Czech University of Life Sciences in Prague

Faculty of Environmental Sciences

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Master Thesis

Spatio-temporal dynamics of the greater flamingo (Phoenicopterus roseus) movement in the Mediterranean region: the case of Saline di Commachio

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DIPLOMA THESIS ASSIGNMENT

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Engineering Ecology
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Thesis title

Spatio-temporal dynamics of greater flamingo (Phoenicopterus roseus) movement in the Mediterranean region: the case of Saline di Commachio breeding colony

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Objectives of thesis

The aim of the thesis is to analyze the greater flamingo movement in relation with climatic variations at the most frequently used lagoons.

Methodology

The data from an international long-term monitoring program of greater flamingo will be analyzed graphically and statistically. The data will be provided by the thesis supervisor, and will consist of georeferenced observations of ringed individuals, covering the period app. 2000-2009. The observational data will be compared with available weather time series using correlation analysis and graphical techniques.

The proposed extent of the thesis

40-60 pages

Keywords

Greater flamingo, spatial distribution, spatial ecology, natal philopatry, population ecology, migratory behavior

Recommended information sources

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Declaration of Authorship

I hereby declare that this thesis is a presentation of my original research work done under the guidance of Ing. Vojtěch Barták, Ph.D. All sources and materials used are documented, wherever contributions of others are involved, every effort is made to indicate this clearly. The thesis was not previously presented to another examination board and has not been published.

Prague, 7th of June Anastasiia Siretckaia

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Prague, 7th of June Anastasiia Siretckaia

Spatio-temporal dynamics of the greater flamingo (Phoenicopterus roseus) movement in the Mediterranean region: the case of Saline di Comacchio

Abstract

This study represents an analysis of the greater flamingo (*Phoenicopterus roseus*) movement in relation with climatic variations at the most frequently used colonies Camargue (France) and Saline di Comacchio (Italy). The analysed georeferenced data of the ringed individuals was created in the scope of the monitoring programme organized in the Mediterranean region. It was used for the analysis in combination with other datasets obtained from the chelsa-climate.org website (Climatologies at high resolution for the earth's land surface areas) with resolution 30 arc.sec.

The analysis showed the increase of fidelity to the maternal colony Saline di Comacchio. The ratio of the present individuals changed from 20% to 50% from age 0 to 10 accordingly. Positive ($r = 0.405$) significant correlation was observed between the instant temperature and presence of flamingos in winter time in Saline di Comacchio. However, analysis of correlation between temperature in spring in the colony and presence of species showed significant negative ($r = -0.618$) results. In Saline di Comacchio site precipitation in December and June was significant for flamingo presence in winter period. In. Parc Ornithologique de Pont de Gau located in Camargue temperature in March and precipitation April and July were significant for species presence in winter period. However, for the breeding time in Camargue individuals are dependent on temperature in May and February and precipitation in March. Weather conditions did not show any effect on movement patterns of flamingos in the regional scale.

Key words: Greater flamingo, spatial distribution, spatial ecology, natal philopatry, population ecology, migratory behavior

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1 Introduction

Flamingos have always been one of the most attractive species that rise birdwatchers' and researchers' interest due to their eye-catching appearance, behaviour to feed and nurse their chicks. Commercial and natural salty wetlands widely spread in the Mediterranean area are the main place for flamingos to forage, breed and nesting, therefore they are considered to be a flagship species for this habitat. During dry years when water levels are extremely low majority of flamingos uses the operational saltpans instead of natural ecosystems namely wetlands and lagoons Thanks to the data collection by ringing individuals and further analysis of their movement some progress was achieved to understand how these individuals collaborate between each other, what influences their choice on breeding site and movement between colonies during life history. Nowadays it is known that movements of the greater flamingos are influenced by individual, intraspecific and environmental factors.

Flamingos are competitive species characterized by the high dispersal ability in young individuals. Dispersal at the early ages can be temporally preferable strategy as it lowers the energy loss for the competing with more adult individuals (Pradel, Hines, *et al.*, 1997). However, for adults natal philopatry is a crucial strategy as it decreases time and energy costs to find and explore the new breeding places. Fidelity to natal site can help to overcome outbreeding and preserve important genes crucial for surviving (Shields, 1982). Environmental conditions such as food resources, hydrology and weather conditions vary significantly between colonies (Balkiz *et al.*, 2010)

Even though flamingos are tend to migrate to warmer places during winter time, they are considered to be as partially migratory species (Johnson, 1989), therefore they can stay the whole year at the breeding site or migrate according to the seasons.

Complex pattern of movements – dispersal, migration or partial migration – have erratic element which makes them difficult to explain and find the impacting drivers.

Nowadays, temperature and precipitation are considered to be positively correlated with the number of the breeding pairs (Coulson, 2008). However, little is known how these parameters during spring and winter time exactly regulate individuals movement, breeding and migration. This thesis contributes to our understanding how local weather in the colonies affect the flamingos dispersal. The analysis was done thanks to the data acquired from the ringing and monitoring of the greater flamingos in the maternal colony, Saline di Comacchio, Italy naturally colonized in the year 2000. The initiative was done in the scope of the international long term monitoring programme.

The thesis provides analyses of the regional and local movement (dispersal and migration) of the greater flamingos born in the Saline di Comacchio in relation to individual characteristics (age effect) and instant and time-lag weather conditions on local and regional levels

1.1 Purpose and objective of the study

The main aim of my thesis was to investigate the greater flamingo (Phoenicopterus roseus) movement in relation with climatic variations at the most frequently used lagoons-Saline di Comacchio (Italy) and Parc Ornithologique in Camargue area (France). The analysis included the following objectives:

1. To evaluate the age effect on the flamingo presence from age 0 to 9 in the maternal colony, Saline di Comacchio during the period 2000-2009
2. To evaluate the instant weather effect (temperature and precipitation) on the flamingo presence in Saline di Comacchio during winter and spring time
3. To evaluate the time lag effect of the weather conditions (temperature and precipitation) on the flamingo presence in winter and breeding time in Saline di Comacchio and Camarge (Parc Ornithologique).
4. To evaluate how weather parameters (temperature and precipitation) affect the regional movement pattern of flamingos between Italy and France in winter and spring seasons

2 Literature review

2.1 Distribution and habitats

The Greater flamingos are spread between tropical and temperate zones, from the Mediterranean region through south-west Asia, Kazakhstan, India and Sri Lanka, along the Persian Gulf, from Ethiopia to the south of Africa, to Botswana and Namibia. The dispersal is mainly dependent on the food availability. The range of species which is the basis of individuals' diet is highly distributed in the world (Johnson and Cezilly, 2007). For example, in hypersaline waters flamingos usually feed on invertebrates such as shrimps, brine-fly larvae and molluscs. Their diet also includes seeds, aquatic plants and organic components from mud. The variety of invertebrate species significantly increases in larva dominance as the salinity of water decreases (Johnson and Cezilly, 2007). Particularly insects such as beetles, dragonflies and bugs are prevalent in fresh water. During spring a lot of individuals prefer to feed on waters with low concentration of salt (Johnson and Cezilly, 2007). Therefore flamingos inhabit saline, alkaline and fresh water ecosystems. They are in turn influenced by climatic changes as, for example, droughts or low precipitation. Therefore flamingo tends to move to the more stable locations in terms of water level such as seacoast or managed salt pans (Johnson and Cezilly, 2007).

The greater flamingos spread on three continents as Europe, Africa and Asia and usually choose temperate climatic conditions. Particularly in the Mediterranean region the biggest colonies are located in Spain, Italy, France and Turkey. The oldest ringing programmes are organised in 1977 in Camargue (France) and since 1986 in Fuente de Piedra (Spain) (Geraci *et al.*, 2012). Dispersal occurs continuously between closely located colonies following the positive experience gained in the breeding periods—breeding success, regardless the high level of natal philopatry observed in Spanish and French colonies (Balkiz *et al.*, 2010). However, more distant dispersal flyways were also documented between Mediterranean colonies (Spain, Italy, France) and Turkey (Balkiz *et al.*, 2007). Camargue and Fuente de Piedra are the crucial colonies for gene flow and all colonies in the Mediterranean belong to one genetically homogeneous and panmictic population (Moritz, 1994). According to the results based on the mitochondrial and microsatellite markers presented by Geraci *et al.* (2012) all Mediterranean colonies must be considered as one evolutionary unit.

The biggest colonies in Italy are Margherita di Savoia and Comacchio located on the Adriatic coast. Comacchio belongs to the largest coastal wetland Valli di Comacchio. It was protected by the Ramsar Convention since 1981 (Borghesi *et al.*, 2011). The salt extraction on the Comacchio saltpans was terminated in 1984 and colonised by flamingo in 2000 (Borghesi *et al.*, 2011). Other big colonies in Italy were observed close to Sardinia, Cagliari, Oristano and were recently also noticed in Tuscany, Ravenna (Johnson and Cezilly, 2007). Flamingos are mainly concentrated nearby basins both of western and eastern sides. They prefer to stay around wetlands or saltpans (former wetlands) actively used for the salt extraction. The latter ones provide stable conditions from year to year, so that high temperatures do not influence significantly the water level. Flamingos breed in the dense colonies in the conditions of high evaporation and it is mostly dependent on the rainfall and water level influenced by the melted snow before the breeding season starts (Johnson and Cezilly, 2007). Nesting sites located in the saltpans are provided with the sufficient food supply usually consisting of the invertebrates. There are plenty of saltpans in Italy which are successfully used for the breeding periods. They are shallow which is preferable for the protection from the predators (Johnson and Cezilly, 2007).

2.2 Reproduction and phenology

Sexual development of individuals goes through the following stages: fledging period, immature individuals, adult and reproductive individuals. The duration of each stage is presented in **Table 1.** Once an individual has good body condition and is able to fly, its movements depend on the annual cycling of periods important for surviving and reproduction (**Table 2**).

Table 1. Sexual development stages and their duration (Johnson and Cezilly, 2007).

Period	**Duration**
Fledging	65-90 days
Immature	1-3 years
Adult	> 3 years
Reproductive	> 5 years

Table 2. Annual life periods and their time (Johnson and Cezilly, 2007).

Period	Months
Breeding	April, May, June, July
Post- breeding	August, September, October
Wintering	November, December, January
Pre-breeding	February, March

Breeding periods are characterized by the moving between breeding sites in order to find safe nesting site, mating and chick provisioning. After the breeding season, the adults remained for several weeks in specific wetlands. In comparison with breeding season the movements in post-breeding season are not frequent and still not well studied (Haig *et al.*, 1998). However, areas utilized in this period can be important for over-wintering, foraging and moulting (Haig *et al.*, 1998). During post-breeding period some individuals may spend winter period in vicinity of the breeding colony which can be 200km (Amat *et al.*, 2002). However, some of them may undertake a long distant flight (Amat *et al.*, 2002), although energetic cost must be paid due to infrequency of such movements.

Flamingos can spend winter periods near the breeding areas, or they can migrate as response to unfavoured environmental conditions. Generally, the migratory behaviour is regulated at the individual level and dependent on individual (age, body condition etc) and environmental (occasional severe weather conditions, lack of food resources etc) trade-offs (Sanz-Aguilar *et al.*, 2012). Pre-breeding season is characterised by movement from over-winter place to the colony where the breeding takes place. It adjusts the following decision whether to breed or not and affected by environmental conditions, food availability etc (Johnson and Cezilly, 2007).

The initiation of breeding is a complicated phenomenon varying in space and time with the significant influence of the climatic factors affecting the colony establishment following by the breeding initiation. **Figure 1 b**elow represents the dates of the Mediterranean region of the egg lying period (Johnson and Cezilly, 2007).

The life cycle of the birds is usually dictated by the gradual increase of the daylight hours or by so called, photoperiod and some others ecological parameters. This increase always correlates with the rise of the food supply at the time of egg development and lying stage and chicks growing. (Johnson and Cezilly, 2007).

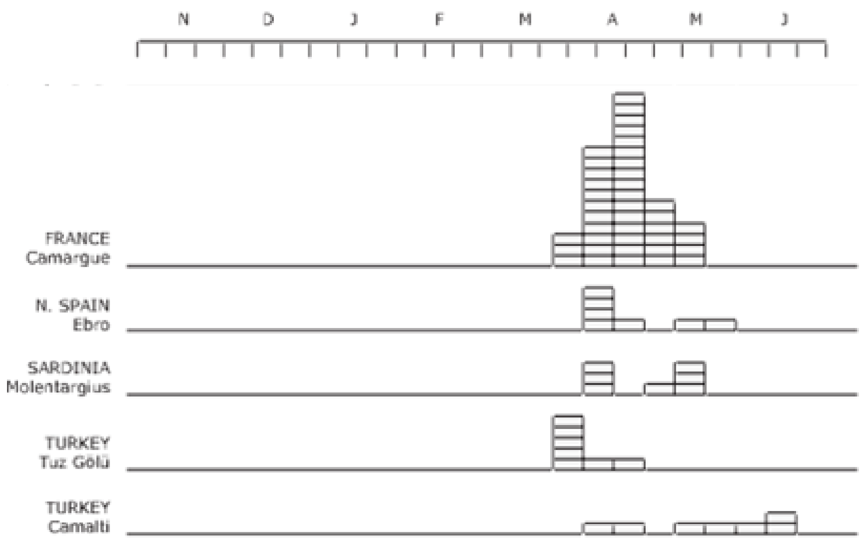

Figure 1.The period of the egg-lying in the Mediterranean.(Johnson and Cezilly, 2007).

2.3 Types of dispersal and migration

Soon after fledging period young individuals tend to leave the birth site and expand the home range radius. This first kind of movement is named post fledging dispersal (Bechet, 2017). Juvenile dispersal usually happens in immature stage when the young individual decides to move farther and settle down in the colony for the first breeding. Soon after the adults annually move between breeding sites, which is called breeding dispersal (Balkiz *et al.*, 2010). Natal dispersal happens at a certain age when the individual decides to come back to the colony where it was born and breed there (Balkiz *et al.*, 2010). Probability of an individual to return to the natal colony is called natal philopatry and usually it increases with age.

Migration is another type of movement occurring periodically between wintering and breeding places (Bechet, 2017). Flamingos are partial migrants (Johnson and Cezilly, 2007). It means that part of the colony spends winter at the breeding site. This strategy will be more discussed in further chapters.

2.4 Natal philopatry

Natal philopatry is the probability of an individual to return for breeding to the place where it was born – its natal colony (Balkiz *et al.*, 2010) . Usually this phenomenon is not strongly expressed in young and inexperienced birds due to inability to cope with strong intraspecific competition. Natal philopatry is advantageous for adults with already gained knowledge after previous dispersal to smaller colonies (Shields, 1982) as it minimizes energy loss of searching new breeding places and it is supported by genetical adaptation to the local conditions. Moreover, it helped to minimize the probability of outbreeding (Shields, 1982) . Thanks to the annual monitoring of the ringed flamingos in the mainland Italy (particularly at Comacchio and Margherita di Savoia) during the period 2000-2009 (Albanese *et al.*, 2007), natal philopatry was perfectly observed in identification of the natal origin of the birds (**Figure 2**).

