Università
Ca'Foscari
Venezia

Scuola Dottorale di Ateneo
Graduate School

Dottorato di ricerca
in Scienze Ambientali
Ciclo XXVI
Anno di discussione 2013

Wildlife strike risk assessment: Development of new methodologies in two International Italian airports

SETTORE SCIENTIFICO DISCIPLINARE DI AFFERENZA: BIO/07

Tesi di Dottorato di Francesca Coccon, matricola 955849

Coordinatore del Dottorato

Prof. Gabriele Capodaglio

Tutore del Dottorando

Prof.ssa Patrizia Torricelli

Co-tutore del Dottorando

Dott.ssa Cecilia Soldatini

Wildlife strike risk assessment:
Development of new methodologies
in two International Italian airports

Francesca Coccon

Supervisor: **Prof. Patrizia Torricelli**
Department of Environmental Science, Informatics and Statistics,
Ca' Foscari University of Venice

Co-supervisor: **Dr. Cecilia Soldatini**
Department of Environmental Science, Informatics and Statistics,
Ca' Foscari University of Venice

PhD candidate: **Francesca Coccon**
Matr.: 955849

PhD coordinator: **Prof. Gabriele Capodaglio**
Department of Environmental Science, Informatics and Statistics,
Ca' Foscari University of Venice

The research reported in this thesis was possible thanks to a collaboration between the Department of Environmental Science, Informatics and Statistics (DAIS) of the Ca' Foscari University of Venice and SAVE S.p.A.

The cover layout of this thesis was realized by Fabio Da Forno.

Dedico questo lavoro di tesi

ai miei genitori

Contents

1. Introduction

Aircraft collisions with wildlife, hereafter wildlife strikes, are a growing threat to civil aviation safety [1, 2]. Of these wildlife strikes, bird-aircraft collisions (hereafter birdstrikes) are of major concern because of the strike frequency and associated damage [3, 2]. Over 229 lives and 221 aircrafts (military and civil) were destroyed worldwide as a result of wildlife strikes from 1988 to 2009 [4-7] and the estimated cost (direct and indirect expenses) to civil aviation worldwide is over U.S. $1.2 billion annually [8]. In the USA alone, 82.057 wildlife strikes (97.5% involving birds) were reported to the Federal Aviation Administration (FAA; 1990–2007) and represent at least U.S. $628 million annually in direct and indirect losses [7]. Importantly, these wildlife-strike statistics reflect an increasing risk to aviation safety [9] due to a) the considerable increase of the air traffic and growth of the civil aviation industry [10] following the World War II; b) the demographic explosion of many large bird species such as sea gulls in the Mediterranean basin [11] and Canada geese in North America [12, 2] and c) the urbanization of synanthropic species populations such as rock doves, starlings or crows and their habituation to live in human-modified habitats and to exploit food sources deriving from human activities [13, 14].

In this regard, a recent study conducted in Europe, where the international air traffic is exponentially increasing, has analyzed the available data on birdstrikes occurred throughout Europe (U.K and Ireland, Western Europe, East Central Europe, Scandinavia, Eastern Baltic States, Southern Europe) pointing out the geographical trend of birdstrikes, thus the most frequently impacted species at a given country [15]. However, although useful to define general guidelines, this general approach should be taken with caution as it could lead to incorrect evaluations relative to wildlife strike risk assessment. In fact, different airports show different environmental features and the distribution of species at airports depends on its geography and surrounding habitats. As a consequence, different species can be considered hazardous at different airports of a given country.

The most frequent point of impact between aircrafts and birds is the front of airplanes. Birdstrikes involving the wings and the landing gear of vehicles are also recurring. More rare but by far the most hazardous, is the ingestion of birds into the turbine engines [16].

Various analyses of the strike data have indicated that, on average, more than 70% of birdstrikes with civil aircraft occurred at or close to airports, generally at altitudes lower than 500 ft (=152 m) [17-20] and in particular during take-off and landings [21-23], because of the limited maneuverability of aircrafts during these phases. In fact, although deeply anthropized and with varied levels of disturbance (e.g. air traffic, human activities, noise, artificial illumination), airports are highly attractive to wildlife, in particular to birds [24]. Some primary characteristics of airports are large grasslands surrounding the runways, well-drained paved surfaces, buildings (e.g. air terminal and hangars) and the trees and bushes along the airport perimeter. Moreover, airports are often located close to woods, ponds or small rivers [25], thus offering a variety of ecological niches to wildlife. As a consequence, airports provide suitable habitats to birds for roosting, feeding and breeding, while disturbance may be a minor factor [13]. Furthermore, birds habituate quickly to conditions of stress and disturbance [26-29] coming back soon to their normal behavioural and activity patterns [30, 31]. Again, at disturbed sites the lower density of wildlife may result in higher foraging and breeding success because of the lower competition for the same resources [32, 33].

The presence of wildlife at airports poses substantial hazards to aviation. However, birds are not equally hazardous to aviation, thus management and prevention actions at airports have to be prioritized by the most hazardous species.

The main factors influencing the birdstrike severity to aircrafts is the aircraft speed [20], the body mass of the impacted bird [23] and the number of individuals involved in the incident. In general, larger bird species and birds with a flocking behaviour are more likely to cause damage to aircrafts, respectively because of the greater mass involved in the collision and the probability of impacting several individuals simultaneously (a multiple birdstrike) thus increasing the chance that a bird will hit a vulnerable part of the aircraft [17, 19].

The International Civil Aviation Authority (hereafter ICAO) detailed the steps that should be taken to monitor and reduce the risk of birdstrike at airports in Annex 14 of the Convention on International Civil Aviation [34]. Furthermore, airport managers are required to follow the regulations of the National Authorities to assess and prevent the wildlife strike risk on and around their property. However, there is no defined level of risk from birdstrikes regarded as acceptable, nor any generally accepted mechanism for quantitatively assessing the risk at a given airport.

The Italian Civil Aviation Authority (hereafter ENAC) provided a series of standards and recommended practices in the Advisory Circular APT-01A [35] and the updated version APT-01B [36].

The main guidelines of APT-01B are:

1) performing an environmental monitoring plan within the airport and in a buffer area with a radius of 13 km from it;
2) collecting data on the wildlife strikes occurring within the airport's perimeter and up to an height of 300 ft (=91.44 m) and submitting them to ENAC;

The environmental monitoring plan should lead to a) the identification of the wildlife present in the airport area (i.e. checklist and relative abundance, seasonal trend, use of the airport habitat and distribution); b) the identification of the attractive sources for birds, within the airfield and in a buffer of 13 Km from it; c) the identification of the airport critical areas, thus subject to a greater risk.

Information from the practical application of the APT-01B guidelines are fundamental for a proper management plan at airports such as habitat manipulation or use of suitable deterrent systems, in order to make the airfield inhospitable to birds, avoid their habituation and thus prevent their attendance at airport.

1.1 Approaches for wildlife strike risk assessment at airports

To reduce and manage the risk of wildlife strike, some airport managers adopt the As Low As Reasonably Practicable (ALARP) approach [37, 38] trying to limit and keep under control the number of birds attending the airport. However, the ALARP risk assessment system provides little guidance on how resources should be targeted to achieve the maximum risk reduction, especially if limited funds for bird management are available [19]. In other cases, airport managers primarily focus on the Bird Control Unit (BCU) which operates a service of control and removal of the wildlife at airports. In particular, the BCU should guarantee the complete dispersion of wildlife before each takeoff and landing. Nevertheless, the BCU operators have often insufficient experience in the ornithology field, as indicated by the Birdstrike Monitoring Form (BSMF) edited by them reporting any information on the species but only defining the genus or family or sometimes even no systematic information [39]. The lack of knowledge, associated to the lack of an appropriate environmental monitoring protocol, lead frequently to marginal or temporary solutions and to manage the risk in the wrong way.

In recent years, several approaches for wildlife strike risk assessment have been developed but the majority of studies have focused on the economic problems linked to wildlife strikes. Dolbeer and colleagues [23] proposed a system for ranking the hazard level of wildlife to aviation on the basis of three main variables: the extent of damage to aircraft caused by the collision, the effect on flight and the cost per strike, developing a relative hazard score for each species by summing the percentage values for the above cited variables. Results from the composite ranking indicated deer, vultures and geese as the most hazardous species to aviation while blackbirds, starlings, sparrows and swallows as the lowest hazardous. Although a collision with a deer has very serious consequences to aviation and in general to airport operations, a birdstrike with starlings or swallows is more likely to occur, thus can be more problematic. Consequently, consider the frequency of the events' occurrence as well as the attendance of wildlife at a given airport is absolutely needed in order to assess the risk correctly. In 2006, Allan proposed a protocol to evaluate the risk at airports by creating a probability-times–severity matrix. This method uses the frequency of strikes reported for different bird species at a given airport over the preceding five years, as a measure of strike probability, and the proportion of strikes with each species resulting in damage to aircraft, as a measure of likely severity. On this basis, action thresholds for particular bird species, above which the airport should take actions to reduce the risk, are defined. Therefore, this method attempts to partition the risk by bird species, focusing the management efforts on those species creating the greatest risk. Although this protocol is now being used at airports in the United Kingdom and elsewhere in the world, its effectiveness in managing risk is limited since it takes no account of a key variable influencing the risk of birdstrike that is the aircraft movement rate [(19)]. In the USA, another method used to reduce the number and severity of birdstrikes is the application of the Bird Avoidance Model (BAM). The BAM models are computer-based and quantitatively or qualitatively assess the risk of damaging birdstrikes, over time and space, relying on the geospatial description of the expected distribution of birds at a given area and the assessment of the hazard they pose. Bird-avoidance models have been developed on two different geographical scale extents: the United States Air Force BAM (USAF, http://www.usahas.com/bam; 9 August 2004) and the Avian Hazard Advisory System (AHAS, http://www.usahas.com; 9 August 2004). The USAF-BAM has been developed to evaluate low-level military-training routes throughout the United States [(40-43)].The model is based upon survey data for the distribution of bird species frequently involved in birdstrikes with low altitude training aircraft. However, the limit of this approach is that it can be overly restrictive on military training. The AHAS combines the predictions of the USAF-BAM with bird-migration forecasts and near-real-time bird-migration monitoring on a national scale. Neural networks are then used to predict the likelihood of birds based upon weather observation and forecast model data from the National Weather Service. When conditions are suitable for migration, areas or routes through which birds should pass are highlighted as a warning [(44)].

In 2005, Zakrajsek and Bissonette developed a nation-wide risk assessment of the avian species hazardous to military aircraft [(45)] by using records from the USAF Birdstrike Database, the largest dataset available for military birdstrikes. Species or species groups were selected when reported to have caused damage to USAF aircraft in the United States. In accordance with AFI 91-204, the USAF classifies damages provoked by birdstrikes by cost, including the estimated cost of human injury and death. Thus, even this method uses an economic perspective to assess the wildlife strike risk at airports. In early 2002, the Netherlands Bird Avoidance Model (NL-BAM) was developed. The NL-BAM is used together with the ROBIN 4 radar system to provide BirdTAMS (e.g. passage of flocks of birds through the airspace) for real time warnings and flight planning, giving an overview of the predicted bird hazards in the Netherlands, to air traffic controllers and flight coordinators[(46)]. However, birds are small targets for radar detection and this may lead to the occurrence of false alarms (false positives) or missed detections (false negatives). Moreover, radars are very expensive and require a regular technical maintenance (47).

A more integrative approach, combining the main ecological and behavioural patterns of the species in relation to air traffic and the birdstrikes recorded for species or species groups at a given airport, has been proposed by Soldatini and colleagues in 2010. The proposed approach for birdstrike risk assessment leaded to the development of the Birdstrike Risk Index BRI (24). In 2011, the BRI was revised and several changes were introduced in the index structure in order to improve its reliability and applicability to different airports (48). The proposed modified version of the Birdstrike Risk Index, the BRI2, has been recently integrated within the APT-01B and adopted as the national Italian standard to calculate the risk of wildlife strike risk at airports (36).

1.2 Research objectives

In such a context, where so many different approaches are followed to assess and keep under control the risk, the standardization of the wildlife strike risk assessment procedures as well as the development of an holistic analytical tool is strongly needed, also to allow comparisons among different airports worldwide.

On this basis, a suitable wildlife strike risk analysis should take into account all the aspects that contribute to create the risk of wildlife strike and thus be founded on:

- an appropriate ecological assessment of the airport;
- the morphological and behavioural features of the species recorded at airport;
- the attractive sources for wildlife, recorded within the airport and in the areas surrounding it.

Therefore, the present research originates from the BRI2 index, currently in use throughout the Italian country, with the aim to develop new methodologies for wildlife strike risk assessment, above all a new bio-geographic risk index which combines the above cited ecological, behavioural and environmental variables. By introducing the environmental factor, never considered before, the new index will represent a crucial and innovative element in the field of risk assessment, allowing not only to assess the risk of wildlife strike at airports and in their surroundings, but also to manage it, for instance by planning specific interventions for strategic land management programs and alert during the high-risk periods.

To develop such new tools, two international Italian airports were considered as study case: The Venice Marco Polo airport and the Treviso Antonio Canova airport.

The selected airports are particularly suitable for this purpose as:

- in increase for air traffic (49, 50);

- highly attended by wildlife, in particular birds, being located in very important naturalistic areas, respectively on the inland border of the Venice lagoon and along the River Sile Regional Natural Park, thus in High Risk Areas;
- the two airports are part of the same management system, SAVE S.p.A., and are located only 20 Km apart from each other.

The present study is also intended to provide information on the following main items:

- the relative attractiveness of sources to wildlife in order to highlight the most appealing ones, thus the most hazardous from an aviation perspective;
- the exploitation of the study airports by wildlife during daytime and different periods;
- a warning on the critical areas of the airports.

Results from this research will help in dealing with airport management problems and safety improvement.

1.3 Outline of the thesis

After a detailed introduction of the two case studies on which the current research project has been developed, the thesis is articulated in two main parts with the addition of a third conclusive one.

The first part is dedicated to the descriptive qualitative and quantitative analysis performed at the target airports and their relative results. In detail, this section is subdivided in four main captions: 1) the analysis on wildlife presence performed at airports in the study period; 2) the analysis of the sources attractive for wildlife within the airports and in a buffer area of 13 Km from them; 3) the wildlife strike risk analysis at the target airports by applying the Birdstrike Risk Index BRI2 to the collected data; 4) the ecological characterization of the airports by applying suitable ecological indexes. In this first part, besides the technical explanation of the protocol used during field activities, particular attention is given to the wildlife species recorded at airports highlighting the daily and seasonal trend as well as the use of the airport habitat and distribution of each species or species group.

The second part of the thesis is dedicated to the development of new methodologies for wildlife strike risk assessment and is organized in two main parts.

The first part focuses on two species among the most hazardous for aviation: the yellow-legged gulls, *Larus michahellis*, and the black-headed gull, *Croicocephalus ridibundus*. After an introductory overview of the target species, from a morphological and ecological point of view, the attention is focused on the definition of the prime drivers for gulls (i.e. the attractive sources suspected to drive gulls in their daily flights) and the development of predictive models on gulls' spatial movements basing on the attractive sources around the airfields, attended by them.

The second part focuses on the development of the bio-geographic risk index or Attraction Risk Index, ARI, technically describing the methods followed to develop it, in the aim of providing a new standardized risk index, easily adaptable to any airport reality and statistically robust.

The third conclusive part of the thesis shows an overall discussion of the research project, highlighting the innovative nature of the proposed analytical tools for wildlife strike risk assessment and their management implications at airports for flight safety improvement.

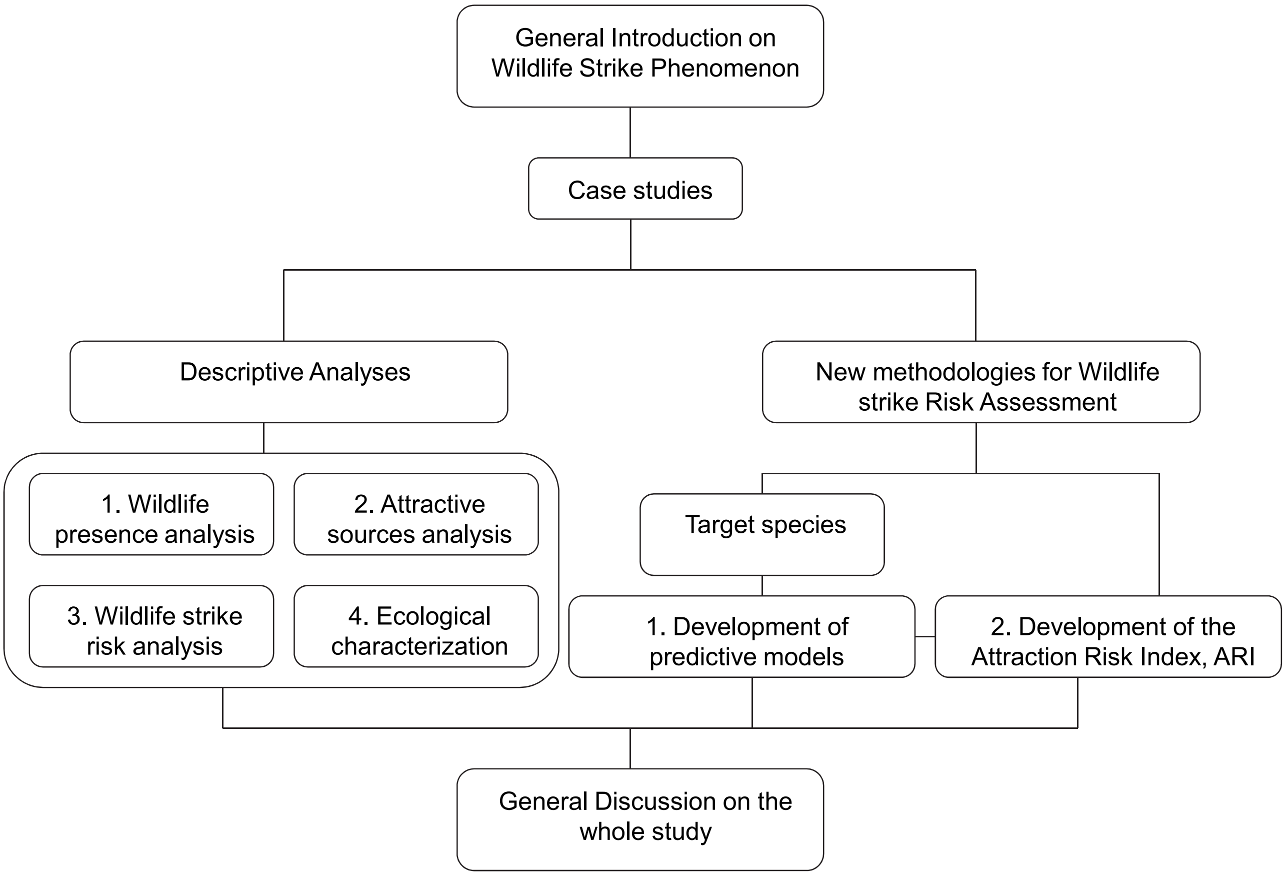


Figure 1: Flowchart of the research activities conducted during the PhD project

2. Case studies

The present study focuses on two International Italian airports: 1) the Venice Marco Polo airport and 2) the Treviso Antonio Canova airport. The two airports are about 20 Km apart from each other and together form the Venetian airport network which covers the third position in the national airport rank, following Rome and Milan, with a mean annual air traffic of 9 million passengers.

2.1 Marco Polo airport

The Marco Polo International airport lies entirely within the territory of Venice municipality, it has an elevation of 2 m on the sea level and it is about 11 Km far from the city of Venice (45° 30' 19'' N; 12° 21' 97'' E - WGS84 Reference System).

Venice airport covers a total area of 2.588 Km^2 and presents two 45 m wide runways running parallel to the edge of the lagoon, surrounded by meadows. The main runway - the 04R-22L – is 3300 m long, while the auxiliary runway - the 04L-22R – is 2700 m long and it is operative only when closed the main one, being generally used as 'taxi way'.

The Venice Marco Polo airport, operative 24h/24, is identified as LIPZ and classified as 4E[1] category civil airport by the International Civil Aviation Organization (hereafter ICAO) [(34)], while the International Air Transport Association (hereafter IATA) designed it as VCE.

VCE is developed on an offshoot of reclaimed land subtracted to the Venice lagoon, which is located in the northern basin of the Adriatic Sea. The north-east and south-east sides of the airport overlook the lagoon while the north-west side borders agricultural fields and the urban centre of Tessera. The air terminal, extended and redesigned in 2002, covers a total area of 60.000 m^2 including 370.00 m^2 of apron. The apron is provided of 53 parks among which 10 are for wide-body, 9 for general aviation, 3 for medium-sized aircrafts that can autonomously maneuver and the remaining part is for small and medium sized aircrafts subjected to the 'push back' operation to get out of the apron [(51)].

In 2012, VCE has registered a total amount of 8,2 million passengers with 84.230 movements and more than 70 scheduled destinations, including 7 long-range ones. The total amount of passengers flying towards international destinations represents 75% of the entire air traffic [(52)].

[1] The numeric element defines the minimal characteristics of the runway as well as the delimiting surfaces of the obstacles; the alphabetic element refers to the aircraft' needs when on the ground (taxiway and parking) in terms of wingspan and distance between the outer edges of the wheels of the main landing gear.

Code ICAO/IATA	LIPZ/VCE
Position	45° 30' 16" N 12° 21' 07" E
Altitude	2.13 m
Runways	04R/22L 3.300m main runway (width: 45m) 04L/22R 2.780m auxiliary runway (width: 45m) auxiliary runway provided with the Surface Movement Ground Control System (SMGCS)
Aircraft parking	53 in total among which: 10 for wide-body, 34 for narrow-body (28 push back - 18 self-manoeuveuring), 9 for General Aviation
Loading class	LCN/PCN 100
ICAO Class	4E
Fire Category	8
NAV AIDS	ILS Cat.IIIb - VOR DME – NDB
Operative time	24H
Fuel Companies	Levorato Marcevaggi-Q8-SHELL
Management Society	SAVE S.p.a.
Handler	AviaPartner - GH Venezia – SAV
Distance from the city of Venice	13 Km through Bretella-Tangenziale; 8,6 Km through SS14 – Triestina

Table 2.1: Identification data of the Venice Marco Polo airport as reported in the website (www.veniceairport.it).

Figure 2.1: Aerial picture of the Venice Marco Polo airport.

2.2 Antonio Canova airport

The Antonio Canova airport has an elevation of 18 m on the sea level, it is 3 Km far from the city centre of Treviso and about 20 Km from Venice (45° 39' 06 " N; 12° 11 ' 56 " E - WGS84 Reference System).

Treviso airport covers a total area of 1.2 km^2 and presents a main runway which is 45 m wide and 2459 m long. The runway is extended along the ENE-WSW axis and lined by two wide aprons (respectively located in the north-east and south sides) and meadows. The two aprons host parks for aircrafts (7 for narrow body and 8 for general aviation), hangars and other airport infrastructures.

ICAO identified the Treviso Antonio Canova airport as LIPH and ranked it within the A class category [34] while IATA designed it as TSF.

TSF is located along the River Sile Regional Natural Park which is an important natural area with abundant water springs, lakes and wetlands, most of which are Special Protection Areas (SPA) and Sites of Community Importance (SCI).

Along the north-west side the airfield is bordered by agricultural fields and the urban centre of Quinto di Treviso, while on the south side it is lined by the Sile river and several wetlands.

TSF is in vocation mainly low cost and stands as the third airport pole in the north-east part of Italy following Venice and Verona. In the last 10 years TSF registered a mean growth of 23% - in relation to the national mean of 4% - reaching a movements/year rate of 1.8 million passengers and still being in growing. Furthermore, the airport will be subject to widening works until 2049. Several works, addressed to adapt and extend the runway, have started in June 2011 and were completed in November 2011. In 2012, TSF has registered a total amount of 2.333.758 passengers with 20.279 movements [53].

Code ICAO/IATA	LIPH/TSF
Position	45° 39' 06" N 12° 11' 56" E
Elevation	17.34 m
Runway	07/25 2459 m
Aircraft parking	7 for narrow body in self manoeuvring, 8 for general aviation
Loading class	ACN 58 / PCN 65
ICAO class	A
Fire Category	7
NAV AIDS	ILS Cat.Ia - VOR DME - NDB
Light AIDS	IMP. LUCI Ia CAT
Operative time	24H
Fuel Companies	AGIP
Management Society	AERTRE S.p.A.
Distance from the city	3 Km from the city centre of Treviso and 20 Km from the city of Venice

Table 2.2: Identification data of the Treviso Antonio Canova airport as reported in the website (www.trevisoairport.it).

Figure 2.2: Aerial picture of the Treviso Antonio Canova airport.

Part I - Descriptive qualitative and quantitative analysis

3. Analysis on wildlife presence and abundance

3.1 Wildlife monitoring activities

The monitoring activities to record the wildlife present at the studied airports have started in January 2010 at VCE while in May 2010 at TSF, proceeding until the end of December 2012. During the whole period, surveys were made twice per month on an hourly basis during daylight from dawn to dusk and were conducted by two expert ornithologists[2]. Observations were performed from a single vantage point from which all the airport area was clearly visible (i.e. the VIP terrace on the south side of the air terminal at VCE and an unused office at the third floor of the terminal on the south-west side at TSF), each one lasting an average of 15 minutes. A telescope with 20x60 zoom lens and a binocular 10x42 were used as standard equipment during surveys. During each census a tour along the outer perimeter of the airfield was also carried out by using the *follow-me* vehicle, specifically granted by the SAVE-airport safety group. This supplementary survey was preferably conducted at dawn and dusk as the peaks of activity for wildlife and in particular for birds. During censuses the abundance and distribution of all the wildlife species attending the airport area were registered. In accordance with the Italian Civil Aviation Authority Advisory Circular, APT01-B [(36)], birds were recorded when flying within the airfield up to an altitude of 300 ft (= 91.44 m), approximating to excess. In order to assess the flight altitude of birds, the control towers of VCE and TSF airports, respectively high 173 ft (=52.73 m) and 130 ft (=39.62 m), were took as reference points. When mixed flocks were present, each species was recorded separately. A technical form was completed during each hourly survey. In this form the following information were noted: the date of sampling, time of sighting, recorded species and number of individuals, activity pattern (if roosted or flying), eventually the direction of flight, any possible behavioural notes and reference location. Variables able to influence the presence/absence and relative abundance of the species such as weather conditions (i.e. visibility, rain, strength and direction of wind, temperature) and information on potential attractants as maintenance works (e.g. mowing, planting, harvesting sheaves) and use of deterrent systems (e.g. falconry, distress call, specific interventions operated by the BCU) were also registered.

[2] Francesca Coccon VCE airport N. 13994, TSF airport N. 11344; Lucio Panzarin VCE airport N. 7223, TSF airport N. 11275

3.2 Subdivision of the study areas

The two studied airports were subdivided into quadrants to create a spatially referenced grid which allowed us to easily associate the recorded individuals with a particular quadrant and thus to the general habitat characteristics of that area. The grid was formed by 60 quadrants (370 x 370 m) for VCE (Figure 3.2 a) and by 16 quadrants (500 x 500 m) for TSF (Figure 3.2 b). Furthermore, to simplify data representation and favour the following analysis, the airport habitats were classified into five main classes: runway, meadows, buildings, water, other (e.g. trees, bushes, fences etc).

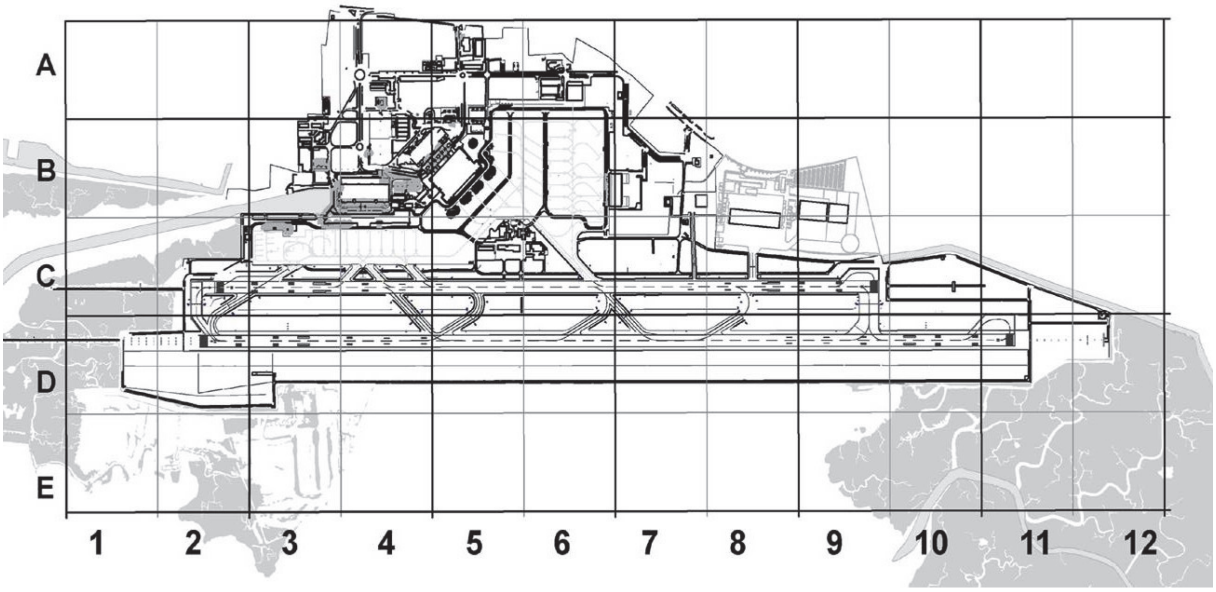


Figure 3.2 a: Spatial referenced grid of VCE airport subdivided into 60 quadrants.

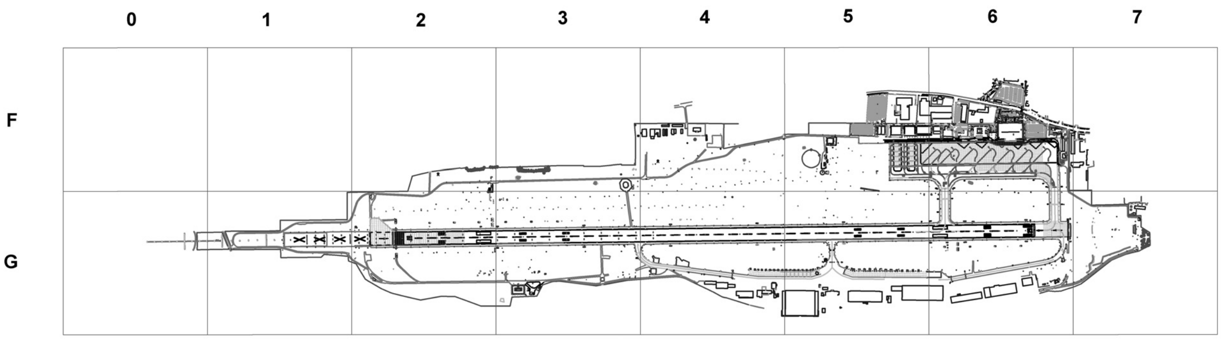


Figure 3.2 b: Spatial referenced grid of TSF airport subdivided into 16 quadrants.

3.3 Data analysis

Data on wildlife presence collected at airports from January 2010 to December 2012 were used to develop a Checklist of the species attending the airfields and the areas surrounding them in the study period. Regarding TSF, data were available from May 2010 (beginning of the monitoring activity at airport) to April 2011 and from January to December 2012. Data were not collected from June to November 2011 as the airport was closed for maintenance and upgrading works and monitoring activities were not allowed. The multi-year study period, including all the biological cycles of avifauna (from wintering to fall migration), represents a solid basis to describe the species richness of the target airports over different seasons, thus provides a useful tool for strategic management plans.

Species recorded at airports were organized in 17 functional groups according to their ecological features (habitat and diet), body size and social behaviour (flocking and non-flocking species). The 17 functional groups, with some example species for each of them, are reported in table 3.3.1.

ID group	Species group	Species examples
1	Grebes and divers	*Podiceps cristatus, Podiceps nigricollis*
2	Cormorant, pelicans, swans and geese	*Phalacrocorax carbo, Cignus olor, Anser anser*
3	Herons, storks, flamingos	*Ardea cinerea, Casmerodius albus, Egretta garzetta*
4	Ducks, pheasants, rallids	*Anas platyrhynchos, Tadorna tadorna, Phasianus colchicus*
5	Birds of prey – large	*Buteo buteo, Circus aeruginosus*
6	Birds of prey – small	*Falco tinnunculus*
7	Seabirds – large	*Larus michahellis, Larus argentatus*
8	Seabirds – small	*Croicocephalus ridibundus, Sterna hirundo*
9	Waders	*Charadrius alexandrinus, Calidris alpina, Recurvirostra avosetta*
10	Doves	*Columba livia, Columba palumbus, Streptopelia decaocto*
11	Owls	*Athene noctua*
12	Swifts and swallows	*Apus apus, Hirundo rustica*
13	Corvids	*Corvus corone cornix, Pica pica*
14	Non flocking passerines and bats	*Motacilla alba, Turdus merula, Picus viridis,*
15	Flocking passerines	*Sturnus vulgaris*
16	Small mammals (<10 Kg)	*Lepus europaeus, Felis catus*
17	Large mammals (>10 Kg)	*Canis lupus familiaris*

Table 3.3.1: Organization of the ecologically related species into 17 functional groups with some example species for each group.

Data collected at airports from January 2011 to December 2012 were used to define the seasonal and daily trend of the recorded groups of species as well as their airport habitat use. Information from these analysis are particularly useful to highlight the peaks of presence of the species recorded at airports over different seasons and during daytime and detect the habitats mainly exploited by them. To simplify data representation, months were grouped in four different periods, each one corresponding to a particular phase of the biological cycle of birds. To uniform the graphical representation of the results, this subdivision of the year was applied to all the recorded groups of species, including the two groups of mammal species (groups 16 and 17). Since the four biological periods of birds correspond approximately to the seasons of the year, when looking at the graphs and maps of groups 16 and 17 - both in the text and annexes – the reader should refer to the season corresponding to a given period (i.e. wintering= winter; spring migration= spring; breeding= summer; fall migration= autumn).

Additionally, time of sunrise and sunset over the months were approximated by considering the average time of dawn and dusk on a given period. These times were then rounded in order to obtain integer values (Table 3.3.2).

Period	Month	Dawn time	Dusk time	Approximate time of dawn	Approximate time of dusk	Hours of daytime
Wintering	January	7:47	16:51	08:00	17:00	09:00
	February	7:16	17:33	07:00	17:00	10:00
Spring migration	March	6:25	18:13	06:00	18:00	12:00
	April	6:27	19:54	06:00	20:00	14:00
	May	5:41	20:32	06:00	20:00	14:00
Breeding	June	5:21	21:00	05:00	21:00	16:00
	July	5:34	20:57	05:00	21:00	16:00
	August	6:09	20:21	06:00	20:00	14:00
Fall migration	September	6:47	19:25	07:00	19:00	12:00
	October	7:24	18:28	07:00	18:00	11:00
	November	7:07	16:42	07:00	17:00	10:00
Wintering	December	7:42	16:27	08:00	16:00	08:00

Table 3.3.2: Subdivision of the year based on the biological cycle of birds and detail on time of dawn and dusk over the months.

Finally, data for the year 2012 (from January to December) were used to define the airport distribution of the recorded groups of species over the periods, in order to highlight the most attended areas and thus the most critical from an aviation safety perspective.

3.4 Results

In the following paragraphs, results from the descriptive analysis performed are presented separately for the two studied airports.

3.4.1 Checklist

3.4.1.1 VCE

A total number of 91 species has been registered at VCE and in the areas surrounding it up to an altitude of 300 ft. Of these, 6 species were resident at airport for the whole study period (i.e. little egret, *Egretta garzetta*, yellow-legged gull, *Larus michahellis*, black-headed gull, *Croicocephalus ridibundus*, hooded crow, *Corvus corone cornix*, magpie, *Pica pica* and starling, *Sturnus vulgaris*). Other species frequently detected at airport were cormorant, *Phalacrocorax carbo*, grey heron, *Ardea cinerea*, mallard, *Anas platyrhynchos*, shelduck, *Tadorna tadorna*, kestrel, *Falco tinnunculus*, rock doves, *Columba livia*, white wagtail, *Motacilla alba*, and lark, *Alauda arvensis*.

Therefore, a nearly constant presence of waterfowls and invasive species, followed by small raptors and passerines has been detected. Although not so common events, 5 species of mammals were also sighted in the airport area. The checklist of species recorded at VCE in the study period is shown in the following table. The identification code of the functional groups of species is reported in the first column of the table.

ID group	Scientific name	Short code	Common English (and Italian) name	2010												2011												2012											
				January	February	March	April	May	June	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December
1	*Podiceps cristatus*	PODCR	Great crested grebe (svasso maggiore)	X	X				X	X	X	X	X	X	X	X	X				X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X
1	*Podiceps nigricollis*	PODNI	Black-necked grebe (svasso piccolo)		X								X											X	X			X										X	X
2	*Cygnus olor*	CYGOL	Mute swan (cigno reale)	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X	X	X				X			X	X	X	X
2	*Phalacrocorax carbo*	PHACA	Cormorant (cormorano)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
2	*Phalacrocorax pygmeus*	PHAPY	Pygmy cormorant (marangone minore)	X		X																	X	X	X			X				X				X	X	X	
3	*Ardea cinerea*	ARDCI	Grey heron (airone cenerino)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
3	*Ardea purpurea*	ARDPU	Purple heron (airone rosso)															X			X												X						
3	*Bubulcus ibis*	BUBIB	Cattle egret (airone guardabuoi)								X											X																	
3	*Casmerodius albus*	CASAL	Great egret (airone bianco maggiore)		X	X				X	X					X	X	X			X		X	X		X										X		X	X
3	*Egretta garzetta*	EGRGA	Little egret (garzetta)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	*Nycticorax nycticorax*	NYCNY	Black-crowned night heron (nitticora)																														X						
3	*Phoenicopterus roseus*	PHORO	Pink flamingo (fenicottero)	X																																			
4	*Anas acuta*	ANAAC	Pintail (codone)		X	X											X												X										
4	*Anas clypeata*	ANACL	Shoveler (mestolone)														X	X																					
4	*Anas crecca*	ANACR	Eurasian teal (alzavola)		X	X	X																																
4	*Anas platyrhynchos*	ANAPL	Mallard (germano reale)	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X				X	X	X
4	*Anas querquedula*	ANAQU	Garganey (marzaiola)		X	X												X																					
4	*Anas strepera*	ANAST	Gadwall (canapiglia)														X																						
4	*Anas sp.*	ANASP	Unidentified ducks	X	X	X																							X	X		X	X						

4	*Gallinula chloropus*	GALCH	Common moorhen (gallinella d' acqua)		X																																		
4	*Mergus serrator*	MERSE	Red-breasted mergan (smergo minore)													X												X											X
4	*Phasianus colchicus*	PHACO	Common pheasant (fagiano comune)			X		X			X	X					X	X		X		X	X	X						X	X	X		X	X	X			
4	*Tadorna tadorna*	TADTA	Shelduck (volpoca)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X
5	*Buteo buteo*	BUTBU	Common buzzard (poiana)	X	X							X	X		X	X									X	X	X	X								X	X	X	X
5	*Circus aeruginosus*	CIRAE	Western marsh harrier (falco di palude)	X	X	X	X	X					X	X	X		X		X	X	X				X	X		X	X	X	X	X	X				X	X	X
5	*Circus cyaneus*	CIRCY	Hen harrier (albanella reale)		X	X								X	X		X										X		X									X	X
5	*Circus pygargus*	CIRPY	Montagu’s harrier (albanella minore)							X							X		X	X																			
5	*Falco peregrinus*	FALPE	Peregrine falcon (falco pellegrino)														X																		X				
6	*Falco columbarius*	FALCO	Merlin (smeriglio)														X																						
6	*Falco tinnunculus*	FALTI	Kestrel (gheppio)	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	*Larus michahellis*	LARMI	Yellow-legged gull (gabbiano reale)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
8	*Chlidonias niger*	CHLNI	Black tern (mignattino comune)							X												X												X	X				
8	*Chroicocephalus ridibundus*	CHRRI	Black-headed gull (gabbiano comune)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
8	*Hydrocoloeus minutus*	HYDMI	Little gull (gabbianello)					X																															
8	*Hydroprogne caspia*	HYDCA	Caspian tern (sterna maggiore)			X																																	
8	*Larus canus*	LARCA	Common gull (gavina)			X																																	
8	*Larus melanocephalus*	LARME	Mediterranean gull (gabbiano corallino)																	X														X					
8	*Sterna hirundo*	STEHI	Common tern (sterna comune)						X										X			X										X	X	X	X				
9	*Actitis hypoleucos*	ACTHY	Common sandpiper (piro piro piccolo)							X		X					X					X	X	X			X							X					
9	*Calidris alpina*	CALAL	Dunlin (piovanello pancianera)		X							X		X		X																					X		

9	*Calidris canutus*	CALCA	Knot (piovanello maggiore)															X																					
9	*Charadrius dubius*	CHADU	Little ringed plover (corriere piccolo)			X																									X			X					
9	*Gallinago gallinago*	GALGA	Snipe (beccaccino)																							X													
9	*Haematopus ostralegus*	HAEOS	Oystercatcher (beccaccia di mare)		X	X	X	X	X	X								X	X	X	X	X		X						X	X	X		X					
9	*Himantopus himantopus*	HIMHI	Black-winged stilt (cavaliere d' italia)			X	X	X	X									X													X								
9	*Limicola sp.*	LIMSP	Unidentified waders			X	X																								X				X				
9	*Numenius arquata*	NUMAR	Curlew (chiurlo maggiore)									X		X									X	X	X	X	X	X			X		X		X	X	X		
9	*Philomachus pugnax*	PHIPU	Ruff (combattente)		X	X	X																																
9	*Pluvialis squatarola*	PLUSQ	Grey plover (pivieressa)	X	X											X			X												X								
9	*Recurvirostra avosetta*	RECAV	Pied avocet (avocetta)		X	X	X	X	X					X																									X
9	*Tringa erythropus*	TRIER	Spotted redshank (totano moro)				X										X		X												X						X		
9	*Tringa nebularia*	TRINE	Common greenshank (pantana)	X	X	X	X				X	X	X	X		X	X	X	X		X	X	X	X	X		X	X			X			X	X	X	X	X	
9	*Tringa ochropus*	TRIOC	Green sandpiper (piro piro culbianco)																					X							X								
9	*Tringa totanus*	TRITO	Common redshank (pettegola)																												X								
9	*Vanellus vanellus*	VANVA	Northern lapwing (pavoncella)												X								X																
10	*Columba livia*	COLLI	Rock doves (piccione selvatico)	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X		X
10	*Columba palumbus*	COLPA	Wood pigeon (colombaccio)					X										X	X	X		X	X					X			X	X	X			X			
10	*Streptopelia decaocto*	STRDE	Collared dove (tortora dal collare)			X																		X						X				X					
10	*Streptopelia turtur*	STRTU	Turtle dove (tortora selvatico)																			X																	
11	*Athene noctua*	ATHNO	Little owl (civetta)																														X						
12	*Apus apus*	APUAP	Common swift (rondone comune)				X	X	X										X	X	X							X			X	X	X						

12	*Delichon urbicum*	DELUR	House martin (balestruccio)			X	X	X	X	X	X							X	X	X	X	X					X		X	X	X	X	X	X				
12	*Hirundo rustica*	HIRRU	Barn swallow (rondine)			X	X	X	X	X	X							X	X	X	X	X	X							X	X		X	X	X				
13	*Corvus cornix*	CORCO	Hooded crow (cornacchia)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
13	*Pica pica*	PICPI	Magpie (gazza)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
14	*Anthus spinoletta*	ANTSP	Water pipit (spioncello)		X																					X													
14	*Cettia cetti*	CETCE	Cetti's warbler (usignolo di fiume)															X																					
14	*Cuculus canorus*	CUCCA	Cukoo (cuculo)																													X		X					
14	*Emberiza calandra*	EMBCA	Corn bunting (strillozzo)			X		X										X			X									X	X	X							
14	*Emberiza schoeniclus*	EMBSC	Reed bunting (migliarino di palude)																										X										
14	*Erithacus rubecula*	ERIRU	Robin (pettirosso)									X																											
14	*Motacilla alba*	MOTAL	White wagtail (ballerina bianca)	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
14	*Oenanthe oenanthe*	OENOE	Green sandpiper (culbianco)									X												X							X				X				
14	*Passer sp.*	PASSP	Unidentified passerines			X										X											X											X	
14	*Picus viridis*	PICVI	Green woodpecker (picchio verde)																			X																	
14	*Turdus merula*	TURME	Blackbird (merlo)			X		X								X		X	X	X							X				X	X						X	X
14	*Upupa epops*	UPUEP	Hoopoe (upupa)																			X																	
15	*Alauda arvensis*	ALAAR	Lark (allodola)		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X			X		X
15	*Anthus pratensis*	ANTPR	Meadow pipit (pispola)	X		X							X		X	X									X	X											X	X	
15	*Carduelis carduelis*	CARCA	European goldfinch (cardellino)																																			X	
15	*Carduelis spinus*	CARSP	Eurasian siskin (lucherino)		X																																X		
15	*Fringilla coelebs*	FRICO	Chaffinch (fringuello)																																		X		
15	*Merops apiaster*	MERAP	Bee-eater (gruccione)								X																												
15	*Motacilla flava*	MOTFL	Yellow wagtail (cutrettola)								X												X									X							
15	*Passer italiae*	PASIT	Italian sparrow		X		X	X	X								X	X			X	X	X	X						X	X		X		X			X	

			(passera d'Italia)																																				
15	*Sturnus vulgaris*	STUVU	Starling (storno)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
16	*Oryctolagus cuniculus*	ORYCU	Rabbit (coniglio)																													X							
16	*Lepus europaeus*	LEPEU	Hare (lepri)		X	X	X	X	X	X					X	X	X	X	X	X	X	X								X		X	X	X	X				
16	*Myocastor coypus*	MYOCO	Nutria (nutria)														X										X												
16	*Vulpes vulpes*	VULVU	Fox (volpe)																												X								
17	*Meles meles*	MELME	Badger (tasso)																						X														

Table 3.4.1.1: Checklist of the species registered at VCE airport from January 2010 to December 2012

3.4.1.2 TSF

At TSF a total amount of 66 species has been recorded. Of these, 5 species were detected at airport during the whole study period (i.e. rock doves, wood pigeons, *Columba palumbus*, collared dove, *Streptopelia decaocto*, hooded crow, and magpies). A nearly constant presence of kestrels, yellow-legged gulls, black-headed gulls, larks, sparrows, *Passer domesticus*, and starlings was registered. A fair presence of aquatic species was also observed at airport. Waterfowls were mainly found along the south side of the airfield, in the areas close to the Sile river and lakes. Mammals were frequently sighted within the airport area, in particular hares and cats, while a single sighting of a big dog (> 10 Kg) occurred during the entire study period.

