ELUCIDATING THE PATTERNS IN MID-WINTER WATERBIRD SURVEYS BY USING CLIMATE, LAKE WATER LEVEL CHANGES AND MACROPHYTE RECORDS

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ABSTRACT

ELUCIDATING THE PATTERNS IN MID-WINTER WATERBIRD SURVEYS BY USING CLIMATE, LAKE WATER LEVEL FLUCTUATIONS AND MACROPHYTE RECORDS

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Impacts of winter climate in Eastern Europe, North Atlantic Oscillation (NAO), water level changes and submerged macrophytes on wintering waterbird community size and structure in three Turkish shallow lakes from three different geographical regions were investigated by using the Mid-Winter Waterbird Survey results from 1967-2016. The study demonstrated that average winter air temperatures in Eastern Europe and combined wintering waterbird community density of the study lakes were negatively correlated. North Atlantic Oscillation was found to have a weak impact on wintering waterbird communities of the study lakes with negative values of NAO Index showing a slight tendency to translate to more waterbird species coming to the study lakes. Although the results were variable across the study lakes, water level was discovered to have a substantial impact on various waterbird community parameters including density and species richness. The study showed that increases in submerged macrophyte abundance and diversity were mostly coupled with an increase in numbers of wintering waterbird communities, probably due to an increased availability and diversity of their food sources. Results of this study suggest that Turkey becomes a

crucial wintering ground for migratory waterbirds when Eastern Europe is having a harsh winter and NAO Index reaches negative highs, and to preserve Turkish shallow lakes as high-quality wintering grounds for migratory waterbirds, lakes should be managed at proper water levels and at macrophyte-dominated states.

Keywords: Waterbird, Submerged Macrophyte, Water Level, Climate, North Atlantic Oscillation

ÖZ

İKLİM, GÖL SU SEVİYESİ DEĞİŞİMLERİ VE SUCUL BİTKİ KAYITLARINI KULLANARAK KIŞ ORTASI SU KUŞU SAYIMLARINDAKİ ÖRÜNTÜLERİN AYDINLATILMASI

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Doğu Avrupa'da kışın hakim olan iklimin, Kuzey Atlantik Salınımı'nın (KAS), su seviyesi değişimlerinin ve su içi bitkilerinin, Türkiye'nin üç farklı coğrafi bölgesinden üç sığ gölde kışlayan su kuşu komünitelerinin yoğunluğu ve yapısı üzerindeki etkisi, 1967-2016 yılları arasındaki Kış Ortası Su Kuşu Sayımları'nın sonuçları kullanılarak incelendi. Bu çalışma gösterdi ki Doğu Avrupa'daki ortalama kış sıcaklıkları ve üç çalışma gölünde kışlayan su kuşlarının toplam sayısı negatif ilişkiyle birbirlerine bağlılar. Kuzey Atlantik Salınımı ise, zayıf da olsa, çalışma göllerinde kışlayan su kuşu komünitesindeki tür zenginliğiyle negative şekilde birbirlerine bağlılar; negatif KAS İndeksi değerleri zayıf bir eğilimle de olsa daha yüksek tür zenginliğiyle ilişkili bulundu. Çalışma göllerin için değişen sonuçlar alınsa da, su seviyesinin aralarında komünite boyutu ve tür zenginliği dahil olmak üzere kışlayan su kuşu komünite değişkenleri üzerindeki etkisinin kaydadeğer boyutlarda olduğu tespit edildi. Çalışmanın su içi bitkilerinin miktarında ve zenginliğindeki artışlar, çoğu zaman, kışlayan su kuşu komünitelerindeki toplam su kuşu sayısında ve çeşitliliğinde bir artışla özdeşleştiğini ve bunun sebebinin, çok büyük ihtimalle, su içi bitkilerinin artmasıyla birlikte yaşanan yiyecek kaynaklarının miktarı ve çeşitliliğindeki artış olduğunu gösterdi. Bu çalışmanın sonuçlarına göre Doğu Avrupa'da sert bir kış yaşandığı ve KAS değerleri negatif şekilde yükseldiği zamanlarda, Türkiye, su kuşları için hayati bir öneme sahip bir kışlama alanına dönüşüyor ve Türkiye'deki sulak alanları, su kuşları için yüksek nitelikli kışlama alanları olarak koruyabilmek için sulak alanların uygun su seviyelerinde ve su içi bitkilerin baskın olduğu şekillerde yönetilmesi gerekiyor.

Anahtar Kelimeler: Su Kuşu, Su İçi Bitkisi, Su Seviyesi, İklim, Kuzey Atlantik Salınımı

To my family and my fiancé…

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LIST OF ABBREVIATIONS

MWS	the Mid-winter Waterbird Survey
NAO	The North Atlantic Oscillation
WL	Water level
HWL	High water level
LWL	Low water level
HM	High macrophyte
LM	Low macrophyte
HE	Herbivore
OM	Omnivore
PI	Piscivore
GU	Opportunistic gulls
INPI	Invertebrate and small fish eaters
IN	Invertebrate eaters
NGO	Non-governmental organization
TAVG	Average daily temperature
TMIN	Minimum daily temperature
Jan	January
Dec-Jan	December and January averaged
$c\alpha$	Cumulative species richness
$s\alpha$	Summed species richness

smα	Summed modified richness
GS	Growing season
α	Species richness
N	Total number
ND	Date not available – no date
SE EU	Eastern Europe
Bulg.	Bulgaria
Rom.	Romania
Mold.	Moldova
Ukr.	Ukraine

CHAPTER 1

INTRODUCTION

1.1 Mid-Winter Waterbird Surveys

Mid-winter Waterbird Surveys (MWS) are semi-standardized bird counts which are done in more than 100 countries in the Western Palearctic and South Asia in mid-winter when waterbird can be found clustered in wetlands and their migratory movements of the waterbirds are at minimum (Çağlayan et.al., 2005; Yavuz & Boyla, 2013). Worldwide, more than 20.000 wetlands are visited every winter by more than 11.000 volunteers who record waterbirds wintering in the wetlands (Yavuz & Boyla, 2013). The MWS are one of the ways in which researchers or conservation bodies can keep track of changes in waterbird population sizes, ecosystem health (birds can serve as an indicator taxon when evaluating wetland ecosystem health – Stolen et al., 2005) and determine the amount of effort which should be directed towards conservation of a waterbird species (Yavuz & Boyla, 2013; Atkinson-Willes, 1969). The MWS results are also used by IUCN or local conservation bodies to designate global or national Red List status of waterbird species (Magnin & Yarar, 1997).

The MWS in Turkey are done as a part of International Waterfowl Census (IWC) which is a census organized by Wetland International in order to follow waterbird populations across the globe (Yavuz & Boyla, 2013). The first ever MWS in Turkey was done by a team lead by foreign researchers in 1967. In between 1967-1973 and 1986-1989, the counts were still organized and executed by foreign birdwatchers. In 1990, 1992, 1993, 1996, 1999, and 2002, the surveys were conducted by an NGO named Doğal Hayatı Koruma Derneği (Yavuz & Boyla, 2013). Starting from 2002, the surveys were done by teams composed of people from birdwatching groups from all over Turkey. Between 2005 and 2013, the surveys were organized by another NGO named Doğa Derneği. Doğa Derneği, has spent a lot of time and effort on the MWS and published the results of the counts in a report format and made the reports available to public. In 2013; however, the state took over the surveys' control completely and no proper report have been published since then. The outputs of the surveys are kept confidential and are corrupted by the government. The MWS data has been used by related governmental bodies to set hunting quotas for bird species. Granting hunting licenses is a serious revenue for the government; therefore, the government has constantly been increasing the hunting quotas and setting more areas as hunting grounds. In 2016, the situation got grave and the hunting quotas for many bird species increased to unacceptable and obviously unsustainable levels. The situation is worsened by the fact that there is almost no wardening in most of the wetlands and the numbers of illegally hunted animals most probably exceed the quotas by tens or even hundreds. Unfortunately, in 2017, hunting quotas were set as almost the same as 2016.

1.2 Study Sites

The study focuses on three shallow lakes from three different geographical regions of Turkey (figure 1.1).

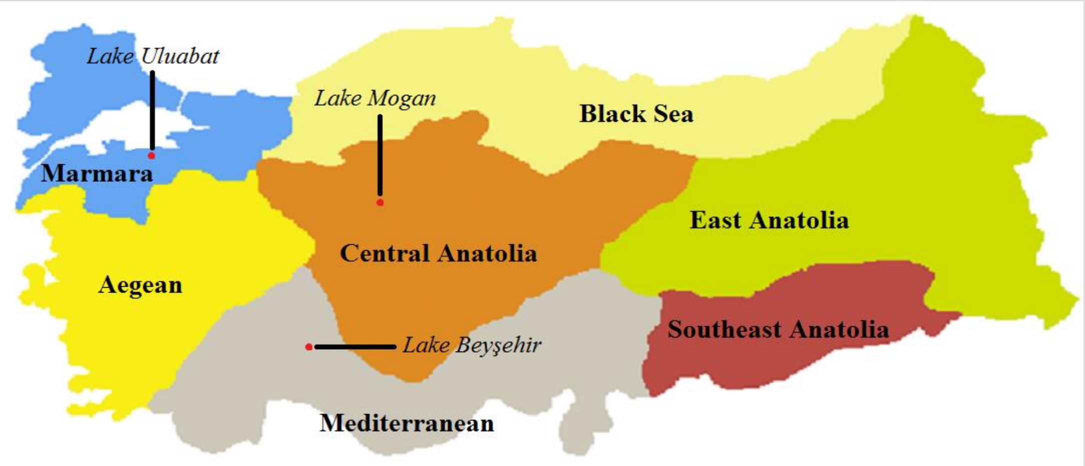

Figure 1.1: Turkey's geographical regions and the three study lakes

Lake Uluabat is located in the Marmara Region at 40.1489° N, 28.6148° E (Altınayar, 1998 a – figure 1.1), in Bursa province. It is a tectonic lake having an average elevation of 7-8 m and covering 240 to 350 km^2 (Altınayar, 1998 a). Lake Uluabat classifies as a shallow lake; its depth ranges from 2,5 to 5 m (Altınayar, 1998 a). The lake is fed by the Mustafakemalpaşa River, several small streams and groundwater (Beklioğlu et al., 2006; Levi et al., 2016) and it lies within the Susurluk Basin (Altınayar, 1998 a). The lake's catchment is dominated by agricultural areas (Levi et al., 2016). Several domestic and industrial effluents combined with the use of agricultural fertilizers in the catchment contributed to the current eutrophic state of the lake (Salihoğlu & Karaer, 2004). The lake's morphometric features are similar to that of Lake Beyşehir; decrease in water level makes the bottom of the lake flatter (Beklioğlu et al., 2006). Lake Uluabat lies on a major migratory bird route and it is an important breeding, feeding and wintering site for many bird species some of which are globally threatened (Aksoy & Özsoy, 2002). As a result, the lake was declared as IBA in 1997 (Magnin & Yarar, 1997) and RAMSAR site in 1998 (Aksoy & Özsoy, 2002; Eken, 2006).

Lake Beyşehir is located in the Mediterranean Region at 37.7724° N, 31.5212° E (Altınayar, 1998 b – figure 1.1). The lake, which is a tectonic-karstic shallow lake, is the biggest freshwater lake in the Turkey and is located in the Konya Closed Basin (Altınayar, 1998 b; Beklioğlu et al., 2006). The lake's average elevation is around 1123 m and its surface area is 647 km^2 at 1122 m and is 750 km^2 at 1125 m (Altınayar, 1998 b) and has an average depth of 7-8 m (Güler et al., 2008). The lake is mainly fed by rivers, streams and groundwater from the Anamas and Sultan Mountains and rainfall in the lake catchment (Altınayar, 1998 b; Beklioğlu et al., 2006, 2014; Levi et al., 2016) and the main source of water loss is evaporation (Altınayar, 1998 b). The lake is located within boundaries of two provinces, Konya and Isparta. Main human activity in the lake's catchment is agriculture (Bucak et al., 2016; Çiftçi et al., 2010), although the area of cultivation has been decreasing (the Turkish Statistical Institute – available at http://tuik.gov.tr). Despite the big scale agriculture in its catchment, the lake classifies as an oligo-mesotrophic lake (Beklioğlu et al., 2014; Bucak, 2017). Due to the lake's morphometric structure, lower water levels create a flatter bottom profile and increases the coverage of shallow areas (Beklioğlu et al., 2006). The lake was declared as Important Bird Area (IBA) in 1997 thanks to the big numbers of wintering waterbirds it harbored in 1996 (Magnin & Yarar, 1997) and it is a Freshwater Key Biodiversity Area (KBA) for the high rate of endemism among the freshwater fish species in the lake (Darwall et al., 2015). Lake Beyşehir lies within borders of two national parks and some part of the lake's catchment is Grade 1 National Site Area (Bucak, 2017).

Lake Mogan is located in the Central Anatolia Region at 39.7633° N, 32.7943° E (figure 1.1), in Ankara province. It is a small and lake with an average surface area of 6,35 km^2 and average depth of 2,1 m (Burnak & Beklioğlu, 2000). The lake is formed by alluvial damming (Karapınar, 2005) and fed mainly by four small inflows (Burnak & Beklioğlu, 2000). Lake Mogan is located within the municipality of Gölbaşı, which has a population of 122,288 according to the results of a population census conducted in 2015 (the Turkish Statistical Institute - available at https://biruni.tuik.gov.tr/medas/). The lake is surrounded by dense human settlements and industrial sites. Cultivated areas make up 68% of the lake's catchment (Beklioğlu et al., 2017). As a result, the lake is exposed to intensive urban, industrial and agricultural pollution (Mangit & Yerli, 2009). The lake is also used for recreational purposes in the spring and summer (Karapınar, 2005). Lake Mogan is classified as a eutrophic lake and algal blooms occur in the lake in the spring and summer months (Mangit & Yerli, 2009). Lake Mogan's morphometric structure also resembles the other two study lakes; lower water level translates to an increase in area of the shallow areas due to the bottom becoming flatter (Beklioğlu et al., 2006). The lake was declared as Special Environmental Protected Area (SPA) in 1990 and is also an IBA (Magnin & Yarar, 1997; Eken, 2006).

1.3 Review of Previous Macrophyte Records of the Study Lakes

When the existing literature was investigated, it was seen that the lake was in a high macrophyte state until the beginning of the new millennium. In 1970's the lake was found to be have a first-class water quality according to the Turkish Water Pollution

Regulation Classification (Environment foundation, 1999) which means that the lake had very low nutrient levels and was in a clear water state (Salihoğlu & Karaer, 2004). In 1980's, the lake's macrophyte coverage started to increase to levels where it became problematic for the fish production in the lake (Altınayar, 1998 a). Finally, in 1997, macrophyte coverage topped at 50-55%. It was around this time when the record numbers of wintering waterbirds (around 429,000 in 1996 and around 288,000 in 1999) were recorded in the lake, leading to a Ramsar site declaration (Altınayar 1998 a; Magnin & Yarar, 1997). However; in the beginning of the 2000's, the lake deteriorated into the worst class on the regulation classification scale and started to become eutrophic lake (Salihoğlu & Karaer, 2004) which persisted until 2011 (Levi et al., 2016).

When change in Lake Beyşehir's macrophyte status over the study year was investigated, it was seen that the lake was in a clear water and macrophyte dominated state in 1960's (Levi et al., (2016)). Then, in early 1980's, when the lake was in a high water level (HWL) state, macrophyte coverage decreased to less than 10% (Beklioğlu et al., 2006; Seçmen & Leblebici, 1982). Starting from 1990's, the lake's macrophyte coverage increased following a decrease in water level (Altınayar 1998b; Beklioğlu et al., 2006; Levi et al., 2016). Later on, high macrophyte coverage of the lakes was confirmed by Kazancı et al., 1999 and Meryem Beklioğlu's personal observations. In late 2000's and early 2010's, the lake started to become eutrophic and entered a scarce macrophyte period which was confirmed by biological shifts pointing to eutrophic conditions such as increase in percent representation of eutrophication-favoring diatom taxa (Levi et al., 2016). Bucak (2017) also reported low macrophyte coverages for 2010 and 2011 which were 17% and 9%, respectively.

The only studies which reported macrophyte status of one or more of the qualifying years were Doğan (2007) and Tan (2002). Tan (2002) reported that the lake was in a low macrophyte state in 2002 and the macrophyte coverage was 15%. Doğan (2007) reported the coverages of different macrophyte species by using satellite imagery and the study's result showed that the lake was in a low macrophyte state in 2006.

1.4 Functional Groups

Our study lakes have a total of 84 wintering waterbird species recorded in between 1967 and 2016, and they exhibited a big diversity in their winter feeding habits. The main sources for the dietary information were Cramp & Simmons, (1977, 1983) and del Hoyo (1996). After determining winter diets of the species, functional groups were formed and each species was assigned a functional group. Functional diversity is an essential component of community biodiversity (Petchey & Gatson, 2002). Functional group richness is a widely used measure of functional diversity making a useful ecological tool (Petchey & Gatson, 2002). A functional group is defined as a set of species in a community which have similar functional attributes, affect the ecosystem processes similarly, conduct similar ecosystem services and respond to external factors similarly (de Bello et al., 2010). Functional groups are formed in order to obtain groups or sets of species having the same roles in an ecosystem and they can be used to study various ecological questions (Pla et al., 2012). Again, depending on the group or groups of organisms being studied and the type of available data, different traits which are related directly to the ecosystem services are used to differentiate the functional groups from each other (Pla et al., 2012).

Although there have been various proposals regarding the number of functional groups that should be defined for a certain study, there is no widely accepted procedure or rule to determine the exact number which should be used (Pla et al., 2012). The right number of the functional groups which should be defined for a study depends on the aim of that study and the studied group or groups of organisms (Pla et al., 2012).

1.5 Impact of Water Level and Submerged Macrophytes on Waterbird Communities

Water level and water level fluctuations are considered as important factors for shallow lake ecosystems and ecosystem functioning (Beklioğlu et al., 2001, 2017; Coops et al., 2003). Naturally, water levels in shallow lakes fluctuate within and between years depending mainly on dominant climatic conditions in the region and anthropogenic activities (Beklioğlu et al., 2001; Blindow, 1992; Gafny & Gasith, 1999). In the Mediterranean Basin (where Turkey is located) intense anthropogenic activities are already causing tremendous changes in water level at an increasing strength (Coops et al., 2003; Beklioğlu et al., 2017). In shallow lakes, such changes in lake water level is known to cause state shifts between the two alternative stable states: clear water state, which is dominated by abundant submerged macrophytes, and turbid water state, which is dominated by huge amounts of phytoplankton (Beklioğlu et al., 2001; Scheffer et al., 1993). These state shifts occur because high water level in the growing season may limit the light availability for submerged plants and may cause a shift to turbid water state, whereas low water level may encourage an increase in coverage of submerged macrophytes by expanding the littoral habitat (Beklioğlu et al., 2006, 2017; Coops et al., 2003). Other living components of the ecosystems are also affected by water level changes (Colwell & Taft, 2000; Coops et al., 2003; Taft et al., 2002). Waterbirds are affected by changing water levels as well but different groups of birds are affected differently by water level (Bancroft et al., 2002; Beklioğlu et al., 2006; Colwell & Taft, 2000; Fredrickson & Reid, 1986; Taft et al., 2002). While most of the waterbird species depend on depths of 0-25 cm to thrive (e.g. most of the dabbling ducks and shorebirds) it is known that capacity of a wetland to support deep water dabbling ducks and diving waterbirds increase with increasing depth (Colwell & Taft, 2000; Perry & Deller, 1996; Taft et al., 2002). Higher winter water levels may also make it harder for waterbirds to reach submerged vegetation limiting the food availability for many wintering waterbirds (Dalby et al., 2013). Taft et al. showed in their 2002 study, which was conducted in several managed wetlands in California, USA, that the greatest waterbird species diversity and abundance are achieved at wetlands with 15-20 cm average depth and 30-40 cm topographic gradients. Water level during the growing season also affects waterbird abundances by determining the extend and size of vegetated area and the littoral zone; larger littoral zone translates to an increase in waterbird abundances, especially that of waterfowl species (Beklioğlu et al.,2006; Hargeby et al., 1994; Jeppesen et al., 1998, Noordhuis et al., 2002; Van Geest et al., 2005).

Macrophytes are highly crucial components of shallow water ecosystems as they provide food and habitat for the organisms and affect various abiotic and biotic variables such as light availability, oxygen concentration, temperature, and diversity, community structure and biomass of groups of organisms including waterbirds (Beklioğlu et al., 2006; Carpenter & Lodge, 1986; Hargeby et al., 1994; Jeppesen et al. 1998; Lillie & Bud, 1992; Milberg et al., 2001; Noordhuis et al., 2002). Macrophytes become even more important for waterbirds in winter because, like many other birds, waterbirds tend to have a more protein-heavy diet during the breeding season and switch to a more omnivorous or herbivorous diet during the winter (Cramp et al., 1977, 1983; del Hoyo et al., 1996). As a result, abundance and diversity of macrophytes have a substantial impact on waterbirds which a lake can support outside the breeding season (Beklioğlu et al., 2006; Froneman et al., 2001; Milberg et al., 2002; Hargeby et al., 1994; Noordhuis et al, 2002). Previous studies from different parts of the world, including the three study lakes of this study, showed that macrophytes, especially submerged macrophytes, have a positive effect on overall waterbird community size and diversity (Beklioğlu et al., 2006; Froneman et al., 2001; Milberg et al., 2001; Noordhuis et al., 2002) Among the submerged macrophytes detected in the study lakes during the study years, one group is extra important. *Chara* species, which are a group of green algae that thrive on clear water conditions and low nutrient levels (Casanova, 2010; "Charophyta - Wikipedia," n.d.; van den Berg et al., 1998) are especially important for wintering waterbirds. This is due to several important features they have. Firstly, *Chara* species have a longer growing season; therefore, when most of the other plants' stems are leaves are depleted by herbivorous organisms towards the end of summer and in the autumn, *Chara* species will still have some growth and will keep on providing food for herbivorous species (Hargeby et al, 1994; Noordhuis 2002). Secondly, *Chara* species, when compared to none-vegetated and *Potamogeton*, another common submerged macrophyte taxon in the region (Seçmen & Leblebici, 1982), covered areas, support a higher biomass and diversity of invertebrates which can also be important winter food sources for omnivorous and invertebrate-consuming waterbird species (del Hoyo et al., 1996; Hargeby et al., 1994; Jeppesen et al., 1998, Lillie & Budd, 1992; Pardue & Webb, 1985; van den Berg et al., 1998). Thirdly, they have a very compact growth form making it possible for them grow in high densities (Casanova, 2010; Noordhuis et al., 2002). Thanks to all these special features, *Chara* species are especially important for wintering waterbirds, and it was shown in a study in the Nederlands that the autumn and winter abundances of many waterbird species have shown a positive correlation with *Chara* biomass and coverage.

In addition to providing food for waterbird species, macrophytes also increase habitat structural diversity and complexity in wetlands which also increases waterbird species richness and density a wetland can support (Elmberg et al., 1993; Froneman et al., 2001).

1.6 Temperature and Fall-winter Migration of Waterbirds

On a broad scale, both biotic and biotic factors, including accessibility of the food sources, competition and thermoregulatory costs (which are dictated by ambient temperatures) shape the wintering distribution of short and medium-distance migratory bird species (Dalby et al., 2013; Zuckerberg et al., 2011). When the winter approaches, many of the bird species take on a migration journey to spend the winter in places where biotic and abiotic conditions are more favorable. As air temperatures start dropping, energetic costs of surviving increase and this becomes the main force driving further migration along the flyway for many bird species (Dalby et al., 2013; Root, 1988). It is also known that the conditions birds experience in winter affect their breeding success in the next breeding season (Nilsson, 1979). However, birds must weigh the pros and cons of staying at a certain location for the winter against taking on the dangerous migration journey (Dalby et al., 2013) because the cost of migrating is also very high (Newton, 2008). They may either stay where they are, where thermoregulatory costs of fighting lower ambient temperature will be high (Dalby et al., 2013; Root, 1988) or migrate further along the flyway to spend the winter in milder and more favorable places (Hargeby et al., 1994). This means that bigger numbers of wintering waterbirds are expected in an area which is having a warm winter when places further up on the flyways are having a harsh winter (Avilova & Eremkin, 2001).

Since winter air temperatures fluctuate from one year to another, the pros and cons of staying at a particular wintering ground change (Ridgill & Fox 1990; Hepp & Hines 1991). This results in changes in wintering distributions of waterbirds from one year to another (Hepp & Hines 1991; Nichols et al., 1983; Ridgill & Fox 1990), which can at least partially be readable from the MWS results. It should also be noted that temperature is not the only abiotic factor affecting the wintering distribution of waterbirds. Winter precipitation patterns (Heitmeyer, 2006), consecutive number of days with subzero temperatures and snow cover (Schummer et al., 2010) are other abiotic factors which are known to have an impact on wintering distributions of birds.

A substantial portion of waterbirds detected in the study lakes is made up of migratory species and perform fall-winter migrations (Cramp & Simmons, 1997, 1983; del Hoyo, 1996). As a result, wintering population sizes of many waterbird species wintering in Turkey change partially with the number of individuals migrating to Turkey in fall and winter. According to previous studies which reviewed ringing data from the region, migratory flyways of several waterbird species across Turkey, East Europe, Eurasia and Northeast Europe are broadly along northeast to southwest, northwest to southeast and north to south axis (Cramp & Simmons, 1977, 1983; Diagana et al., (n.d.); and Fiedler et al., (n.d.) a, b, c, d). Therefore, conditions in areas lying north, northeast and northwest of Turkey are expected to affect number of waterbirds wintering in Turkey.

1.7 The North Atlantic Oscillation

The North Atlantic Oscillation (NAO) is one of the most prominent atmospheric patterns in the Northern Hemisphere (Hurell, 2003). It dictates climate variability in most parts of the Northern Hemisphere, especially during winters (Hurell, 1995, 2003). The North Atlantic Oscillation Index (NAO Index) is based on differences between sea level pressure in Subtropical High, near the Azores, and sea level pressure in Subpolar Low, near the Iceland (Kerimoğlu, 2008; Hurrell, 1995). It the most important mode of atmospheric variability in the Northern Hemisphere and has strong control over the weather and climate in the much of the Northern hemisphere

(Greatbatch, 2000; Hurrell, 1995, 1996; Kerimoğlu, 2008). In his 1996 study, Hurrell found out that the NAO explains 31% of the variation in winter surface air temperature in areas which are located north of 20°N. However, the NAO is less powerful in explaining climatic variability in warmer seasons (Rogers, 1990). Positive values of the NAO Index are brought about by stronger centers of pressure in Subtropical High and Subpolar Low and they result in moist and warm weather in much of the Europe and the Eurasian Continent and cold and dry weather in Eastern Mediterranean, Southern Europe and the Middle East (Greatbatch, 2000; Hurrell, 1995; Kerimoğlu, 2008). On the contrary, the negative values of the NAO Index are caused by weaker pressure differences in the Subtropical High and Subpolar Low and bring opposite patterns of temperature and precipitation (Hurrell, 1995). NAO’s impact of climatic conditions in Turkey has been studied and it is now known that the NAO’s impact on climate in Turkey is consistent with that of Southern Europe (Türkeş & Erlat, 2003, 2005; Kalaycı & Kahya, 2006; Karabörk et al., 2005). Furthermore, Kerimoğlu has showed in his 2008 study that the NAO affects temperature and evaporation patterns in Turkey and might have some effect on the water level fluctuations in the country.