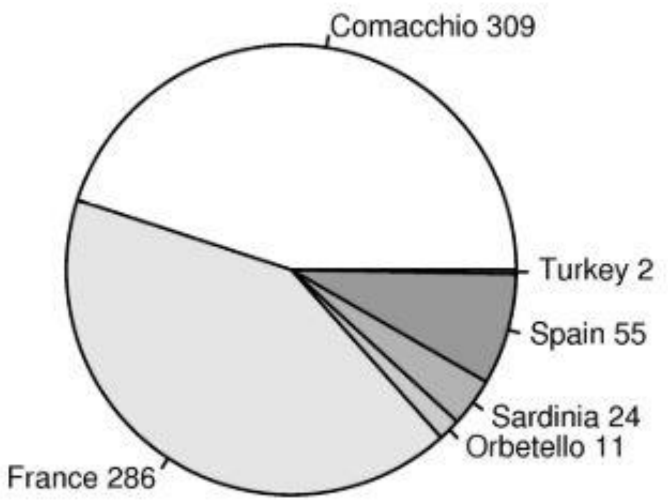

Figure 2. The natal origin of the birds breeding at Comacchio 2000-2007 (min 22 flamingos in 2000 and maximum 267 in 2007) (Albanese *et al.*, 2007)

The breeding success overview characterized by the amount of the fledged juveniles was provided for the period 2000-2007 (**Figure 3**). According to Albanese *et al.* (2007) breeding at the natal colony has long-term effect on the large-scale dispersal between breeding sites, although the advantage of natal philopatry in terms of survivability was not proved.

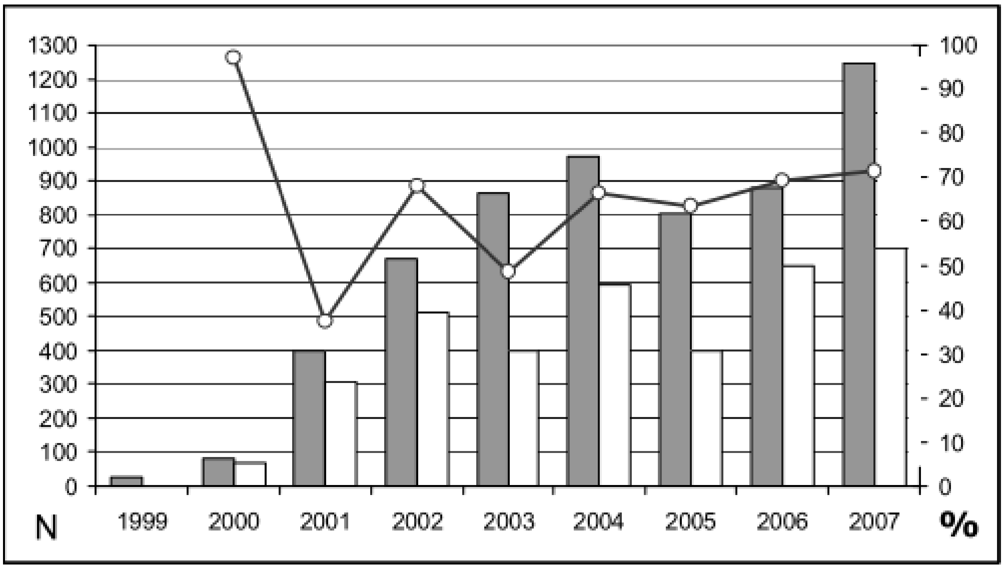

Figure 3. Data on the colony size and number of fledged juveniles at Comacchio. Grey bar: number of the breeding pairs; white bars: number of the fledged chicks; the black line (related to the second y-axis): the ratio of the chicks being ringed(Albanese *et al.*, 2007)

2.5 Flight and navigation

2.5.1 Navigation

The ability of flamingos to detect the best climatic conditions kilometres away stays a secret for a scientist. For the successful journey migrants must depart with the sufficient fuel/energy to manage with the unfavourable climatic conditions. (Pennycuick, 2008). Nevertheless, it might be possible that the bird can detect changes of pressure in the atmosphere and thus predict the information on the breeding probability (Bechet, 2017).

As flamingos are long-live birds, they are able to use the gained experience for navigation. When travel, flocks consist of the mixture of young and older individuals, therefore the old ones can pass the knowledge to juveniles (Bechet, 2017). The migration of the Greater flamingo takes place at night; hence the stars might be used for the navigation. At daytime they can follow the landscape patterns, as well as winds and man-made infrastructures can assist in recognising the path. The birds are able to memorize the mental maps facilitating to find the favourable nesting place (Bechet, 2017), stop-over and feeding places.

Deeper study of bird navigations proved (Nováková *et al.*, 2017) that the alignment of the body to the solar location, wind direction or to the communicative signals inside the flock can help them to find the right way to the winter or nesting site. Magnetic alignment is estimated to be preferable for the orientation in the colonies. Desynchronised movement of the flock can cause collisions during the take-off or landing. Due to the large body size, it is impossible for flamingos to change the course of the last landing phase called "landing roll"(Nováková *et al.*, 2017). It was assumed (Bucher *et al* ., 2000) that the flamingos have a common reference indicator for the harmonized movements especially during unpredictable stressor (predator) which is crucial for the one of the largest birds living in the high dense colonies during breeding, migration and feeding.

To conclude, the Greater Flamingo shows orientation according to the sun position, magnetic field and wind direction. It was proposed (Nováková *et al.*, 2017) that heading based on the magnetic field is adjusted according to the sun and serves as "heading indicator". It assists the birds as preparation to one-directed take-off for the whole colony in case of the unexpected event such as predation or danger. Mental map according to the results (Collett T.S. and Baron J., 1994) is calibrated by the magnetic field and the sun . Due to the aerodynamics the wind direction is most effective indicator for the landing or take-off. In case this indicator is absent the next in the rank of importance is the alignment according to the magnetic field. If the days are sunny, flamingos prefer to orientate according to the solar azimuth (Nováková *et al.*, 2017). Unfortunately, it is still unknown the orientation of the birds during the night-time, in case of disturbed magnetic fields and the reason of the better alignment in the morning time. If the visual cues are available (mental map) they are supposed to be more dominant in orientation than the magnetoreception.

Another phenomenon can be mentioned here as nonsense orientation (Thake, 1981). The term describes the preferable orientation for the group of birds which is not connected to the migration or to the breeding site. Formation of colonies (or flocks) is dictated by the common preferred flyway which is more prominent than in the single birds. The nonsense orientation according to Thake (1981) has the adaptive meaning especially in the case of so called "escape situation". Kenward (1978) showed that the smaller the flocks, the more they suffer from predation. If some number of birds has the similar significant preferable orientation as other birds in the surrounding, then the colony can be formed (Thake, 1981). Leave the place in case of the “escape situation” such as attack by the predator can sufficiently foster the return to the feeding area as the use of landscape patterns is more time consuming.

2.5.2 Influence of climatic factors on dispersal

State of wetlands from the hydrological point of view is significantly dependent on the rainfall during winter and evapotranspiration in summer. They provide both nesting sites and food supply for a colony. Hence, the network of wetlands in the Mediterranean area in both local and regional scale affords the persistence of the Greater flamingos (Nager *et al.*, 2010).

Wetlands are variably spread over the Mediterranean area and environmental conditions are strongly linked with the fluctuation of the number of breeding pairs. (Nager *et al* 1996) According to the Perrins *et al* (1991) the individuals who bred in Camargue and experienced cold winter in 1984-1985, died during this extreme climatic event, which, however, did not affect anyhow the amount of breeding pairs in the next summer. There was observed high number of first -time breeders directly after cold spell in 1985 which can be explained by outbalancing of mortality of adult individuals by younger ones. (Pradel, Johnson, *et al.*, 1997) Therefore, the losses of the colony triggered by severe climatic events were compensated by a large pool of first-time breeding birds. It was shown that during winter the flamingos migrate across the whole area, but there was no regular pattern observed. (Nager *et al.*, 2010) To conclude, there is evident dependence of the colonial birds on the hydrological state of the wetlands. In turn, hydrological conditions are determined by the combination and interaction of climatic factors such as rainfall and temperature patterns. The nesting time or even the decision whether to breed or not is tightly connected with the climatic factors, especially with the water level and rainfall. For example, in case one year brings the high rainfall, it results of fully refilled underground water. Hence, even the moderate rainfall of the next year may lead to the sufficiently higher levels of surface water. This creates the perfect conditions for the flamingos to breed and nest.

The number of individuals are highly dependent on the local climatic factors, but unlikely on conditions in another place (Nager *et al* 1996). Even though there is some movement between two colonies in Spain and Camargue, droughts in Spain do not stimulate local breeders to immigrate to Camargue during this period.

If flamingo colony prefers to breed in stable conditions such as saltpans, rainfalls seem to have the lower significant impact on the decision whether to breed or not. However, in some cases it affects the period of the breeding start, the number of birds taking place in breeding and the outcome. The availability of invertebrates is especially crucial for females as this food resource holds necessary nutrients for the egg development. Therefore, such crucial climatic factors as water level and rainfall influence by food supply the number of couples to breed each year. Decrease of food availability leads to the disturbed breeding success, general avoidance to breed (Cezilly and Johnson, 1995).

Flamingos usually are able to produce one egg (Johnson and Cezilly, 2007), therefore cannot afford to trade off the size of the clutch against the quality of the chick. Hence, if the water level is low and the availability of food is insufficient, the couples can refuse to breed due to the low probability of successful rearing of the chick. On the contrary, the flooding around the breeding site can prompt the birds to start nesting and breeding (Johnson and Cezilly, 2007).

Cezilly and Johnson (1995) proved the positive correlation between the water levels and the number of flamingo couples in Camargue region in March when the breeding period starts. Breeding pairs exponentially increase with the rise of water depth (**Figure 4**) (Johnson and Cezilly, 2007). Water availability directly affects the body state of the fledgling due to increased food supply. Especially this is important for the females for which invertebrates are the source crucial nutrients for the egg production. Therefore, there are variety of components contributing to the individuals presence and the output of the breeding such as disturbance, climatic and anthropogenic factors (Cézilly *et al.*, 2015).

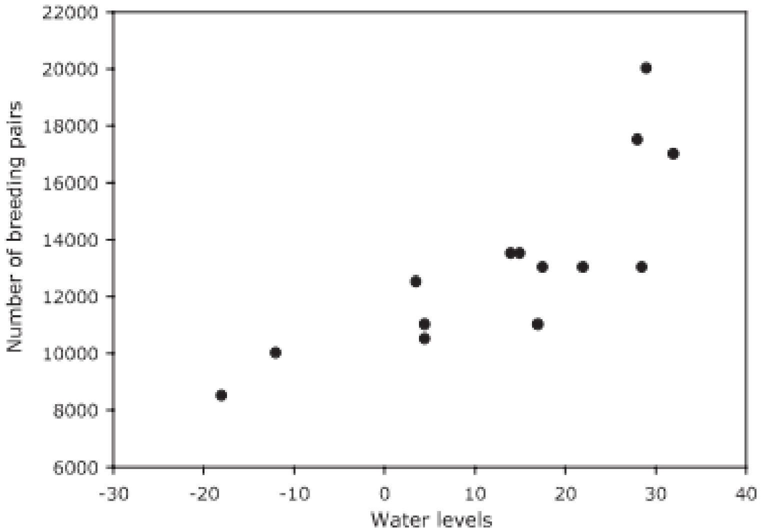

Figure 4. Correlation between the mean of water level in March 1984-97 and the number of breeding pairs in the Camargue (Johnson and Cezilly, 2007)

Coulson (2008) showed that the amount of water in winter time and determines the flooding dates in operational salt pans which in turn influences the egg-lying time. However, Green *et al* (1989) reported the absence of direct dependency between rainfall in winter period and the number of breeding couples in spring. The result was explained by the operation of the Vaccares system which mostly dependent on wind, water flow and input of the drainage water.

In another study conducted earlier in Spain (Cézilly *et al.*, 2015), occupation of the breeding site was dependent on the rainfall during winter season, September-February, in Sevilla, which is located nearby the major feeding area for the colonies. Although there was no identified correlation between water levels effect and productivity of the colony, it was detected (Cézilly *et al.*, 2015) the increased difficulty in fledging due to high water availability. Taking such natural ecosystems as wetlands climatic change of water levels seems to affect the success of breeding impacting the food supply (Hafner, Pineau and Kayser, 1994).

Many bird species including flamingos inhabit both natural and man-made environments for breeding, foraging and nesting. Salt pans contribute or even if handled appropriately can be equivalent to natural habitats. (Glahn, J.F., Dixson, Littauer and Mccoy, 1995). Availability of wetlands and lagoons affect the breeding success of flamingos. (Bechet A., Germain C., 2009) Water level in the Mediterranean area is highly dependent on winter precipitation which fluctuates from season to season. On the contrary the salt pans used for the production and extraction of salt perform the relatively stable water regime. It explains the popularity of this habitat for the breeding species serving as nesting and foraging place (Bechet A., Germain C., 2009). In the Mediterranean area the importance of saltpans is especially crucial due to droughts in summertime (Masero J. A., 2003). Nevertheless, in France flamingos can be observed in radius 100 km from the colony in marshes or lagoons, therefore the individuals are not completely dependent on the saltpans in terms of feeding place. Results showed (Bechet A., Germain C., 2009) that 18-60% of the habitat used for breeding by the Greater flamingos are saltpans. During the extreme dry periods this habitat is more important as a refuge place. Bechet A., Germain C. (2009) predicted that termination of the saltpans operation can negatively influence the increase of population. During dry years where the water levels are extremely low majority of flamingos uses the operational saltpans instead of natural ecosystems such as wetlands and lagoons. For example, in the dry year 1989 in salt pans in Camargue, the ratio of breeding individuals was twice as high as in the previous year with normal temperature (53% and 26%, respectively) (Bechet A., Germain C., 2009), thus this habitat served as a backup shelter.

