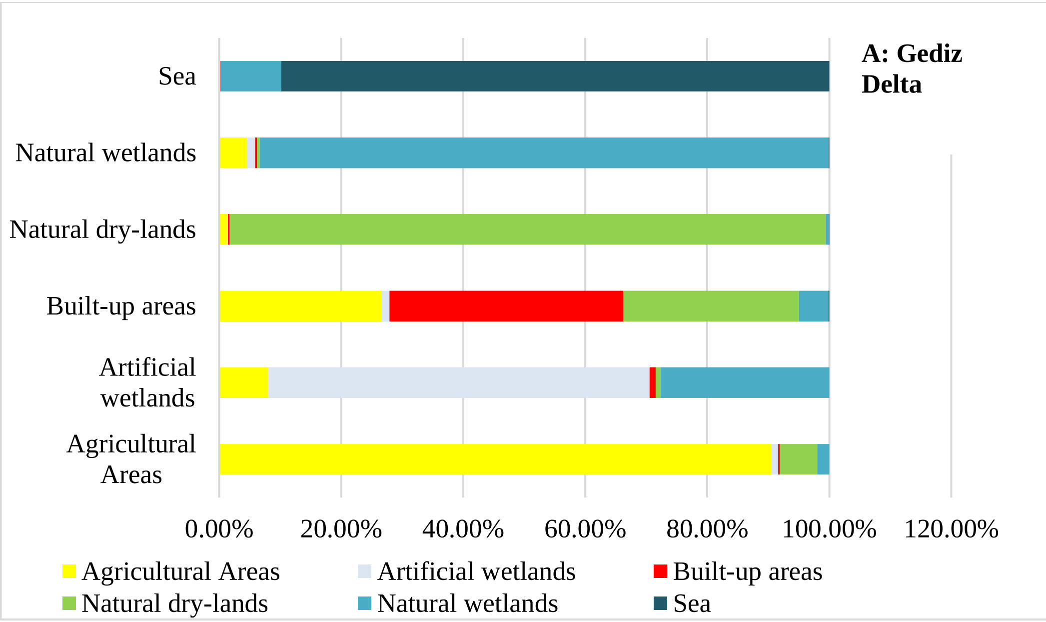


Figure 3: A- Percentage change of each LULC class in the Ramsar site and the Gediz Delta between 1984 and 2019. LULC was classified into 6 categories: Built-up Areas, Agricultural area, Natural dry lands, Natural wetlands, Artificial wetlands and Sea.



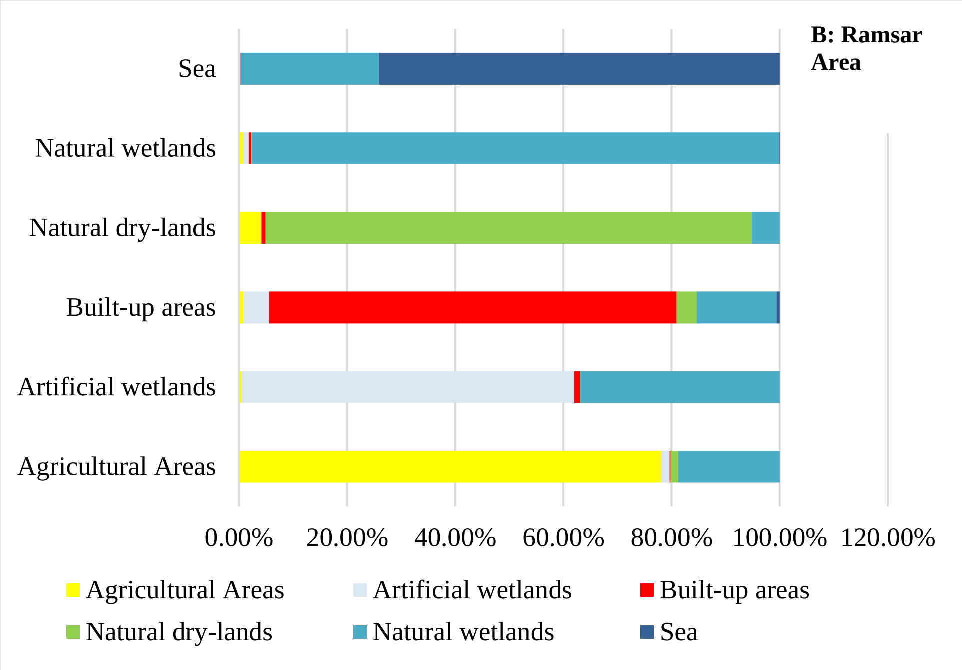


Figure 4: Composition of land cover and land use category from 1984 to 2019 for Gediz Delta. A: Gediz Delta, B: Ramsar Area.

REFERENSE

Arslan, D., Oliver, A., Yaşar, Ç., Ismail, İ.B., Döndüren, Ö., Ernoul, L., Beck, N., and Çiçek, K., 2018. Distribution and current status of herpetofauna in the Gediz Delta (Western Anatolia, Turkey). Herpetology Notes, 11, 1–15.

Gediz Delta Management Plan, 2007. Gediz Deltası Sulak Alan Yönetim Planı, [Gediz Delta Management Plan]. İzmir, Turkey, T.C. Çevre ve Orman Bakanliği Doğa Koruma ve Milli Parklar Genel Müdürlüğü, Doğa Koruma Dairesi Başkanlığı, Sulak Alanlar Şubesi Müdürlüğü.

Weise, K., Höfer, R., Franke, J., Guelmami, A., Simonson, W., Muro, J., O'Connor, B., Strauch, A., Flink, S., Eberle, J., Mino, E., Thulin, S., Philipson, P., van Valkengoed, E., Truckenbrodt, J., Zander, F., Sánchez, A., Schröder, C., Thonfeld, F., Fitoka, E., Scott, E., Ling, M., Schwarz, M., Kunz, I., Thürmer, G., Plasmeijer, A., and Hilarides, L., 2020. Wetland extent tools for SDG 6.6.1 reporting from the Satellite-based Wetland Observation Service (SWOS). Remote Sensing of Environment, 247, 111892.

APPENDİX 2

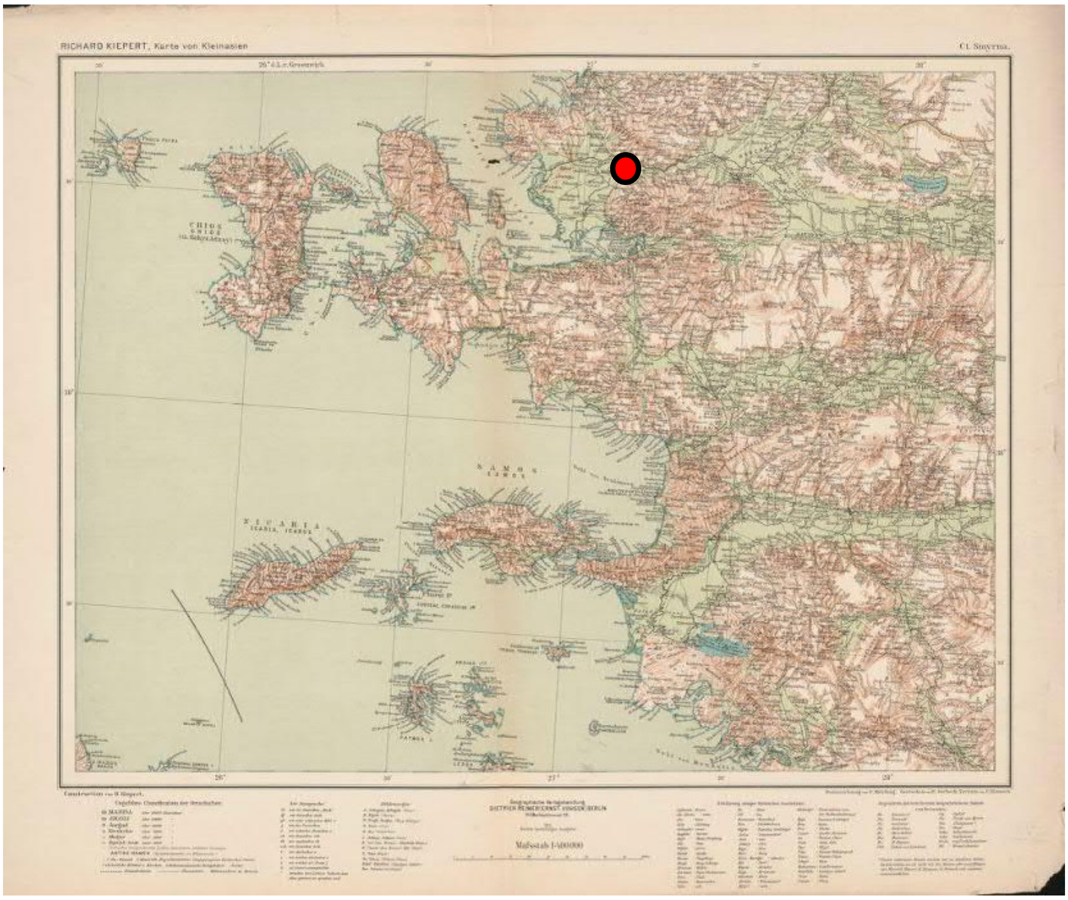


Figure 1: Aegean region 1915 Map, Location of Gediz Delta is marked with red. Click for the original map. The map created by (Kiepert 1908)
The map downloaded from Library of Congress Geography and Map Division Washington, D.C. 20540-4650 USA dcu. (*https://hdl.loc.gov/loc.gmd/g7430m.gct00325*).