1.8 Aim and Objectives

Aim of this study is to discover the impact of winter temperatures in Eastern Europe, North Atlantic Oscillation, water level changes and submerged macrophytes on wintering waterbird community density and structure in three Turkish shallow lakes which are Lake Uluabat, Lake Beyşehir and Lake Mogan. Following research objectives will be used to achieve this aim

1) Gathering and processing winter temperature data in Eastern Europe and statistically analyzing it together with various waterbird community variables to reveal any relationship in between them.

2) Using statistical analyses to see the impact of NAO on wintering waterbird communities in the study lakes.

3) Gathering water level data for the study lakes and putting them through statistical analyses together with various waterbird community variables to see if there is any relation between.

4) Using previous work about submerged macrophytes in the study lakes to learn about the submerged macrophytes status of the study lakes in the past and using this knowledge to discover any existing relationship various properties of wintering waterbird communities of the study lakes and submerged macrophytes in the lakes.

It should also be noted that the current study is the first of its kind in Turkey in that it used the Mid-Winter Waterbird Survey data to decode relations between wintering waterbird communities and climate, water level changes and submerged macrophytes.

CHAPTER 2

MATERIAL & METHODS

2.1 Mid-Winter Waterbird Surveys

2.1.1 Sources and Availability of the Survey Data

The Mid-Winter Waterbird Survey (MWS) results for the three study lakes were obtained from several published reports (which were Onmuş et al. (2007), Suseven et al. (2006), Yavuz & Boyla (2013), Yavuz & Kartal (2011)), Doğa Derneği's (Birdlife Turkey) archive (all records from 1967 to 2012), and from the general director of Turkish Mid-Winter Waterbird Survey National Committee, Assoc. Prof. Kiraz Erciyas (for Lake Mogan - from 2012 to 2016 and for Lake Uluabat from 2012 to 2015). Although the MWS have been conducted in Turkey since 1967, there are many multi-year gaps during which no MWS were conducted in the study lakes. Table 2.1 gives the full list of years for which the MWS data was available. Some of these MWS results were not included in the study for various reasons (see section 2.1.3). These years are given in red color in the table.

Various parameters deduced from the MWS results, such as wintering waterbird community size and species richness, were then analyzed statistically together with the climatic data, water level data and macrophyte data to determine any existing relationship or interactions in between.

Table 2.1: List of the available Mid-Winter Waterfowl Survey years with their dates (dates are given in day.month format, ND = No date, X = No MWS available, red-colored counts are omitted from the analyses).

	Lake Uluabat	Lake Beyşehir	Lake Mogan
1967-1968	15.01 – X	ND – X	X – X
1969-1970	09.01 – 15.01	ND – X	X – X
1971-1972	15.01 – 15.01	X – X	16.01 – 16.01
1973-1974	15.01 – X	X – X	05.01 – 07.01
1975-1976	X – X	X – X	16.01 – X
1977-1978	X – X	X – X	X – X
1978-1980	X – X	X – X	X – X
1981-1982	X – X	X – X	X – X
1983-1984	X – X	X – X	X – X
1985-1986	X – 15.01	X – X	X – X
1987-1988	15.01 – ND	X – X	X – X
1989-1990	15.01 – ND	X – 15.01	X – ND
1991-1992	X – X	X – ND	X – ND
1993-1994	ND – X	X – X	ND – X
1995-1996	17.01 – ND	X – ND	X – ND
1997-1998	X – X	X – X	X – X
1999-2000	ND – X	ND – X	ND – X
2001-2002	X – ND	X – ND	X – ND
2003-2004	X – X	X – X	X – X
2005-2006	ND – 10.02	ND – ND	ND – ND
2007-2008	21.01 – 05.02	17.02 – ND	19.02 – X
2009-2010	01.02 – 15.02	ND – ND	X – 2010
2011-2012	29.01 – 07.02	20.01 – 31.01	22.01 – 18.01
2013-2014	25.01 – X	03.02 – X	20.01 – X
2015-2016	ND - ND	ND - ND	ND – ND

2.1.2 The Mid-Winter Waterbird Survey Methodology

Under normal circumstances, mid-Winter Waterbird surveys in Turkey are conducted between 15th of January and 15th of February every year. Unfortunately, for the study lakes, the exact dates on which the counts were conducted were not always available; 50% of the MWS had no known count dates. For those which the dates of the counts were known, the date of the count changed from 5th of January to 19th of February (see table 2.1). Figure 2.1 shows the percent distribution of the MWS count dates in terms of week of the month for the MWS years for which the exact date was known.

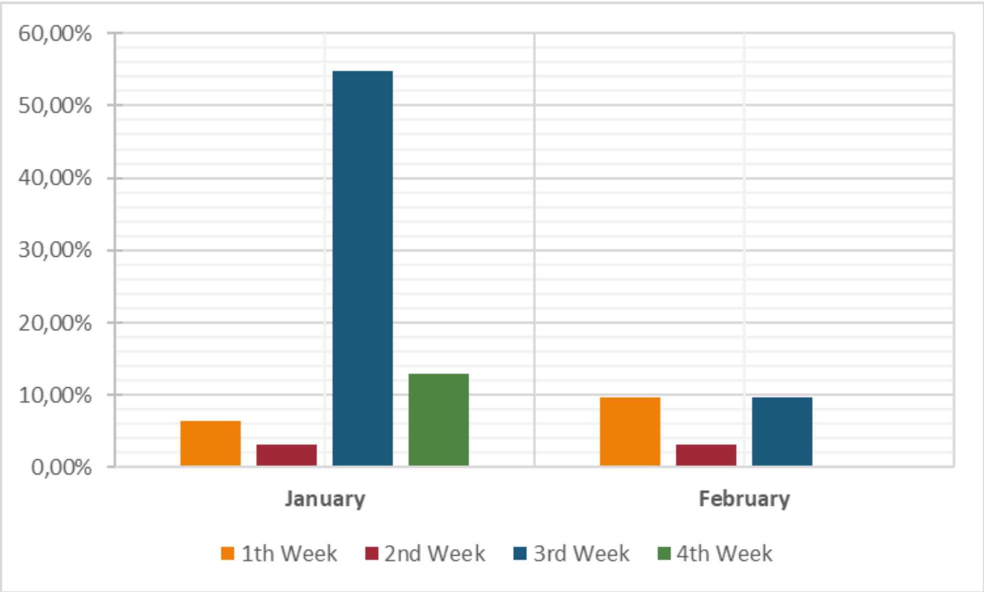

Figure 2.1: Percent distribution of the MWS dates of the study lakes in terms of week of the month.

The reason why the count dates are variable and distributed over 35 days is because unlike the other European countries, all of the target wetlands in Turkey cannot be counted in such a small time frame as one day or a weekend because the number target wetlands is too high and there aren't enough birdwatchers and volunteers to count them all in one or two days.

As far as the field methodology is concerned, Wetland International's internationally accepted and applied methods are followed in Turkey. The coordinates (in the form of latitude and longitude) of the observation spots which the birdwatchers and volunteers use to count the birds are noted and marked on maps and the same spots are used every year to perform the counts (Yavuz & Boyla, 2013; Yavuz & Kartal, 2011). This helps to make the counts more standard and comparable. The number and location of the spots are chosen carefully so that when combined, they can cover all or most of the wetlands. Although not always done, some basic observation information like time of the day, duration of the observation, number and identity of the observers and weather conditions are also noted. During the observations, observers identify and count all the waterbirds they can see or hear. When the observers cannot identify a bird, it is recorded under one of the four categories: unidentified waterbirds, unidentified waterbird, unidentified ducks and unidentified gulls. Although, it is up to the observers to choose which one of them will be used, these four categories are the only ones which are encountered in MWS records of the three study lakes. To make the counts as standard as possible, most of the wetlands are counted by the same person or people for as long as possible. However, after a while the MWS teams or some members of them change. The number of the counters are also dynamic; usually all the people who volunteer for the surveys are accepted and taken to the field. Although all waterbirds are currently being recorded in the context of MWS (Yavuz & Boyla, 2013), some bird taxa were not recorded in the past, such as shorebirds and common kingfishers (see section 2.1.4). Until 2002, when the 3rd edition of Waterbird Population Estimates, which sets the standards and guidelines for the MWS, was published, waterbird definition was more like a waterfowl definition excluding many avian taxa present in the current definition which all the birds belonging to the following families *Gaviidae, Podicipedidae, Pelecanidae, Phalacrocoracidae, Anhingidae, Ardeidae, Balaenicipitidae, Scopidae, Ciconiidae, Threskiornithidae, Phoenicopteridae, Anhimidae, Anatidae, Pedionomidae, Gruidae, Aramidae, Rallidae, Heliornithidae, Eurypygidae, Jacanidae, Rostratulidae, Dromadidae, Haematopodidae, Ibidorhynchidae, Recurvirostridae, Burhinidae, Glareolidae, Charadriidae, Scolopacidae, Thinocoridae, Laridae, Sternidae* and *Rynchopidae* (Wetlands

International, 2017). Before this definition, waterbirds were defined as birds which are dependent upon wetlands (Wetlands International, 2017) and this waterfowl like definition was then abandoned for the more comprehensive definition given above. It is because of this definition change, that some bird taxa were not recorded in MWS in the past are now being recorded (see section 2.1.4).

2.1.3 Exclusion of Certain Counts

Unfortunately, not all MWS results were suitable for the statistical analyses conducted in the study. For the sake of simplicity and because the details of each count were not known (e.g. number and identity people who did the count and weather on the count day), it was assumed that there was no difference in counting effort and conditions in any of the years for all the study lakes. Although this assumption cannot be 100% true, the fact that many of the lakes were counted by the same person or people for long periods of time, from the same spots, and around the same dates, it is practical to assume that the counts are somehow standard or semi-standard in terms of effort and counting conditions. Without making this assumption, one cannot effectively use statistical tools to discover ecological or biological information patterns embedded in the oldest and longest ornithological national dataset available in Turkey which is MWS. Still, enormous effort was spent to improve the standardization level of the dataset used. Exclusion of some of the counts was done in this context. Some of the counts were excluded from either some or all the analyses due to several reasons. Firstly, people sometimes report unidentified waterbirds (see section 2.1.2) in MWS results which may cause problems for some of the statistical analyses. Overall, around 60% of the counts in the study lakes reported at least one of four kinds of unidentified birds (see section 2.1.2). Although it is perfectly normal and acceptable to have some unidentified individuals in a MWS report, some of the counts reported too many unidentified individuals. Therefore, it was decided to exclude such counts from all the analyses except for the total number related analyses. Here, an assumption is made which is the number of birds reported is still accurate for the counts which reported too many unidentified individuals. This is because it is easier to just see and count waterbirds than identifying them (Bibby et al., 2000); therefore, observers who cannot successfully identify a group of waterbirds can still count them successfully. 50% was set as the threshold for the exclusion purpose; that is, the counts which reported more than 50% unidentified birds were excluded. This was done because having too many unidentified individuals would blur the results of the taxa or taxon related analyses (e.g. species richness analyses). However, as stated above, such counts were still included in total number related analyses. Secondly, some of the counts reported too few species and reported the numbers in multipliers of 5, 10 or 100 which can both be sources of error in the statistical analyses. Luckily, these counts made up only about 4% of all the counts (only two years). Existence of such counts probably points to a methodological error for those years and if that's the case, they should be excluded from all the analyses in order not to increase level of unstandardization in the dataset. Here, a decrease in sample size is traded for a possible increase in standardization level. Thirdly and lastly, every once in a while, a very talented or experienced birdwatcher go and count a wetland and this increases the number of species observed drastically. There was only one count of this type in which the counting crew had an extremely experienced birdwatcher among them and he was able to identify almost 2.5 times more species (see section 4.1) than the mean number of species. This count was also excluded from all the analyses except for total number related analyses. Again, this is because everyone would be able to count practically the same number of individuals but not everyone would be able to identify that many species.

2.1.4 Exclusion and Merging of Certain Taxa

Once again, to keep the counts as standardized as possible, it was decided to exclude some taxa from the analyses. First group of species to be excluded was shorebirds. In Turkey, shorebirds were not being counted in the MWS until 2002. Then, people started to include them in their reports and as a result, we only see shorebirds in the counts done in the recent years (see section 2.1.2). After discovering this, it was decided that all shorebird species should be excluded from all the analyses in order not to cause any bias or error in abundance, diversity and functional group related analyses. Shorebirds were not the only taxon which was excluded from the analyses. Common kingfisher (*Alcedo atthis*) showed a similar pattern; it was only present in recent years' counts. Therefore, we decided to exclude it from the study.

There were some other taxa which had the potential to cause error in the analyses conducted. *Larus argentatus* was a species; more correctly a species complex in the past (Collinson et al., 2008; Liebers et al., 2001, 2004; Yésou, 2002). Eventually, what scientists thought were subspecies were redefined as species and the species complex was split. Five of those newly defined species can be seen in Turkey. However, only four of those gull species were recorded in the three study lakes during the MWS. These were yellow-legged gull (*Larus michaellis*), lesser black-backed gull (*Larus fuscus*), Armenian gull (*Larus armenicus*) and Caspian gull (*Larus cachinnans*). The problem in our dataset was that all those species used to be counted as just one species in the MWS in the distant past. This would, of course, affect the species diversity analyses and constitute a source of bias. Therefore, in this study, *Larus argentatus* complex species were always merged and counted as one species to make it possible to compare diversity of the counts before and after the split. To calculate the total number of individuals belonging to the complex, the numbers of the newly defined species were simply summed. No other taxon was excluded from the analyses.

2.2 Formation of Functional Groups

As stated in the aims of the study section, two of the aims of this study are to evaluate the impact of water level and submerged macrophytes on wintering waterbird community size, structure and diversity. As stated in section 1.3, in addition to taxonomic diversity, functional diversity is also an important measure of community diversity (Pethchey & Gatson, 2002). This is why functional group richness, which is an important element of functional diversity, is used as an investigatory tool in this study. Functional groups are defined using traits which are directly related to ecosystem functions the organisms of interest conduct (Pla et al., 2012). The chosen traits should also relate to the aim of the study and the available trait data (Pla et al., 2012). Keeping in mind the aim given in the beginning of this section, dietary habits of the waterbirds were decided to be used in designating functional groups for this study. It is scientifically meaningful to use dietary features of species to form functional groups because those who feed on the same or similar food sources will probably conduct similar ecosystem services and respond to external changes similarly (de Bello et al. 2010). It is also a widely used method in forming avian functional groups (Pla et al., 2012). In this study, waterbird species were categorized under five main functional groups according to their winter food habits: herbivores (HE), omnivores (OM), piscivores (PI), invertebrate consumers (IN), and invertebrate and small fish consumers (INPI). We used winter food habits of the species to assign each species to functional groups because all the MWS are done in winter and almost all the waterbird species exploit different food sources at different times of the year (Cramp et al., 1977, 1983; del Hoyo et al., 1996). Table 2.2 gives detailed information about each of these functional groups and Appendix A gives the full list of species belonging to each functional group and the references used in the functional group assignment process. This type of functional group classification relates well to the study and its aims because it is expected to incorporate the status of submerged macrophytes and water level, both of which are important components of shallow lake ecosystems and have the ability to cause important ecological changes (Bancroft et al., 2002; Battisti et al., 2006; Beklioğlu et al., 2006; Coops et al., 2003; Colwell & Taft, 2000; Jeppesen et al. 1998). Both macrophytes and water level affect the food web structure and availability and diversity of certain avian food sources and thus there is a strong relation between them and the waterbird food sources (Diehl & Kornijów, 1998; Hargeby et al. 1994; Jeppesen et al. 1998; Milberg et al., 1993; Noordhuis et al., 2002; Vakkilainen, 2005; Tománková et al., 2013).

Table 2.2: Functional groups used in the study and details regarding their winter dietary habits

Functional Group	Details
Herbivore (HE)	Species which chiefly feed on plant material during the winter months
Omnivore (OM)	Species which feed on both plant and animal material (although at changing proportions) during the winter months
Piscivore (PI)	Species which feed chiefly on fish during the winter months
Generalist gulls (GU)	Gull species which are not strictly dependent on lakes and have an opportunistic and generalist during winters
Invertebrate and small fish consumer (INPI)	Species which feed chiefly on small fish and invertebrates during the winter months
Invertebrate consumer (IN)	Species which feed chiefly on aquatic macro invertebrates during the winter months

Because we are also trying to understand the effect of water level on the community and because not all of these functional groups have species that feed exactly the same way (e.g. some OM waterbirds forage at shallow parts and shores of the lakes, while some other forage by diving and looking for food on the lake bottom), for three of the functional groups some sub-functional groups were formed. HE, OM, PI and INPI were further divided into two sub groups: one covering the species which mostly use very shallow parts and shores of the lakes and the other covering the species which frequent the remaining open water parts of the lakes. No detailed statistical analyses were conducted regarding the eight resulting sub-functional groups; they were solely formed to be used in functional group richness analyses.

The functional groups formed were statistically analyzed (see section 2.7) together with water level and macrophyte data to reveal any relationship in between.

2.3 Water Level Data

2.3.1 Sources and Availability of the Water Level Data

Water level data was for the study lakes were obtained from Directorate of Water Affairs (DSI) Ankara and Bursa offices (for Lake Beyşehir and Lake Uluabat, respectively) and from Middle East Technical University Limnology Laboratory's database (for Lake Mogan). The data was either in the form first day of the month measurements (for Lake Uluabat) or in the form of monthly averages (for Lake Beyşehir and Lake Mogan). Similarly, water level measurements were presented either in the form of meters above the sea level (for Lake Beyşehir) or in the form of net depth measurements at the deepest point of the lake (for Lake Uluabat and Lake Mogan). List of the year for which both water level data and MWS was available for the study lakes is given in table 2.3. These also are the years which qualified for LWL-HWL analysis.

Table 2.3: List of years for which both water level and MWS data was available for the study lakes.

Study Lake	Available Years
Lake Uluabat	1967, 1970, 1971, 1972, 1973, 1988, 1989, 1990, 1993, 1995, 1996, 1999, 2002, 2005, 2006, 2008, 2009, 2011, 2012, 2013, 2015
Lake Beyşehir	1967, 1969, 1990, 1992, 1996, 1999, 2002, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012
Lake Mogan	1973, 1974, 1975, 1999, 2002, 2006, 2007, 2010, 2011, 2012, 2013, 2015, 2016

2.3.2 Winter and Growing Season Water Level Data

For this study, average winter water level and average growing season water level data were chosen as the two water level parameters to be used. Average winter water level was calculated as the average of January and February water level measurements. The reason why January and February were chosen is because all MWS in Turkey (both for which the exact day of the counts was known and for which the exact date of the counts were not known) are done in January and February months. Average of January and February measurements serves a parameter to give us idea about the water level at the time of the counts. For the calculation of the average macrophyte growing season water level, the growing season needed to be defined at first. Growing season for macrophytes vary from one region to another and with yearly climatic conditions (Rooney & Kalff, 2000). This study included three lakes from three different geographical regions and the it was decided that the best time frame to cover and represent macrophyte growing season (will be called growing season from now on) in all of the three study lakes would be starting from March and ending in August. Then, average of the first day of the month measurements for spring and summer months were used to calculate the average growing season water level. Because the study's main subject was wintering waterbird communities and the MWS, the study's main season of interest was winter. During winter of a certain year, all the present macrophytes in the lake are the ones which grew during the previous macrophyte growing season (i.e. spring and summer). For example, all the macrophytes present in a lake during the MWS of 2002 are the ones which grew in the lake during 2001's growing season. As a result, the previous year's growing season water level data was the relevant proxy to study winter months and growing season water level averages given in the study for every study year is actually representing the previous year's water level measurements.

2.3.3 Determination of Low Water Level and High Water Level Years

Upon calculating the average winter and growing season water levels for the study lakes and years, each study year was classified into low water level (LWL) and high water level (HWL) according to their average winter water level and growing season water level. Following Beklioğlu et al. (2006), z-scores were calculated for the average winter water level and growing season water level of each study year and for the long term (calculated by using all the available data) average winter water level and average growing season water level. Then, those falling below the related long-term z-scores were designated as LWL and those falling above it were designated as HWL years. Full list of qualifying (i.e. years for which both MWS and water level data was available) winter LWL, winter HWL, growing season LWL and growing season HWL years for each study lake is given table 3.1. Afterwards, LWL and HWL groups were compared on the basis of several community related variables, such as total abundance of a particular functional group, by using the statistical methods listed in section 2.7.

2.4 Submerged Macrophyte Data

2.4.1 Sources and Availability of the Macrophyte Data

For Lake Uluabat and Lake Beyşehir, main data source was Levi et al. (2016) which studied littoral and pelagic sediment cores (taken in 2011) from these lakes and reported the number of macrophyte macrofossil present in the core. See Levi et al. (2016) for a detailed description of the methodology followed. In addition, Altınayar (1998a), Beklioğlu et al. (2006) and Salihoğlu & Karaer (2004) were also used to confirm and correct the classifications (i.e. low macrophyte – high macrophyte classification – see section 2.4.2) to see if they actually were accurate. How the confirmations and corrections were done is explained in detail in section 2.4.2. For Lake Beyşehir, Beklioğlu et al. (2006), Bucak (2017), Kazancı et al. (1999), Seçmen & Leblebici (1982) and Beklioğlu personal observations were used to confirm and correct the macrophyte status classifications done. Furthermore, other types of information provided in Levi et al. (2016) (e.g. historical diatom data) were also used to make further corrections. How that was done is explained in section 2.4.2 in detail. For Lake Mogan, main source of macrophyte related data was the direct measurements done in the field by the members of Middle East Technical University Limnology Laboratory. Detailed methodology followed during the samplings is explained in section 2.4.2. Tan (2002) and Doğan (2007) were the only studies which could serve as a source of confirmation and correction for the output of the macrophyte status classification done in the current study (see section 2.4.2). Full list of years for which both macrophyte data and MWS data was available is given in table 2.4.

Table 2.4: List of years for which both macrophyte and MWS data was available for the study lakes.

Study Lake	Available Years
Lake Uluabat	1967, 1970, 1971, 1972, 1973, 1988, 1989, 1990, 1993, 1995, 1996, 1999, 2002, 2005, 2006, 2008, 2009, 2011, 2012, 2013, 2015, 2016
Lake Beyşehir	1967, 1969, 1990, 1992, 1996, 1999, 2002, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2015, 2016
Lake Mogan	1973, 1974, 1975, 1990, 1992, 1996, 1999, 2002, 2006, 2007, 2010, 2011, 2012, 2013, 2015, 2016

2.4.2 Determination of Low Macrophyte and High Macrophyte Years and Extrapolation and Correction of the Available Data

Levi et al. (2016) which is the main source of historical submerged macrophyte data for Lake Uluabat and Lake Beyşehir studied littoral and pelagic cores (taken in 2011) from the lakes and reported the number of macrophyte macrofossil parts per cm^3 at every 2.5 cm (see the article for a detailed information about the methodology followed). As a result, macrophyte data was available only for some years of the study period which covers the time frame between 1967 to 2016. To obtain macrophyte data for the years falling in between the studied years (i.e. years/dates which do not correspond to the 2.5 cm intervals), the data from the closest measurement was used. Since Levi et al. (2016) also reported the sediment accumulation rates, it was possible to pick the closest studied year and assign the same macrophyte status (i.e. low macrophyte or high macrophyte) to its neighboring years. Although this kind of extrapolation requires some assumptions, it was the only way to have an idea about the submerged macrophyte status in the lakes for the rest of the study years, and the other sources listed in section 2.4.1 and other information provided in Levi et al. (2016)

(e.g. historical diatom data) were also used to confirm the macrophyte status assignments (see section 3.2.2).

Although Levi et al. (2016) reported submerged macrophyte fossils quantitatively (parts per cm^3), type of data presented there cannot be considered as actual quantitative representation of the source plants (Birks, 2002). Because the amount plant parts deposited at a place and eventually preserved in the sediment depends on various factors other than sole biomass of the plant, such as water flow, wind turbulence, storms, lake morphometry, chemical conditions near the site, taxon the plant belongs to and the type of body structures (Birks, 1973, 1980, 2002). For all these reasons, quantitative plant macrofossil data was converted into a present-absent type of data and used in that format. By using the historical submerged macrophyte data for each of Lake Uluabat and Lake Beyşehir's study years, submerged macrophyte scores were calculated for each year. When determining the scores for each macrophyte species' presence of all macrophyte taxa was given an equal score (which was 1) but presence of macrophytes belonging to *Chara* genus. This family of macrophytes is a good indicator of macrophyte-favoring conditions in the lake (like a clear water state) and are especially important for wintering waterbirds due to several features they have which are listed in section 1.4 (Casanova, 2010; Hargeby et al., 1994; Noordhuis et al., 2002). Therefore, presence of *Chara* genus was given a higher score (which was 2) than the other macrophyte taxa. To calculate the overall submerged macrophyte score for a certain year in a lake, scores for all of the present macrophyte taxa were simply summed. Then, the threshold levels were set for Lake Uluabat and Lake Beyşehir and years which were below a certain threshold score were assigned as low macrophyte (LM) years and those which were above the threshold were assigned as high macrophyte (HM) years. To set the threshold values for the lakes, other information from Levi et al. (2016) such as diatom related data and percent representation of planktonic and benthic diatom taxa and other existing literature (a full list of which is given in the beginning of this section) were used as guidelines. After that, the resulting classification output was compared with the existing literature (see section 1.2) and other data presented in Levi et al. (2016). This confirmation and correction process served as a verification tool for the classification. For Lake Mogan, direct observations and measurements were used instead of core-sourced historical macrophyte data which was not available. Every year, at the end of the growing season, in August or September, members of Middle East Technical University Limnology Laboratory get on a boat and study the Lake Mogan's submerged macrophytes. By using a Sigurd Olsen rake and an Ekman grab, they collect plant samples from the lake bottom and water column. The sampling is done along 18 transects which are positioned on the lake and separated by 180 to 220m distance (Tan, 2002). The crew uses a GPS device to follow their position and do the sampling at certain intervals along the transect. An average of nine samplings are done along each transect (Tan, 2002). Afterwards, species identification of the plant samples is done in the laboratory and percent of the lake bottom covered with macrophytes (will be called coverage or macrophyte coverage from now on) and percent plant volume infested (PVI%) are calculated. For this study, macrophyte coverage was chosen as the representative of Lake Mogan's macrophyte status and low and high macrophyte years were decided by using this information. An average was calculated by using all the available coverage data and the years falling below the average were designated as LM and those falling above the average were designated as HM years. Then, Tan (2002) and Doğan (2007) were used to confirm the results of the classification.

Due to the fact the MWS are conducted in January and February and macrophyte growing and sampling seasons are in spring and summer, previous years' macrophyte records were used when evaluating macrophyte status of a MWS year. That is, to know about the macrophyte status in Lake Mogan during January 2002, 2001's sampling results should be used because 2002's sampling will sample macrophytes of the next growing season.

After the classification was done, LM and HM years were compared on the basis of various community properties by using the statistical methods listed in section 2.7.