As it was mentioned before, populations of birds, particularly the Greater Flamingos, are influenced by such variables as temperature and water levels (Bechet *et al* 2008). In bigger scale we can model and predict how they react to the climate change. In the study Bechet *et all* (2008) evaluated how flamingo population is regulated by hydrological variables in Camargue. The amount of breeding pairs, breeding success and state of the body condition are positively influenced (Bechet *et al* 2008) by water depth in Vaccares in spring and Rhone river flooding in winter. Both brought additional water and nutrient discharge. North Atlantic Oscillation is negatively correlated (Bechet *et al* 2008) with Vaccares and Rhone water levels. Although the number of breeding pairs increased thanks to the flooding date shifted 10 days earlier which increased water depth by 10 cm (Bechet *et al* 2008), the total body state of the chicks was decreased. High-density pressure of the population was proposed (Bechet *et al* 2008) to be the main cause of this reduction. Although Camargue is a managed system it still responds to the climatic changes. The overall breeding success is regulated by both climate and human management of the salt pan (Bechet *et al* 2008), where water discharge is affected by dykes and operation constructions along the Rhone river. The response of the bird population linked to NAO in the inhabited regions of the Mediterranean area. The change of climate variables is diverse and not directly predicted (Hurrell, 1995). NAO index is connected to the decrease of atmospheric moisture (Hurrell, 1995). Hydrological management and habitat heterogeneity either buffer the impact of climate variabilities or rise their effect in case of exceeded temperature or precipitation limits. Hence, rainfall and water availability are positively correlated (Bechet *et all* 2008), however the response of this combination is smoothed by anthropogenic modifications of the area. Low NAO values in winter provoke higher water depth and discharge which in turn attracts more individuals (Bechet *et all* 2008). The Greater Flamingos were positively influenced only by the higher water availability in Vaccares (Roussiez *et al.*, 2006), although the discharge of Rhome river was linked to the worse conditions of chicks' body. Probably it was connected with the increase of contaminants and metals in water suspended in the river (Roussiez *et al.*, 2006), although the conclusion is quite speculative. Nonetheless, the enlarged number of individuals promoted the high population density pressure (Bechet *et all* 2008), therefore the chicks experienced lower body state which is one of the parameters (along with the fledging) of juvenile dispersal in the Mediterranean area. Effect of the excessive rainfall in the northern part of the Mediterranean region with the following rise of the sea level is smoothed by the construction system established on the commercial salt pans (Bechet *et all* 2008). Hence, the human impact such as the regulation of flooding date to mitigate the damage of rice fields in Camargue plays bigger role than the climatic variations (Tourenq *et al.*, 2001). Another Mediterranean species of birds, gulls Larus genei, are affected by NCO more significantly (Bechet *et all* 2008), as they inhabit less managed areas for breeding and foraging.

2.5.3 Flight behaviour

To be airborne the Greater Flamingo needs to run on the water surface about several metres. However, in case of facing the wind, they can ascend to the air directly when open the wings. Being in the air, they extend legs and neck. Flocks are formed in the V-shape or skeins. Flamingos fly higher if there is tail-wind, but in case of the head-wind, they tend to keep closer to the water surface(Johnson and Cezilly, 2007). Moreover, the height depends on wind direction, power and the character of the area crossed (sea, land) (Brooke and Birkhead, 1991). It was observed that over the sea flamingos are keeping the lower height than when they are crossing the land surface. The average speed during the flight is 50-60 km/h, if the wind direction and strength are favourable. In case of unexpected disturbance, the birds are not able to build skeins (Brown *et al.*,1982) but keep in the flocks and change the flight orientation fast and synchronically.

2.6 Dispersal

Knowledge on the population structure and dynamics is important to understand the fitness, reproduction and survivability of the whole population (Greenwood, 1980). The dispersal is influenced at individual level by such factors as age, sex, or at the population level as the colony density, or by general environmental characteristics of the site, for example, food or the landscape (Greenwood, 1980). Generally speaking, both main factors, exogenous and endogenous, are supposed to play the major role in post-fledging dispersal: aggression of the older individuals to the younger ones, fluctuation of the availability of the food resources and the body state (Morandini *et al.*, 2019). These factors trigger the dispersal and play the crucial role for the juveniles to increase their awareness of the sites for feeding or breeding.

2.6.1 Influence of individual characteristics on dispersal

Based on the study result published by Barbraud, Johnson and Bertault (2003) the hypothesis of the migration dependence on the body condition was proved as the mechanism triggering the movements from the site of birth to the first wintering place. Moreover, the body state is influenced by the final localities. For example, being in good body condition at fledging, the distance of dispersal is high, whereas the intermediate body condition decreases the distance of movement. Surprisingly, the distance length of an individual with poor body condition according to the results was quite controversial: the movement is either minimal or slightly decreases. If individuals breeding in the site with high quality resources have higher chance of the good body condition, they anyway will face with the high intraspecific competition for the resources. Hence, juveniles even with the good body state might be moved away to the worse sites by older flamingos (Barbraud, Johnson and Bertault, 2003).

No dependency between sex and survivability was found (Barbraud, Johnson and Bertault, 2003), but probably during the first reproduction females have higher mortality. Post-fledging dispersal is influenced by age, therefore there is a high probability for the individual to leave the maternal colony between fledging period and first winter and then it sharply decreases. Wintering faithfulness to the first site was also confirmed (Barbraud, Johnson and Bertault, 2003).

The body mass is the critical limiting factor to those flamingos who fly to long distance sites, such as Tunisia, 800-850 km over water (Johnson, 1989). As it was mentioned before the flight in skeins helps to decrease the energy loss. If they fly over the sea the need in energy reserves is significantly higher than by those flamingos who fly to short distance areas (Weimerskirch *et al.*, 2001). The same dependency pattern was shown in another species as, for example, in Spanish imperial eagles. Dispersal distance was higher in those young species with low levels of blood urea which works as a surrogate of nutrition condition (Ferrer *et al.*, 1993). In another study (Belthoff and Dufty, 1998) the hypothesis was proposed where the dispersal distance of screech-owls is based on the hormonal changes, the body mass and social incentive in the population. For example, corticosterone increases in the blood plasma before the dispersal via interaction of endogenous and exogenous factors. As it was concluded (Belthoff and Dufty, 1998) when the corticosterone is at the normal level, the birds with normal physical condition will disperse, but the ones with poor condition will stay on the natal site and continue to feed.

Nowadays a relationship is identified between the body state and the dispersal of the young individuals. There were proposed two main explanations as the main reason of the juvenile dispersal. First, the birds search the place in order to spend winter in more acceptable conditions even in the case of the Mediterranean area (Barbraud, Johnson and Bertault, 2003). For instance, extreme winter conditions in 1984-1985 significantly decreased the survivability of the young individuals by 41,7% (Lebreton, J-D., Burnham, K., Clobert, 1992). The dispersal in this case can help juveniles to overcome the unfavourable conditions. The second reason, and probably the most significant, is the intraspecific competition among individuals based on the age dominance or so-called despotic dispersal. This is the type of dispersal when some individuals limit others from living in a given area of habitat, thus the last group must use less quality site (Rendón *et al.*, 2001). The breeding success is higher in better quality area taken by the older individuals, and the younger ones were pushed to the less favourable places. In case of the greater flamingo the choice of the best breeding site might be explained by the experience, i.e. age (Rendón *et al.*, 2001). Experienced individuals have better ability to evaluate the quality of the future nesting site which gives them an advantage over the younger individuals. In high dense colonies those birds that came later for breeding may be limited in their choice as the better sites are already taken by more experienced ones. Rendón *et al.* (2001) suggested that the individuals gain knowledge during their life, therefore there is positive correlation between age and experience.

Another factor influencing the dispersal is heterozygosity. Gillingham *et al.* (2013) determined it as the crucial intrinsic factor for different stages of dispersal. It was studied the correlation between the multi-locus heterozygosity (MLH) and fitness of the individual and suggested that MLH influences dispersal in 2 ways. First, heterozygosity is negatively associated with the dispersal. Dispersal takes energy and affects the survivability(Shafer and Poissant, 2011). High density of individuals on habitat presses less competitive individuals to leave from the natal place (Shafer and Poissant, 2011). Second, inbreeding increases expression of recessive alleles and therefore there is a loss of heterozygote preferences which leads to the decrease of dispersal ability. One of the best sites with high breeding success in Mediterranean area is Camargue (Gillingham *et al.*, 2013). Due to the high density of flamingos it's also one of the highest places where the competition for the qualitative nesting site takes place. Heterozygosity might be negatively associated with departure in case of high competition, but on the other hand it can be positively associated with transience and settlement if inbreeding leads to the negative outcomes of dispersal ability (Gillingham *et al.*, 2013). Forstmeier *et al*. (2012) suggested that the loss of heterozygosity is the main cause of the inbreeding depression. Hence, the inbreeding depression increases the probability of homozygous fledglings to move from the natal place due to the low fitness traits and, therefore, the competition skills. However, heterozygous individuals have 20% probability higher to stay at the natal site during the first winter due to the significant fitness characteristics (Gillingham *et al.*, 2013). Thus, the younger individuals are forced to leave the place and find the less competitive area or shift the breeding season to the next year. During wintering over 50% of fledglings are forced to move to another site due to the lack of competitive skills as the main reason (Gillingham *et al.*, 2013).

This leads to the suggestion that heterozygotes have the privilege for the first-time breeding.

If we talk about long-distance dispersal the juveniles going to Africa have lower survival. Nevertheless, about 73% young birds (Barbraud *et al.*, 2003) for post-fledging dispersal are choosing north and west African area. As the study showed (Gillingham *et al.*, 2013) homozygotes for the post-fledging dispersal are likely to choose intermediate distance such as Italy, however for long-distance heterozygotes choose Africa.

To summarise, the dispersal pattern of juveniles and young individuals is dependent on complex interactions between the MLH, intrinsic and extrinsic factors.

2.6.2 Extreme climatic events and flamingo movements

Studying and modelling of the effect of gradual temperature fluctuations are important in combination with the extreme climatic events. The influence of 2 cold spells occurred in January 1985 and February 2012 was analysed on the energetics of the greater flamingo and proved (Deville *et al.*, 2014) that individuals who were close to the energetic limit are more susceptible to the small drop of temperature. Energetic limit itself can be caused by the long-lasting starvation undoubtedly connected with low body mass (Deville *et al.*, 2014). Cold temperatures stimulate energy requirements, especially to support stable body temperature. Moreover, during the cold spells majority of ponds in Camargue were covered by ice which led to the inaccessibility to forage. It’s still questionable what causes preliminarily the death of individuals: temperature of the air or the reduction of food supply. The period when the cold spells occur is also important and determines the mortality. For example, spells that occured later in winter period caused more deaths than earlier ones and lack of energy storage was proposed (Deville *et al.*, 2014) to be the cause. Due to the spell in February 2012, the egg lying was shifted 3 months later. As it was mentioned earlier in the thesis the Greater Flamingos are the partial migrants meaning that part of the colony can migrate whereas other part stays at the breeding site or nearby. Severe climatic events can cause two types of behaviour depending on the body conditions: fatter flamingos may urgently migrate once the cold spell appears, however weaker ones use wait-and-see strategy and, in case of short-term spell does not cause death, overcome the extreme event, restore energy and then either migrate or stay the whole winter at the site (Vavrus *et al.*, 2006).

2.6.3 Human disturbance and the presence of the Greater Flamingos

The salt concentration and shallow water in wetlands are the most crucial ecological conditions for the flamingos to occupy the habitat (Ayache et al., 2006). The presence of species is strongly correlated with the water depth and the human disturbance (Ayache et al., 2006) . Generally, flamingos tend to keep the distance from the shores where they can face with human. Unfortunately, young individuals are less experienced and quite often come close enough to the shore and suffer from humans and domestic animals. Due to the urbanization, wetlands area as well as water quality is dramatically reducing. Water discharges from urban and industrial activities increase the water depth and salinity, raise the concentration of organic pollutants in wetlands (Ayache et al., 2006). Shallow waters with the high concentration of microorganisms are the crucial food source for the birds.

The naturally established colony in the former Saline di Comacchio saltpans shows a good example of the conservation activities: it was ranked as Special Area of Conservation and classified as a highly important area by Ramsar Convention (Mazneva, 2017). Special efforts were undertaken as well in operational area of Camargue regions. Unfortunately, majority of non-protected areas occupied by flamingos are located in Africa and Tunisia (Mazneva, 2017). These areas are crucial to protect and reclaim as wintering places for flamingos migrating from the Mediterranean region.

2.7 Climate reanalysis

Data on weather conditions with high-resolution is crucial for many applications in ecological sciences. This chapter will present the CHELSA data used for the analysis introduced in the thesis and its advantages over other existing data sets. CHELSA consists of monthly temperature and precipitation values and bioclimatic variables derived from them, in GeoTIFF format with global spatial coverage, for the period 1979-2013 (Karger *et al.*, 2017).

CHELSA is a downscaled model of the ERA-Interim climatic reanalysis to a high resolution of 30 arc sec. Temperature values are based on the algorithm of atmospheric temperature downscaling. Precipitation values are based on the algorithm which includes the orographic predictors such as height of boundary layer, wind fields etc with a bias correction. (Karger *et al.*, 2017)

Climatologies based on downscaling are preferable for the ecological analysis. Nowadays the global distribution of meteorological stations is discriminated by funding and accessibility, therefore information on climate in some regions such as mountain or lowland areas has low quality (Hijmans *et al.*, 2005). Downscaling in a global scale is problematic due to inconsistency of measures when a variable is present in one month but absent in another. Moreover, downscaling is challenging when dynamic predictors (wind fields) have to be integrated. Their presence highly influences the regression model parameters used for relationship between the predictor and location of the record. Therefore, generally downscaling approach is often applied for a single region. (Wilby, R. L. & Wigley, 1997).

To overcome these problems Model Output Statistics algorithm was applied on data from ERA-interim reanalysis with the following correction. As the result temperature and precipitation values were improved with a good representation at a small scale. To reduce this accumulation, additional bias was applied for the correction. The results for the precipitation and temperature algorithm were validated. (Karger *et al.*, 2017).

Importance of the CHELSA data is in the increased accuracy of climatologies especially precipitation which subsequently enhances the analysis of species disperal. Because precipitation is an accumulated parameter, errors in precipitation sums can accumulate over time, and hence additional correction step was applied (Meyer-Christoffer, 2018).

CHELSA data in comparison with ERA-Interim has smaller biases in precipitation and improved spatial prediction of climatic variables in comparison with WorldClim. The validation results show that including orographic and boundary layer effects improves the variables accuracy. Although improvements are not consistent and differ from region and months, most of them are still successful. Therefore, CHELSA can be applied as an improved climatic dataset over other products such as WordClim. (Karger *et al.*, 2017).

3 Methodology

Statistical methods were applied to the three datasets: georeferenced data of the ringed Greater Flamingos dispersal in the Mediterranean area, provided by the supervisor, and climatic datasets for the mean temperature and precipitation obtained from the chelsa-climate.org. The data is an output of the long-term monitoring program undertaken during the period 1994-2000. All analyses described were done in ArcGIS (ESRI 2011) and the R software (R Core Team, 2013). All graphs in R were done with the application of ggplot function (package ggplot2) (Wickham, 2016).

3.1 Study area

The thesis was focused on the flamingos born in Saline di Comacchio located in the north of Italy. It is a part of big coastal wetlands named Valli di Comacchio (Mazneva, 2017). Comacchio saltpans were actively used for the industrial salt extraction and stopped operating in 1985. They are connected to the sea by channels and defined with high tidal regime according to the Mediterranean norms (Albanese *et al.*, 2007). As the Comacchio saltpans were ceased, there is no management of water levels which explains the high variability of the breeding success at the site.

Camargue is another region for which the analysis was implemented. It is located on the south of France in the vicinity of Rhone River and includes regions where flamingos annually breed: ıle de Camargue, salt pans of the Salin-de-Giraud and Aigues-de-Mortes, Petite Camargue, Languedoc and Etang du Fangassier (Bechet A., Germain C., 2009). This area is actively used for the commercial salt extraction, therefore salt pans form the majority of it. Generally, the salt pans include about 100 lagoons through which the sea water is regularly pumped in during the period of March-September (Lemaire and Tamisier, 1987). They provide sufficient water depth and simplify the reproduction in breeding period.