The checklist of the species recorded at TSF in the study period is shown in the following table. Again, the identification code of the groups of species is reported in the first column of the table.

ID group	Scientific name	short code	Common English (and Italian) name	2010								2011				airport closed	2012											
				May	June	July	August	September	October	November	December	January	February	March	April		January	February	March	April	May	June	July	August	September	October	November	December
2	*Cygnus columbianus*	CYGCO	Tundra Swan (cigno minore)																X	X	X						X	
2	*Cygnus olor*	CYGOL	Mute swan (cigno reale)							X					X		X	X						X	X			
2	*Phalacrocorax carbo*	PHACA	Cormorant (cormorano)					X	X	X	X	X	X	X			X	X	X	X				X	X	X	X	X
2	*Phalacrocorax pygmeus*	PHAPY	Pygmy cormorant (marangone minore)																		X							
3	*Ardea cinerea*	ARDCI	Grey heron (airone cenerino)	X	X	X			X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
3	*Bubulcus ibis*	BUBIB	Cattle egret (airone guardabuoi)	X	X					X		X	X	X				X				X	X			X	X	
3	*Casmerodius albus*	CASAL	Great egret (airone bianco maggiore)										X		X				X				X					
3	*Egretta garzetta*	EGRGA	Little egret (garzetta)	X	X				X	X					X						X	X	X	X	X		X	X
4	*Anas platyrhynchos*	ANAPL	Mallard (germano reale)	X		X	X	X			X		X	X	X		X		X	X	X	X	X	X	X	X		X
4	*Anas sp.*	ANASP	Unidentified ducks											X	X													
4	*Fulica atra*	FULAT	Eurasian Coot (folaga)																	X								
4	*Phasianus colchicus*	PHACO	Common pheasant (fagiano comune)		X			X						X	X			X	X	X	X	X	X	X	X	X	X	X
4	*Tadorna tadorna*	TADTA	Shelduck (volpoca)																		X							
5	*Buteo buteo*	BUTBU	Common buzzard (poiana)					X		X	X	X	X	X			X	X	X	X	X			X	X	X	X	X
5	*Circus aeruginosus*	CIRAE	Western marsh harrier (falco di palude)	X																								
5	*Circus cyaneus*	CIRCY	Hen harrier (albanella reale)																	X								
5	*Circus pygargus*	CIRPY	Montagu's harrier (albanella minore)																	X								
6	*Accipiter nisus*	ACCNI	Eurasian Sparrowhawk (sparviere)								X						X						X			X		
6	*Falco tinnunculus*	FALTI	Kestrel (gheppio)	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X
7	*Larus michahellis*	LARMI	Yellow-legged gull (gabbiano reale)	X				X		X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X
8	*Chroicocephalus ridibundus*	CHRRI	Black-headed gull (gabbiano comune)		X			X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X
8	*Larus melanocephalus*	LARME	Mediterranean gull (gabbiano																				X					

			corallino)																									
9	*Calidris temminckii*	CALTE	Temminck's Stint (gambecchio nano)																		X							
9	*Tringa glareola*	TRIGL	Wood Sandpiper (piro piro boscherecchio)																	X								
10	*Columba livia*	COLLI	Rock doves (piccione selvatico)	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
10	*Columba palumbus*	COLPA	Wood pigeon (colombaccio)	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
10	*Streptopelia decaocto*	STRDE	Collared dove (tortora dal collare)	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
10	*Streptopelia turtur*	STRTU	Turtle dove (tortora selvatico)																			X						
12	*Apus apus*	APUAP	Common swift (rondone commune)	X		X									X					X	X	X	X	X				
12	*Delichon urbicum*	DELUR	House martin (balestruccio)	X	X	X	X													X	X	X	X	X				
12	*Hirundo rustica*	HIRRU	Barn swallow (rondine)	X	X	X	X								X				X	X	X	X	X	X	X			
12	*Ptyonoprogne rupestris*	PTYRU	Eurasian Crag Martin (rondine montana)							X				X	X			X	X	X	X	X	X	X		X		
12	*Riparia riparia*	RIPRI	Sand Martin (topino)																				X					
13	*Corvus cornix*	CORCO	Hooded crow (cornacchia)	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
13	*Garrulus glandarius*	GARGL	Jay (ghiandaia)			X	X	X									X	X			X	X		X				
13	*Pica pica*	PICPI	Magpie (gazza)	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
14	*Cettia cetti*	CETCE	Cetti's warbler (usignolo di fiume)																X									
14	*Emberiza calandra*	EMBCA	Corn bunting (strillozzo)	X											X													
14	*Emberiza schoeniclus*	EMBSC	Reed bunting (migliarino di palude)										X														X	
14	*Erithacus rubecula*	ERIRU	Robin (pettirosso)														X		X						X	X	X	
14	*Lanius collurio*	LANCO	Red-backed Shrike (averla piccola)			X																						
14	*Monticola solitarius*	MONSO	blue rock thrush (passero solitario)	X	X																							
14	*Motacilla alba*	MOTAL	White wagtail (ballerina bianca)										X				X		X	X		X	X	X	X	X	X	X
14	*Oenanthe oenanthe*	OENOE	Green sandpiper (culbianco)																					X				
14	*Passer sp.*	PASSP	Unidentified passerines		X							X	X	X	X		X	X	X	X			X	X			X	X
14	*Phoenicurus ochruros*	PHOOC	Black Redstart (codirosso spazzacamino)							X																	X	
14	*Picus canus*	PICCA	Grey-headed Woodpecker (picchio cenerino)																X									
14	*Picus viridis*	PICVI	Green woodpecker (picchio							X	X	X			X				X				X	X		X		

			verde)																									
14	*Regulus regulus*	REGRE	Goldcrest (regolo)																							X	X	
14	*Saxicola rubetra*	SAXRU	Whinchat (stiaccino)	X				X													X							
14	*Saxicola torquatus*	SAXTO	Common stonechat (saltimpalo)				X						X		X													
14	*Troglodytes troglodytes*	TROTR	Eurasian Wren (scricciolo)								X																	
14	*Turdus merula*	TURME	Blackbird (merlo)	X		X			X					X	X				X	X	X	X	X			X		X
15	*Alauda arvensis*	ALAAR	Lark (allodola)	X	X	X	X	X	X	X	X		X	X	X			X	X	X	X	X		X	X	X	X	X
15	*Anthus pratensis*	ANTPR	Meadow pipit (pispola)								X	X																X
15	*Anthus trivialis*	ANTTR	Tree pipit (prispolone)					X																	X			
15	*Carduelis cannabina*	CARCA	Linnet (fanello)																							X	X	
15	*Carduelis carduelis*	CARCA	European goldfinch (cardellino)					X					X															
15	*Carduelis chloris*	CARCH	European Greenfinch (verdone)														X			X	X							
15	*Fringilla coelebs*	FRICO	Chaffinch (fringuello)										X	X				X										
15	*Galerida cristata*	GALCR	Crested Lark (cappellaccia)						X					X														
15	*Passer italiae*	PASIT	Italian sparrow (passera d'italia)	X	X	X	X	X	X	X	X				X			X	X	X	X	X	X	X	X	X	X	X
15	*Sturnus vulgaris*	STUVU	Starling (storno)	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X
16	*Felis silvestris catus*	FELCA	Cat (gatto)																X		X	X	X	X		X		
16	*Lepus europaeus*	LEPEU	Hare (lepri)	X	X	X	X								X			X	X	X	X	X	X	X			X	
17	*Canis lupus familiaris*	CANLU	Dog (cane)																					X				

Table 3.4.1.2: Checklist of the species registered at TSF from the beginning of the monitoring activity at airport in May 2010 to December 2012.

3.4.2 Seasonal trend and use of the habitat

As previously reported, the activity trend during daytime of different periods has been investigated for each of the recorded groups of species. Information on wildlife peaks of presence at airport are fundamental in order to improve the efficiency of wildlife control on the aerodrome and help to manage and keep under control the risk of wildlife strike. Wildlife abundance on the five main categories of airport habitats was also studied in order to define the most attractive one and thus potentially the most hazardous for aviation. In the following paragraphs, two summary graphs for each of the studied airport are presented. The first graph shows the seasonal trend of the groups of species registered at airport during wintering, spring migration, breeding and fall migration periods. The second one outlines the airport habitat exploitation by the functional groups. The latter shows only individuals detected while lying on the ground and not those recorded in flight. Detailed graphs for each of the group of species are reported in annex I. Graphs in annex I show the abundance of individuals during the four biological periods in relation to the number of hours from dawn.

3.4.2.1 VCE

The most abundant groups of species detected at VCE airport were the flocking passerines (group 15), mainly represented by the starlings, the small (group 8) and large (group 7) seabirds, essentially constituted by the black-headed gull and the yellow-legged gull respectively and the group 4, almost entirely formed by mallards and shelducks. Although these functional groups were detected at airport during the four biological periods, flocking passerines registered the higher peak of presence during autumn migration, while large and small seabirds were more abundant during the breeding period. Regarding ducks, a higher amount of individuals was found during spring and winter seasons.

Several species representative for the groups 1, 2, 3, 10 and 13 were also present at airport throughout the year but in lower quantities. Group 12 is formed by long-distance migrant species which breed in the study area and winter in Africa. As expected, species belonging to this group were detected at airport only during spring and summer seasons. Regarding the use of the habitat (Figure 3.4.2.1 b) groups 1, 3, 4, 7 and 8 were closely linked to the aquatic environment in all the phases of their biological cycle. On the contrary, flocking passerines, corvids, swifts and swallows were primarily attracted by meadows surrounding runways, where they could find insects and other invertebrates for feeding and in the case of passerines a shelter from predators. Finally, doves were mainly registered while roosting on meadows and in the airport buildings.

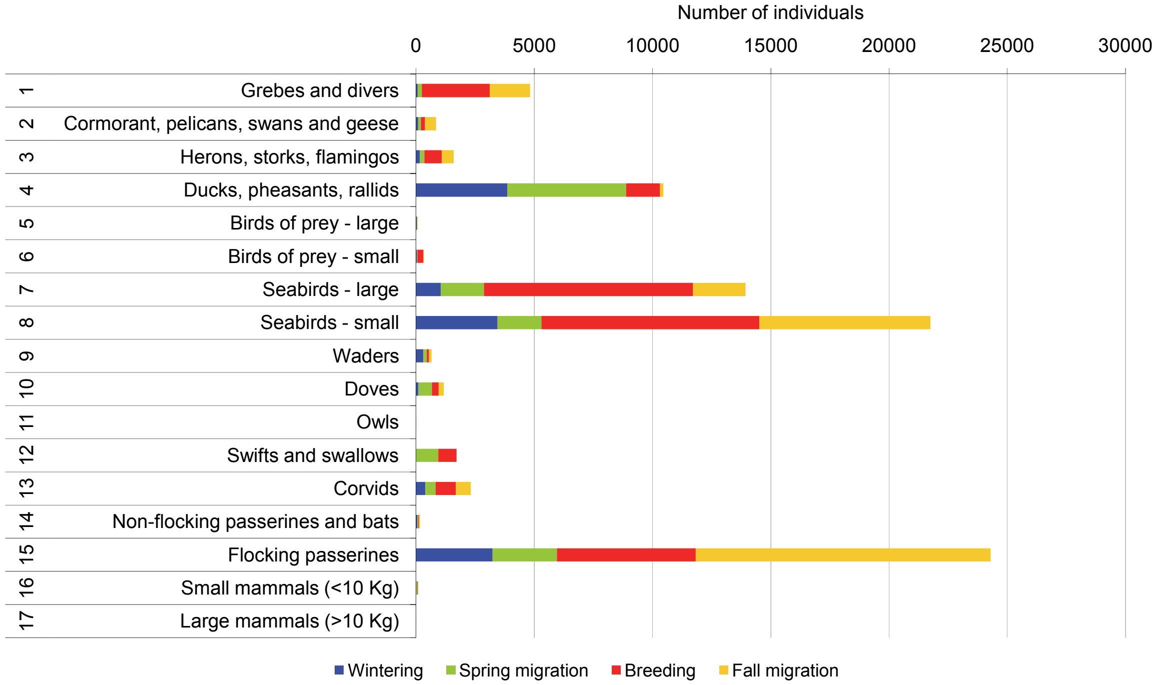


Figure 3.4.2.1 a: Seasonal trend of the groups of species recorded at VCE from January 2011 to December 2012.

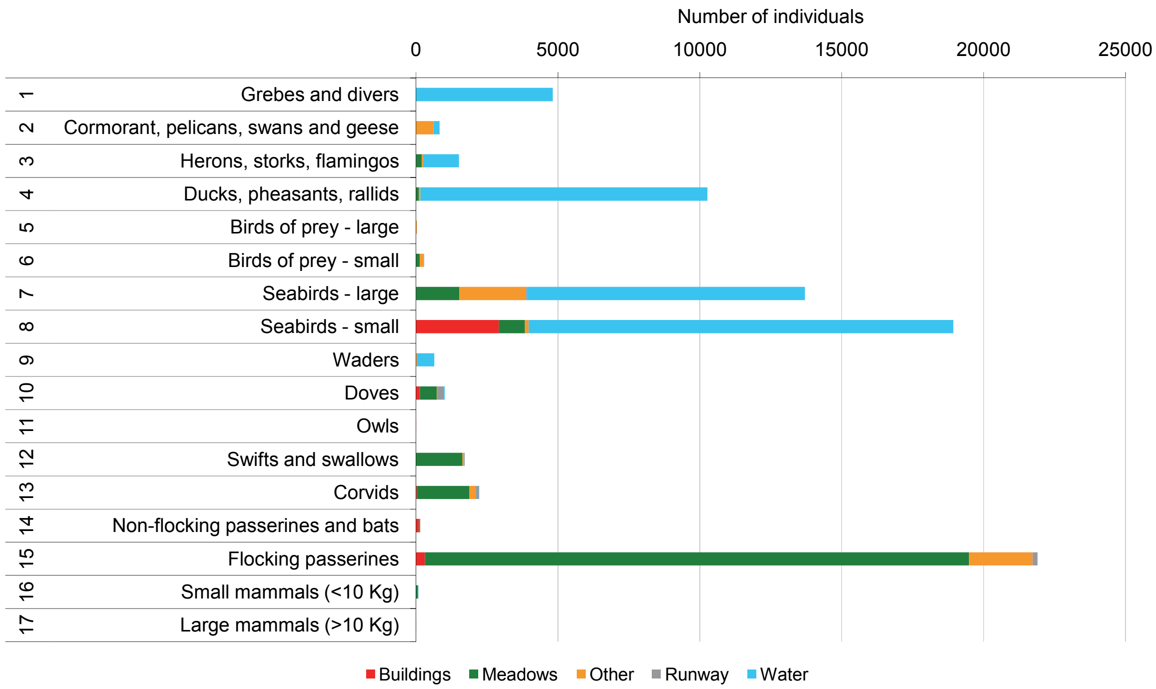


Figure 3.4.2.1 b: Distribution of the groups of species recorded at VCE from January 2011 to December 2012 in the five main airport habitats.

3.4.2.2 TSF

During the study period, four groups of species were by far the most abundant at TSF airport. Flocking passerines group - the most part of it represented by starlings - had the higher amount of individuals, followed by doves, corvids, swifts and swallows. Flocking passerines showed a peak of presence in the breeding and fall migration periods, doves and corvids were almost equally present at airport during each of the four biological phases while the presence of swifts and swallows was almost entirely registered in spring and summer seasons with some sightings in autumn, during migration for wintering in Africa. The other groups of species detected at airport in the study period showed lower quantities of individuals.

Regarding the use of the habitat (Figure 3.4.2.2 b) flocking passerines, corvids, swifts and swallows primarily attended meadows surrounding runways for feeding and roosting, while doves were mostly registered on the airport buildings while roosting, sunning and breeding or on the headlights of the air terminal, on the fence along airport perimeter and sometimes on the runway.

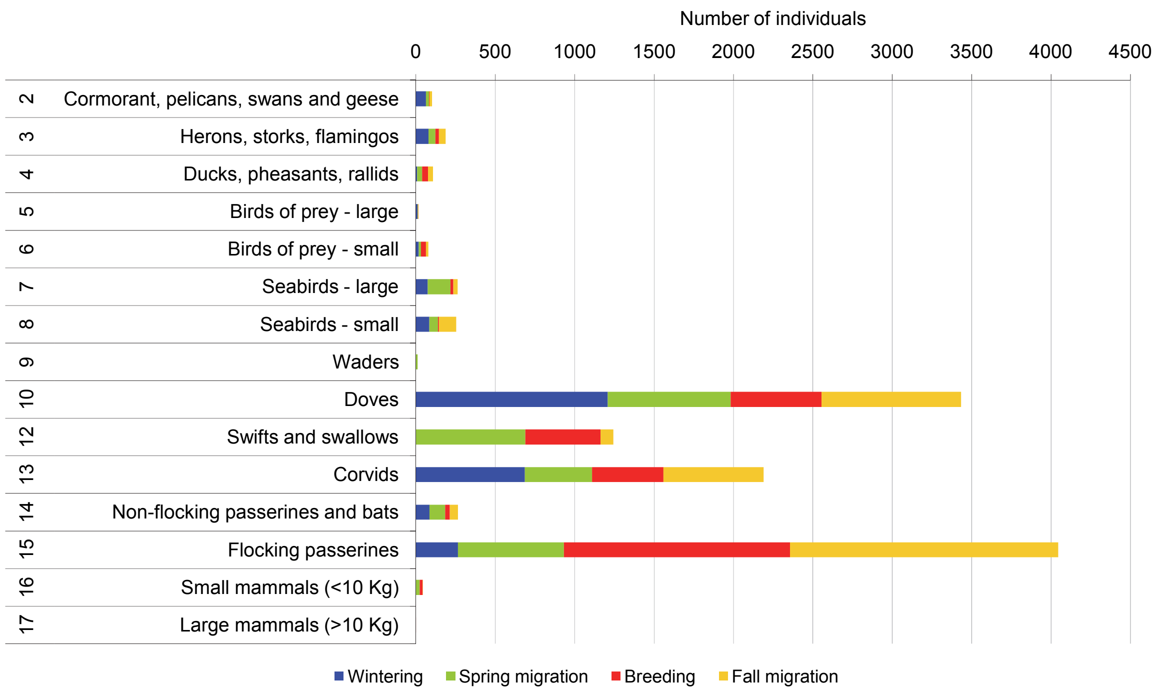


Figure 3.4.2.2 a: Seasonal trend of the groups of species recorded at TSF from January 2011 to December 2012.

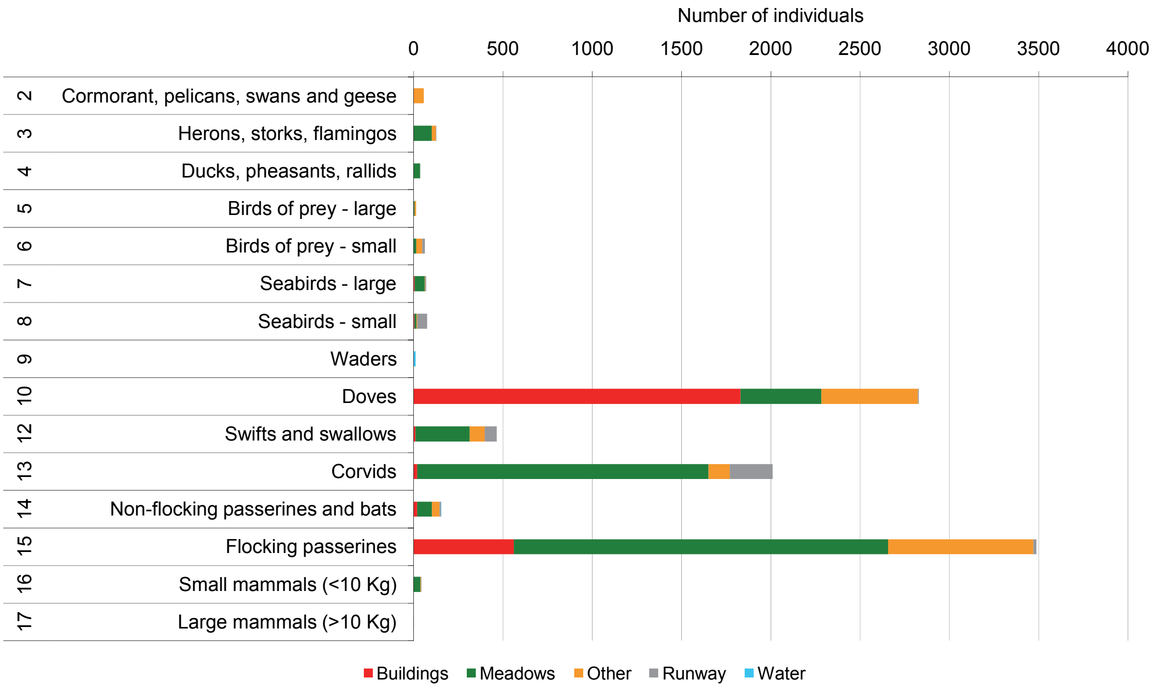


Figure 3.4.2.2 b: Distribution of the groups of species recorded at TSF from January 2011 to December 2012 in the five main airport habitats.

3.4.3 Seasonal distribution of the functional groups of species

The seasonal distribution of the groups of species recorded at the studied airports from January to December 2012 has been also studied. The Geographical Information System (GIS) was used to map the abundance of the functional groups during the different periods of the year (i.e. wintering, spring migration, breeding and fall migration). Therefore, four maps for each group of species have been elaborated. To realize these maps, the geo-referenced grids used during the wildlife monitoring activities at airports and reported in paragraph 3.2 (Figs. 3.2 a and b) were used as reference. Information from this study are particularly needed in order to define the airport areas with a higher concentration of wildlife during the specific phases of their biological cycle and thus the areas on which strict controls are highly recommended in order to prevent the risk of wildlife strike.

Detailed maps referring to each group of species recorded at VCE and TSF in the study period are reported in annex II. In the following paragraphs, four summary maps for each of the studied airport are presented. These summary maps show - through pie charts - the percentage composition of the species groups attending particular areas of the airports, over different periods.

3.4.3.1 VCE

Results from the summary maps in figure 3.4.3.1 show that in winter time the sensible area of the airport, where the runways are (C and D zones), was mainly attended by flocking passerines (group 15), corvids (group 13) and doves (group 10). Areas overlooking the Venice lagoon (zone E) were mostly attended by the species of group 4 (e.g. mallards and shelducks), black-headed gulls (group 8) and, although in minor percentage, yellow-legged gulls (group 7) and herons (group 3). The latter group was almost entirely registered in the portions of salt-marsh in the north-east side of the airfield.

During spring migration a conspicuous presence of swifts and swallows (group 12) has been registered in the C and D zones. These migratory species were sighted primarily while flying over the fields surrounding the runways, in search of insects. Flocking passerines, mainly consisting of starlings, doves, corvids and non-flocking passerines such as the white wagtail and the blackbird (group 14) were also recorded in the sensible zone. As in winter time, zone E was almost entirely attended by waterfowls such as ducks and waders (group 9), followed by black-headed gulls and yellow-legged gulls. The latter two species were also found respectively in C8 and D7, while flying over the fields. In these quadrants gulls were observed especially on rainy days.

In the breeding season, as previously cited (see par. 3.4.2.1), a peak of presence of gulls has been registered. Gulls were found not only while feeding or roosting in the water areas along the Venice lagoon, but also while exploiting the runways and fields around them in search of insects and other invertebrates for feeding themselves and their offspring. In this period a significant presence of grebes (group 1) and herons (e.g. grey heron and egret) was also found in the areas bordering the lagoon.

During fall migration, a large amount of yellow-legged gulls and black-headed gulls was observed in the whole airport area. In this period, gulls were primarily sighted in circular flight above runways and meadows or in large flocks towards inland, probably to reach the numerous attractive sources located in that areas (e.g. landfills, fish farms, agricultural fields). Flocking passerines and corvids were also quite abundant in the C and D zones while herons, grebes and cormorants (group 2) primarily attended the water and salt-marsh areas in zones D10 and E.

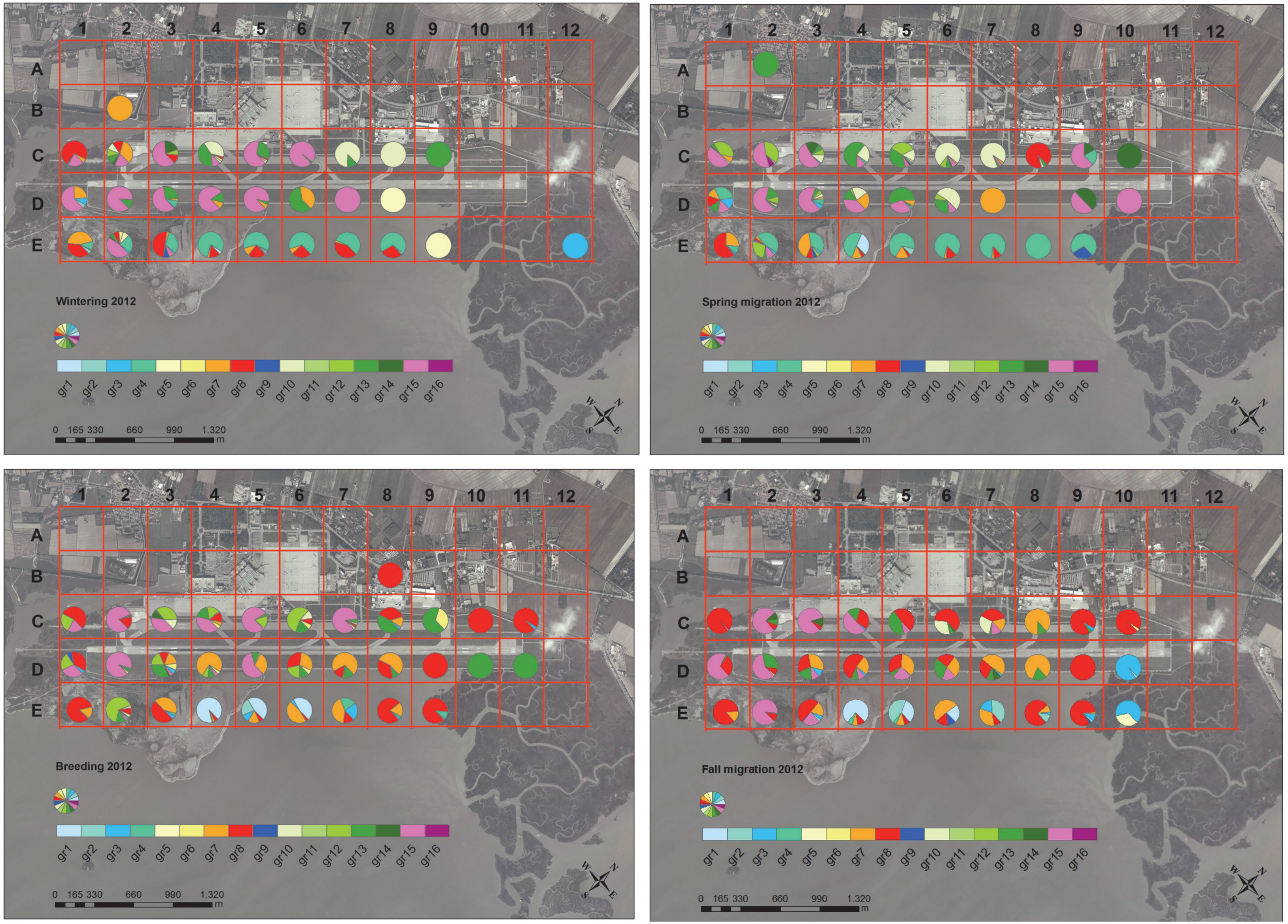


Figure 3.4.3.1: Seasonal distribution of the species groups recorded at VCE from January to December 2012.

3.4.3.2 TSF

The seasonal distribution of the groups of species recorded at TSF in the study period (from January to December 2012) is reported in figure 3.4.3.2. Results from the cartographic elaborations highlight that in winter time the runway area is primarily exploited by corvids (group 13), doves (group 10), flocking passerines (group 15) and, although in smaller percentage, by large and small seabirds (i.e. yellow-legged gulls and black-headed gulls). Individuals of waterfowl species belonging to groups 2 (cormorants and mute swans) and 3 (grey herons and egrets) were registered in the quadrants G2 to G4, as close to the lakes of the River Sile Regional Natural Park, while a significant percentage of blackbirds and white wagtails (group 14) was found in quadrant G1. Doves and starlings were detected at airport in the whole year, primarily in the F zone while roosting on the air terminal or on the roofs of hangars. A considerable presence of gulls was detected in wintering and spring migration periods in quadrants F6-F7, the most part of them while crossing the airport area towards north-west. In spring and summer seasons, a large amount of swifts and swallows has been registered in the entire airport area, especially in the G zone while flying over the fields around runway for feeding on insects. Finally, during fall migration a great extent of starlings was found in the F5-F7 and G5-G7 zones while corvids, wood pigeons and doves, herons, black-headed gulls and a small percentage of mallards were found in the rest part of the airfield.

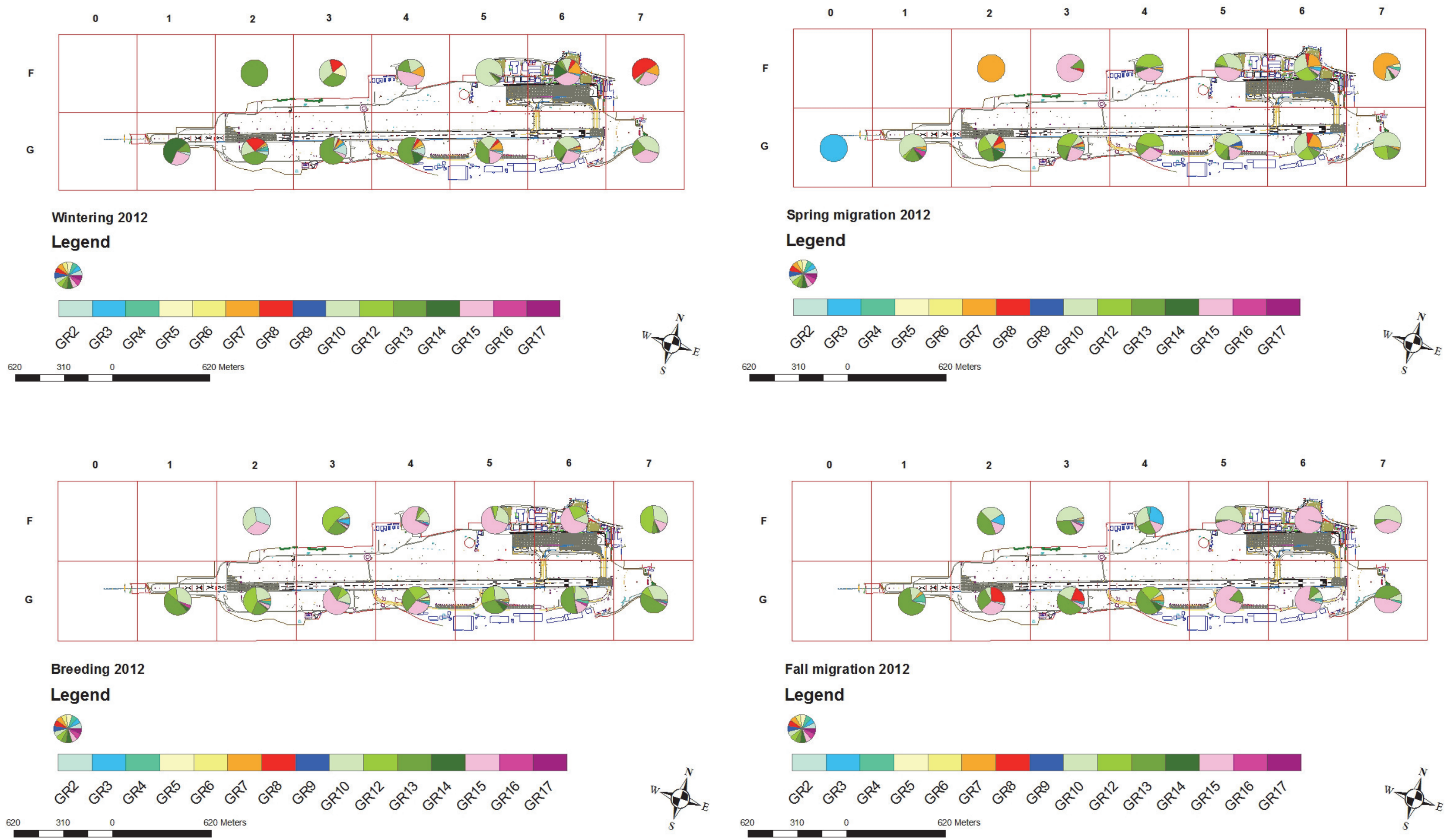


Figure 3.4.3.2: Seasonal distribution of the groups of species recorded at TSF from January to December 2012.

4. Analysis of the sources potentially attractive for wildlife

4.1 Ecological assessment

According to ICAO Annex 14 and ENAC guidelines [(54)], an environmental assessment within the studied airports and in a buffer area of 13 Km from them has been performed in order to identify the attractive sources for wildlife, as potentially hazardous for aviation. The 13 Km buffer is based on the statistic that 99% of birdstrikes occur below 2000 ft (=609 m) and that an aircraft on a normal approach would descend into this buffer approximately at this distance from the runway [(55)]. Therefore the presence of attractive sources in this spatial range could lead to the occurrence of birds-aircrafts collisions. ENAC recommends as attractive for wildlife three main categories of sources: 1) *wetlands* 2) *vegetation* and 3) *humans' activities and man-made structures*.

The first category of attractive sources includes the following elements:

- Sewage plants
- Lakes and water basins (natural and artificial)
- Rivers and channels
- Fish farms
- Protected natural areas (SCI and SPA)

The second category includes:

- Urban parks and gardens
- Agricultural fields
- Meadows

The third category includes:

- Landfills[3] [(56, 57)]
- Animal farms
- Industrial areas
- Airports

The *Corine Land Cover* (*Coordination of Information on the Environment Land Cover, CLC*) was used to extract information on land cover of the study areas and the *Geographical Information System (GIS)* was used to map the identified attractive sources with their geo-referenced locations. Given the intricate branching of channels and small rivers present in the study areas, this category was not transferred into the maps in order to facilitate their comprehension.

---

[3] Municipality Solid Waste (MSW); landfills for sanitary and veterinary wastes, waste transfer stations; and post-closure landfills.

As previously reported, the analysis of wildlife-attractant sources within the airport area have been also performed in order to define the suitable actions needed to keep under control and prevent the wildlife strike risk. Airports offer a large variety of habitats to wildlife. One of the primary characteristics of an aerodrome is the presence of extended open terrains such as the grasslands surrounding the runways and the large paved surfaces. Both these features are extremely attractive to wildlife. Regarding meadows, many bird species (e.g. starlings, blackbirds, swifts and swallows) depend on earthworms, snails and other insects, thus they usually exploit these areas in search of them. Grasslands are also exploited by predators for feeding on reptiles, amphibians or small mammals (e.g. rodents or rabbits). Furthermore, several very common plants growing among the grass (e.g. *Trifolium spp.*, *Taraxacum officinale*, *Stellaria media* etc) constitute food for pigeons, game birds (e.g. quails, pheasants, mallards), finches and some passerine species. Therefore, in order to reduce the attractiveness of grasslands and avoid the wildlife attendance on it, a correct use of herbicides and insecticides should be done. Grasslands and paved surfaces are also attended by birds as the unobstructed view and open space provides them shelter and protection from predators and for flocking species a mutual protection. In order to make the fields unsafe for birds and impede the gregarious nature of flocking species, the grass should be maintained at an height of 20-30 cm [(36)]. Another airport habitat highly attractive to birds is represented by the buildings and other installations such as radar towers, aerodrome lighting gantries, electricity distribution pylons and airport enclosures. Airport buildings (e.g. air terminal and hangars) are mostly used by pest species such as doves and starlings or swallows for roosting, sunning or nesting, while the other structures are attended by numerous species for perching, especially by birds of prey. Bushes, hedgerows and trees are also attractant for birds as provide food and shelter for nesting and roosting. Finally, open standing water such as ponds or basins attract waterfowls (e.g. ducks, herons, cormorants) and other bird species for drinking.

4.2 Mapping of the attractive sources for wildlife

In the following paragraphs two thematic maps for each of the studied airports are presented. The first map shows the attractive sources identified within a buffer area of 13 Km from the target airport, while the second one presents the attractive elements present within the airfield and in the areas adjacent it. Maps were realized with ArcGIS 9.3.

4.2.1 VCE

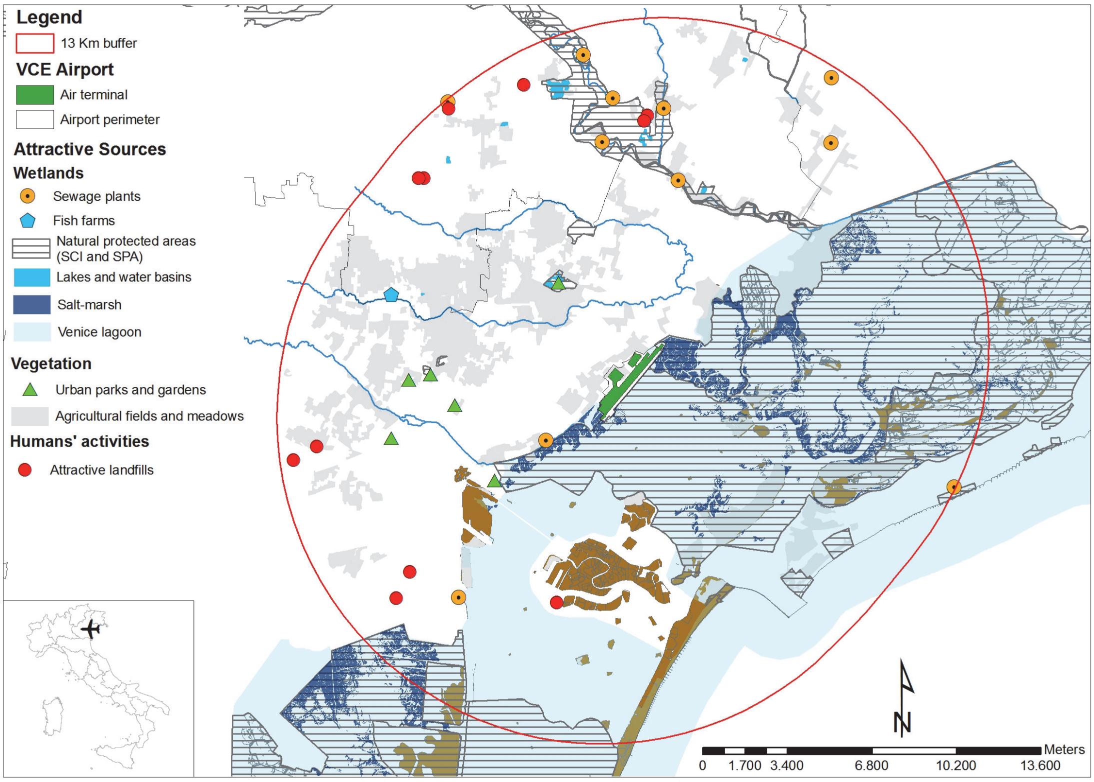


Figure 4.2.1 a: Map of the attractive sources for wildlife within a 13 Km buffer from VCE airport.

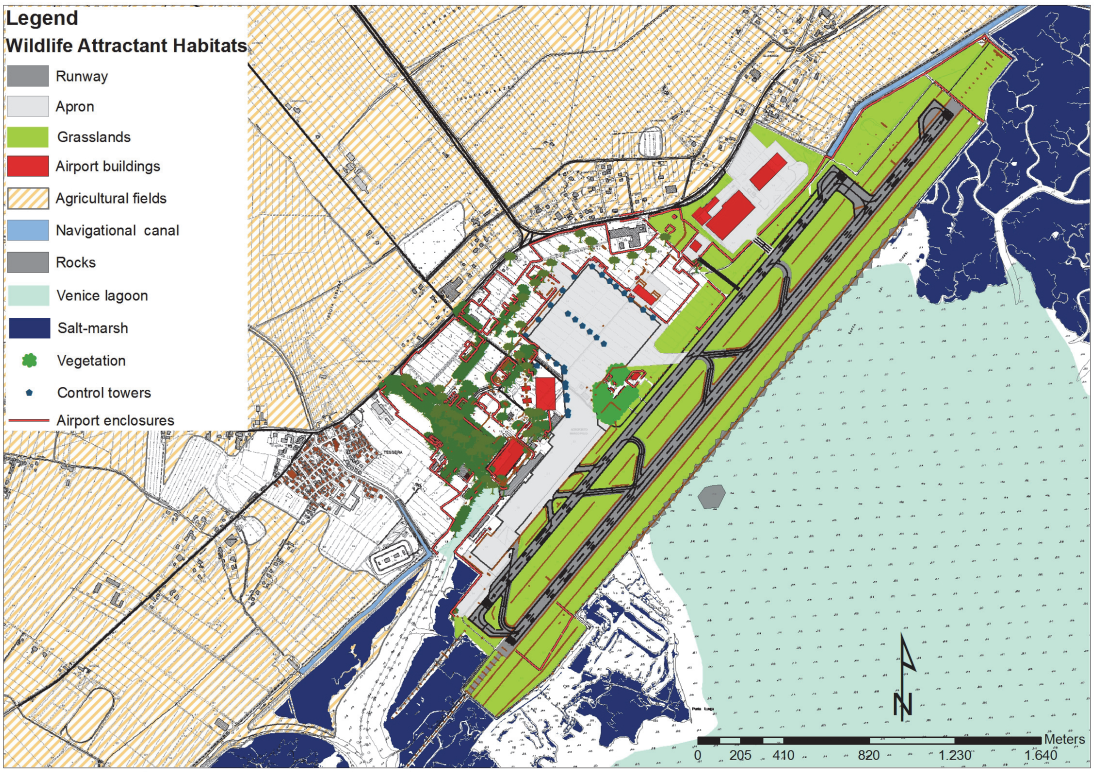


Figure 4.2.1 b: Map of the attractive sources within the airport area and in the areas adjacent it.

4.2.2 TSF

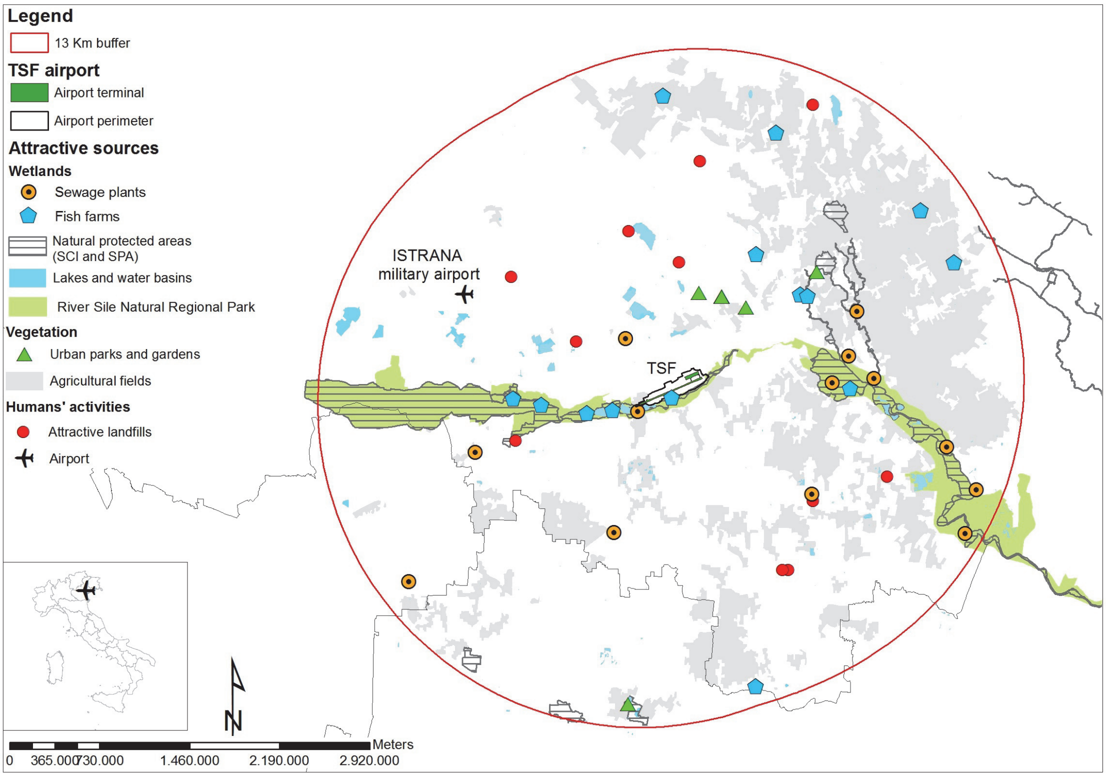


Figure 4.2.2 a: Map of the attractive sources for wildlife within a 13 Km buffer from TSF airport.