2.5 Upstream on the Fall-winter Migratory Flyways: Eastern Europe

As stated in the aims section of the thesis, successfully estimating how harsh the winter has been in upstream parts of the migratory flyways before the MWS dates and investigating its effect on wintering waterbird communities in the three study lakes are among the main aims of the current study. To serve that purpose, places which are upstream parts of the fall-winter migratory waterbird flyways needed to be determined first. Following the information given in section 1.5, four countries from Eastern Europe countries were chosen to represent the upstream places on the fall-winter migratory flyway of waterbirds. These countries were Ukraine, Moldova, Romania and Bulgaria (figure 2.2). The reason why these particular countries were chosen is because they are the closest countries to Turkey in north and northwest directions (figure 2.2) which makes them closest upstream places on fall-winter migratory flyways and because existing information regarding waterbird migration in the region shows that most of the migratory wintering waterbirds migrates to western half of Turkey, where all the study lakes are located), through these countries during their fall-winter migration (Cramp et al., 1977, 1983; Diagana et al., (n.d.); Fiedler et al., (d.n.) a, b, c, d; Gilbert et al., 2006,). If; however, the study included lakes from the eastern half of Turkey, then northeast to southwest flyway would also be considered and some more countries or regions (possibly Georgia) would be included in the study as well.

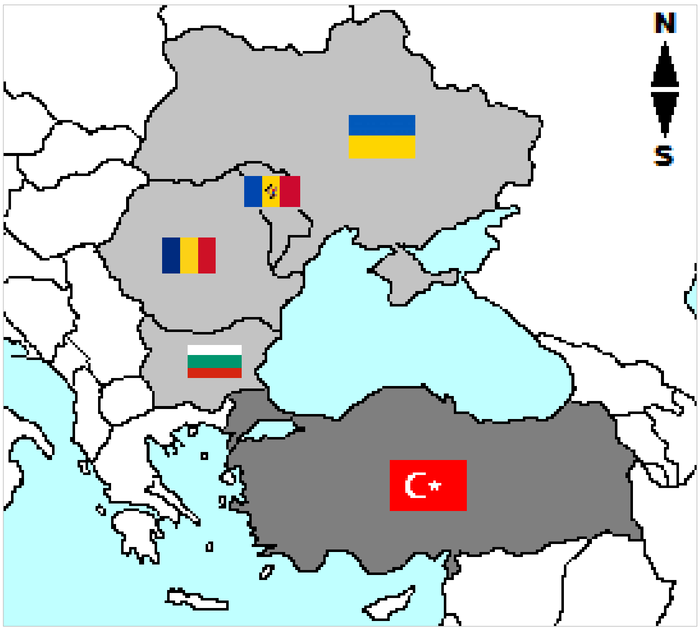

Figure 2.2: Turkey and the four Eastern Europe countries chosen for the study. From top to bottom: Ukraine, Moldova, Romania, Bulgaria and Turkey.

The reason why country borders were used as criteria instead of some other criteria, such as city borders and regional borders, is because datasets were way more easily accessible for whole countries than the other options were.

2.6 Climatic Data

2.6.1 Winter Air Temperatures in Eastern Europe

Historical air temperature records from four countries from Eastern Europe: Ukraine, Moldova, Romania and Bulgaria were retrieved from National Oceanic and Atmospheric Administration's (NOAA) Global Historical Climatology Network (GHCN) database (Climate Data Online (CDO) - The National Climatic Data Center's (NCDC), n.d.). While retrieving the data for a certain year and country, data from all the available land-based stations was downloaded. To obtain the country's average for a temperature parameter of interest, an average was calculated for all the stations from that country. For this study, daily average (TAVG) and daily minimum (TMIN) temperature data for 1st of December to 31th of January (December-January) and 1th of January to 31th of January were chosen as the climatic parameters to be used. In other words, average TAVG and TMIN for December-January and January were used as surrogates for winter temperature in the four study countries. The exact count dates for most of the MWS weren't known (table 2.1); nevertheless, the surrogates or proxies of choice needed to cover temperature information in Eastern Europe before the count dates. December-January and January temperature proxies seemed like the best candidates to serve that purpose and thus they were chosen in this study.

Land-based stations from which temperature data was obtained were not always active. Number of the available stations from which temperature data was collected changed from one year to another for all of the four countries. This had the potential to cause some problems for the study. From 1967 to 2016 (which was our study period), many of the stations in the four countries stopped operating and new ones were established. This have the potential to affect the calculated average December-January TAVG and TMIN values. To tackle this possible source of error, stations which were always active for the study period were detected and the data from only those stations was used. For example, in Moldova, which is a small country (see figure 2.1) only one station qualified and thus data from only one station was used in the statistical analyses. However, this was not always how the problem was solved. For the countries where the active number of stations is high (more than 15), regardless of the number and identity of the active stations, means were calculated for all the available stations and used in the analyses. This makes sense because as the number of stations increase (or as the sample size increases), the chances of accurately approximating the country's real average (or the statistical population mean) increase. Therefore, if a country has 17 active stations and 24 active stations the year after, for example, it was assumed that the averages of both of this sets will give us a good approximation of the country's average temperature and all the active stations would be used in mean TAVG and TMIN calculations.

After collecting and arranging all the available data, Eastern Europe's winter air temperature and different properties of wintering waterbirds communities of the study lakes were analyzed statistically (see section 2.6) to determine the interactions if there was any.

2.6.2 The North Atlantic Oscillation (NAO) Index

Hurrell North Atlantic Oscillation Index data was retrieved from National Centers for Environmental Information Database (North Atlantic Oscillation (NAO), National Centers for Environmental Information (NCEI), n.d.). Monthly NAO measurements for the study years were downloaded and mean NAO value for December and January were calculated for each year. NAO Index for December-January was obtained by calculating the arithmetic mean of the NAO values for the two months.

Then, December-January NAO and January NAO index values and various wintering avian community parameters were analyzed to reveal the interactions in between.

2.7 Statistics

The study includes comparisons of pairs of samples on the basis of various ecological variable (e.g. functional group richness). Most of the source data used in this study was in the form counts of things, proportions and indices such as total waterbird abundance and abundance of a particular functional group. It is known that such types of data do not qualify for widely used parametric tests such as t-tests (Cohen & Fowler, 1996). This is because the data needs to be normally distributed to qualify for such parametric tests. Mann-Whitney U-test, which is also known as Wilcoxon Rank Sum Test, is distribution-free non-parametric technique which compared the medians of the two samples (Cohen & Fowler, 1996; Mann & Whitney, 1947; Wilcoxon, 1945). It is simply used to detect statistical differences between two samples. Because the test is distribution-free, it is suitable for use on data such as the ones used in the current study.

Pearson' correlation coefficient or product moment correlation coefficient is a parametric coefficient which measures the correlation between the two readings that fall on the 45° line drawn from the origin (Cohen & Fowler, 1996; I-Kuei Lin, 1989). It simply measures the degree to which a change in one variable is accompanied by another one (Cohen & Fowler, 1996). Since this statistic was a parametric one, required transformations were used on the raw data before this statistic was calculated. Transformation methods used in the study were chosen according to the guidelines in Cohen & Fowler (1996). Transformation methods used in the study were log-10 and arcsine transformations which were used for counts and ratios (including percentages), respectively.

There were several biodiversity measures used in the study. The first one was species richness. Species richness is simply the number of species in an observation (Magurran, 2013). It is an important measure of community diversity (Colwell & Gotelli, 2001). The species richness data used in the study, which came from the MWS results, seemed to be biased and error-prone sometimes. Therefore, another richness measure was defined for the study. Called modified species richness, this measure was simply a modified version of species richness which didn't include sightings reporting less than 10 individuals. This community diversity parameter was created to omit the rare species from the overall species richness. This was need because the MWS cannot be standard in terms of effort which might be a source of error. As discussed in section 4.1 in detail, there is a steady species richness increase in the MWS results which seems to be stemming from observer-sourced bias. In other words, modified species richness was created as a part of the efforts to increase the level of standardization in the data. When examined closely, it is seen that observations that report species and their abundances tend to have small numbers of sightings for many of the species present on the checklist (Bibby et al., 2000). The number of species reported is highly dependent of the observer(s); a talented and more experienced observer is expected to identify and report more of these rare species which might be hard to get for a beginner-level observer (Bibby et al., 2000). Change in effort is also expected to generate a similar pattern; increase in effort is expected increase the number of species detected up to a certain extent (Bibby et al., 2000; Gregory et al., 2004). Modified species richness parameter was created to ease the effect of these observer or effort-sourced bias in the source data.

Cumulative species richness and summed species richness were the other richness indices used in the study. Cumulative species richness was defined as the cumulative species richness present in the whole set of samples which were the study lakes in this case. It can also be defined as the whole collection of species present in the study lakes or the overall species richness of the study lakes. Summed species was simply the sum of the species richness values of the set samples; that is, the three study lakes.

Table 2.5 summarizes the types of data which were used for the final analyses in this study.

Table 2.5: Types of available data and data used in the analyses

	Low Macrophyte
Waterbird Counts	Discrete numbers
Air Temperature	Continuous numbers
Water Level	Continuous numbers
Macrophyte	Present/absent for Lake Uluabat and Lake Beyşehir Discrete numbers for Lake Mogan

CHAPTER 3

RESULTS

3.1 Impact of Climate on Wintering Waterbird Communities

3.1.1 Effect of Winter Temperatures in Eastern Europe on Wintering Waterbird Communities in Turkey

December-January daily average temperature (TAVG) measurements for Ukraine (TAVG Ukr.), Moldova (TAVG Mold.), Romania (TAVG Rom.), Bulgaria (TAVG Bulg.) and all of them combined (TAVG SE EU) are given in the figure below.

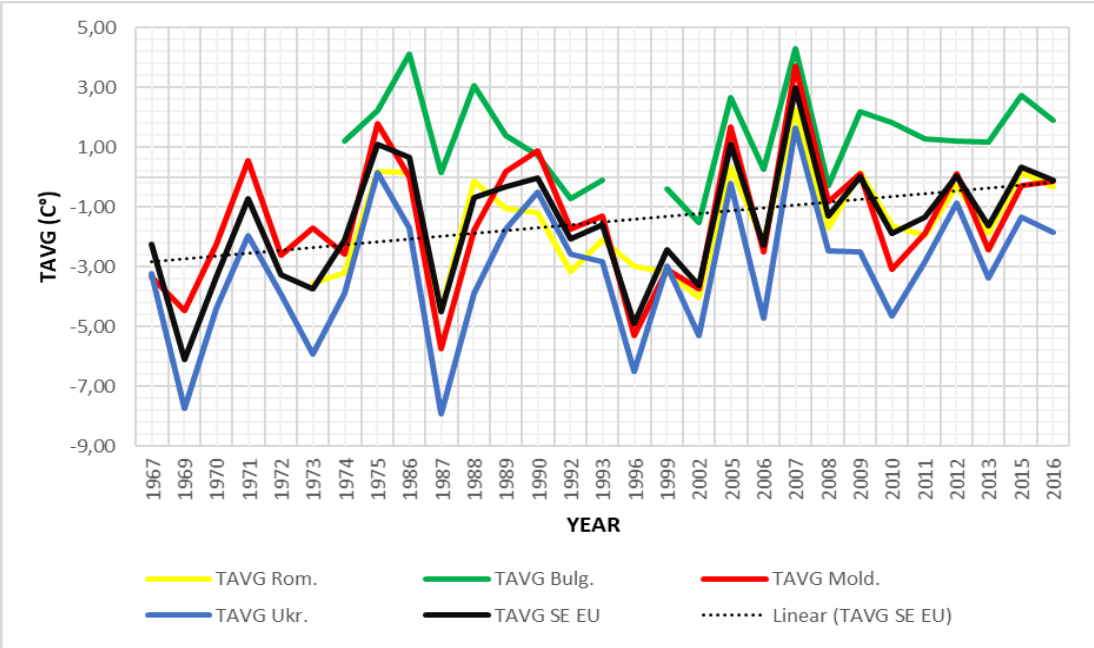

Figure 3.1: Changes in December-January mean daily average temperature values (TAVG) for Ukraine (TAVG Ukr.), Moldova (TAVG Mold.), Romania (TAVG Rom.), Bulgaria (TAVG Bulg.) and all of these four Eastern Europe countries combined (TAVG SE EU) during the study years. Dashed line: trendline for TAVG SE EU.

This study showed that number of wintering waterfowl in the three Turkish shallow lakes, at least partially, were related to the winter air temperatures in countries lying north and northwest of Turkey; the same year's average and minimum winter air temperatures in Ukraine, Moldova, Romania and Bulgaria seemingly affect the number of birds coming south and southeast, to Turkey, to spend the winter. It was shown in this study that both average daily air temperatures and minimum daily air temperatures averaged for 1th of December to 31th of January showed moderate to strong and negative correlations with cumulative number of waterbirds counted in the study lakes during the Mid-Winter Waterfowl Survey of the same year (table 3.1). The correlation for Dec-Jan TAVG almost achieved statistical significance at 95% confidence level ($p=0.06$) and the linear correlation for Dec-Jan TMIN fell barely short of statistical significance (p=0.11). Furthermore, the biggest number of waterbirds counted in the three study lakes in a single year was for 1996 when winter temperatures in Southeastern Europe hit a big law after 1969 (figure 3.1). Although not as strong, similar and negative correlation coefficients were observed for January average and minimum temperatures in the four Eastern Europe countries and cumulative number of wintering waterbirds in the study lakes (table 3.1). Nevertheless, both of these correlations failed to achieve statistical significance (p=0.36 for TAVG and p=0.69 for TMIN). When examined alone, it seemed like the study lakes were affected by winter air temperatures in Eastern Europe in different ways and magnitudes (table 3.1).

Table 3.1: Pearson's Correlation Coefficients for mean December-January (Dec-Jan) and January (Jan) daily average (TAVG) and minimum temperatures (TMIN) in the four Eastern Europe countries combined and cumulative number of wintering waterbirds counted in the study lakes

Winter Air Temperature	**Lake Uluabat**	**Lake Mogan**	**Lake Beyşehir**	**Lakes Combined**
Dec-Jan TAVG	-0.462	0.091	0.225	-0.731
Dec-Jan TMIN	-0.452	0.143	0.281	-0.654
Jan TAVG	-0.202	0.334	0.407	-0.409
Jan TMIN	-0.109	0.417	0.469	-0.183

Species richness indices in the study lakes seemed to be related to winter air temperatures in Eastern Europe as well. Moderate and positive correlations were detected between cumulative species richness and both December-January and January average temperatures in the four Eastern Europe countries but both of these correlations failed to reach statistical significance (p=0.22 and p=0.33, respectively). The correlations between Dec-Jan TAVG and Jan TAVG, and summed species richness were weak and positive. Test of significance for these linear correlations showed that they failed to reach statistical significance (p=0.46 and p=0.99, respectively). Summed modified species richness showed a weak and negative correlation with Dec-Jan TAVG and Jan TAVG (table 3.2) and they too were insignificant (p=0.93 and p=0.49).

Table 3.2 Pearson's (r) Correlation Coefficients for mean December-January (Dec-Jan) and January (Jan) daily average temperatures (TAVG) in the four Eastern Europe countries combined and cumulative species richness (cα), summed species richness (sα), and summed modified species richness (smα) in the three study lakes

Studied Pairs	Pearson's r
Dec-Jan TAVG – cα	0.535
Jan TAVG - cα	0.431
Dec-Jan TAVG - sα	0.338
Jan TAVG - sα	0.006
Dec-Jan TAVG - smα	-0.043
Jan TAVG - smα	-0.317

When studied individually, it was seen that wintering waterbird numbers in each of the study lakes exhibited different degrees of correlation with average winter air temperatures in Eastern Europe (table 3.3). Among them, Lake Uluabat, which is the northernmost of the study lakes (also the closest lake to the four Eastern Europe countries - see figure 1.1 and 2.2), showed the only negative correlation with winter air temperatures in Eastern Europe countries. In contrast, the other two lakes, exhibited weak to moderate and positive correlations with the winter air temperature in Eastern Europe (table 3.2). When the correlation between average and minimum December-January air temperatures in each of the four Eastern Europe countries and cumulative number of wintering waterbirds in the study lakes was studied, it was seen that all the four countries generated negative correlations (table 3.2). Among them, Moldova and Romania had the strongest negative correlations, strengths of which were moderate. The weakest correlation coefficients were found for Ukraine.

Table 3.3: Pearson's Correlation Coefficients for average December-January (Dec-Jan) daily average (TAVG) and minimum temperatures (TMIN) in the four Eastern Europe countries and cumulative number of wintering waterbirds counted in the study lakes

Winter Air Temperature	Ukraine	Moldova	Romania	Bulgaria
Dec-Jan TAVG	-0.130	-0.502	-0.519	-0.414
Dec-Jan TMIN	-0.120	-0.444	-0.341	-0.118

3.1.2 Effect of NAO Index on Number of Wintering Waterbirds in Turkey

The figure 3.2 shows Hurrell's NAO Index values for December-January (Dec-Jan) and January (Jan) of the study years.

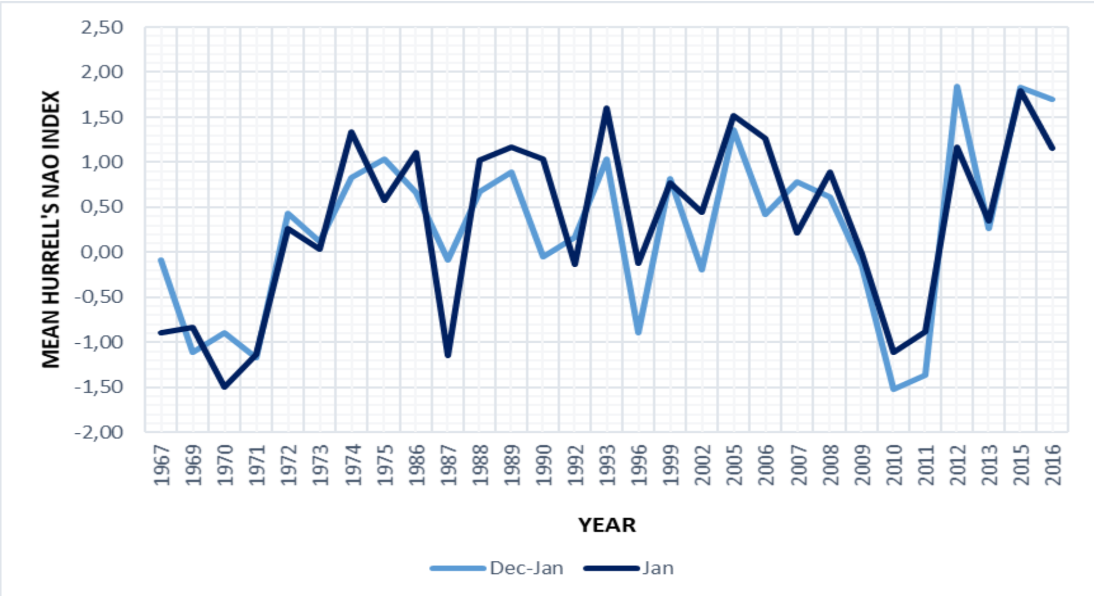

Figure 3.2: Change in Hurrell's NAO Index values over the study years

When the graph in figure 3.1 is examined, it can be seen that the NAO has hit four big lows: one in 1970, one in 1987, one in 1996 and another one in 2010 and 2011, and five big highs: one in 1974, one in 1993, one in 2005 and 2006, one 2012 and another in 2015.

Table 3.4 shows Pearson's correlation coefficients calculated for the NAO index values and various wintering waterbird community parameters for the study lakes. The current study showed that the NAO Index and cumulative wintering waterbird numbers in the three study lakes were weakly and negatively correlated to each other and these correlations were statistically insignificant (p=0.62 and p=The effect of the NAO on cumulative species richness of wintering waterbird communities in the study lakes was either weak or almost non-existing. Linear correlation coefficients calculated for average December-January (Dec-Jan) and average January (Jan) NAO Index values and cumulative species richness in the were found to be weak in strength and both correlations were statistically insignificant (p=0,52 and p=0,97, respectively). When summed species richness for the study lakes was examined for any linear correlations with NAO Index values, it was seen that the summed species richness was slightly and negatively correlated with both Dec-Jan NAO Index and Jan NAO Index. However, both of these correlations were statistically insignificant (p=0,84 and p=0,42, respectively). Lastly, some near significant levels of correlations were detected between NAO and summed modified species richness. Both Dec-Jan and Jan NAO indices generated moderate to strong and negative linear correlation coefficients. Both correlations approached conventional levels of significance (p=0,10 and p=0,08, respectively).

Table 3.4 Pearson's (r) Correlation Coefficients for average December-January (Dec-Jan) and January (Jan) NAO Index values and cumulative number of wintering waterbirds (N), cumulative species richness (cα), summed species richness (sα), and summed modified species richness (smα) in the three study lakes

Studied Pairs	**Pearson's r**
Dec-Jan NAO Index - N	-0.236
Jan NAO Index - N	-0.273
Dec-Jan NAO Index – cα	0.297
Jan NAO Index - cα	-0.018
Dec-Jan NAO Index - sα	-0.092
Jan NAO Index - sα	-0.369
Dec-Jan NAO Index - smα	-0.670
Jan NAO Index - smα	-0.708

3.2. Low Water Level – High Water Level and Low Macrophyte – High Macrophyte Classification Results

3.2.1 Low Water Level – High Water Level Classification

Table 3.5 gives the result of LWL-HWL classification for winter and growing season water levels of each study year.

Table 3.5: List of winter LWL, winter HWL, growing season LWL and growing season HWL years for each study lake.

Study Lake	Winter LWL	Winter HWL	Growing Season LWL	Growing Season HWL
Lake Uluabat	1973, 1988, 1989, 1990, 1993, 1995, 1996, 2005, 2006, 2008, 2009, 2012, 2013	1967, 1970, 1971, 1972, 1999, 2002, 2011, 2015	2013, 2012, 2009, 2008, 2006, 2005, 2002, 1996, 1995, 1993, 1990, 1989, 1973	2015, 2011, 1999, 1988, 1972, 1971, 1970, 1967
Lake Beyşehir	1996, 1999, 2002, 2005, 2006, 2007, 2008, 2009, 2010, 2011	1967, 1990, 2012	1990, 1996, 1999, 2002, 2005, 2006, 2007, 2008, 2009, 2010	1967, 2011, 2012
Lake Mogan	1973, 1974, 1975, 2002, 2006, 2007, 2010	1999, 2011, 2012, 2013, 2015, 2016	1973, 1974, 1975, 2002, 2006, 2007	1999, 2010, 2011, 2012, 2013, 2015, 2016

Changes in the study lakes’ mean winter water level and mean growing season water level during the study period are shown figure 3.3. Note that the horizontal axes in this section are all out of scale.

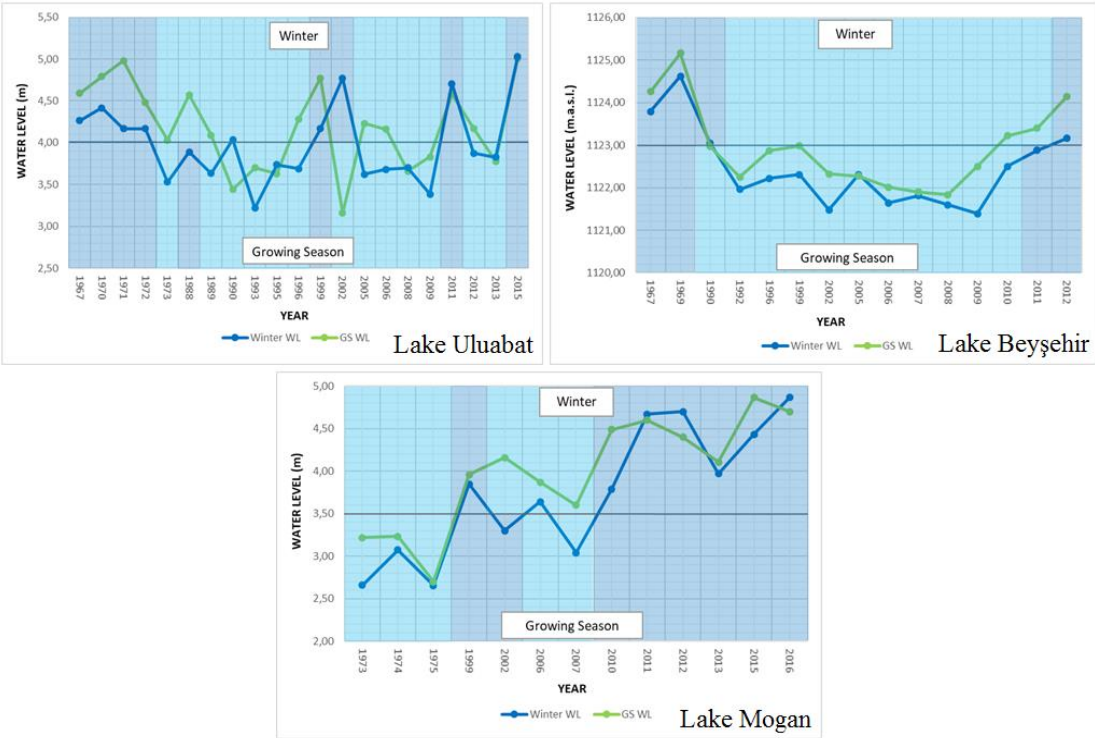

Figure 3.3: Change in the study lakes' mean winter water level and mean growing season water level over the study years. Shading in the upper half of the graph shows winter LWL and HWL years (light blue: LWL, dark blue: HWL) and shading in the lower half of the graph shows growing season LWL and HWL years (LWL= low water level, HWL= high water level)

3.2.2 Low Macrophyte – High Macrophyte Classification

Crosschecking with the previous studies showed that the classification method used in the study was accurate for all of the study years except for one. This finding showed that the methodology followed when classifying years into LM and HM years was, in fact, pretty accurate. The only classification result which needed to be corrected was Lake Beyşehir's 2011 classification. By using the current methodology, that year and the years classification of which were obtained by extrapolating the classification result for 2011, which were 2009 and 2010, were classified as HM years. However, when investigated more carefully, the other information present in Levi et al. (2016)

showed that those years were actually LM years. A high percent representation of planktonic diatom taxa and presence of a diatom species, *Aulacoseira granulata*, which is a typical species of eutrophic water bodies (Wolin & Stone, 2010). both pointed to turbid and scarce macrophyte conditions. As a result, Lake Beyşehir's 2011 (along with 2009,2010 classifications of which were obtained by extrapolating 2011's classification) classification was corrected to HM. Apart from this, no other correction was needed and the classification methodology used generated results which were in line with previous published results.

According to the macrophyte status classification used in the current study, which was mainly based on Levi et al. (2016) and validated by previous studies listed in section 1.3, two different periods were recognized for Lake Uluabat: a HM period starting from 1970's and extending to 1999 and a LM period starting from 2000 and extending to 2015, four different periods were recognized for Lake Beyşehir: a HM period starting from in 1960's, a LM period in early 1990's, a HM period starting between 1992 and 2009 and a LM period starting from 2010 and lasting until 2012 and extending to 1999 and a LM period starting from 2000 and extending to 2015, and six different periods were recognized for Lake Mogan: a LM period in 2002 and 2006, a HM period in 2007, a LM period starting in 2010 and ending in 2012, a HM period in 2013, a LM period in 2015 and finally a HM period in 2016. Table 3.6 shows the list of LM and HM years for which both macrophyte data and the MWS data was available.