Besides saltpans, Camargue consists of permanent and brackish lagoons (Heurteaux, 1992), temporary and freshwater marshlands. Temporary marshlands are vulnerable to flooding caused by autumn and winter rainfall, susceptible to droughts occurring during the period of mid to late May (Lemaire and Tamisier, 1987). Parc Ornithologique de Pont de Gau chosen as study place located on the network of islands surrounded by marshes along the Rhone river. The site was chosen as the example of natural habitat for the Greater Flamingo.

3.2 Original datasets

The data collection of flamingo dispersal was organized in the scope of International Flamingo conservation program. It was led by the Italian Institute of Environmental Protection and Research with the focus on individuals born in Saline di Comacchio colony naturally colonized in 2000 (Albanese *et al.*, 2007). Directly after hatching the chicks were ringed with plastic PVC (polyvinyl chloride). This procedure was organised in early July and at the same time already ringed individuals were recorded in all known wetlands of the Mediterranean region (Albanese *et al.*, 2007).

Georeferenced data of the Greater Flamingo born in Saline di Comacchio (further specified in the text as original flamingo dataset) consists of 25234 observations, 2668 individuals with 20 variables over the period 2000-2009 . In the data table, each row corresponds to one observation of one individual. **Table 3** below shows how many individuals were ringed each year.

Table 3. Number of ringed individuals each year

Year	Recorded individuals
2000	65
2001	103
2002	341
2003	189
2004	394
2005	253
2006	433
2007	439
2008	247
2009	204
Total	2668

Variables (i.e. columns of the data table) used for the main results describe the unique name (“PVC” column) of the individual, “RingingSit” column as the place where the individual was born with its latitude (“RingingLat”), longitude (“RingingLng”) and date of new-born individual recording (“RingingDat”), sites name where the individual was observed (“ControlSit”) with its latitude (“LatControl”) and longitude (“LngControl”), the date when it was recorded (“ControlDat” and additional column “Year”), and the age of the bird when it was observed at the place (“Age_inYear”, “Age_inMont”).

Value "Saline di Comacchio" was chosen for variable "RingingSit" to be able to compute the percentage of those individuals being observed in Comacchio/Camarque, therefore the variable "ControlDat" performs values “Saline di Comacchio” (Italy) and “Parc ornithologique de Pont de Gau” (Camargue, France) (further named as sites of interest). “ControlDat” covers period from 2000 to 2009 including all observed individuals in “RingingSit”. **Table 4** below shows the list these variables from the original dataset used for the analysis with the description and examples of their values.

For each analysis described below only flamingos older than three months were chosen. The reason of this selection is the ability of young birds to be airborne and disperse at an average age of 80 days (Johnson and Cezilly, 2007).

Table 4. Description of original variables used for the analysis

Original variable	Description of variable	Value example
PVC	Unique code of ringed individual	IBZ
RingingSit	Place name where individual was ringed	“Saline di Comacchio”
RingingLat	Latitude of place where individual was ringed	44.65
RingingLng	Longitude of place where individual was ringed	12.2
RingingDat	Date when individual was ringed	10.7.2001
ControlSit	Place name where individual was observed	“Valle Bertuzzi”
LatControl	Latitude of the place of observed individual	44.78
LngControl	Longitude of the place of observed individual	12.216670
ControlDat	Date when individual was observed	21.06.2004
Age_inYear	Age in years of individual observed	1
Age_inMont	Age in months of individual observed	12

3.2.1 New variables in original dataset

During analysis additional variables were created (see Appendix, Chapter 1) and added as new columns to the original data table. Variables X and Y represent the ETRS coordinates of the “ControlSit” values. These coordinates were computed in ArcGIS software (ESRI 2011) via application of geographic coordinate system transformations tool. Longitude and latitude of ControlSit sites in the original flamingo dataset were converted on the flat projection, therefore further calculations of distance can be achieved on the terrestrial area.

"Distance" variable was computed thanks to the previous step and represents distance between Saline di Comacchio (Italy) or Parc Ornithologique, (Camargue, France) and the "ControlSit" places. Variables "comacchio" and "camargue" show if individual was exactly in or in a range of interested sites (limited within a radius less than 1000 m). Variables "breeding" and "wintering" represent if the individuals were in the site of interest in April-July (breeding season) and November-January (winter season) periods respectively. **Table 5** below shows the list of these computed variables with the description and example of their values.

Table 5. Description of the created variables from the original dataset

Created variable	Description of variable	Value example
X	ETRS coordnates of the "ControlSit" site	173886.0
Y		1628720
distance	distance between the site of interest and "ControlSit" site	8617.806
comacchio	shows if "ControlSit" belongs to"Saline di Comacchio"	TRUE/FALSE
camargue	shows if "ControlSit" belongs to "Parc ornithologique de Pont de Gau"	TRUE/FALSE
breeding	shows if the individuals were present in the site of interest in breeding	TRUE/FALSE
wintering	shows if the individuals were present in the site of interest in wintering	TRUE/FALSE

3.2.2 Climatic datasets

Other datasets were obtained from the chelsa-climate.org website (Climatologies at high resolution for the earth's land surface areas) with resolution 30 arc.sec. The data currently hosted by the Swiss Federal Institute for Forest, Snow and Landscape Research. The datasets for mean temperature and precipitation were downloaded as rasters in the GeoTIFF format, presenting local values with global coverage of the particular month and year. These values are binded with geographic coordinates they correspond to.

The coding of the files looks as below:

For temperature: CHELSA_tmean_[year]_[month]. V1.2.1.tif

For precipitation: CHELSA_prec_[year]_[month]. V1.2.1.tif

The units for the temperature and precipitation values in monthly rasters are expressed in dozens of Kelvins (K) and millimetres (mm) accordingly.

3.3 Flamingo presence in the study colonies

To visualize how the presence of observed individuals varied in the colonies during the study period (see Appendix, Chapter 3), the variable as a ratio of presence was computed. It is defined as proportion of individuals who were in the colony or its vicinity (within radius 1000m) after dispersal divided by the total ringed individuals The result was represented as the two time series plots of flamingo ratios present in the colonies Saline di Comacchio and Parc Ornithologique (Camargue) against the period 2000-2009.

3.4 Age effect on dispersal

To analyse how flamingo natal philopatry varies with age (see Appendix, Chapter 4), "natal philopatry" was defined as a probability of an individual being observed during breeding season in its natal colony. This probability was estimated for each individual and season as the number of its observations made during a particular breading season in Comacchio, divided by the number of all its observations during that period (table "flam.inds"). This proportion was further averaged across the whole population for each age class (table "inds.mean") and plotted against age using bar plot.

To quantify the possible effect of age on natal philopatry, a binomial generalized linear model (GLM) with logit link function was fitted, with the proportion of an individual's observations made in Comacchio (during breeding season) as a response and its age as a continuous predictor. A goodness-of-fit of the model was estimated by the Nagelkerke's pseudo R^2 value, which is a commonly used generalization of the standard linear-model coefficient of determination for GLMs (Nagelkerke, 1991). The model prediction plot (including Wald 95% confidence bands) was then added into the bar plot mentioned above.

3.5 Instant weather effect on flamingo presence

The analysis of instant temperature effect (see Appendix, Chapter 5) evaluates the dependency between the flamingo presence in Saline di Comacchio and monthly temperature fluctuations. The investigation was done separately for the whole year and for breeding period. Each raster with temperature recordings was loaded to the working directory and assigned to the date (15-month-year) when the data with values was obtained (dataset "temp"). These operations were done with the application of package raster (raster function) (Hijmans *et al.*, 2019), and lubridate (as.Date function) (ISO 8601, 1988).

Ratio of individuals present in the colony was estimated for each month as the number of individuals present in Comacchio divided by the total number of all observations (table "flam.sum"). The temperature values were extracted from the rasters and matched with the appropriate months when flamingos were observed inside Saline di Comacchio (table "df.cor"). Dependency between the temperature and proportion of flamingo in the colony during the whole year and the breeding season was analysed with the application of Spearman correlation test. This method was chosen as the data does not come from the normal distribution. The result was visualized in a scattered plot.

Analogically to the previously described procedure the instant precipitation (dataset "prec" with precipitation recordings) effect on flamingo presence during the whole year and breeding season (see Appendix, Chapter 5) was analysed.

3.6 Time-lag effect of weather on flamingo presence

Analysis of time-lag effect of weather on flamingo presence identifies whether flamingos respond to temperature /precipitation fluctuations at the given month after some period of time. Time-lag effect was investigated separately for the breeding and winter seasons. Breeding season was stated for the period between April-July (variable "breeding"), therefore time lag =0 equals to April, time lag=1 identifies March etc. Wintering season was stated for the period November-January (variable "winter"), therefore time lag=0 equals to November, time lag =1 identifies October etc.

The proportion of individuals breeding inside Saline di Comacchio was estimated for each year as the number of observations present in the breeding season in the colony divided to the total number of all its observations (table “breed.sum”) with the application of ddply function (plyr package) (Wickham, 2011). Analogically the proportion of individuals wintering inside Saline di Comacchio was assessed for each year as the number of observations in the colony in winter season divided to the total number of all its observations (table “winter.sum”) with the application of ddply function (plyr package) (Wickham, 2011). Dependency between the proportion of flamingos breeding or wintering inside Saline di Comacchio and time-lag of temperature (dataset “temp”) fluctuations was evaluated via application of correlation test, method “spearman” (see Appendix, Chapter 6). The transitional result was represented as a table (“breed.cor” and “winter.cor” for breeding and wintering periods accordingly) with correlation value (Spearman correlation coefficient) of each time-lag (month) and its significance (p value). The final outcome of the analysis was presented as the time series plot.

Analogically to the procedure described above for temperature parameter, the time-lag effect of precipitation on flamingo presence in Saline di Comacchio during breeding and winter periods was examined (see Appendix, Chapter 6). The final outcome of the analysis was visualized as the time series plot.

The time-lag effect of temperature and precipitation on flamingo presence in Parc Ornithologique in Camargue during spring and winter seasons was analysed with the application of the same approach as for the Saline di Comacchio place described above.

3.7 Weather effect on regional movements of flamingos

The analysis of regional weather effect on flamingo movement evaluates whether temperature/precipitation fluctuations in two big colonies— Saline di Comacchio (Italy) and Saline de Giraud (Camargue, France)— influence the dispersal of individuals (see Appendix, Chapter 7). The temperature/precipitation values were extracted from the rasters and matched with the coordinates where flamingos were observed tables (“flam” and “flam2” accordingly). The average values were computed for the each month of the period 2000-2009 ("means" and “means2”) A few recordings derived from the precipitation raster were extremely high with the value 65535mm, therefore these outliers were excluded from the further analysis with the range of precipitation 28mm-329mm (“flam3”). The table with the list of all big colonies in the Mediterranean area was obtained (Johnson and Cezilly, 2007) (“bsites”) and coordinates to the each of this place were assigned The following step was extract temperature/precipitation values from the rasters to the corresponding coordinates of these colonies ("curves" and "curves2" accordingly).

The result was presented separately for regional temperature and precipitation values. It was visualized by the time series plot summarizing the fluctuation of the temperature/precipitation in Saline di Comacchio and Salin de Giraud colonies together with the mean of temperature/precipitation recordings in the places where the flamingos were observed.

4 Results

4.1 Flamingo presence in the study colonies

In summer period (identified approximately) the presence ratio varied from 75% to 80% in Comacchio (**Figure 5**) Camargue from 2% to 12% (**Figure 6**). The ratio of observed individuals in winter season (identified approximately) in Camargue ranged from 3% to 7% approximately and in Comacchio from up to 30%. In comparison with Parc Ornithologique where presence of species looks more accidental the dispersal of flamingos in Comacchio site has more periodic pattern of presence.

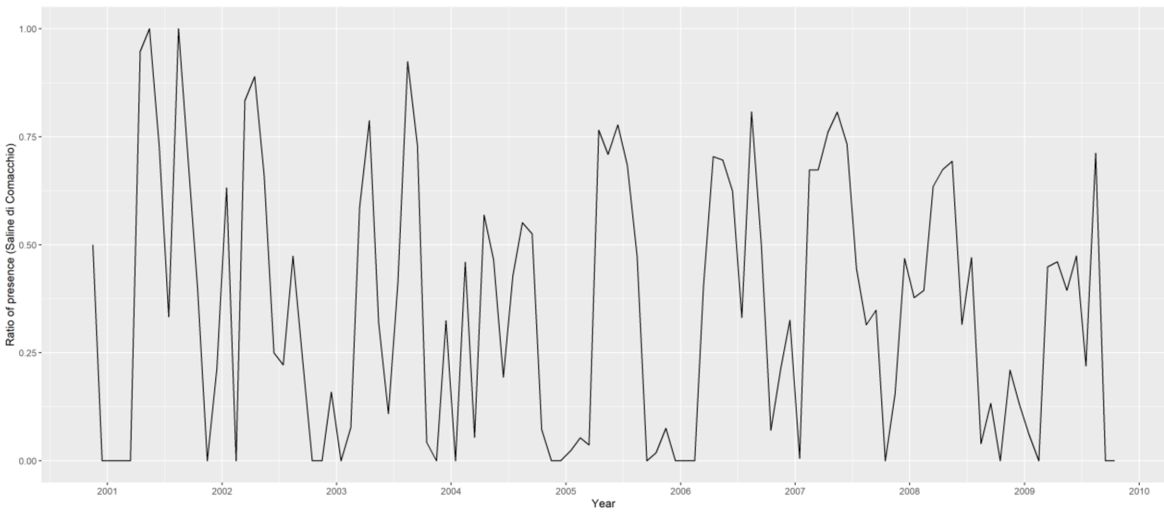

Figure 5. Presence of flamingos in Saline di Comacchio during 2000-2009. The ratio of presence was identified as the proportion of individuals who were in the colony or its vicinity (within radius 1000m) after dispersal divided by the total ringed individuals.