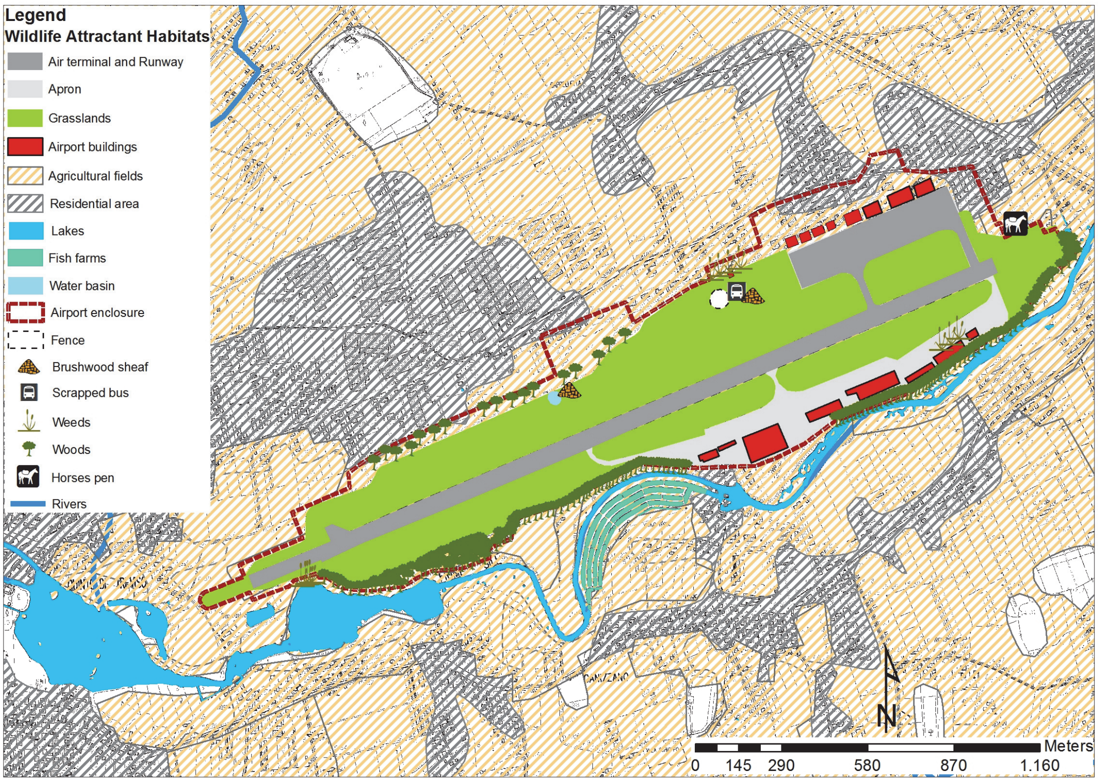


Figure 4.2.2 b: Map of the attractive sources within the airport area and in the areas adjacent it.

5. Wildlife strike risk analysis by the application of the Birdstrike Risk Index BRI2

5.1 Introduction

The Birstrike Risk Index BRI2 developed by Soldatini and colleagues in 2011 and adopted by ENAC as a national standard in APT 01B [48, 36], is a tool capable of describing the wildlife strike risk at a given airport in a specific period.

In order to calculate the BRI2 index the following factors have to be considered:

- the average weight (*W*) and the average number of individuals (*Ag*) of each species group recorded in the study airport (see table 3.3.1 in par. 3.3);
- the mean number of impacts per year recorded for each specific group (*BS*);
- the mean number of flights per year *(TFN)*;
- the effect on flight (*EOF*) caused by the impacts.

According to ICAO and ENAC guidelines, EOF is defined as the effect of wildlife strike on the aircraft and includes five main categories of severity, from no effects to catastrophic ones (table 5.1). In order to use a conservative approach, BRI2 considers the 95th percentile EOF recorded for each species group (EOF^{95}).

EOF value	Category	Description
1	None	None
2	Minor	Delay
3	Substantial	Precautionary landing, aborted take-off
4	Serious	Engine (s) shutdown, forced landing, vision obscured
5	Catastrophic	Damage sustained makes it inadvisable to restore aircraft

Table 5.1: Categories of the effect on flight (EOF) provoked by wildlife strikes.

The above described variables are combined in the following equation which describes the pattern and history of a specific group of species *k*.

Equation 1:

$$GF_k = W_k \cdot Ag_k \cdot \frac{BS_k}{TFN} \cdot EOF_k^{95}$$

In order to define the wildlife strike risk posed by each specific group of species, the standardized GF_k is multiplied by the mean daily number of individuals of the *k* group during the study period (DB_k), leading to equation 2:

$$GSR_k = \frac{GF_k}{\sum_{k=1,N} GF_k} \cdot DB_k$$

where N is equal to the total number of the functional groups of species present in the study airport.

Finally, the BRI2 index is obtained by multiplying the GSR_k by the mean daily flight traffic calculated on a monthly basis (*DF*) and dividing it by the monthly average of flights per year ($\overline{TFN}$).

Equation 3:

$$BRI2 = \left(\frac{\sum_{k=1,N} GSR_k \cdot DF}{\overline{TFN}} \right)$$

Therefore, the BRI2 index assesses the risk of wildlife strike basing on the historical trend of wildlife observations, air traffic and impacts recorded at a given airport, in order to identify the periods of the year critical to aviation.

5.2 Data analysis

In order to assess the wildlife strike risk at the studied airports and allow for comparisons between them, the BRI2 algorithm has been calculated. The BRI2 was applied to data on air traffic and wildlife presence recorded at airports from January 2010 to December 2012 and considering the wildlife strikes occurred up to an altitude of 300 ft (=91.44 m) from 2003 to 2012 at VCE and from 2008 to 2012 at TSF. The wildlife presence data came from the monitoring activities performed at airports, while the aircraft movement data and the wildlife strike data were provided from the SAVE airport authority. Furthermore, in order to compare the risk path expected by BRI2 with the strikes history registered at airports in the study period, a detailed analysis of the wildlife strikes occurred from 2003 to 2012 at VCE and from 2008 to 2012 at TSF has been performed. A summary of the data used for the analysis is reported in table 5.2.

Airport	Air traffic data (years)	Wildlife data (years)	Wildlife strike data (years)
VCE	2010-2012	2010-2012	2003-2012
TSF	2010-2012	2010-2012	2008-2012

Table 5.2: Time series data available for the wildlife strike risk analysis performed at VCE and TSF airports.

5.3 Results

Results obtained from the application of the BRI2 index to the studied airports are depicted in figure 5.3.1. The BRI2 shows a clear seasonal trend with higher values in late summer months at VCE, while in summer (June-July) at TSF. Table 5.3.1 reports the BRI2 monthly scores during the three years of study for both the airports and highlights the values above the attention threshold, which is set at BRI2=0.5. Regarding TSF, the risk was acceptable during the whole study period, except for

June 2010 when a BRI2 of 0.52 has been detected. This higher risk value is attributable to the breeding period associated to a considerable number of impacts occurred with hazardous species such as black-headed gulls (group 8) and crows (group 13). Regarding VCE, peaks in BRI2 scores are due to the fall migration movements in association to the large presence of juveniles of migratory species, gulls and kestrels which have a higher probability of collision with aircrafts, because of their inexperience.

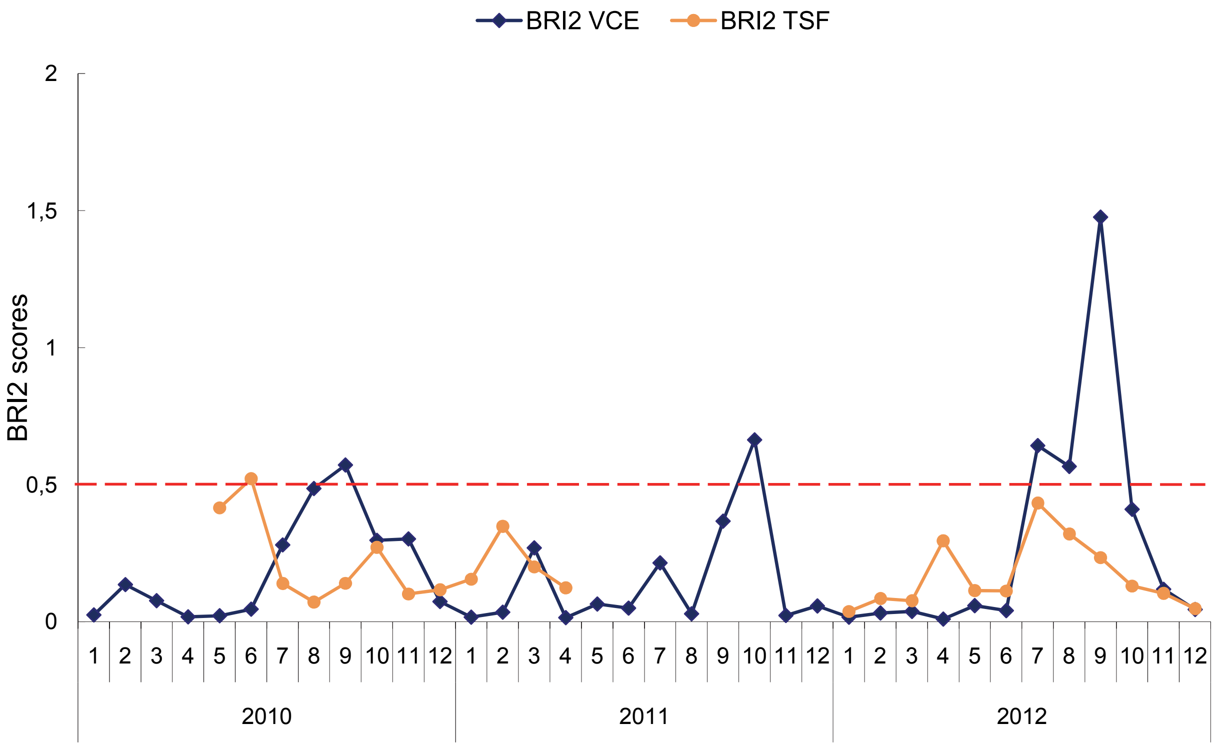


Figure 5.3.1: BRI2 scores for VCE and TSF airports in the period Jan 2010-Dec 2012.

Airport	year	1	2	3	4	5	6	7	8	9	10	11	12	annual mean
VCE	2010	0.02	0.14	0.08	0.02	0.02	0.05	0.28	0.49	0.57	0.30	0.30	0.07	0.19
	2011	0.02	0.03	0.27	0.01	0.06	0.05	0.21	0.03	0.37	0.66	0.02	0.06	0.15
	2012	0.02	0.03	0.04	0.01	0.06	0.04	0.64	0.57	1.48	0.41	0.12	0.04	0.29
TSF	2010					0.42	0.52	0.14	0.07	0.14	0.27	0.10	0.12	0.22
	2011	0.16	0.35	0.20	0.12									0.21
	2012	0.04	0.08	0.08	0.30	0.11	0.11	0.43	0.32	0.23	0.13	0.10	0.05	0.17

Table 5.3.1: BRI2 monthly values for VCE and TSF airports in the period 2010-2012. The green color indicates the scores are under the attention threshold of BRI2>0.5, while the orange one indicates the scores are above it.

Wildlife strike data are here presented either grouped by species groups, or by the four biological periods in which the year is subdivided, in order to define the groups of species most hazardous to aviation, as well as the most critical periods of the year. By observing the wildlife strike history recorded at airports (Figure 5.3.2 a), it is clear that most of the impacts have occurred with species of groups 6 (i.e. kestrels), 7 (i.e. yellow-legged gulls), 8 (e.g. black-headed gulls) and 12 (i.e. swifts and swallows). Wildlife strikes also frequently occurred with several species of group 15, among which the starlings and small mammals (group 16). Regarding the time of the year in which the impacts occurred, most of them were recorded in the breeding season, while wintering was the safest period at both the airports (Figure 5.3.2 b). Therefore, a correspondence between the risk path expected by BRI2 and the strikes history registered at airports was found, with lower risk scores in winter and higher values in late-summer.

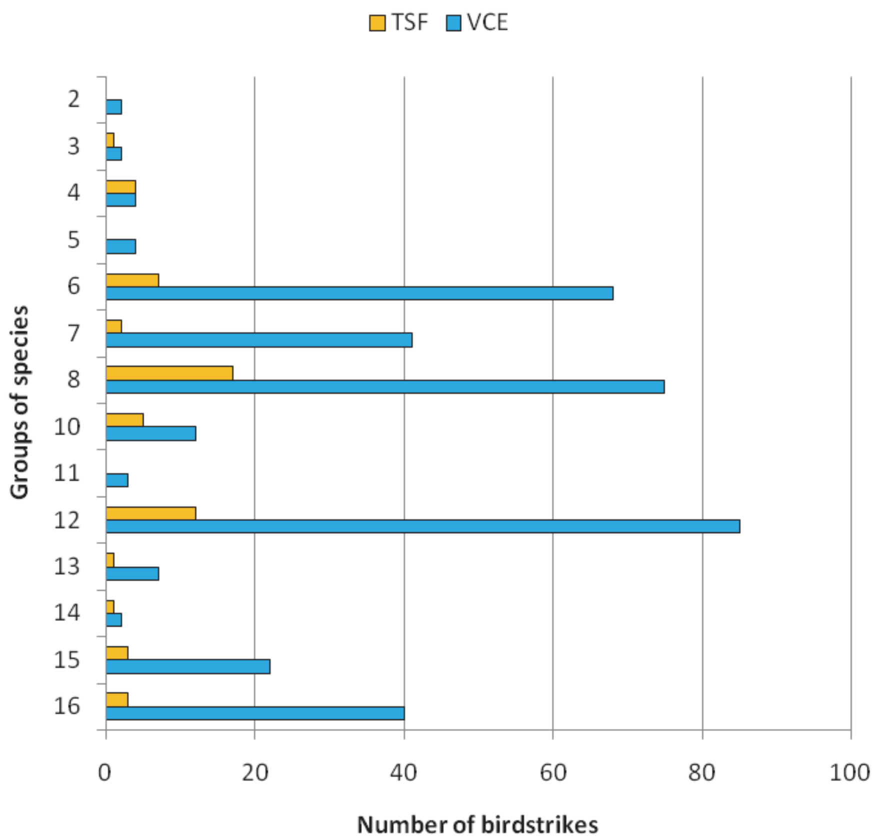


Figure 5.3.2 a: Wildlife strikes, grouped by the functional groups of species, recorded at VCE from 2003 to 2012 and from 2008 to 2012 at TSF.

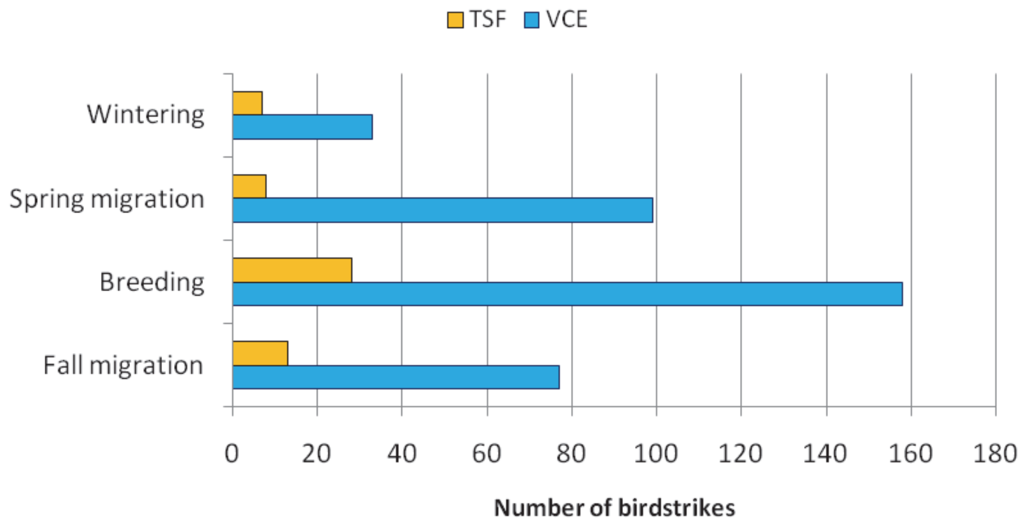


Figure 5.3.2 b: Wildlife strikes, grouped by the four biological periods of the year, recorded at VCE from 2003 to 2012 and from 2008 to 2012 at TSF.

6. Ecological characterization of the airports

6.1 Introduction

A detailed ecological analysis has been performed in order to describe the wildlife present at the studied airports and specifically the communities attending the five micro-habitats in which the airports have been subdivided: runway, meadows, buildings, water and other.

Recorded wildlife was described from a biodiversity, ecological, trophic and conservationist perspective.

6.2 Data analysis

Wildlife presence data available from 2005 to 2012 for VCE and from 2010 to 2012 for TSF were used for the analysis.

In order to measure the wildlife community diversity at the target airports, the following indexes were applied [(58)]:

- the *Margalef index*, d, as a measure of species richness. The higher the index, the greater the diversity;
- the *Shannon-Wiener index*, H, as a measure of evenness of samples. This index increases as both the richness and the evenness of the community increase. The Shannon-Wiener index gives particular importance to rare species and it is independent of sample size;

- the *Berger-Parker* and *Simpson indexes*, D, as a measure of dominance. Since evenness and dominance are conceptually opposed, when D increases, diversity (in terms of evenness) decreases.

To complete the wildlife characterization from a biodiversity point of view, information on species constituting 90% of the community (i.e. dominant species), the number of species attending a given airport or a specific micro-habitat and the total number of orders were also reported.

In order to describe the wildlife community from the ecological, trophic and conservationist side, the environment exploited by species (aquatic or terrestrial), their type of diet (generalist, herbivorous or predatory) and eventually their presence in Annex I of Birds Directive[59] have been investigated.

Finally, in order to evaluate differences in the wildlife community composition among the five habitats in which the airports were subdivided and define the species characteristics of each of them, a SIMPER (Similarity Percentage) analysis has been performed. The Bray-Curtis similarity index[60, 61] was used as implicit to SIMPER. The overall significance of difference was assessed by applying a One-Way ANOSIM (Analysis Of Similarities)[62]. ANOSIM and SIMPER analyses were performed using the software PRIMER Version 6.1.13[63]. Results from the ANOSIM and SIMPER analysis, both for VCE and TSF airports, are reported in annex III.

6.3 Results

Results for the two airports are presented in table 6.3. Starting from VCE, a moderate wildlife community diversity is found. In fact, despite a high value of species richness (r= 127; d= 22.09), the evenness index is low (H= 3.16) and the corresponding dominance one very high (D= 6) with only 8 species constituting 90% of the total community. Dominant species are reported in scientific shorter form in the table. Among these, just 2 species are sufficient to cover 50% of the community (i.e. black-headed gull and yellow-legged gull). After gulls, in order of abundance, we find starlings, avocets, shelducks, grebes, mallards and dunlins. Therefore, except for starlings, dominant species at Venice airport are water birds. The abundant presence of waterfowls at VCE, which constitute 74% of the total wildlife community, is primarily linked to the water and salt-marsh areas along the edge of the lagoon, where they usually roost and feed. As a consequence, the majority of the community is predatory (72%) mainly feeding on fish, winkles, crabs or insects, in the case of starlings or swifts and swallows. Finally, 27 species of conservation interest were recorded at VCE in the study period. Such protected species are reported in table 6.4.

Based on results from the one-way analysis of similarities (ANOSIM), a significant difference in the species composition attending the five habitats of VCE airport was detected (Global R= 0.764, P= 0.001). Subsequent similarities percentages analysis (SIMPER) was used to identify the species

that most strongly contribute to differences in wildlife community composition among the airport habitats. Results from the analysis performed for each of the airport habitats indicate a greater biodiversity at *meadows* (r= 81; d= 16.50) and *water* (r= 77; d= 13.74). While the first habitat is primarily attended by starlings, accounting for than 40% of the total community, as expected, the second one is dominated by gulls (> 50%). Airport *buildings* are almost exclusively attended by black-headed gulls (45%) followed by white wagtails (20%), starlings (19%) and, in minor percentage, by doves and passerine species. *Runways* are mainly exploited by crows (33%), doves (16%), larks (13%) and kestrels (12%). As the latter species frequently collide with aircrafts, the runway habitat is thus particularly hazardous for aviation. Finally, the *other* habitat category including trees, bushes, hedgerows, headlights and the airport enclosure, is almost entirely constituted by cormorants and kestrels, accounting for more than 50% (see table 6.3 and annex III).
Regarding TSF, the *Margalef index* (d= 15.14) and the species richness (r= 66) indicate a quite high level of biodiversity. The most abundant species detected at airport and constituting 90% of the entire wildlife community are starlings and doves, representing alone 53% of the population, followed by swallows (13%), crows (12%), wood pigeons (5%), magpies (4%), black-headed gulls (1.6%) and yellow-legged gulls (1.5%). Contrary to Venice airport, 95% of the species recorded at Treviso airport are terrestrial, primarily linked to the vegetation within the airfield and the agricultural fields around it. Relatively to their dietary habits, the majority of species is predatory or insectivorous (49%), 32% is herbivorous (frugivorous or granivorous) and 18% represented by only 3 species (i.e. yellow-legged gull, magpie and crow) is feeding generalist. With respect to the conservation interest, 9 protected species were detected at TSF in the considered period (table 6.4).
Results from the ANOSIM test indicated a significant difference in the species composition attending the five airport habitats at TSF airport (Global R= 0.696, P= 0.001). *Meadows* (r= 45; d= 11.17) and *other* (r= 36; d= 10.44) categories show a higher wildlife community diversity. The first one is mainly attended by crows (32%), magpies (24%), starlings (16%) and, in minor percentage, by doves, swallows and larks. The *other* habitat category, here mainly represented by trees, the headlights of the aerodrome, fences and sticks, is in the large majority exploited by crows, magpies, and wood pigeons, accounting for more than 50%. In minor part it is attended by kestrels, starlings, cormorants, Eurasian collared doves and passerines. Kestrels were often recorded at airport while roosting on the sticks around the runway, waiting for hunting some prey. Regarding *buildings*, just three species contribute to form more than 90% of the total wildlife community that is doves, starlings and Eurasian collared doves primarily attending the roofs of hangars and the air-station for roosting, sunning and sometimes nesting. Very few species and relative few individuals are found at the *water* habitat (r= 5). These species (i.e. *Calidris temminckii*, temminck's stint, *Tringa glareola*,

wood sandpiper, rock dove, white wagtail and common pheasant) were recorded while roosting or drinking in a big puddle of water formed at airport as a result of storms. Finally, *runway* is exploited by crows for more than 60% and in minor percentage by magpies, kestrels, swallows and doves.

Airport		Biodiversity							Ecological characterization		Diet			Conservation
		Index of species richness – d - Margalef	Index of evenness – H - Shannon-Wiener	Index of dominance - D - Berger-Parker & Simpson	Number of dominant species	Dominant species	Total number of species - r	Number of Orders	Waterfowl (number of species and percentage)	Terrestrial birds (number of species and percentage)	Feeding generalists (number of species and percentage)	Herbivorous (number of species and percentage)	Predators (number of species and percentage)	Number of species in the Birds Directive Annex I
VCE		22.09	3.16	0.24; 6.00	8	CRORI, LARMI, STUVU, RECAV, TADTA, PODCR, ANAPL, CALAL;	127	22	63 (74%)	64 (26%)	3 (24%)	37 (4%)	87 (72%)	27
Habitats	Runway	10.50	3.49	0.27; 7.42	7	CORCO, COLLI, ALAAR, FALTI, PICPI, LARMI, STUVU;	38	11	16 (24.85%)	22 (75.15%)	3 (19.99%)	12 (26.42%)	23 (53.59%)	6
Habitats	Meadows	16.50	1.82	0.73; 1.84	7	STUVU, CORCO, LARMI, PICPI, ALAAR, COLLI, ARDCI;	81	18	28 (8.99%)	53 (91.01%)	3 (13.31%)	26 (7.00%)	52 (79.69%)	15
Habitats	Buildings	7.49	1.28	0.79; 1.56	5	CRORI, MOTAL, STUVU, COLLI, PASDO;	32	10	9 (80.14%)	23 (19.86%)	3 (1.08%)	11 (5.70%)	18 (93.22)	1
Habitats	Water	13.74	2.70	0.31; 4.65	7	CRORI, LARMI, TADTA, PODCR, RECAV, ANAPL, ARDCI;	77	16	56 (99.78%)	21 (0.22%)	3 (31.53%)	20 (3.94%)	54 (64.53%)	17
Habitats	Other	8.70	0.89	0.87; 1.31	6	PHACA, FALTI, STUVU, PICPI, CORCO, LARMI;	42	10	16 (10.01%)	26 (89.99%)	3 (6.07%)	10 (0.35%)	29 (93.58%)	8
TSF		15.14	3.12	0.30; 5.63	8	STUVU, COLLI, HIRRU, CORCO, COLPA, PICPI, CRORI, LARMI;	66	14	20 (5%)	46 (95%)	3 (18%)	25 (32%)	38 (49%)	9
Habitats	Runway	6.78	2.79	0.44; 4.21	7	CORCO, HIRRU, COLLI, CRORI, PICPI, FALTI, STUVU;	21	8	4 (10.08%)	17 (89.92%)	3 (52.68%)	10 (13.45%)	8 (33.88%)	0
Habitats	Meadows	11.17	2.72	0.38; 4.54	8	CORCO, PICPI, STUVU, COLLI, HIRRU, ALAAR, COLPA, FALTI ;	45	13	10 (1.45%)	35 (98.55%)	3 (28.27%)	19 (17.66%)	23 (54.07%)	3
Habitats	Buildings	7.03	1.45	0.63; 2.06	3	COLLI, STUVU, STRDE;	26	7	2 (0.25%)	24 (99.75%)	3 (1.41%)	9 (65.78%)	14 (32.82%)	0
Habitats	Water	3.29	2.02	0.36, 3.67	-	-	5	4	2 (66.67%)	3 (33.33%)	0 (0%)	2 (21.21%)	3 (78.79%)	1
Habitats	Other	10.44	2.62	0.37; 3.76	8	CORCO, PICPI, COLPA, FALTI, STUVU, PHACA, STRDE, PASDO;	36	11	7 (4.83%)	29 (95.17%)	3 (7.08%)	14 (46.26%)	19 (46.66%)	3

Table 6.3: Ecological characterization of the wildlife community recorded at VCE from 2005 to 2012 and at TSF from 2010 to 2012.

Airport	Scientific name	short code	Common name	Runway	Meadows	Buildings	Water	Other
VCE	*Alcedo atthis*	ALCAT	Kingfisher (martin pescatore)				X	
	Anthus campestris	ANTCA	Tawny Pipit (calandro)		X			
	Ardea purpurea	ARDPU	Purple heron (airone rosso)	X	X		X	
	Charadrius alexandrinus	CHAAL	Kentish Plover (fratino)	X	X		X	
	Chlidonias niger	CHLNI	Black tern (mignattino comune)				X	X
	Circus aeruginosus	CIRAE	Western marsh harrier (falco di palude)	X	X		X	X
	Circus cyaneus	CIRCY	Hen harrier (albanella reale)	X	X		X	X
	Circus pygargus	CIRPY	Montagu’s harrier (albanella minore)	X	X			
	Egretta garzetta	EGRGA	Little egret (garzetta)	X	X	X	X	X
	Falco columbarius	FALCO	Merlin (smeriglio)		X			
	Falco peregrinus	FALPE	Peregrine falcon (falco pellegrino)		X		X	X
	Falco vespertinus	FALVE	Red-footed Falcon (falco cuculo)		X			
	Himantopus himantopus	HIMHI	Black-winged stilt (cavaliere d' italia)				X	
	Lanius collurio	LANCO	Red-backed Shrike (averla piccola)					X
	Larus melanocephalus	LARME	Mediterranean gull (gabbiano corallino)		X		X	
	Nycticorax nycticorax	NYCNY	Black-crowned night heron (nitticora)		X			
	Pernis apivorus	PERAP	European honey-buzzard (falco pecchiaiolo)		X			
	Phalacrocorax pygmeus	PHAPY	Pygmy cormorant (marangone minore)				X	X
	Philomachus pugnax	PHIPU	Ruff (combattente)				X	
	Phoenicopterus roseus	PHORO	Pink flamingo (fenicottero)				X	
	Pluvialis apricaria	PLUAP	European Golden Plover (piviere dorato)		X			
	Recurvirostra avosetta	RECAV	Pied avocet (avocetta)		X		X	
	Sterna albifrons	STEAL	Little Tern (fraticello)				X	
	Sterna hirundo	STEHI	Common tern (sterna comune)				X	X
	Tringa glareola	TRIGL	Wood Sandpiper (piro piro boschereccio)				X	
TSF	*Circus pygargus*	CIRPY	Montagu’s harrier (albanella minore)		X			
	Egretta garzetta	EGRGA	Little egret (garzetta)		X			X
	Lanius collurio	LANCO	Red-backed Shrike (averla piccola)					X
	Larus melanocephalus	LARME	Mediterranean gull (gabbiano corallino)		X			
	Picus canus	PICCA	Grey-headed Woodpecker (picchio cenerino)					X
	Tringa glareola	TRIGL	Wood Sandpiper (piro piro boscherecchio)				X	

Table 6.4: Species of conservation interest recorded at the five micro-habitats of VCE and TSF airports in the study periods.

7. Discussion

Information from the descriptive qualitative and quantitative analysis performed allowed to describe the airports reality from the wildlife point of view defining their presence trend, airport habitat use and distribution on a daily and seasonal basis. The recorded groups of species were unevenly distributed at airports, concentrating in some areas more than others. In addition, seasonal differences in the species distribution were found at both the airports. These differences were related in part to the different habitats present in the airport areas, in part to the ecological needs of the species during different phases of their biological cycle.

Information on the wildlife daily peaks of activity and on the most attractive airport areas allow to focus the control and dissuasive actions (e.g. use of distress calls, falconry, BCU operations etc) in periods with higher activity and movements and in areas where a higher concentration of individuals was recorded. Furthermore, information from this study can help in decision planning and risk management in order to modify the airport habitats to make them less appealing to wildlife. Regarding VCE, the salt-marsh and the areas along the edge of the lagoon must be taken into careful consideration since they offer considerable food availability and refuge for hazardous species such as black-headed gulls and yellow-legged gulls and are exploited by mallards and shelducks for breeding. In addition, although not found within the airport area or in the proximity of runways thus less hazardous for aviation, these areas are also attended by waders.

With regards to TSF, the quadrants G1-G4 showed to have the highest concentration of wildlife thus resulted the most hazardous from an aviation perspective. These areas are particularly attractive for wildlife since adjacent to the Sile Natural Regional Park and the fish farm basins, along the south side, and to the cultivated fields along the north side.

Finally, the calculated BRI2 index allowed to describe the wildlife strike risk at the studied airports basing on three main variables involved in the occurrence of an impact: 1) the wildlife presence 2) the air traffic and 3) the birdstrikes recorded for groups of species. The wildlife strike risk analysis performed highlighted the periods when the occurrence probability of wildlife strikes is higher, thus when the preventive actions to control and reduce wildlife at airport are particularly needed. Although not predictive, since developed on historical data, the BRI2 index provides cues for the wildlife strike risk in future scenarios due to the seasonality of wildlife presence and thus can be used for risk prevention and safety improvement.

Part II – New methodologies for Wildlife Strike Risk Assessment

8. Development of a predictive model on the spatial movements of two hazardous species for aviation in relation to attractive sources

8.1 Introduction

In the past 30 years, several species of gulls (*Larus* spp.) have undergone a widespread population explosion, particularly in Europe, such as to be considered superabundant. A species is superabundant if a) it demonstrates a strong and sustained demographic and often geographic expansion; b) its population level is higher than ever previously recorded; and c) it interferes with the interests of humans [64-66]. Gulls are often found to be superabundant due to their adaptable, opportunistic and gregarious nature, which makes them highly adapted to live in human-modified habitats [64]. The demographic increase of gulls is primarily attributed to the establishment of open-air landfills in the proximity of urban sites, the development of industrial fisheries, the protection of several areas where they can find suitable conditions to breed [67-69], the protection from human disturbance and the reduction in environmental contaminants [70]. This population explosion has created many conflicts with humans. Gulls have recently begun to colonise towns and coastal cities [71, 72], nesting on the roofs of buildings [73-76] and causing disturbance to inhabitants due to their noise, fouling and the aggression of the adults in defense of their young [77]. Other problems linked to the spread of gulls are damage to agriculture [78], predation on wildlife [79], transmission of diseases [80] and collisions with aircrafts [66, 81]. Many gull species are feeding generalists that take advantage of artificial food sources resulting from human activities such as landfills, fishery bycatch, sewage outfalls and slaughterhouses [82]. Landfills represent a local and abundant food resource for some gull populations. For example, in the herring gull, *Larus argentatus*, a higher breeding success has been widely documented in pairs nesting near landfills compared to those nesting further away. Moreover, it has been found a positive relationship between brood size and the quantity of refuse in the chicks' diet as well as a reduction in the number of pairs attempting to breed and in their breeding success following the closure of a nearby landfill [83]. Gulls are known to be particularly hazardous to aircraft [84] and are very good long-distance travellers, commuting more than 50 km/day between suitable feeding and roosting/breeding sites [85]. Normally, gulls move to attractive sites for foraging early in the morning and return to their colonies several times during the day or to roosting sites in the evening. Gulls also exhibit seasonal differences in spatial distribution, foraging inland in the winter season, primarily depending on garbage and other resources coming from human activities, but taking advantage of coastal food availability in the summer [86].

These movements pose a significant hazard to flight safety when flocks of birds pass through the same airspace as aircrafts [87-89], leading to a potential increase in the birdstrike risk along these air corridors.
Several studies on the influence of anthropogenic waste on gulls [90, 91] and gulls' spatial movements have been conducted, but they have mostly focused on landfills, since considered the primary attractive elements [92, 93, 83] and driving forces of gulls' foraging flights [86, 88]. Nevertheless, fish farms and crop-fields are also attractive for gulls [82]. Consequently, the presence of such elements in the vicinity of an airport needs to be addressed and kept under control, as this combination can objectively increase hazards to aviation [94]. In order to predict the occurrence of the most likely flight lines of gulls and prevent the impacts along the air corridors shared by aircrafts and birds, the identification of the key factors influencing gulls' movements during daytime and different seasons is thus fundamental. In this study, five categories of sources were selected as prime drivers for gulls according to literature and personal observations. Following ENAC guidelines [54, 56], these attractive sources were considered when present in a buffer area with a radius of 13 km from the studied airports (i.e. VCE and TSF).
In our opinion, gulls use different air corridors depending on the period of the year and time of the day, according to their ecological needs (i.e. chick rearing or wintering period).
The objective of this research was to develop a predictive model of gulls' flight directions, during daytime and different periods of their biological cycle, using the attractive sources around the target airports as proxies for their flight routes.

8.2 The target species

The study has been conducted on two species particularly hazardous for aviation: the yellow-legged gull and the black-headed gull, which are common and abundant in the Mediterranean basin [66]. Species are considered hazardous to air traffic when causing birdstrikes with aircrafts.
These two species were primarily selected for the following reasons:
a) the above mentioned high exploitation of anthropogenic sources;
b) the high value of Group Specific Risk (GSR) they show at both the studied airports (table 8.2). As previously cited (see par. 5.1), this risk score considers the average weight and average abundance of a given group of species, the mean number of birdstrikes recorded per year and the effect on flight provoked by the impacts [24, 48];
c) the great concern they pose at airports, given the extent of damage caused by their collisions with aircrafts (e.g. reported cost and effects on flights) [23, 95, 96].

ID group	Species groups	GSR VCE	GSR TSF
1	Grebes and divers	0.00	0.00
2	Cormorant, pelicans, swans and geese	0.09	0.00
3	Herons, storks, flamingos	0.45	0.73
4	Ducks, pheasants, rallids	2.66	0.72
5	Birds of prey - large	0.01	0.00
6	Birds of prey - small	1.23	0.67
7	Seabirds - large	**199.87**	**2.76**
8	Seabirds - small	**339.13**	**7.91**
9	Waders	0.00	0.00
10	Doves	3.05	20.46
11	Owls	0.00	0.00
12	Swifts and swallows	1.83	2.81
13	Corvids	1.55	1.87
14	Non-flocking passerines and bats	0.00	0.02
15	Flocking passerines	31.03	3.93
16	Large mammals >10 Kg	1.37	0.66
17	Small mammals <10 Kg	0.00	0.00

Table 8.2: Group Specific Risk (GSR) calculated on data from 2005 to 2012 for VCE and from 2010 to 2012 for TSF. The GSR values for yellow-legged gulls (group 7) and black-headed gulls (group 8) are highlighted in bold.

8.2.1 The yellow-legged gull *Larus michahellis* (Naumann, 1840)

The yellow-legged gull is a large size gull (length 52-58 cm; wingspan 120-140 cm), defined as the Mediterranean and Mid-Atlantic counterpart of the Herrig gull (97) (Figure 8.2.1 a, b). This species regularly breeds on Italian coasts and since 1970 is present on the North Adriatic coasts and in the Venice lagoon. In 2003, the natural population of yellow-legged gulls in Venice lagoon was estimated at 3096 breeding pairs (98, 77), but the population is still increasing in the lagoon and in the city of Venice.

a)

b)

Figure 8.2.1 a, b: **Yellow-legged gull**, juvenile (a) and adult (b) (pictures of Nicola Lotto).

8.2.2 The black-headed gull *Croicocephalus ridibundus* (Linnaeus, 1766)

The black-headed gull is a small-medium size gull (length 34-38 cm, wingspan 100-110) [97] (Figure 8.2.2 a, b). This species is rather common in Italy during the whole year, reaching peaks of presence in our country in late summer and spring. The adult plumage is different in winter and summer. In winter the adult has white head with dark ear-spot and faint variable dark bars above the ear-spot and neck. In summer time the adult is easily recognizable by the typical dark brown hood. Black-headed gulls breed in Italy since 1960, while the presence of their colonies in the Venice lagoon is documented from about 1990 [99].

a)

b)

Figure 8.2.2 a, b: **Black-headed gull**, adult winter (a) (picture of Nicola Lotto) and adult summer (b) (picture of Emanuele Stival).

8.3 Methods

8.3.1 Definition of the prime drivers for gulls

As previously cited, five categories of sources were defined as prime drivers for gulls. These sources were agricultural fields [100], urban parks, fish farms, landfills (including the MSW, those treating sanitary and veterinary wastes, the waste-transfer stations and the post-closure landfills) [70, 56, 57] and the colonies of gulls located in Venice lagoon, to which they return several times a day to feed their chicks or simply roost.

The selected attractive sources with their geo-referenced locations are mapped in figure 8.3.1. Given the high agricultural productivity of the study area and the large dispersion of fields, this category has been not transferred into the map to facilitate its comprehension.

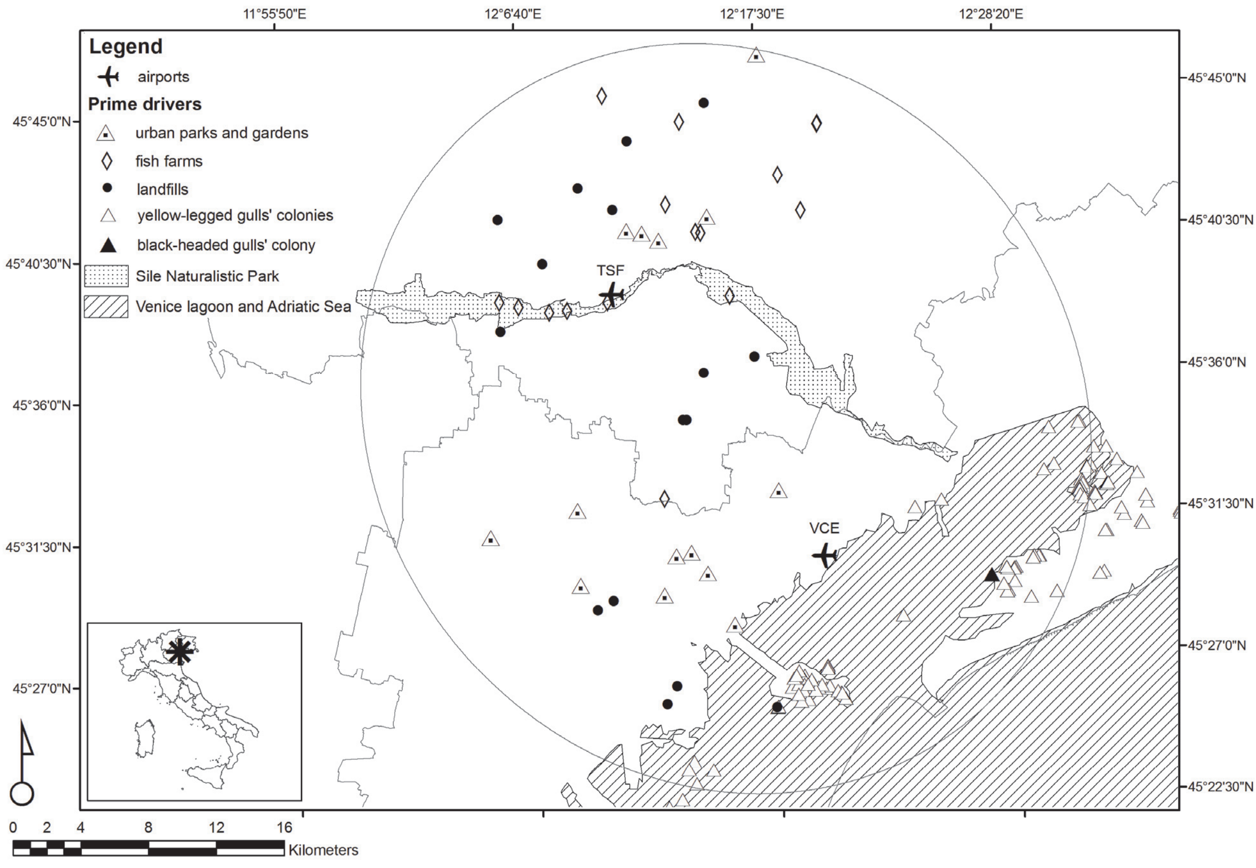


Figure 8.3.1: Study sites and attractive sources for gulls within an approximate merged buffer area with a radius of 13 km from VCE and TSF airports.

8.3.2 Data collection

Data on gulls' abundance from 2006 to 2011, available from the 'Atlante ornitologico del Comune di Venezia' [101], were used to define gulls' attendance at the five categories of attractive sources, while data on wildlife presence collected from November 2005 to August 2011 at VCE airport and from March 2010 to April 2011 at TSF were used to extract information on gulls' flight directions during daytime and different seasons. Additionally, the relative abundance of gulls detected in flight, while crossing the airport airspace, was mapped in order to identify the air corridors most commonly used by them in different times of the day and periods. Data were grouped by the four periods of birds' biological cycle (from wintering to fall migration) and in four main time slots (from dawn to dusk). Time slots were defined according to civil twilight time tables and approximated by considering the average time of dawn and dusk, depending on the target period. This allowed to account for differences in daylight length over the seasons (Table 8.3.2).

Period	Dawn	Morning	Afternoon	Dusk	Estimated hours of daytime
Wintering	7:00-8:00	9:00-12:00	13:00-15:00	16:00-17:00	10
Spring migration	6:00-8:00	9:00-12:00	13:00-18:00	19:00-20:00	14
Breeding	5:00-8:00	9:00-12:00	13:00-19:00	20:00-22:00	17
Fall migration	7:00-8:00	9:00-12:00	13:00-17:00	18:00-19:00	12

Table 8.3.2: Subdivision of the year in the four main biological phases of birds and detail on the time slots of the day over the periods.

8.4 Data analysis

In order to assess the relative attractiveness of sources to gulls and thus determine which of the elements was more hazardous from an aviation safety perspective, the attendance of gulls at the five categories of attractive sources during daytime have been studied. As gulls' abundance data were not normally distributed, differences in the exploitation of sources by gulls, throughout the day, were analysed by applying the non-parametric Kruskal-Wallis test, followed up by the post hoc Nemenyi' s test for multiple comparisons.