Table 3.6: List of LM and HM years for each study lake

Study Lake	Low Macrophyte (LM)	High Macrophyte (HM)
Lake Uluabat	2012, 2011, 2010, 2009, 2008, 2007, 2006, 2005, 2002	1999, 1996, 1995, 1993, 1990, 1989, 1988, 1987, 1986, 1973, 1972, 1971, 1970, 1969, 1967
Lake Beyşehir	1990, 1992, 2010, 2011, 2012	1967, 1996, 1999, 2002, 2005, 2006, 2007, 2008, 2009
Lake Mogan	2007, 2010, 2011, 2012, 2013	2002, 2006, 2015, 2016

3.3 Impact of Water Level and Submerged Macrophytes on Wintering Waterbird Communities

3.3.1 Lake Uluabat

Change in the size of Lake Uluabat's wintering waterbird community over the study years is given in figure 3.4.

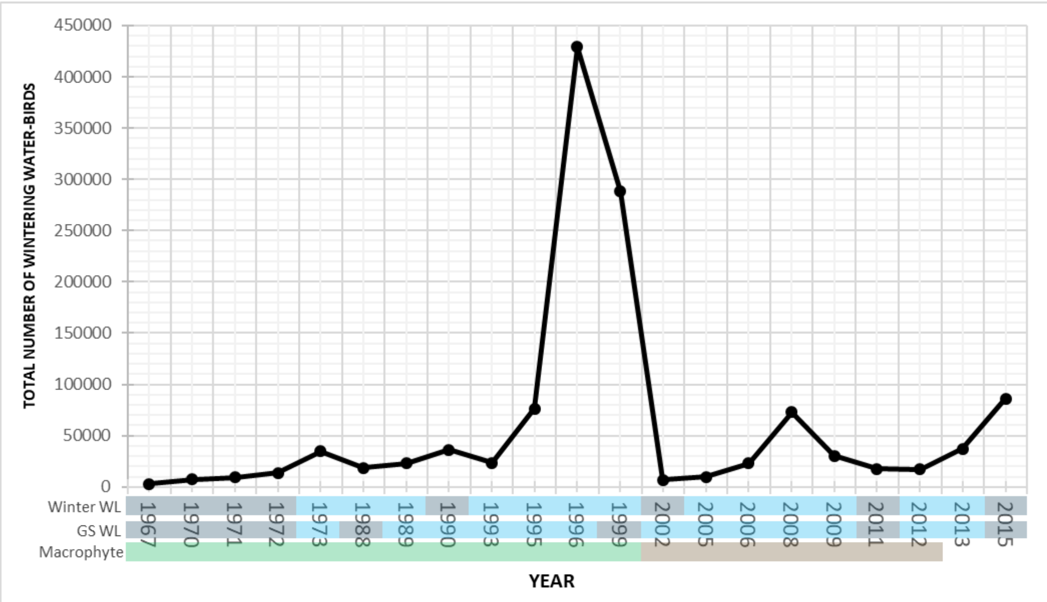

Figure 3.4: Change in wintering waterbird community size in Lake Uluabat over the study years and in relation to water level and macrophyte status classification. Shading below the graph: light blue=LWL years, dark blue=HWL years, green=HM years and brown=LM years (GS = growing season, WL = water level, LM=low macrophyte, HM=high macrophyte)

This study showed that the relationship between winter and growing season water level and total number of wintering waterbirds in Lake Uluabat was weak to moderate. Winter LWL years attracted about 1.18 times more waterbirds on average and the difference between the medians of winter LWL and HWL years in terms of the number of waterbirds they harbored showed a strong trend toward statistical significance (see figure 3.5 - U=27; p=0.08, Mann-Whitney U-test). The correlation between the two was very weak, negative and insignificant (Pearson's r= -0.07, p=0.77). Analysis for growing season water level yielded similar results. When compared to growing season HWL years, growing season LWL years harbored around 1.14 times wintering waterbirds on average but the difference between the medians of the two groups was found to be statistically insignificant (U=34; p=0.21, Mann-Whitney U-test). Linear correlation between them was weak, positive and insignificant (Pearson's r= 0.14, p=0.55).

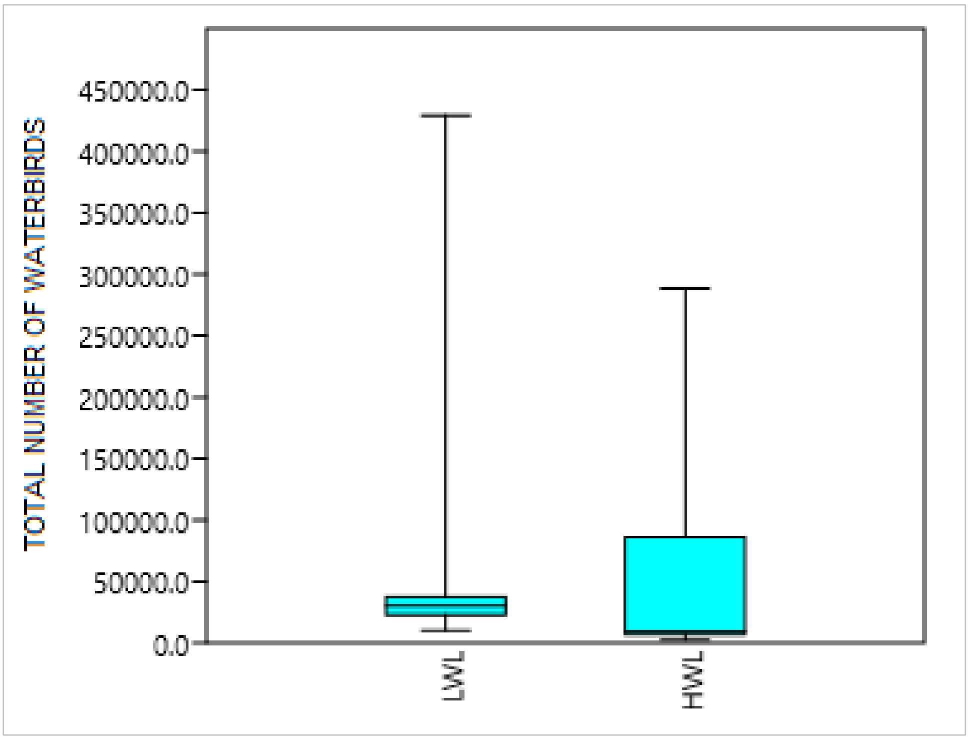

Figure 3.5: Box plot for total number of wintering waterbirds during Lake Uluabat's winter low water level (LWL) and winter high water level (HWL) years (quartile method: rounding).

Comparison of HM and LM years in terms of total number of wintering waterbirds failed to yield statistically significant differences. Although HM years attracted, on average, 2.38 times more wintering waterbirds, the medians of HM and LM years in terms of the community size were not statistically different from each other (U=64; p=0.85, Mann-Whitney U-test).

Figure 3.6 summarizes the change in species richness and modified species richness of wintering waterbird community in Lake Uluabat over the study years.

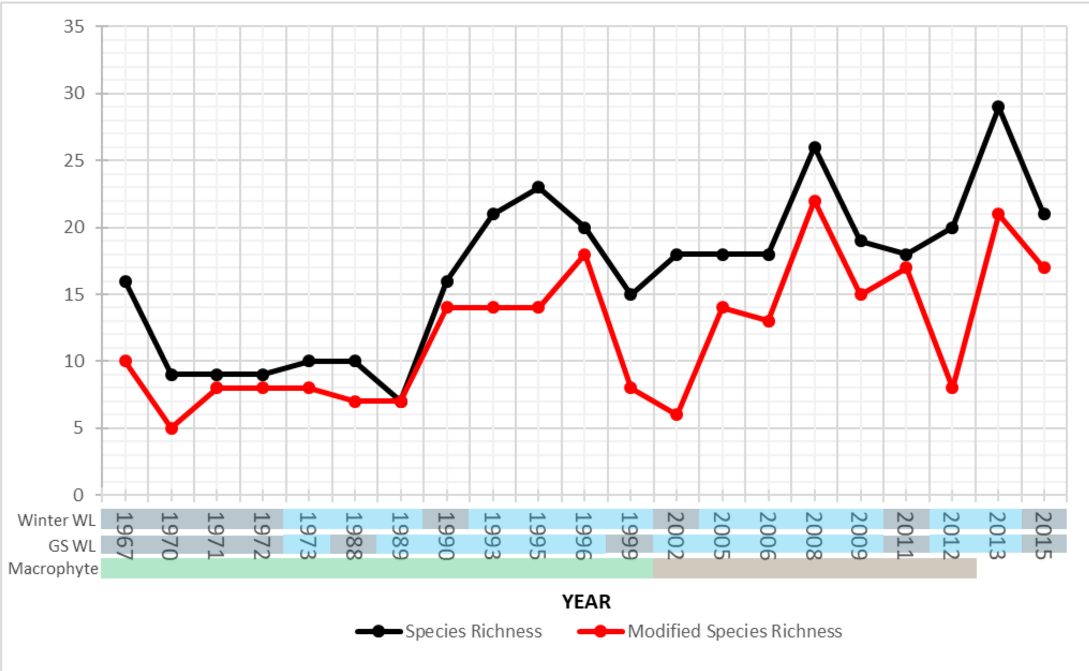

Figure 3.6: Change in Lake Uluabat's wintering waterbird community species richness and modified species richness over the study years and in relation to water level and macrophyte status classification. Shading below the graph: light blue=LWL years, dark blue=HWL years, green=HM years and brown=LM years.

When species richness and modified species richness values for LWL and HWL years compared, some near-significant and significant differences were detected. Mean species richness for winter LWL years was 1.27 higher than that of winter HWL years and the difference between the medians was found to be near-borderline significance (U=21, p=0.10, Mann-Whitney U-test). Similarly, mean modified species richness for winter LWL years was 1.36 times higher than that of winter HWL years and the difference between the medians of the two groups showed a very slight tendency toward significance (U=27, p=0.18, Mann-Whitney U-test). In addition, both species richness indices were discovered to have a slight, negative and insignificant correlation with the average winter water level in the lake (Pearson's r = -0.11, p=0.63 and Pearson's r= -0.17, p=0.47 for species richness and modified species richness, respectively). When growing season water level groups were compared, similar results were obtained. When averaged across the study years, it was seen that growing season LWL years had around 1.41 times more waterbird species and the two water level groups were found to have median values which are significantly different from each other (see figure 3.7 - U=21; p=0.04, Mann-Whitney U-test).

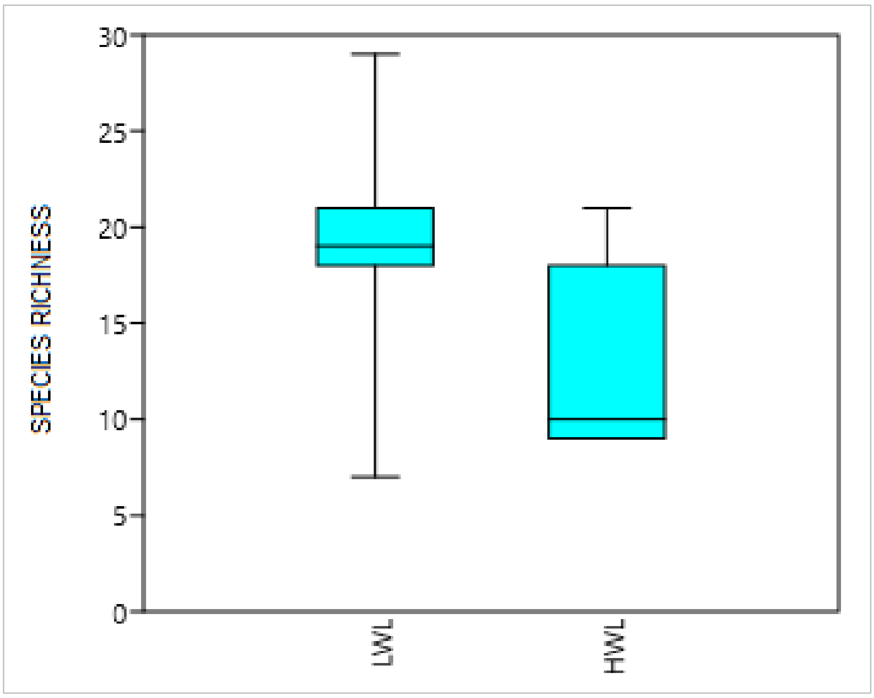

Figure 3.7: Box plot species richness of the wintering waterbird community in Lake Uluabat's growing season low water level (LWL) and growing season high water level (HWL) years (quartile method: rounding).

Growing season LWL years also had 1.34 times higher mean modified species richness when compared to growing season HWL years but the difference between the median values of the two groups was not statistically significant ($U=34.5$; $p=0.21$, Mann-Whitney U-test). Overall, both species indices were slightly to moderately and negatively correlated to average growing season water level with species richness having a statistically significant correlation and modified species richness having an insignificant one (Pearson's $r = -0,45$, $p= 0.04$ and Pearson's $r= -0.25$, $p=0.27$ for species richness and modified species richness, respectively).

The analyses investigating the relationship between submerged macrophyte status of the lake and the two species richness indices showed that LM years attracted 1.42 times more species on average and the difference between the medians of LM and HM years was found to be statistically significant ($U=17.5$; $p=0.04$, Mann-Whitney U-test). Results were similar for modified species richness comparison. LM years had, on average, 1.35 times higher modified species richness when compared to HM years. However, the difference between the medians of the two groups failed to exhibit any statistical significance ($U=26.5$; $p=0.20$, Mann-Whitney U-test).

Change in PI, OM, HE and GU functional groups' percent representations are given in the form of 100% stacked area chart in figure 3.8 and changes in percent representations of INPI and IN functional groups are given in figure 3.9. Table 3.7 shows functional group, dabbling duck and diving duck abundances for Lake Uluabat's LWL and HWL years and table 3.8 shows the same for the lake's LM and HM years.

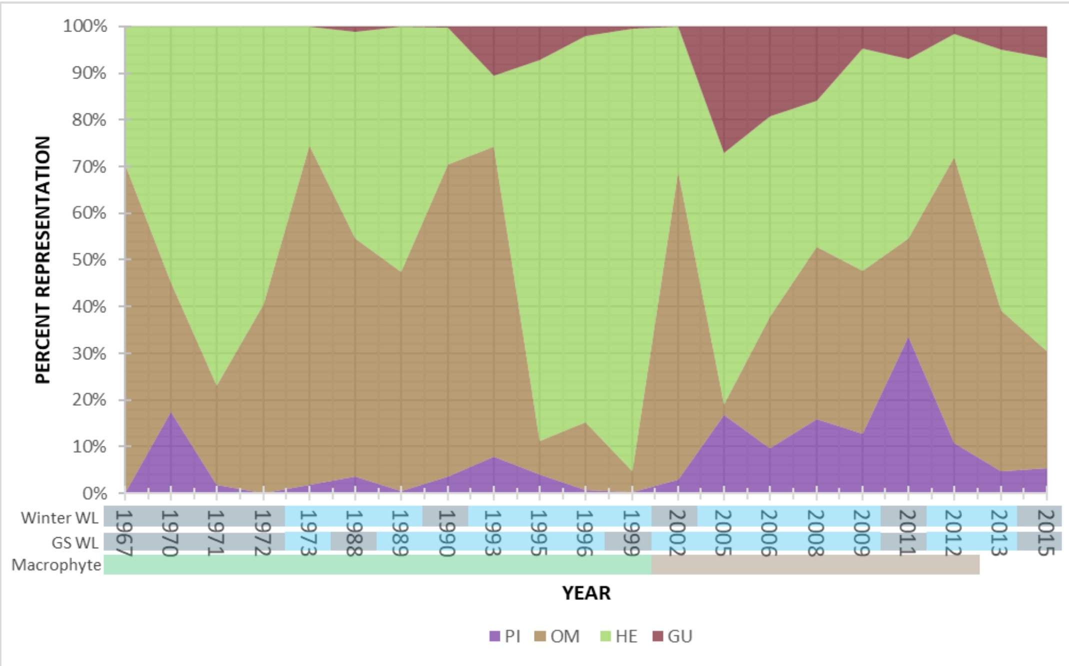

Figure 3.8: 100% stacked area chart for percent representation of PI, OM, HE and GU functional groups in Lake Uluabat's wintering waterbird community. Shading below the graph: light blue=LWL years, dark blue=HWL years, green=HM years and brown=LM years.

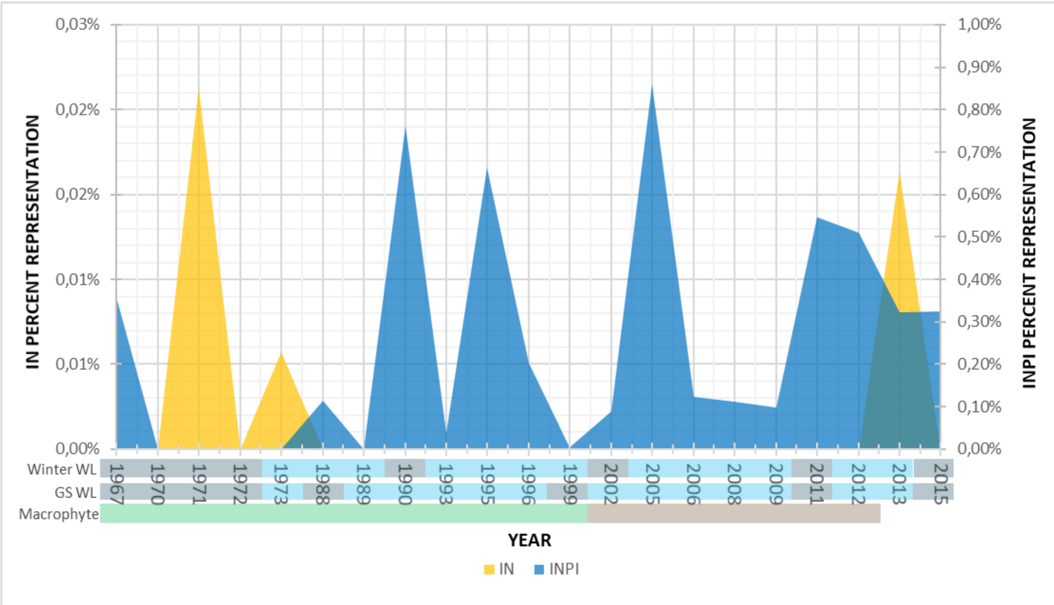

Figure 3.9: Percent representation of INPI and IN functional groups in Lake Uluabat's wintering waterbird community. Shading below the graph: light blue=LWL years, dark blue=HWL years, green=HM years and brown=LM years.

Table 3.7: Abundances (given as mean ± standard deviation) of the individual functional groups, dabbling ducks (Dabb) and diving ducks (Div) for Lake Uluabat's winter and growing season (GS) LWL and HWL years. Pairs which are significantly different from each other at 90% confidence level are given in bold.

	Winter LWL	Winter HWL	GS LWL	GS HWL
PI	1899.54±1540.88	1538.88±2017.05	1870.38±1568.81	1586.25±1989.45
OM	**14542.69±13639.64**	**6568.50±6427.48**	14252.38±13809.38	7040.25±6395.74
HE	35886.00±83268.89	44095.38±87996.44	35494.77±83414.57	1053.63±1816.71
GU	**2214.62±2409.96**	**1031.13±1828.47**	2200.77±2422.10	44731.13±87678.64
INPI	162.54±245.50	49.88±89.68	161.38±246.19	51.78±88.90
IN	0.62±1.64	0.25±0.66	0.62±1.64	0.25±0.66
Dabb	794.38±1144.32	811.88±976.26	794.85±1144.00	811.13±979.88
Div	**14842.46±13488.07**	**6552.88±6419.60**	14550.92±13666.97	7026.63±6388.18

Table 3.8: Abundances (given as mean ± standard deviation) of the individual functional groups, dabbling ducks (Dabb) and diving ducks (Div) for Lake Uluabat's low macrophyte (LM) and high macrophyte (HM) years. Significantly different pairs are given in bold.

	Low Macrophyte	High Macrophyte
PI	**2738.14±2159.98**	**966.08±939.43**
OM	6364.29±4674.98	17631.75±14667.09
HE	6484.57±3345.62	58405.75±107954.33
GU	**1957.29±2070.30**	**1324.75±2266.05**
INPI	59.43±34.03	142.08±265.78
IN	0	0.33±0.75
Dabb	654.56±1111.36	903.42±1052.25
Div	8651.11±6283.76	13959.58±14533.78

Investigation of relationship between individual functional groups and water level have showed that some functional groups exhibited statistical differences between LWL and HWL groups. The current study showed that average number of OM individuals was 2.21 times higher for winter LWL years when compared to winter HWL years and the difference between the medians of the two groups showed a favorable trend towards statistical significance (U=28; p=0.09, Mann-Whitney U-test). Similar results were obtained for growing season LWL and HWL years; LWL years had about 2.02 times more OM waterbirds on average when compared to HWL years and the difference between the medians of the groups showed a weak trend toward significance (U=39.5; p=0.14, Mann-Whitney U-test). Linear correlation between average winter water level and number of OM waterbirds in the community and the linear correlation between average growing season water level and number of OM waterbirds in the community were weak, negative and insignificant (Pearson's r= -0.18, p=0.43 and Pearson's r= -0.10, p=0.67, respectively). GU functional group also showed some statistical differences between the water level groups. Winter LWL years had, on average, 2.14 times more GU waterbirds and the difference between the medians of winter LWL and winter HWL years showed a strong trend toward conventional level of significance (U=28; p=0.08, Mann-Whitney U-test). Results were similar for growing season water level groups but this time the difference between the water level groups was not that significant; growing season LWL years hosted, on average, 2.09 time more GU waterbirds in winters but the difference between the medians of the two groups failed to reach significance, although showing a very slight tendency toward it (U=0.33; p=0.17, Mann-Whitney U-test). Linear correlation coefficients for number of wintering GU waterbirds in the lake and winter water level and growing season water level measurements were very weak, negative and insignificant (Pearson's r= -0.10, p= 0.67 and Pearson's r= 0.05, p=0.82, respectively). When PI functional group was of concern, it was seen that no statistically significant differences were detected between winter and growing season water level groups. Although winter LWL years had around 1.23 times more wintering PI waterbirds, the difference between the medians of winter water level groups failed to reach statistical significance, although showing a very slight tendency (U=33; p=0.18, Mann-Whitney U-test). Similar results were obtained for the growing season water level groups comparison; growing season LWL years had 1.18 times more wintering PI waterbirds on average but the difference between them and their HWL counterparts in terms of their median values was insignificant (U=35; p=0.23, Mann-Whitney U-test). Linear correlations between average winter and growing season water level and number of PI individuals in the wintering waterbird community were weak and insignificant (Pearson's r= 0.11, p=0.68 and r= -0.04, p=086, respectively). No significant differences were detected when winter and growing season water level groups were compared in terms of number of HE individuals in their wintering waterbird community. The study showed that winter HWL years attracted 1.23 times more HE waterbirds on average but the medians of winter LWL and HWL years failed to differ significantly (U=39; p=0.36, Mann-Whitney U-test). Comparison of growing season water level groups yielded similar results; growing season HWL years harbored, on average, 1.26 times more wintering HE waterbirds but the difference between the medians of the two water level groups was insignificant (U=47; p=0.74, Mann-Whitney U-test). The analyses also showed that linear correlations between the number of HE individuals in the lake's wintering waterbird community and winter and growing season water level were almost non-existing or weak and insignificant (Pearson's r= -0.01, p=0.95 and Pearson's r=0.20, p=0.36, respectively). When the winter water level groups were compared on the basis of the number of INPI waterbirds they had, it was seen that winter LWL years harbored 3.26 time more wintering INPI waterbirds and the difference between the medians of winter LWL and HWL years exhibited a weak trend toward significance (U=30; p=0.12, Mann-Whitney U-test). Results were similar for the comparison of growing season water level groups; growing season LWL years attracted 3.12 times more INPI waterbirds in winters but the difference between the medians of the two water level groups was insignificant this time (U=34; p=0.20, Mann-Whitney U-test). When the water level groups were compared on the basis of their functional group richness, it was seen that both winter and growing season LWL years had a slightly higher mean number of functional groups when compared to their HWL counterparts (1.19 and 1.23 times, respectively). However, the statistical analyses have shown that the winter LWL and HWL did not have significantly different medians (U=36; p=0.23, Mann-Whitney U-test). In contrast, when growing season LWL and HWL years were compared, it was discovered that the difference between medians of the two groups on the basis of their functional group richness showed a favorable statistical trend toward significance (U=29; p=0.09, Mann-Whitney U-test).

When submerged macrophyte groups were compared on the basis individual functional groups, some noteworthy differences were discovered. The study showed that HM years attracted 9.01 times more HE birds on average than did LM years; however, this difference was insignificant (U=29; p=0.29, Mann-Whitney U-test). As for the OM functional group, the results were similar; HM years harbored 2.14 times more OM waterbirds on average but the difference between the medians of LM and HM years failed to reach significance (U=29; p=0.29, Mann-Whitney U-test). Unlike HE and OM functional groups, LM and HM years did exhibit a significant difference when PI functional group was concerned. The number birds belonging to the PI functional group was, on average, 2.84 times higher for LM years when compared to HM years. This difference between the two groups was statistically significant; LM years had a significantly higher median for number PI birds in the community than did

HM years (U=21, p=0.02, Mann-Whitney U-test). GU was another functional group for which close-to-significant differences were detected between the submerged macrophyte groups. Statistical analyses showed that LM years attracted 1.77 times more GU birds on average but the difference between LM and HM years in terms of number of GU birds showed a decent trend toward significance (U=21; p=0.10, Mann-Whitney U-test). When LM and HM years were investigated for differences in number of wintering INPI waterbirds, it was found out that HM years harbored 2.39 times more INPI waterbirds; however, the difference between the two showed a weak trend toward but failed to achieve statistical significance (U=25; p=0.15, Mann-Whitney U-test). The study also showed that LM and HM years had a statistically significant difference in terms of number of functional groups they harbored. On average, LM years were found to have 1.35 times more functional groups in the wintering waterbird communities. The difference between the medians of LM and HM years in terms of number of functional groups they have was statistically highly significant (see figure 3.10 - U=10; p=0.01, Mann-Whitney U-test).