REFERENCES

Abrego, N., Norberg, A., and Ovaskainen, O., 2017. Measuring and predicting the influence of traits on the assembly processes of wood-inhabiting fungi. Journal of Ecology, 105 (4), 1070–1081.

Adams, W.M., Small, R.D.S., and Vickery, J.A., 2014. The impact of land use change on migrant birds in the Sahel. Biodiversity, 15 (2–3), 101–108.

Aksu, A.E., Konuk, T., Ulug, A., Duman, M., and PIPER, D.W., 1990. Quaternary tectonic and sedimentary history of Eastern Aegean Sea shelf area. Jeofizik, 4 (1), 3–35.

Aksu, A.E., Piper, D.J.W., and Konuk, T., 1987. Late Quaternary tectonic and sedimentary history of outer Izmir and Candarli bays, western Turkey. Marine Geology, 76, 89–104.

Akyol, D. and Sönmez, İ.Ö., 2018. Wetlands under the Pressure of Urbanization: The Gediz Delta Case-Science, Ecology and Engineering Research in the Globalizing World. ST Kliment Ohridski University Press.

Alderson, J. and Sander, H.A., 2021. Combining historical accounts with contemporary bird survey data identifies changes in an avian community over a period of anthropogenic change. Ibis.

Alevkayali, Ç. and Tağil, Ş., 2018. Ortak Malların Trajedisi Üzerine Teoriler: Gediz Deltası'nda Arazi Kullanımı-Arazi Örtüsü Değişimi. Süleyman Demirel Üniversitesi Fen-Edebiyat Fakültesi Sosyal Bilimler Dergisi, (43), 120–142.

Almond, R.E., Grooten, M., and Peterson, T., 2020. Living Planet Report 2020-Bending the curve of biodiversity loss. World Wildlife Fund.

Anadón, J.D., Giménez, A., Perez, I., Martinez, M., and Esteve, M.A., 2006. Habitat selection by the spur-thighed tortoise Testudo graeca in a multisuccessional landscape: implications for habitat management. Biodiversity & Conservation, 15 (7), 2287–2299.

Arslan, D., Ernoul, L., Béchet, A., Döndüren, Ö., Siki, M., and Galewski, T., Unpublished work. Using literature and expert knowledge to determine changes in a Turkish wetland bird community over the last 40 years.

Arslan, D., Oliver, A., Yaşar, Ç., Ismail, İ.B., Döndüren, Ö., Ernoul, L., Beck, N., and Çiçek, K., 2018. Distribution and current status of herpetofauna in the Gediz Delta (Western Anatolia, Turkey). Herpetology Notes, 11, 1–15.

Arslan, D., Olivier, A., Ernoul, L., Béchet, A., and Çiçek, K., 2021. Demography, distribution, and threat assessment of the Spur-thighed Tortoise (*Testudo graeca*) in the Gediz Delta, Turkey (Reptilia: Testudines). Zoology in the Middle East, 67 (3), 216–227.

Arslan, Ş. and Akyol, A., 2020. Güney Gediz Deltası 2020 Yılı Üreyen Kuş Atlası Çalışması. İzmir, Turkey: Doğa Derneği.

Attum, O., Eason, P., Cobbs, G., and El Din, S.M.B., 2006. Response of a desert lizard community to habitat degradation: do ideas about habitat specialists/generalists hold? Biological conservation, 133 (1), 52–62.

Avdan, A.O., 2020. The making of consurbia: Conservation, urbanization, and socio-environmental change in Turkey's Gediz Delta. Thesis. Arts & Social Sciences: Department of Sociology and Anthropology.

Aydin, S. and Kucuksezgin, F., 2012. Distribution and chemical speciation of heavy metals in the surficial sediments of the Bakırçay and Gediz Rivers, Eastern Aegean. Environmental Earth Sciences, 65 (3), 789–803.

Babbie, E.R., 2007. The Practice of Social Research. 11th ed. Thomson Higher Education.

Balkız, Ö., 2006. Metapopulation dynamics of the greater flamingo in the Mediterranean (implications for conservation). PhD Thesis. Université de Montpellier 2 Sciences et Techniques du Languedoc, Montpellier.

Balkız, Ö., Onmuş, O., Sıkı, M., Döndüren, Ö., Gül, O., Arnaud, A., Germain, C., İsfendiyaroğlu, S., Özbek, M., Çağlayan, E., Araç, N., Parmak, B., Özesmi, U., and Béchet, A., 2015. Turkey as a crossroad for Greater Flamingos Phoenicopterus roseus: evidence from population trends and ring-resightings (Aves: Phoenicopteridae). Zoology in the Middle East, 61 (3), 201–214.

Balkiz, O., Özesmi, U., Pradel, R., Germain, C., Siki, M., Amat, J.A., Rendón-Martos, M., Baccetti, N., Bechet, A., and others, 2009. An update of the greater flamingo Phoenicopterus roseus in Turkey. Special Publication 1 Proceedings of the IVth International Workshop on the Greater Flamingo in the Mediterranean region and northwest Africa. Bulletin of the IUCN-SSC/Wetlands International Flamingo Specialist Group.

Ballance, D.K. and Lee, S.L.B., 1961. Notes on autumn migration at the Bosphorus and in the Aegean. Ibis, 103 (2), 195–204.

Barnosky, A.D., Matzke, N., Tomiya, S., Wogan, G.O., Swartz, B., Quental, T.B., Marshall, C., McGuire, J.L., Lindsey, E.L., and Maguire, K.C., 2011. Has the Earth's sixth mass extinction already arrived? Nature, 471 (7336), 51–57.

Barrett, K. and Guyer, C., 2008. Differential responses of amphibians and reptiles in riparian and stream habitats to land use disturbances in western Georgia, USA. Biological Conservation, 141 (9), 2290–2300.

Bates, D., Mächler, M., Bolker, B., and Walker, S., 2015. Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67, 1–48.

Besnard, A.G. and Secondi, J., 2014. Hedgerows diminish the value of meadows for grassland birds: Potential conflicts for agri-environment schemes. Agriculture, Ecosystems & Environment, 189, 21–27.

Binbir Gıda Tuzla İşletmesi, 2021. History | Corporate | Binbirgida [online]. Available from: https://www.binbirgida.com/en-us/corporate/history [Accessed 16 Jul 2021].

BirdLife International, 2017. European birds of conservation concern: populations, trends and national responsibilities. Cambridge, UK: BirdLife International.

BirdLife International, 2019. IUCN Red List of Threatened Species: Phoenicopterus roseus. IUCN Red List of Threatened Species.

BirdLife International, 2021. Important Bird Areas factsheet: Gediz Delta. [online]. Available from: http://datazone.birdlife.org/site/factsheet/gediz-delta-iba-turkey/text [Accessed 27 Aug 2021].

Biró, M., Molnár, Z., Öllerer, K., Lengyel, A., Ulicsni, V., Szabados, K., Kiš, A., Perić, R., Demeter, L., and Babai, D., 2020. Conservation and herding co-benefit from traditional extensive wetland grazing. Agriculture, Ecosystems & Environment, 300, 106983.

Boissinot, A., Besnard, A., and Lourdais, O., 2019. Amphibian diversity in farmlands: Combined influences of breeding-site and landscape attributes in western France.

Agriculture, Ecosystems & Environment, 269, 51–61.

Boivin, N.L., Zeder, M.A., Fuller, D.Q., Crowther, A., Larson, G., Erlandson, J.M., Denham, T., and Petraglia, M.D., 2016. Ecological consequences of human niche construction: Examining long-term anthropogenic shaping of global species distributions. Proceedings of the National Academy of Sciences, 113 (23), 6388–6396.

Bolca, M., Özen, F., and Güneş, A., 2014. Land use changes in Gediz Delta (Turkey) and their negative impacts on wetland habitats. Journal of Coastal Research, 30 (4), 756–764.

Bonebrake, T.C., Christensen, J., Boggs, C.L., and Ehrlich, P.R., 2010. Population decline assessment, historical baselines, and conservation: Inferring population declines. Conservation Letters, 3 (6), 371–378.