In order to define the occurrence of a particular category of attractive sources along the cardinal directions and thus determine the most representative element for each way, a geographical frequency analysis of the prime drivers for gulls (frequency of the sources *per* section of land) has been performed.

Information from the above cited analysis were linked to information from a preliminary analysis on yellow-legged gulls and black-headed gulls' flight directions, in relation to the compass heading of their flight path, performed by using a visual inspection of radar plots.

Finally, in order to prevent the occurrence of birdstrikes at the studied airports, predictive models on gulls' spatial movements during daytime and different periods have been developed.
All data were analysed using R version 2.15.0 [102] and significance was set at $P < 0.05$ for all the performed analyses.

8.4.1 Fitting the predictive model

Given the large number of colonies of yellow-legged gulls present in Venice lagoon and the consequent high probability they crossed the Venice Marco Polo airport, the predictive models on gulls' flight lines were developed on this reference airport and species. In order to predict the likely flight lines of yellow-legged gulls through VCE airport during daytime, the independence between the response (flight direction of yellow-legged gulls) and explanatory (time slot of the day) variables was tested by applying a Pearson Chi-squared test. Afterwards, explorative analysis performed by following Zuur et al. criteria [103, 104], showed a considerable overdispersion and a non-linear relationship between the response and the explanatory variables. To deal with overdispersion, a smoother-based method Generalised Additive Modelling (GAM) from the 'mgcv' R package [105-107] was fitted. Additionally, a marked zero inflation was detected in the data. Therefore, a binomial distribution and a logit link function, a P-spline for cyclic data (cp) [108], a maximum value of degrees of freedom of 4 (k=5) and a Generalised Cross Validation (GCV) criterion to optimise the model were used.
Four models with different smoothers were fitted to be compared. Flight direction in degrees, considered as interaction, was included in all candidate models:
m1) yellow legged gulls' presence/absence ~ s (flight direction: daylight hours) + period;
m2) yellow legged gulls' presence/absence ~ s (flight direction: period) + time slot;
m3) yellow legged gulls' presence/absence ~ s (flight direction: time slot) + period;
m4) yellow legged gulls' presence/absence ~ s (flight direction: period) + daylight hours.
The Akaike Information Criterion, AIC, [109, 110] was computed in order to assess the best model among the sets of candidates. In particular, the Δ AIC and Akaike weights (*w*) were considered for comparing the models. If a minimal difference in the AIC values was detected (≤ 2 units), the easiest model to be interpreted and the most useful in the context of this study was selected.
Additionally, in order to predict the likely flight direction of yellow-legged gulls in two specific periods of the year, or the breeding and wintering seasons, another GAM with binomial distribution and a logit link function was fitted:
m5) yellow legged gulls' presence/absence ~ s(flight direction: breeding/wintering periods).

8.4.2 Testing the selected modelling approach

The reliability of the proposed modelling approach, developed on yellow-legged gulls at VCE airport to predict their flight lines during daytime, was tested. The selected model was first fitted to data on yellow-legged gulls from TSF airport and then to data on black-headed gulls at VCE. The aim was to detect any possible difference in the spatial movement trend of the gull species at the studied airports in order to describe their habits and relative use of attractive sources.

Finally, in order to test the model predictions on gulls' spatial movements in breeding and wintering and thus evaluate if any differences in the distribution of impacts were present in the two considered periods, the birdstrike events occurred with the studied species at VCE airport were studied by applying the Mann-Whitney-Wilcoxon test for non parametric data. Data on gulls-aircrafts strikes were available from 2003 to 2012.

8.5 Results

8.5.1 Attractiveness of the sources to gulls

A significant difference in the abundance of gulls was found between the selected categories of attractive sources (Kruskal-Wallis test, $\chi^2 = 144.715$, df = 4, $P < 0.05$) (Figure 8.5.1 a). Additionally, the following post hoc Nemenyi' s analysis for multiple comparisons revealed a significant difference in means between all the attractive sources categories ($P < 0.05$), except for fish cultures and fields (P = 0,180).

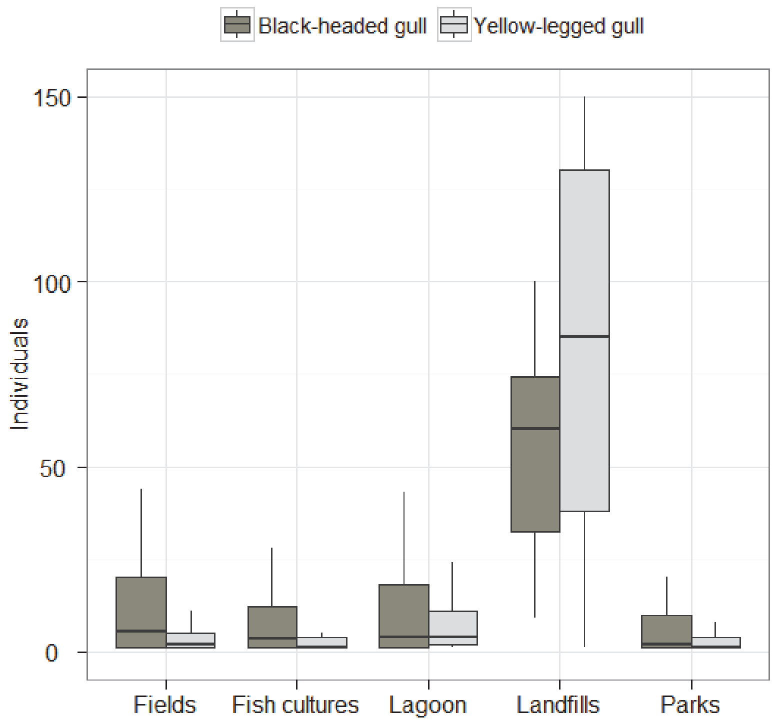


Figure 8.5.1 a: Median and inter-quartile range (IQR) of yellow-legged gulls and black-headed gulls at the five categories of attractive sources.

Gulls differently used the attractive sources depending on the time of the day (Kruskal-Wallis test, χ^2 = 12.844, df = 3, $P < 0.05$) (Figure 8.5.1 b). They primarily exploited landfills at dawn and morning times, fish cultures and fields in the afternoon and Venice lagoon in the evening. Results from the Nemenyi' s test performed are shown in table 8.5.1. The multiple comparisons among the attractive sources were performed by excluding the categories for which data were not available.

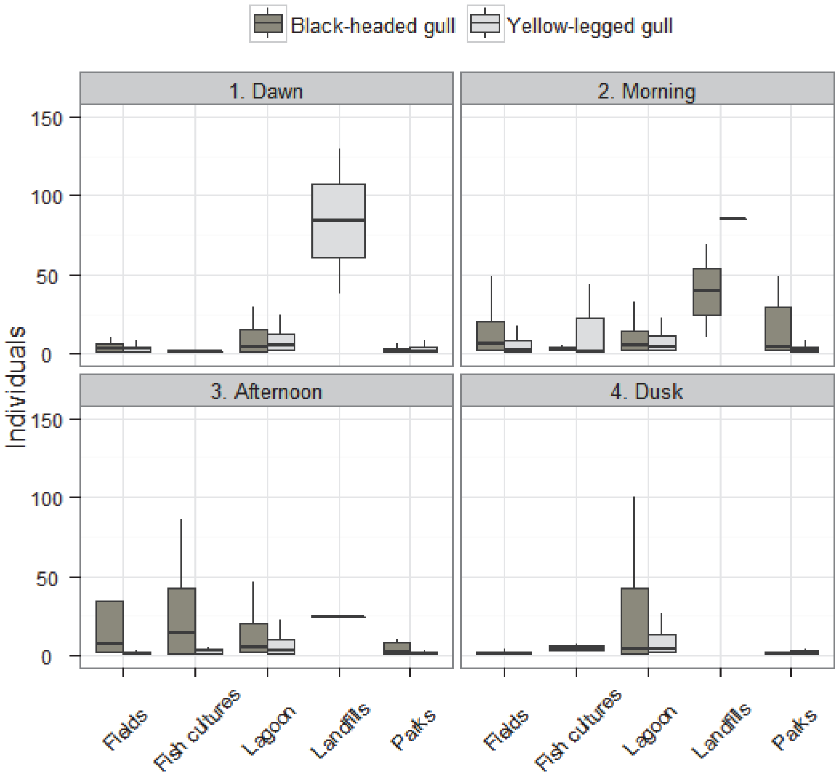


Figure 8.5.1 b: Median and inter-quartile range (IQR) of yellow-legged gulls and black-headed gulls at the five categories of attractive sources during daytime.

Attractive Sources	Dawn	Morning	Afternoon	Dusk
Fish cultures - Fields	0.998	0.999	0.266	0.385
Lagoon - Fields	**0.000**	0.193	**0.000**	**0.000**
Landfills - Fields	0.585	0.901	0.060	0.124
Parks - Fields	**0.000**	0.418	0.716	0.201
Lagoon - Fish cultures	**0.000**	**0.022**	**0.000**	**0.002**
Landfills - Fish cultures	**0.039**	0.370	0.950	0.993
Parks - Fish cultures	**0.000**	0.064	**0.030**	**0.017**
Landfills - Lagoon	**0.000**	0.060	**0.000**	**0.001**
Parks - Lagoon	**0.000**	**0.009**	**0.000**	**0.001**
Parks - Landfills	**0.000**	**0.010**	**0.004**	**0.008**

Table 8.5.1: Nemenyi post hoc test performed between the means of yellow-legged gulls and black-headed gulls' abundance at the selected categories attractive sources, in different time slots of the day. P-values of significant differences are reported in bold.

8.5.2 Geographical frequency of the attractive sources

By looking at table 8.5.2, a higher percentage of agricultural fields, followed by landfills and fish farms, is found on the north and west sides of VCE airport. On the south and east sides of the airport, main attractions for gulls are represented by their colonies and Venice lagoon, while the west and

south-west sides are mainly constituted by fields and urban parks. Therefore, at VCE, the attractive sources are concentrated along specific cardinal directions.
On the contrary, at TSF the attractive sources are sparsely distributed along all the cardinal directions, except for gulls' colonies which are primarily located on the south-east side of the airport (Table 8.5.2).

VCE	**North**	**North-East**	**East**	**South-East**	**South**	**South-West**	**West**	**North-West**
Urban parks	0.70	0.00	0.00	0.00	0.00	2.25	3.90	1.38
	(12.50)	(0.00)	(0.00)	(0.00)	(0.00)	(6.25)	(50.00)	(31.25)
Landfills	4.17	0.00	0.00	0.00	2.78	4.50	0.98	7.73
	(26.67)	(0.00)	(0.00)	(0.00)	(2.22)	(4.44)	(4.44)	(62.22)
Fish farms	2.78	0.00	0.00	0.00	0.00	0.00	0.49	1.93
	(50.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(6.25)	(43.75)
Gulls' colonies	0.00	3.50	82.36	6.39	94.63	9.00	0.00	0.00
	(0.00)	(6.49)	(42.86)	(1.30)	(44.16)	(5.19)	(0.00)	(0.00)
Agricultural fields	92.35	96.50	17.64	93.61	2.58	84.25	94.63	88.96
(Km^2)	(27.11)	(14.08)	(0.72)	(1.50)	(0.09)	(3.82)	(19.79)	(32.88)
TSF	**North**	**North-East**	**East**	**South-East**	**South**	**South-West**	**West**	**North-West**
Urban parks	1.29	4.12	0.00	0.41	4.10	1.43	0.00	0.00
	(6.25)	(31.25)	(0.00)	(6.25)	(43.75)	(12.50)	(0.00)	(0.00)
Landfills	7.73	2.47	2.64	2.44	2.93	0.00	10.73	15.18
	(13.33)	(6.67)	(13.33)	(13.33)	(11.11)	(0.00)	(20.00)	(22.22)
Fish farms	2.58	5.77	0.44	0.00	0.59	0.72	4.77	0.00
	(12.50)	(43.75)	(6.25)	(0.00)	(6.25)	(6.25)	(25.00)	(0.00)
Gulls' colonies	0.00	0.00	3.08	24.83	4.68	0.00	0.00	0.00
	(0.00)	(0.00)	(9.21)	(80.26)	(10.53)	(0.00)	(0.00)	(0.00)
Agricultural fields	88.40	87.63	93.84	72.32	87.71	97.85	84.51	84.82
(Km^2)	(7.01)	(10.85)	(21.80)	(18.15)	(15.30)	(13.94)	(7.24)	(5.71)

Table 8.5.2: Percentage of the attractive sources present in a buffer area of 13 Km from VCE and TSF airports, along the eight cardinal directions. In parenthesis, the relative percentage of each category is reported.

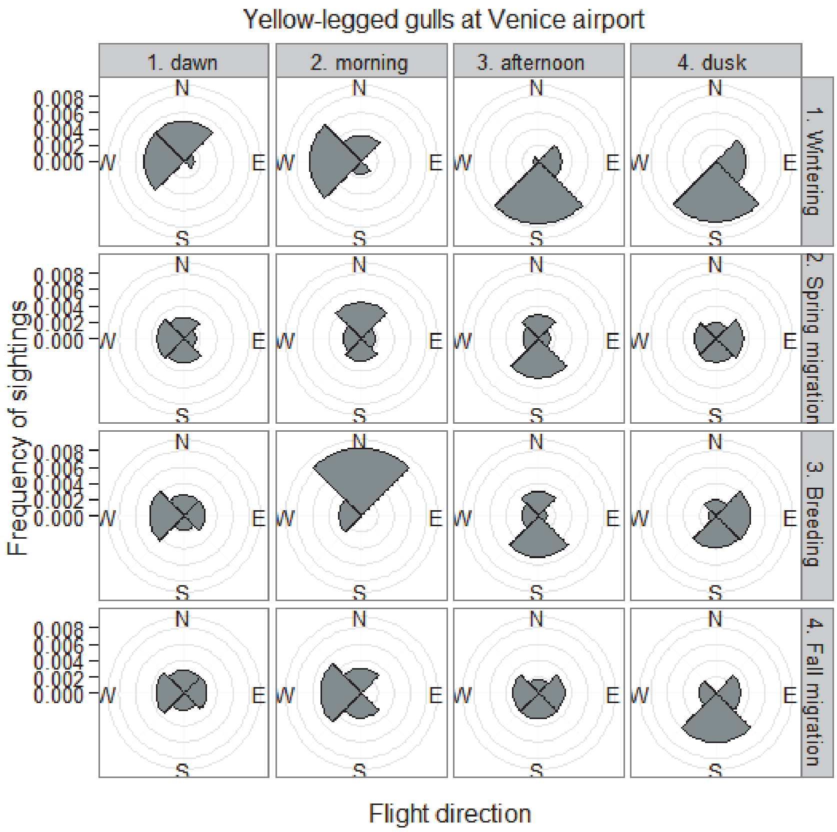
8.5.3 Flight pattern of gulls during daytime and different periods

A strong interdependence between the response variable *'flight direction of gulls'* and explanatory variable *'time slot of the day'* was found for both the airports and species (Pearson Chi-squared test, df = 3, $P < 0.05$).

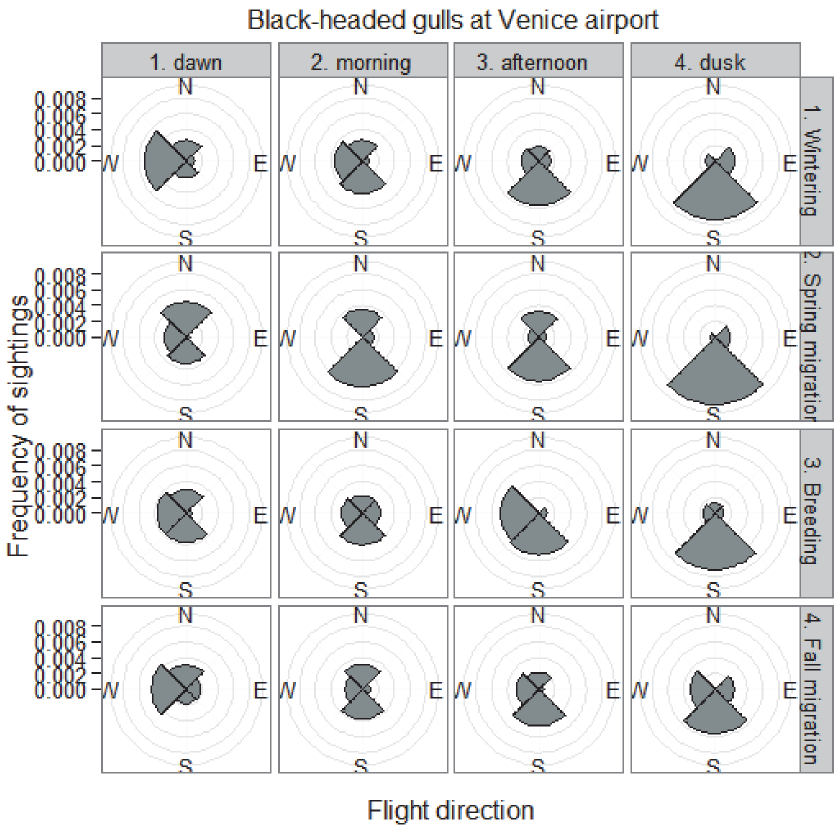
At VCE, yellow-legged gulls and black-headed gulls showed similar trends in their flight path, mainly moving north/north-west at dawn and morning time, while flying towards south in the afternoon and evening (Figs. 8.5.3 a and b).

At TSF, gulls' presence was recorded during wintering and spring migration, therefore data were available for these two periods only. Here, yellow-legged gulls flew primarily north at dawn and morning time, while in the rest of the day they headed towards different directions. Despite the various routes followed, a main flight line towards south-east can be identified in the afternoon and evening (Figure 8.5.3 c).

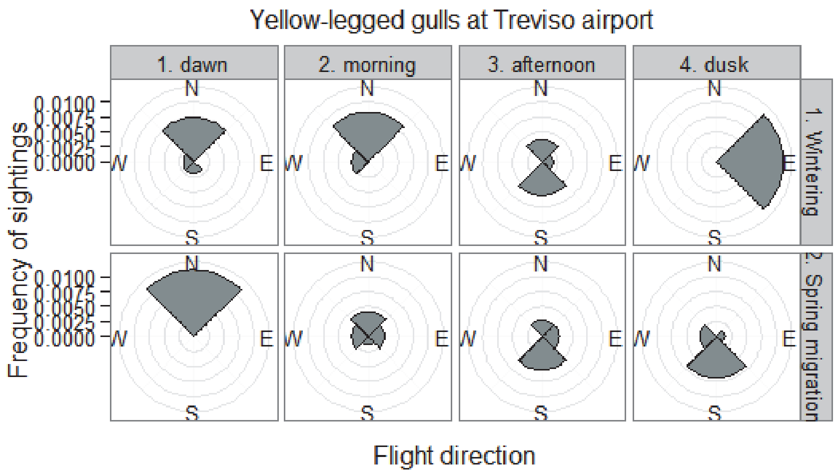
a)



b)



c)



Figs. 8.5.3 a, b, c: Flight pattern of yellow-legged gulls and black-headed gulls through the studied airports, during daytime of different periods. Data on gulls' flight direction were available from November 2005 to August 2011 at VCE and from March 2010 to April 2011 at TSF.

8.5.4 Air corridors of gulls during daytime and different periods through the studied airports

Regarding to gulls observed in flight while crossing the airport airspace, at VCE a higher presence of yellow-legged gulls and black-headed gulls was recorded during spring migration, while the lowest one was detected in wintering. Except for winter time, in which gulls were registered primarily in the afternoon to exploit the milder hours of the day, in the other periods most of the sightings were detected at dawn and dusk (Figure 8.5.4.1). This is not surprising since the peaks of activity for birds [111]. On the contrary, at TSF airport gulls crossing the airport area were mostly sighted in the wintering period, especially in the middle part of the day (i.e. morning and afternoon) (Figure 8.5.4.2). In annex IV, detailed maps showing the air corridors used by gulls during daytime of different periods are reported for both the studied airports.

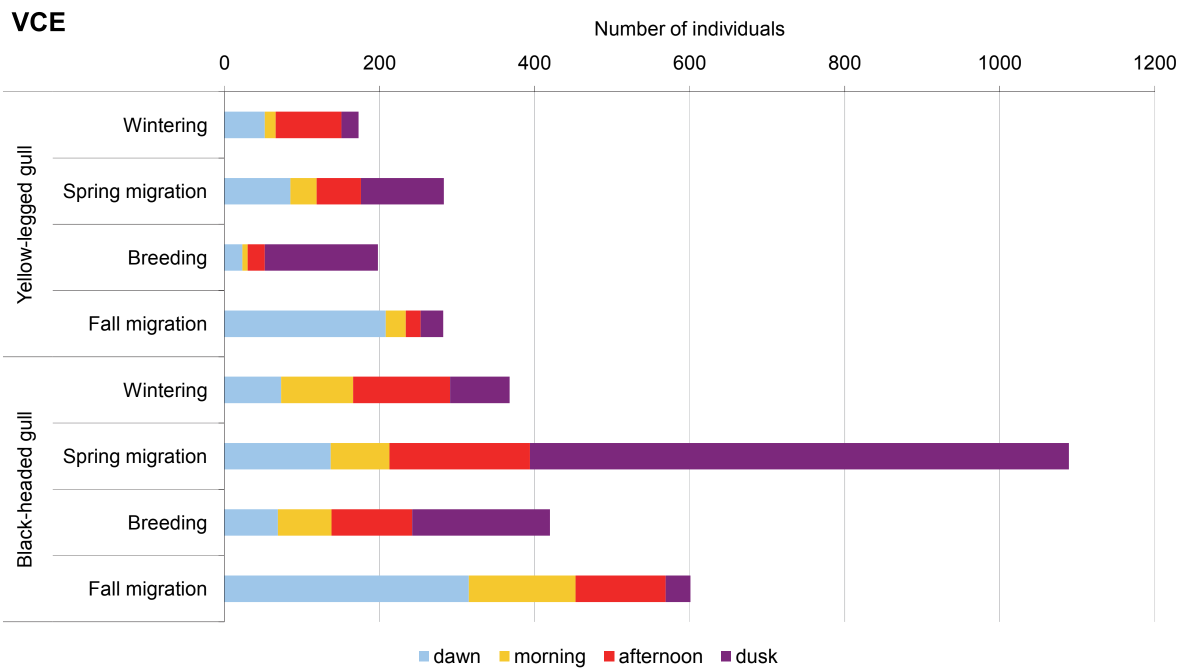


Figure 8.5.4.1: Abundance of yellow-legged gulls and black-headed gulls recorded while crossing the Venice Marco Polo airport airspace from November 2005 to August 2011. Data are grouped by daytime and different periods .

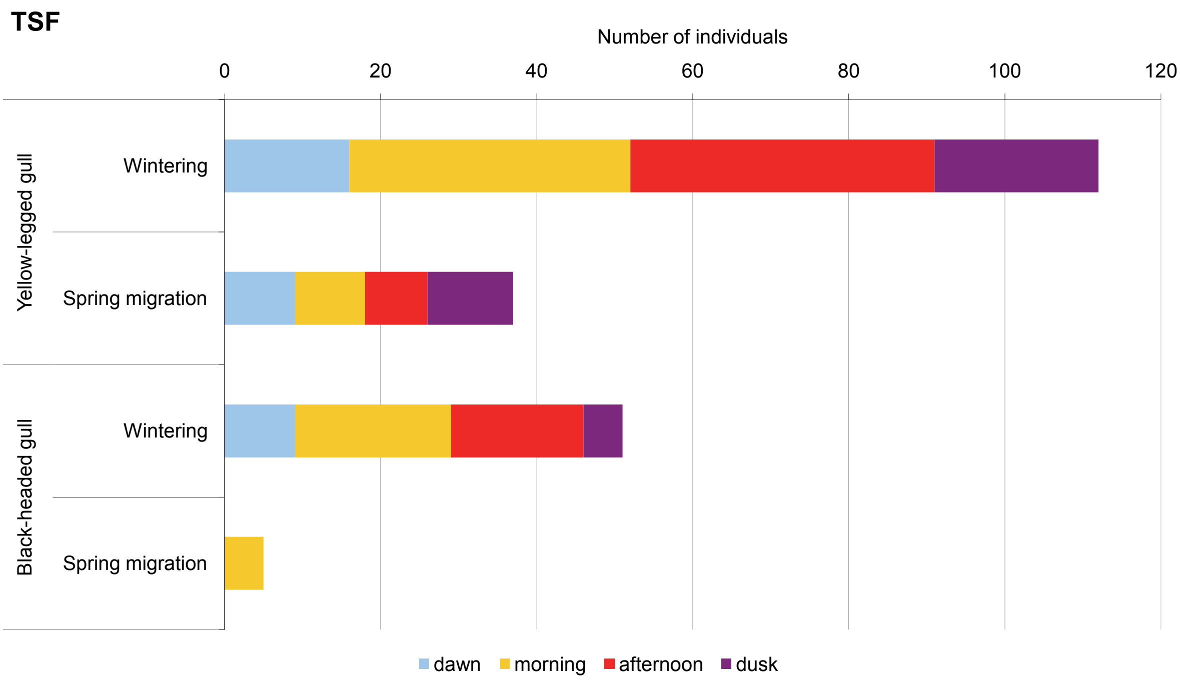


Figure 8.5.4.2: Abundance of yellow-legged gulls and black-headed gulls recorded while crossing the Treviso Antonio Canova airport airspace from March 2010 to April 2011. Data are grouped by daytime and different periods.

8.5.5 Model prediction on yellow-legged gulls' flight lines

The comparison among the four tested Generalized Additive Models is reported in table 8.5.5.1. The different model selection criteria (AIC, Δ AIC and Akaike weight, *w*) indicated model 3 (AIC_{m3} = 1839.885) to be the best supported by the data, with a Δ AIC < 2 and accounting for more than 74% of the weight. Therefore, m3 was selected to predict the likely flight direction of yellow-legged gulls during daytime at VCE airport. Since birds are more active and mobile at dawn and dusk time, it is needed to concentrate especially on these periods, as there is a higher probability of birdstrikes' occurrence. Information from the selected predictive model allow to focus on the activity peaks of gulls, since it outlines their flight paths at different times of the day.

GAM models	Independent variables	AIC	Δ AIC	*w*
m1	daylight hours + period	1940.834	100.949	0.000
m2	period + time slot	1842.012	2.126	0.257
m3	**time slot + period**	**1839.885**	**0.000**	**0.743**
m4	period + daylight hours	1956.808	116.923	0.000

Table 8.5.5.1: List of the four tested Generalized Additive Models, GAM, with their dependent variables, Akaike Information Criterion AIC, Delta AIC (Δ AIC) and Akaike weight (*w*) values. The model selection criteria highlighted model 3 to be the best supported by the data.

The model indicated a spatial movement trend of yellow-legged gulls towards north and west at dawn and morning time, while a directional change was registered in the afternoon and evening with gulls primarily moving towards south (Figure 8.5.5.2; Table 8.5.5.2).

Yellow-legged gulls' flight lines during daytime of different periods at Venice airport (VCE)

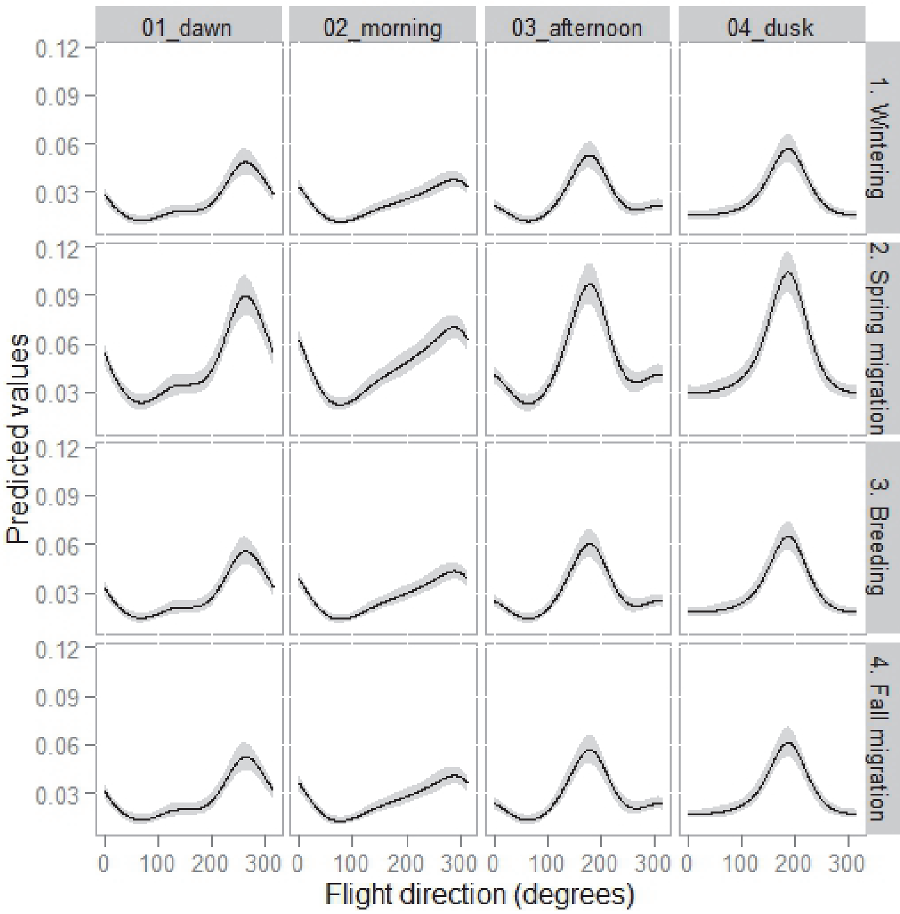


Figure 8.5.5.2: Presence probability for yellow-legged gulls' flight lines during daytime of different periods, at VCE airport. The solid black line represents the predicted values obtained by the fitted GAM model, m3, while the grey shadow effect represents the standard error estimates, returned for each prediction.

Parametric coefficients:	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-3.67377	0.09570	-38.389	**< 0.05**
Spring migration	0.60561	0.10931	5.540	**< 0.05**
Breeding	0.11393	0.12376	0.921	0.357
Wintering	-0.05152	0.13929	-0.370	0.711
Approximate significance of the smooth terms:	**EDF**	**F**		***p*-value**
s (degree: dawn)	3.382	8.245		**< 0.05**
s (degree: morning)	3.366	7.780		**< 0.05**
s (degree: afternoon)	3.615	11.779		**< 0.05**
s (degree: dusk)	3.347	12.076		**< 0.05**
R-sq.(adj) = 0.00964 Deviance explained = 3.22%				
GCV score = 0.29501 Scale est. = 0.29416 n = 6152				

Table 8.5.5.2: Parametric components (estimated parameters, standard errors, *t*-values and *p*-values) and approximate significance of the smooth terms (estimated degrees of freedom, F-test values and *p*-values) of the generalized additive model, m3. Significant factors are highlighted in bold.

With regards to the predictive model on yellow-legged gulls' flight lines in breeding and wintering periods, m5, a clear pattern towards south was found in summer. During winter a directional trend towards north/north-west and south-west was registered (Figure 8.5.5.3; Table 8.5.5.3). A detailed analysis on the flight lines of gulls in the wintering period showed a trend towards north at dawn and morning and towards south/south-west in the afternoon and evening (data not shown).

Yellow-legged gulls' flight lines in breeding and wintering periods at Venice airport (VCE)

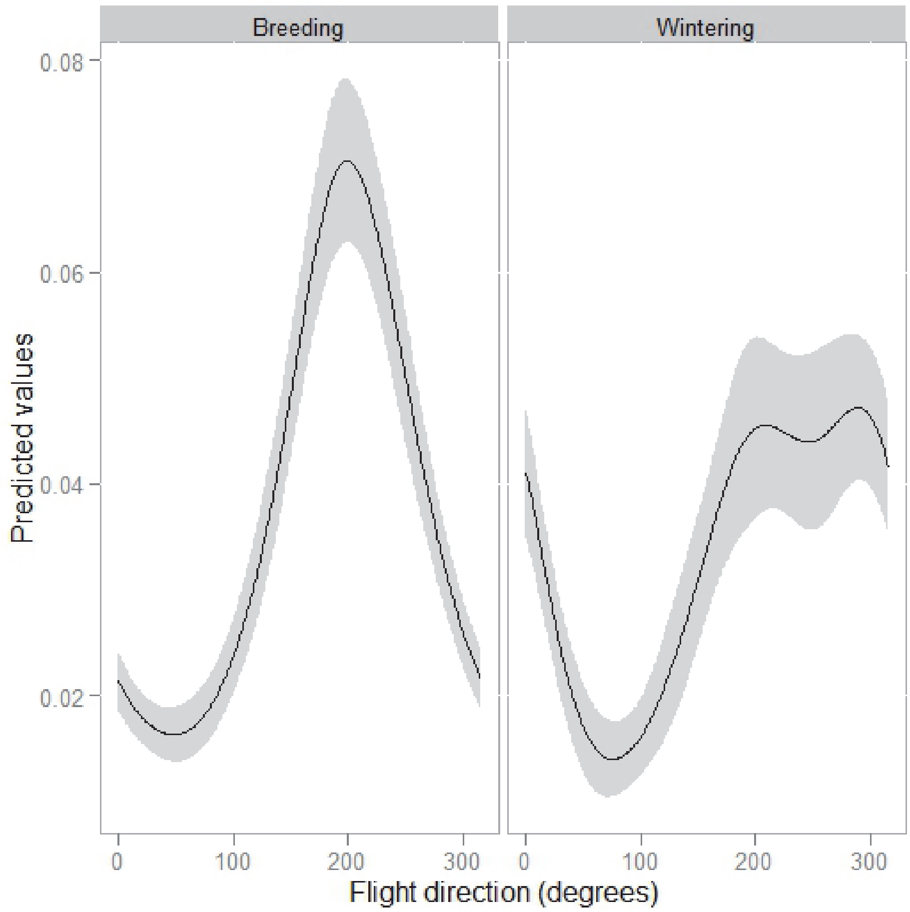


Figure 8.5.5.3: Presence probability for yellow-legged gulls' flight lines in breeding and wintering periods, at VCE airport. The solid black line represents the predicted values obtained by the fitted GAM model, m5, while the grey shadow effect represents the standard error estimates, returned for each prediction.

Parametric coefficients:	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	-3.41497	0.06612	-51.65	**< 0.05**
Approximate significance of the smooth terms:	**EDF**	**F**		***p*-value**
s (degree: breeding)	2.300	21.593		**< 0.05**
s (degree: wintering)	3.182	4.669		**< 0.05**
R-sq.(adj) = 0.00712 Deviance explained = 2.98%				
GCV score = 0.29829 Scale est. = 0.29747 n = 2376				

Table 8.5.5.3: Parametric components (estimated parameters, standard errors, *t*-values and *p*-values) and approximate significance of the smooth terms (estimated degrees of freedom, F-test values and *p*-values) of the generalized additive model, m5. Significant factors are highlighted in bold.

8.5.6 Test of the predictive modelling approach

As previously cited the predictive modelling approach, developed on yellow-legged gulls at VCE airport, was tested by fitting it first to data on yellow-legged gulls from TSF airport and then to data on black-headed gulls at VCE airport. Results from the first test performed, revealed that at TSF yellow-legged gulls moved towards north, south and west at dawn, towards north and west in the morning and primarily towards south-east in the afternoon and evening (Figure 8.5.6.1; Table 8.5.6.1).

Yellow-legged gulls' flight lines during daytime of different periods at Treviso airport (TSF)

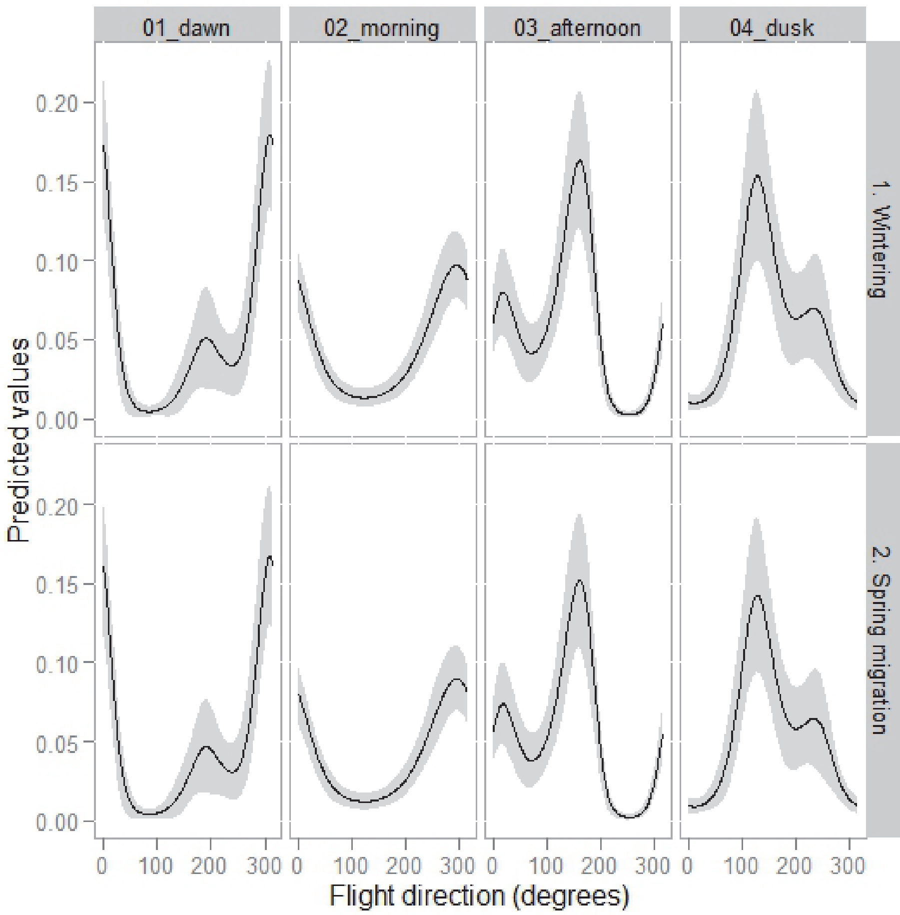


Figure 8.5.6.1: Presence probability for yellow-legged gulls' flight lines during daytime of different periods, at TSF airport.

Parametric coefficients:	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-3.3020	0.1765	-18.71	**< 0.05**
Wintering	0.0863	0.2053	0.42	0.674
Approximate significance of the smooth terms:	**EDF**	**F**		***p*-value**
s (degree: dawn)	3.388	6.971		**< 0.05**
s (degree: morning)	2.206	7.470		**< 0.05**
s (degree: afternoon)	3.944	5.464		**< 0.05**
s (degree: dusk)	3.254	4.542		**< 0.05**
R-sq.(adj) = 0.019 Deviance explained = 9.57%				
GCV score = 0.39501 Scale est. = 0.38732 n = 760				

Table 8.5.6.1: Parametric components and approximate significance of the smooth terms of test 1. Significant factors are highlighted in bold. At TSF, data were available only for wintering and spring migration periods.

Results from the second test performed show that black-headed gulls had a flight pattern similar to that shown by yellow-legged gulls at VCE airports, basically flying towards north and west at dawn and towards south in the afternoon and evening. A single difference was found in the morning, with gulls primarily flying southwards (Figure 8.5.6.2; Table 8.5.6.2).

Black-headed gulls' flight lines during daytime of different periods at Venice airport (VCE)

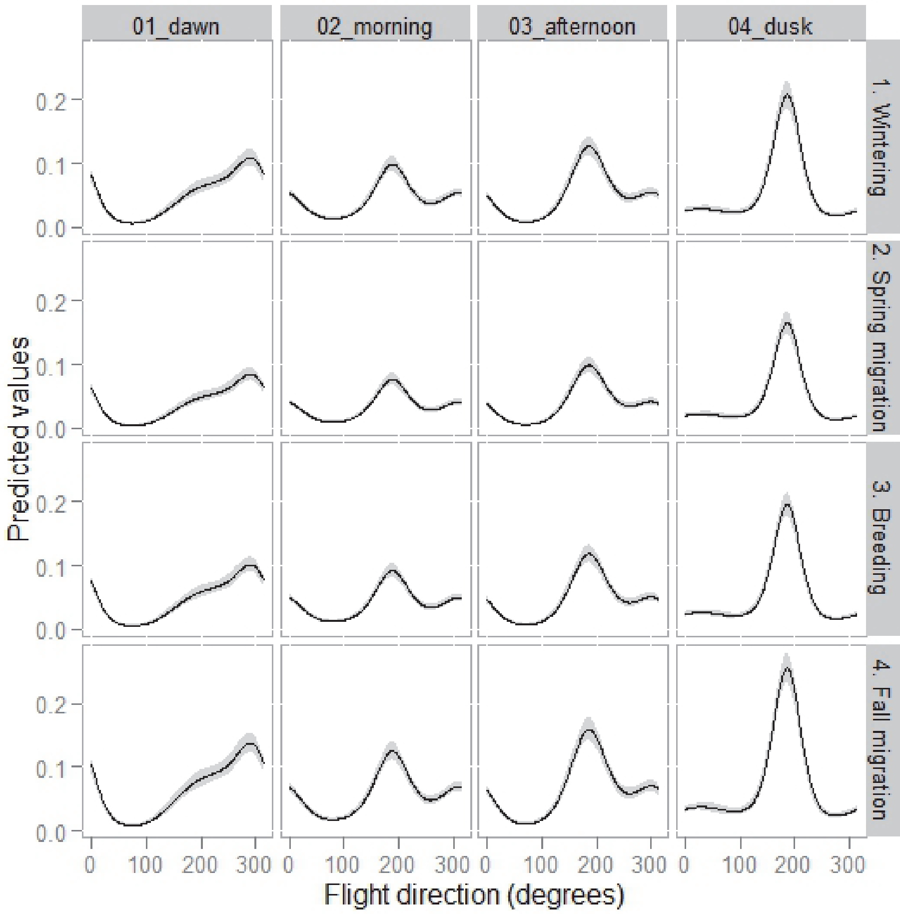


Figure 8.5.6.2: Presence probability for black-headed gulls' flight lines during daytime of different periods, at VCE airport.

Parametric coefficients:	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	-2.97355	0.06886	-43.181	**< 0.05**
Spring migration	-0.48990	0.09871	-4.963	**< 0.05**
Breeding	-0.25708	0.08900	-2.889	**< 0.05**
Wintering	-0.21287	0.09732	-2.187	**< 0.05**
Approximate significance of the smooth terms:	**EDF**	**F**		***p*-value**
s (degree: dawn)	3.837	25.71		**< 0.05**
s (degree: morning)	3.860	21.10		**< 0.05**
s (degree: afternoon)	3.868	30.48		**< 0.05**
s (degree: dusk)	3.905	69.14		**< 0.05**
R-sq.(adj) = 0.0375 Deviance explained = 6.9%				
GCV score = 0.37014 Scale est. = 0.36912 n = 7080				

Table 8.5.6.2: Parametric components and approximate significance of the smooth terms of test 2. Significant factors are highlighted in bold.

Finally, the analysis of birdstrikes occurred with yellow-legged gulls and black-headed gulls at VCE airport, in breeding and wintering, did not indicate any significant difference between the studied periods (Wilcoxon test, W = 72.5, P = 0.088) (Figure 8.5.6.3).

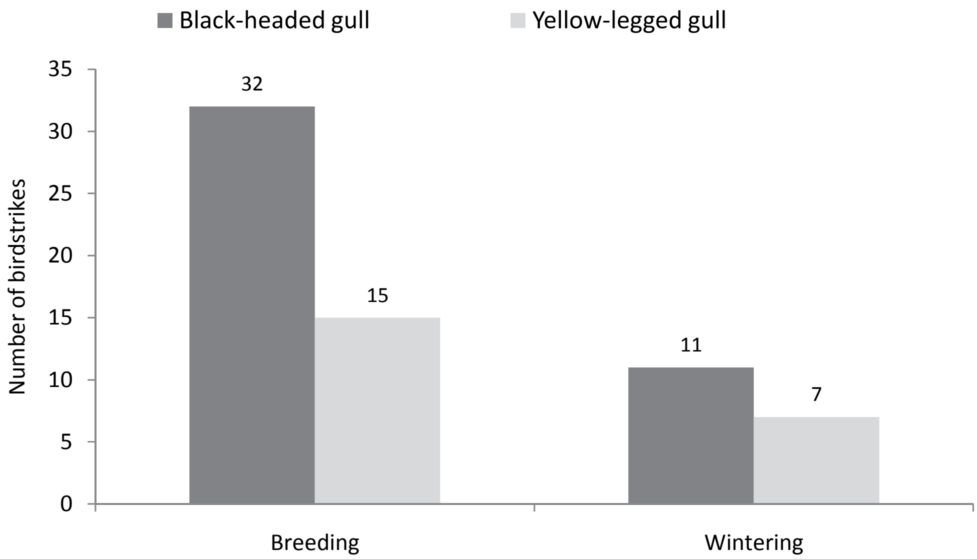


Figure 8.5.6.3: Birdstrikes occurred with yellow-legged gulls and black-headed gulls at VCE airport. Data were available from 2003 to 2012.