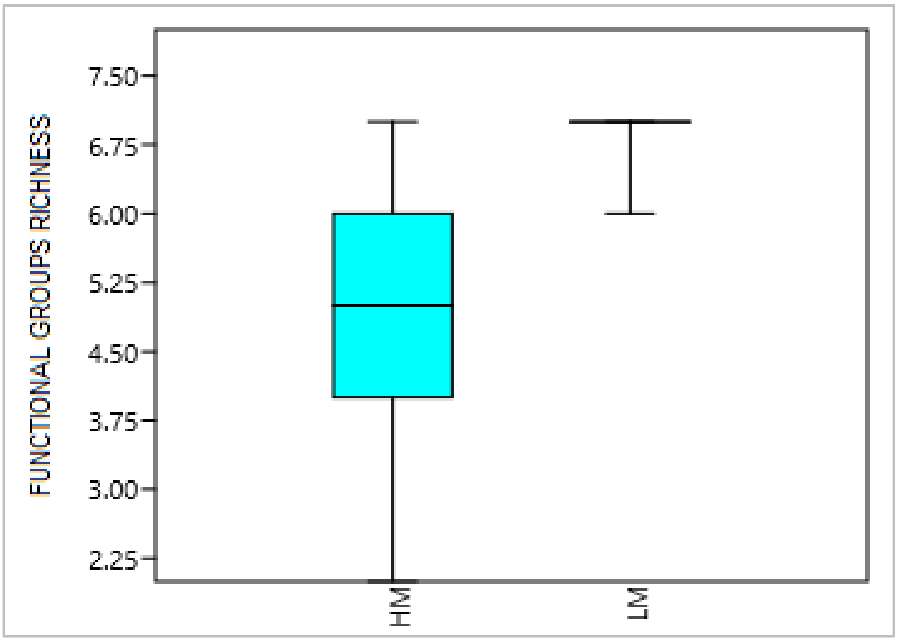

Figure 3.10: Box plot for functional group richness of Lake Uluabat's low macrophyte (LM) and high macrophyte (HM) years (quartile method: rounding).

As for total number of dabbling ducks in the community, winter LWL and HWL years didn't differ from each other significantly; the medians of the two groups were not statistically different (U=49; p=0.86, Mann-Whitney U-test). The results were similar for the growing season water level groups; the medians of LWL and HWL years did not differ from each other statistically (U=47; p=0.75, Mann-Whitney U-test). Number of diving ducks; however, showed some noteworthy differences between LWL and HWL years. The analysis has shown that winter LWL years were attracted around 2.27 times more diving ducks on average when compared to winter HWL years. The difference between the medians of the two groups only marginally failed to be significant at the 95% level (U=28; p=0.06, Mann-Whitney U-test). Similarly, growing season LWL years had around 2.07 times higher mean number of diving ducks when compared to growing season HWL years. The difference between the medians of the two groups showed a weak trend toward significance (U=30; p=0.12, Mann-Whitney U-test). Both average winter water level and average growing season water level were found to be slightly and negatively correlated to the number of wintering diving ducks in the lake but these correlations were both statistically insignificant (Pearson's r = -0.19, p=0.40 and Pearson's r= -0.12, p=0.62 for average winter water level and average growing season water level, respectively).

As far as submerged macrophyte status of the lake was concerned, no significant differences were discovered in terms of the number of dabbling ducks in the community (U=38; p=0.77, Mann-Whitney U-test). When LM and HM years were compared in terms of number of diving ducks they attracted, it was seen that the number of diving ducks that visited the lake during HM years was 2.20 times higher than the number of diving ducks that did so during LM. Nevertheless, the difference between the medians of the two groups failed to attain any statistical significance (U=27; p=0.22, Mann-Whitney U-test).

3.3.2 Lake Beyşehir

Change in number of wintering waterbirds in Lake Beyşehir over the study years is given in the figure 3.11.

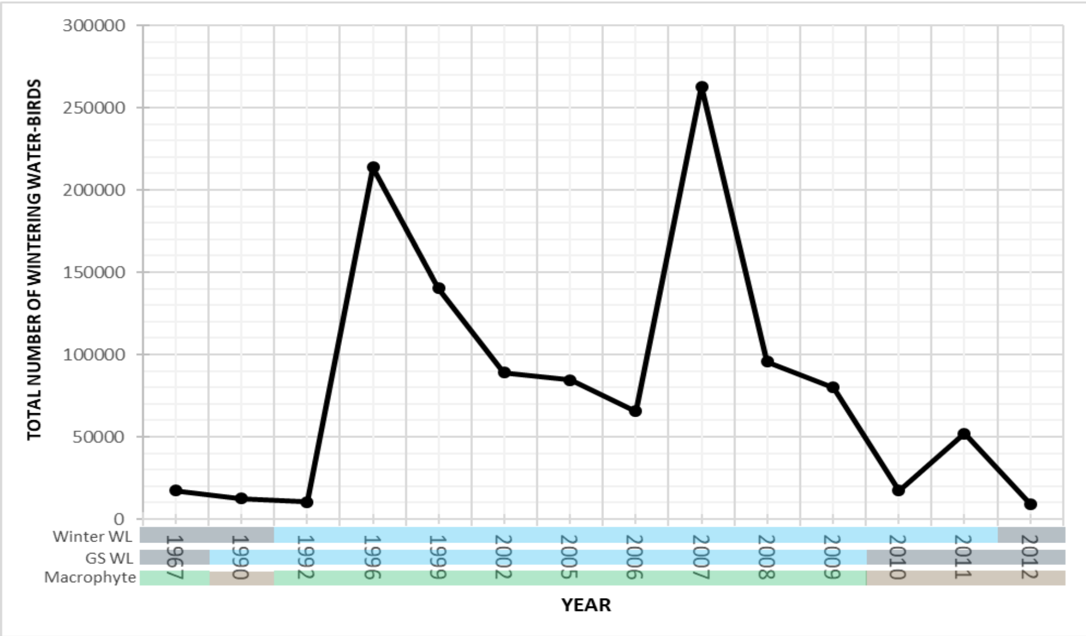

Figure 3.11: Change in wintering waterbird community size in Lake Beyşehir over the study years and in relation to water level and macrophyte status classification. Shading below the graph: light blue=LWL years, dark blue=HWL years, green=HM years and brown=LM years (GS = growing season, WL = water level, LM=low macrophyte, HM=high macrophyte)

The relationship between water level and wintering waterbird community size in Lake Beyşehir was powerful. When winter LWL and HWL years were compared, it was discovered that the number of wintering waterbirds was, on average, 9.79 times higher for the former. The difference between the medians of the two water level groups was statistically highly significant ($U=4$; $p=0.01$, Mann-Whitney U-test). Growing season LWL and HWL years exhibited a similar pattern; growing season LWL years had, on average, 4.84 times more wintering waterbirds than did the HWL years. This difference was statistically significant as well ($U=5$; $p=0.03$, Mann-Whitney U-test). Furthermore, moderate and negative correlations were detected between winter water level and total number of wintering waterbirds and between mean growing season water level and total number of winter waterbirds with the former falling barely short of conventional levels of significance and the latter being statistically significant (Pearson's r = -0.49, p=0.06 and Pearson's r= -0.51, p=0.05 respectively).

When the submerged macrophyte groups were compared based on total number of wintering waterbirds they harbored, some significant differences were discovered. The study showed that HM years, when compared to their LM counterparts, attracted 5.74 times more wintering waterbirds on average. It was also seen that the difference between the medians of the two was statistically highly significant (U=2, p=0.01, Mann-Whitney U-test).

Figure 3.12 shows the change in species richness and modified species richness of Lake Beyşehir's wintering waterbird community over the study years.

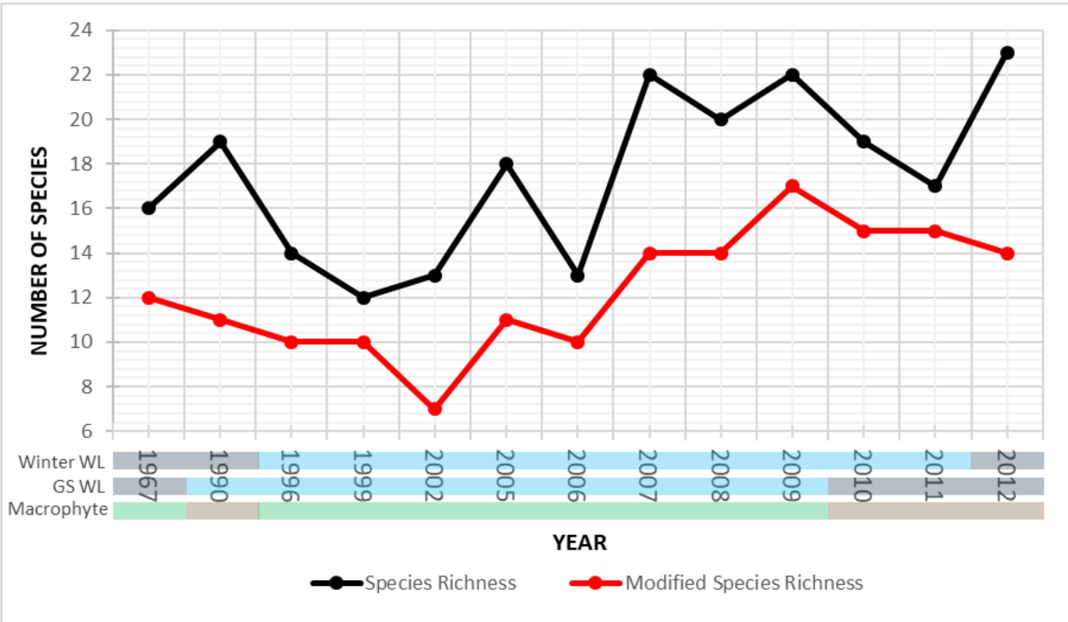

Figure 3.12: Change in Lake Beyşehir's wintering waterbird community species richness and modified species richness over the study years and in relation to water level and macrophyte status classification. Shading below the graph: light blue=LWL years, dark blue=HWL years, green=HM years and brown=LM years.

This study showed that species richness and modified species richness of Lake Beyşehir's wintering waterbird community were related to water level to some extent. When winter LWL and HWL years were compared based on their waterbird species richness, it was seen that the HWL years had 1.57 times more species on average and this difference was statistically significant ($U=1$; $p=0.02$, Mann-Whitney U-test). However, correlation between average winter water level and species richness was very weak and insignificant (Pearson's $r=0,07$, $p=0.81$). When modified richness was considered, no significant differences between winter LWL years and HWL years were found ($U=14.5$; $p=0.96$, Mann-Whitney U-test). The relationship between growing season water level and the two species richness indices was discovered to be very weak. Growing season water level groups showed no significant difference between their median values for species richness and modified species ($U=12$; $p=0.68$ and $U=8,5$; $p=0.30$, respectively, Mann-Whitney U-test). Linear correlation between growing season water level and the two species richness indices were both very weak and insignificant (Pearson's $r=0.06$, $p=0.84$, Pearson's $r=0.16$, $p=0.60$).

When LM and HM years were compared in terms of their species richness and modified species richness, no significant differences were discovered. Although LM years had 1.17 times higher species richness, the difference between the medians of LM and HM years failed to achieve statistical significance ($U=10$; $p=0.25$, Mann-Whitney U-test). Similar results were obtained for modified species richness; although LM years had 1.18 higher modified species richness on average, the difference between the medians of the LM and HM years was not statistically significant but did show a very weak trend toward significance ($U=8.5$; $p=0.16$, Mann-Whitney U-test).

Change in PI, OM, HE and GU functional groups' percent representations are given in the form of 100% stacked area chart in figure 3.13 and changes in percent representations of INPI and IN functional groups are given in figure 3.14. Table 3.9 shows functional group, dabbling duck and diving duck abundances for Lake Beyşehir's LWL and HWL years and table 3.10 shows the same for the lake's LM and HM years.

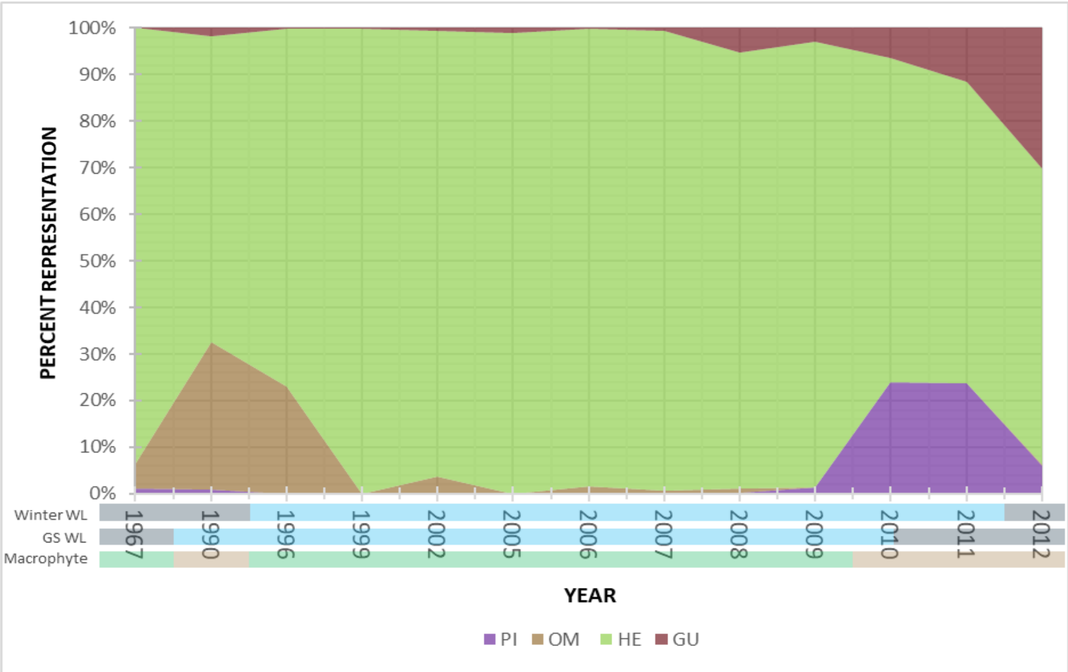

Figure 3.13: 100% stacked area chart for percent representation of PI, OM, HE and GU functional groups in Lake Beyşehir's wintering waterbird community. Shading below the graph: light blue=LWL years, dark blue=HWL years, green=HM years and brown=LM years.

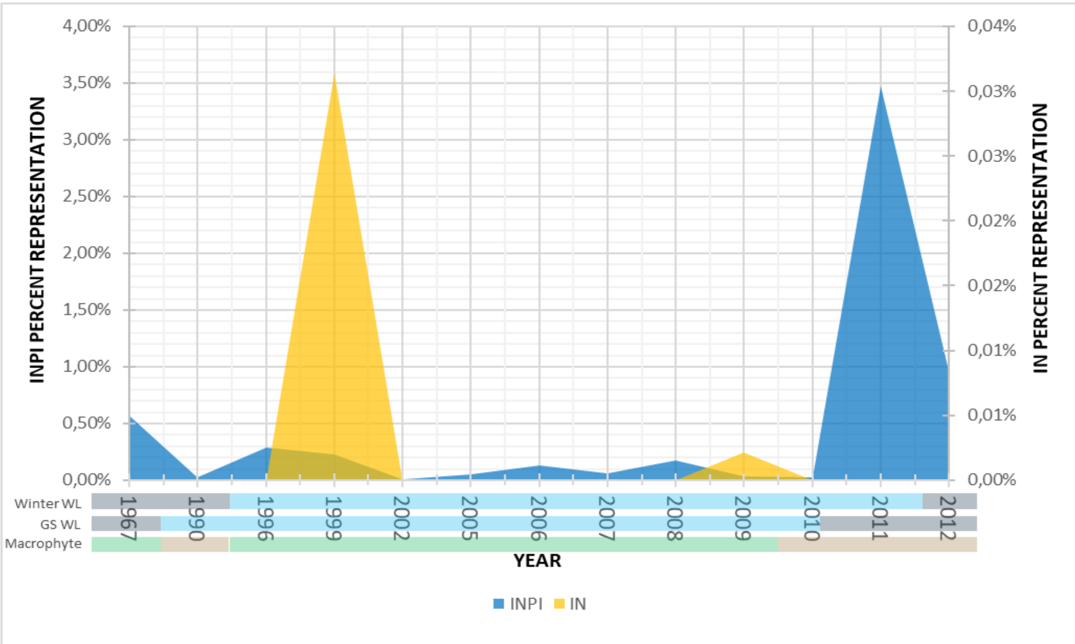

Figure 3.14: Percent representation of INPI and IN functional groups in Lake Uluabat's wintering waterbird community. Shading below the graph: light blue=LWL years, dark blue=HWL years, green=HM years and brown=LM years.

Table 3.9: Abundances (given as mean ± standard deviation) of the individual functional groups, dabbling ducks (Dabb) and diving ducks (Div) for Lake Beyşehir's winter and growing season (GS) LWL and HWL years. Pairs which are significantly different from each other at 90% confidence level are given in bold.

	Winter LWL	Winter HWL	GS LWL	GS HWL
PI	1585.90±3171.14	276.67±186.91	558.60±1225.68	3701.00±4719.14
OM	5590.60±14488.73	1540.00±1584.03	5961.50±14388.43	303.67±401.17
HE	97734.60±68723.96	9810.33±4504.36	95675.80±71043.18	16673.00±9238.61
GU	1667.90±1812.88	969.67±1229.89	1180.00±1447.93	2596.00±2076.56
INPI	115.30±109.74	76.00±65.91	75.60±55.37	208.33±147.99
IN	2.80±7.45	0	2.80±7.45	0
Dabb	1420.80±1417.33	6239.67±6586.16	1414.40±1415.38	6261.00±6571.89
Div	10973.40±15943.94	1672.67±1554.49	11346.90±15725.15	427.67±582.19

Table 3.10: Abundances (given as mean ± standard deviation) of the individual functional groups, dabbling ducks (Dabb) and diving ducks (Div) for Lake Beyşehir's low macrophyte (LM) and high macrophyte (HM) years. Significantly different pairs are given in bold.

	Low Macrophyte	High Macrophyte
PI	3783.00±4112.60	173.00±312.47
OM	948.75±1603.45	6304.44±15110.48
HE	13418.25±8881.53	105900.44±67601.84
GU	2274.75±1852.23	1165.44±1541.92
INPI	158.25±154.62	83.11±53.49
IN	0	3.11±7.80
Dabb	1332.25±642.26	3066.44±4640.77
Div	967.25±1608.02	13320.33±16267.52

Among the functional groups, HE was the one showing the most pronounced differences between the water level groups. Total number of HE waterbirds was discovered to be significantly different between LWL and HWL water level groups. Winter LWL years had an astonishing 9.96 times higher average number of HE waterbirds wintering in the lake than did winter HWL years and the difference between the medians of the two groups was statistically significant (U=1; p=0.02, Mann-Whitney U-test). Linear correlation between average winter water level and number of HE birds was moderate, positive and almost statistically significant (Pearson's r= -0.52, p=0.06). Results for growing season water level groups were similar; growing season LWL years had, on average, 5.74 times more wintering HE waterbirds than did growing season HWL years. The difference between the medians of the two groups showed a robust trend toward significance (U=4; p=0.08, Mann-Whitney U-test). Furthermore, a statistically significant and moderately strong negative linear correlation between average growing season water level and number of HE birds was discovered (Pearson's r= -0.57, p=0.04). OM functional group also showed some near-significant differences between LWL and HWL years. Although winter water level groups had no significant difference based on the number of OM waterbirds in the community (U=14; p=0.93, Mann-Whitney U-test), growing season water level groups did show some near-significant differences. Growing season LWL years had 19.63 times higher average number of wintering OM waterbirds when compared to their HWL counterparts and the difference between the medians of the two groups was found to be trending weakly toward significance (U=6; p=0.15, Mann-Whitney U-test). When compared in terms of number PI waterbirds in the wintering waterbird community, it was seen that winter LWL years had 5.73 time more PI birds on average. However, the difference between the medians of winter LWL and HWL years failed to attain any statistical significance (U=11; p=0.55, Mann-Whitney U-test). Linear correlation between winter water level and number of wintering PI waterbirds in Beyşehir was weak, positive and insignificant (Pearson's r=0.24, p=0.40). In contrast, comparison of growing season water level groups showed that growing season HWL years were the ones which attracted more PI waterbirds. The study showed that Lake Beyşehir's growing season HWL years had 6.63 time more PI waterbirds in their wintering waterbird community and the difference between the medians of the two water level groups showed a strong trend toward statistical significance at 95% confidence level (U=4; p=0.08, Mann-Whitney U-test). Linear correlation between average winter water level and number of wintering PI waterbirds and average growing season water level were both weak, positive and insignificant (Pearson's r=0.24, p=0.43 and Pearson's r=0.29, p=0.34, respectively). As far as GU functional group was concerned, no statistically significant differences were discovered between the water level groups. Although winter LWL years attracted 1.72 times more wintering GU waterbirds on average, the difference between winter LWL and HWL years was not significant (U=10; p=0.45, Mann-Whitney U-test). Similar results were obtained for the comparison of growing season water level groups. Growing season LWL years were found to have 2.20 times more GU waterbirds on average but the difference between the medians of the two water level groups was from achieving any significance (U=11; p=0.55, Mann-Whitney U-test). The analyses also showed that linear correlation between number of wintering GU waterbirds in the community and winter water level, and growing season water level and number of wintering GU waterbirds in the community were both almost non-existing and insignificant

(Pearson's r= -0.09, p=0.76 and Pearson's r= -0.04, p=0.89, respectively). When winter water level groups were compared on the basis of the number of INPI waterbirds in their wintering waterbird community, it was seen that winter LWL years had 1.52 times more INPI waterbirds on average. Nevertheless, the difference between the medians of winter LWL and HWL years was far from being significant (U=13; p=0.80, Mann-Whitney U-test). Results of the comparison of growing season water level groups generated similar results but this time with a more significant difference. The study showed that growing season LWL years had 2.76 times more INPI individuals in their wintering waterbird community and the difference between the medians of the two water level groups showed a weak trend toward statistical significance (U=6; p=0.15, Mann-Whitney U-test). The study also showed that linear correlation between winter water level and number of INPI individuals in the wintering waterbird community, and growing season water level and number of INPI individuals in the wintering waterbird community were both weak and insignificant (Pearson's r=0.23, p=0.46 and Pearson's r=0.23, p=0.44, respectively). When the functional group richness of LWL and HWL years was compared, neither winter water level groups nor growing season water level groups showed statistically significant difference (U=10; p=0.48 and U=10; p=0.49, respectively, Mann-Whitney U-test).

When LM and HM years were compared based on their functional groups, some statistically significant differences were observed. The analyses showed that LM years attracted shockingly more PI waterbirds; LM years attracted 21.87 times more PI waterbirds on average when compared to HM years and the medians of the LM and HM years in terms of number of PI individuals in the community differed from each other significantly (U=5; p=0.05, Mann-Whitney U-test). As far as OM functional group was concerned, HM years had 6.64 times more OM individuals when compared to their LM counterparts. However, the difference between the medians of the two failed to achieve statistical significance (U=11; p=0.32, Mann-Whitney U-test). Strong statistical differences were found between LM and HM years when HE functional group was of concern. HM years attracted 7.89 times more HE individual on average and the difference between the medians of two groups was statistically highly significant (U=1; p=0.01, Mann-Whitney U-test). It was also discovered that LM years attracted 1.95 times more GU waterbirds on average but the difference between LM and HM years in terms of their medians for number of GU birds in the community was insignificant (U=10; p=0.25, Mann-Whitney U-test). It is also worth noting that the only years during which IN waterbirds were detected in the lake was HM years. Despite the fact that LM years attracted 1.94 times more INPI wintering waterbirds, the difference between the medians of the two groups was not significant (U=11.5; p=0.50, Mann-Whitney U-test). Comparison of LM and HM years based on their functional group richness generated similar results. HM years were discovered to have only slightly more functional groups in their wintering waterbird communities but the difference between the medians of HM and LM years failed to attain any statistical significance (U=13; p=0.45, Mann-Whitney U-test).

Comparisons of the water level groups on the basis of dabbling duck and diving duck numbers also yielded significant results. When winter LWL and HWL years were compared in terms of number of wintering dabbling ducks they had, it was seen that the HWL years had 4.40 times higher average number of dabbling ducks and the difference between the median values of winter LWL and HWL years was near-borderline significance (U=5; p=0.11, Mann-Whitney U-test). Growing season water level group comparisons generated similar results; HWL years had 4.42 times higher mean number of dabbling ducks wintering in the lake when compared to LWL years. The difference between the medians of the two groups showed a strong trend toward significance (U=4; p=0.08, Mann-Whitney U-test). Diving duck numbers also showed some notable differences between the water level groups. Winter LWL years attracted, on average, 4.56 times more diving ducks but statistical analysis demonstrated that the two water level groups did not have statistically different medians for number of diving ducks (U=11; p=0.55, Mann-Whitney U-test). Growing season LWL years, on the other hand, attracted an astonishing 26.53 times more diving ducks on average and the difference between the medians of growing season LWL and HWL years showed a strong trend toward significance at 95% confidence level (U=4; p=0.08, Mann-Whitney U-test).

LM and HM groups exhibited some statistically significant differences when wintering dabbling and diving duck numbers were of concern. HM years were discovered to have 2.30 times more dabbling ducks in their wintering waterbird community than LM years. Nevertheless, the difference between the medians of the two groups was far from reaching significance (U=16; p=0.82, Mann-Whitney U-test). In contrast, diving duck numbers showed a significant difference between the two groups. HM years attracted, on average, 12.74 times more diving ducks during winter times that did LM years and the difference between the two was statistically significant (U=5; p=0.05, Mann-Whitney U-test).

3.3.3 Lake Mogan

Change in the size of Lake Mogan's wintering waterbird community over the study years is given in figure 3.15.

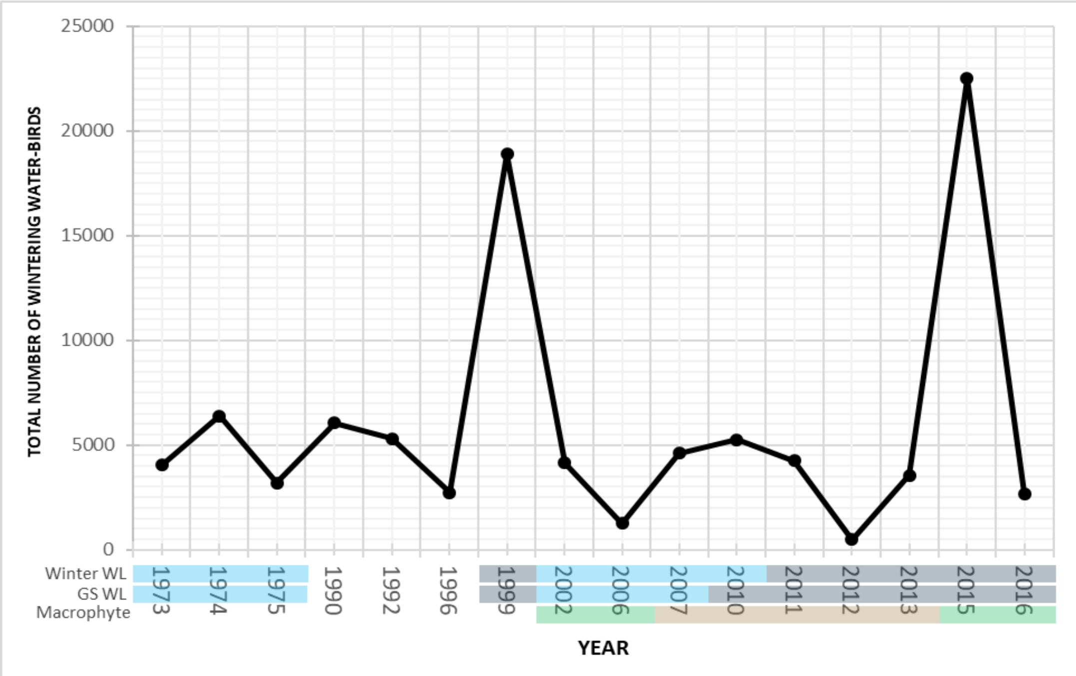

Figure 3.15: Change in wintering waterbird community size in Lake Mogan over the study years and in relation to water level and macrophyte status classification. Shading below the graph: light blue=LWL years, dark blue=HWL years, green=HM years and brown=LM years (GS = growing season, WL = water level, LM=low macrophyte, HM=high macrophyte)

The effect of water level on wintering waterbird numbers in Lake Mogan was somehow different from the other two study lakes. Unlike the other two study lakes, winter HWL years harbored, on average, 2.09 times more waterbirds than winter LWL years but there was no statistical difference in the medians of the two groups (U=18; p=0.72, Mann-Whitney U-test). As for growing season water level groups, the results were similar; growing season HWL years had 2.04 times more birds on average but the difference between the medians of LWL and HWL years was not significant (U=15; p=0.51, Mann-Whitney U-test). The analyses also showed that linear correlations between both mean winter and mean growing season levels and total number of wintering waterbirds in the lake were weak, positive and insignificant (Pearson’s r = 0.14, p=0.64 and Pearson’s r=0.26, p=0.40, respectively).