Borges, E.R., Dexter, K.G., Pyles, M.V., Bueno, M.L., Santos, R.M. dos, Fontes, M.A.L., and Carvalho, F.A., 2021. The interaction of land-use history and tree species diversity in driving variation in the aboveground biomass of urban versus non-urban tropical forests. Ecological Indicators, 129, 107915.

Boylan, K.D. and MacLean, D.R., 1997. Linking species loss with wetlands loss. National Wetlands Newsletter, 19 (6), 13–17.

Braje, T.J. and Erlandson, J.M., 2013. Human acceleration of animal and plant extinctions: A Late Pleistocene, Holocene, and Anthropocene continuum. Anthropocene, 4, 14–23.

Buckland, S.T., Magurran, A.E., Green, R.E., and Fewster, R.M., 2005. Monitoring change in biodiversity through composite indices. Philosophical Transactions of the Royal Society B: Biological Sciences, 360 (1454), 243–254.

Burnham, K.P. and Anderson, D.R., 2002. A practical information-theoretic approach. Model selection and multimodel inference, 2.

Butler, S.J., Boccaccio, L., Gregory, R.D., Vorisek, P., and Norris, K., 2010. Quantifying the impact of land-use change to European farmland bird populations. Agriculture, Ecosystems & Environment, 137 (3), 348–357.

Castro-Expósito, A. de, García-Muñoz, E., and Guerrero, F., 2021. Reptile diversity in a Mediterranean wetlands landscape (Alto Guadalquivir region, southeastern Spain): are they affected by human impacts? Acta Herpetologica, 16 (1), 27–36.

Çetin, H.C., Harmancıoğlu, N., Sarıyıldız, A., and Silay, A.E., 2009. Gediz nehri su kalitesi parametrelerinin eğilim analizi. TMMOB İzmir Kent Sempozyumu, 603–611.

Chace, J.F. and Walsh, J.J., 2006. Urban effects on native avifauna: a review. Landscape and Urban Planning, 74 (1), 46–69.

Chamberlain, D.E. and Crick, H.Q.P., 1999. Population declines and reproductive performance of Skylarks Alauda arvensis in different regions and habitats of the United Kingdom. Ibis, 141 (1), 38–51.

Chase, J.M., 2007. Drought mediates the importance of stochastic community assembly. PNAS, 104 (44).

Christoffersen, L.E., 1997. IUCN: A Bridge-Builder for Nature Conservation. Green Globe Yearbook, 59–70.

CMP, C.M.P., 2021. About Conservation Standards (CS). The Open Standards for the Practice of Conservation.

Cohen, J.E., 2003. Human Population: The Next Half Century. Science, 302 (5648), 1172–1175.

Cordier, J.M., Aguilar, R., Lescano, J.N., Leynaud, G.C., Bonino, A., Miloch, D., Loyola, R., and Nori, J., 2021. A global assessment of amphibian and reptile responses to land-use changes. Biological Conservation, 253, 108863.

Crnobrnja-Isailovic, J., 2007. Cross-section of a refugium: genetic diversity of amphibian and reptile populations in the Balkans. In: S. Weiss and N. Ferrand, eds. Phylogeography of Southern European Refugia: Evolutionary perspectives on the origins and conservation of European biodiversity. Dordrecht: Springer Netherlands, 327–337.

Cummings, V., 2014. Hunter-Gatherers in the Post-Glacial World [online]. The Oxford Handbook of the Archaeology and Anthropology of Hunter-Gatherers. Available from: https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199551224.001.0001/oxfordhb-9780199551224-e-027 [Accessed 11 May 2020].

Daoud-Bouattour, A., Muller, S.D., Jamaa, H.F.-B., Saad-Limam, S.B., Rhazi, L., Soulié-Märsche, I., Rouissi, M., Touati, B., Jilani, I.B.H., Gammar, A.M., and Ghrabi-Gammar, Z., 2011. Conservation of Mediterranean wetlands: Interest of historical approach. Comptes Rendus Biologies, 334 (10), 742–756.

Darwall, W., Carrizo, S., Numa, C., Barrios, V., Freyhof, J., and Smith, K., 2014. Freshwater Key Biodiversity Areas in the Mediterranean Basin Hotspot: Informing species conservation and development planning in freshwater ecosystems. IUCN, Cambridge, 86.

Dauphiné, N. and Cooper, R.J., 2009. Impacts of free-ranging domestic cats (Felis catus) on birds in the United States: a review of recent research with conservation and management recommendations. In: Proceedings of the fourth international partners in flight conference: tundra to tropics.

Davidson, N.C., 2014. How much wetland has the world lost? Long-term and recent trends in global wetland area. Marine and Freshwater Research, 65 (10), 934–941.

Davidson, N.C., Fluet-Chouinard, E., and Finlayson, C.M., 2018. Global extent and distribution of wetlands: trends and issues. Marine and Freshwater Research, 69 (4), 620–627.

Davraz, A., Sener, E., and Sener, S., 2019. Evaluation of climate and human effects on the hydrology and water quality of Burdur Lake, Turkey. Journal of African Earth Sciences, 158, 103569.

De Laet, J. and Summers-Smith, J.D., 2007. The status of the urban house sparrow *Passer domesticus* in north-western Europe: a review. Journal of Ornithology, 148 (2), 275–278.

De Wit, R., Vincent, A., Foulc, L., Klesczewski, M., Scher, O., Loste, C., Thibault, M., Poulin, B., Ernoul, L., and Boutron, O., 2019. Seventy-year chronology of Salinas in southern France: Coastal surfaces managed for salt production and conservation issues for abandoned sites. Journal for Nature Conservation, 49, 95–107.

Delibacak, S. and Okur, B., 2000. Infiltration rate and heavy metal contents in common soils of the Gedİz delta. Ege Üniversitesi Ziraat Fakültesi Dergisi, 37 (1), 9–16.

Denizli, Ö., 2021. Gediz Havzası ölmesin, öldürülmesin. Özgür Denizli. Available from: https://ozgurdenizli.com/gediz-havzasi-olmesin-oldurulmesin/ [Accessed on 2021-11-17]

Devictor, V., Julliard, R., Couvet, D., Lee, A., and Jiguet, F., 2007. Functional homogenization effect of urbanization on bird communities. Conservation Biology, 21 (3), 741–751.

Dixon, M.J.R., Loh, J., Davidson, N.C., Beltrame, C., Freeman, R., and Walpole, M., 2016. Tracking global change in ecosystem area: The Wetland Extent Trends index. Biological Conservation, 193, 27–35.

Donald, P.F., Sanderson, F.J., Burfield, I.J., and van Bommel, F.P.J., 2006. Further evidence of continent-wide impacts of agricultural intensification on European farmland birds, 1990–2000. Agriculture, Ecosystems & Environment, 116 (3), 189–196.

Döndüren, Ö., 2015. Gediz Nehri Havzası'nda Leylek (*Ciconia ciconia* L., 1758) Popülasyonunun Tespiti, Popülasyon Değişimlerinin ve Popülasyonu Etkileyen Etmenlerin Belirlenmesi İle Türün Göç Dinamikleri Üzerine Araştırmalar. Ege Üniversitesi, İzmir, Turkey.

Dora, E.Ç., Sunlu, U., and Ergen, Z., 2007. Heavy Metal Concentrations In Hediste diversicolor (Polychaeta) And Sediments From Homa Lagoon (Izmir Bay-Turkey). Rapp. Comm. int. Mer Médit, 38, 1.

Dudley, N. and Alexander, S., 2017. Agriculture and biodiversity: a review. Biodiversity, 18 (2–3), 45–49.

Dudley, N., 2008. Guidelines for applying protected area management categories. Iucn.

Durmuşkahya, C., 2005. Aşağı Gediz havzası vejetasyon ekolojisi / Vegetation ecology of lower Gediz basin. Ege Üniversitesi, İzmir, Turkey.

Ebird, 2020. Ebird: An online database of bird distribution and abundance [web application]. Ebird, Cornell Lab of Ornithology, Ithaca, New York [online]. Available from: http://www.ebird.org [Accessed 12 Aug 2020].

Efe, R., 2007. Environmental change and wetland management: A case study in the Gediz Delta Ecosystem (Western Turkey). Presented at the International Conference of Global Changes and Problems-Theory and Practice, Sofia, Bulgaria: Sofia University 'St. Kliment Ohridski' Faculty of Geology and Geography, 16–22.

Eken, G., 1997. The breeding population of some species of waterbirds at Gediz Delta, Western Turkey. Zoology in the Middle East, 14 (1), 53–68.

Eken, G., Bozdoğan, M., İsfendiyaroğlu, S., Kılıç, D.T., and Lise, Y., 2006. Türkiye'nin önemli doğa alanları. Ankara, Turkey: Doğa Derneği.

Ekoloji Birliği, 2020. Gediz Nehri'nda balık ölümleri devam ediyor! [online]. Ekoloji Birliği. Available from: https://ekolojibirligi.org/gediz-yataginda-oksijensizlikten-binlerce-balik-oldu/ [Accessed 3 Nov 2021].