8.6 Discussion

In this study five categories of sources were defined as prime drivers for gulls and were mapped with their geo-referenced locations within a merged buffer area of 13 km from the studied airports. The abundance of gulls at such sources, as well as their spatial movements through the airports during daytime and different seasons, were studied in order to link the gulls' flight routes to the attractive sources. Results from the performed analysis showed that yellow-legged gulls and black-headed gulls differently attended the selected categories of sources. A larger abundance of individuals was detected at landfills followed by fields and the Venice lagoon, where gulls' colonies and roosts are located. This suggests that such elements are the most attractive for gulls, thus highly hazardous to aviation if present in the areas surrounding airports. As a consequence, a proper risk management plan should focus especially on these three categories of attractive sources in order to lower the risk of birdstrike, by keeping gulls' movements under control. In addition, a different exploitation of the attractive sources by gulls was found, depending on the time of the day. Landfills were mostly used at dawn and morning times, fields and fish cultures during the afternoon, while the Venice lagoon in the evening. This strongly supports the initial hypothesis that gulls followed different routes depending on the period of the year and time of the day, according to their ecological needs. As previously cited, birds have peaks of activity in the early morning and late evening, with many fewer movements in the middle of the day[112]. This leads to a higher probability of birdstrikes' occurrence especially in these periods. In the current study, a predictive model on gulls' spatial movements during daytime has been developed in order to improve the flight safety at airports. Outlining the flight directions of gulls specifically in each of the four time slots of the day, this predictive model allows to focus on the most hazardous periods for aviation and therefore to prevent the risk of birdstrike along the air corridors followed by gulls. Results from the predictive models on yellow-legged gulls and black-headed gulls at VCE airport revealed similar patterns of flight, during daytime, between the studied species. This suggests similar customs of the gull species and, in particular, a similar use of the attractive sources present in the areas surrounding the airport. Results from the geographical frequency analysis of the attractive sources performed in the study area, showed a large percentage of landfills on the north and west sides of both the studied airports. Therefore, the airport crossing by gulls towards these directions can be interpreted as going inland to reach feeding sites, in particular refuse dumps. The conspicuous presence of gulls at landfills during dawn and morning times, strongly supports this interpretation. A single difference was found for black-headed gulls in the morning time, with gulls primarily flying southwards. Gulls were probably headed to the Venice lagoon which occupies the entire area, together with the city of Venice, along this direction. During the afternoon and evening, both the species flew south to return to their colonies and roost sites.

With regards to the predictive model on yellow-legged gulls' flight lines in breeding and wintering developed for VCE airport, a different trend was found in the two periods. Gulls primarily flew southwards in summer and both north and south in winter. As previously reported, a detailed analysis on the flight lines of gulls in the wintering period showed a trend towards north at dawn and morning and towards south/south-west in the afternoon and evening. It is widely known that gulls' diet in winter, when food is scarce and there are no chicks to feed, is primarily based on garbage [113] while, in the breeding period, gulls show a preference for feeding their chicks on fish caught at sea [113, 86, 114]. Since VCE borders the Venice lagoon on the south side and the mainland on the north, the model predictions agree with existing knowledge that gulls primarily exploit inland food sources during the winter season, while attend mainly coastal areas in summer, when the milder climate allows them to find food for themselves and their nestlings close to the breeding ground and the possibility of capturing food at sea is higher. Although the predictive model outlined a double crossing of VCE airport by gulls in the cold season, to go and come back from the attractive sources located inland, thus potentially a higher number of impacts should be registered in this period, any significant difference in the gulls' strike rate was found between breeding and wintering periods. Results from the model fitted to yellow-legged gulls at TSF airport, showed a different pattern of flight than that found for the same species at VCE airport. Yellow-legged gulls moved towards north, south-east and west at dawn, towards north and west in the morning and primarily towards south-east in the afternoon and evening. Therefore, at dawn and morning time, it is quite difficult to define a clear flight path, since gulls are moving towards different directions.

This situation is based in the locations of the attractive sources, which are ubiquitously present around the airfield. Gulls flying towards north and west are probably reaching the numerous landfills and agricultural fields, which are widespread along these ways. This result highlights that in a situation in which attractive sources are ubiquitously present around the airport, gulls will not follow a unique predictable direction. With equal probability, in the morning time, the airport will be crossed by different flight-lines headed towards the categories of sources present in the surrounding areas. On the contrary, during afternoon and evening gulls fly south-east, probably heading towards Venice lagoon. This agrees with the trend found at VCE that is the return of gulls to their colonies and roosting sites.

Results from the analysis of gulls' attendance on the selected five categories of attractive sources during daytime and the application of the developed predictive modelling approach at two airports with a different arrangement of the sources around them, allowed to state that gulls are strongly influenced by the spatial distribution of the attractive sources, in their daily flights.

Habitats in which airports are located are highly variable, thus the potential for an airport to be crossed daily by gulls is not always concrete. If an airport shows a scenario similar to that of VCE, with attractive food sources and gulls' colonies on opposite sides of it, with high probability a daily crossing of gulls, with very clear flight lines, will be registered. In contrast, if an airport stands in a situation similar to TSF, with attractive sources spread around it, different routes of gulls will be recorded in the airport airspace. Again, in the case of attractive sources located far away from the airport area, maybe only accidental or even no gull crossings will be registered, as individuals will follow different air corridors to reach the distant sites. In this latter case, predictability based on gulls' seasonal and daily movements is less reliable.

To reduce the risk of birdstrikes and their impact on flight operations en route as well as in and around airfields, other predictive models have recently been developed. Shamoun-Baranes and colleagues [(115)] developed two web-based Bird Avoidance Models, providing fine-resolution and frequent predictions of bird densities in an interactive GIS, available on the internet. These models integrated data and expert knowledge on bird distributions and migratory behaviour to provide hazard maps to aviation, but they did not consider the spatial movements of birds while going to forage or roost. Baxter et al. (2003) developed a predictive model to estimate the number of gulls that may use landfill sites in summer as well as the probability of a potentially hazardous winter flight-line between a landfill and a roosting site. Nevertheless this method is limited, not taking in account other categories of prime drivers for gulls and so excluding *a priori* other routes potentially hazardous for aviation.

Alternatively, several countries (e.g., Netherlands, Germany, Belgium, Israel, USA) have used radar to monitor bird flight lines and migration, providing real-time warnings to air crews. However, radar monitoring alone does not make possible to forecast migration intensity without the development and application of models. Again, birds are very small targets for radar detection, leading to the possibility of incurring false alarms (false positives) or missed detections (false negatives).

With respect to these scientific methods, the developed models permit to forecast the flight lines of gulls during daytime and different periods, basing on the prime attractive sources around the airfields, previously identified by the environmental monitoring. Additionally, this study provided an attractiveness ranking of the sources, with landfills at the first place followed by agricultural fields and the Venice lagoon. These information are particularly needed since they can be used to plan specific interventions for strategic land management plans and habitat manipulations in the vicinity of the aerodromes, such as relocating the most appealing sources so that gulls won't cross the airports while going to and from them. In accordance with this, a proper wildlife and environmental monitoring, leading to identify the hazardous species for aviation and their prime drivers in the areas surrounding airports, is fundamental for predicting the occurrence probability of species flight lines. In fact, knowing beforehand the locations of the attractive sources for a given species, allows airport managers to define in advance their possible routes through the airport area and the period in which they will occur. To summary up, the developed modelling approaches, allowing to assess the risk at airports and along the air corridors shared by aircrafts and gulls, besides alerting airport managers in the high-risk periods, provide a tool for a long-term strategy birdstrike risk reduction.

9. Development of a Bio-Geographic Risk Index

9.1 Introduction

In the following paragraphs a new birdstrike risk index is proposed with the aim to integrate and improve the previously developed BRI2 index [48]. Besides the wildlife factor (i.e. wildlife presence with its morphological and behavioural features), the birdstrike factor (i.e. impacts occurred with a given group of species) and the recorded air traffic, this new risk index considers the environmental features around the study airport, including the attractive sources for wildlife. For this reason, we called this bio-geographic risk index ARI (Attraction Risk Index). As reported in the previous chapter, birds are normally attracted by specific categories of sources (e.g. fields, wetlands, landfills etc). The idea behind the development of the ARI index is that, if these sources are present around the aerodrome, there will be a high probability that birds pass through the airport area to reach them. This leads to the possible occurrence of birdstrikes. As birds have specific ecological needs depending on the biological period of the year (e.g. food supply and exploitation of resources), the Attraction Risk Index is period-dependent.

The new ARI index was developed with the aim to assess the risk at airports and in their surroundings, specifically for each period of the year (from wintering to fall migration), simply by focusing on the probability for a given species to cross the airport area, which is based on the attractive sources presence around the airport. Since the ARI index focuses on the airport flight crossing probability, only the 15 groups of bird species, listed in table 3.3.1, have been considered for the analysis.

9.2 Methods

9.2.1 Study area and data collection

The ARI index was developed using VCE as case study . For this study, nine categories of sources were selected as potentially attractive for birds: 1) agricultural fields; 2) urban area; 3) Venice lagoon; 4) coastline; 5) wetlands; 6) industrial area; 7) landfills; 8) urban parks; 9) fish farms. According to ICAO and ENAC guidelines [54, 34], sources were considered when present within a buffer area of 13 Km from the main runway of VCE airport. As reported in paragraph 4.1, the 13 Km buffer is based on the statistic that 99% of birdstrikes occur below 2000 ft and that an aircraft on a normal approach would descend into this buffer approximately at this distance from the runway [55].

Data on wildlife presence collected in the study area from 2006 to 2011 and derived from the "Atlante ornitologico del Comune di Venezia" [101] were used to define the relative abundance of the recorded bird species at the various categories of attractive sources, during the four phases of their biological cycle (about 65.500 records).

In addition, data on wildlife presence from the monitoring activities conducted at airport from 2005 to 2012 (about 26.800 records) as well as birdstrikes data from 2003 to 2012 (367 records) and air traffic data from 2005 to 2012 (96 records), directly provided by the SAVE airport authority, were used to calculate the Group Specific Risk or GSR factor on a period basis (see chapter 5 for details).

9.2.2 Data analysis

The study area of 13 Km buffer around VCE was subdivided into a spatially referenced grid with 1 km^2 cells (with 1 cell = 1 unite) and, according to the Corine Land Cover classification, each cell was associated to one of the nine categories of attractive sources (Figure 9.3.1). Furthermore, in order to assign a different level of risk to the attractive sources, based on their relative position to VCE, the study area was subdivided in three buffer zones, respectively of 3 Km (first buffer), 7 Km (second buffer) and 13 Km (third buffer) (Figure 9.3.2).

The exploitation of attractive sources by birds in the four periods of a given year of study was defined by counting the number of individuals of the recorded species in each cell of the grid, while the relative abundance of sources in the study area was detected by counting the number of cells for each category.

The probability for a *k* group of species to be attracted by a *i* category of sources, in a specific period of the year, P(A), was thus found by applying the following equation:

Equation 1:

$$P(A)_{i,p}^{k=1,..,15} = \frac{\dfrac{NB_{i,p}^{k}}{NC_i}}{\sum_{i=1}^{9} \dfrac{NB_{i,p}^{k}}{NC_i}}$$

where NB is the number of individuals of a *k* group of species recorded in the cells of a specific category of attractive sources (*i*= 1, 9) in a specific period of the year (*p*= 1, 4) and NC is the number of cells of the *i* category of sources.

Afterwards, the relative abundance of attractive sources in the three buffer zones, NS, was defined by counting the number of cells of the *i* category within each of the three buffer zones. The resulted values were then normalized so that their sum would be equal to 1.

Finally, a specific proximity weight, PW, was set to each of the three buffers so that the attractive sources present in the first buffer were considered more hazardous to aviation than those in the third buffer, since closer to the sensible area of the runway.

It is known that aircrafts fly at an altitude of about 2000 ft (=609 m) when at 13 Km from the runway, around 1400 ft (=426 m) when at 7 Km and at 600 ft (=182 m) when at 3 Km. The PW values were defined on the basis of the presence/absence of the species groups flying within the altitudinal range of a given buffer [(116)]. An indicator variable, *I*, was associated to each of the recorded groups of species to define their presence/absence within the three buffer zones. The *I* variable is equal to 1 when the group of species is present, while it takes the value 0 if absent (see table 9.2). Consequently, the higher the number of species flying within a specific buffer, the higher the value of PW.

It is widely known that most bird species live and fly at low altitudes (about 500 ft) [(116)], thus potentially all 15 groups of species may be recorded within the altitudinal range of the first 3 Km buffer. Accordingly, a PW of 0.5 was conferred to it. The second 7 Km buffer ranges from 600 ft to 1400 ft. At these altitudes a total of 10 groups of species may be detected. Therefore, a PW of 0.3 was set to the second buffer. Finally, the 13 Km buffer ranges from 1400 ft to over 2000 ft and it is primarily attended by migratory species which can reach great heights, up to 20000 ft. A PW of 0.2 was thus assigned to the latter buffer.

ID group	Species group	*I* 3 Km	*I* 7 Km	*I* 13 Km
1	Grebes and divers	1	0	0
2	Cormorant, pelicans, swans and geese	1	1	1
3	Herons, storks, flamingos	1	1	1
4	Ducks, pheasants, rallids	1	1	0
5	Birds of prey - large	1	1	1
6	Birds of prey - small	1	1	0
7	Seabirds - large	1	1	0
8	Seabirds - small	1	1	0
9	Waders	1	0	0
10	Doves	1	0	0
11	Owls	1	0	0
12	Swifts and swallows	1	1	1
13	Corvids	1	0	0
14	Non-flocking passerines and bats	1	1	1
15	Flocking passerines	1	1	1

Table 9.2: Indicator variable *I* defining the presence/absence of the bird species groups within the altitudinal range of the three buffer zones (presence= 1; absence= 0).

In order to calculate the GSR of a *k* group of species[48] on a period basis, the following equations were applied:

Equation 2:

$$GF_p^{k=1,..,15} = W^k \cdot Ag^k \cdot \frac{BS_p^k}{TFN_p} \cdot EOF^{95}{}_p^k$$

where W and Ag depend on the features of the *k* group of species and represent respectively the average weight and the median flock size of the group. The BS variable represents the number of impacts occurred with the *k* group of species per period and TFN the mean value of flights per year per period. Finally, the EOF^{95} is the effect on flight caused by the impacts recorded with the group of species in the considered period (see chapter 5 for details).

At this point, the GSR of a *k* group of species in a given period is obtained by multiplying the standardized GF with the mean number of individuals of the *k* group of species recorded in that specific period, DB.

Equation 3:

$$GSR_p^{k=1,..,15} = \frac{GF_p^k}{\sum_{k=1}^{15} GF_p^k} \cdot DB_p$$

9.2.3 Attraction Risk Index

As previously cited, the ARI index assesses the risk of birdstrikes in a specific period of the year, based on the probability that birds pass through the airport area to reach the attractive sources in the areas surrounding it. The airport crossing probability, P(C), is based on two main factors: the attractiveness of the various sources present around the study airport and their total amount. The attractiveness of sources depends on the ecology and diet of the target species, as well as on the time of the year. The amount of sources depends on the geographical and environmental characteristics of the place where the airport is located.

Therefore, P(C) depends on the probability for a given species to be attracted by a particular category of attractive sources in a specific period of the year, P(A), and on the presence of such sources around the airport. The attractive sources presence, ASP, quantifies the probability to find a specific category of attractive sources in the study area and depends on the number of sources of a given category within a specific buffer, NS, and the proximity weight calculated for each buffer, PW.

As the attractive sources are not hazardous for aviation if located in zones inaccessible to birds, the variable *I*, indicating the presence/absence of the groups of species at the three buffers, was also considered. In this way, if a group of species does not fly at the altitudes associated to a specific buffer, attractive sources in it are automatically excluded.

Therefore, the probability to find the *i* category of attractive sources within the first 3 Km buffer is given by the following equation:

Equation 4:

$$ASP_{i=1,..,9}^{3Km} = NS_{i=1,..,9}^{3Km} \times I^{3Km,k=1,..,15} \cdot PW^{3Km}$$

where I_k is the indicator variable taking 1 if a given group of species is present in that buffer and 0 if absent.

ASP must be calculated for each of the nine categories of attractive sources, for each of the three buffers. As an example, the probability to find the landfills category (*i*= 7) in the study area and that such sources influence the species group of large seabirds (group 7), is obtained by the following equation:

$$ASP_{i=7} = ASP_{i=7}^{3Km} + ASP_{i=7}^{7Km} + ASP_{i=7}^{13Km} =$$
$$= (NS_{i=7}^{3Km} \times I^{3Km,k=7} \cdot PW^{3Km}) + (NS_{i=7}^{7Km} \times I^{7Km,k=7} \cdot PW^{7Km}) + (NS_{i=7}^{13Km} \times I_{k=7}^{13Km,k=7} \cdot PW^{13Km})$$

Therefore, supposing to have 10 landfills in the first buffer, 12 landfills in the second one and 2 in the third one, the following equation will be returned:

$$ASP_{i=7} = (0.42 \times 1 \cdot 0.5) + (0.50 \times 1 \cdot 0.3) + (0.08 \times 0 \cdot 0.2) = 0.36$$

At this point, the probability for a *k* group of species to cross the airport area in a specific period of the year, P(C), is equal to the sum of the product between the probability for that group of species to be attracted by a specific source in the target period of the year, P(A) and the related probability to find the sources around the study airport, ASP.

Equation 5:

$$P(C)_p^{k=1,..,15} = \sum_{i=1}^{9} (P(A)_{i,p}^{k} \times ASP_i)$$

As an example, to find the airport crossing probability for the species group of large seabirds in the wintering period, the following equation has to be applied:

$$P(C)_{p=1}^{k=7} = (PA_{i=1,p=1}^{k} \times ASP_{i=1}) + (PA_{i=2,p=1}^{k} \times ASP_{i=2}) + \ldots + (PA_{i=9,p=1}^{k} \times ASP_{i=9})$$

Now, the risk of birdstrike posed to aviation by a *k* group of species in a specific period of the year, here called Group Attraction Risk, GAR, is obtained by summing the probability for that group of species to cross the airport area in the considered period, P(C), with the related GSR.

Equation 6:

$$GAR_{p}^{k=1,..,15} = P(C)_{p}^{k} + GSR_{p}^{k}$$

Finally, the Attraction Risk Index, ARI, for a specific period of the year is given by the following equation:

Equation 7:

$$ARI_{p} = \left(\frac{\sum_{k=1}^{15} GAR_{p} \cdot DF_{p}}{\overline{TFN}} \right)$$

where DF is the mean daily flight traffic per period and $\overline{TFN}$ the average of flights per period.

The ARI risk scores were then normalized so that ranged from 0 to 1 and the attention threshold was set at 0.5, as for BRI2 index [(36)]:

Equation 8:

$$ARIstd_{p} = \frac{ARI_{p} - \min \overset{4}{\underset{p=1}{ARI}}}{\left(\max \overset{4}{\underset{p=1}{ARI}} - \min \overset{4}{\underset{p=1}{ARI}} \right)}$$

In order to test the reliability of the new developed risk index, the ARI index was first compared with the birdstrikes events recorded at VCE airport from 2005 to 2012 and then with the BRI2 index [(48)].

9.3 Results

Results from the subdivision of the study area in 1 Km^2 cells and the following association of the quadrants to a particular category of attractive sources are depicted in figure 9.3.1. Figure 9.3.2 shows the three buffer zones to which attractive sources were assigned, with the related level of hazard. Finally, as an example, the number of individuals of large and small seabirds (group 7 and 8 respectively) recorded in the cells of the grid in the four biological periods of 2011 is represented in figure 9.3.3. Maps relative to group 7 indicate a greater exploitation of the inland areas in winter time - specifically a greater number of gulls were recorded at the industrial area and landfills - while a greater use of the Venice lagoon was detected in summer. This result agree with our findings from the predictive model on yellow legged gulls' flight lines in breeding and wintering periods, developed for VCE airport (see chapter 8, par. 8.5.5), according to which gulls primarily move southwards in the breeding period while they fly towards north/north-west in winter to exploit the anthropogenic sources.

As previously reported, information from the performed analysis allowed us to define the P(A) variable or the probability for the *k* group of species to be attracted by a *i* category of attractive sources in a specific period of the year.

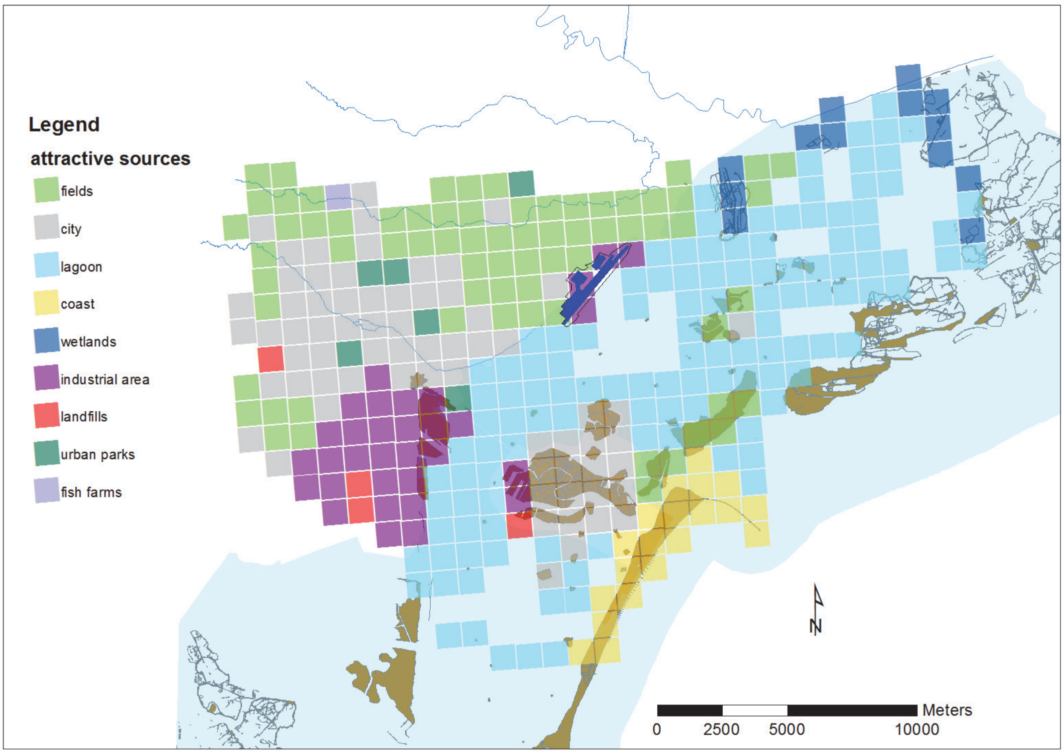


Figure 9.3.1: Subdivision of the study area in 1 Km^2 cells and association of the quadrants to the attractive sources categories, in accordance with the CLC classification.

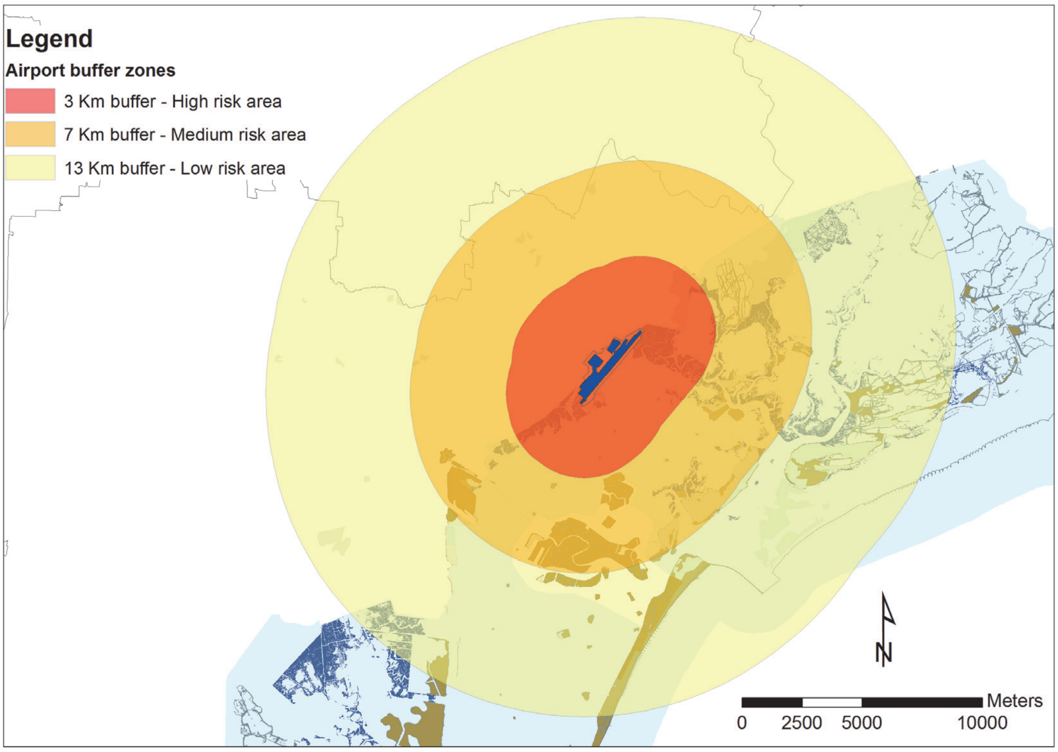


Figure 9.3.2: Subdivision of the study area in three buffer zones and related level of birdstrike risk.

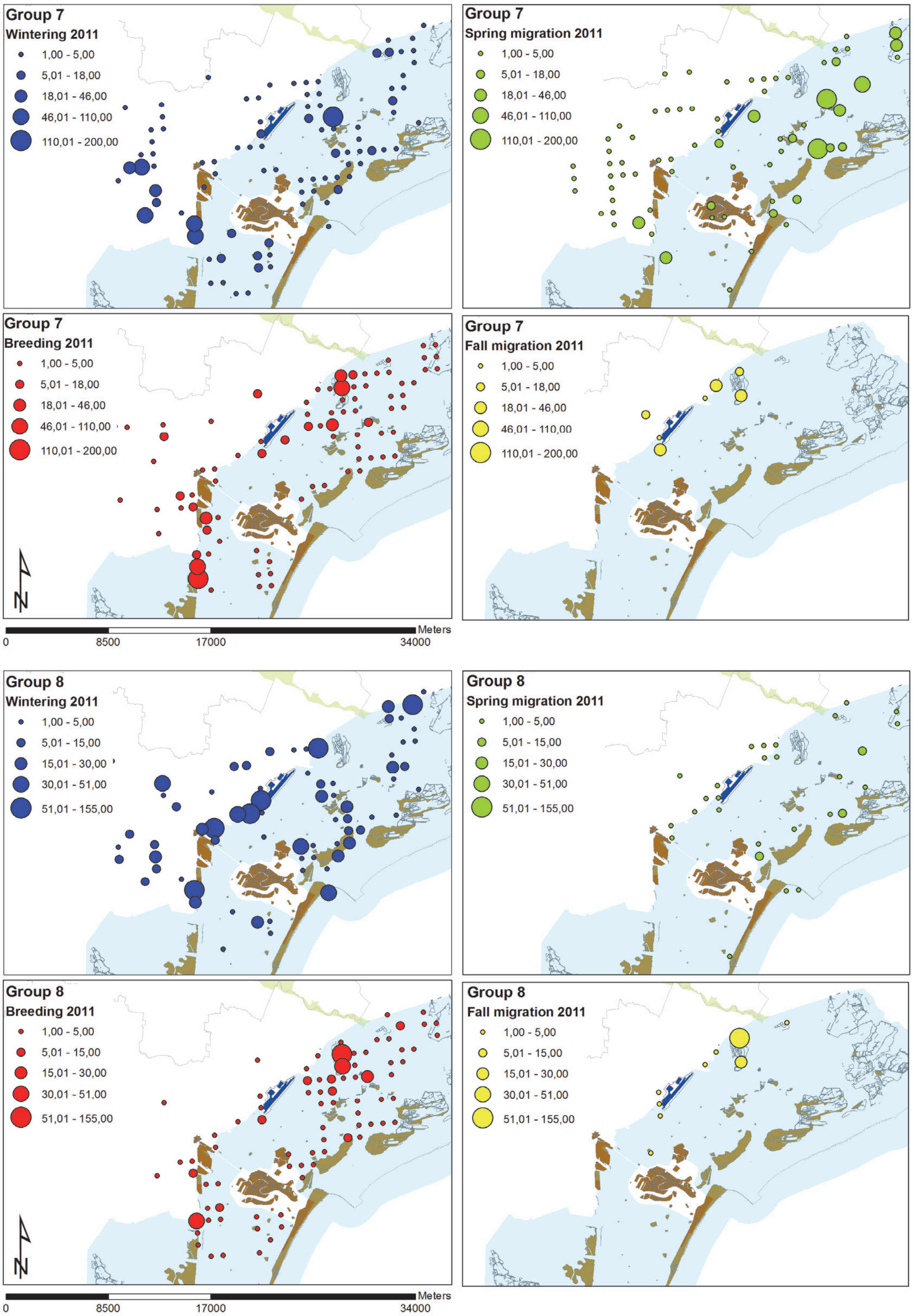


Figure 9.3.3: Relative abundance of the group 7 and 8 at the attractive sources categories present in the study area, in the four biological periods of 2011. Data from 2006 to 2011, derived from the "Atlante Ornitologico del Comune di Venezia", were used to perform this analysis.

Results from the application of the ARI risk index to VCE airport are depicted in figure 9.3.4 and corresponding table. The graph shows the trend of ARI in the four biological periods of the study years. At VCE, the higher risk of birdstrike was registered in fall migration, followed by the breeding period. In general, this pattern is attributable to the autumn migration movements, associated to the presence of juveniles which frequently incur in impacts with aircrafts, because of their inexperience. In autumn, values above the attention threshold of 0.5 were registered in 2005 and from 2009 to 2012, with the latter showing the maximum peak of risk (ARI= 1). Such high risk values are mainly attributable to the large presence of groups of species particularly hazardous for aviation as group 1 (grebes and divers), groups 7 and 8 (large and small seabirds) and group 15 (flocking passerines), in association with the high probability for these species to cross the airport area in the target periods – based on the attractive sources presence around the airport - and the recorded number of impacts and related effects on flights. The peak of risk in 2012 can be explained by considering the total number of impacts (BS= 14). Of these, 9 impacts occurred with the group of species 7 (in particular with yellow-legged gulls) and had substantial effects on flights (BS= 9; EOF^{95}= 3). In the breeding period, a risk score of 0.72 was found in 2012. In fact, a great presence of individuals belonging to groups 1 (N= 1940), 7 (N= 2261) and 8 (N= 4161), in addition to a total number of 24 birdstrikes, were recorded in this period. Of these, 4 impacts occurred with the group of species 6 (i.e. kestrels), 3 with the group 7 (i.e. yellow-legged gulls), 6 with the group 8 (i.e. black-headed gulls), 10 with group 12 (i.e. swifts and swallows) and 1 with group 15 (i.e. starlings).

The ARI risk scores are significantly lower in wintering and spring migration. Such a trend is in line with the birdstrike events recorded at airport from 2005 to 2012 (see table 9.3.5). In fact, the highest number of impacts occurred in late summer, while the lowest one in winter time. In spring migration, a high number of birdstrikes was registered but most of them occurred with swifts and swallows (group 12) and none or minor effect on flight was detected (EOF^{95}= 1 or 2). Finally, the comparison of the annual mean scores between the ARI and the BRI2 index, is shown in table 9.3.4 and figure 9.3.5 a and b. The graphs show a similar trend of the two indexes, although the ARI risk scores are significantly higher than those outlined by BRI2. A peak of risk is detected in 2012, due to particularly high ARI risk scores in the breeding (ARI_{2012}= 0.72) and fall migration (ARI_{2012} =1) periods. High risk values are also highlighted by the BRI2 index, which indicates risk scores above the attention threshold from July to September 2012 (BRI_{2Jul}= 0.64; BRI_{2Aug}= 0.57; BRI_{2Sep}= 1.48) (see chapter 5, tab 5.3.1 for details), however the 12-months calculated average smoothes the risk, lowering such risk peaks.

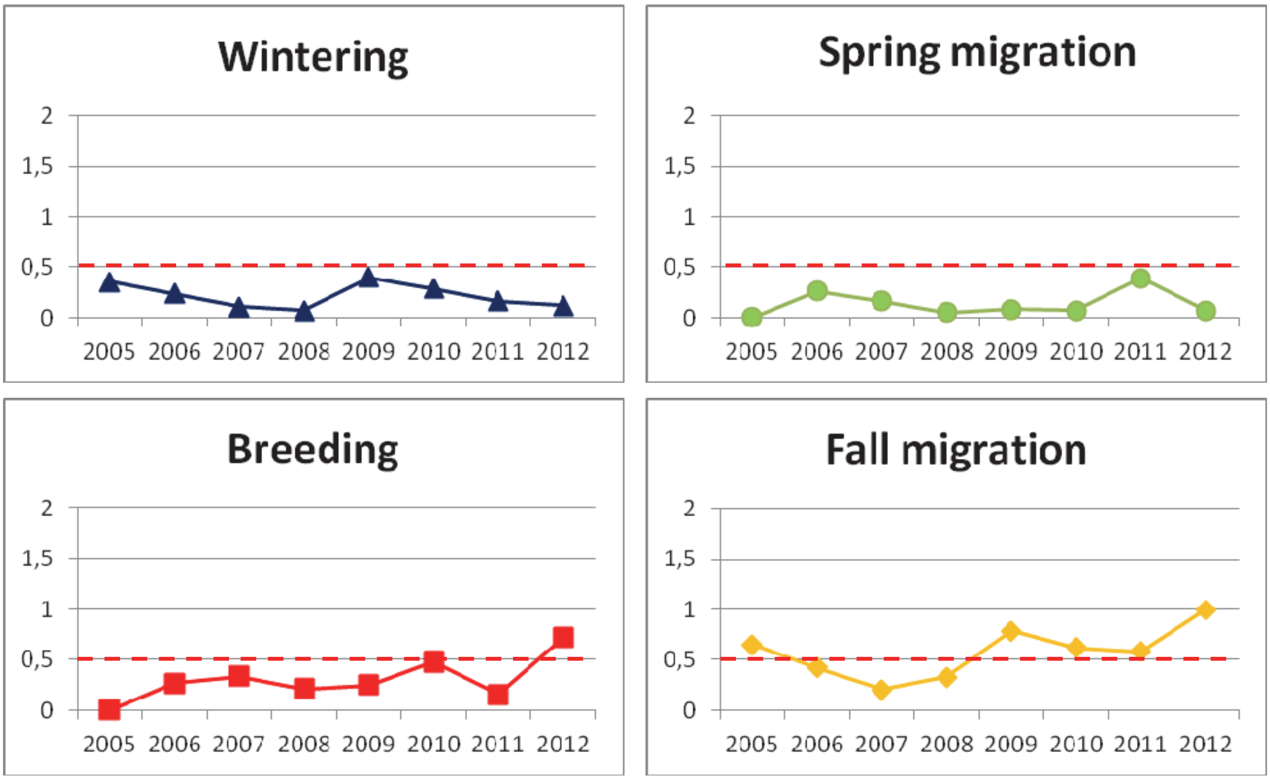


Figure 9.3.4: ARI risk scores for VCE airport in the four biological periods of the study years 2005-2012.

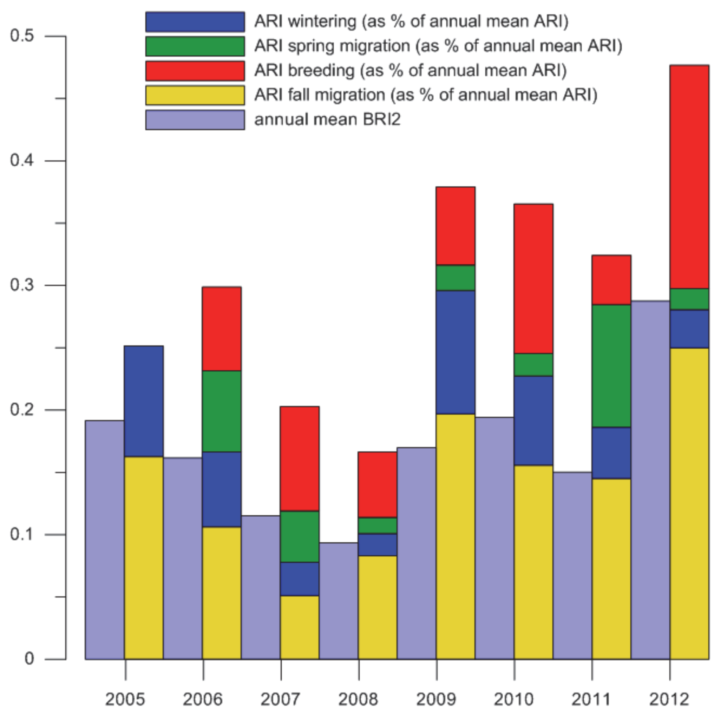
Year	ARI Wintering	ARI Spring migration	ARI Breeding	ARI Fall migration	ARI annual mean	BRI2 annual mean
2005	0,35	0,00	0,00	0,65	0,25	0,19
2006	0,24	0,26	0,27	0,43	0,30	0,16
2007	0,11	0,17	0,33	0,20	0,20	0,12
2008	0,07	0,05	0,21	0,33	0,17	0,09
2009	0,40	0,08	0,25	0,79	0,38	0,17
2010	0,29	0,07	0,48	0,62	0,37	0,19
2011	0,16	0,39	0,16	0,58	0,32	0,15
2012	0,12	0,07	0,72	1,00	0,48	0,29

Table 9.3.4: ARI scores for VCE airport in the period 2005-2012. The green color indicates the values are under the attention threshold of ARI>0.5, while the orange one indicates the values are above it.

Group of species	BS Wintering	BS Spring migration	BS Breeding	BS Fall migration
2				2
3	1	1		
4	1	1		
5		1	1	1
6		5	22	17
7	6	3	7	14
8	6	7	24	7
10		1	9	1
12		38	33	5
13			4	1
14		1	1	
15	3	7	5	3
BS total	**17**	**65**	**106**	**51**

Table 9.3.5: Birdstrike events recorded at VCE airport from 2005 to 2012. Impacts are subdivided by group of species and period of the year.

a)



b)

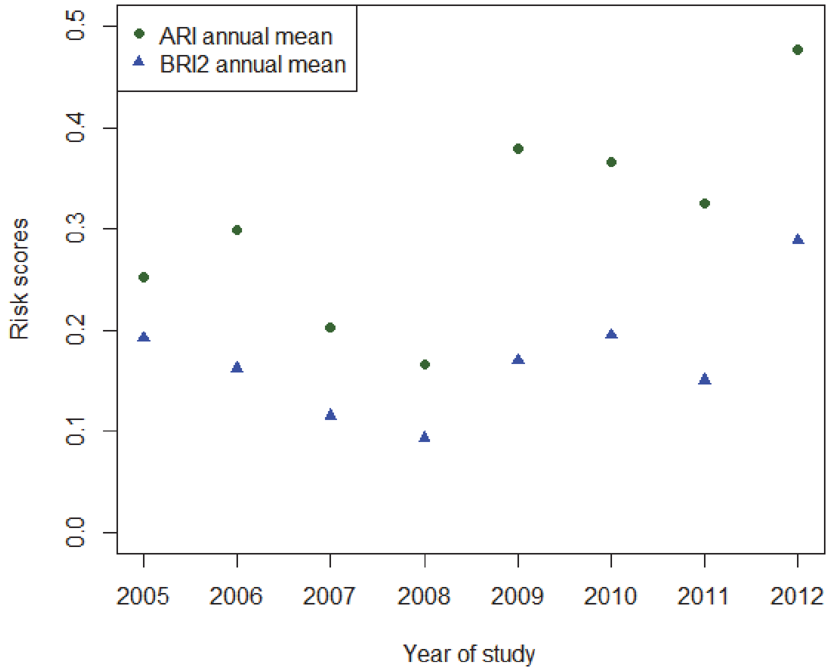


Figure 9.3.5 a and b: Comparison of the annual mean scores between the ARI and the BRI2 indexes for the period 2005-2012. In figure 9.35a the ARI of the four biological periods is represented as percentage of the annual mean values.

9.4 Discussion

It is known that the presence of sources such as landfills, fields or wetlands around airports greatly contribute to attract birds for roosting, feeding or breeding. This leads to a high probability for wildlife to cross the airport area and thus to an increase of the birdstrike risk. The key aspect of the ARI index is to consider the environmental factor around the study airport, besides the recorded birdstrikes and air traffic. Until now, several approaches for birdstrike risk assessment have been proposed worldwide but, of these methods, none has taken into account the environmental features and the attractive sites for wildlife. Therefore, the ARI index stands as an innovative tool in the field of the birdstrike risk analysis. Furthermore, the ARI index assesses the birdstrike risk depending on the period of the year. This is fundamental since birds have different ecological needs and behaviours, according to their biological periods (chick rearing, migration or wintering period). Thus a different hazard, posed to aviation by the airport crossings of birds, is present at airports in different periods. Importantly, results obtained by applying the ARI algorithm to VCE airport demonstrated that the developed bio-geographic risk index is consistent with the birdstrike events recorded at airport from 2005 to 2012. Therefore, the ARI is a sound tool for assessing the hazard at airports and describe future risk scenarios. Additionally, the comparison between the ARI and BRI2 index(48) highlights that ARI better adheres to the trend of risk, maintaining high signals of hazard even if spread on the year. As a consequence, the ARI approach seems to be more conservative and reliable.

Finally, although the ARI algorithm has been currently applied exclusively to VCE, this risk index is easily exportable to other airport realities by performing a careful environmental monitoring in the buffer area of 13 Km from the study airport, to detect the wildlife presence and abundance at the attractive sources present in it. Information on the exploitation of sources, in different periods of the year, can be used for proper landscape planning decisions or habitat manipulations in the vicinity of aerodromes (e.g. landfills closure or relocating) in order to lower the airport crossings by birds and thus the risk of birdstrikes. According to ENAC guidelines, the environmental monitoring should be repeated every 5 years in order to take into account the possible environmental changes occurred in the meantime (e.g. closure of landfills, change of use of an area, buildings construction etc) and thus update the attractive sites present in the target area.

Further studies will focus on several international airports with different environmental features and surrounding habitats, thus different attractants for birds. In this way, it will be possible to create some 'case studies' representative of a specific airport reality which may be used as reference by the airport safety managers, in order to assess the birdstrike risk at airports, through the application of the ARI risk index. Furthermore, we will investigate the possibility to estimate a statistical predictive model to forecast future values of the ARI index, by fitting an *autoregressive integrated moving average* model (ARIMA) [(117)] that is a generalization of an *autoregressive moving average* (ARMA) model. The reliability of the ARIMA model will be then tested on VCE and TSF airports, in order to predict the risk of birdstrike in the long period.

9.5 Nomenclature

Variable	Description
k	group of species (k=1, 15)
i	attractive sources category (i=1, 9)
p	biological period of birds (p= 1, 4)
NB	number of individuals of a k group of species recorded in the cells of a i category of attractive sources
NC	number of cells of the i category of sources
P(A)	probability for a k group of species to be attracted by a i category of attractive sources in a specific period of the year
NS	number of sources of the i category within each of the three buffer zones
PW	proximity weight for each buffer zone
I	presence/absence of the k group of species within the three buffer zones
W	average weight of the k group of species
Ag	median flock size of the k group of species
BS	number of impacts occurred with the k group of species per period per year
EOF[95]	effect on flight caused by the impacts recorded with the k group of species per period per year
TFN	mean value of flights per year per period
GF	group factor of a k group of species
DB	mean number of individuals of the k group of species per period per year
GSR	group specific risk of a k group of species
P(C)	airport crossing probability for a k group of species in a specific period of the year
ASP	probability to find a i category of attractive sources in the study area of 13 Km from the airport
GAR	group attraction risk of a k group of species
DF	mean daily flight traffic per period per year
$\overline{TFN}$	monthly average of flights per period per year
ARI	attraction risk index per period

Table 9.5: List of the variables considered by the ARI risk index with related short description. Variables are organized in the table in order of appearance in the text.

10. General discussion

The increasing trend of wildlife strikes recorded worldwide in recent years poses a serious threat to aviation safety [118]. Therefore, the adoption of strategies aimed to limit the wildlife-aircrafts collisions and keep under control the risk at airports is strongly needed. The current PhD research fits into this perspective taking the BRI2 Index, or the current National Italian standard for birdstrike risk assessment, as the starting point to develop new tools which may be used by airport managers to improve the aviation safety worldwide.

It is widely known that the main factors influencing the birdstrike occurrence are the air traffic and wildlife presence. In our opinion, the very first step for a proper birdstrike risk assessment procedure is a deep knowledge of the wildlife present at the studied airport and its surroundings. Thus, an accurate wildlife monitoring activity, lasting at least one year, should be conducted at airports in order to register the species present in the study area and understand their behavioural habits. Information on wildlife species and relative abundance, in association with details on their feeding customs, exploitation of airport habitats as well as their daily and seasonal trend of presence, are particularly needed to define suitable preventive actions plans and properly manage the hazard posed to aviation by wildlife. For instance:

- by making the airport unattractive to wildlife (e.g. removing any food source, roosting sites and water basins and limiting the vegetation along the airport perimeter);
- by prioritizing management decisions, addressing dissuasive actions towards those species causing the most damage to aviation safety or focusing them at the airport areas most attended by wildlife.