When the relationship between submerged macrophyte status of the lake and wintering waterbird community size was investigated, no statistically significant differences were detected. Although HM years harbored 2.11 times more wintering waterbirds on average, HM and LM groups' medians did not differ statistically from each other (U=9; p=0.90, Mann-Whitney U-test).

Figure 3.16 shows the change in species richness and modified species richness of Lake Mogan's wintering waterbird community over the study years.

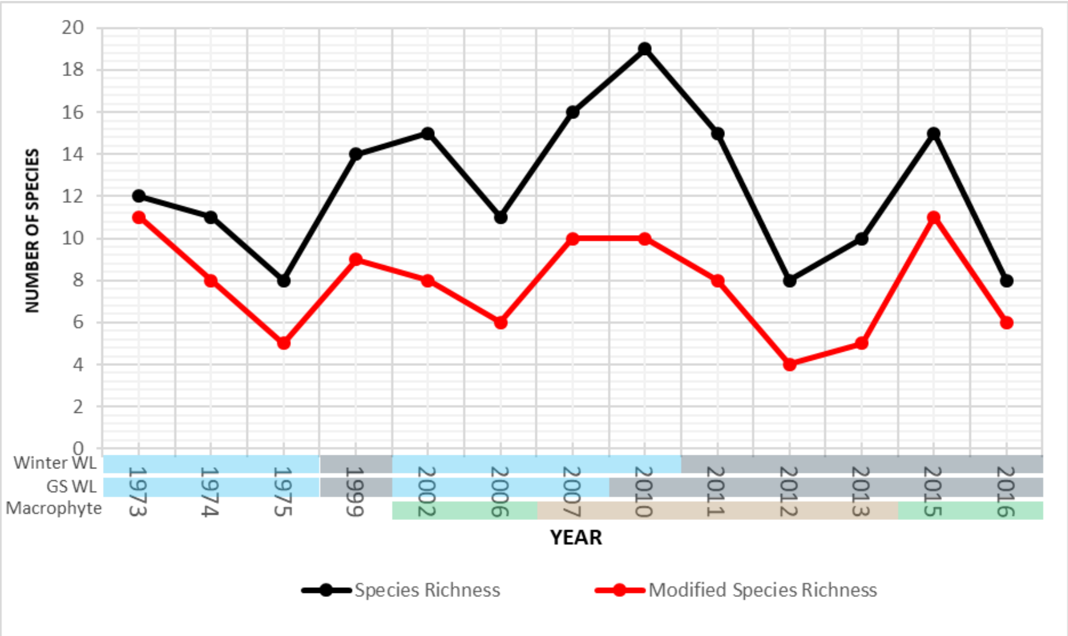

Figure 3.16: Change in Lake Mogan's wintering waterbird community species richness and modified species richness over the study years and in relation to water level and macrophyte status classification. Shading below the graph: light blue=LWL years, dark blue=HWL years, green=HM years and brown=LM years.

When the effect of mean winter water level on species richness and modified species richness of the wintering waterbird community in the lake was investigated, it was discovered that winter LWL and HWL groups showed no statistical difference between their medians based on their species richness and modified species richness, (U=21; p=0.94 and U=18; p=0.82, respectively, Mann-Whitney U-test). Analysis for growing season LWL and HWL groups generated similar results. Growing season LWL and HWL groups didn't differ from each other statistically in terms of medians of their species richness and modified species richness (U=17; p=0.72 and U=18; p=0.79, respectively, Mann-Whitney U-test). While mean winter water level showed a slight, negative and insignificant linear correlation with the two species richness indices (Pearson's r = -0.07, p=0.81 and r= -0.26, p=0.40 for species richness and modified species richness, respectively), mean growing season water level showed a slight, positive and insignificant linear correlation with species richness and modified species richness (Pearson's r = 0.30, p=0.32 and r=0.07, p=0.83 for species richness and modified species richness, respectively).

Comparison of LM and HM years in terms of species richness and modified species richness yielded no significant differences. According to the MWS results conducted in Lake Mogan, LM years had just barely higher species richness on average. However, the difference between the medians of the two groups was not statistically significant (U=7.5; p=0.61, Mann-Whitney U-test). Analyses regarding modified species richness showed that HM years had just barely higher modified species richness on average but the two groups did not differ from each other in terms of their median values for modified species richness (U=8.5; p=0.85, Mann-Whitney U-test).

Change in OM, HE and GU functional groups' percent representations are given in the form of 100% stacked area chart in figure 3.17 and changes in percent representations of PI and INPI functional groups are given in figure 3.18. Table 3.11 shows functional group, dabbling duck and diving duck abundances for Lake Mogan's LWL and HWL years and table 3.12 shows the same for the lake's LM and HM years.

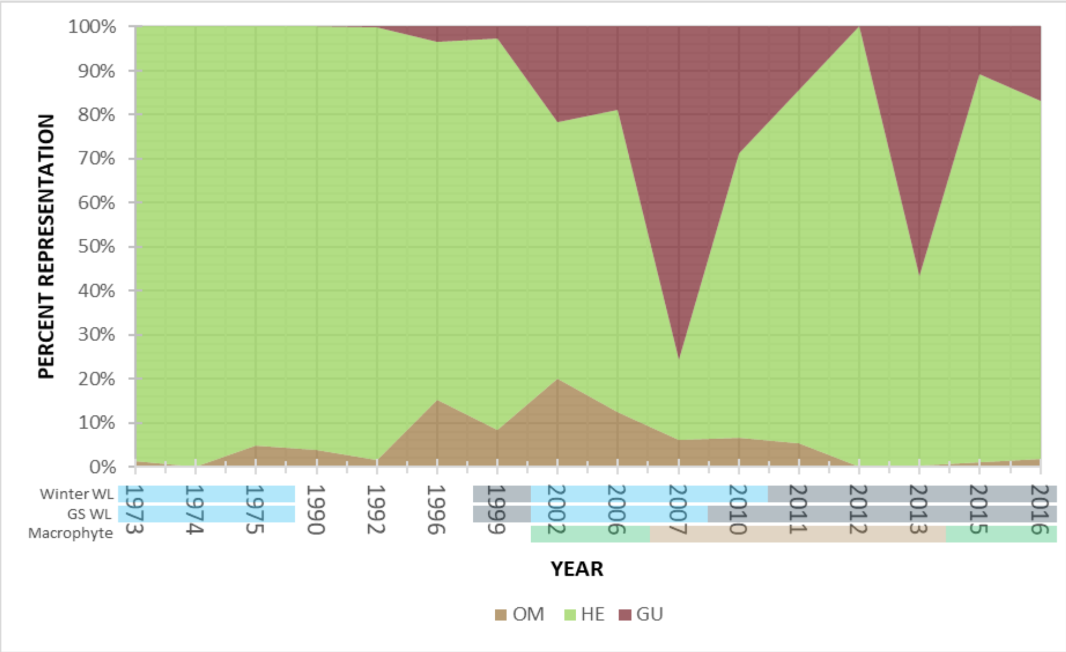

Figure 3.17: 100% stacked area chart for percent representation of OM, HE and GU functional groups in Lake Mogan's wintering waterbird community. Shading below the graph: light blue=LWL years, dark blue=HWL years, green=HM years and brown=LM years.

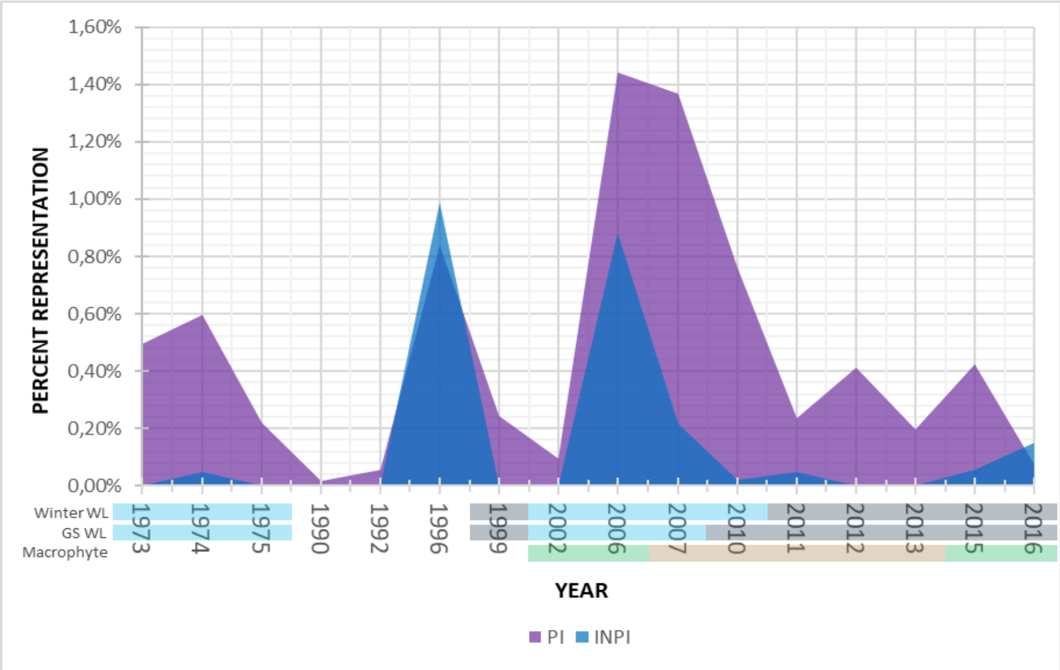

Figure 3.18: Percent representation of PI and INPI functional groups in Lake Mogan's wintering waterbird community. Shading below the graph: light blue=LWL years, dark blue=HWL years, green=HM years and brown=LM years.

Table 3.11: Abundances (given as mean ± standard deviation) of the individual functional groups, dabbling ducks (Dabb) and diving ducks (Div) for Lake Mogan's winter and growing season (GS) LWL and HWL years. Pairs which are significantly different from each other at 90% confidence level are given in bold.

	Winter LWL	**Winter HWL**	**GS LWL**	**GS HWL**
PI	27.00±33.97	27.14±19.44	25.00±20.22	28.86±31.78
OM	259.71±256.56	357.00±566.10	244.50±274.18	356.14±524.11
HE	2968.43±1771.05	7337.17±7792.56	2901.50±1904.73	6770.43±7346.89
GU	865.86±1173.47	996.33±893.88	760.00±1236.16	1068.43±846.18
INPI	3.57±4.50	3.17±4.63	4.00±4.73	2.86±4.36
IN	0	0	0	0
Dabb	1890.29±1288.83	1334.17±1101.04	1866.17±1390.63	1434.29±1048.45
Div	328.86±331.82	353.50±679.89	244.50±280.43	422.29±651.62

Table 3.12: Abundances (given as mean ± standard deviation) of the individual functional groups, dabbling ducks (Dabb) and diving ducks (Div) for Lake Mogan's low macrophyte (LM) and high macrophyte (HM) years. Significantly different pairs are given in bold.

	Low Macrophyte	**High Macrophyte**
PI	24.40±23.43	29.75±38.17
OM	174.00±143.06	319.50±301.19
HE	1918.80±1242.79	6277.75±7767.86
GU	1507.40±1186.89	1003.50±861.12
INPI	2.60±3.77	7.00±5.24
IN	0	0
Dabb	1354.00±1051.27	631.25±349.47
Div	244.60±314.64	286.75±321.89

When the water level groups were compared on the basis of individual functional groups, no statistically significant results were found. As far as HE functional group was concerned, both winter HWL and growing season HWL years harbored more wintering HE birds on average than did their LWL counterparts; HWL year groups harbored 2.33 and 1.82 times more HE birds, respectively. However, these differences were not statistically significant (U=18; p=0.72 and U=18; p=0.83 for winter and growing season water level groups, respectively, Mann-Whitney U-test). Number of HE birds in the wintering waterbird community was also found to be slightly and positively correlated to winter and growing season water levels; however, neither of these correlations was statistically significant (Pearson's r =0.15, p=0.63 and Pearson's r =0.22, p=0.47 for winter water level and growing season water level groups, respectively). When OM functional group was the subject of comparison, it was seen that the both HWL groups attracted more OM waterbirds on average; winter HWL years attracted 1.37 times more and growing season HWL years attracted 1.46 times more wintering OM waterbirds on average. Nevertheless, the difference between the medians of HWL and LWL groups was from being significant (U=17; p=0.63 and U=21; p=0.94 for winter water level and growing season water level groups, respectively, Mann-Whitney U-test). Comparisons for GU functional group yielded similar results. Winter HWL years attracted 1.41 times more GU waterbirds on average but the difference between winter HWL and LWL years failed to reach statistical significance (U=13.5; p=0.31, Mann-Whitney U-test). Similarly, growing season HWL years harbored 1.40 times more INPI waterbirds when compared to their LWL counterparts and the difference between the two water level groups was also insignificant (U=20.5; p=0.64, Mann-Whitney U-test). When the water level groups were compared on the basis of number of wintering PI individuals in their wintering waterbirds communities, it was seen that number of PI waterbirds were almost the same for winter and growing season water level groups. Consequently, no statistically significant differences were observed between LWL and HWL years (U=16.5; p=0.57 and U=19.5; p=0.87 for winter water level groups and growing season water level groups respectively, Mann-Whitney U-test). Linear correlation between average winter water level and number of PI waterbirds and average growing season water level and number of PI waterbirds were very weak or almost non-existing (Pearson's r=0.03, p=0.93 and Pearson's r= -0.13, p=0.67, respectively). When LM and HM years were compared on the basis of the number of functional groups their wintering waterbird communities had, no statistical differences were found (U=15; p=0.43 and U=20; p=0.94 for winter and growing season water level groups, respectively, Mann-Whitney U-test) and the two groups had, on average, almost equal numbers of functional groups. Linear correlation between winter water level and functional group richness, and growing season water level and functional group richness were both weak, positive and insignificant (Pearson's r=0.21, p=0.49 and Pearson's r=0.22, p=0.46, respectively).

Winter LWL and HWL year groups showed no statistical difference between the total number of wintering dabbling ducks; the medians of the two groups weren't statistically different (U=18; p=0.72, Mann-Whitney U-test). The results were similar for growing season LWL and HWL years; the two group didn't differ statistically on the basis of total dabbling duck numbers and the medians for the two were not statistically different (U=13; p=0.34, Mann-Whitney U-test). Still, mean number of dabbling ducks for winter LWL was 1.30 times higher than that of winter HWL and mean number of dabbling ducks for growing season LWL was 1.64 times higher than that of growing season HWL. There was also a slight to moderate, negative and insignificant linear correlation between number of dabbling ducks and average water level (Pearson's r = -0.36, p=0.23). Linear correlation between growing season water level and number of wintering dabbling ducks was moderate, negative and it showed a notable trend towards significance (Pearson's r= -0.46, p=0.11). Diving duck numbers were not significantly different for water level groups, either. Although winter HWL years had, on average,1.73 times and growing season HWL years had 1.75 times more diving ducks compared to their LWL counterparts, the analyses generated no statistical differences between the medians of the water level groups (U=19; p=0.83 and U=19, p=0.94, respectively, Mann-Whitney U-test).

Comparison of LM and HM years in terms of individual functional groups failed to generate any statistically significant results. Analyses about HE functional group showed that HM years hosted 3.27 times more HE waterbirds on average but the difference between the medians of LM and HM years was not significant (U=7; p=0.54; Mann-Whitney U-test. When PI functional group was the subject of comparison for LM and HM years, it was discovered that HM years had 1.22 times more wintering PI waterbird when compared to LM years. However, the difference between the two was from being significant (U=9.5; p=0.98, Mann-Whitney U-test). No significant differences were discovered for OM functional group, either. Although HM years attracted 1.84 times more OM waterbirds on average, the difference between the medians of LM and HM years failed to attain significance (U=8; p=0.71, Mann-Whitney U-test). As far as GU functional group was concerned, it was seen that HM years had 1.50 times more wintering GU waterbirds on average. Nevertheless, the difference between the medians of LM and HM years in terms of number of GU waterbirds they had in winter was not significant (U=8; p=0.71, Mann-Whitney U-test). When LM and HM years were compared in terms of number of wintering INPI waterbirds they had, it was discovered that HM years attracted 2.69 times more INPI waterbirds in winter but the difference between the two groups was far from being significant (U=5; p=0.26, Mann-Whitney U-test). Comparison of LM and HM years in terms of functional group richness showed that HM years had

1.11 times higher average functional group richness but the difference between the two groups' medians was far from being statistically significant (U=10; p=0.90, Mann-Whitney U-test).

When LM and HM years were compared in terms number of dabbling and diving ducks in the wintering waterbird community, no statistically significant differences were detected. Although LM times attracted, on average, 2.14 times more dabbling ducks in winter, the difference between the medians of LM and HM years was not significant (U=6; p=0.39, Mann-Whitney U-test). As far as the number of diving ducks in the community was concerned, it was seen that HM years had 1.17 times more diving ducks on average yet the difference between the medians of LM and HM years was almost non-existing (U=9.5; p=0.97, Mann-Whitney U-test).

CHAPTER 4

DISCUSSION

4.1 Impact of Climate on Wintering Waterbird Communities

For this study, December-January (from December 1st to January 31th) and January (from January 1^{s}t to January 31th) were chosen as the two time frames to represent winter season. Between them, December-January is expected to have a stronger explanatory power simply because it includes two times more days and covers the winter days before the MWS dates (which are mostly around mid-January in Turkey – see table 2.1 and section 2.1.2) more thoroughly. During their fall-winter migration, waterbirds keep moving further along their migratory flyways if ambient temperatures at a certain place drop too much and staying there starts becoming metabolically too costly (Perdeck & Clason, 1980; Ridgill & Fox, 1990; Root, 1988). Therefore, if a migratory waterbird is seen in lake in Turkey during a MWS, the bird may be there because it has experienced harsh climatic conditions in the recent past (possibly in Eastern Europe) and migrated further south, to Turkey, to spend the winter. For that reason, including December days makes it possible to better approximate climatic conditions a wintering waterbird in Turkey has experienced before it came to Turkey and helps this study to reach one of its aims which is to see if the temperatures in Eastern Europe somehow affect the wintering waterbird community size and diversity in Turkish lakes. January temperature proxies alone wouldn't be able to contain as much information. Still, January proxies were included in some of the analyses to see if the assumptions above were correct and if January alone has more explanatory power than previously thought. February was not included simply because the study has used MWS data and MWS are, as stated above, conducted mostly in mid-January and those which were conducted in February were mostly conducted in early February (see table 2.1). Therefore, to avoid irrelevant data, February temperature data was not included in this study.

The reason why Ukraine, Moldova, Romania, and Bulgaria were chosen for the study is mentioned in section 2.5.2. Considering the fact that all of the three study lakes are located in the western half of Turkey (see figure 1.1) and most of waterbird migratory flyways cross these four countries (Diagana et al., (n.d.); Fiedler et al., (n.d.) a, b, c, d), it was a wise decision to choose these countries to represent places where a migratory wintering waterbird spotted in Turkey has been to before it came to Turkey. However, if the study covered lakes from eastern parts of Turkey, it would also be necessary to include countries which are located in Eastern or Northeastern Turkey because some of the migratory waterbird populations (especially those breeding in Northeast Asia) enter Turkey through a separate, northeast to southwest flyway (Diagana et al., (n.d.); Fiedler et al., (n.d.) a-b-c-d).

This study has demonstrated that winter air temperatures in the four Eastern Europe countries (Ukraine, Moldova, Romania, and Bulgaria) has some decent impact on cumulative wintering waterbird community density in the three study lakes and possibly in many more parts of Turkey. Cumulative number of wintering waterbirds in the study lakes was calculated only for the years during which all of the three lakes were visited for the MWS (see table 2.1). The analyses showed that December-January TAVG and TMIN averaged for the four Eastern Europe countries and the total number of wintering waterbirds counted in the study lakes were moderately-strongly, negatively, yet insignificantly correlated to each other (table 3.1). Similar but weaker correlations were observed for January TAVG and TMIN averages as well (table 3.1). This implies that as the winter temperatures in the four Eastern Europe countries decline, more migratory waterbirds migrate to the study lakes and possibly to many other parts of Turkey to spend the winter. This finding is perfectly in line with the expectations and previous findings in the literature. As ambient temperatures decline, thermoregulatory costs of fighting cold weather increase and availability of food sources decrease (Dalby et al., 2013; Ridgill & Fox, 1990; Root, 1988; Schummer et al., 2010) and the birds start conserving energy by various means, increase food intake, or metabolize their internal reserves to survive (Blem, 2000). As an alternative, they take a totally different path and migrate further along the flyway to find places where abiotic and biotic conditions are more favorable (Avilova and Eremkin 2001; Dalby et al. 2013; Robertson et al.,2017; Zuckerberg et al. 2011). In Eurasia and Eastern Europe, the paths they follow are broadly along north to south, northwest to southeast or northeast to southwest directions (see section 1.6). For the places in the western half of Turkey, the flyways of concern are mostly along north to south and northwest to southeast. As a result, it is plausible to expect that if Eastern Europe having a harsh winter, some good fraction of waterbirds there ends up migrating to western half of Turkey in search of more favorable climatic conditions during winter. By looking at the results of the study, it seems like this the case with this study. In summary, moderate to strong negative linear correlation coefficients were found for TAVG and TMIN averaged across the four Eastern Europe countries and cumulative number of wintering waterbirds in the study lakes which implies that as winter ambient temperatures start dropping in Eastern Europe, more waterbirds migrate further south and southeast to spend the winter in Turkey. However, it should be noted that ambient temperature itself is not the only factor driving further fall-winter migration in waterbirds. Other abiotic factors such as, water temperature, temporary flooding, snow cover, ice cover and number of days with below zero temperatures are also expected to play a role in shaping winter distributions of waterbirds (Dalby et al., 2013; Heitmeyer, 2006; Schummer et al., 2010). Winter temperature representatives used in this study, which are daily average (TAVG) and daily minimum (TMIN) temperatures for December 1st to January 31th (December-January) and for January 1st to January 31th (January), somehow cover most of these abiotic factors as TMIN and TAVG are temperature dependent indices themselves and those other abiotic factors are mostly temperature dictated. Snow cover and flooding events are; however, partially independent from air temperature patterns. Therefore, including them in the study would surely increase the power of the results. Schummer et al. (2010) demonstrated that composite indices including an array of variables including some of the listed ones above into temperature indices can have high power in explaining dabbling duck winter distribution and abundances. In addition, it was shown in another study that air temperature alone is not the prominent driving factor in shaping wintering distributions of dabbling ducks and temperature in connection with other factors such as food availability, ice cover and local densities of waterbirds (which are also partially dictated by air temperature) probably may explain winter distribution and densities of waterbirds better (Dalby et al., 2013; Schummer et al., 2010). Unfortunately, such data was not available for the four study countries in any usable format, so they weren't included in this study. Nevertheless, the high-power correlations found in this study demonstrates that air temperature indices also have a good explanatory power in winter distribution and abundances of waterbirds.

When examined individually, the strongest linear correlation values for a single lake was observed for Lake Uluabat. Lake Uluabat is the northernmost of the study lakes which makes it spatially closest lake to the four Eastern Europe countries (see figure 1.1 and 2.2). Considering the routes that migratory waterbirds take during their fall-winter migration, it makes perfect sense to assume that the migration driving effect of winter temperatures in Eastern Europe will be most pronounced in Lake Uluabat. The other two study lakes are located several hundred kilometers down the flyways when compared to Lake Uluabat (see figure 1.1) and there are many more wetlands in between Lake Uluabat and the other study lakes. For these reasons, the migration driving effect of winter temperatures in Eastern Europe is expected to fade away as the distance between Eastern Europe and the target wetland increases. Presence of wetlands located further up on the flyway, between Lake Uluabat and the other study lakes is also expected to weaken the migration driving effect of winter temperatures in Eastern Europe on wintering waterbird communities. This is simply because waterbirds may come across suitable wetlands on their way, cease their migration and decide to settle there to spend the winter until the abiotic and biotic conditions become intolerable or until spring migration begins. This will cause some fraction of waterbirds to settle in wetlands for wintering (Hargeby et al., 1994) before they even reach Lake Mogan or Lake Beyşehir which may weaken the effect of winter temperature in Eastern Europe on wintering waterbird numbers in these lakes. There are some other factors which might be blurring the effect of winter temperature in Eastern Europe on wintering waterbird numbers in these two study lakes. Linear correlation coefficients for number of wintering waterbirds and winter temperatures in the four Eastern Europe countries were found to be weak and positive for Lake Mogan and Lake Beyşehir (see table 3.1). Among the three study lakes, Lake Mogan is the one which is located in the coldest region (comparison made by using winter temperature data from National Oceanic and Atmospheric Administration's Climate Prediction Center Database) and it gets frozen almost every winter and stays so for about two months (Mangit & Yerli, 2010). When a lake or a water body is frozen, it hampers the feeding of water-dependent birds and decrease the food availability (Avilova & Eremkin, 2001; Schummer et al., 2010). Therefore, during winter, increasing ice coverage may force birds to leave a certain site and move down the flyway to a more suitable one (Avilova & Eremkin, 2001). This alone is a strong factor affecting the number of waterbirds wintering at a site and it most probably has an effect on wintering waterbird density in Lake Mogan (also see section 4.1). Therefore, intensive freezing of the lake is, most probably, one of the main factors blurring the migration-driving effect of winter temperatures in Eastern Europe on waterbird numbers in Lake Mogan. The observed weak and positive correlations for Lake Beyşehir could be explained in similar ways. The presence of high numbers of wetlands further up on the flyway and the fact that Lake Beyşehir is the furthermost study lake from Eastern Europe might again be contributing factors. Other than the distance and the presence of wetlands further up on the flyway, freezing may also be playing an important role. It is known that Lake Beyşehir is also frozen partially in winters which probably affect wintering waterbird communities to a certain extend. To summarize, differential freezing and ice coverage and the effect of increasing distance between the source and recipient places, that is the distance between the four Eastern Europe countries and the study lakes, seem to be the underlying reasons for the observed deviations we observe for Lake Mogan and Lake Beyşehir. Nevertheless, these weak deviations are not strong enough to blur the moderate-strong and negative linear correlation this study has discovered between the total number of wintering waterbirds in the three lakes and average and minimum winter temperatures in Eastern Europe, which is perfectly in line with findings and postulates of various studies

(Avilova & Eremkin, 2001; Dalby et al., 2013; Robertson et al., 2017; Ridgill & Fox, 1990; Root 1988; Schummer et al., 2010; Zuckerberg et al., 2011).