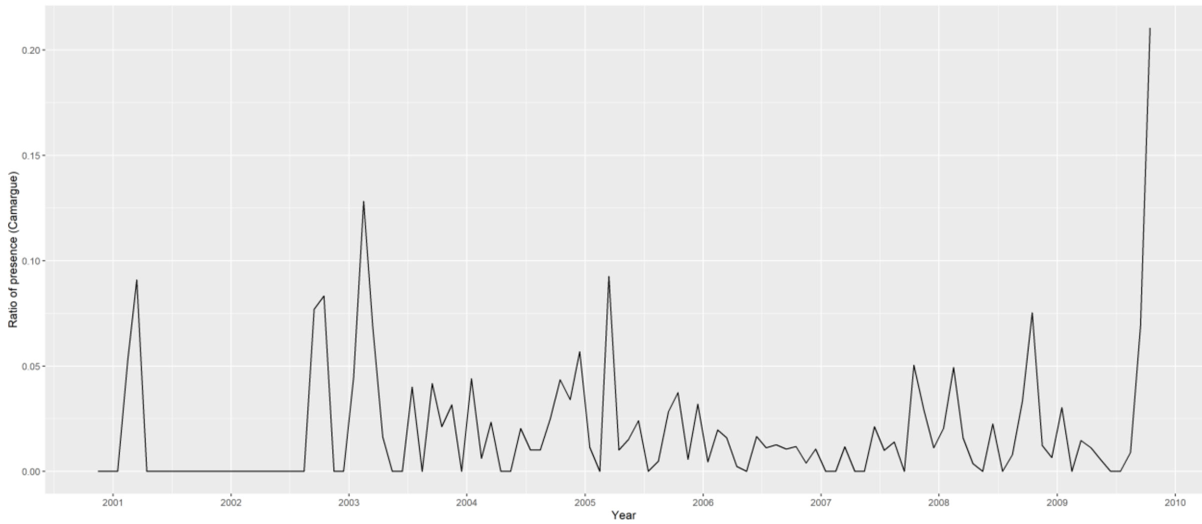

Figure 6. Presence of flamingos in Parc Ornithologique during 2000-2009. This ratio of presence was identified as the proportion of individuals who were in the colony or its vicinity (within radius 1000m) after dispersal divided by the total ringed individuals

4.2 Age effect on dispersal

The mean natal philopatry, i.e. the probability of an individual being observed in its natal colony during breeding season, averaged across individuals, varied with age approximately from 0.4 to 0.8. When plotted against age (**Figure 7**), an approximate linear increasing trend could be identified, with the lowest values being observed in the lowest two age classes, and the highest philopatry being observed in age class 9.

This trend was further confirmed by the GLM model (see **Table 6**, and the thick black line in the **Figure 7**). The model explained 7.2 % of the natal philopatry variability (Nagelkerke's R^2) and didn't suffer from overdispersion (dispersion parameter = 1.14). Residual deviance was 10567 on 9242 degrees of freedom.

Table 6. Table of coefficients for the binomial GLM model of natal philopatry on age

Coefficient	Estimate	Std. Error	z value	p-value
Intercept	-1.03754	0.03992	-25.99	< 2x10-16
Age	0.2456	0.01158	21.2	< 2x10-16

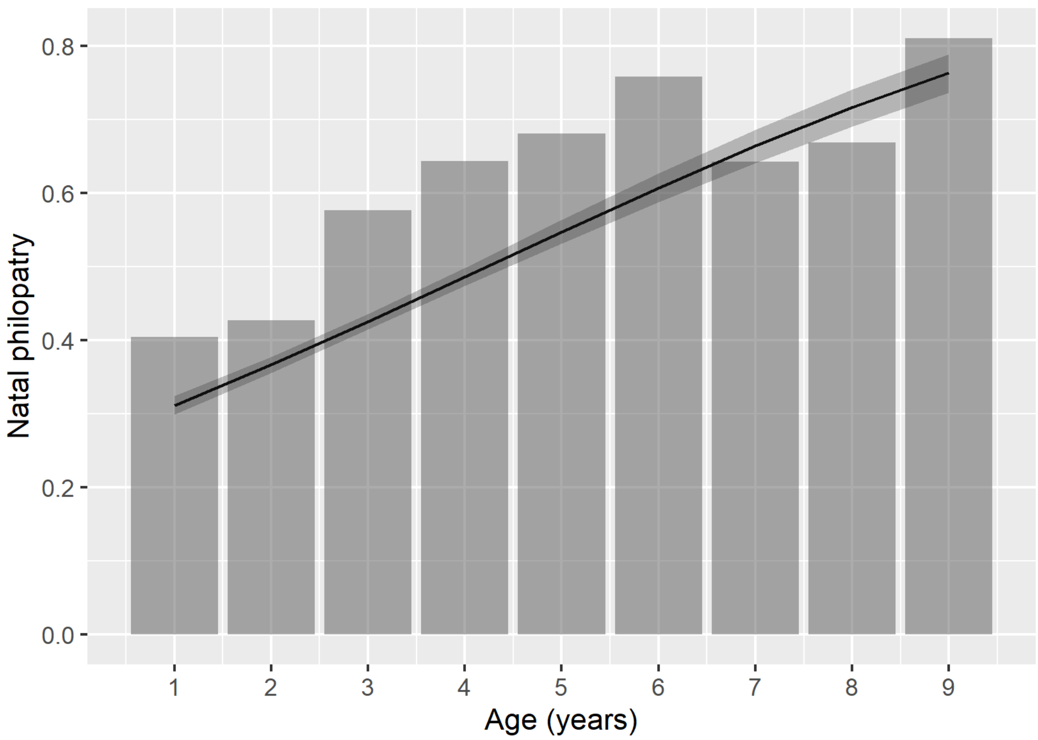

Figure 7. Effect of age on natal philopatry. Natal philopatry was estimated as the proportion of observations of an individual made during a breeding season in its natal colony. Grey bars present natal philopatry values averaged over the whole population. The thick black line presents a prediction of a binomial GLM model of natal philopatry on age. The grey shaded area along the line presents Wald 95% confidence bands

4.3 Instant weather effect on flamingo presence

The analysis of dependency between the temperature in Saline di Comacchio and ratio of individuals present in the site during the whole year showed significant positive correlation (Figure 8) where correlation coefficient is 40% (**Table 7**). From temperature 5^0C to 15^0C (winter season) most of individuals were not observed in Saline di Comacchio. From 17^0C to 28^0C the presence ratio has scattered character varying from 18% to 90% approximately (**Figure 8**). Low ratio of presence in lower temperatures —up to 7^0C ratio varies from 7% to 25%— and highly scattered ratio of presence in higher temperatures —from 7^0C presence varies from 0% up to 100%— generates the linear relationship between the temperature and presence of individuals during winter and breeding season.

Table 7. Correlation test for the dependency between the temperature inside Saline di Comacchio and ratio of present individuals during the whole year and breeding season

	Test	p -value	Corr. coefficient value
All year	**Spearman**	1.47E-05***	0.405
Breeding season		5.82E-05***	-0.618

[a] P-value (level of significance): '*' < 0.05, '**' < 0.01, '***' < 0.001

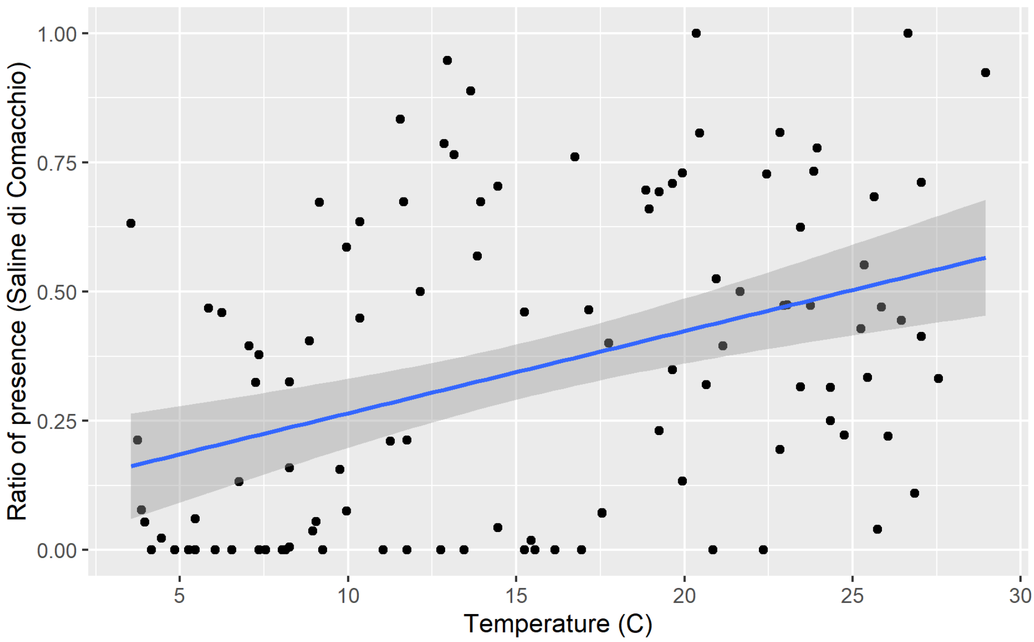

Figure 8. Instant temperature effect on flamingos presence inside Saline di Comacchio during the whole year. Ratio of presence in the colony was estimated for each month as the proportion of individuals present in Comacchio and plotted against the temperature at the given month

The analysis of dependency between the temperature in saline di Comacchio during the period 2000-2009 and ratio of the individuals present there in breeding season showed

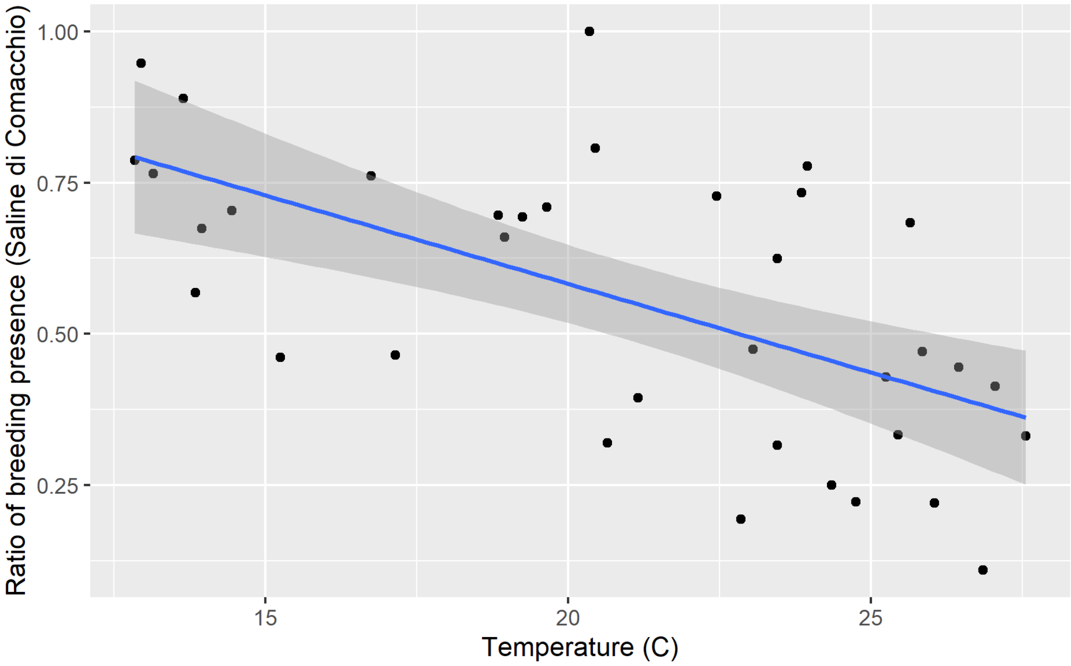

Figure 9. Instant temperature effect on flamingos presence inside Saline di Comacchio during breeding season. Ratio of presence in the colony was estimated for each month of breeding season as the proportion of individuals present in Saline di Comacchio and plotted against the temperature at the given month

significant negative correlation (**Figure 9**). According to the results the significance of correlation test is 62% (**Table 7**). The highest number of observed individuals varies from 17°C to 28°C with presence 25% to 80%.

The analysis of dependency between the precipitation in Saline di Comacchio and ratio of individuals present there during the whole year showed insignificant negative correlation (**Figure 10**) with correlation coefficient value 5% (**Table 8**). The ratio of presence is highly scattered from 0% to 75% with precipitation values varying from 25mm to 75 mm.

The analysis of dependency between the precipitation in Saline di Comacchio and ratio of individuals present there during breeding period showed insignificant positive correlation (**Figure 11**) with correlation coefficient value 30% (**Table 8**). The ratio of presence is highly scattered from 25% to 80% with precipitation values varying from 25mm to 75 mm.

Table 8. Correlation test for the relationship between the precipitation inside Saline di Comacchio and ratio of present individuals

	Test	p-value	Corr. coefficient value
All year	**Spearman**	0.5885	-0.053
Breeding season		0.07965	0.296

P-value (level of significance): '*' < 0.05, '**' < 0.01, '***' < 0.001

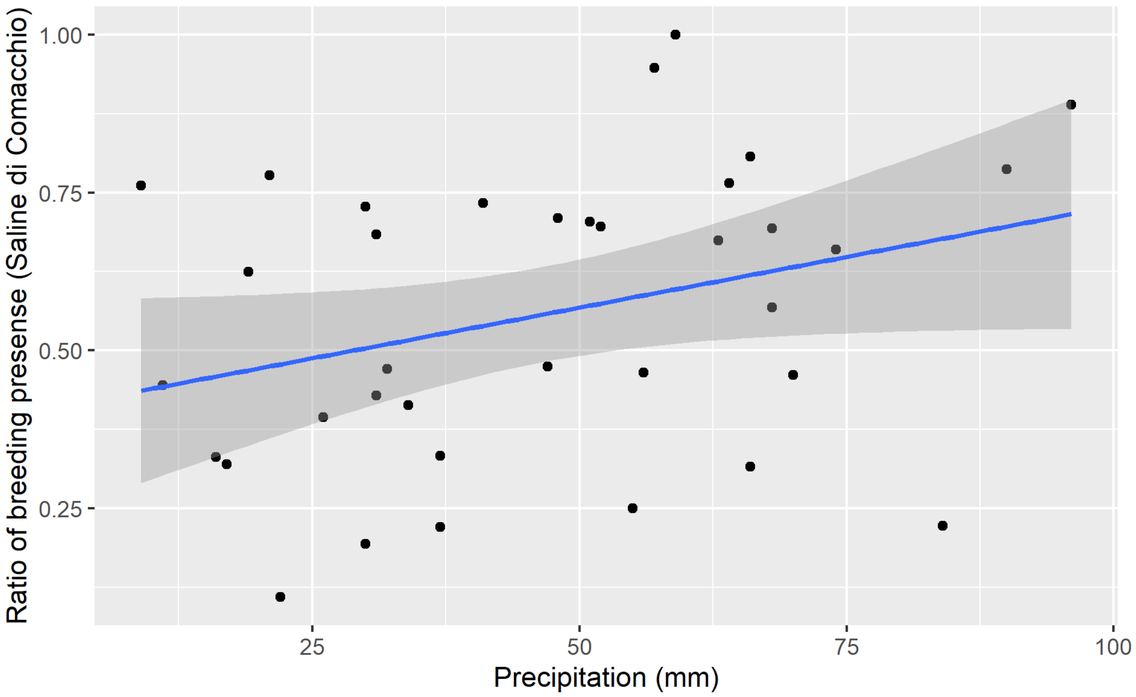

Figure 10. Instant precipitation effect on flamingos presence inside Saline di Comacchio during the whole year. Ratio of presence in the colony was estimated for each month as the proportion of individuals present in Saline di Comacchio and plotted against the precipitation at the given month.