Such information has been integrated with those relating to the environmental features and human activities present around airports. In fact, it is widely recognized that sources such as landfills, wetlands or agricultural fields in the surrounding areas of an airport are crucial in attracting wildlife [119, 54, 56]. This necessarily leads to the possibility that birds pass through the airport area to reach them, leading to the possible occurrence of birdstrikes.

Given the key-role of sources in affecting birds, in the current PhD research we developed predictive models on flight directions of birds, using the attractive sources around airports as proxies for their flight routes. In recent past, a demographic explosion and increased urbanization of many synanthropic bird species have been observed [120]. Among these species, yellow-legged gulls, *Larus michahellis*, and black-headed gulls, *Croicocephalus ridibundus*, dramatically increased in the last 20 years in Italy and Europe, so to be considered pests [121, 66, 122, 77]. Furthermore, gulls are recognized as hazardous species to aviation worldwide [23, 84], being even the most involved in birdstrike accidents in Italy [123]. Such a trend was also confirmed for VCE and TSF airports, therefore predictive GAM models were developed using these two species as study-case, with the aim to define their flight directions during daytime and different periods.

Information from this study are particularly useful as they allow to forecast the spatial movements of gulls and thus to prevent the birdstrikes occurrence along the air corridors shared by aircrafts and birds. Importantly, such information can be used to plan strategic land management or habitat manipulations in the vicinity of aerodromes (e.g. remove the most appealing sources for wildlife, thus the most hazardous from an aviation safety perspective) in order to avoid the airport crossing by gulls and thus lower the risk of birdstrike. The developed modelling approach can be easily adapted to different airport realities, simply by focusing on the prime drivers for the target species.

The final objective of the research was to develop a new integrated bio-geographic risk index or Attraction Risk Index (ARI) for birdstrike risk assessment. The innovation of the ARI risk index is that it takes into account the environmental characteristics and attractive sites for wildlife around airports, besides the wildlife factor, the birdstrike factor and the recorded air traffic. Although exclusively applied to VCE, the new risk index has proved to be a sound and reliable tool for assessing the birdstrike risk at airports, being consistent with the birdstrike events recorded at VCE in the period of study (2005-2012). Furthermore, the ARI algorithm can be exported to other airport realities, by performing a careful environmental monitoring in the buffer area of 13 Km from the study airport in order to detect the wildlife present at the attractive sources in it. Additionally, as birds have different ecological needs according to their biological periods (breeding, migration and wintering periods), the ARI risk index assesses the risk of birdstrike specifically for each phase of the year. This is particularly interesting since it allows to manage the risk separately for different periods and to address precautionary actions directly for a given period.

Finally, thanks to the study carried out in the course of this PhD project, we have moved from assessing the risk of birdstrike at airports, to manage it not only within the airport area but also in its surroundings.

Future developments of the research will be addressed to test the reliability of the ARI risk index by applying it to different airports and to the development of suitable statistics models in order to predict the risk of birdstrike at airports in the long period and thus to provide a tool for a long-term strategy birdstrike risk reduction.

References

1. Dolbeer RA, Wright SE, Weller J et al. Wildlife strikes to civil aircraft in the united states, 1990-2009. Washington, D.C., USA.
2. Dolbeer R. Increasing trend of damaging birdstrikes with aircraft outside the airport boundary: Implications for mitigation measures. Human–Wildlife Interactions, 2011; 5 (2):235-48.
3. DeVault TL, Belant JL, Blackwell BF et al. Airports offer unrealized potential for alternative energy production. Environmental Management 2012; 49:517-22.
4. Richardson WJ, West T. Serious birdstrike accidents to military aircraft: Updated list and summary. In Proceedings of International Bird Strike Committee meeting. Amsterdam, The Netherlands; 2000. 67-98 p.
5. Thorpe J. Fatalities and destroyed aircraft due to bird strikes, 1912-2002
In Proceedings of the International Bird Strike Committee meeting. Warsaw, Poland; 2003. 85-113 p.
6. Thorpe J. Fatalities and destroyed aircraft due to bird strikes, 2002-2004 (with an appendix of animal strikes). In Proceedings of the International Bird Strike Committee meeting Athens, Greece; 2005. 17-24 p.
7. Dolbeer RA, Wright SE. Wildlife strikes to civil aircraft in the united states, 1990-2007. Washington, D.C., USA.
8. Allan JR. The costs of bird strikes and birdstrike prevention. In Proceedings of the National Wildlife Research Center special symposium. Fort Collins, Colorado, USA; 2002. 147-53 p.
9. Dolbeer RA. Birds and aircraft compete for space in crowded skies. ICAO Journal, 2006; 61 (3):21-4.
10. Kelly TC, Allan J. Ecological effects of aviation. In: The Ecology of Transportation: Managing Mobility for the Environment Series Ecological effects of aviation. Springer; 2006; p. 5-24.
11. Vidal E, Medail F, Tatoni T. Is the yellow-legged gull a superabundantbird species in the mediterranean? Impacton fauna and flora, conservation measuresand research priorities. Biodiversity and Conservation, 1998; 7 (8):1013-26.
12. York D, Cummings J, Wedemeyer K. Movements and distribution of radio-collared canada geese in anchorage, alaska. NORTHWESTERN NATURALIST, 2000; 81 (1):11-7.
13. Mallord JW, Dolman PM, Brown AF et al. Linking recreational disturbance to population size in a ground-nesting passerine. Journal of Applied Ecology, 2007; 44 (1):185-95.
14. Evans J, Boudreau K, Hyman J. Behavioural syndromes in urban and rural populations of song sparrows. Ethology, 2010; 116 (7):588-95.
15. Kitowski I. Civil and military birdstrikes in europe: An ornithological approach. Journal of Applied Science, 2011; 11 (1):183-91.
16. Martino JP, Skinn DA. Study of bird ingestions into small inlet area aircraft turbine engines (may 1987-april 1689)FAA Technical Center Atlantic City International Airport N.J. 08405
17. Milsom TP, Horton N. Birdstrike. An assessment of the hazard on uk civil aerodromes 1976-1990. York: Central Science Laboratory; 1995.
18. Canada T. Sharing the skies: An aviation guide to the management of wildlife hazards. In., Series Sharing the skies: An aviation guide to the management of wildlife hazards. Ottawa: Transport Canada Aviation Publishing Division; 2001.
19. Allan JR. A heuristic risk assessment technique for birdstrike management at airports. Risk Analysis, 2006; 26 (3):723-9.
20. Dolbeer RA. Height distribution of birds recorded by collisions with civil aircraft. Journal of Wildlife Management, 2006; 70 (5):1345-50.

21. Barras SC, Dolbeer RA. Reporting bias in birdstrikes at john f. Kennedy international airport, new york, 1979-1998. In Proceedings of 25th International Birdstrike Committee, 2000. Amsterdam; 2000.
22. Barras SC, Wright SE. Civil aircraft collisions with birds and other wildlife in ohio, 1990-1999. Ohio Journal of Science, 2002; 102 (2):2-7.
23. Dolbeer RA, Wright SE, Cleary EC. Ranking the hazard level of wildlife species to aviation. Wildlife Society Bulletin, 2000; 28 (2):372-8.
24. Soldatini C, Georgalas V, Torricelli P et al. An ecological approach to birdstrike risk assessment. European Journal of Wildlife Research, 2010; 56:623-32.
25. Robinson AP. Modelling the birdstrike risk from hazardous birds attracted to restored mineral extraction sites. In Proceedings of 27th International Birdstrike Committee, 2005. Athens; 2005.
26. Soldatini C, Albores-Barajas YV, Torricelli P et al. Testing the efficacy of three deterring systems in two gull species. Applied Animal Behaviour Science, 2008; 110 (3-4):330-40.
27. GILL JA. Approaches to measuring the effects of human disturbance on birds. Ibis, 2007; 149 (s1):9-14.
28. Walker BG, Dee Boersma P, Wingfield JC. Habituation of adult magellanic penguins to human visitation as expressed through behavior and corticosterone secretion. Conservation Biology, 2005; 20 (1):146-54.
29. Albores-Barajas YV, Soldatini C, Furness RW. Are burrow nesting seabird chicks affected by human disturbance? Waterbirds, 2009; 32 (4):572-8.
30. Baudains TP, Lloyd P. Habituation and habitat changes can moderate the impacts of human disturbance on shorebird breeding performance. Animal Conservation, 2007; 10 (3):400-7.
31. Rees EC, Bruce JH, White GT. Factors affecting the behavioural responses of whooper swans (cygnus c. Cygnus) to various human activities. Biological Conservation, 2005; 121 (3):369-82.
32. Mallord JW, Dolman PM, Brown AF et al. How perception and density-dependence affect breeding woodlarks lullula arborea Ibis, 2007; 149 (s1):15-.
33. Sutherland WJ. Future directions in disturbance research. Ibis, 2007; 149:120-4.
34. ICAO. Annex 14 to the convention on international civil aviation. In. 5th end., Series Annex 14 to the convention on international civil aviation. 2009.
35. ENAC. Circolare apt01-a direttiva sulle procedure da adottare per la prevenzione dei rischi di impatto con volatili negli aeroporti (advisory circular apt01-a guideline on the procedures to be taken to prevent the birdstrike risk at the airports). In., Series Circolare apt01-a direttiva sulle procedure da adottare per la prevenzione dei rischi di impatto con volatili negli aeroporti (advisory circular apt01-a guideline on the procedures to be taken to prevent the birdstrike risk at the airports). 2007.
36. ENAC. Circolare apt01-b procedure per la prevenzione dei rischi di impatto con volatili ed altra fauna selvatica (wildlife strike) negli aeroporti (advisory circular apt01-b procedures for preventing the wildlife strike risk at the airports) In., Series Circolare apt01-b procedure per la prevenzione dei rischi di impatto con volatili ed altra fauna selvatica (wildlife strike) negli aeroporti (advisory circular apt01-b procedures for preventing the wildlife strike risk at the airports) 2011.
37. CAA. Cap 680 bird control on aerodromes. In., Series Cap 680 bird control on aerodromes. London; 1998.
38. Rochard JBA. The civil aviation authority's approach to bird hazard risk assessment. In 25th Meeting International Birdstrike Committee. Amsterdam; 2000. 127–38 p.
39. Allan JR. A protocol for bird strike risk assessment at airports. In IBSC25/WP-OS3, 17-21 April. Amsterdam; 2000. 30-46 p.
40. DeFusco RP. Modeling bird hazards to aircraft: A gis application study Photogrammetric Engineering and Remote Sensing 1993; 59:1481-7.

41. Lovell CD. The united states air force bird avoidance model for low-level training flights. Great Plains Wildlife Damage Control Workshop, 1997; 13 (162-170).
42. DeFusco RP, Turner RA. Dodging feathered bullets. The Combat Edge, 1998; 6 (19-20).
43. Burney C. Bam (bird avoidance model) 101. Flying Safety 1999; 55:12-5.
44. Kelly TA, Merritt R, White R et al. The avian hazard advisory system (ahas): Operational use of weather radar for reducing bird strike risk in north america. In Proceedings of the International Bird Strike Committee Meeting; 2000. 1-7 p.
45. Zakrajsek EJ, Bissonette JA. Ranking the risk of wildlife species hazardous to military aircraft. Wildlife Society Bulletin, 2005; 33 (1):258-64.
46. Shamoun-Baranes J, Bouten W, Sierdsema H et al. The netherlands bird avoidance model. 2006.
47. Addy Borst N. Be real; the effectiveness of avian radars. In IBSC Conference, 25-29 June. Stavanger, Norway; 2012.
48. Soldatini C, Albores-Barajas Y., Lovato T. et al. Wildlife strike risk assessment in several italian airports: Lessons from bri and a new methodology implementation. PLoS ONE, 2011; 6 (12):6.
49. Save SpA. Comunicato stampa del 15 dicembre 2009 - aeroporto treviso: Ottenuta concessione quarantennale. In., Series Comunicato stampa del 15 dicembre 2009 - aeroporto treviso: Ottenuta concessione quarantennale. 2009.
50. Save SpA. Comunicato stampa del 07 luglio 2011- aeroporto di venezia: Traffico in forte crescita nel mese di giugno In., Series Comunicato stampa del 07 luglio 2011- aeroporto di venezia: Traffico in forte crescita nel mese di giugno 2011.
51. SAVE SpA. Piano d'azione aeroporto marco polo di venezia - tessera (action plan venice marco polo airport - tessera).
52. Soldatini C, Coccon F, P. T. Monitoraggio faunistico e analisi del rischio di wildlife strike presso l'aeroporto marco polo di venezia (wildlife monitoring and wildlife strike risk analyses at the venice marco polo airport)Department of Environmental Science, Informatics and Statistics, Ca' Foscari University of Venice.
53. Soldatini C, Coccon F, P. T. Monitoraggio faunistico e analisi del rischio di wildlife strike presso l'aeroporto antonio canova di treviso (wildlife monitoring and wildlife strike risk analyses at the treviso antonio canova airport) Department of Environmental Science, Informatics and Statistics, Ca' Foscari University of Venice.
54. ENAC. Informativa tecnica linee guida relative alla valutazione delle fonti attrattive di fauna selvatica in zone limitrofe agli aeroporti (technical information guidelines for the evaluation of attractive sources for wildlife in airport proximities). In., Series Informativa tecnica linee guida relative alla valutazione delle fonti attrattive di fauna selvatica in zone limitrofe agli aeroporti (technical information guidelines for the evaluation of attractive sources for wildlife in airport proximities). 2009.
55. CAA. Cap 772 birdstrike risk management for aerodromes. In., Series Cap 772 birdstrike risk management for aerodromes. TSO; 2008.
56. ENAC. Informativa tecnica valutazione della messa in opera di impianti di discarica in prossimità del sedime aeroportuale (technical information evaluation of the implementation of landfills in the vicinity of the airport). In., Series Informativa tecnica valutazione della messa in opera di impianti di discarica in prossimità del sedime aeroportuale (technical information evaluation of the implementation of landfills in the vicinity of the airport). 2008.
57. Washburn BE. Evaluation of trash-transfer facilities as bird attractantsU.S. Department of Transportation
Federal Aviation Administration Office of Airport Safety & Standards.
58. Odum EP. Basi di ecologia. Padova: Piccin; 1988.

59. Directive 2009/147/ec of the european parliament and of the council on the conservation of wild birds
In., Series Directive 2009/147/ec of the european parliament and of the council on the conservation of wild birds
2009.
60. Bray JR, and J. T. Curtis. An ordination of the upland forest communities of southern wisconsin. Ecological Monographs 1957; 27:325-49.
61. Yoshioka P. Misidentification of the bray-curtis similarity index. Mar Ecol Prog Ser, 2008; 368:309-10.
62. Clarke K. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 1993; 18:117-43.
63. Clarke K, Gorley R. Primer v6: User manual/tutorial. Primer-e, plymouth. . 2006.
64. Blokpoel H, Spaans AL. Introductory remarks: Superabundance in gulls: Causes, problems and solutions. In Acta XX Congressus Internationalis Ornithologici, 2-9 december. Christchurch, New Zealand; 1991. 2359-61 p.
65. Feare CJ. Control of bird pest populations. In: Bird population studies: relevance to conservation and management. Series Control of bird pest populations. Oxford: Oxford University Press; 1991; p. 463-87.
66. Vidal E, Medail F, Tatoni T. Is the yellow-legged gull a superabundant bird species in the mediterranean? Impact on fauna and flora, conservation measures and research priorities. Biodiversity and Conservation, 1998; (7):1013-26.
67. Beaubrun PC. Controllo numerico di una specie in espansione: Il gabbiano reale larus cachinnans (numerical control of a growing species: The yellow-legged gull larus cachinnans). In La gestione degli studi ambiente costieri e insulari de Mediterraneo (X. Monbailliu and A. Torre, eds) Medmaravis, Alghero; 1994. 353–79 p.
68. Bosch M, Oro D, Ruiz X. Dependence on food from human activities in the yellow-legged gull larus cachinnans at two western colonies. Avocetta, 1994; 18:135-9.
69. Oro D, Bosch M, Ruiz X. Effects of a trawling moratorium on the breeding success of the yellow-legged gull larus cachinnans. Ibis, 1995; 137:547-49.
70. Belant JL. Gulls in urban environments: Landscape-level management to reduce conflict. Landscape and Urban Planning, 1997; 38 (3):245-58.
71. Raven SJ, Coulson JC. The distribution and abundance of larus gulls nesting on buildings in britain and ireland. Bird Study, 1997; 44 (1):13-34.
72. Vincent T. Ecologie et comportements des populations de goélands argentés (larus argentatus argenteus brehm, 1822) en milieu urbain : L'exemple de la ville du havre (seine-maritime, france) (ecology and behaviour of herring gulls populations (larus argentatus argenteus brehm, 1822) in urban zones : The example of havre city (seine-maritime, france): Thèse Diplôme Etudes Doctorales, Univ. Rouen, France; 1994. 326 p.
73. Coulson JC. The status of the kittiwake in the british isles. Bird Study, 1963; 10:147-79.
74. Cramp S, Simmons KEL. Handbook of the birds of europe, the middle east and north africa: The birds of the western palearctic. Oxford: Oxford University Press; 1983.
75. Gibbons DW, Reid JB, Chapman RA. The new atlas of breeding birds in britain and ireland: 1988-1991. London: T & AD Poyser; 1993.
76. Dwyer CP, Belant JL, Dolbeer RA. Distribution and abundance of roof-nesting gulls in the great lakes region of the united states. Ohio Journal of Science 1996; 96 (1):9–12.
77. Soldatini C, Albores-Barajas YV, Mainardi D et al. Roof nesting by gulls for better or worse? Italian Journal of Zoology, 2008:295-303.

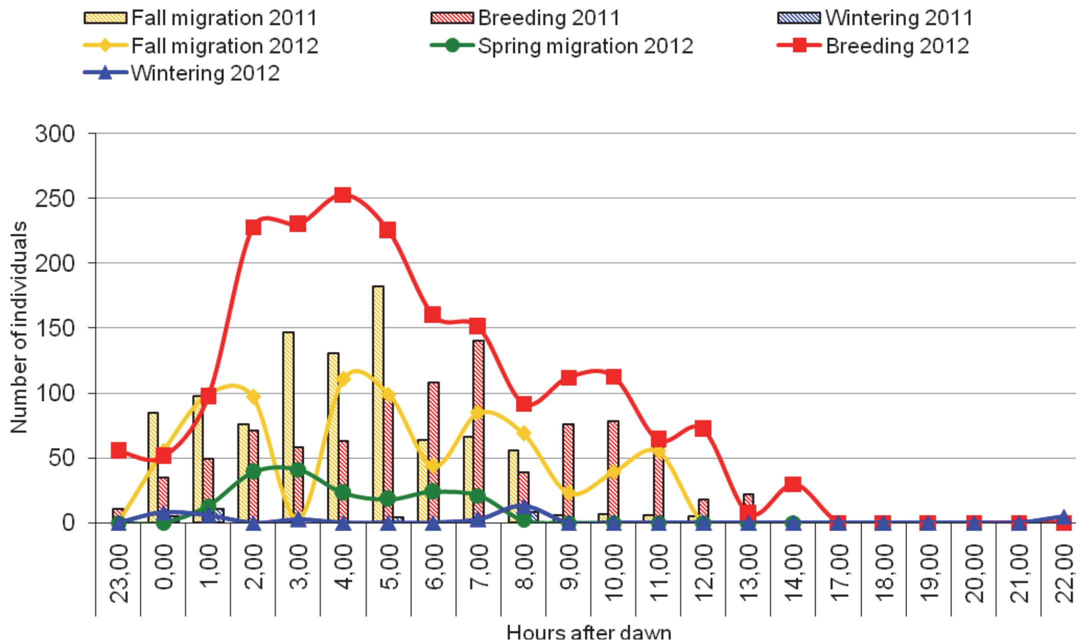
78. Blokpoel H, Struger J. Cherry depredation by ring-billed gulls larus delawarensis in the niagara peninsula, ontario. Can. Field Nat. , 1988; 102:430-3.
79. Swennen C. Gull predation upon eider somateria mollissima ducklings: Destruction or elimination of the unfit? Ardea, 1989; 77:21-45.
80. Monaghan P, Shedden CB, Ensor K et al. Salmonella carriage by herring gulls in the clyde area of scotland in relation to their feeding ecology. J. Appl. Ecol., 1985; 22:669-80.
81. Dolbeer RA, Belant JL, Sillings JL. Shooting gulls reduces strikes with aircraft at kennedy john f. International-airport. Wildlife Society Bulletin, 1993; 21 (4):442-50.
82. Furness RW, Monaghan P. Seabird ecology. In., Series Seabird ecology. Blackie, London, UK; 1987.
83. Sol D, Arcos JM, Senar J. C. The influence of refuse tips on the winter distribution of yellow-legged gulls larus cachinnans. Bird Study, 1995; 42 (3):216-21.
84. Mackinnon B. Sharing the skies. In: An Aviation industry guide to the management of wildlife hazards. Series Sharing the skies. Ottawa: Transport Canada; 2001.
85. Horton N, Brough T, Rochard J. The importance of refuse tips to gulls wintering in an inland area of south-east england. Journal of Applied Ecology, 1983; 20:751-65.
86. Baxter AT, St. James K, Thompson R. et al. Predicting the birdstrike hazard from gulls at landfill sites. In IBSC 26 Warsaw, 5-9 May 2003; 2003.
87. Baxter AT. Evaluating bird control for the waste management industry. J.Wastes Management, 2001.
88. Baxter AT, Cropper P. Aeronautical studies to determine the spatial movements of hazardous species In IBSC 27 Athens 2005; 2005.
89. Sodhi NS. Competition in the air: Birds versus aircraft. The Auk, 2002; 119 (3):587-95.
90. Bertellotti M, Yorio P. Spatial and temporal patterns in the diet of the kelp gull in northern chubut, patagonia. Condor, 1999; 101 790–8.
91. Bertellotti M, Yorio P. Utilisation of fishery waste by kelp gulls attending coastal trawl and longline vessels in northern patagonia, argentina Ornis. Fenn. , 2000; 77:105–15.
92. Baxter AT. Effectiveness of best practice bird control on landfill sites in relation to gull feeding behaviour. In Proceedings of 27th International Birdstrike Committee, 2005. Athens; 2005.
93. Giaccardi M, Yorio P. Temporal patterns of abundance and waste use by kelp gulls (larus dominicanus) at an urban and fishery waste site in northern coastal patagonia, argentina. Ornitologia Neotropical, 2004; 15 (1):93-102.
94. ICAO. Annex 14: Airport planning manual (doc. 9184 – an/902) - part 2: Land use and environmental control.
95. Dolbeer RA, S. E. Wright, J. Weller et al. Wildlife strikes to civil aircraft in the united states 1990–2008. Washington, D.C., USA.
96. Washburn BE, G. E. B, L. A. K-B. Using dietary analyses to reduce the risk of wildlife–aircraft collisions. Human-Wildlife Conflicts 2011; 5 (2):204-9.
97. Olsen KM, Larsson H. Gulls of europe, asia and north america. London.: Christopher Helm; 2003. 608 p.
98. Soldatini C, Albores-Barajas YV, Mainardi D et al. A widespread gull population in a complex wetland: Habitat specific methods to census breeding pairs. Avocetta, 2009.
99. Scarton F. La nidificazione del gabbiano comune, larus ridibundus, in laguna di venezia: Anni 1989.1990 (breeding of black-headed gull, larus ridibundus, in the lagoon of venice: Years 1989-1990). Riv. ital. Orn., 1991; 61 (3.4):148-50.
100. Vernon J. Feeding habitats and food of the black-headed and common gulls. Bird Study, 1970; 17 (4):287-96.

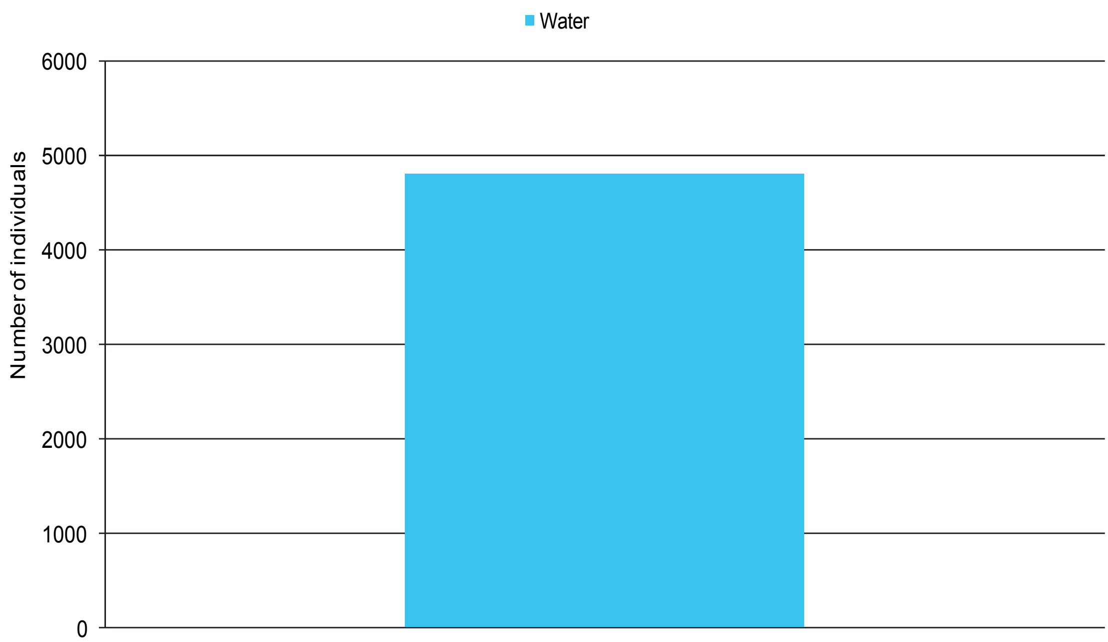
101. Bon M, Stival E, Semenzato M et al. Uccelli di laguna e di città. L'atlante ornitologico nel comune di venezia 2006-2011(birds of the lagoon and the city. Birds atlas in the municipality of venice 2006-2011). Venezia: Marsilio; 2013.
102. R Development Core T. R: A language and environment for statistical computing 2012.
103. Zuur AF, Ieno EN, Smith GM. Analysing ecological data: Springer; 2007. (Statistics for biology and health).
104. Zuur AF, Ieno EN, Elphick CS. A protocol for data exploration to avoid common statistical problems. Methods in Ecology & Evolution, 2009.
105. Wood SN. Stable and efficient multiple smoothing parameter estimation for generalized additive models. Journal of the American Statistical Association, 2004; 99 (467):673-86.
106. Wood SN. Generalized additive models: An introduction with r: Chapman and Hall/CRC; 2006.
107. Wood SN. Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. Journal of the Royal Statistical Society 2011; 73 (1):3-36.
108. Eilers PHC, Marx BD. Flexible smoothing with b-splines and penalties. Statistical Science, 1996; 11 (2):89-121.
109. Akaike H. A new look at the statistical model identification. IEEE Transactions on Automatic Control, 1974; 19 (6):716-23.
110. Burnham KP, Anderson DR. Model selection and multimodel inference - a practical information-theoretic approach. New York: Springer-Verlag; 2002.
111. Bibby C, Jones M, Marsden S. Expedition field techniques bird surveys Cambridge, U.K.: BirdLife International; 2000.
112. Bibby CJ, Burgess N, Hill D et al. Bird census techiques. In. Vol. second, Series Bird census techiques. London: Academic Press; 2005; p. 1-302.
113. Belant JL, Seamans T. W., Gabrey S. W. et al. The importance of landfills to nesting herring-gulls. Condor, 1993; 95 (4):817-30.
114. Soldatini C, Riccato F, Torricelli P. et al. Yellow legged gulls' diet and foraging locations In XV Meeting of the Italian Society of Ecology. Torino; 2005.
115. Shamoun-Baranes J., Bouten W, Buurma L et al. Avian information systems: Developing web-based bird avoidance models. Ecology and Society, 2008; 13 (2):38.
116. Scott GR. Elevated performance: The unique physiology of birds that fly at high altitudes. The Journal of Experimental Biology, 2011; 214 (15):2455-62.
117. Box GEP, Jenkins GM, Reinsel GC. Time series analysis: Forecasting and control (1994) - third edition, englewood cliffs, nj: Prentice hall, 197-199
118. Thorpe J. Update on fatalities and destroyed civil aircraft due to bird strikes with appendix for 2008 & 2009. In 29th Meeting of the International Bird Strike Committee. Cairns (Australia); 2010.
119. Blackwell BF, DeVault TL, Fernandez-Juricic E et al. Wildlife collisions with aircraft: A missing component of land-use planning for airports. Landscape and Urban Planning, 2009; 93 (1):1-9.
120. Moller AP. Successful city dwellers: A comparative study of the ecological characteristics of urban birds in the western palearctic. Oecologia, 2009; 159 (4):849-58.
121. Thomas GJ. A review of gull damages and management methods at nature reserves. Biol. Conserv. , 1972; 4:117-27.
122. Rock P. Urban gulls: Problems and solutions. British birds, 2005; 98:338-55.
123. Montemaggiori A. Il problema del birdstrike in italia: Situazione attuale e scenari futuri. Alula, 2009; XVI (1-2):420-5.

Annex I – Seasonal and daily trend and Use of the habitat of the functional groups of species

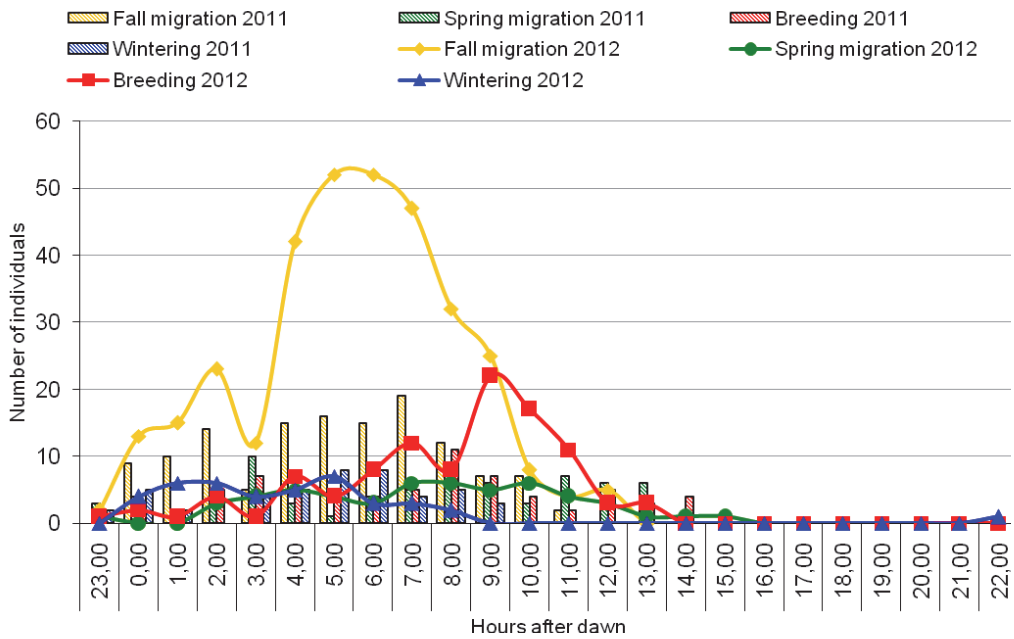
Venice Marco Polo Airport – VCE

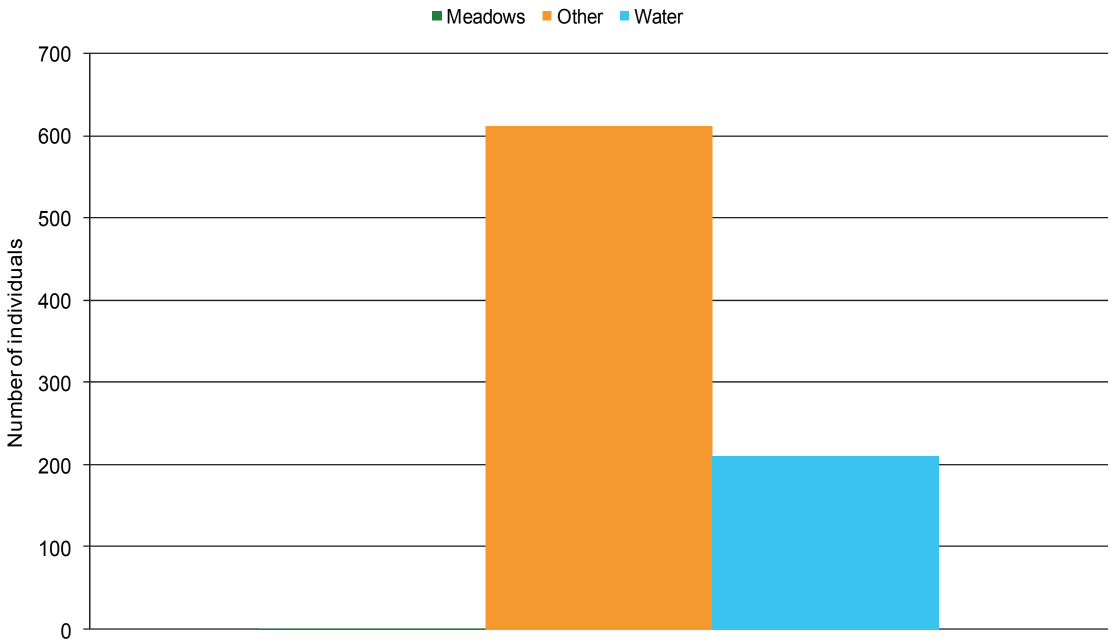
Group 1 – Grebes and divers



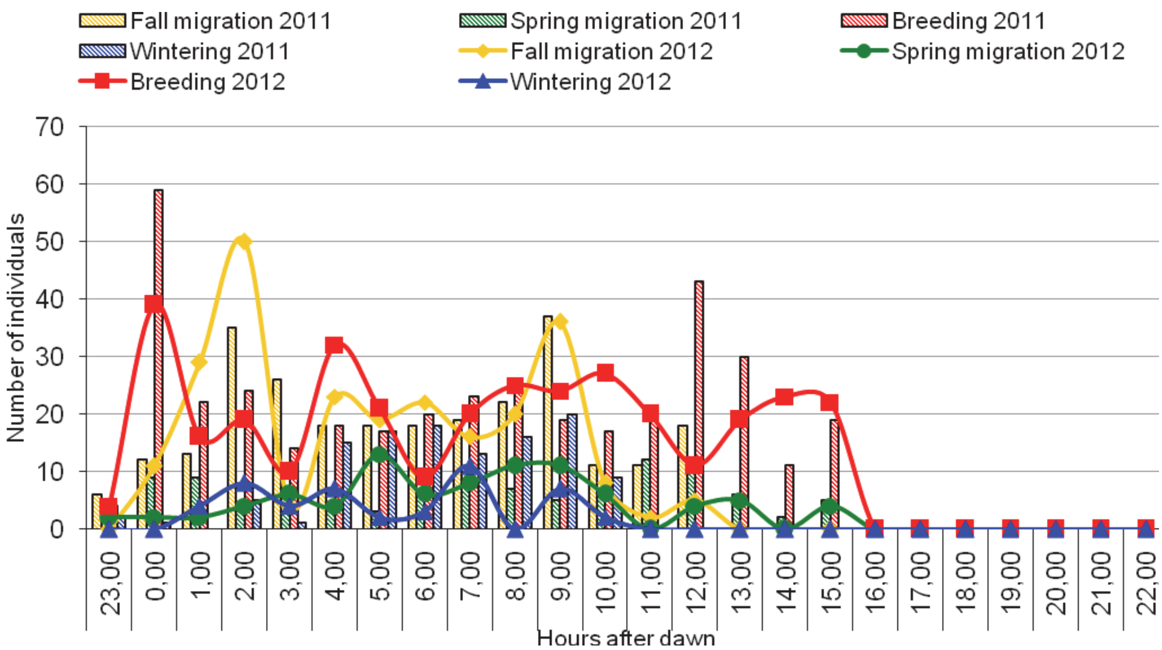


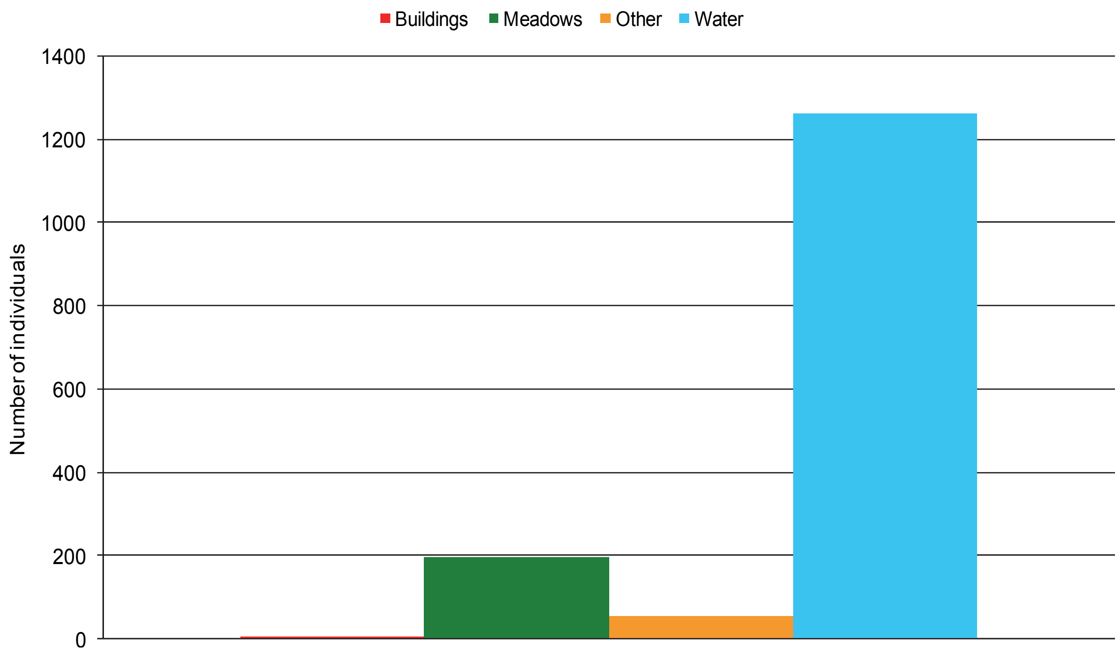
Group 2 – Cormorants, pelicans, swans and geese