When the individual correlation coefficients between the winter temperatures in the four Eastern Europe countries and total number of waterbirds wintering in the three study lakes studied, it was seen that the lowest correlation coefficients were for Ukraine (see table 3.3) which is the furthermost and the easternmost of the study countries. The remaining three countries all had similar linear correlation coefficients. This, once again, showed that it is plausible to assume that the idea of distance weakening the migration-driving effect of winter air temperature in upstream parts of the flyways, which was put forward early in this section, is valid. This also makes it safe to say that correlation coefficients for Ukraine and total number of wintering waterbirds in some other set of the lakes from eastern half of Turkey would probably be stronger than what was discovered in this study. However, as stated early in this section, if the study had covered lakes from the eastern half of Turkey, including countries lying northeast of Turkey (e.g. Georgia) in the analyses would probably make more scientific sense.

Effect of NAO on wintering waterbird numbers in the study lakes was discovered to be weak but in line with the expectations. As mentioned in section 1.7, generally, positive values of NAO Index mean warm winter conditions in much of the Northern Europe and Eurasia and harsh winters in Turkey whereas, negative values of NAO Index mean harsh winter conditions in the Northern Europe and Eurasia and mild winters in Turkey (Cullen et al., 2000; Greatbatch, 2000; Hurrell, 1995, 1996; Kerimoğlu, 2008; Küçük et al., 2009). This implies, from waterbirds' point of view, that when NAO Index is at its positive highs, the winters are milder furher up on the migratory flyways and less birds need to migrate down the flyway to Turkey to spend the winter. On the contrary, when NAO Index is at its negative highs, harsher and colder winter climate is expected in places located further up on the flyways (Cullen et al., 2000; Greatbatch, 2000; Hurrell, 1995, 1996; Kerimoğlu; 2008, Küçük et al., 2009) which means more birds may need to migrate to Turkey to spend the winter where climatic conditions are expected to be milder and more favorable. In the light of the above expectations, we would expect to see a negative correlation with NAO Index value and the total number of wintering waterbirds counted in the study lakes and this was exactly the case in this study (see table 3.4). However, the strength of the correlation was discovered to be slight. This might be because of the fact that NAO is only able to explain a fraction of winter air temperature changes in the study area (Hurrell, 1996). Given the limited explanatory power of NAO Index and presence of many other factors which have potential to affect the observed impact of NAO on wintering waterbird numbers (e.g. freezing of the lakes), linear correlation coefficients this study generated are still good enough to conclude that there is a decent negative correlation between NAO Index values and number of waterbirds that come to the three study lakes (and possibly to most of Turkey) to spend the winter. This study's finding of NAO having an effect on avian migration (winter migration in this case) and distribution of waterbirds (winter distribution in this case) is consistent with results of previous studies. Zipkin et al. discovered in their 2010 article that NAO had significant power in explaining winter distribution of several sea duck species along the Atlantic coasts of the USA and Canada. In another study, Rainio et al., (2006) showed that waterbirds adjust the time they spend at their wintering sites and timing of their spring migration depending on NAO and harshness of winter they experience. Furthermore, Vahatalo et al., (2004) and Sokolov & Kosarev, (2003) showed in their studies that time passerines spent at their wintering sites and, timing of departure from wintering sites, timing of the spring migration and arrival of the birds to their breeding grounds depend on NAO and climatic conditions it brings to the related parts of the world. Although insignificant, the slight tendency observed in this study was in line with these finding by showing that the winter distribution and migration of waterbirds in the region was somehow related to NAO.

The effect of winter temperatures in Eastern Europe on species richness indices was variable. For cumulative species richness calculated for the three lakes, moderate, positive and non-significant correlations were discovered. This is opposite of what was expected. All waterbird species included in this study have different physical attributes. As a result, thermoregulatory costs of fighting cold weather is different for each of those species because lower critical temperature, which is defined as the minimum temperature an organism can tolerate, changes from one species to another depending on factors like body mass, insulation and normal temperature ranges the organism is adapted to (Dalby et al., 2013; Kendeigh et al., 1977). When ambient temperatures drop below the lower critical temperature (possibly in winter for the Northern Hemisphere), costs of thermoregulation for organisms increase substantially (Dalby et al., 2013). Because different species have different lower critical temperatures, a differential migratory response is expected for different species during fall and winter (Dalby et al., 2013). In theory, this is expected to affect waterbird species composition wintering in Turkish lakes; colder winter in upstream parts of the flyway is expected to cause more species to migrate to Turkey where conditions are milder. When this hypothesis was tested using linear correlation, it was seen that the hypothesis didn’t hold for average TAVG calculated for the four Eastern countries and cumulative species richness; linear correlation coefficients for average TAVG in the Eastern Europe and cumulative species richness in the three study lakes was moderate and positive. If the above hypothesis was true, the two would have a negative linear correlation. To be able to explain this finding ,which contradicts the expected results, one needs to look deeper into the MWS results history. As stated in the methodology section of the thesis, in order to conduct all the analyses conducted in this study and to be able to see the effect of various variables such as winter temperature in Eastern Europe on wintering waterbird communities, the assumption that the MWS were more or less standardized needed to be made. This assumption may be true in practice considering the factors listed in section 2.1.2. Still, there was a visible pattern in the results which could not be ignored. When the raw species richness of the counts were studied, it was seen that for all three of the study lakes, number of species detected in MWS showed tendency to increase over the study years (figure 4.1).

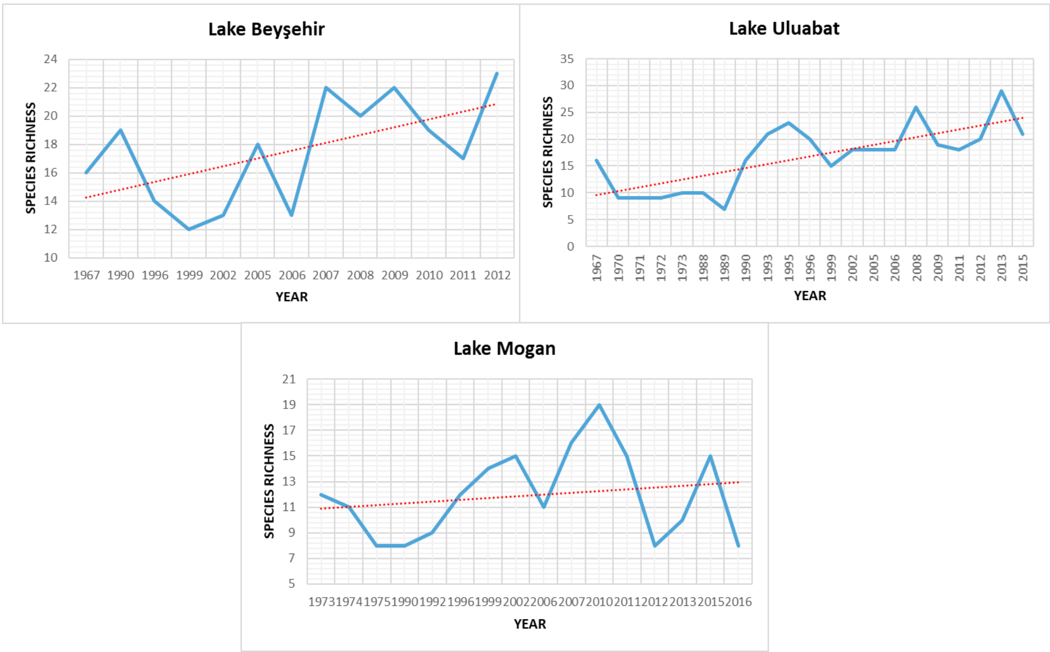

Figure 4.1: Change in the number of waterbird species detected during the MWS in the study lakes. Dashed lines are the trendlines.

Figure 4.1 clearly shows the steady increase in species richness of wintering waterbird communities in the study lakes. However, it is very unlikely that this increase is due to an increase in the number of waterbirds that are actually coming to Turkey to spend the winter (it is even more unlikely considering the fact that Eastern Europe has been warming up steadily as shown in figure 3.1). The reason for this phenomenon may be something to do with the birdwatchers and counters who conduct the MWS. The number and skill level of birdwatchers in Turkey has been increasing since the introduction of the MWS in 1960's. Such an increase may be visible in the results in the form of increased number of species detected. Therefore, the steady increase in the number of waterbird species detected during the MWS since the introduction of birdwatching and MWS in Turkey may be due to an increase in the number of skilled birdwatchers and the increase in overall skill and experience level of the birdwatchers. This makes sense because the number of species detected is highly dependent on the observer(s) who are conducting the counts (Bibby et al., 2000; Gregory et al., 2004).

A good example of this can be seen in the results of 2010 MWS conducted in Lake Uluabat. In 2010, one of the Turkey's best birdwatchers, Soner Bekir, performed the count and the number of waterbird species he reported (those which qualified to be used in this study) was 39. Average species richness for Lake Uluabat's wintering waterbird community is 16.79 for the rest of the years. For this reason, 2010's Lake Uluabat MWS results were excluded from the study but it was a clear example to show the effect of observers on the number of species detected. Getting back to the starting point of the discussion, this phenomenon may be (and possibly is) the reason why moderate and positive linear correlation coefficients were found for average winter temperatures in Eastern Europe and cumulative species richness in the study lakes. When summed species richness of the study lakes was tested for any linear correlation with average TAVG in Eastern Europe, it was seen that there was a slight positive correlation for December-January and almost no correlation for January, both of which could be attributed, again, to the phenomenon discussed above. However, when summed modified species richness values were inspected, it was seen that there were slight to moderate and negative correlations between winter average temperatures in Eastern Europe and summed modified species richness values (table 3.2). As stated earlier in this section, a negative correlation was expected here. Although they were not statistically significant (see section 3.1.1), these two negative linear correlations might make the assumption about the observer's effect on the detected number of species sound reasonable. As stated in section 2.7, the reason why modified species richness was formed and used in the first place was because the study needed something that can get rid of any possible bias caused by the effort or observers. Therefore, we expect this richness index to be more reliable in being free of effort and observer-sourced bias. For this reason, it is plausible to assume that the number of species coming to the study lakes to spend the winter increases slightly with decreasing temperatures in upstream parts of the flyway such as the four Eastern Europe countries used in the study.

NAO's effect on species richness indices was variable as well. When the effect of NAO on cumulative species richness in the three study lakes was of studied, it was seen that there was a weak and positive correlation for Dec-Jan NAO and almost no correlation for Jan NAO. The expected linear correlation for NAO and species richness indices is negative for the same reasons that were discussed in the previous paragraph; more negative NAO means colder winters in the Northern Europe and Eurasia and more waterbird species coming to Turkey to spend the winter. Once again, the results found contradicted this expectation. The reason for this contradiction may again be because of the observer phenomenon which assumes that increase in the species richness over time is due to the observers increasing skill and experience level. Summed species richness and NAO index values yielded weak and negative correlation coefficients which seemed just like the correlation between TAVG in Eastern Europe, a bit more close to the expectations. Finally, when summed modified species richness and winter NAO values were tested for any correlation, a moderate to strong negative correlation was discovered. Furthermore, these correlations were found to show a strong trend toward statistical significance ($p=0.10$ for Dec-Jan NAO and $p=0.08$ for Jan NAO). Just like in the case of winter TAVG and richness indices, the results that approximated the expectations in the best way belonged to the modified richness related index. This, once again, showed that modified species richness might be better at getting rid of any observer or effort based bias and at approximating the true patterns.

4.2 Impact of Water Level and Submerged Macrophytes on Wintering Waterbird Communities

4.2.1 Impact of Water Level on Wintering Waterbird Communities

The current study showed that the relationship between water level and wintering waterbird community density can be highly strong. It was discovered that Lake Beyşehir's winter LWL and growing season LWL years attracted highly significantly and significantly more wintering waterbirds, respectively. Furthermore, winter water level and growing season water level were both moderately and negatively correlated to the wintering waterbird community density with the former almost reaching significance at 95% confidence level ($p=0.06$) and the latter being statistically significant at the same level. These findings are perfectly in line with previous findings reported in the literature. Bancroft et al. (2002), Beklioğlu et al. (2006), Colwell & Taft (2000), Taft et al. (2002) and Perry & Deller (1996) all reported increases in number of waterbirds a wetland can support with at low water levels. This is because of increased availability of more foraging grounds for waterbirds which have limited lengths to their legs, necks and beaks, increased production of some food sources (e.g. some invertebrates) and because of the increase in the total area the lake's littoral zone covers (might not always be true but true for Lake Beyşehir – see section "Lake Işıklı" in Beklioğlu et al, 2006 for an exception), which is especially important during macrophyte growing season (Battisti et al., 2006; Perry & Deller, 1996; Taft & Colwell, 2000; Taft et al., 2002). Among these, increase in littoral zone's coverage is particularly important due to its effect on development and biomass of macrophytes which can have tremendous effects in shallow lake ecosystems (Beklioğlu et al. 2006, 2017; Coops et al., 2003; Hanson & Butler, 1994; Hargeby et al., 1994; Jeppesen et al., 1998; Moss, 2009; Noordhuis et al., 2002; Taft & Colwell, 2000; van Geest et al., 2005 – also see section 4.2.2). It is also known that most of the waterbird species depend on 0-25cm depth range to survive whereas only a small portion of waterbirds need depths higher than 25cm, (Colwell & Taft, 2000; Cramp et al., 1977, 1983; Taft et al. 2002) Therefore, the finding that Lake Beyşehir's LWL years attracted significantly more waterbirds in winter conform to the expectations as well. For Lake Uluabat no statistically significant differences were discovered between LWL and HWL years in terms of total number of wintering waterbirds but it was discovered that both winter and growing season LWL years of Lake Uluabat attracted more wintering waterbirds on average than did their HWL counterparts ($p=0.23$ and $p=0.21$ in Mann-Whitney U-test). Although not statistically significant, the very slight tendencies observed here are in line with the expectations and previous findings which are given earlier in the paragraph. In contrast, Lake Mogan exhibited an inverse pattern; both winter and growing season HWL years attracted around 2.10 times more wintering waterbird when compared to their LWL counterpart but the differences between the water level groups was not significant. Although the findings here were not significant, the slight tendency observed here was investigated for an explanation and the only one plausible explanation was found and it was found when the historical satellite imageries of the lake were compared. It can be seen from figure 3.5 that there is an increase in water level of Lake Mogan over the study years. This is also visible from the satellite images of the lake: some areas of the lake have been flooded following the increase in the water level (figure 4.2). Both of the satellite images are taken by the same imaging system and at the same time of the year.

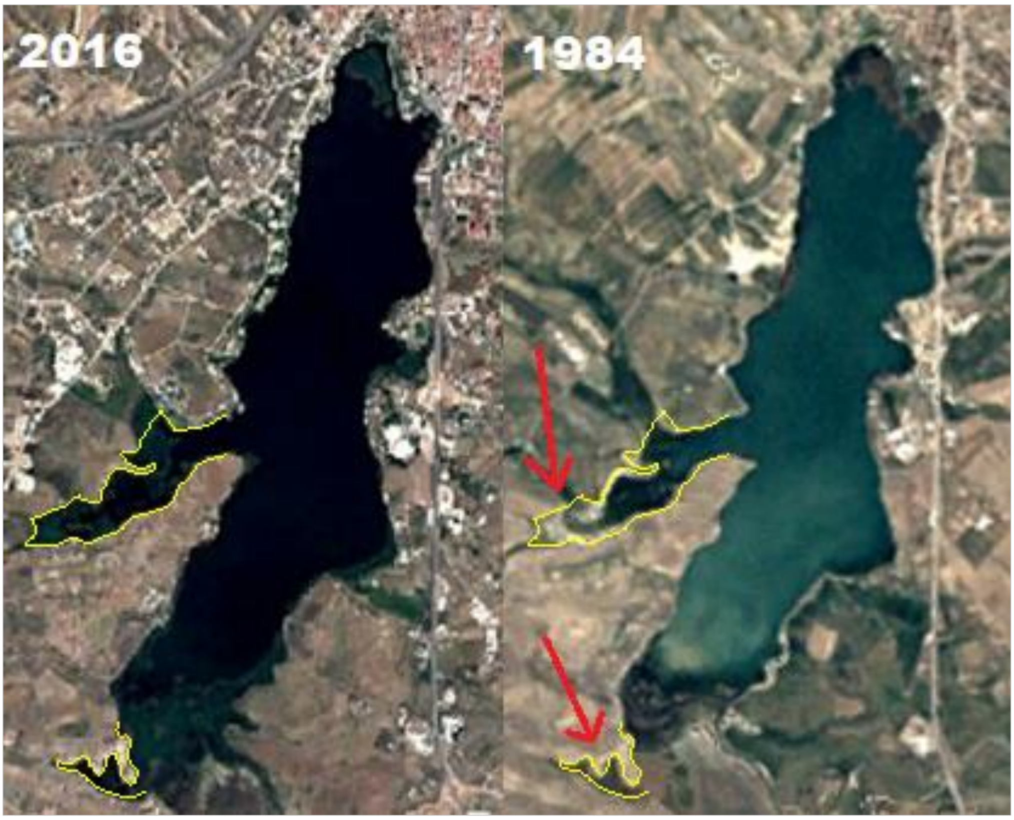

Figure 4.2: Satellite imagery showing Lake Mogan in 1984 and 2016. Images: Landsat/Copernicus, retrieved from Google Earth on 13.09.2017. Image dates: 31.12.2016 and 31.12.1984 from left to right

These newly flooded areas are known to harbor a huge variety of waterbirds throughout the year, as long as they are flooded (Özgencil personal observation.; Özgencil, 2016). It is also known that these areas start to dry out in summer Özgencil, personal observation). This is because Lake Mogan's water level fluctuates intraannually like most of the shallow lakes in the region and when the evaporation increases during summer, water level drops (Beklioğlu et al., 2006, 2017; Coops et al., 2003). These newly flooded areas offer invaluable habitats and refuge for the waterbirds breeding and wintering in the lake because there are no ecologically similar places in this small lake (Özgencil, personal observation). Doğan (2007) demonstrated that these areas are in fact well vegetated in terms of submerged macrophytes as well. It is also known that one of these areas are visited for the MWS (Özbahar, personal communication). Considering all these factors, it seems plausible to assume that HWL years might be attracting more waterbirds because these important and shallow habitat patches are flooded to a higher extent during HWL years. Although it is certain that these areas are attracting serious numbers of breeding and wintering waterbirds, this hypothesis needs to be tested to reach a scientifically reliable conclusion. Still, it stands as a seemingly plausible hypothesis which might actually be one of the reasons why Lake Mogan deviated from the expected patterns. This hypothesis was obviously not true for the other two lakes which are highly larger than Lake Mogan and presence or absence of such small habitat patches are not expected to cause any big changes in wintering waterbird community densities of these big lakes.

When the impact of water level on species richness was studied, some significant patterns were discovered. The study showed that Lake Uluabat's winter LWL and growing season LWL years both had significantly higher species when compared to their HWL counterparts. As far as modified richness was concerned, LWL years again had the edge but this time the difference showed a favorable trend toward significance but failed to reach it ($p=0.11$ in Mann-Whitney U-test). Both of these findings were in line with what was observed in the previous studies which reported that the highest waterbird species richness are seen in shallower wetlands with variable topography and an average depth of 15-20 cm (Colwell & Taft, 2000; Taft et al., 2002) which is because of the factors listed in the first paragraph of this section. For Lake Beyşehir, contrasting results were obtained. Unlike Lake Uluabat, Lake Beyşehir's winter HWL years were the ones which had significantly higher species richness in their wintering waterbird communities. No significant differences were found between growing season LWL and HWL years in terms of species richness and modified species richness. Lake Mogan's LWL and HWL water level groups were found to be almost no different from each other in terms of the two species richness indices. When examined closely, some possible reasons were found to explain Lake Beyşehir's and Lake Mogan's cases. It can be seen from table 3.5 that more than half of the lake's HWL years correspond to the most recent study years and among these years was 2012 which had the greatest species richness among all the study years. As discussed in section 4.1, a steady background increase in species richness was observed for all of the study lakes which was probably due to observer-sourced bias. This might be a contributing factor to Lake Beyşehir's high species richness in winter. Another possible explanation may be the increase in the area of the lake as it is known that the bigger wetlands tend to have a higher species richness (Colwell & Taft, 2000; Taft et al., 2002). However, this does not apply well to the big wetland/lakes; therefore, this seem to be a weak candidate to explain the observed pattern. Still another explanation could be the fact that some of the species require deeper water and their densities and diversities increase with increasing (up to a certain point) water level (Colwell & Taft, 2000). Such species are mostly diving species. To be able to test this hypothesis would require studying all the diving species (not just the ducks) separately, which was not in the context of the current study. The study's failure in reporting higher species richness indices for Lake Mogan's LWL years could be because of the same factors listed above and because of the fact that during HWL years some valuable habitats are flooded (see figure 4.2) which might be attracting more species and which might also compensate for the species richness difference between LWL years, which are expected to attract more species, and HWL years.

The current study showed that the effect of water level on some of the individual functional groups in the wintering waterbird communities of the study lakes was significant. When the water level groups were compared on the basis of HE waterbirds they harbored, it was seen that both winter ($p=0.02$) and growing season ($p=0.08$) LWL years of Lake Beyşehir had higher medians. Beklioğlu et al. (2006) reported that water level and the plant coverage in this lake (and the two other study lakes) is inversely correlated. Consequently, seeing more HE waterbirds during LWL years is what is expected and observed here. This finding is also in line with previous studies which reported increases in numbers of HE waterbirds in lake following an improvement in the macrophyte status (e.g. Beklioğlu et al., 2006; Hargeby et al., 1994; Noordhuis, 2002; Van Geest et al., 2005). For Lake Uluabat, the study failed to document any significant findings for HE and water level relationship in Lake Beyşehir and Uluabat. The reason why the study failed to generate any significant results between LWL and HWL years was possibly because of a single year, 1999. This year was a HM and HWL year at the same time and it attracted huge numbers of HE waterbirds (see figure 3.10) blurring the differences between LWL and HWL year groups. For Lake Mogan, the reason for the failure might be because of the balancing effects of HWL years generating high quality and well-vegetated habitats (see figure 4.2 – Doğan, 2007) and LWL years having a higher plant coverage (Beklioğlu et al., 2006). When OM functional group was of concern, analyses generated some near-significant results for Lake Uluabat. The study showed that Lake Uluabat's winter LWL years had higher numbers of OM waterbirds and the difference between the two water level groups was significant at 90% confidence level. In addition, Lake Uluabat's and Lake Beyşehir's growing season LWL years also attracted more OM waterbirds but the differences between them and their HWL counterparts was statistically insignificant. These findings were also in concordance with the expectations: more OM waterbirds are expected during high macrophyte years (Carpenter & Lodge, 1986; Jeppesen et al., 1998; Lillie & Budd, 1992; Pardue & Webb, 1985; Tománková et al., 2013; van den Berg et al., 1998) which are mostly LWL years for the study lakes (Beklioğlu et al., 2006). This is because HM years are expected to harbor a higher diversity and abundance of both macroinvertebrate and macrophyte food sources (see section 4.2.2 as well). The reason why the expected patterns were not observed for Lake Mogan might again be because of the blurring effect caused by HWL years' creating some high-quality habitats. As for GU functional group, some near-significant differences were detected between the water level groups. For Lake Beyşehir, growing season HWL years were found to harbor more GU waterbirds during winters ($p=0.08$ in Mann-Whitney U-test) which was as expected because HWL years tend to create more eutrophic states which favor increases in total fish biomass which is the main food of the species in the GU functional group if they ever use the lakes for feeding (Cramp & Simmons, 1977). In contrast, for Lake Uluabat, the results were opposite of this finding; LWL years were the ones which had higher GU numbers (p=0.08 in Mann-Whitney U-test). This finding was really hard to explain but it might still be explained partially by the fact that these opportunistic and behaviorally flexible GU species (see Appendix A) might be utilizing some other food sources which are abundant during LWL years or they might be performing kleptoparasitism during LWL years due to some factors such as increased densities of other bird groups (Brockmann & Barnard, 1979), which might be making it possible for them to thrive during LWL years. There were no statistically significant differences between the water level groups in terms of number of PI waterbirds in the wintering waterbird community of the study lakes. When INPI functional group was studied, it was seen that the LWL years of the study lakes tend to have higher numbers of INPI waterbirds but the differences were not statistically significant. This might be because of the fact that INPI waterbirds might utilizing differential amounts of their macroinvertebrate and fish preys (which are found more abundant in LWL and HWL years, respectively) according to their availability. This, in turn, is expected to make it harder to detect any differences between the water level groups in terms of INPI waterbirds. No statistically significant differences were discovered for functional group richness comparisons of the water level groups.

4.2.2 Impact of Submerged Macrophytes on Wintering Waterbirds Communities

High macrophyte (HM) and low macrophyte (LM) years for the study lakes were defined by the methods listed in section 2.4.2. For Lake Uluabat and Beyşehir, the classification system and criteria used was subjective in nature and it stood as a possible source of error. Therefore, it needed to be confirmed to see if the classification was in fact meaningful and successfully represented the related years. To do that information from several past studies was used (full lists of these studies are given in section 2.4.1). The previous studies reported detailed, most of the time in the form percent macrophyte coverage, information about the macrophyte status of the study lakes. As stated in 2.4.2, all of this available information was used to test if the classification system used in this study correctly assigned the macrophyte status of the lakes. Fortunately, available information from the published literature was in concordance with almost all (see section 3.2.2) output of the classification and extrapolation methods used in the study. Such detailed information was not available for all the study years; therefore, it was not possible to see if all the years were assigned correctly. Nevertheless, high confirmation rate of the classification and extrapolation system used in the study in estimating the past macrophyte status of the lakes seemed promising and accurate enough to conclude that the methodology used in the study was a reliable one. For Lake Mogan, the only possible source of error for the macrophyte status classification was the fact that not all the samplings were done at the same time of the year. Although they were not too much apart from each other temporally (temporally the farthest ones were about one and a half month apart from each other), the temporal distance between the sampling dates can surely cause errors in submerged coverage estimations with later ones reporting lower macrophyte coverage (which actually was the case for the study years – later ones did report lower coverage values). This is because the samplings were done in late August and September which correspond to, as stated in section 2.4.1, the times during which most of the macrophytes are no longer growing and being degraded by natural processes such as grazing by waterbirds (van den Berg et al., 1998). Although this might be a source of error, there are some factors which increase the reliability of the samplings such as strictly standard field procedures followed during the samplings. Furthermore, Tan (2002) and Doğan (2007) confirmed that the classification results for 2002, 2006 and 2007 were accurate. Nevertheless, the source data used in classifying Lake Mogan's MWS years into LM and HM years was a possible source of error for the study.