Ellis, E.C., 2015. Ecology in an anthropogenic biosphere. Ecological Monographs, 85 (3), 287–331.

Erinç, S., 1955. Gediz ve Büyük Menderes deltalarının morfolojisi [Morphology of Gediz and Great Menderes deltas]. Presented at the Dokuzuncu coğrafya meslek haftası tebliğler ve konferanslar, İstanbul: Türk Coğrafya Kur. Yay, 33–66.

Ernoul, L. and Wardell-Johnson, A., 2014. Adapting international conservation strategies to local context: perceptions of biodiversity values and management responsibility in two Mediterranean deltas. International Journal of Biodiversity Science, Ecosystem Services & Management, 1–13.

Ernoul, L., Sandoz, A., and Fellague, A., 2012. The evolution of two great Mediterranean Deltas: Remote sensing to visualize the evolution of habitats and land use in the Gediz and Rhone Deltas. Ocean & coastal management, 69, 111–117.

Ewers, R.M. and Didham, R.K., 2006. Confounding factors in the detection of species responses to habitat fragmentation. Biological Reviews, 81 (1), 117–142.

Fellows, I., Fellows, M.I., Rcpp, L., and Rcpp, L., 2018. Package 'wordcloud'. R Package, Maintainer Ian and Rcpp, Linking To and Rcpp.[(accessed on 4 February 2021)].

Fewster, R.M., Buckland, S.T., Siriwardena, G.M., Baillie, S.R., and Wilson, J.D., 2000. Analysis of population trends for farmland birds using generalized additive models. Ecology, 81 (7), 1970–1984.

Ficetola, G.F., Padoa-Schioppa, E., Monti, A., Massa, R., Bernardi, F.D., and Bottoni, L., 2004. The importance of aquatic and terrestrial habitat for the European pond turtle (Emys orbicularis): implications for conservation planning and management. Canadian Journal of Zoology, 82 (11), 1704–1712.

Finlayson, C.M., Davidson, N.C., Spiers, A.G., and Stevenson, N.J., 1999. Global wetland inventory – current status and future priorities. Marine and Freshwater Research, 50 (8), 717–727.

Flynn, D.F.B., Gogol-Prokurat, M., Nogeire, T., Molinari, N., Richers, B.T., Lin, B.B., Simpson, N., Mayfield, M.M., and DeClerck, F., 2009. Loss of functional diversity under land use intensification across multiple taxa. Ecology Letters, 12 (1), 22–33.

Fraixedas, S., Galewski, T., Ribeiro-Lopes, S., Loh, J., Blondel, J., Fontès, H., Grillas, P., Lambret, P., Nicolas, D., Olivier, A., and Geijzendorffer, I.R., 2019. Estimating biodiversity changes in the Camargue wetlands: An expert knowledge approach. PLOS ONE, 14 (10), e0224235.

Furness, R.W., Greenwood, J.J.D., and Jarvis, P.J., 1993. Can birds be used to monitor the environment? In: Birds as monitors of environmental change. Springer, 1–41.

Galewski, T. and Devictor, V., 2016. When Common Birds Became Rare: Historical Records Shed Light on Long-Term Responses of Bird Communities to Global Change in the Largest Wetland of France. PLOS ONE, 11 (11), e0165542.

Galewski, T., Collen, B., McRae, L., Loh, J., Grillas, P., Gauthier-Clerc, M., and Devictor, V., 2011. Long-term trends in the abundance of Mediterranean wetland vertebrates: from global recovery to localized declines. Biological Conservation, 144 (5), 1392–1399.

Galewski, T., Segura, L., Biquet, J., Saccon, E., and Boutry, N., 2021. Living Mediterranean Report – Monitoring species trends to secure one of the major biodiversity hotspots. Arles (FRA) : Tour du Valat.

García-Navas, V. and Thuiller, W., 2020. Farmland bird assemblages exhibit higher functional and phylogenetic diversity than forest assemblages in France. Journal of Biogeography, 47 (11), 2392–2404.

Garden, J.G., Mcalpine, C.A., Possingham, H.P., and Jones, D.N., 2007. Habitat structure is more important than vegetation composition for local-level management of native terrestrial reptile and small mammal species living in urban remnants: A case study from Brisbane, Australia. Austral Ecology, 32 (6), 669–685.

Gardener, M., 2014. Community ecology: analytical methods using R and Excel. Pelagic Publishing Ltd.

Gardner, R.C. and Finlayson, C., 2018. Global Wetland Outlook: State of the World's Wetlands and Their Services to People. Rochester, NY: Social Science Research Network, SSRN Scholarly Paper No. ID 3261606.

GDNCNP, 2020. Korunan Alanlar İstatistikleri, 2019 (Statistic for protected areas 2019). Available from: https://www.tarimorman.gov.tr/DKMP/Menu/18/Korunan-Alan-Istatistikleri. Accessed on 08.12.2020

Gediz Delta Management Plan, 2007. Gediz Deltası Sulak Alan Yönetim Planı, [Gediz Delta Management Plan]. İzmir, Turkey, T.C. Çevre ve Orman Bakanliği Doğa Koruma ve Milli Parklar Genel Müdürlüğü, Doğa Koruma Dairesi Başkanlığı, Sulak Alanlar Şubesi Müdürlüğü.

Gediz Delta Management Plan, 2020. Gediz Deltası Sulak Alan Yönetim Planı, [Gediz Delta Management Plan]. İzmir, Turkey, T.C. Çevre ve Orman Bakanliği Doğa Koruma ve Milli Parklar Genel Müdürlüğü, Doğa Koruma Dairesi Başkanlığı, Sulak Alanlar Şubesi Müdürlüğü.

Gediz Nehri'nde Balık Ölümleri Devam Ediyor [online], 2019. Available from: http://www.yapi.com.tr/haberler/gediz-nehrinde-balik-olumleri-devam-ediyor_175332.html [Accessed 3 Nov 2021].

Gediz'de Söğüt Tartışması [online], 2015. Haberler.com. Available from: https://www.haberler.com/gediz-de-sogut-tartismasi-6923286-haberi/ [Accessed 10 Nov 2021].

Geijzendorffer, I., Chazée, L., Gaget, E., Galewski, T., Guelmami, A., Perennou, C., Davidson, N., and McInnes, R., 2018. Mediterranean wetlands outlook 2: Solutions for sustainable Mediterranean wetlands. Secretariat of the Ramsar Convention.

Geijzendorffer, I.R. and Roche, P.K., 2013. Can biodiversity monitoring schemes provide indicators for ecosystem services? Ecological Indicators, 33, 148–157.

Geijzendorffer, I.R., Beltrame, C., Chazee, L., Gaget, E., Galewski, T., Guelmami, A., Perennou, C., Popoff, N., Guerra, C.A., Leberger, R., Jalbert, J., and Grillas, P., 2019. A More Effective Ramsar Convention for the Conservation of Mediterranean Wetlands. Frontiers in Ecology and Evolution, 7, 21.

Gelman, A. and Rubin, D.B., 1992. Inference from Iterative Simulation Using Multiple Sequences. Statistical Science, 7 (4), 457–472.

Gibbs, J.P., 2000. Wetland Loss and Biodiversity Conservation. Conservation Biology, 14 (1), 314–317.

Gil-Tena, A., De Cáceres, M., Ernoult, A., Butet, A., Brotons, L., and Burel, F., 2015. Agricultural landscape composition as a driver of farmland bird diversity in Brittany (NW France). Agriculture, Ecosystems & Environment, 205, 79–89.

Giosan, L., Syvitski, J., Constantinescu, S., and Day, J., 2014. Climate change: protect the world's deltas. Nature, 516 (7529), 31–33.

Goertzen, D. and Suhling, F., 2019. Urbanization versus other land use: Diverging effects on dragonfly communities in Germany. Diversity and Distributions, 25 (1), 38–47.

Gotelli, N.J. and Colwell, R.K., 2011. Estimating species richness. Biological diversity: frontiers in measurement and assessment, 12 (39–54), 35.

Greenwood, J.J., 2003. The monitoring of British breeding birds: a success story for conservation science? Science of the Total Environment, 310 (1–3), 221–230.

Guelmami, A., Unpublished work. Gediz Delta Land Use and Land Cover Changes.

Gül, O., 2014. Gediz Deltası (İzmir) ve Büyük Menderes deltası (Aydın)'nda üreyen tepeli pelikan (*Pelecanus crispus bruch*, 1832) populasyon büyüklüğünün, değişiminin, göçlerinin, üreme ve beslenme biyolojilerinin araştırılması [Investigation of population size and trend, migration movements, breeding and feeding biology of dalmatian pelican (Pelecanus crispus bruch, 1832) populations breeding in Gediz Delta (İzmir) and Buyuk Menderes delta (Aydin)]. PhD Thesis. Ege Üniversitesi, İzmir, Turkey.