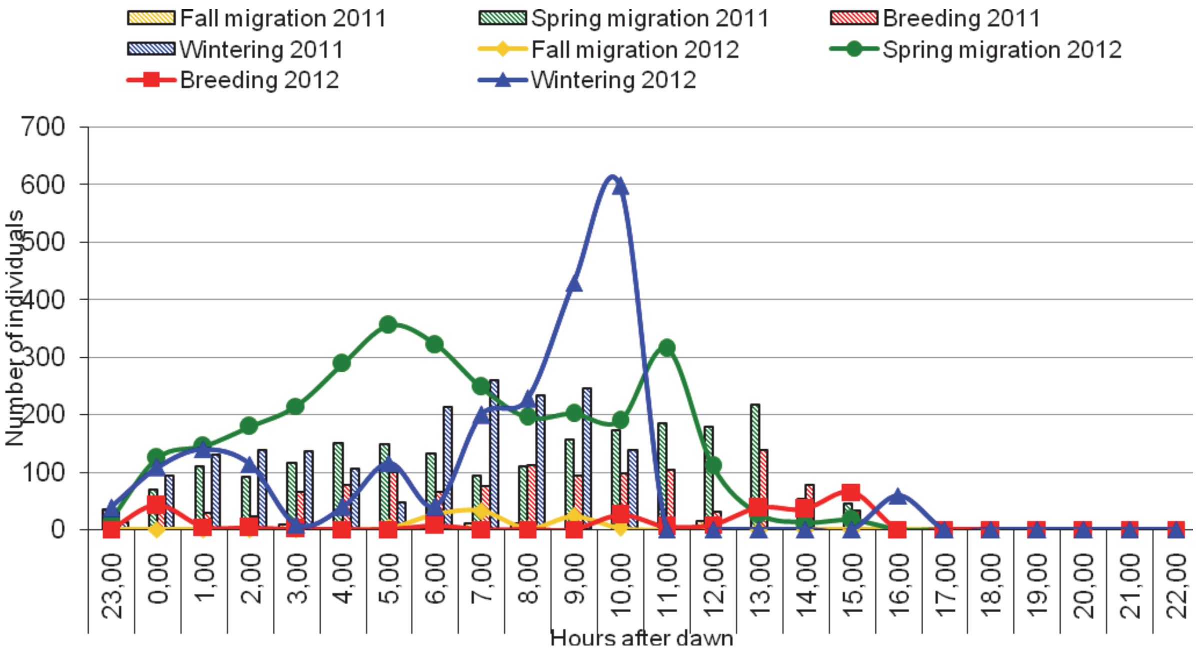


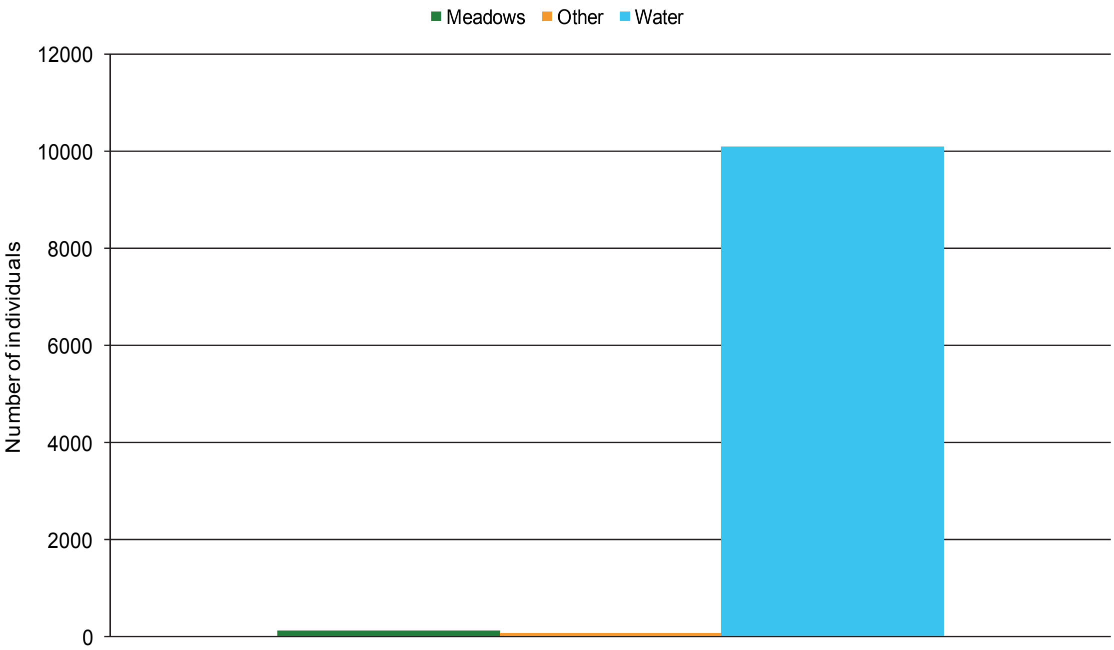
Group 3 – Herons, storks, flamingos



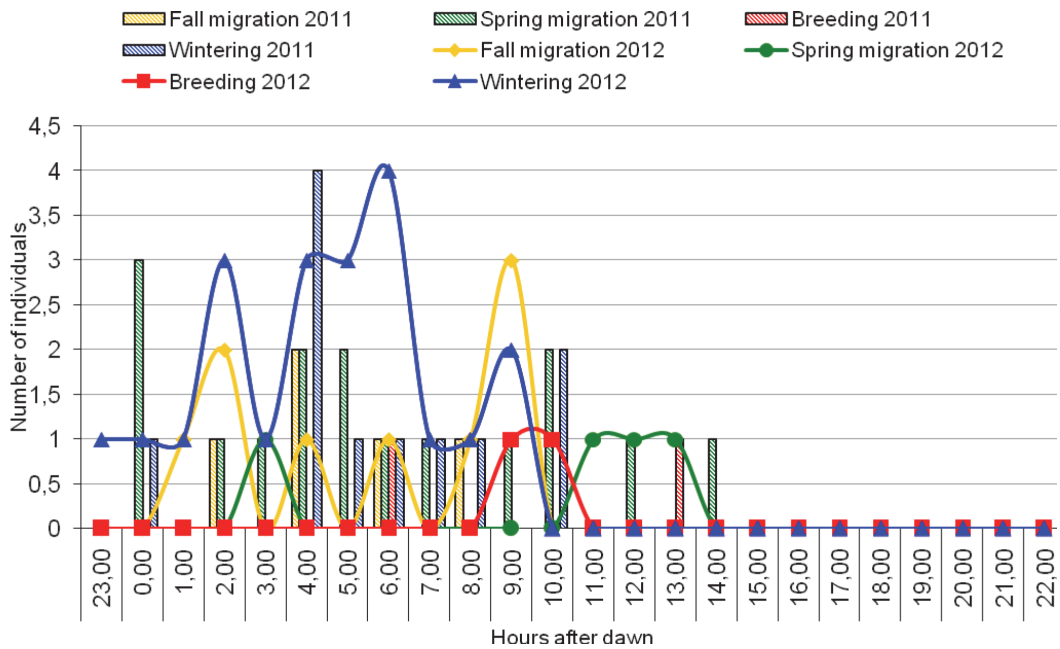


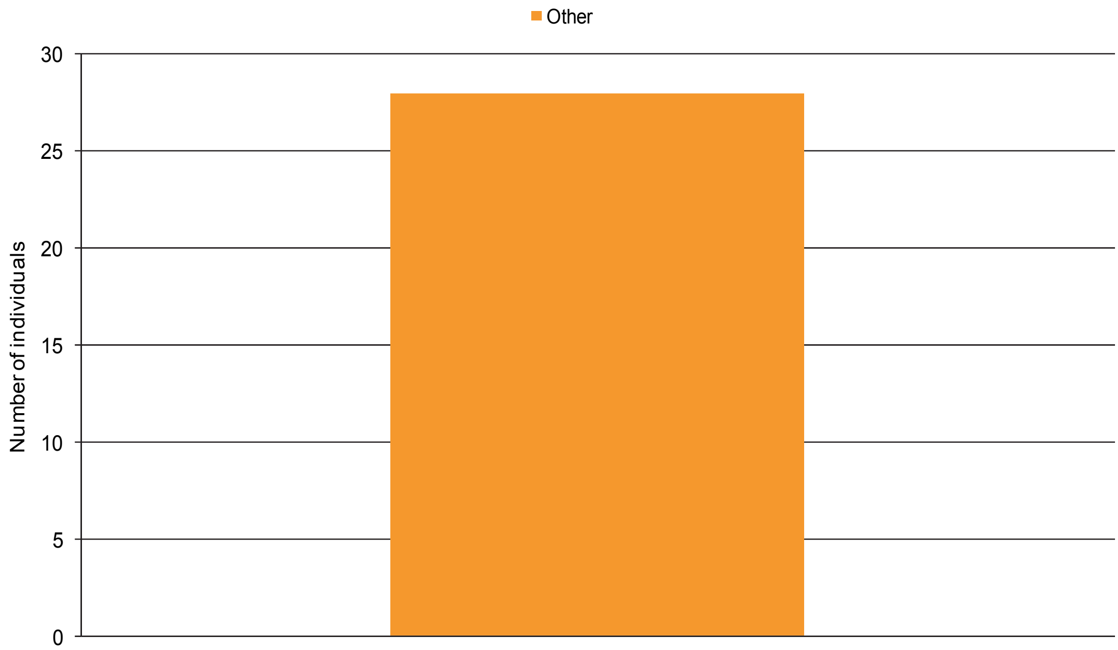
Group 4 – Ducks, pheasants, rallids



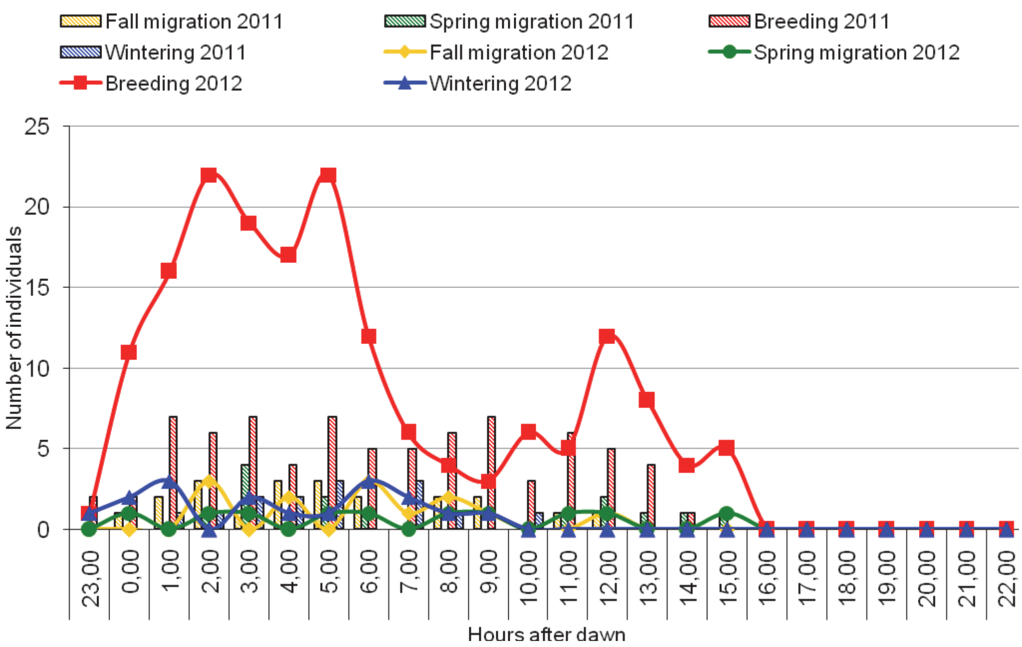


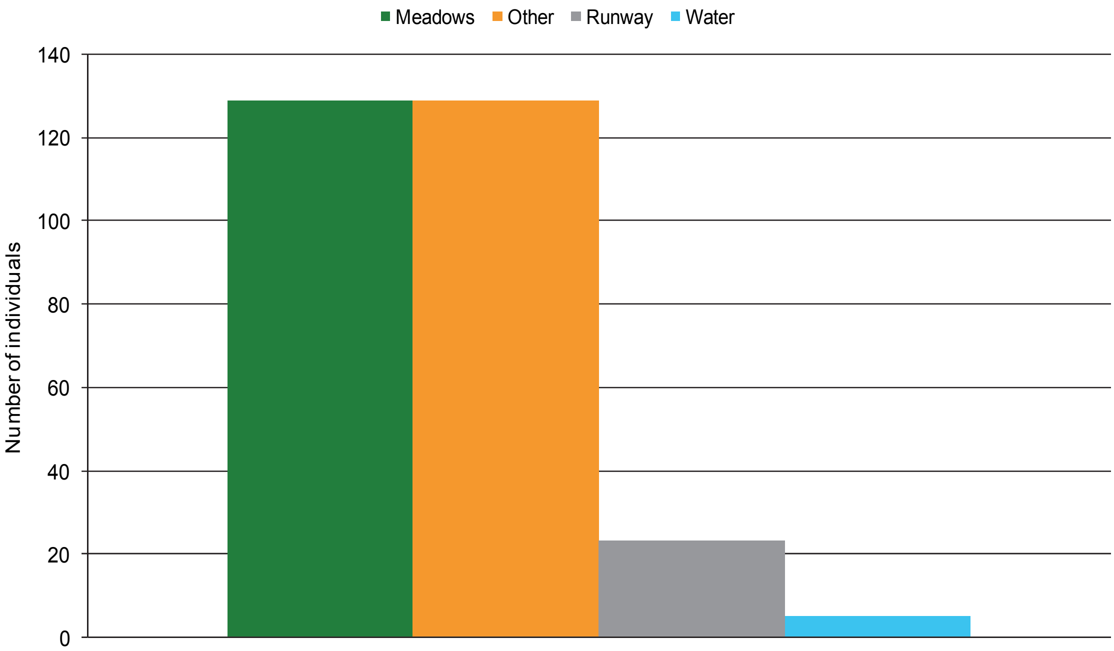
Group 5 – Birds of prey large



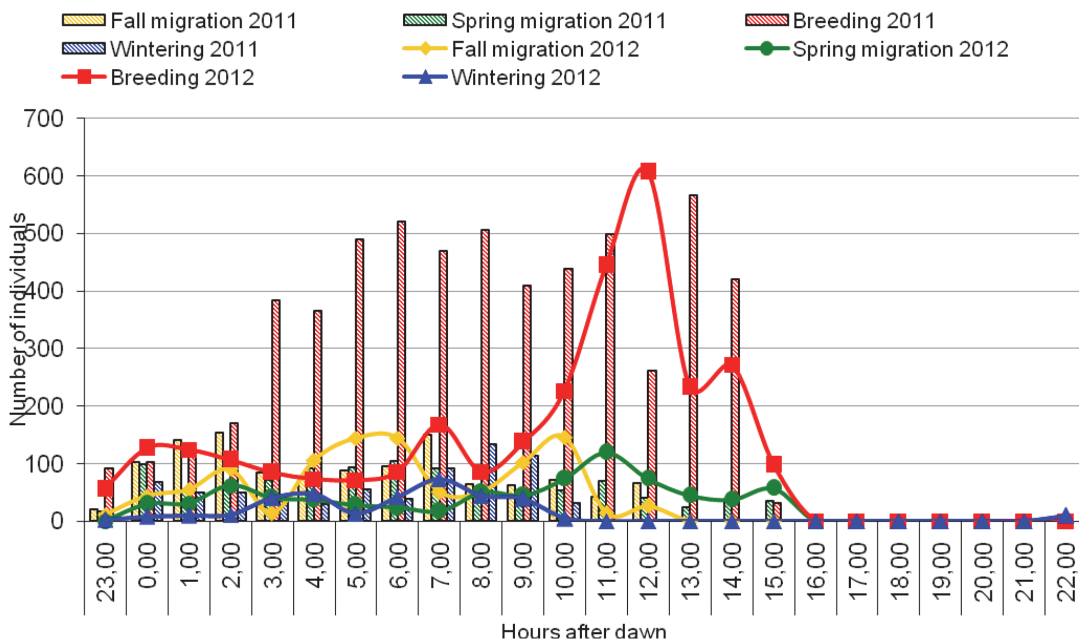


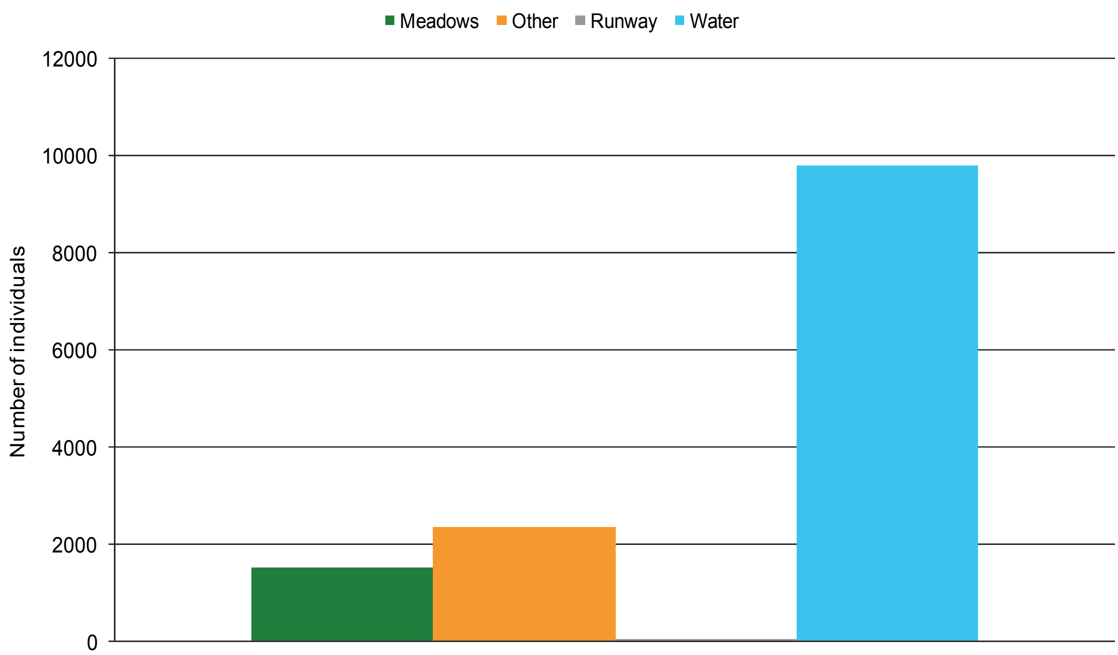
Group 6 – Birds of prey small



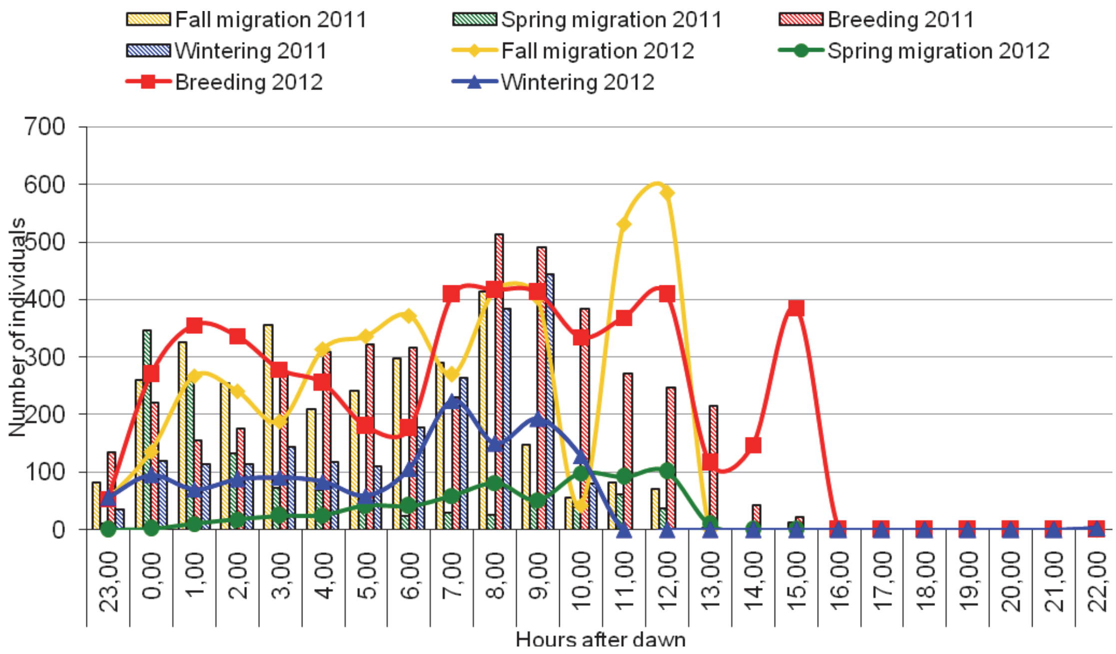


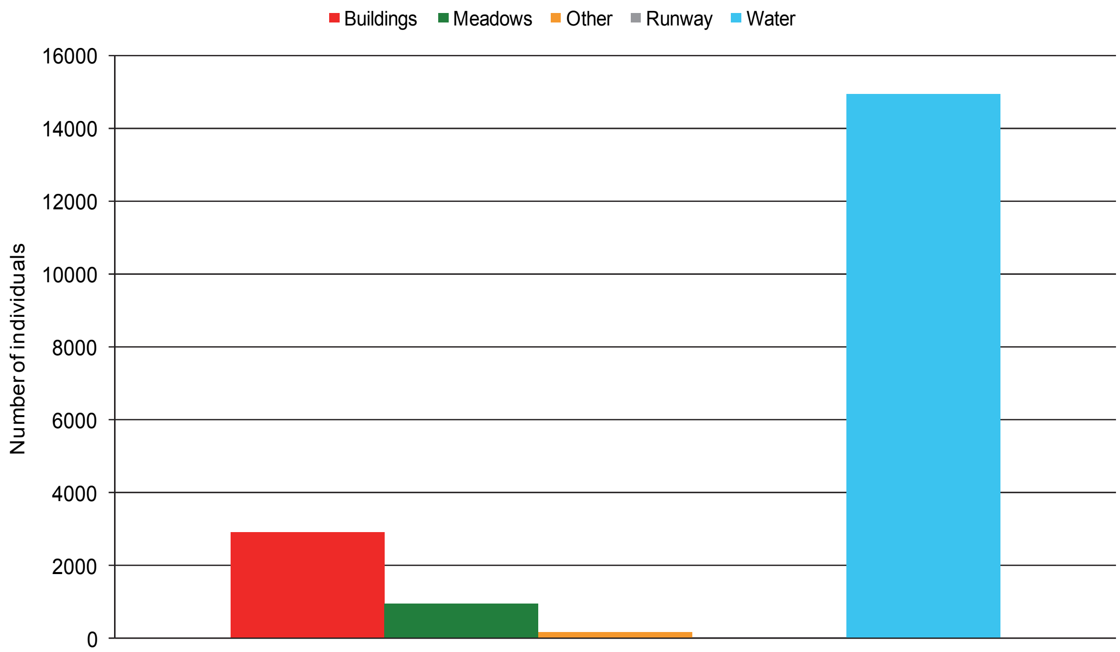
Group 7 – Large seabirds



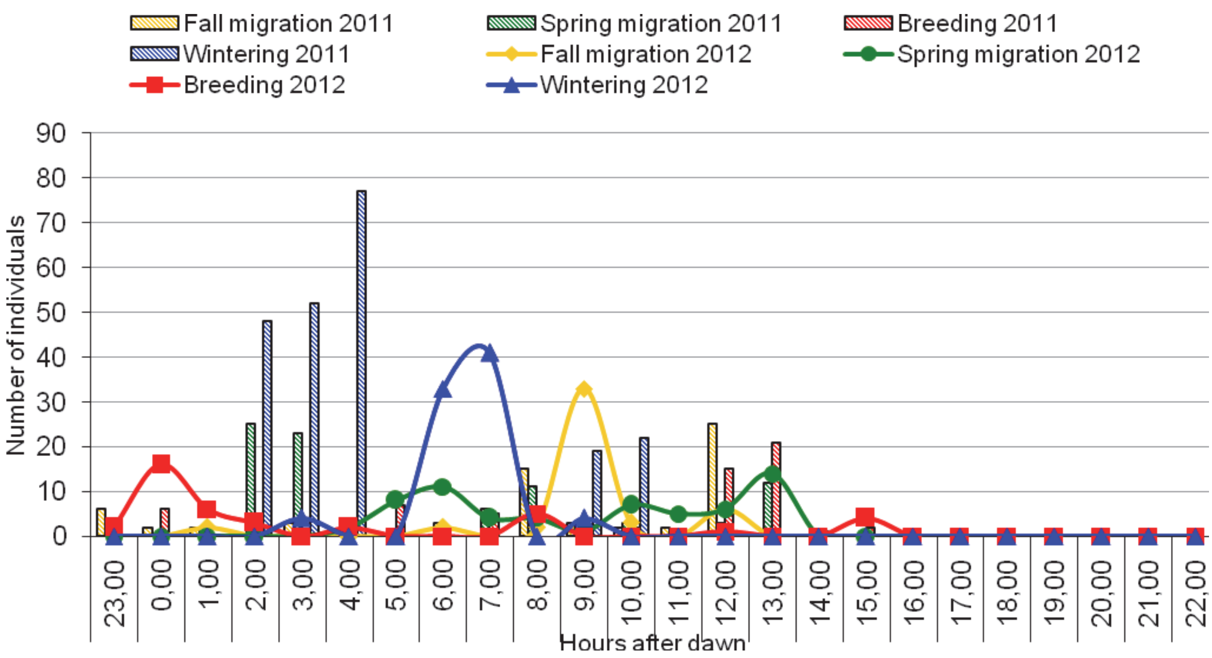


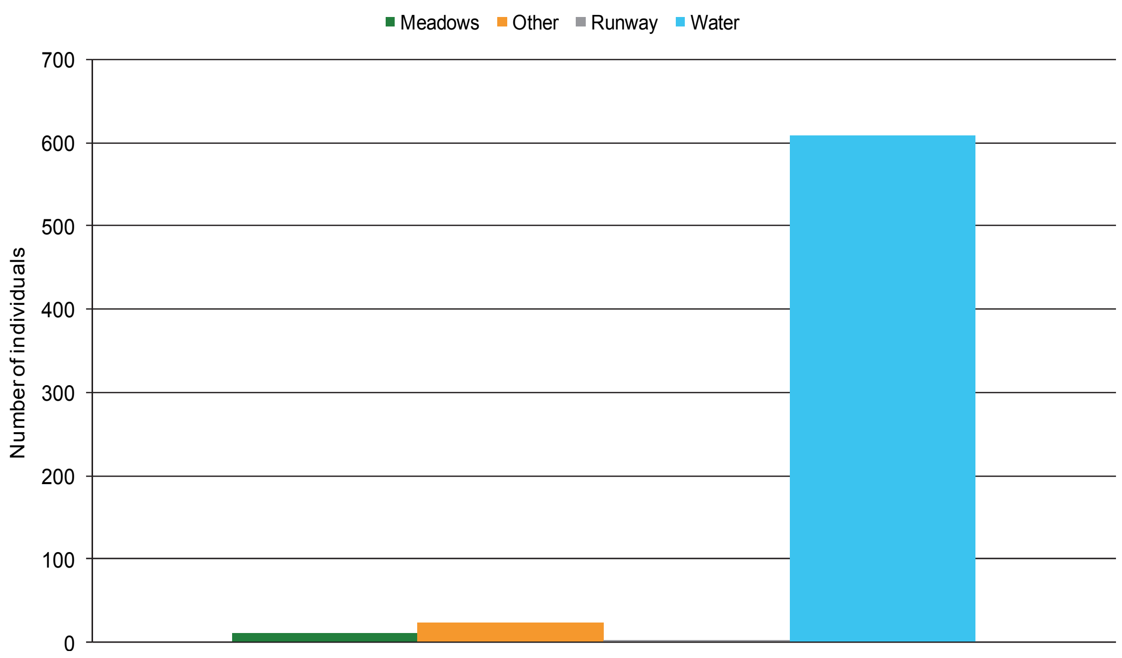
Group 8 – Small seabirds



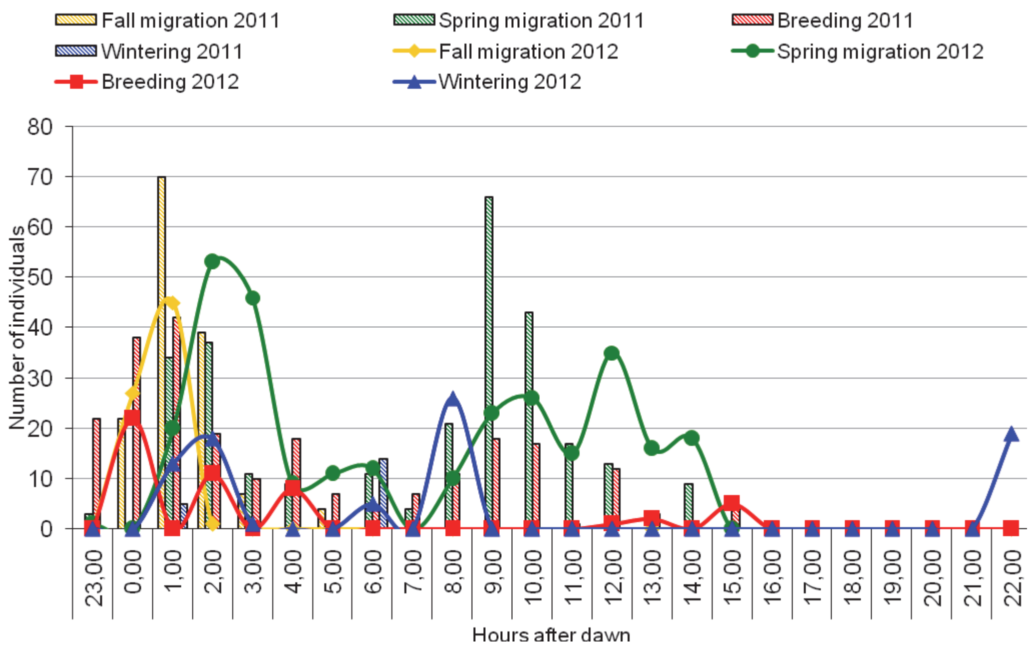


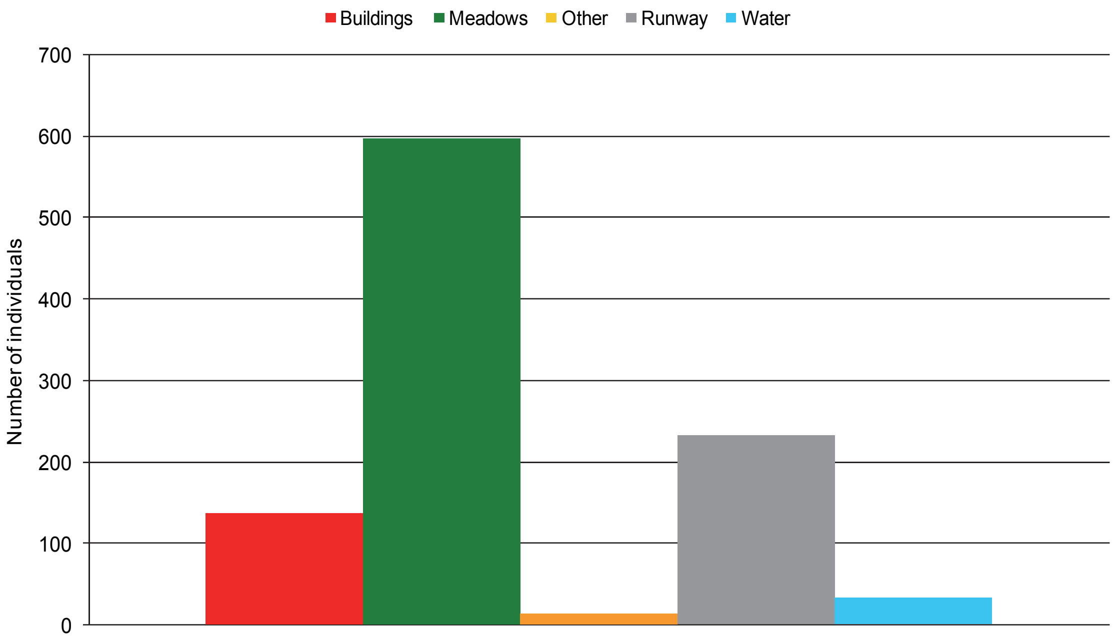
Group 9 – Waders



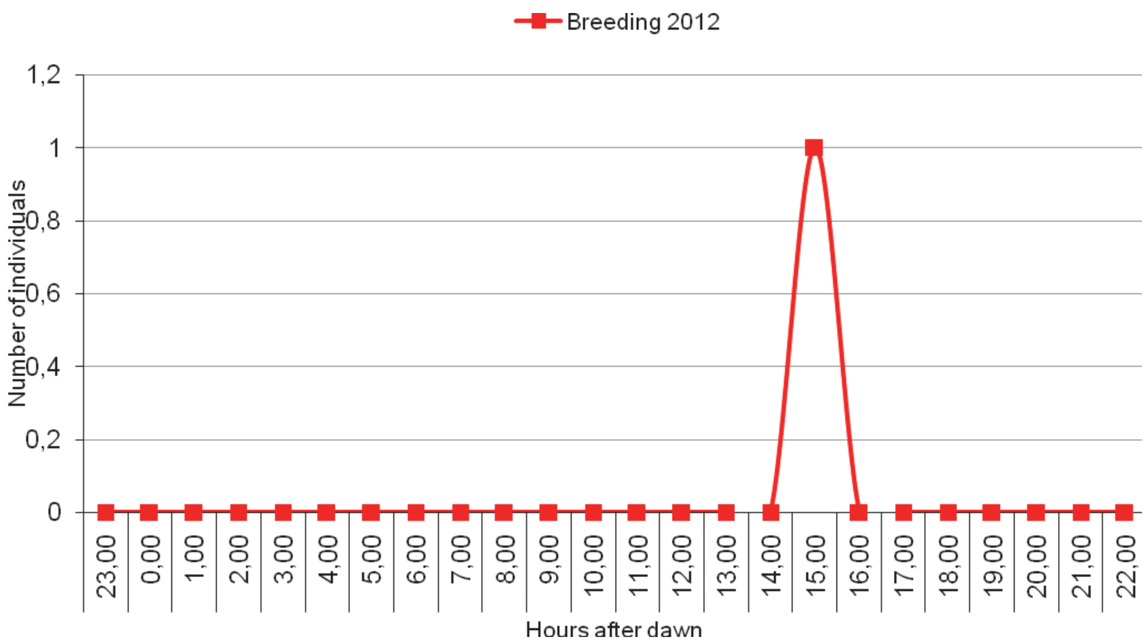


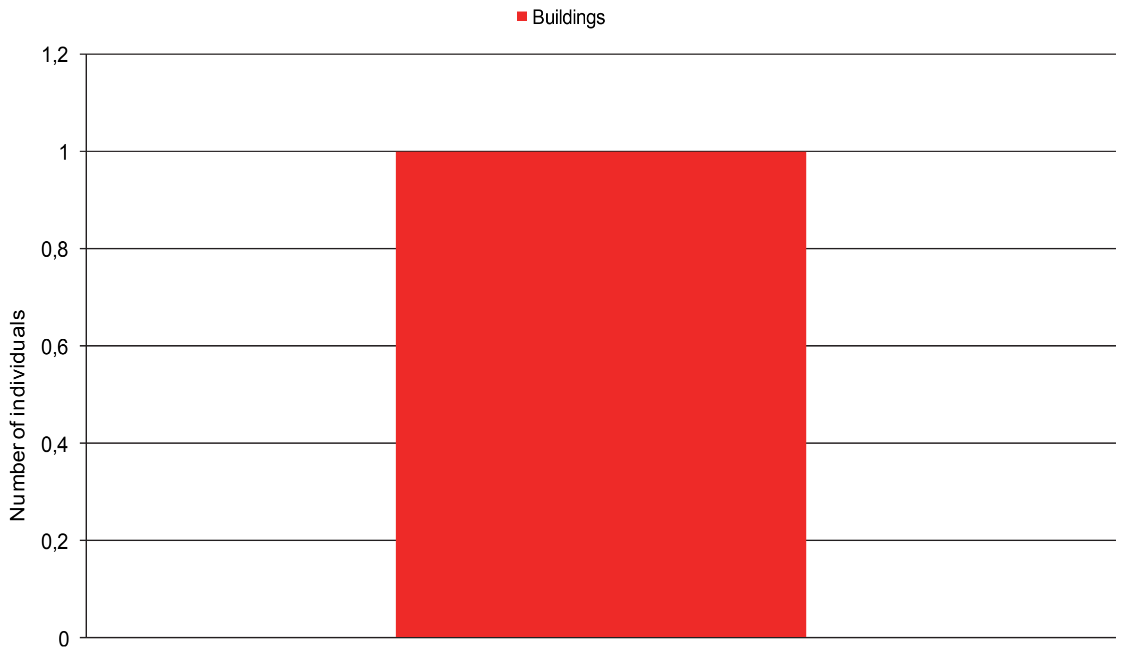
Group 10 – Doves



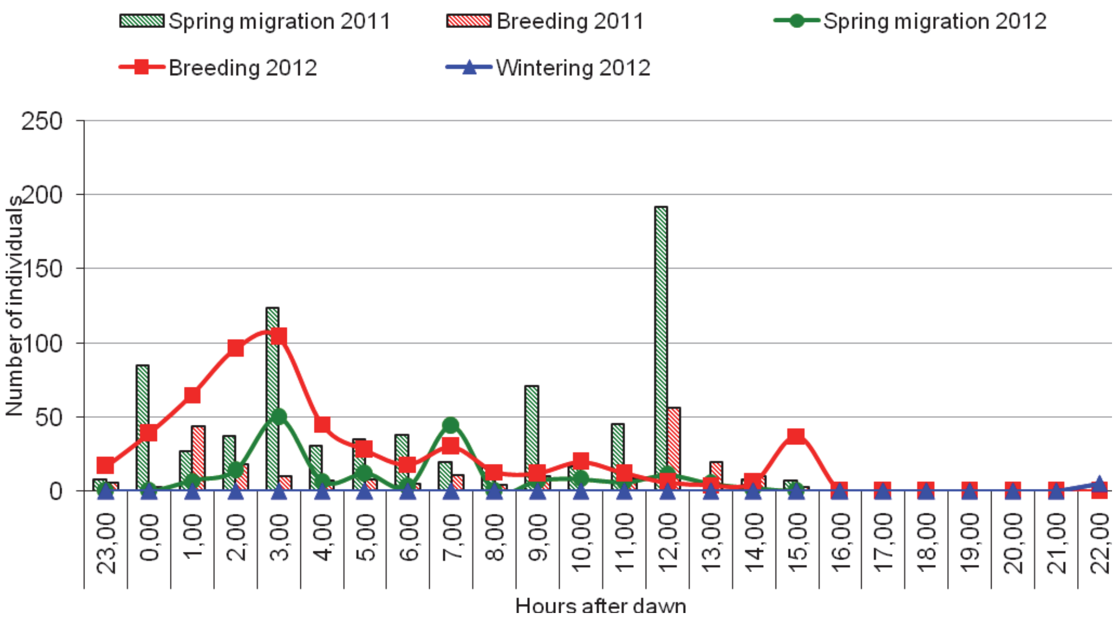


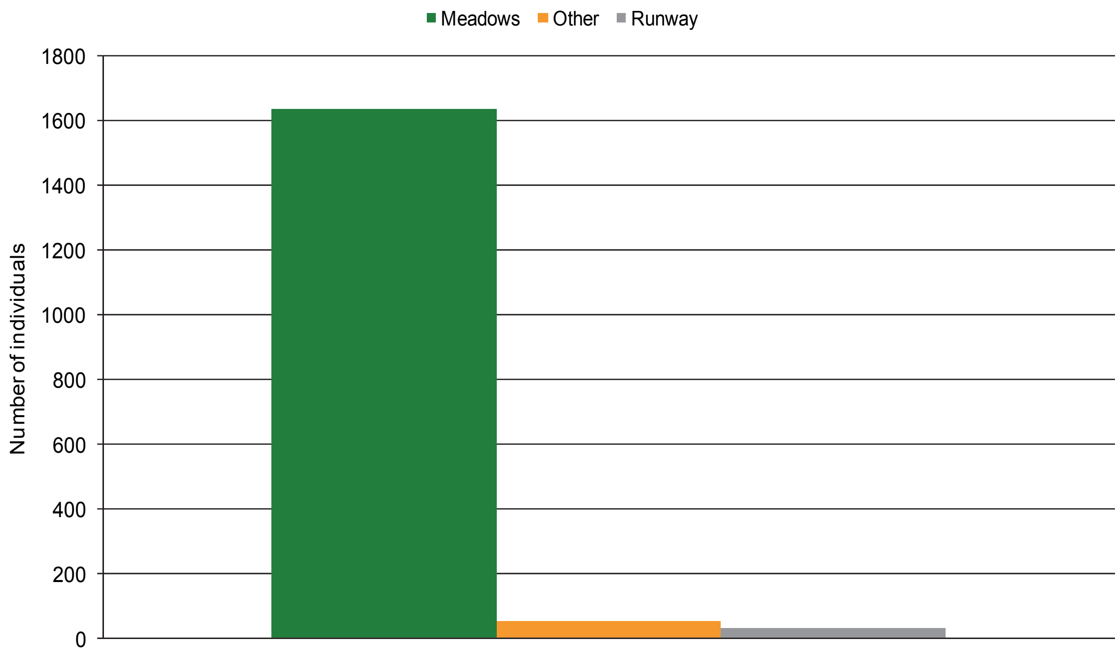
Group 11 – Owls



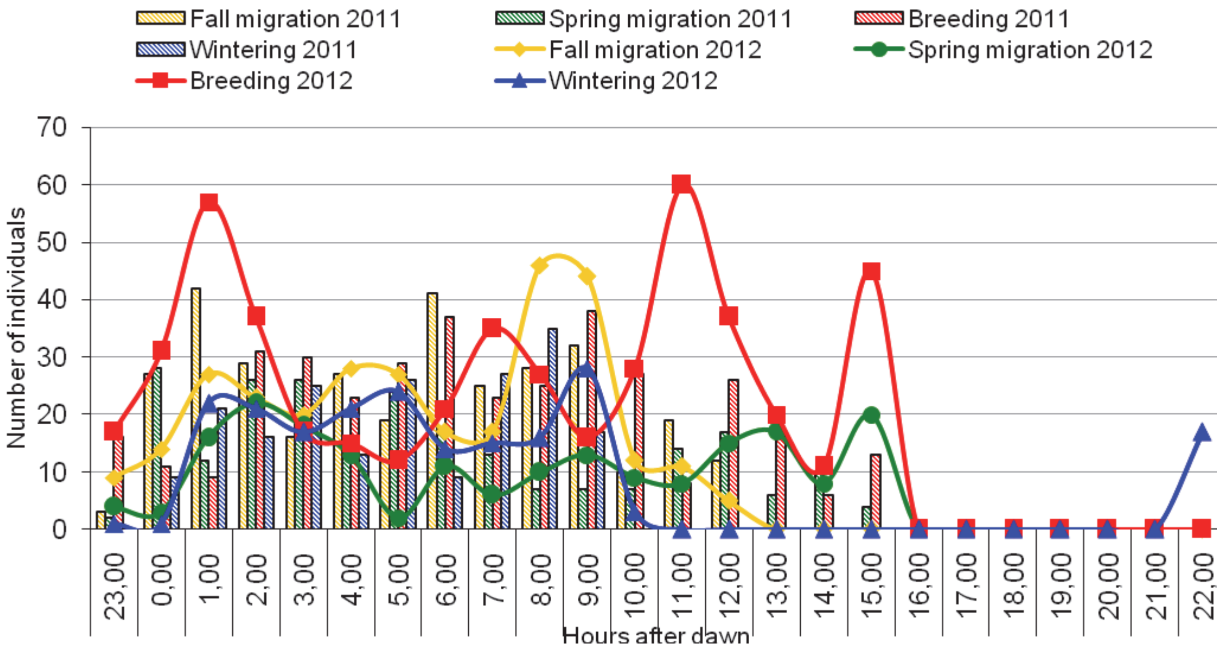


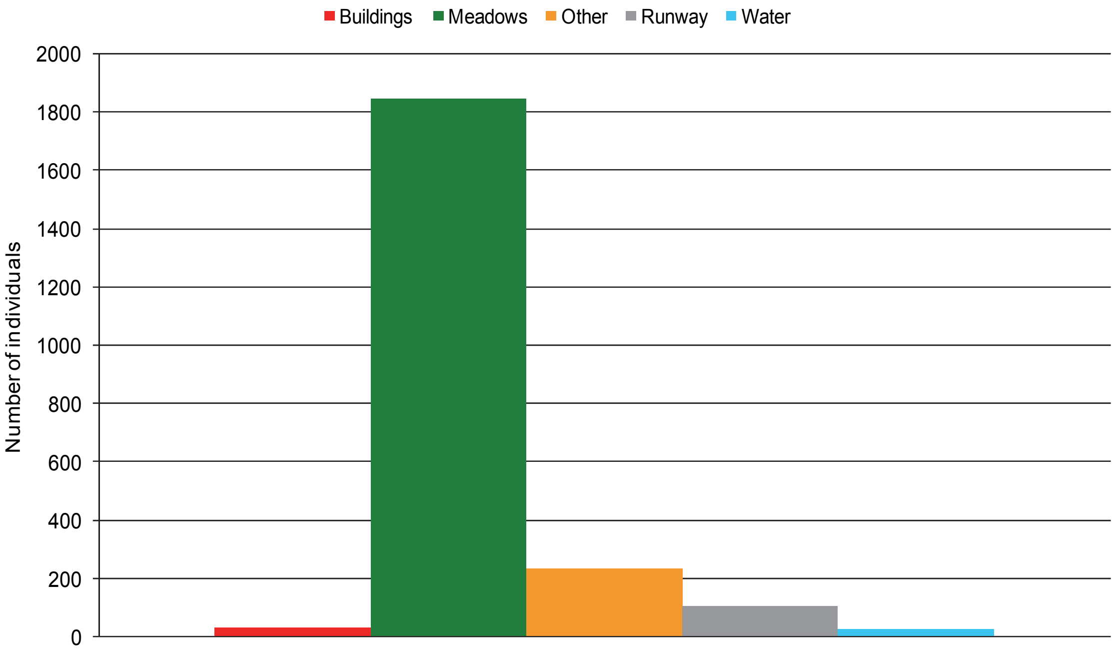
Group 12 – Swifts and swallows



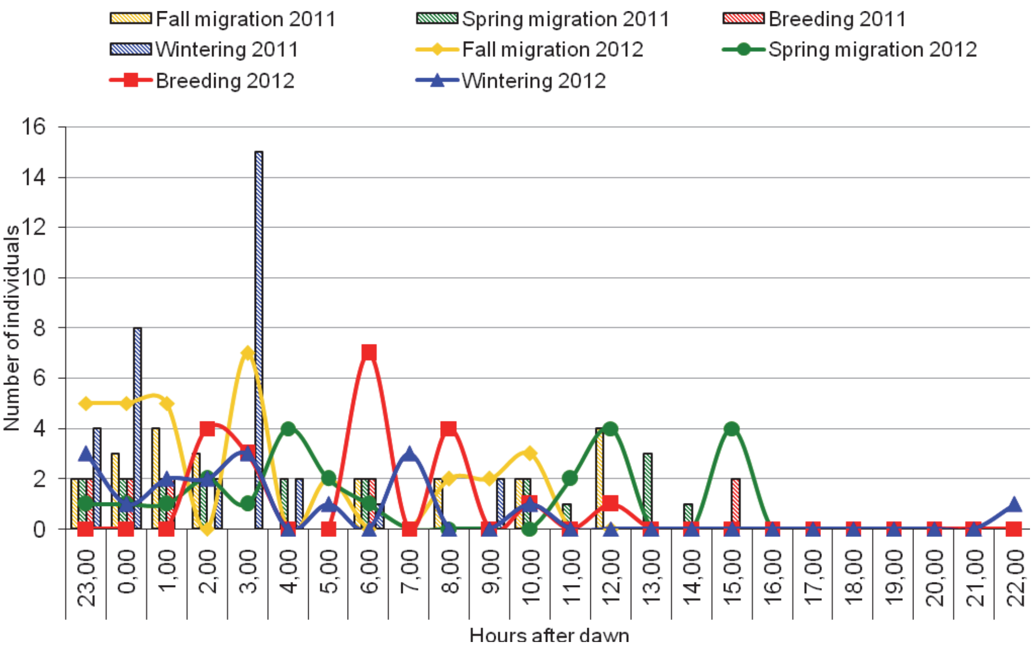


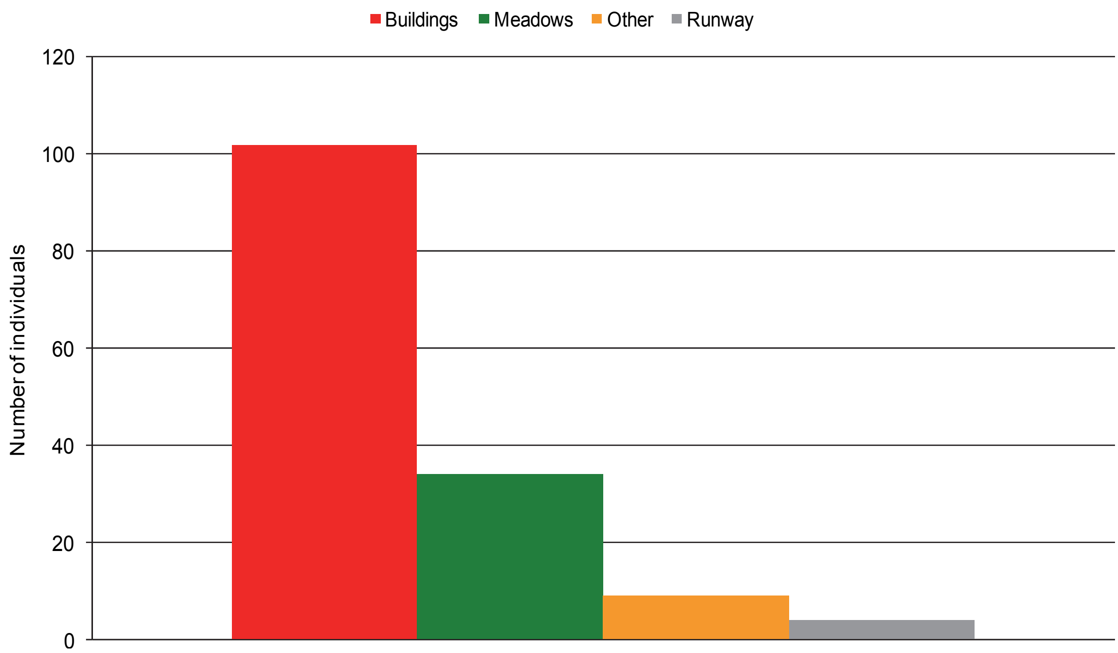
Group 13 – Corvids



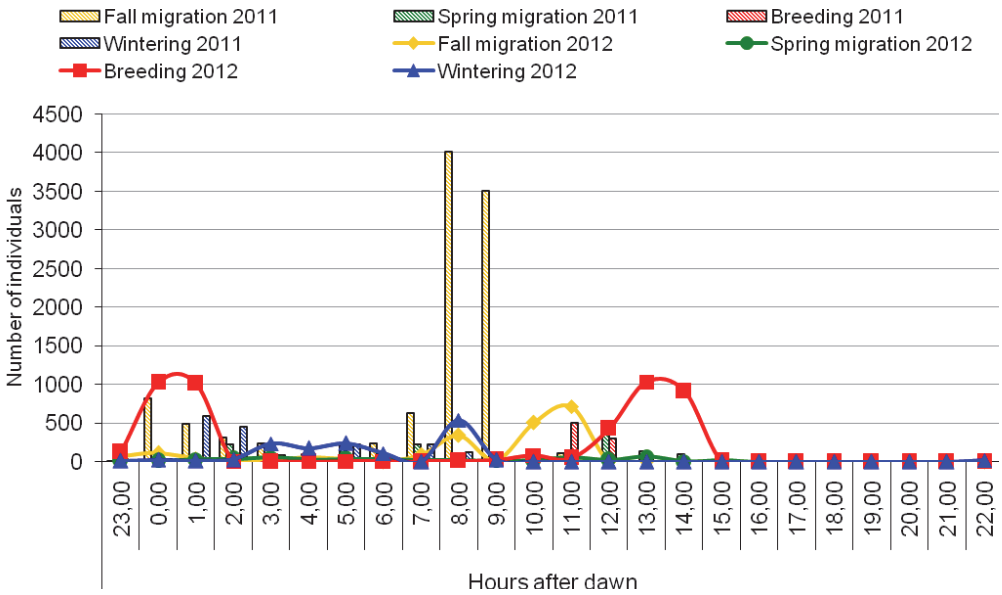


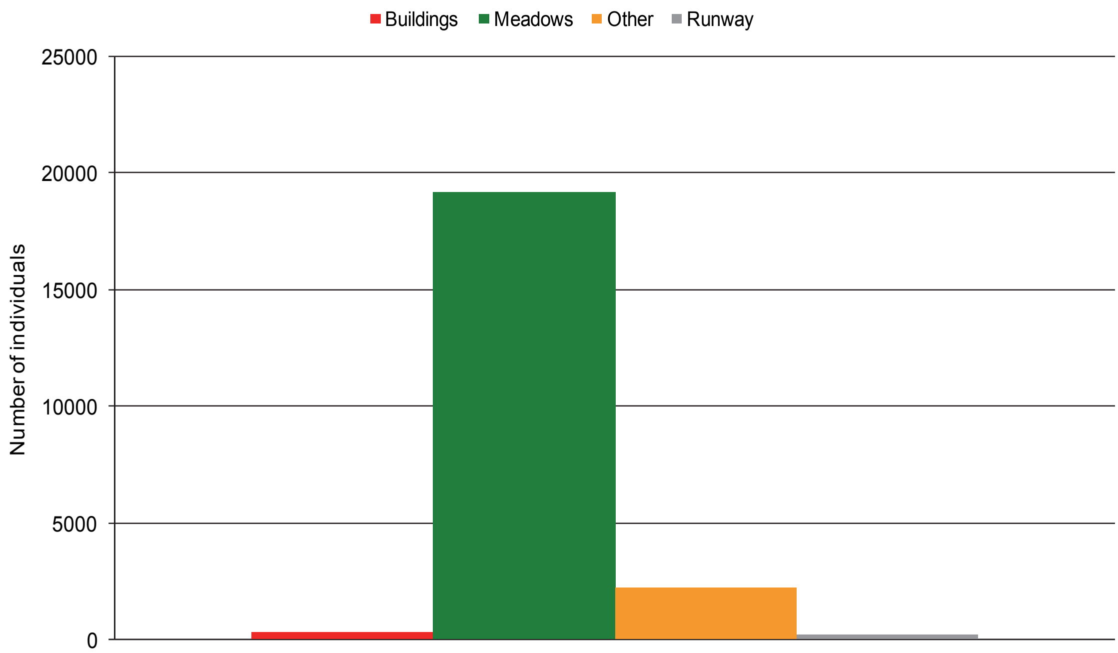
Group 14 – Non flocking passerines and bats