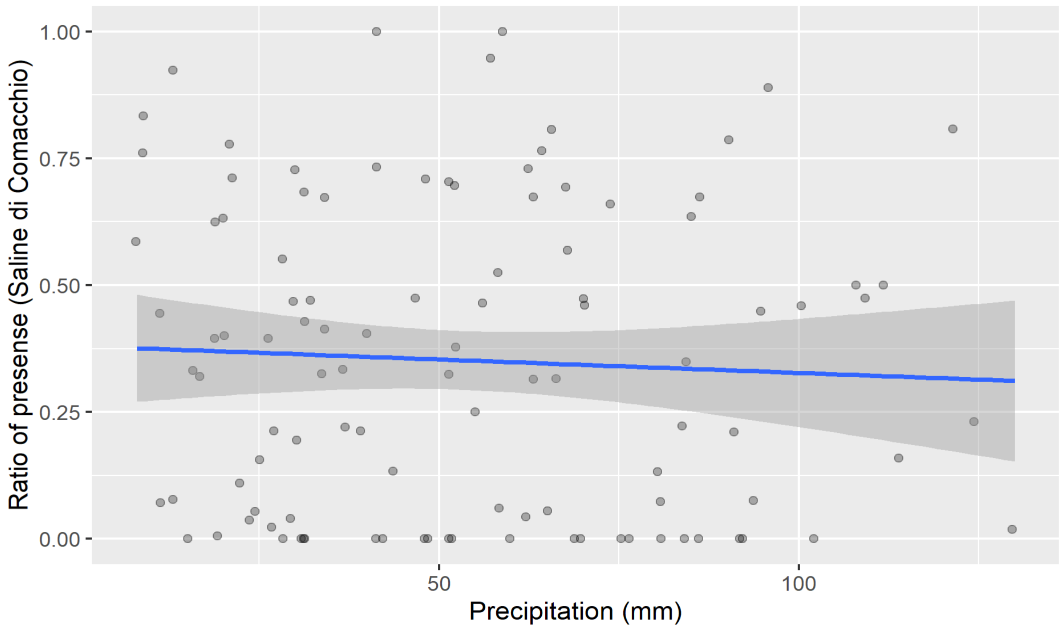

Figure 11. Instant precipitation effect on flamingos presence inside Saline di Comacchio during breeding season. Ratio of presence in the colony was estimated for each month of breeding season as the proportion of individuals present in Saline Comacchio and plotted against the precipitation at the given month.

4.4 Time-lag effect of weather on flamingo presence

The analysis of time-lag effect of temperature on the flamingo presence in Saline di Comacchio during the breeding period showed insignificant results for the all months. Nevertheless, highest correlation coefficient values are 49% and 51% detected for months with lag=6 (October), lag=7(September) (**Figure 12)**with relatively small p-values as 0.18 and 0.16 accordingly (Appendix, Chapter 6).

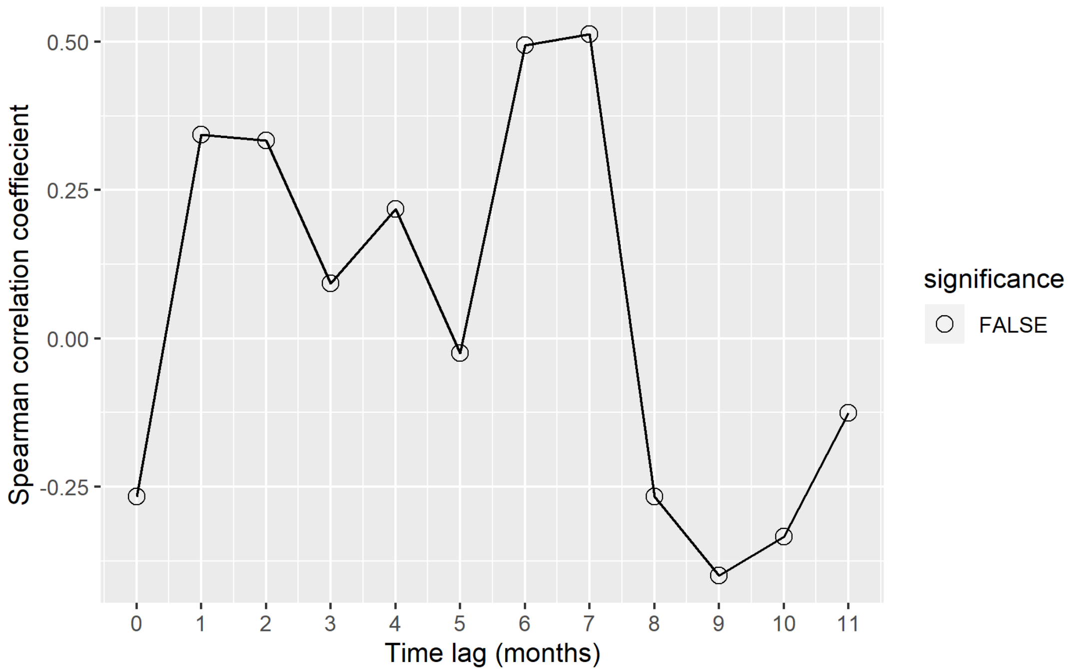

Figure 12. Time-lag effect of temperature on the Greater flamingo presence in breeding season in Saline di Comacchio. The ratio of individuals was estimated as proportion of observations breeding inside Saline di Comacchio. Breeding season was stated for the period between April-July, therefore time lag =0 equals to April, time lag=1 identifies March etc. Dependency between this ratio of flamingos and time-lag of temperature fluctuations was evaluated via application of correlation test, method "spearman" (Spearman correlation coefficient) of each time-lag (month) and its significance (p value).

The analysis of time-lag effect of temperature on the flamingo presence in Saline di Comacchio during the winter season showed insignificant results for the all months. The highest correlation coefficient values are 48% and 63% was detected for months lag=8(February), lag=9(March), (**Figure 13**), but with relatively small p-values as 0.18 and 0.08 accordingly (Appendix, Chapter 6).

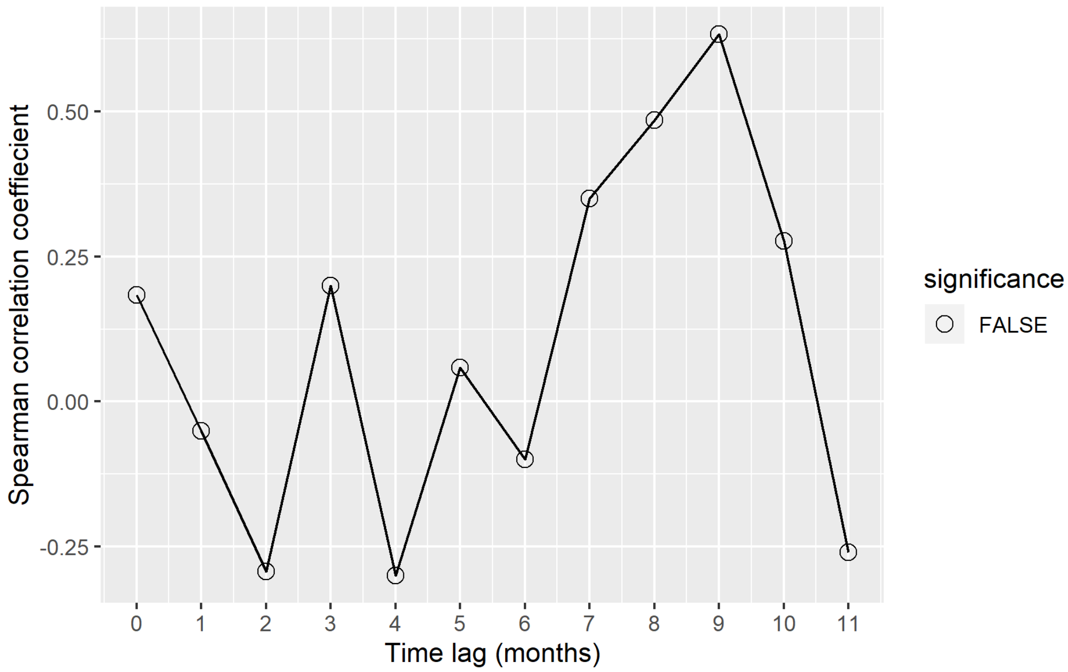

Figure 13. Time-lag effect of temperature on the Greater flamingo presence in winter season in Saline di Comacchio. The ratio of individuals was estimated as proportion of observations wintering inside Saline di Comacchio. Winter season was stated for the period between November-January, therefore time lag=0 equals to November, time lag =1 identifies October. Dependency between this ratio of flamingos and time-lag of temperature fluctuations was evaluated via application of correlation test, method "spearman" (Spearman correlation coefficient) of each time-lag (month) and its significance (p value).

The analysis of time-lag effect of precipitation on the flamingo presence in Saline di Comacchio during the breeding period showed insignificant results for the all months with the lowest correlation coefficient values as 47% (negative value) detected for months lag=0(April), lag=10(June) (**Figure 14**). The correlation coefficient is not significant, but has relatively small p-values as 0.21 and 0.2 (Appendix, Chapter 6).

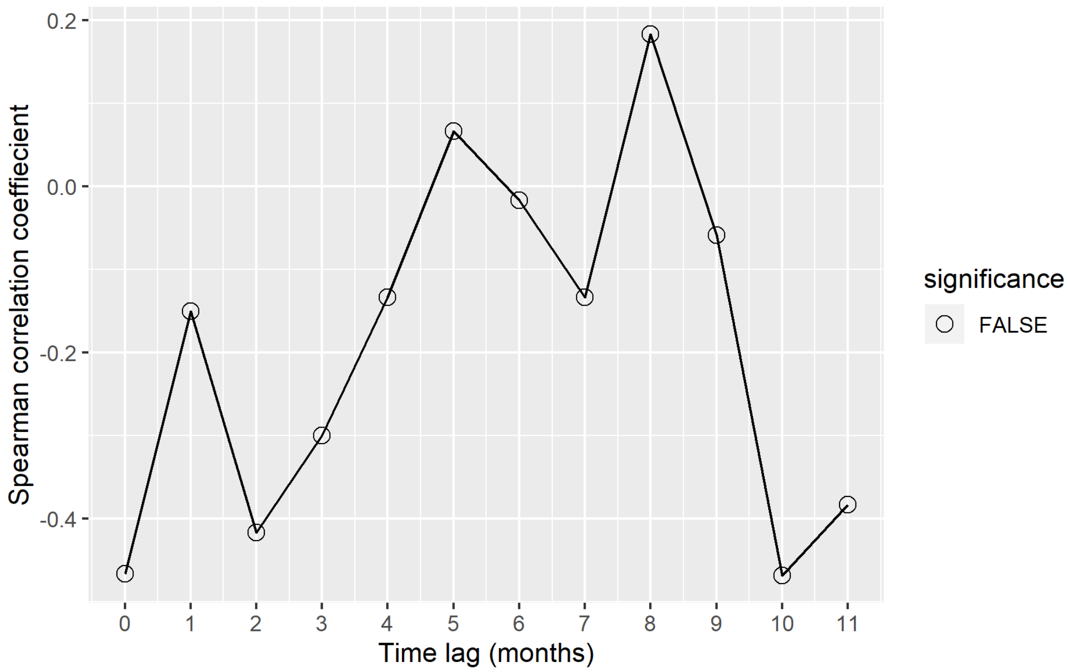

Figure 14. Time-lag effect of precipitation on the Greater flamingo presence in breeding season in Saline di Comacchio. The ratio of individuals was estimated as proportion of observations breeding inside Saline di Comacchio. Breeding season was stated for the period between April-July, therefore time lag =0 equals to April, time lag=1 identifies March etc Dependency between this ratio of flamingos and time-lag of precipitation fluctuations was evaluated via application of correlation test, method "spearman" (Spearman correlation coefficient) of each time-lag (month) and its significance (p value).

The analysis of time-lag effect of precipitation on the flamingo presence in Saline di Comacchio during the winter period showed significant correlation coefficient 90% for month lag=5(June) and significant correlation value 72% (negative) for month lag=11(December) **(Figure 15**) with p-values 0.001 and 0.04 accordingly (Appendix, Chapter 6). Therefore, higher precipitation in June attracts more individuals for wintering period, and high precipitation in December attracts less individuals (and vice versa).

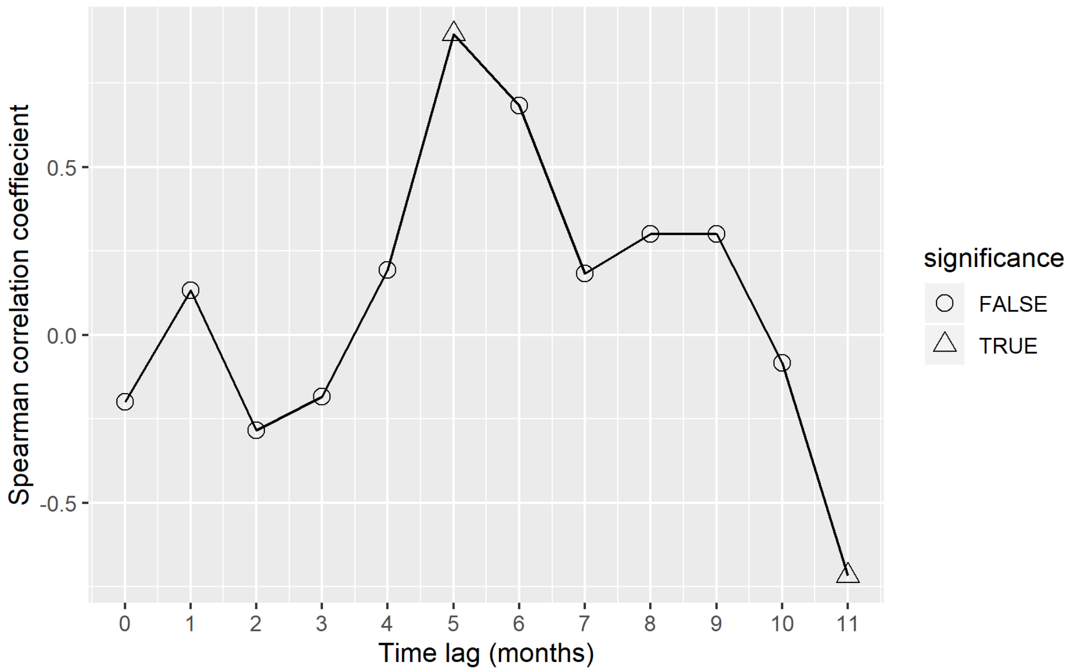

Figure 15. Time-lag effect of precipitation on the Greater flamingo presence in winter season in Saline di Comacchio. The ratio of individuals was estimated as proportion of observations wintering inside Saline di Comacchio. Winter season was stated for the period between November-January, therefore time lag=0 equals to November, time lag =1 identifies October. Dependency between this ratio of flamingos and time-lag of precipitation fluctuations was evaluated via application of correlation test, method "spearman" (Spearman correlation coefficient) of each time-lag (month) and its significance (p value).

The analysis of time-lag effect of temperature on the flamingo presence in Parc Ornithologique (Camargue) during breeding period showed significant correlation coefficients (negative) as 70% and 86% for months lag=11(May), lag=2 (February) (**Figure 16**) with p-values 0.003 and 0.03 accordingly (Appendix, Chapter 6). Therefore, higher temperature in these months attracts less individuals (and vice versa) for the breeding season to Camargue (Parc Ornithologique).