Gürsoy-Ergen, A., 2019. Hope for the White-headed Duck, *Oxyura leucocephala* (Aves: Anatidae) in Turkey despite a declining breeding population and abandonment of its traditional wintering area? Zoology in the Middle East, 65 (2), 116–127.

Hager, H.A., 1998. Area-sensitivity of reptiles and amphibians: Are there indicator species for habitat fragmentation? Écoscience, 5 (2), 139–147.

Heip, C.HR., Herman, P.MJ., and Soetaert, K., 1998. Indices of diversity and evenness. Oceanis, 24 (4), 61–87.

Hepcan, Ş., Hepcan, Ç.C., Bouwma, I.M., Jongman, R.H.G., and Özkan, M.B., 2009. Ecological networks as a new approach for nature conservation in Turkey: A case study of İzmir Province. Landscape and Urban Planning, 90 (3), 143–154.

Hevia, V., Carmona, C.P., Azcárate, F.M., Torralba, M., Alcorlo, P., Ariño, R., Lozano, J., Castro-Cobo, S., and González, J.A., 2016. Effects of land use on taxonomic and functional diversity: a cross-taxon analysis in a Mediterranean landscape. Oecologia, 181 (4), 959–970.

Hill, M.O., 1973. Diversity and Evenness: A Unifying Notation and Its Consequences. Ecology, 54 (2), 427–432.

Hoekstra, J.M., Boucher, T.M., Ricketts, T.H., and Roberts, C., 2005. Confronting a biome crisis: global disparities of habitat loss and protection. Ecology Letters, 8 (1), 23–29.

Hooke, R.L., Martín Duque, J.F., Pedraza Gilsanz, J. de, Hooke, R.L., Martín Duque, J.F., and Pedraza Gilsanz, J. de, 2012. Land transformation by humans: A review [online]. Available from: https://eprints.ucm.es/id/eprint/20528/ [Accessed 15 Jul 2021].

Inger, R., Gregory, R., Duffy, J.P., Stott, I., Voříšek, P., and Gaston, K.J., 2015. Common European birds are declining rapidly while less abundant species' numbers are rising. Ecology Letters, 18 (1), 28–36.

Isenring, R., 2010. Pesticides and the loss of biodiversity. Pesticide Action Network Europe, London, 26.

IUCN, 2012. Threats Classification Scheme (Version 3.2) [online]. Available from: https://www.iucnredlist.org/resources/threat-classification-scheme [Accessed 19 Oct 2021].

Izbaş, 2021. İzbaş İzmir Serbest Bölgesi [online]. Available from: https://www.izbas.net/iletisim [Accessed 14 Oct 2021].

Izsu, 2021. Çiğli Atık Su Arıtma Tesisi [online]. Available from: https://www.izsu.gov.tr/tr/TesisDetay/1/80/1?AspxAutoDetectCookieSupport=1 [Accessed 14 Oct 2021].

"İzmir Körfez Geçişi Projesi İptal Kararı İzmir Halkına Armağandır' [online], 2019. Sivil Sayfalar. Available from: https://www.sivilsayfalar.org/2019/01/02/izmir-korfez-gecisi-projesi-iptal-karari-izmir-halkina-armagandir/ [Accessed 3 Nov 2021].

Jetz, W., Thomas, G.H., Joy, J.B., Hartmann, K., and Mooers, A.O., 2012. The global diversity of birds in space and time. Nature, 491 (7424), 444–448.

Johnson, P.T.J., Hoverman, J.T., McKenzie, V.J., Blaustein, A.R., and Richgels, K.L.D., 2013. Urbanization and wetland communities: applying metacommunity theory to understand the local and landscape effects. Journal of Applied Ecology, 50 (1), 34–42.

Kampichler, C., Van Turnhout, C.A., Devictor, V., and Van Der Jeugd, H.P., 2012. Large-scale changes in community composition: determining land use and climate change signals. PloS one, 7 (4), e35272.

Kaneda, T. and Haub, C., 2021. How Many People Have Ever Lived on Earth? [online]. PRB. Available from: https://www.prb.org/articles/how-many-people-have-ever-lived-on-earth/ [Accessed 15 Jul 2021].

Kaplan, A., 2012. How Effective Could 'Landscape Management' Tool Address Mitigation of Cultural and Natural Threats on Coastal Wetlands System? In: H.J.S. Fernando, Z. Klaić, and J.L. McCulley, eds. National Security and Human Health Implications of Climate Change. Dordrecht: Springer Netherlands, 307–316.

Kaplan, A., Güler, G.G., Küçükerba, E.V., Kurucu, Y., Ölgen, M.K., Türkyilmaz, B., Siki, M., and Akgün, A., 2005. Kıyı Sulak Alan Sistemi Bağlamında Gediz Deltasının İşlevleri ve Üzerindeki Baskılar Yönüyle Değerlendirilmesi, 14, 17.

Karadeniz, N., Tırıl, A., and Baylan, E., 2009. Wetland management in Turkey: Problems, achievements and perspectives, 4 (11), 106–1119.

Katayama, N., Osawa, T., Amano, T., and Kusumoto, Y., 2015. Are both agricultural intensification and farmland abandonment threats to biodiversity? A test with bird communities in paddy-dominated landscapes. Agriculture, Ecosystems & Environment, 214, 21–30.

Kayan, İ. and Öner, E., 2016. Sedimantolojik ve paleontolojik verilerle gediz delta ovasinda (İzmir) alüvyal jeomorfoloji araştirmalari. Ege Coğrafya Dergisi, 24 (2), 0–0.

Keil, P., Storch, D., and Jetz, W., 2015. On the decline of biodiversity due to area loss. Nature Communications, 6 (1), 8837.

Keller, V.; Herrando, S.; Voríšek, P.; Franch, M.; Kipson, M.; Milanesi, P.; Martí, D.; Anton, M.; Klvanová, A.; Kalyakin, M.V.; Bauer, H.-G.; Foppen, R.P.B. (2020). European breeding bird atlas 2: Distribution, abundance and change. Lynx Edicions/European Bird Census Council (EBCC): Barcelona. ISBN 9788416728381. 967 pp.

Kiepert, R., 1908. Karte von Kleinasien. Berlin: D. Reimer E. Vohsen, to 1915, 1908. Map.

Kingsford, R.T., Basset, A., and Jackson, L., 2016. Wetlands: conservation's poor cousins. Aquatic Conservation: Marine and Freshwater Ecosystems, 26 (5), 892–916.

Kirwan, G., Demirci, B., Welch, H., Boyla, K., Özen, M., Castell, P., and Marlow, T., 2010. The birds of Turkey. Bloomsbury Publishing.

Kirwan, G.M., Martins, R.P., Eken, G., and Davidson, P., 1998. Checklist of the Birds of Turkey: OSME Sandgrouse Supplement 1, 32p.

Korkmaz, H., 2014. Antakya-Kahramanmaraş Graben alaninda kurutulan sulak alanlarin (Amik gölü, Emen gölü ve Gâvur gölü batakliği) modellerinin oluşturulmasi. Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 5 (9), 19–37.

Koschová, M., Rivas-Salvador, J., and Reif, J., 2018. Continent-wide test of the efficiency of the European union's conservation legislation in delivering population benefits for bird species. Ecological Indicators, 85, 563–569.

Krebs, C.J., 1999. Ecological Methodology.,(Benjamin Cummings/Addison-Wesley Educational Publishers Inc.: Menlo Park, CA.).

Krüper, T., 1869. Beitrag zur Ornithologie Klein-Asiens. Journal für Ornithologie, 17 (1), 21–45.

Kucuksezgin, F., Uluturhan, E., and Batki, H., 2008. Distribution of heavy metals in water, particulate matter and sediments of Gediz River (Eastern Aegean). Environmental Monitoring and Assessment, 141 (1), 213–225.

Kumerloeve, H., 1986. Bibliographie der Säugetiere und Vögel der Türkei (rezente Fauna): unter Berücksichtigung der benachbarten Gebiete und mit Hinweisen auf weiterführendes Schrifttum [Bibliography of the mammals and birds of Turkey (recent fauna): considering the neighboring areas and with references to further literature]. Zoologisches Forschungsinstitut und Museum Alexander Koenig.

Le Viol, I., Jiguet, F., Brotons, L., Herrando, S., Lindström, \AAke, Pearce-Higgins, J.W., Reif, J., Van Turnhout, C., and Devictor, V., 2012. More and more generalists: two decades of changes in the European avifauna. Biology letters, 8 (5), 780–782.

Lewis, S.L. and Maslin, M.A., 2015. Defining the Anthropocene. Nature, 519 (7542), 171–180.

Lillo, A., Matteau, J.-P., Kokulan, V., and Benalcazar, P., 2019. The Contribution of Wetlands Towards a Sustainable Agriculture in Canada. Rochester, NY: Social Science Research Network, SSRN Scholarly Paper No. ID 3484143.