When the relationship between macrophyte status and wintering waterbird community sizes were investigated, it was seen that the relationship between Lake Uluabat's macrophyte status and its wintering waterbird community sizes was statistically insignificant. The lakes' HM years hosted, on average, 2.38 times more waterbirds in winter but the differences between its LM and HM years in terms of their medians for total number of wintering waterbirds was not statistically significant. The effect of macrophytes on wintering waterbird community size in Lake Beyşehir was tremendous. Lake Beyşehir's HM years attracted 5.74 times more wintering waterbirds on average and this time, the difference between the medians of LM and HM years was statistically highly significant. Although the results for Lake Uluabat was statistically insignificant, the fact that its HM years showed a slight tendency to attract more wintering waterbirds on average and the fact that Lake Beyşehir's HM years attracted highly significantly more wintering waterbirds both conformed to previous findings in the literature which reported increases in waterbird numbers with increasing macrophyte coverage, biomass and/or diversity (Beklioğlu et al., 2006; Hanson & Butler, 1994; Hargeby et al., 1994; Milberg et al., 2001; Noordhuis et al., 2002). Submerged macrophytes are important components of shallow lake ecosystems and their impact on waterbird communities can be tremendous (Beklioğlu et al., 2006; Hanson & Butler, 1994; Hargeby et al., 1994; Jeppesen et al., 1998; Moss, 2009; Noordhuis et al., 2002). Positive effect of macrophyte abundance and diversity on waterbirds outside their breeding season is result of several factors including the plants being primary food sources of many of the waterbirds in winter, their presence creating suitable habitat for other important winter food sources such as macroinvertebrates, and the submerged plant structures increasing habitat complexity and creating changes in the food web which are beneficial for waterbirds (Cramp & Simmons, 1977, 1983; Hanson & Butler, 1994; Hargeby et al., 1994; Jeppesen et al., 1998; Milberg et al., 2002; Noordhuis et al., 2002; Tománková et al., 2013). Therefore, improvement in macrophyte status of shallow lakes is expected to translate to an improvement in their capacity to support more waterbirds in winter which was what was observed with Lake Uluabat and Lake Beyşehir.

When the study lakes' HM and LM years were compared on the basis of the species richness indices, some noteworthy differences were discovered. The current study showed that Lake Uluabat's LM years had significantly higher wintering waterbird species richness than HM years did. Results were similar for Lake Beyşehir. Although not significant, Lake Beyşehir's LM years had slightly higher average species richness when compared to their HM counterparts. When modified species richness was concerned, neither Lake Uluabat nor Lake Beyşehir exhibited significant difference between their LM and HM years but for both of these lakes, LM years had slightly higher average modified species richness. As stated in section 3.2.2, the only LM period for Lake Uluabat and most of the LM periods for Lake Beyşehir corresponded to the most recent study years (see figures 3.2 and 3.7). It seems likely that the gradual background increase in the number of species detected (figure 4.1) which was probably due to the observer effect mentioned in section 4.1 might again be responsible for the increase in species richness and modified species richness of the LM years (which mostly corresponded to the most recent years for Lake Uluabat and Lake Beyşehir). Once again, as explained in section 1.7 and 4.1, modified species richness is expected to provide more bias free results than species richness does. The fact that there was no significant difference between LM and HM years in terms of modified species richness for these two study lakes is therefore a more reliable output. In summary, the study failed to document any increase in Lake Uluabat's and Lake Beyşehir's wintering waterbird species richness with improving macrophyte status, which was documented by various studies such as Elmberg et al., (1993), Froneman et al., (2001), Hanson & Butler, (1994) and Milberg et al., (2002) and the reason for this failure might be the gradual background increase in number of waterbird species reported in the MWS over time. The study failed to discover any statistical differences between LM and HM years of Lake Mogan in terms of the two species richness which could possibly be attributed to the fact that HWL years leave some valuable habitat patches flooded as discussed in section 4.2.1 but these years are also the years which were expected to have a limited macrophyte coverage as put forward in Beklioğlu et al. (2006). These factors, along with

The study also showed that the study lakes' LM and HM years differed significantly on the basis of some individual functional groups. When Lake Uluabat's and Lake Beyşehir's LM and HM years were compared in terms of number of HE waterbirds they harbored in winters, the two lakes' HM years were found to harbor around 9.01 times and 7.89 time more wintering HE waterbirds on average. For Lake Uluabat this difference failed to reach statistical significance but for Lake Beyşehir the difference was statistically highly significant. The very slight tendency observed with Lake Uluabat and the very strong difference observed with Lake Beyşehir were both in line with the expectations. Increase in macrophyte abundance or diversity is expected to increase the number of HE waterbirds a lake can support outside the breeding season (Beklioğlu et al., 2006; Froneman et al., 2001; Hargeby et al., 1994; Jeppesen et al., 1998; Milberg et al., 1993; Noordhuis et al., 2002;) because macrophytes, especially submerged ones, are important food sources for herbivore birds during winter (Cramp et al., 1977; del Hoyo et al., 1996; Delnicki & Reinecke, 1986; Jeppesen et al., 1998; Miller, 1987; Noordhuis et al., 2002; Paulus, 1983). When the study lakes' LM and HM years were compared in terms of number of PI individuals in their wintering waterbird community, once again, some significant differences were discovered. The current study showed that both Lake Uluabat and Lake Beyşehir's LM years attracted significantly higher numbers of wintering PI waterbirds with Lake Beyşehir's LM years attracting more than a stunning 20 times more wintering PI waterbirds on average. This finding conformed to the previous studies from the literature. It is known that the biomass of bottom feeding species like carps and tenches show an inverse correlation with submerged macrophytes (through complex positive feedback loop mechanisms) and that eutrophic conditions which are characterized by low macrophyte coverage and diversity (Moss, 2009) lead to an increase in overall fish biomass of the lakes (Altınayar, 1998a, 1998b; Beklioğlu et al., 2006, 2017; Diehl, 1988; Jeppesen et al., 1998; Miller & Crowl, 2006). Low macrophyte conditions also provide a better hunting ground for dive-chasing piscivores like great cormorants because macrophytes can serve as physical barriers for the piscivore divers and refuge for the fish; as a result, scarce macrophyte periods are expected to attract more piscivore waterbirds (Jeppesen et al., 1998; Milberg et al., 1993). This was exactly the case with Lake Uluabat and Beyşehir, in which scarce macrophyte years attracted significantly higher numbers of PI waterbirds in winter. As far as GU functional group was concerned, it was seen that the average number of GU waterbirds was higher for Lake Uluabat's and Lake Beyşehir's LM years. For Lake Uluabat, the difference between LM and HM year's medians was significant at 90% confidence level whereas for Lake Beyşehir it failed to reach statistical significance (1.95 times more GU but p=0.25 in Mann-Whitney U-test). The significant (at 90% confidence level) result for Lake Uluabat and the very slight tendency seen with Lake Beyşehir were in concordance with the expectations and previous work in the area; more gulls are expected under high nutrient and low macrophyte conditions (e.g. Martinetto et al., 2010). Gulls which belong to GU functional group in this study (see appendix A) are mostly opportunistic and behaviorally flexible species. Also, because of their flexible nature, they are not tied strictly to the aquatic ecosystems for obtaining food (Robledano et al., 2011). However, when they are actually using freshwater lakes, big portions of their winter diets are made up of fish (Cramp et al, 1983; del Hoyo et al., 1996; Gwiazda et al., 2011; Poot, 2003). Therefore, more GU waterbirds are expected during LM years and this was exactly what was discovered with Lake Uluabat and partially with Lake Beyşehir. As far as OM functional group was concerned, it was seen that HM years came out on top for both Lake Uluabat and Lake Beyşehir. When compared, it was seen that the HM years of Lake Uluabat and Lake Beyşehir harbored, on average, 2.14 times and 6.64 times more wintering OM waterbirds, respectively than their LM years did but these differences were statistically insignificant. Nevertheless, the very slight tendencies detected here seem to conform to the expected results. The omnivorous species included in this study feed on green parts of aquatic plants and macroinvertebrates found in lakes (Philips, 1991, Cramp et al., 1977; del Hoyo et al., 1996 - see appendix A). As mentioned earlier in this section, macrophytes are known to provide habitat for many epiphytic (those living on or attached to macrophytes) and benthic (bottom dwelling ones) macroinvertebrates and abundances of both epiphytic and benthic macroinvertebrates show a strong positive correlation with macrophyte diversity and abundance (Carpenter & Lodge, 1986; Jeppesen et al., 1998; Lillie & Budd, 1992; Pardue & Webb, 1985; Tománková et al., 2013; van den Berg et al., 1998). In another study conducted by Kökmen et al. in 2007, which was a LM year for Lake Uluabat, diversity of benthic macroinvertebrates in the lake was discovered to be very low; which further confirms the role of macrophytes in increasing macroinvertebrate diversity and abundance. In summary, macrophytes are expected to contribute positively to number of OM waterbirds a wetland can support in winter because they both serve as food source for omnivorous waterbirds and harbor high abundances of macroinvertebrates which are also important food sources for them. Therefore, the very slight tendencies observed for Lake Uluabat and Lake

Beyşehir seem to be in line with expectations and previous studies' findings e.g. Beklioğlu et al. (2006), Hanson & Butler (1994), Hargeby et al. (1994), Milberg et al. (1993) and Noordhuis et al. (2002). Similarly, number of INPI waterbirds was also higher for Lake Uluabat's HM years. The study showed that HM years attracted 2.39 times more INPI waterbirds on average and the difference between the median values of LM and HM years showed a weak trend toward significance but failed to reach conventional levels of significance ($p=0.15$ in Mann-Whitney U-test). The reason why HM years attracted more INPI waterbirds is probably because of the same reasons listed above for OM functional group. INPI waterbirds in this study feed on very small fish and aquatic macroinvertebrates. Contribution of each of these to the overall winter diet of INPI waterbirds changes from one place to another depending on several abiotic and biotic factors including temperature, competition and availability and abundance of each of the food sources in the ecosystem (Cramp et al, 1977; del Hoyo et al., 1996). In Lake Uluabat, it seems like macroinvertebrates are more important winter food sources for the species belonging to INPI functional group. This conclusion was drawn by using the finding that INPI waterbirds were more common during the times of high macroinvertebrate times (although not so significantly) which were HM years. In contrast, for Lake Beyşehir, LM years were the ones which attracted more wintering INPI waterbirds but the difference between LM and HM years was insignificant. Although this sounds like an unexpected result, the fact that these birds' diets and relative contribution of invertebrates and fish to the overall diet depends on many factors, some of which are listed above. Although statistically insignificant, the very slight tendency observed might be pointing to a more fish-heavy diet of INPI waterbirds in Lake Beyşehir. For the time being, it is impossible to know if this is really true; a detailed winter diet analysis for INPI birds wintering in the lake and a fish species inventory would be needed to give a definite answer. It is also worth mentioning that the only diving IN waterbird in the study, *Bucephala clangula* or goldeneye, which feeds exclusively on aquatic macroinvertebrates, was observed in Lake Uluabat and Lake Beyşehir during HM years possibly owing to the fact that submerged macrophytes increase the abundance and diversity of aquatic macroinvertebrates (Carpenter & Lodge, 1986; Jeppesen et al., 1998; Lillie & Budd, 1992; Milberg et al., 1993; Pardue & Webb, 1985; Tománková et al., 2013; van den Berg et al., 1998). The results for comparison of the LM and HM years in terms of functional group richness showed that Lake Uluabat's LM years had highly significantly higher numbers of functional groups in their wintering waterbird communities when compared to their HM counterparts, and Lake Beyşehir's LM and HM years had almost the same functional group richness. Previous studies showed that the improvement or introduction of submerged macrophytes resulted in an increase in number of waterbird species (Elmberg et al., 1993; Froneman et al., 2001; Hanson & Butler, 1994; Milberg et al., 2002). Since functional groups richness is expected to increase with increasing species numbers, a higher number of species was expected for HM years. Macrophytes are also expected to increase the habitat structural diversity, heterogeneity and abundance and diversity of various types of food sources (e.g. macroinvertebrates) (Elmberg et al., 1993; Hanson & Butler, 1994; Hargeby et al., 1994; Jeppesen et al., 1998, Lillie & Bud, 1992; Pardue & Webb, 1985) which is expected to further increase the number of functional groups a wetland can support. For all these reasons, a higher functional group richness was expected for HM years but the study generated contrasting results: Lake Uluabat's LM years had higher functional group richness and Lake Beyşehir's LM and HM years were not different from each in terms of number of functional groups their wintering waterbird communities had. The reason why the study failed to document higher numbers of functional groups for HM years in Lake Uluabat and Lake Beyşehir might again be because of the background increase in reported species richness over time (due to the observer effect) which would also translate to an increase in functional group richness (keep in mind for Lake Uluabat LM years were always and for Lake Beyşehir they were mostly the most recent years – see section 3.2.2). Another explanation could be the overestimation of role of macrophytes in increasing the number of functional groups a wetland can support. Detailed and bias-free future studies may be able to document the role of macrophytes on functional group richness of wintering waterbird communities.

When Lake Uluabat's and Lake Beyşehir's LM and HM groups were compared in terms of the number of dabbling ducks they harbored in winter, no significant differences were discovered. The current study showed that Lake Uluabat’s LM and HM years attracted almost the same numbers of wintering dabbling ducks and Lake Beyşehir’s HM years attracted 2.30 time more wintering dabbling ducks on average and both of these findings were statistically insignificant. The reason why the study failed to discover could be because of the feeding biology of the dabbling ducks. Dabbling ducks included in this study are short-necked, non-diving ducks which feed mostly by strategies like dabbling and upending (Cramp et al., 1977; del Hoyo et al., 1996). It is because of this, Noordhuis et al. argues in their 2002 article, dabbling ducks respond less strongly to changes in submerged macrophyte coverage or biomass. Authors of the same paper claim that the reason why their study and many other studies failed to find any strong bond with the number of dabbling ducks in lakes and macrophyte biomass is because water level also play an important role in determining the amount of available macrophyte food source. An increase in macrophyte coverage at depth of 2 m, for example, might not mean much for a dabbling duck unless those plants’ stems and leaves reach close to the water surface where the dabbling ducks can reach and consume them. As a result, solid correlations or relationships between macrophyte status and dabbling duck numbers might be hard to find. This might explain why studies like the current study, Noordhuis et al. (2002) and Beklioğlu et al. (2006) failed to discover strong changes in dabbling duck numbers when macrophyte status of lakes change. To tackle this problem, Noordhuis et al. (2012) suggestion can be followed and macrophyte status in relation with water level can be studied. When a two-level classification system was used and HM-LWL (HM and LWL at the same time) and HM-HWL (HM and HWL at the same time) years for Lake Uluabat and Lake Beyşehir were defined and compared on the basis of number of dabbling ducks they had in winters, it was seen that HM-HWL years had significantly higher number of wintering dabbling ducks. This was surprising. However, when the MWS data for the lakes was further investigated, it was seen that *Fulica atra* or Eurasian coot, which was the dominant herbivore in Lake Uluabat and Lake Beyşehir, was significantly more abundant for HM-LWL years of the both lakes. The reason why the analyses failed to show HM-LWL years didn’t have higher numbers of dabbling ducks than HM-HWL years might be because of higher numbers of Eurasian coots might be suppressing the capacity of the two lakes to support wintering dabbling ducks through competition over macrophyte food sources and decreasing the amount of available macrophyte food sources for diving ducks. In summary, the current study failed to document the expected increase in dabbling ducks with increasing macrophyte biomass or diversity (which some other studies did document by the way e.g. Hargeby et al. (1994)) in Lake Uluabat and Lake Beyşehir and the reason for that might perhaps be something to do with competition rather than macrophyte status directly. While the difference between Lake Beyşehir's and Lake Uluabat's LM and HM years on the basis of wintering dabbling duck numbers was insignificant, some significant and noteworthy differences were discovered for diving ducks. This study showed that Lake Uluabat's HM years attracted, on average, 2.20 times more diving ducks in winter when compared to LM years but difference was not significant ($p=0.22$ in Mann-Whitney U-test). For Lake Beyşehir; however, HM year attracted 12.74 times more wintering diving ducks on average and the difference between LM and HM year was statistically significant. This strong relation and the slight trend seen with Lake Uluabat were both in concordance with findings of previous studies which reported increased numbers of diving ducks with improving or increasing macrophyte status such as Beklioğlu et al. (2006), Hanson & Butler (1994), Noordhuis et al. (2002) and decreased numbers of diving ducks with the loss of macrophytes due to eutrophication such as Tománková et al. (2014). Findings of the current study was also in line with the expectations. Diving ducks detected in the three study lakes are either omnivorous (2 species) or herbivorous (2 species) species. As stated above in OM functional group related part, submerged macrophytes are crucial for wintering waterbirds because they directly serve as food source and create suitable habitat for macroinvertebrate foods of the waterbirds (Carpenter & Lodge, 1986; Hargeby et al., 1994; Jeppesen et al., 1998; Lillie & Budd, 1992; Pardue & Webb, 1985; Tománková et al. (2014); van den Berg et al., 1998). Therefore, HM years are expected to have a higher supporting capacity for wintering diving ducks and the strong relation observed with Lake Beyşehir and the very slight tendency observed with Lake Uluabat seem to conform to that.

The results of the analyses regarding Lake Mogan's macrophyte status and wintering waterbird community was full of statistically insignificant findings; none of the LM-

HM analyses generated statistically significant results. Although a couple of differences in averages which conformed to the expectations were found (larger community size, higher HE number, higher OM number, higher INPI number, higher functional group richness for HM years – higher GU number for LM years), almost all of the analyses the results were statistically meaningless. There might be a couple of possible explanations for the study's failure of documenting any significant results for LM-HM analyses. One possible explanation for the study's failure could be something to do with the climate in the region. Lake Mogan is located in the coldest climatic region among the study lakes (Climate Data Online (CDO) | National Climatic Data Center (NCDC)," n.d.) and the lake is at least partially frozen for around two months of the winter (Mangit & Yerli, 2010 – although partially, Lake Beyşehir is also frozen in some years – see section 1.2). When Ankara's, the city where Lake Mogan is located, historical winter temperature records were checked, it was seen that for three out of four HM years, the number of days in January and February with subzero average temperatures were around 20 whereas the average for the rest of years (between 2002 and 2016 – years which qualified for LM-HM analyses) was around 11. Therefore, it seems possible that the low winter temperatures in Ankara during some of the HM years and the resulting possibility of extensive freezing might be one of many reasons why the study failed to document the expected patterns with changing macrophyte coverage in Lake Mogan. It should also be noted that Beklioğlu et al. did in fact found out in their 2006 article that breeding waterfowl community responded positively to improving macrophyte status of the lake. This also supports the above hypothesis asserting that the effect of harsh weather and resulting freezing might be blurring the underlying patterns. Low sample size available for Lake Mogan's LM-HM analyses (only 9 years qualified for the analysis – 4 HM and 5 LM years) also seems like a possible contributor for the low power of the analyses. With increasing sample size, representative power of the analyses increases and it gets easier to discover the real underlying patterns, if there are any (Fowler & Cohen, 1996). Therefore, more accurate, perhaps statistically more significant, results might have been found, if the sample size was higher for the qualifying years. Different dates of sampling for the lake's macrophyte coverage might also be acting as a bigger source of error than previously thought. As stated in beginning of this section, sometimes, macrophyte coverage sampling trips were done at different times. Although the temporally farthest ones were around 45 days apart from each other, this much of time difference might be playing a more important role in changing the representative power of the sampling for the related year's macrophyte coverage than previously assumed. Beklioğlu et al. (2006) reported that z-score of the lake's average annual water level and the lake's binary plant index which describes high/low macrophyte cover were negatively and significantly correlated to each other. Considering the temporal distance between the sampling dates and the possibility of them causing various errors in the analyses and that Beklioğlu et al. (2006) demonstrated a significant correlation between water level and macrophyte coverage, perhaps using growing season water level or some other indices combining the measured coverage data and growing season water level might just be a better idea to make LM and HM year classification for Lake Mogan. In summary, the harsh winters experienced in the region during HM years, the really low sample size and the possibility of different sampling dates being a source of error might be the reason why the current study failed to document any significant results and if these factors were eliminated, the analyses might have yielded crisper, more accurate and more significant results.

CHAPTER 5

CONLCUSSIONS

Waterbirds, like many other organisms, have their winter distributions constrained by environmental factors such as ambient temperatures (Root 1988, 2010). The current study showed that harsh winters in upstream parts of the fall-winter migratory flyways may be forcing waterbirds to migrate further along the flyways and come to milder Turkey to spend the winter. This means Turkey, an already very important wintering ground for waterbirds in the region, becomes even more important when upstream places on the fall-winter migratory flyways like Eastern Europe are having a harsh winter. In other words, when places like Northern Eurasia and Eastern Europe are having an extreme winter, Turkey is expected to host seriously high proportions of the region's migratory waterbird populations. From a conservationist point of view, this means that it is vital to have a proper web of protected areas and conservation measures in place to be able to protect all those waterbirds which migrates and takes refuge in Turkey during winter. Conservations and decision-makers should also keep in mind that having too many wintering waterbirds is one of the ways to assign strong and effective protected area status to wetlands. Therefore, when the upstream parts on the flyway are having a harsh winter, more effort should be spent in conducting the Mid-Winter Waterbird Surveys and as many wetlands as possible should be visited in order not to miss any wetland which might attract very high numbers or important species of waterbirds. Similar conclusion can be drawn for the North Atlantic Oscillation (NAO). When the NAO Index values reach negative highs, winter conditions in upstream parts of the fall-winter migratory flyway are expected to get harsh and force more waterbirds to migrate to Turkey where the conditions are expected to be milder when the NAO Index values are negative (Greatbatch, 2000; Hurrell, 1995; Kerimoğlu, 2008). Therefore, similar measures should be considered for the times when the NAO Index values are negative.

Results of the current study regarding the impact of water level and submerged macrophytes on wintering waterbird communities also have some important implications. The existing literature show that low winter water levels usually mean a higher capacity of wetlands to support wintering waterbirds which is probably due to a higher accessibility of food sources for most waterbird species. The current study failed to confirm this information for one of the study lakes (see section 4.2.1) probably because of a combination factors like freezing of the lake during winter, and high water level resulting in flooding of some ecologically unique parts of the lake. Lower growing season water levels are expected to increase the waterbird supporting capacity of shallow lakes by increasing the total area the littoral covers in a lake. Although this is not true for every lake (see section "Lake Işıklı" in Beklioğlu et al. (2006)), it is true for lakes having morphometric features like those of the study lakes (Beklioğlu et al., 2006). This is expected to increase capacities of lakes in supporting many of the waterbird groups (but not piscivores and generalist gulls – see section 4.2.1 and 4.2.2). The study's results confirmed these expectations with several exceptions. As far as submerged macrophytes are concerned, it is expected to see an increase in number and diversity of waterbirds a shallow lake can support with improvements in macrophyte status of the lakes. Submerged macrophytes are crucial components of shallow lake ecosystem and they generally cause huge changes in the ecosystem and food web which result in higher densities of waterbirds being attracted to the lakes. This study confirmed increases in total number of wintering waterbirds being attracted to the study lakes, increases in abundances of several waterbird groups (such as herbivores and omnivores – see section 4.2.1 and 4.2.2) and decreases in some other waterbird groups (such as piscivores) with improvements in the macrophyte status of the lakes. Although water level and macrophyte status of the lakes are not expected to directly affect the number of waterbirds migrating to Turkey from Eastern Europe or other places further up on the flyways to spend the winter, considering the wintering ground philopatry observed with some waterfowl species (Robertson & Cooke, 1999) and the potential of water level and macrophytes in positively affecting the number and diversity of waterbirds a lake can support, conservationists and decision makers should put uttermost effort in conserving the lakes at appropriate water levels (which is usually low - especially during growing season) and at macrophyte-dominated clear water states.

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APPENDIX A

STUDY SPECIES AND THEIR FUNCTIONAL

Table A: Study species and their functional group assignments

SPECIES	**FUNCTIONAL GROUP**
White-headed duck (*Oxyura leucocephala*)	OM
Common pochard (*Aythya ferina*)	OM
Northern shoveler (*Anas clypeata*)	OM
Common moorhen (*Gallinula chloropus*)	OM
Tufted duck (*Aythya fuligila*)	OM
Common shelduck (*Tadorna tadorna*)	OM
Pied avocet (Recurvirostra avosetta)	IN
Goldeneye (*Bucephala clangula*)	IN
Greater flamingo (*Phoenicopterus roseus*)	IN
Cattle egret (*Bubulcus ibis*)	IN
Great cormorant (*Phalacrocorax carbo*)	PI
Pallas's gull (*Ichthyaetus ichthyaetus*)	PI
Red-necked grebe (*Podiceps grisegena*)	PI
Pygmy cormorant (*Phalacrocorax pygmeus*)	PI
White pelican (*Pelecanus onocrotalus*)	PI
Dalmatian pelican (*Pelecanus crispus*)	PI
Great crested grebe (*Podiceps cristatus*)	PI
Red-breasted merganser (*Mergus merganser*)	PI
Common merganser (*Mergus merganser*)	PI
Smew (*Mergellus albellus*)	PI
Little egret (Egretta garzetta)	PI
Squacco heron (*Ardeola ralloides*)	PI
Black stork (*Ciconia nigra*)	PI

Table A continued

Grey heron (*Ardea cinerea*)	PI
Great bittern (*Botaurus stellaris*)	PI
Black-crowned night heron (*Nycticorax nyticorax*)	PI
Great egret (*Ardea alba*)	PI
Purple heron (*Ardea purpurea*)	PI
Little gull (*Hydrocoloeus minutus*)	INPI
Little grebe (*Tachybaptus ruficolis*)	INPI
Horned grebe (*Podiceps auritus*)	INPI
Black-necked grebe (*Podiceps nigricollis*)	INPI
Slender-billed gull (*Larus genei*)	INPI
Sandwich tern (*Sterna sandvicensis*)	INPI
Whiskered tern *(Chlidonias hybrid)*	INPI
Little bittern (*Ixobrychus minutus*)	INPI
Eurasian spoonbill (*Platalea leucorodia*)	INPI
Mute swan (*Cygnus olor*)	HE
Whooper swan (*Cygnus cygnus*)	HE
Tundra swan (*Cygnus columbianus*)	HE
Greylag goose (*Anser anser*)	HE
Egyptian goose (*Alopochen aegyptiaca*)	HE
Eurasian wigeon (*Anas penelope*)	HE
White-fronted goose (*Anser albifrons*)	HE
Eurasian coot (*Fulica atra*)	HE
Ruddy shelduck (*Tadorna ferruginea*)	HE
Gadwall (*Anas strepera*)	HE
Red-crested pochard (*Netta rufina*)	HE
Eurasian teal (*Anas crecca*)	HE
Mallard (*Anas platyrhynchos*)	HE
Northern pintail (*Anas acuta*)	HE
Common crane (*Grus grus*)	HE
Ferruginous Duck (*Aythya nyroca*)	HE
Mew gull (Larıus canus)	GU
Caspian gull (*Larus cachinnans*)	GU
Mediterranean gull (*Larus melanocephalus*)	GU
Armenian gull (*Larus armenicus*)	GU
Black-headed gull (*Chroicocephalus ridibundus*)	GU

Table A continued

Lesser black-backed gull (*Larus fuscus*)	GU
Yellow-legged Gull (*Larus michahellis*)	GU