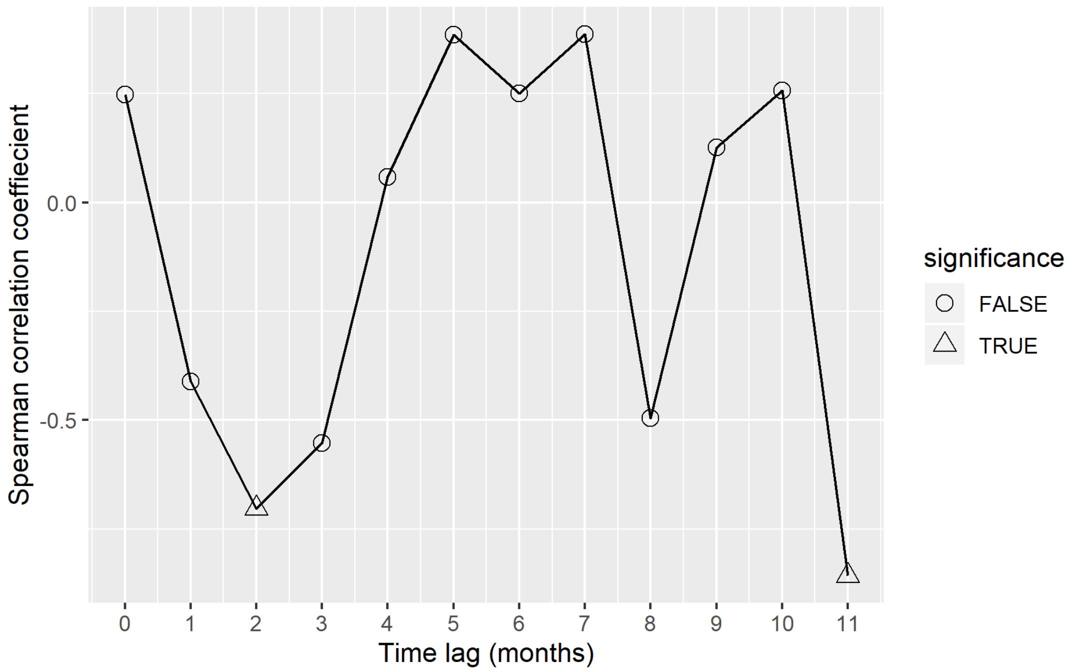

Figure 16. Time-lag effect of temperature on the Greater flamingo presence in breeding season in Parc Ornithologique (Camargue). The ratio of individuals was estimated as proportion of observations breeding inside Camargue colony. Breeding season was stated for the period between April-July, therefore time lag =0 equals to April, time lag=1 identifies March etc Dependency between this ratio of flamingos and time-lag of temperature fluctuations was evaluated via application of correlation test, method "spearman" (Spearman correlation coefficient) of each time-lag (month) and its significance (p value).

The analysis of time-lag effect of temperature on the flamingo presence in Parc Ornithologique (Camargue) during wintering showed significant correlation value (negative) 68% for month lag=8 (March) (**Figure 17**) with p-value 0.04 (Appendix, Chapter 6). Therefore, higher temperature in March attracts less individuals (and vice versa) to come for wintering period to Parc Ornithologique (Camargue).

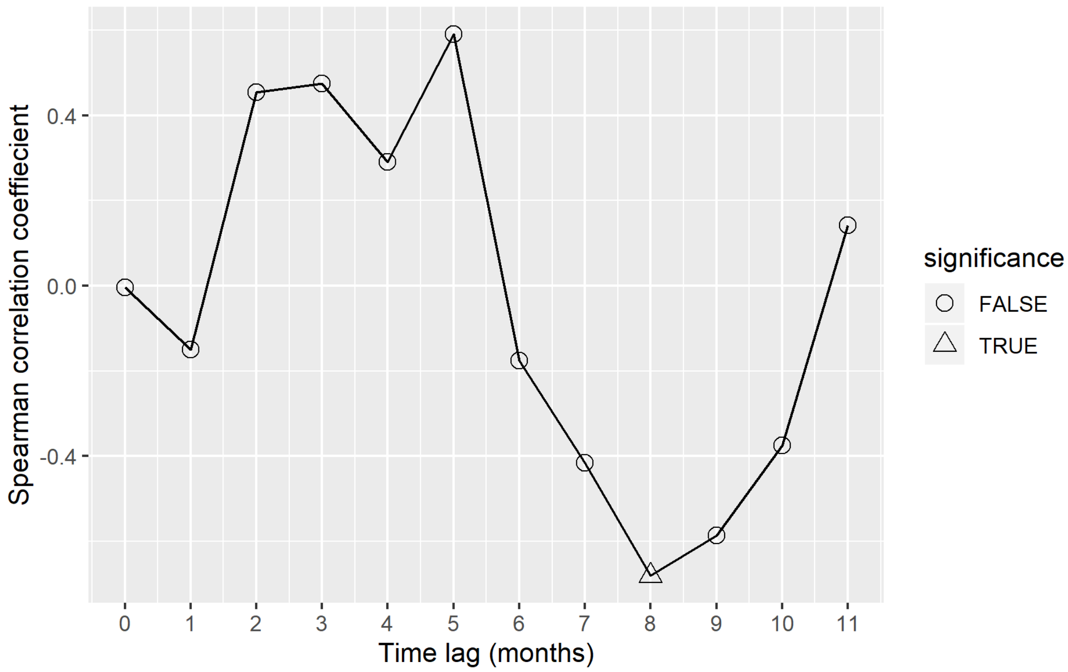

Figure 17. Time-lag effect of temperature on the Greater flamingo presence in winter season in Parc Ornithologique (Camargue).The ratio of individuals was estimated as proportion of their observations wintering inside Camargue. Winter was stated for the period between April-July, therefore time lag =0 equals to April, time lag=1 identifies March etc Dependency between this ratio of flamingos and time-lag of temperature fluctuations was evaluated via application of correlation test, method "spearman" (Spearman correlation coefficient) of each time-lag (month) and its significance (p value).

The analysis of time-lag effect of precipitation on the flamingo presence in Parc Ornithologique (Camargue) during breeding season showed significant correlation coefficient value (negative) 92% for lag=1(March) (**Figure 18**) with p-value 0.0004 (Appendix, Chapter 6). Therefore, higher precipitation in March attracts less individuals (and vice versa) for the breeding season in Camargue (Parc Ornithologique)

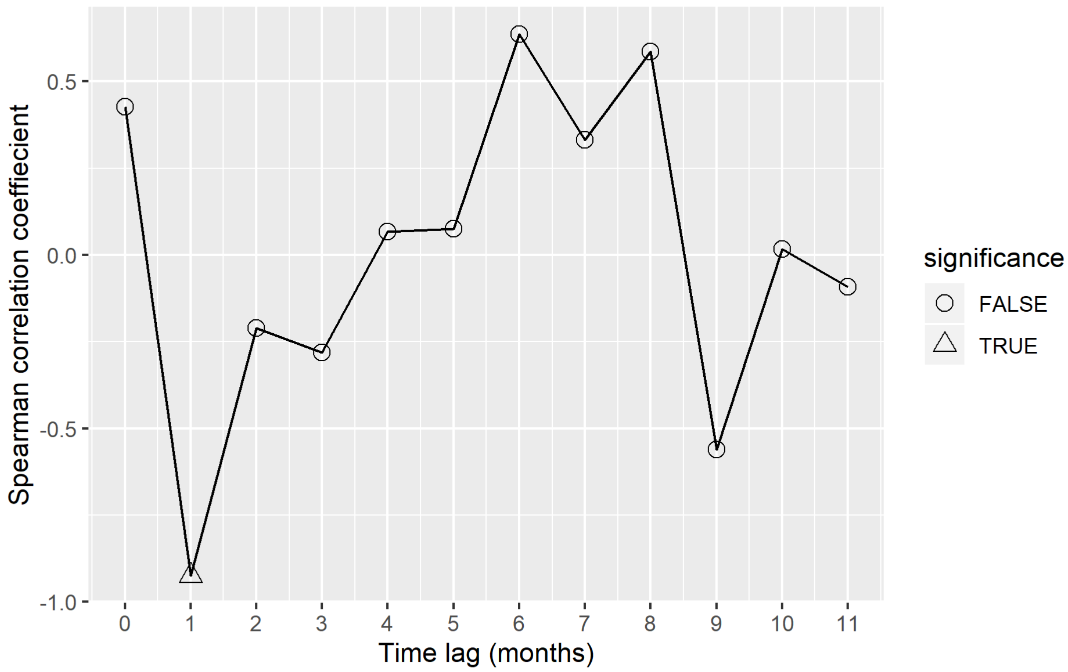

Figure 18. Time-lag effect of precipitation on the Greater flamingo presence in breeding season in Parc Ornithologique (Camargue). The ratio of individuals was estimated as proportion of observations breeding inside Camargue colony. Breeding season was stated for the period between April-July, therefore time lag =0 equals to April, time lag=1 identifies March etc Dependency between this ratio of flamingos and time-lag of precipitation fluctuations was evaluated via application of correlation test, method "spearman" (Spearman correlation coefficient) of each time-lag (month) and its significance (p value).

The analysis of time-lag effect of precipitation on the flamingo presence in Parc Ornithologique (Camargue) during winter season showed significant correlation coefficient values (negative) 88% for month lag=4 (July) and 68% for month lag=7 (April) (**Figure 19**) with p-values 0.002 and 0.04 accordingly (Appendix, Chapter 6). Therefore, higher temperature in July attracts less individuals (and vice versa) and high temperature in April attracts more individuals for the wintering period in Parc Ornithologique (Camargue).

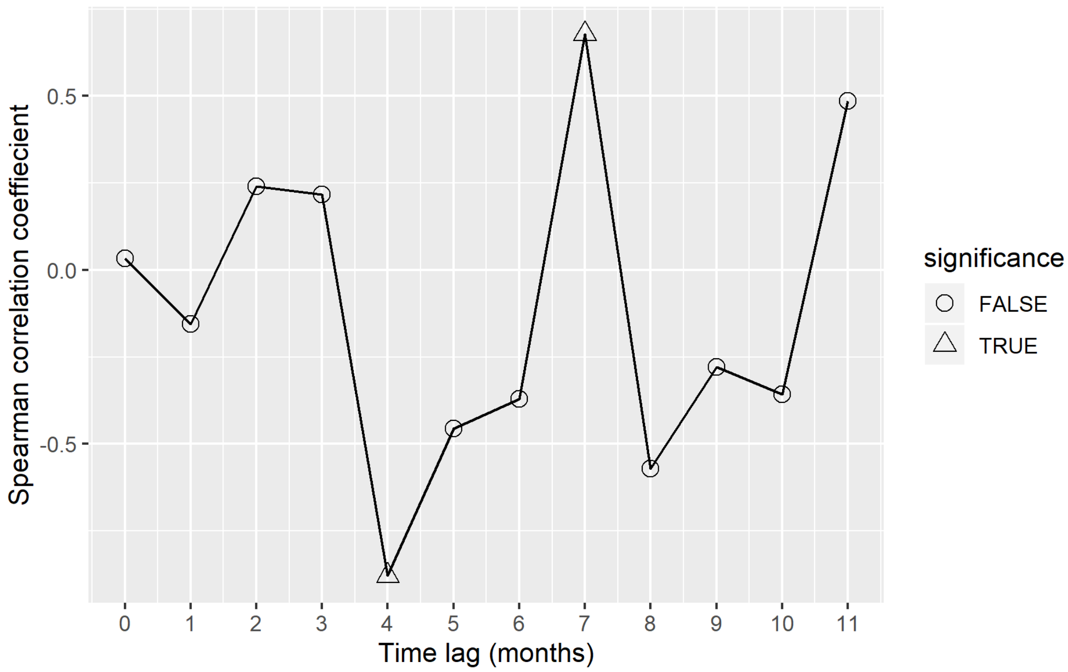

Figure 19. Time-lag effect of precipitation on the Greater flamingo presence in winter season in Parc Ornithologique (Camargue). The ratio of individuals was estimated as proportion of their observations wintering inside Camargue. Winter was stated for the period between April-July, therefore time lag =0 equals to April, time lag=1 identifies March etc Dependency between this ratio of flamingos and time-lag of precipitation fluctuations was evaluated via application of correlation test, method “spearman” (Spearman correlation coefficient) of each time-lag (month) and its significance (p value).

4.5 Weather effect on regional dispersal of flamingos

The analysis of temperature effect on regional dispersal showed that recorded individuals preferred temperature range from 25^0C to 28^0C (high peaks on the graph) for the breeding period (**Figure 20**). However, in winter season (low peaks on the graph) the temperature conditions in Camargue from 12^0C to 10^0C were more favourable for flamingos. Regardless the local temperature in natal colony Saline di Comacchio flamingos prefer to spend winter in another place where temperature is approximately 10^0C higher. In **Figure 20** it is a distance between the chosen conditions by flamingo (blue line) and the temperature values in Comacchio (light blue line). Therefore, even if the temperature was higher in wintering season than the previous year in Italian site, birds still preferred different place with 10^0C warmer conditions.

The analysis of the precipitation effect on the regional dispersal showed that individuals preferred conditions in Comacchio area. During breeding season, the precipitation for flamingos in Camargue was too high varying from 100mm to 250mm (**Figure 21**). The preferred range was around 100mm which is similar to Comacchio conditions. During winter season the precipitation in Camargue was too low ranging from 0 mm to 10 mm, however the favoured conditions were from 10mm to 30mm which are closely overlapping with values in Italian site.

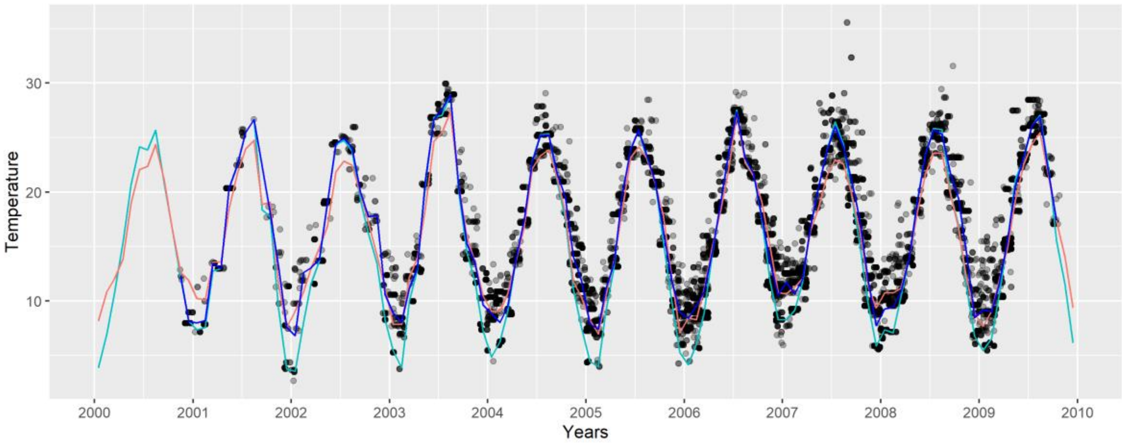

Figure 20. Fluctuation of the temperature in Saline di Comacchio (light-blue) and Salin de Giraud (red line) colonies together with the mean of temperature recordings in the places where the flamingos were observed (blue).