Loh, J., Green, R.E., Ricketts, T., Lamoreux, J., Jenkins, M., Kapos, V., and Randers, J., 2005. The Living Planet Index: using species population time series to track trends in biodiversity. Philosophical Transactions of the Royal Society B: Biological Sciences, 360 (1454), 289–295.

Macarthur, R.H., 1965. Patterns of Species Diversity. Biological Reviews, 40 (4), 510–533.

Magurran, A.E., 1988. Ecological diversity and its measurement. Princeton university press.

Mallet, P., Béchet, A., Galewski, T., Mesléard, F., Hilaire, S., Lefebvre, G., Poulin, B., and Sirami, C., 2022. Different components of landscape complexity are necessary to preserve multiple taxonomic groups in intensively managed rice paddy landscapes. Agriculture, Ecosystems & Environment, 328, 107864.

Mao, Q., Liao, C., Wu, Z., Guan, W., Yang, W., Tang, Y., and Wu, G., 2019. Effects of Land Cover Pattern Along Urban-Rural Gradient on Bird Diversity in Wetlands. Diversity, 11 (6), 86.

Margules, C.R. and Pressey, R.L., 2000. Systematic conservation planning. Nature, 405 (6783), 243–253.

Márquez-Ferrando, R., Figuerola, J., Hooijmeijer, J.C., and Piersma, T., 2014. Recently created man-made habitats in Doñana provide alternative wintering space for the threatened Continental European black-tailed godwit population. Biological Conservation, 171, 127–135.

Mathevet, R., Tourenq, C., and Mesléard, F., 2002. Agricultural policies, land-use and waterbird conservation: the case study of a major Mediterranean wetland, the Camargue. Cybergeo : European Journal of Geography.

McLaughlin, A. and Mineau, P., 1995. The impact of agricultural practices on biodiversity. Agriculture, Ecosystems & Environment, 55 (3), 201–212.

Mediterranean Wetland Observatory, 2014. Land cover: Spatial dynamics in Metierranean coastal wetlands from 1975 to 2005.Thematic collection 2. France: Tour du Valat.

Menemen’e bağlı Çaltı’daki taş ocağı projesi iptal edildi - Evrensel [online], 2021. Available from: https://www.evrensel.net/haber/350900/menemene-bagli-caltidaki-tas-ocagi-projesi-iptal-edildi [Accessed 10 Nov 2021].

Mérö, T.O., Lontay, L., and Lengyel, S., 2015. Habitat management varying in space and time: the effects of grazing and fire management on marshland birds. Journal of Ornithology, 156 (3), 579–590.

Meyer, D., Hornik, K., and Feinerer, I., 2008. Text mining infrastructure in R. Journal of statistical software, 25 (5), 1–54.

Mistry, J., Berardi, A., and Simpson, M., 2008. Birds as indicators of wetland status and change in the North Rupununi, Guyana. Biodiversity and Conservation, 17 (10), 2383.

Mittelbach, G.G. and Schemske, D.W., 2015. Ecological and evolutionary perspectives on community assembly. Trends in Ecology & Evolution, 30 (5), 241–247.

Mittermeier, R.A., Turner, W.R., Larsen, F.W., Brooks, T.M., and Gascon, C., 2011. Global Biodiversity Conservation: The Critical Role of Hotspots. In: F.E. Zachos and J.C. Habel, eds. Biodiversity Hotspots: Distribution and Protection of Conservation Priority Areas. Berlin, Heidelberg: Springer, 3–22.

Morelli, F., Benedetti, Y., Ibáñez-Álamo, J.D., Jokimäki, J., Mänd, R., Tryjanowski, P., and Møller, A.P., 2016. Evidence of evolutionary homogenization of bird communities in urban environments across Europe. Global Ecology and Biogeography, 25 (11), 1284–1293.

Moreno-Rueda, G. and Pizarro, M., 2007. The relative influence of climate, environmental heterogeneity, and human population on the distribution of vertebrate species richness in south-eastern Spain. Acta Oecologica, 32 (1), 50–58.

Morgado, R., Pedroso, R., Porto, M., Herrera, J.M., Rego, F., Moreira, F., and Beja, P., 2021. Preserving wintering frugivorous birds in agro-ecosystems under land use change: Lessons from intensive and super-intensive olive orchards. Journal of Applied Ecology, 58 (12), 2975–2986.

Morgado, R., Santana, J., Porto, M., Sánchez-Oliver, J.S., Reino, L., Herrera, J.M., Rego, F., Beja, P., and Moreira, F., 2020. A Mediterranean silent spring? The effects of olive farming intensification on breeding bird communities. Agriculture, Ecosystems & Environment, 288, 106694.

Morgan, S.A., Hansen, C.M., Ross, J.G., Hickling, G.J., Ogilvie, S.C., Paterson, A.M., Morgan, S.A., Hansen, C.M., Ross, J.G., Hickling, G.J., Ogilvie, S.C., and Paterson, A.M., 2009. Urban cat (Felis catus) movement and predation activity associated with a wetland reserve in New Zealand. Wildlife Research, 36 (7), 574–580.

Muneret, L., Mitchell, M., Seufert, V., Aviron, S., Djoudi, E.A., Pétillon, J., Plantegenest, M., Thiéry, D., and Rusch, A., 2018. Evidence that organic farming promotes pest control. Nature Sustainability, 1 (7), 361–368.

Murray-Rust, D.H. and Svendsen, M., 2001. Performance of Locally Managed Irrigation in Turkey: Gediz Case Study. Irrigation and Drainage Systems, 15 (4), 373–388.

Newbold, T., Bentley, L.F., Hill, S.L., Edgar, M.J., Horton, M., Su, G., Şekercioğlu, Ç.H., Collen, B., and Purvis, A., 2020. Global effects of land use on biodiversity differ among functional groups. Functional Ecology, 34 (3), 684–693.

Newbold, T., Hudson, L.N., Hill, S.L.L., Contu, S., Lysenko, I., Senior, R.A., Börger, L., Bennett, D.J., Choimes, A., Collen, B., Day, J., De Palma, A., Díaz, S., Echeverria-Londoño, S., Edgar, M.J., Feldman, A., Garon, M., Harrison, M.L.K., Alhusseini, T., Ingram, D.J., Itescu, Y., Kattge, J., Kemp, V., Kirkpatrick, L., Kleyer, M., Correia, D.L.P., Martin, C.D., Meiri, S., Novosolov, M., Pan, Y., Phillips, H.R.P., Purves, D.W., Robinson, A., Simpson, J., Tuck, S.L., Weiher, E., White, H.J., Ewers, R.M., Mace, G.M., Scharlemann, J.P.W., and Purvis, A., 2015. Global effects of land use on local terrestrial biodiversity. Nature, 520 (7545), 45–50.

Nivet, C. and Frazier, S., 2004. A review of European wetland inventory information. Collaborative Report by Wetlands International and Institute for Inland Water Management and Wastewater Treatment, 262.

Nopper, J., Riemann, J.C., Brinkmann, K., Rödel, M.-O., and Ganzhorn, J.U., 2018. Differences in land cover – biodiversity relationships complicate the assignment of conservation values in human-used landscapes. Ecological Indicators, 90, 112–119.

Oliver, T.H. and Morecroft, M.D., 2014. Interactions between climate change and land use change on biodiversity: attribution problems, risks, and opportunities. WIREs Climate Change, 5 (3), 317–335.

Onmuş, O. and Sıkı, M., 2011. Shorebirds in the Gediz Delta (İzmir, Turkey): breeding and wintering abundances, distributions, and seasonal occurrences. Turkish Journal of Zoology, 35 (5), 615–629.

Onmuş, O. and Siki, M., 2013. Impacts of anthropogenic activities and habitat degradation on breeding waterbirds. Turkish Journal of Zoology, 37 (3), 249–261.

Onmuş, O., 2008. Gediz Deltası’nda üreyen su kuşu türlerinin yuvalama alanlarının izlenmesi ve bu kolonilerin yönetilmesi [Monitoring And Management Of Nest Sites Of Breeding Waterbirds At The Gediz Delta]. PhD Thesis. Doktora tezi, Ege Üniv. Fen Bil. Enst. İzmir.

Onmuş, O., Durusoy, R., and Eken, G., 2009. Distribution of breeding birds in the Gediz Delta, Western Turkey: (Aves). Zoology in the Middle East, 47 (1), 39–48.

Onmuş, O., Sıkı, M., Sarıgül, G., and Crivelli, A.J., 2011. Status and development of the population of the globally threatened Dalmatian Pelican, Pelecanus crispus, in Turkey: (Aves: Pelecanidae). Zoology in the Middle East, 54 (1), 3–17.

Ovaskainen, O. and Abrego, N., 2020. Joint Species Distribution Modelling: With Applications in R. Cambridge: Cambridge University Press.