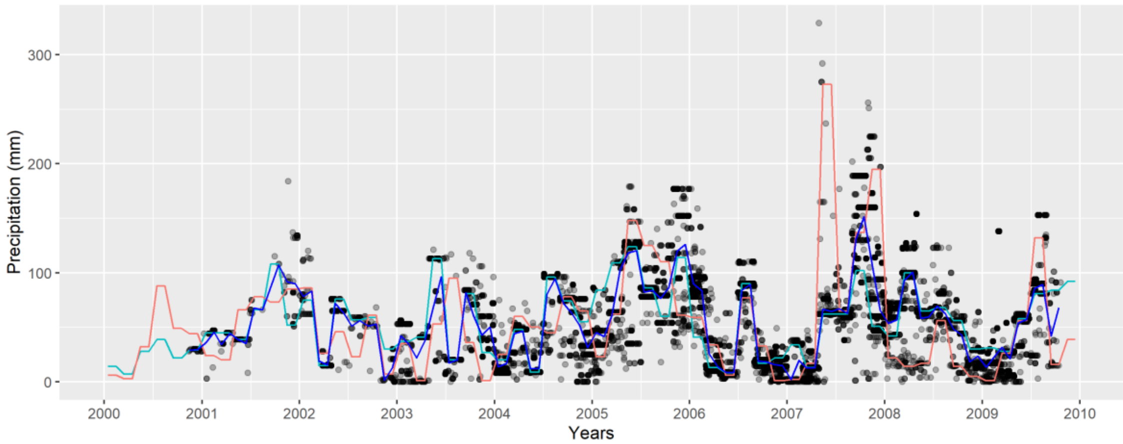

Figure 21. Fluctuation of precipitation in Saline di Comacchio (light-blue) and Salin de Giraud (red line) colonies together with the mean of precipitation recordings in the places where the flamingos were observed (blue).

5 Discussion

5.1 Age effect on dispersal

The proportion of flamingos returning back to the maternal colony, Saline di Comacchio, increased with their age (**Figure 7**). This result coincides with the findings of programme where ringed flamingos were monitored during the period 2000-2009 in Italy (Albanese *et al.*, 2007). It was shown that almost half of the colony breeding at Comacchio was composed by individuals born here (natal origin) (**Figure 2**). The same conclusions were provided in another diploma thesis with the analysis on the same flamingo datasets (Mazneva, 2017). Therefore, we can suggest that observed individuals tend to stay within a limited area around the vicinity of the place where they fledged. High fidelity to the maternal colony could be formed by the first successful breeding at the site, low level of disturbance and stability of Saline di Comacchio place. The analogical findings (Sanz-Aguilar *et al.*, 2012) were obtained from a long-term study undertaken in National Park in Camargue, France. The reason of the high proportion of birds leaving the colony in the early ages could be due to the high competition with older individuals where younger ones were pushed to less qualitative places following an ideal despotic dispersal (Rendón *et al.*, 2001). In case of good body condition young individuals could migrate for breeding to other colonies to explore another place for foraging or nesting. Therefore, the dispersal can be temporally preferable strategy as it lowers the energy loss for the competing with more adult individuals (Pradel, Hines, *et al.*, 1997). For the experienced individuals natal philopatry is more beneficial as it decreases the costs of exploring the new breeding places and genetically supported to local conditions (Balkiz *et al.*, 2010).

The results provided on the **Figure 5** showed that in the middle of the breeding period in Saline di Comacchio there is a sharp short decrease of individuals in the colony which is restored directly. These drops are especially visible in the start of the analysed period 2001-2004. Since 2004 these drops have smoothed character and in some years are absent at all (2005, 2007). In order to explain this pattern, it is important to highlight that each year we have new young observed individuals, not able to breed yet and eventually competitively weaker. We can suggest that part these individuals was pushed away by more experienced and competitive individuals which can be the cause of these drops, but at the same time each year we have more those flamingos who were ringed earlier in the colony. Therefore, being more experienced they manage to stay and breed in the natal place. This observation supports the result showing the presence of natal philopatry in the studied colony. **Figure 6** showed that the presence of flamingos in Parc Ornithologique has irregular character. It can be explained by the dependence of individuals on weather conditions in Camargue varied each year, water levels and food source availability. Moreover, young individuals are not able to compete with more experienced ones, therefore we can mention low ratio of presence in the start of the analysed period 2000-2003 and more frequent presence each year since 2003.

5.2 Instant weather effect on flamingo presence

The occurrence of flamingos was positively associated with the temperature in the whole year (**Figure 8**), but negatively correlated with temperature during the spring (**Figure 9**) (Bouma, 2019). The higher temperature is directly connected with the increase of food resources, maintains good body state (Morandini *et al.*, 2019), provides other sufficient conditions for surviving during the whole year. Negative correlation between the temperature in spring and presence of individuals can be explained by the acceleration of water evaporation in wetlands with the following decrease of food sources, nesting sites and protection from predators (Nager *et al.*, 2010). In another research (Johnson and Cezilly, 2007) it was reported that low food availability was associated with the changed behaviour of the flamingos: disturbed breeding success, general avoidance to breed.

Analysis of instant effect of precipitation on flamingo presence shows insignificant correlations for the whole year and spring, therefore no firm conclusions can be drawn. However, another study (Cézilly *et al.*, 2015) undertaken in the Vaccares system in Camargue says that no direct dependency between rainfall and the number of the present flamingos was identified.

Climatic factors, precipitation and temperature, are crucial factors affecting the flamingo presence. However, from the results of correlation tests, significant parameter for individuals whether to leave or not can be preliminarily stipulated by the temperature fluctuations.

5.3 Time-lag effect of weather on flamingo presence

The analysis of time-lag effect of temperature on flamingo presence in Italy in breeding and winter periods showed no significant correlations. However, high correlation coefficients with relatively small p values can suggest some probable dependency. For example, such results were achieved for time-lag temperature effect on spring and winter periods and time-lag precipitation effect on spring. Therefore, theoretically higher temperature in these months could attract more individuals for the breeding season to the site. To confirm this suggestion further research is required with the bigger sample size and detection of another influential factor. It can help to achieve strong significant results and justify ecologically meaningful explanation of weather role for months with the highest correlation values (**Figure 12** and **Figure 13**). (Federico Morelli, 2020, personal communication).

The analysis of time-lag effect of precipitation on flamingo presence in Italy showed significant correlations only for winter period. These months were June and December. June is the breeding month, therefore could be important for the decision whether to stay or not longer for winter, for example, due to sufficient supply of food. December is the winter month for the species, thus weather conditions at this time can be indicative on the level of weather severity.

Analysis for spring occupancy in Comacchio showed the highest insignificant correlation for April and June months. Potential explanation could be the influence of NAO that brings high water availability in the summertime (Bechet et all 2008). However, in another study (Cézilly et al., 2015) undertaken in Spain it was proved that the colonising of site for the breeding is influenced on the rainfall during winter season (September-February). Probably, for the Italy these months responsible for the choice are shifted. These interpretations must be taken as suggestion and be confirmed by the further researches.

Importance of temperatures in February and May on the flamingo presence in breeding season in Camargue can be explained not only by the weather characteristics. Density dependent variables and other factors can play a role. February is a pre-breeding period for the species which can be important for the decision whether to stay or not. Even February is not yet the breeding season, flamingos tend to start coming to the colony, therefore competition for the nesting place start working. As May is already the breeding season and the correlation is negative, the higher temperature in this month creates high density pressure (Johnson and Cezilly, 2007), therefore individuals could refuse to breed and find another place for foraging or another nesting place in the areas nearby.

According the correlation test the presence in winter season was influenced by temperature fluctuations is March. The breeding place in the Parc Ornithologique is a natural wetland, therefore weather conditions are tightly connected with NAO values and can affect temperatures in winter time (Bechet A., Germain C., 2009).

As it was already mentioned (Johnson and Cezilly, 2007) the weather characteristics during the pre-breeding season, can strongly regulate the movements and occurrence of flamingos in their colonies during the breeding season. March precipitation in Camargue influence the hydrology of the wetland, namely water level. According to the results presented in **Figure 18** negative correlation coefficient high water levels are connected with lower presence of flamingos. Therefore lower occurrence of species in spring can be explained by unavailability of couple to find the appropriate nesting place (Bechet *et all* 2008) in this habitat serving as nesting and foraging place (Bechet A., Germain C., 2009). This result contradicts with the results provided by Bechet A., Johnson Alan R., (2008) who showed that increased water level in Vaccares system (natural wetlands) positively influence the number of breeding couples. In the same research authors also stated that positive effect of water levels in the lagoons can be smoothed by management of water exchange with the sea operated by the salt company. Therefore, further investigation of impact of water level in breeding period on flamingo presence is required.

Explanation of precipitation influence in July and April for the species presence in Camargue in wintertime can be quite speculative. Cézilly *et al.*, 2015 shows no direct dependency between rainfall and the number of breeding couples in winter period. According to the results presented on the **Figure 19** it can be suggested that low precipitation in July predicts good conditions for the upcoming winter due to influence of NAO values (Bechet A., Johnson Alan R., 2008). Higher precipitation in April can influence winter occurrence of flamingo indirectly via increased food resources and in turn sufficient body condition to overcome the severe conditions. More researches on would help to increase our knowledge on indirectly effects of precipitation on flamingo presence in winter time.

5.4 Weather effect on regional dispersal of flamingos

As shown in a research (Nager *et al* 1996) the number of individuals in the colony are highly dependent on the local climatic factors, but unlikely conditions in another place.

For example, even though there is some movement between two colonies in Spain and Camargue, droughts in Spain do not affect local flamingos to move during this period to Camargue site. Analysis of weather effect presented in this thesis did not show any direct movement response from flamingos neither to temperature nor to precipitation. The occurrence of flamingos can be driven mostly by experience-dependent natal philopatry for breeding areas and previous experience for winter areas. Environmental conditions between natal places vary significantly: weather, food resources, parasites etc (Balkiz *et al.*, 2010). Therefore, an individual can be genetically adapted to the place where it was born (Balkiz *et al.*, 2010). In addition to this, fidelity to natal site can help to overcome outbreeding and preserve important genes crucial for surviving (Shields, 1982). Weather can be one of the additional factors attracting individuals to the specific areas: smooth temperatures did not negatively affect the hydrological conditions on the wetlands for winter period; good combination of temperature and precipitation fluctuations were the best for nesting, chicken fledging, food supply and population density in breeding time.

6 Conclusion

High fidelity to the maternal colony Saline di Comacchio was observed for the ringed individuals. The analysis showed that the ratio of the present individuals in the colony ranges from 0.2 to approximately 0.58 from age 0 to 10 accordingly. High fidelity to the maternal colony could be formed by the first successful breeding at the site. (Albanese *et al.*, 2007). The reason of the high proportion of birds leaving the colony in the early ages could be due to the high competition with older individuals where younger ones were pushed to less qualitative places (Sanz-Aguilar *et al.*, 2012).

Positive significant correlation coefficient with a standard notation r=0.405 between the instant temperature effect and presence of flamingos in Saline di Comacchio could be explained by increase of food resources, maintains good body state (Morandini *et al.*, 2019), provides other sufficient conditions for surviving during the whole year. However, significant negative correlation coefficient with a standard notation r=-0.618 between temperature in spring and presence of species in the colony can be explained by the acceleration of water evaporation in wetlands with the following decrease of food sources, nesting sites and protection from predators (Nager *et al.*, 2010). Low food availability was reported (Johnson and Cezilly, 2007) to be associated with the changed behaviour of the flamingos: disturbed breeding success, general avoidance to breed. Both correlations for precipitation were not statistically significant, the results could be “apparent” and senseless from the ecological point of view (Morelli, 2020, personal communication). Climatic factors, precipitation and temperature, are crucial factors affecting the flamingo presence. However, based on the results more significant parameter for individuals whether to leave or not is the temperature fluctuations (Morelli, 2020, personal communication).

Time-lag effect of precipitation in Comacchio in June and December is significant for flamingo presence in winter period, however no firm conclusion was proposed for these months. However, in a study (Cézilly et al., 2015) undertaken in Spain the colonising of site for the breeding is influenced by the rainfall during winter season (September-February). Probably, for Italy these months responsible for the choice are shifted (Morelli, 2020, personal communication). The presence of flamingos in their breeding area is clearly affected by weather characteristics. Time-lag effect of weather conditions for species presence in breeding period in Camargue was significant for February, May and March. The result is likely to be explained by the density dependent variables: number of individuals and accompanied stress factors etc. As March and May are already the breeding season, the higher temperature these months could create high density pressure (Johnson and Cezilly, 2007), therefore individuals could refuse to breed and find another place for foraging or another nesting place in the areas nearby. The time-lag effect of March temperature and precipitation in July and April in Camargue winter period showed significant results for flamingo presence. Probably temperature and precipitation parameters are connected with NAO values which in turn influences conditions in winter time. This suggestion needs further investigations to be supported or rejected. However, some studies say (Cézilly *et al.*, 2015) that there is no direct dependency between rainfall and the number of individuals in winter, therefore another factors have the bigger impact on their presence. Effect of the excessive rainfall in the northern part of the Mediterranean region with the following rise of the sea level is smoothed by the construction system established on the commercial salt pans of Camargue region (Bechet *et all* 2008). Probably weather conditions in this period are connected with NAO values and can affect temperatures in winter time (Bechet A., Germain C., 2009). Further researches are needed to identify the time-lag effect of weather conditions in Saline di Comacchio and Camargue on flamingo presence with the emphasis on winter periods.

Weather effect on regional dispersal of flamingos did not show any direct movement response from flamingos neither to temperature nor to precipitation. The dispersal of flamingos in breeding period can be driven mostly by experience-dependent natal philopatry (Albanese *et al.*, 2007) (Sanz-Aguilar *et al.*, 2012)(Morelli, 2020, personal communication) and by previous experience in winter areas (Barbraud, Johnson and Bertault, 2003).

Summarising all said above we can conclude that weather is a crucial driver of movement patterns of the flamingo species in the Mediterranean region. In terms of instant weather conditions, temperature was more important factor impacting the presence of individuals in Comacchio site. However, time-lag effect of weather on flamingo presence is more complex: in former commercial site, Saline di Comacchio, none of the weather variables have the significant effect except precipitation in winter time, but in the natural site, Parc Ornithologique in Camargue, both temperature and precipitation have the significant influence on the species presence in winter or breeding period. Among weather parameters experience-dependent natal philopatry plays the crucial role in the presence of individuals in the maternal colony Saline di Comacchio, and generally in dispersal during breeding period and migration. Even though some significant results during the data analysis were achieved, they still do not explain the whole movement patterns. More likely there are other drivers influencing the flamingo choice to where, when and how to disperse and migrate

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