Ovaskainen, O., Tikhonov, G., Norberg, A., Guillaume Blanchet, F., Duan, L., Dunson, D., Roslin, T., and Abrego, N., 2017. How to make more out of community data? A conceptual framework and its implementation as models and software. Ecology letters, 20 (5), 561–576.

Özgencil, İ.K. and Uslu, A., 2021. Update on the status of White-headed Duck Oxyura leucocephala and its breeding phenology in Central Anatolia, Turkey. Sandgrouse, 43.

Palacín, C. and Alonso, J.C., 2018. Failure of EU Biodiversity Strategy in Mediterranean farmland protected areas. Journal for Nature Conservation, 42, 62–66.

Parlak, H., Çakır, A., Boyacıoğlu, M., and Arslan, Ö.Ç., 2006. Heavy Metal Deposition in Sediments from the Delta of the Gediz River (Western Turkey): A Preliminary Study. E. Ü. Su Ürünleri Dergisi, 23 (4), 445–448.

Perennou, C., Gaget, E., Galewski, T., Geijzendorffer, I., and Guelmami, A., 2020. Chapter 11 - Evolution of wetlands in Mediterranean region. In: M. Zribi, L. Brocca, Y. Tramblay, and F. Molle, eds. Water Resources in the Mediterranean Region. Elsevier, 297–320.

Perennou, C., Guelmami, A., Paganini, M., Philipson, P., Poulin, B., Strauch, A., Tottrup, C., Truckenbrodt, J., and Geijzendorffer, I., 2018. Mapping Mediterranean Wetlands With Remote Sensing: A Good-Looking Map Is Not Always a Good Map. Advances in Ecological Research, 58, 243–277.

Pickaver, A., Ferreira, M., Veiga, J., Steign, R., Czerniak, P., Heinichen, B., and Volckaert, A., 2009. A European inititiative to support ICZM.

Pierluissi, S., 2010. Breeding Waterbirds in Rice Fields: A Global Review. Waterbirds: The International Journal of Waterbird Biology, 33, 123–132.

Pievani, T., 2014. The sixth mass extinction: Anthropocene and the human impact on biodiversity. Rendiconti Lincei, 25 (1), 85–93.

Pocock, M.J.O., Roy, H.E., Preston, C.D., and Roy, D.B., 2015. The Biological Records Centre: a pioneer of citizen science. Biological Journal of the Linnean Society, 115 (3), 475–493.

Popoff, N., Gaget, E., Béchet, A., Dami, L., du Rau, P.D., Geijzendorffer, I., Guelmami, A., Mondain-Monval, J.-Y., Perennou, C., Suet, M., Verniest, F., Deschamps, C., Taylor, N.G., Azafzaf, H., Bendjedda, N., Bino, T., Borg, J.J., Božič, L., Dakki, M., Encarnação, V., Erciyas-Yavuz, K., Etayeb, K., Gaudard, C., Hatzofe, O., Langendoen, T., Ieronymidou, C., Mikuska, T., Molina, B., Petkov, N., Portolou, D., Qaneer, T., Sayoud, S., Šćiban, M., Topić, G., Uzunova, D., Vine, G., Vizi, A., Zenatello, M., Abdou, W., and Galewski, T., 2021. Gap analysis of the Ramsar site network at 50: over 150 important Mediterranean sites for wintering waterbirds omitted. Biodiversity and Conservation.

Ramsar Convention on Wetlands, 2018. Global Wetland Outlook: State of the World's Wetlands and their Services to People. Gland, Switzerland: Ramsar Convention Secretariat.

Ramsar Convention Secretariat, 2016. The fourth strategic plan 2016-2024. Ramsar handbooks for wise use of wetlands. Gland, Switzerland: Ramsar Convention Secretariat, No. 5th edition, Vol. 2.

Redford, K.H., Hulvey, K.B., Williamson, M.A., and Schwartz, M.W., 2018. Assessment of the Conservation Measures Partnership's effort to improve conservation outcomes through adaptive management. Conservation Biology, 32 (4), 926–937.

RIS, R.S.I.S., 2021. Information Sheet on Ramsar Wetlands (RIS) – 2006-2008 version. https://rsis.ramsar.org/.

Ritchie, H. and Roser, M., 2013. 'Land Use'. Published online at OurWorldInData.org. [online]. ourworldindata. Available from: https://ourworldindata.org/land-use [Accessed 13 Oct 2021].

Robledano, F., Esteve, M.A., Farinós, P., Carreño, M.F., and Martínez-Fernández, J., 2010. Terrestrial birds as indicators of agricultural-induced changes and associated loss in conservation value of Mediterranean wetlands. Ecological Indicators, 10 (2), 274–286.

Roca, E. and Villares, M., 2012. Public perceptions of managed realignment strategies: the case study of the Ebro Delta in the Mediterranean basin. Ocean & Coastal Management, 60, 38–47.

Rocha-Ortega, M., Rodríguez, P., and Córdoba-Aguilar, A., 2019. Can dragonfly and damselfly communities be used as bioindicators of land use intensification? Ecological Indicators, 107, 105553.

Salafsky, N., Salzer, D., Stattersfield, A.J., Hilton-Taylor, C., Neugarten, R., Butchart, S.H.M., Collen, B., Cox, N., Master, L.L., O'Connor, S., and Wilkie, D., 2008. A Standard Lexicon for Biodiversity Conservation: Unified Classifications of Threats and Actions: Classifications of Threats & Actions. Conservation Biology, 22 (4), 897–911.

Schutz, A.J. and Driscoll, D.A., 2008. Common reptiles unaffected by connectivity or condition in a fragmented farming landscape. Austral Ecology, 33 (5), 641–652.

Schwartz, M.W., Deiner, K., Forrester, T., Grof-Tisza, P., Muir, M.J., Santos, M.J., Souza, L.E., Wilkerson, M.L., and Zylberberg, M., 2012. Perspectives on the Open Standards for the Practice of Conservation. Biological Conservation, 155, 169–177.

Scott, J.M., Csuti, B., Jacobi, J.D., and Estes, J.E., 1987. Species Richness. BioScience, 37 (11), 782–788.

Sebastián-González, E. and Green, A.J., 2016. Reduction of avian diversity in created versus natural and restored wetlands. Ecography, 39 (12), 1176–1184.

Şekercioğlu, Ç.H., Anderson, S., Akçay, E., Bilgin, R., Can, Ö.E., Semiz, G., Tavşanoğlu, Ç., Yokeş, M.B., Soyumert, A., İpekdal, K., Sağlam, İ.K., Yücel, M., and Nüzhet Dalfes, H., 2011. Turkey's globally important biodiversity in crisis. Biological Conservation, 144 (12), 2752–2769.

Şekercioğlu, Ç.H., Daily, G.C., and Ehrlich, P.R., 2004. Ecosystem consequences of bird declines. Proceedings of the National Academy of Sciences, 101 (52), 18042–18047.

Selous, F.C., 1900. XXIII.——A Fortnight's Egg-collecting in Asia Minor. Ibis, 42 (3), 405–424.

Sevinç, N., 2000. Wetland conservation within the framework of city planning. Master. Izmir Institute of Technology (Turkey).

Sıkı, M. and Öktem, N., 1992. Çamaltı Tuzlası_Homa Dalyanı Kuş Türlerinin Revizyonu [Çamaltı Saltpan_Homa Dalyan Bird Species Revision]. Journal of Faculty of Science Ege Üniversity, 14 (1), 39–51.

Sıkı, M., 1985. Çamaltı Tuzlası- Homa Dalyani Kuş türleri ve Bazı türlerin Biyolojileri üzerine araştırmalar [Çamaltı Saltworks- Homa Dalyani Studies on Bird Species and Biology of Some Species]. PhD Thesis. Ege Üniversitesi, İzmir, Turkey.

Sıkı, M., 1988. Çamaltı Tuzlası - Homa Dalyanı Kuş Türleri [Çamaltı Saltpan - Homa Dalyan Bird Species]. TÜBİTAK Doğa Türk Zooloji Dergisi, 13 (3), 272–283.

Sıkı, M., 2020. Gediz deltasi'ndaki İzmir kuş cennetini yaşatma mücadelesi (1982-2018). İzmir, Turkey: Kanguru Yayınları.

Sıkı, M., Tok, C.V., Mermer, A., and Tosunoğlu, M., 1998. İzmir Kuşcenneti'nin Avifaunası ve Herpetofaunası [Avifauna and Herpetofauna of İzmir Bird Paradise]. Presented at the 14.Ulusal Biyoloji Kongresi, Samsun, 181–193.

Sönmez, Ö. and Onmuş, O., 2006. Sulak Alan Yönetim Planı Süreci Gediz Deltası Örneğinde SosyoEkonomik Analiz Çalışmaları. Planlama dergisi, 3, 17–26.

Souchay, G. and Schaub, M., 2016. Investigating Rates of Hunting and Survival in Declining European Lapwing Populations. PLOS ONE, 11 (9), e0163850.

Spampinato, G., Sciandrello, S., del Galdo, G., Puglisi, M., Tomaselli, V., Cannavò, S., and Musarella, C.M., 2019. Contribution to the knowledge of Mediterranean wetland biodiversity: Plant communities of the Aquila Lake (Calabria, Southern Italy). Plant Sociol, 56, 53–68.

Sripanomyom, S., Round, P.D., Savini, T., Trisurat, Y., and Gale, G.A., 2011. Traditional salt-pans hold major concentrations of overwintering shorebirds in Southeast Asia. Biological Conservation, 144 (1), 526–537.

Stein, A., Gerstner, K., and Kreft, H., 2014. Environmental heterogeneity as a universal driver of species richness across taxa, biomes and spatial scales. Ecology Letters, 17 (7), 866–880.

Stephens, T., 2019. What is the Point of International Environmental Law Scholarship in the Anthropocene? Rochester, NY: Social Science Research Network, SSRN Scholarly Paper No. ID 3382013.

Strickland, H.E., 1836. List of birds noticed or obtained by him in Asia Minor, in the winter of 1835 and spring of 1836. Proc Zool Soc London, 4, 97–102.

Suzer, E.U., Kontaş, A., and Yılmaz, E.C., 2015. Assessment of heavy metal pollution of surface sediments from lagoon areas of Gediz Delta (Izmir Bay). Journal of Fisheries and Aquatic Sciences (Su Ürünleri Dergisi), 32 (2), 79–87.

Swingland, I.R., 2001. Biodiversity, definition of. Encyclopedia of biodiversity, 1, 377–391.

Tapan, D. S., Ayas, C., Đş, G., Beton, D., & Çakırığlu, Đ. (2008). Türkiye'deki RAMSAR alanları değerlendirme raporu. WWF-Türkiye (Doğal Hayatı Koruma Vakfı), İstanbul.

Teyssedre, A. and Robert, A., 2015. Biodiversity trends are as bad as expected. Biodiversity and Conservation, 24 (3), 705–706.

Tikhonov, G., Opedal, Ø.H., Abrego, N., Lehikoinen, A., de Jonge, M.M.J., Oksanen, J., and Ovaskainen, O., 2020. Joint species distribution modelling with the r-package Hmsc. Methods in Ecology and Evolution, 11 (3), 442–447.

Tiraş, M., 2011. Çamalti tuzlasi. Doğu Coğrafya Dergisi, 12 (18), 291–300.

Tonini, J.F.R., Beard, K.H., Ferreira, R.B., Jetz, W., and Pyron, R.A., 2016. Fully-sampled phylogenies of squamates reveal evolutionary patterns in threat status. Biological Conservation, 204, 23–31.

Tosunoğlu, Z., 2017. İzmir'in Kıyı Dalyanları (Coastal Dalyans of Izmir). In: İzmir Balıkçılığı. İzmir, Turkey: İzmir Büyükşehir Belediyesi, 304.

Tourenq, C., Bennetts, R.E., Kowalski, H., Vialet, E., Lucchesi, J.-L., Kayser, Y., and Isenmann, P., 2001. Are ricefields a good alternative to natural marshes for waterbird communities in the Camargue, southern France? Biological Conservation, 100 (3), 335–343.

TRAKUŞ, 2020. Türkiye'nin Anonim Kuşları [TRAKUS Turkey's Birds Anonymous] [online]. [Accessed 2 Aug 2021].

Tryjanowski, P., Skórka, P., Sparks, T.H., Biaduń, W., Brauze, T., Hetmański, T., Martyka, R., Indykiewicz, P., Myczko, Ł., Kunysz, P., Kawa, P., Czyż, S., Czechowski, P., Polakowski, M., Zduniak, P., Jerzak, L., Janiszewski, T., Goławski, A., Duduś, L., Nowakowski, J.J., Wuczyński, A., and Wysocki, D., 2015. Urban and rural habitats differ in number and type of bird feeders and in bird species consuming supplementary food. Environmental Science and Pollution Research, 22 (19), 15097–15103.

TUIK, T.S.I., 2020. Address Based Population Registration System Results, 2019. Website.

Tulger, G., Bilgiç, E., and Gündüz, O., 2015. Deniz Seviyesi Yükselmesi Durumunda Gediz Deltasinin Su Altinda Kalma Analizi. Presented at the VIII. Ulusal Hidroloji Kongresi, Harran Üniversitesi, Şanlıurfa.

Ünal, M. and Canli, M., 2019. Sulak Alanların Yok Edilmesinin Etkileri ve Amik Gölü Örneği [The Effects of Wetland Destruction and the Example of Lake Amik]. Doğanın Sesi, (4), 49–66.

Underwood, E.C., Viers, J.H., Klausmeyer, K.R., Cox, R.L., and Shaw, M.R., 2009. Threats and biodiversity in the mediterranean biome. Diversity and Distributions, 15 (2), 188–197.

Vallejo, B.M., Aloy, A.B., and Ong, P.S., 2009. The distribution, abundance and diversity of birds in Manila's last greenspaces. Landscape and Urban Planning, 89 (3), 75–85.

Vitousek, P.M., Mooney, H.A., Lubchenco, J., and Melillo, J.M., 1997. Human Domination of Earth's Ecosystems | Science. Science, 277 (5325), 494–499.

von Gonzenbach, G., 1859. Excursionen an die Brüteplätze von Sterna, Larus und Glareola im Golf von Smyrna im Frühling 1859. Journal für Ornithologie, 7 (5), 393–398.

Wanger, T.C., Iskandar, D.T., Motzke, I., Brook, B.W., Sodhi, N.S., Clough, Y., and Tscharntke, T., 2010. Effects of Land-Use Change on Community Composition of Tropical Amphibians and Reptiles in Sulawesi, Indonesia. Conservation Biology, 24 (3), 795–802.

Ward, R.J., Griffiths, R.A., Wilkinson, J.W., and Cornish, N., 2017. Optimising monitoring efforts for secretive snakes: a comparison of occupancy and N-mixture models for assessment of population status. Scientific Reports, 7 (1), 18074.

Warton, D.I., Blanchet, F.G., O'Hara, R.B., Ovaskainen, O., Taskinen, S., Walker, S.C., and Hui, F.K.C., 2015. So Many Variables: Joint Modeling in Community Ecology. Trends in Ecology & Evolution, 30 (12), 766–779.

Weise, K., Höfer, R., Franke, J., Guelmami, A., Simonson, W., Muro, J., O'Connor, B., Strauch, A., Flink, S., Eberle, J., Mino, E., Thulin, S., Philipson, P., van Valkengoed, E., Truckenbrodt, J., Zander, F., Sánchez, A., Schröder, C., Thonfeld, F., Fitoka, E., Scott, E., Ling, M., Schwarz, M., Kunz, I., Thürmer, G., Plasmeijer, A., and Hilarides, L., 2020. Wetland extent tools for SDG 6.6.1 reporting from the Satellite-based Wetland Observation Service (SWOS). Remote Sensing of Environment, 247, 111892.

Weller, M.W., 1999. Wetland birds: habitat resources and conservation implications. Cambridge University Press.

Whittaker, R.H., 1972. Evolution and Measurement of Species Diversity. TAXON, 21 (2–

3), 213–251.

Winfree, R., Dushoff, J., Crone, E.E., Schultz, C.B., Budny, R.V., Williams, N.M., and Kremen, C., 2005. Testing Simple Indices of Habitat Proximity. The American Naturalist, 165 (6), 707–717.

Xu, T., Weng, B., Yan, D., Wang, K., Li, X., Bi, W., Li, M., Cheng, X., and Liu, Y., 2019. Wetlands of International Importance: Status, Threats, and Future Protection. International Journal of Environmental Research and Public Health, 16 (10).

Yaman, E., 2001. Gediz Deltasında kuluçkaya yatan kuş türlerinin tespiti ve bazı türlerin biyolojileri üzerine araştırmalar [The Determination of the bird species in Gediz Delta and investigation on biology of some birds]. Master. Ege Üniversitesi, İzmir, Turkey.

Yarar, M. and Magnin, G., 1997. Türkiye'nin Önemli Kuş Alanları (Important Bird Areas of Turkey)–Publications of Wildlife Protection Service.

Yılmaz, Y.Ş., 2016. Planlamada Ekolojik Duyarli Alanlarin Belirlenmesi: Gediz Deltasi Sulak Alani Örneği [Defining Ecologically Sensitive Areas In Planning: Case Of Gediz Delta Wetland]. Master. Karadeniz Teknik Üniversitesi Fen Bilimleri Enstitüsü, Şehir Ve Bölge Planlama Anabilim Dali.

Zuur, A.F., Ieno, E.N., Walker, N.J., Saveliev, A.A., and Smith, G.M., 2009. Mixed effects models and extensions in ecology with R. Springer.

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