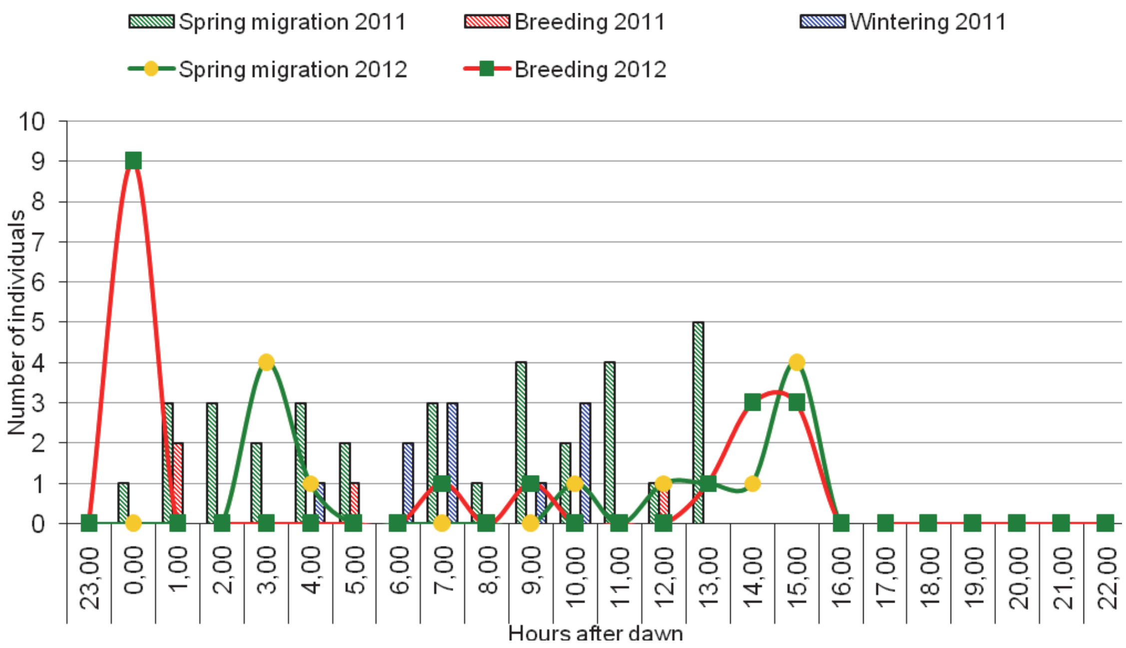


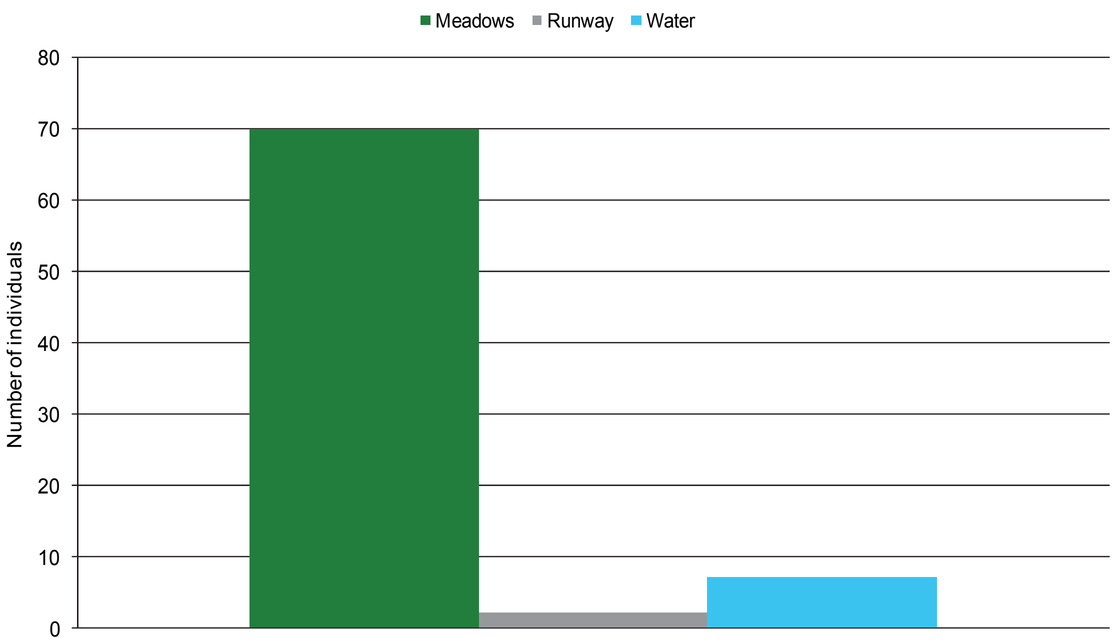
Group 15 – Flocking passerines



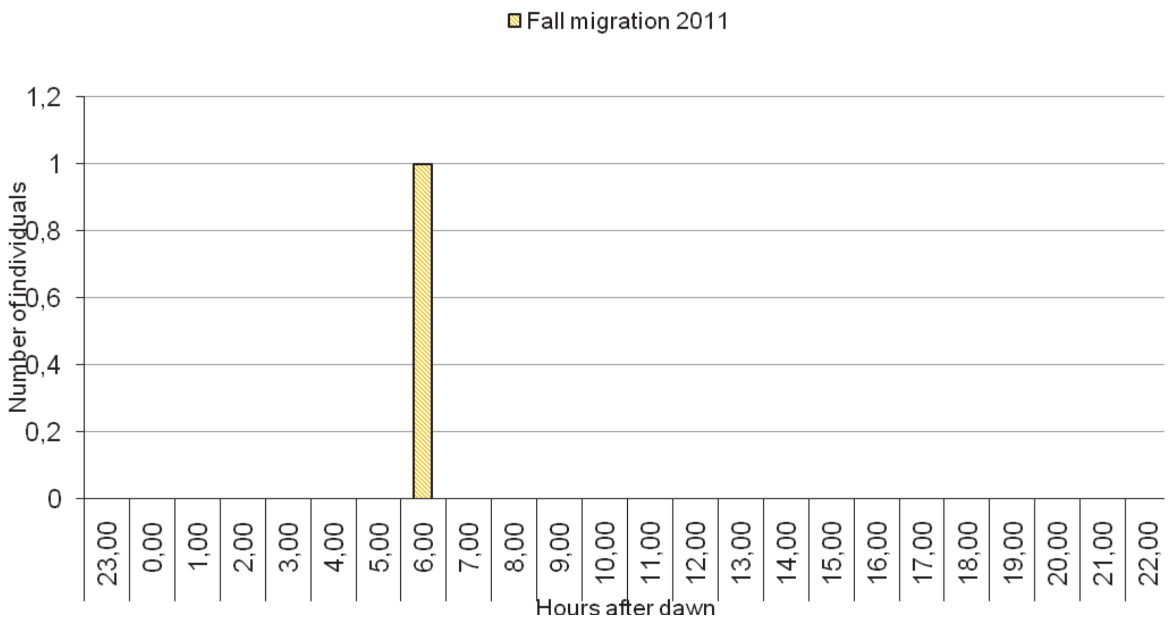


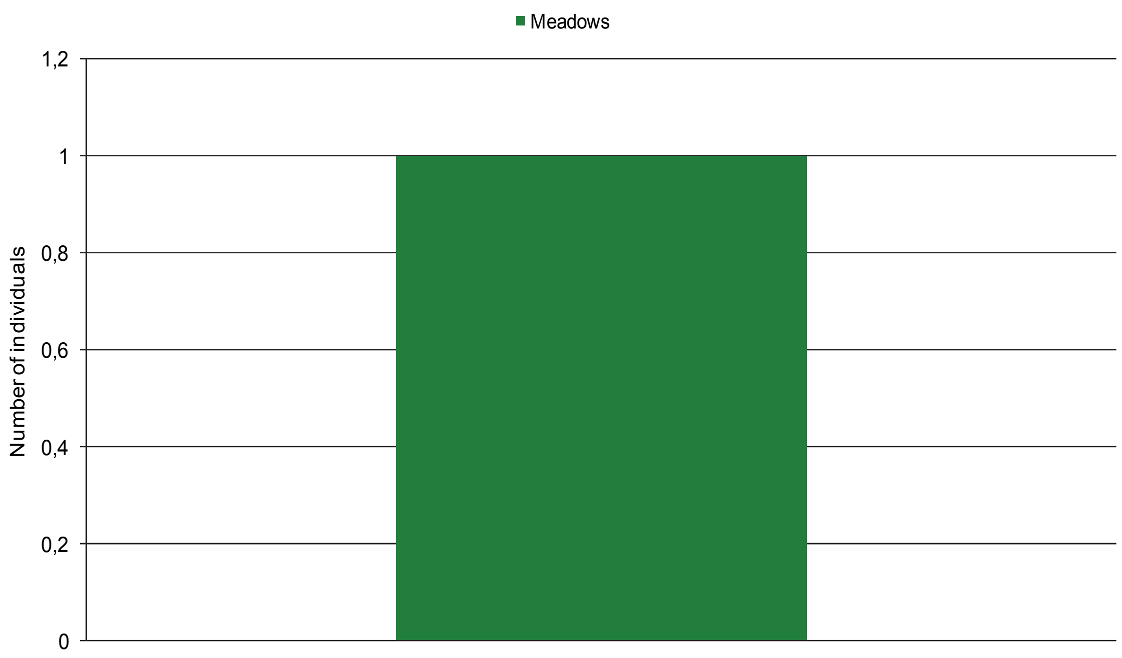
Group 16 – Small mammals (<10 Kg)





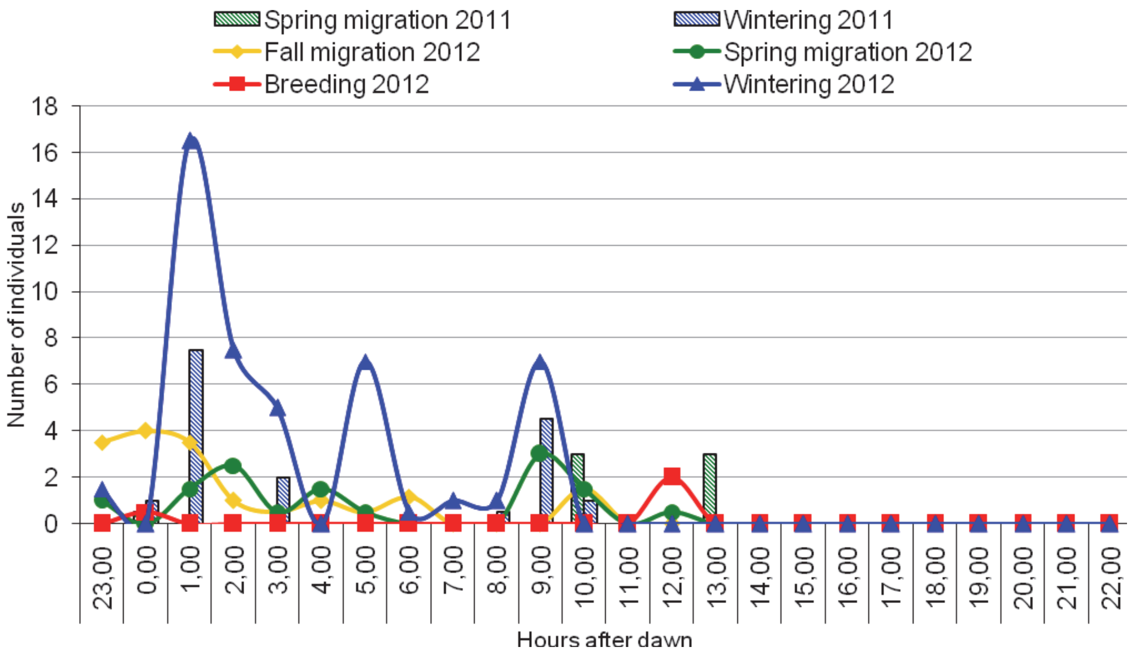
Group 17 – Large mammals (> 10 Kg)

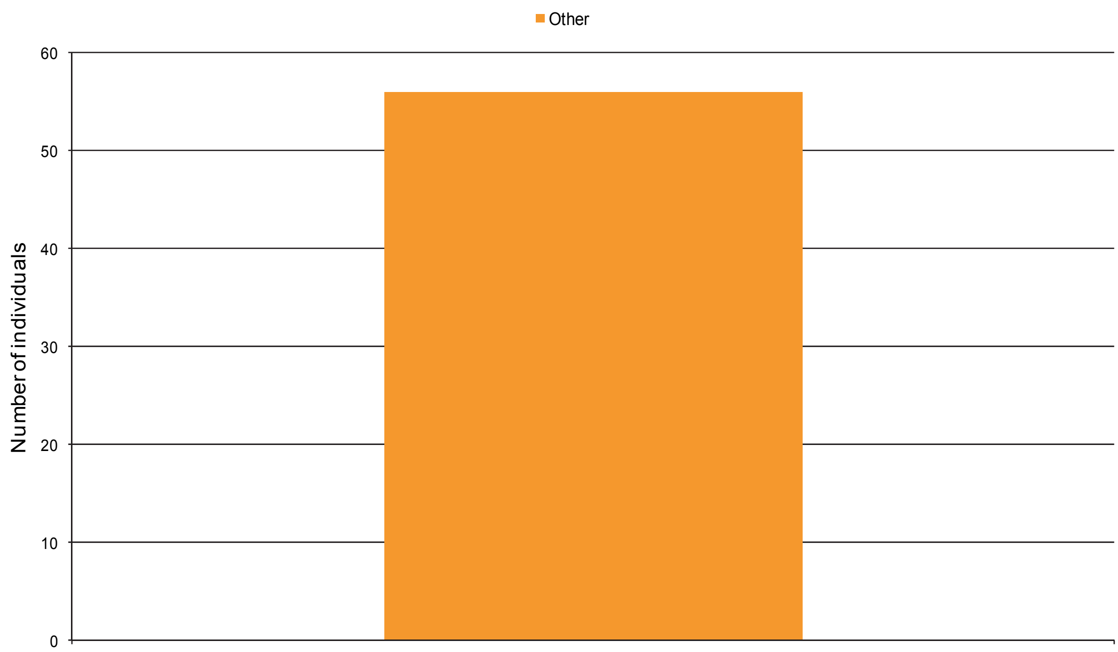




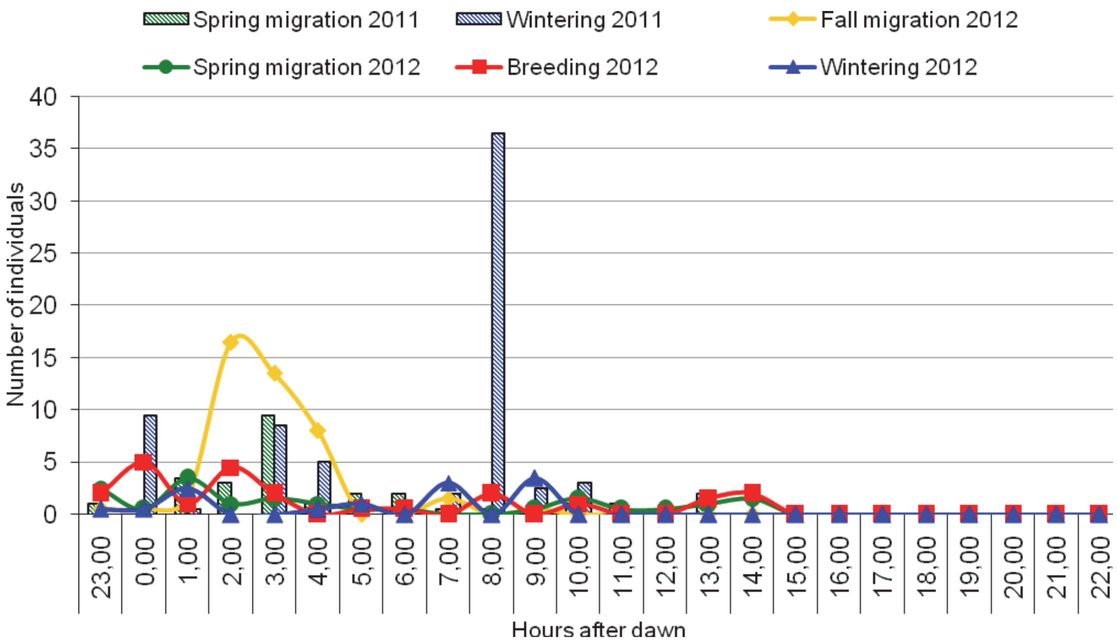
Treviso Antonio Canova airport – TSF

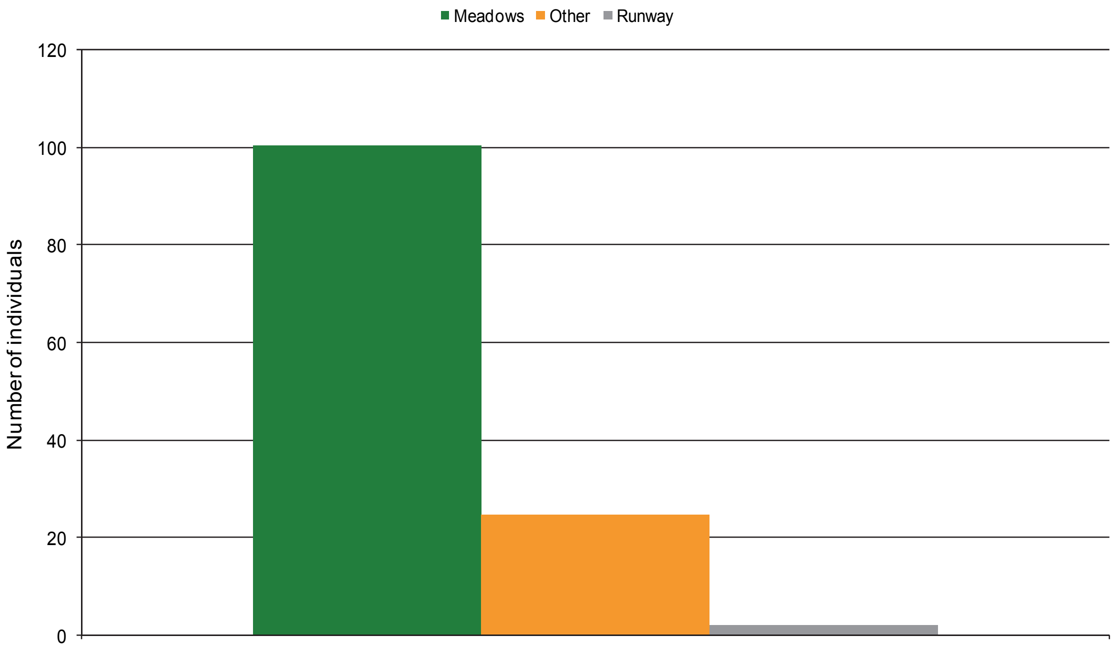
Group 2 – Cormorants, pelicans, swans and geese



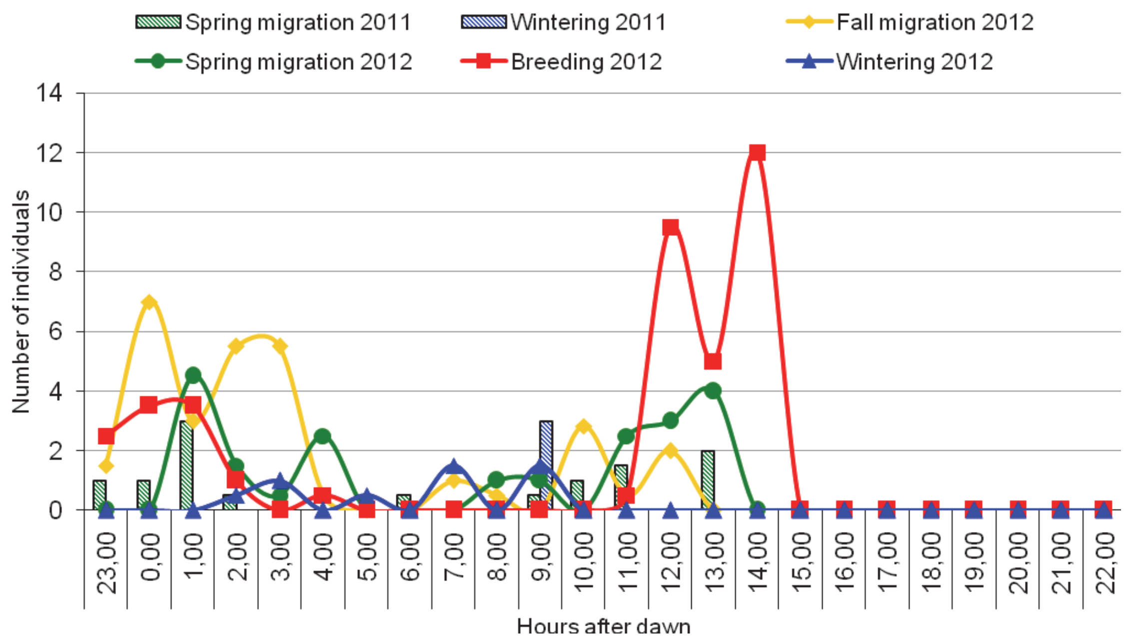


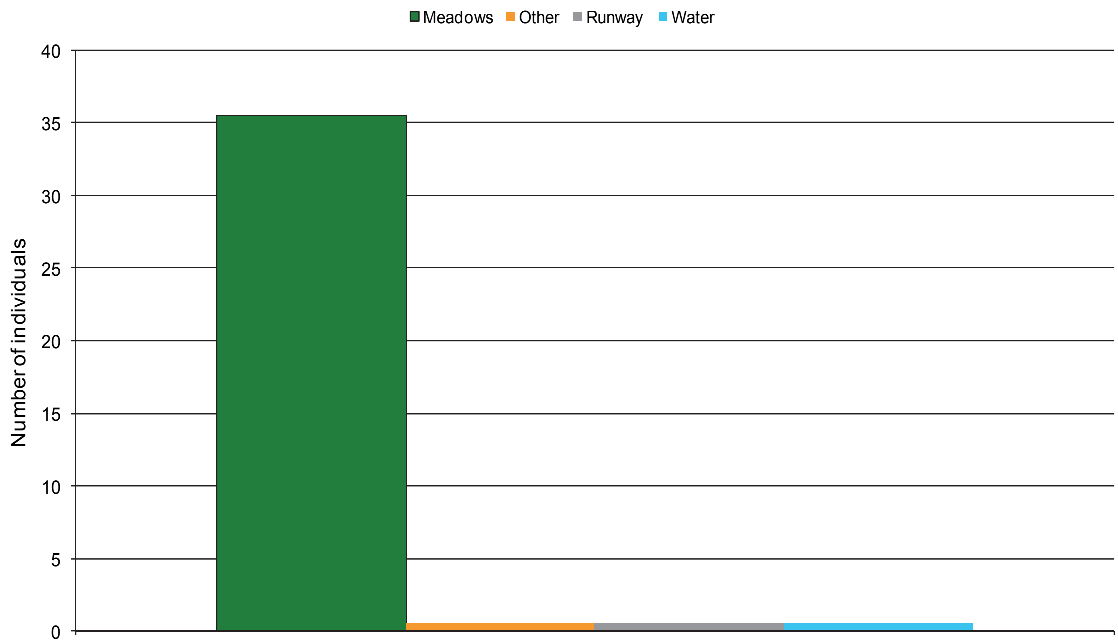
Group 3 – Herons, storks, flamingos



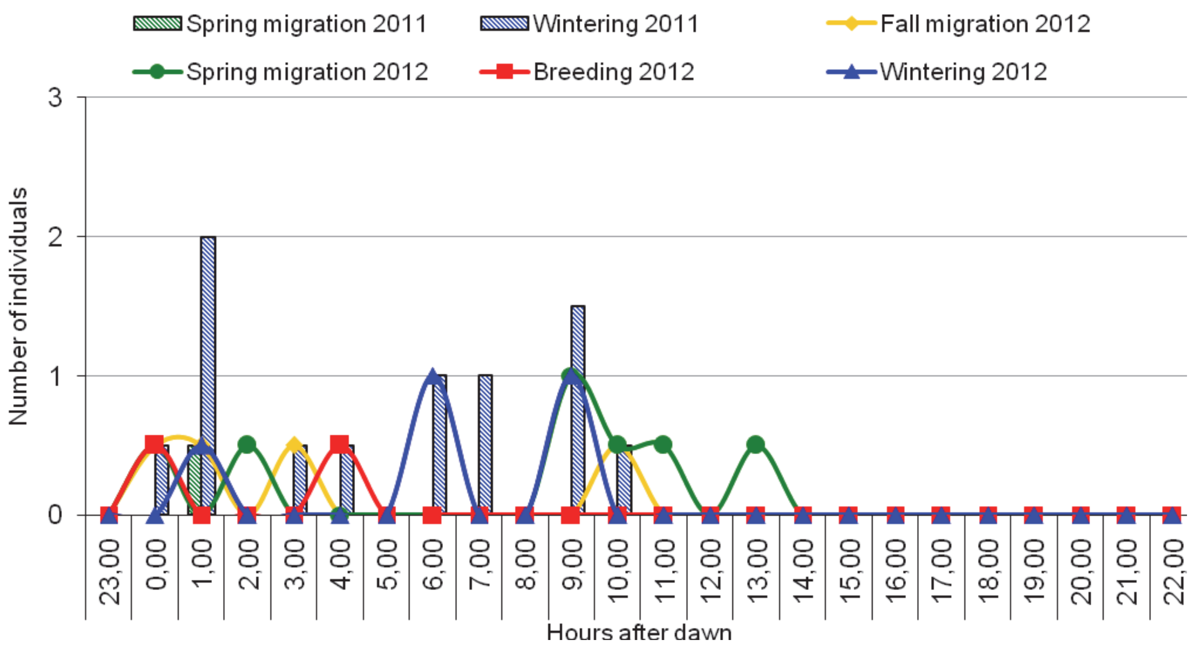


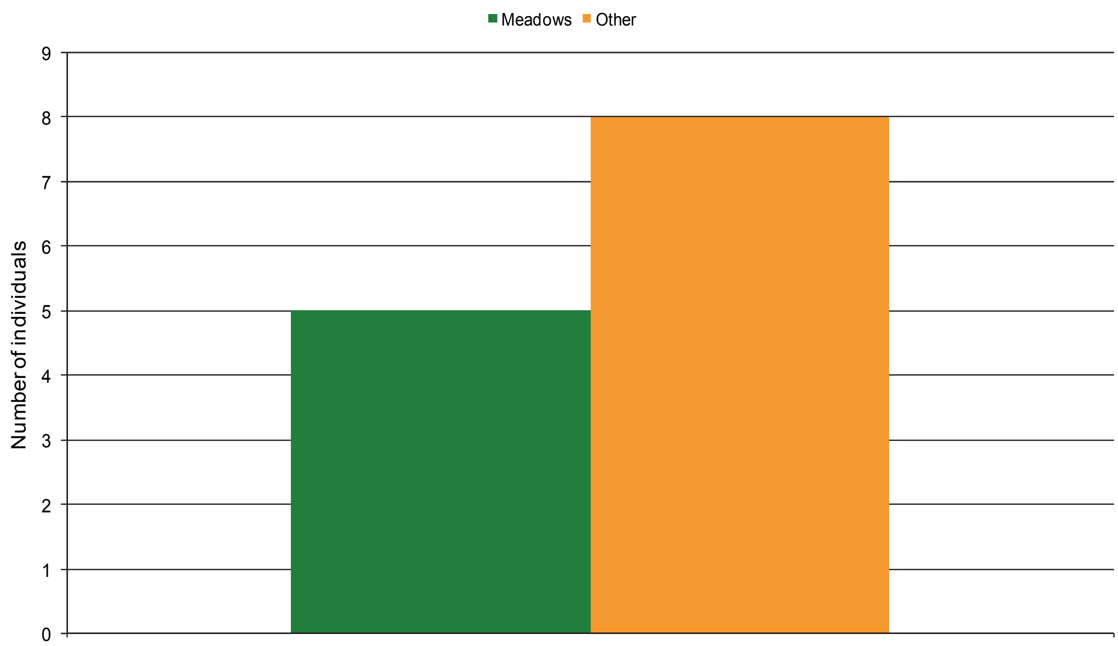
Group 4 – Ducks, pheasants, rallids



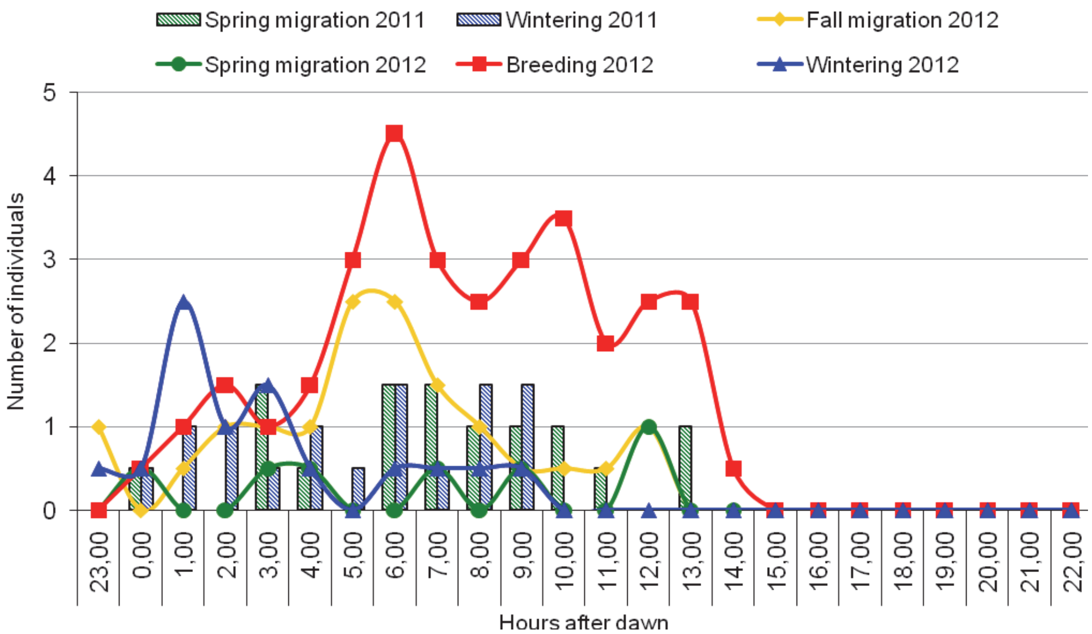


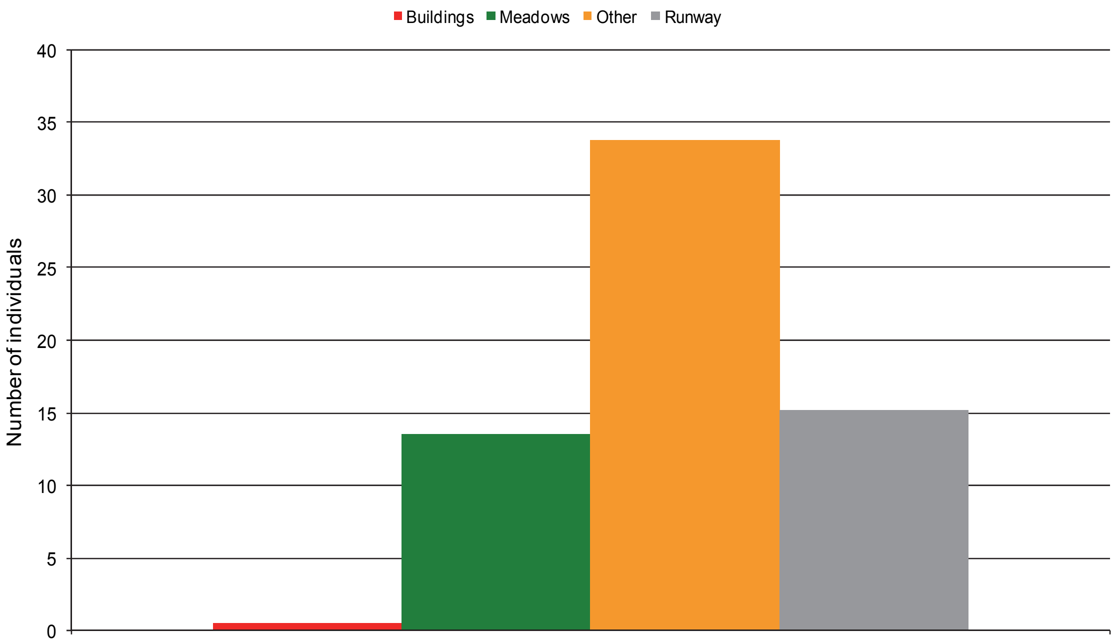
Group 5 – Birds of prey large



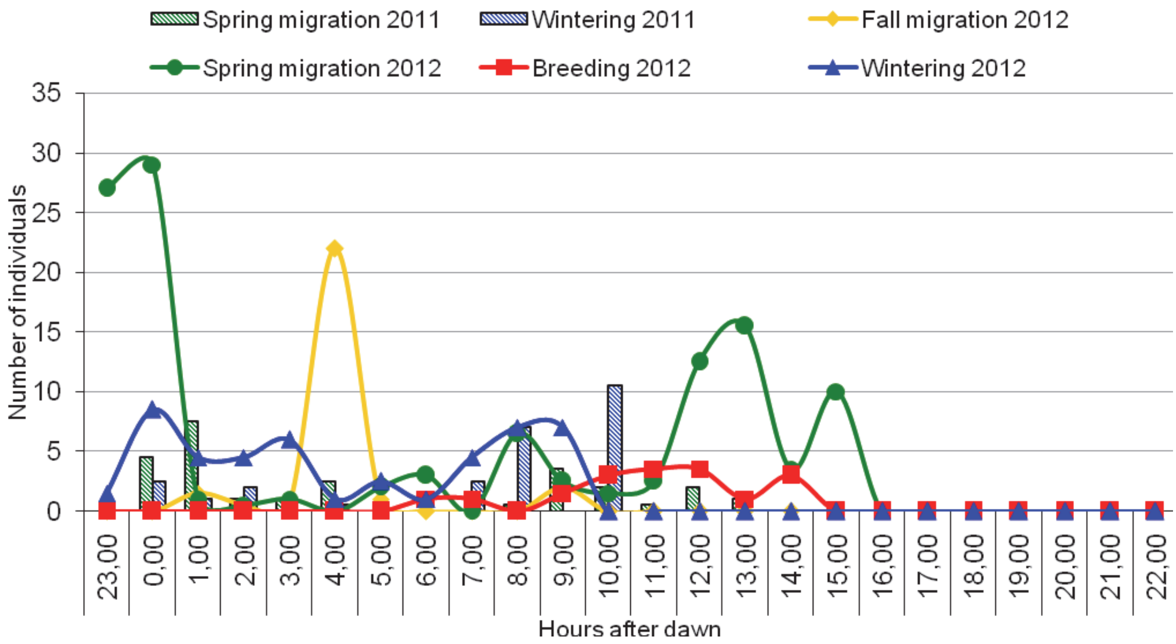


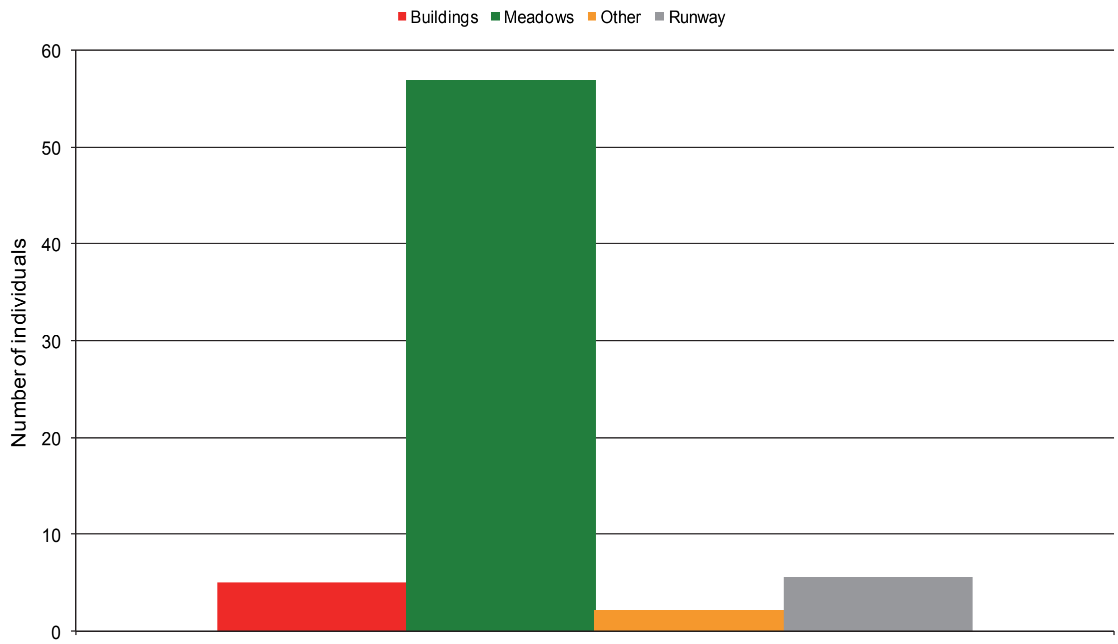
Group 6 – Birds of prey small



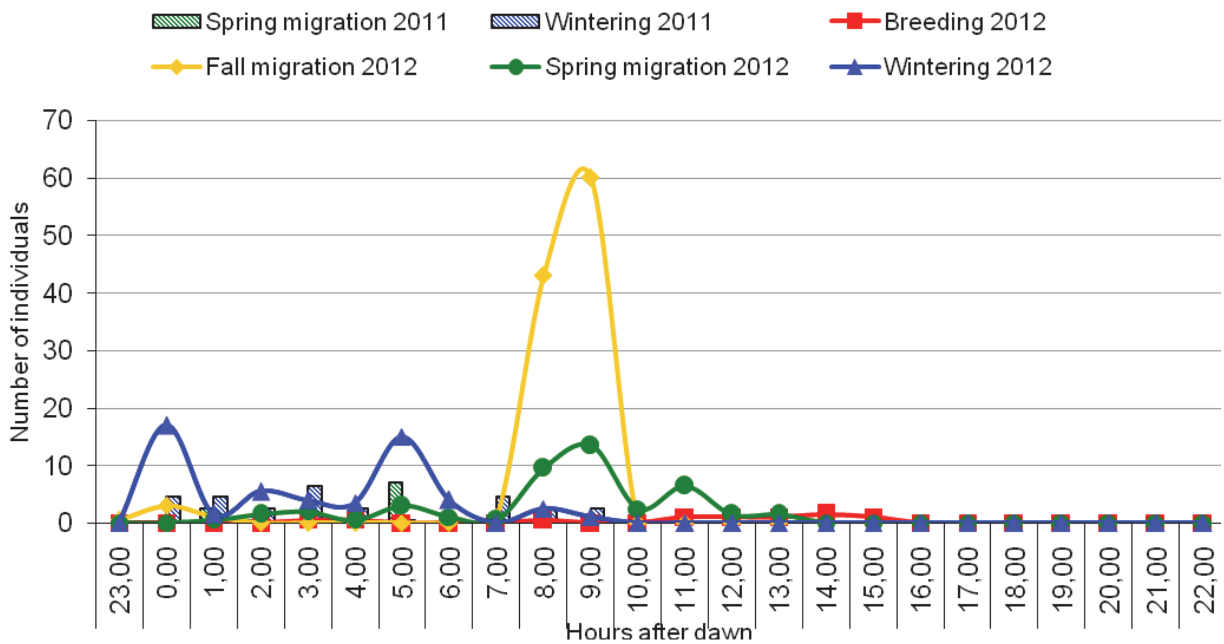


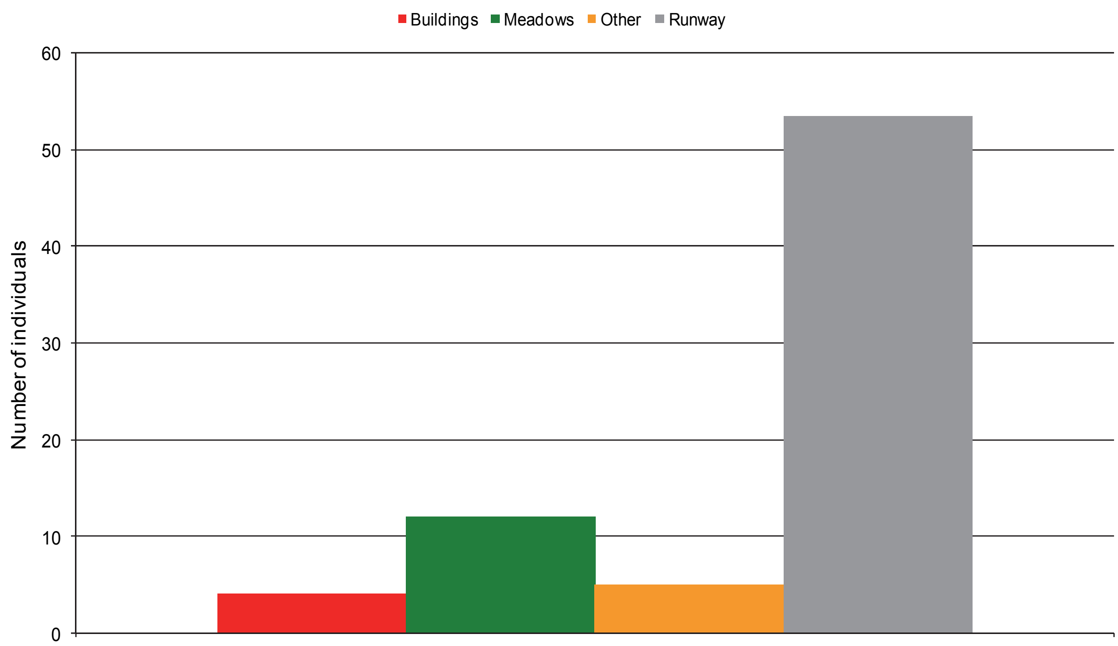
Group 7 – Large seabirds



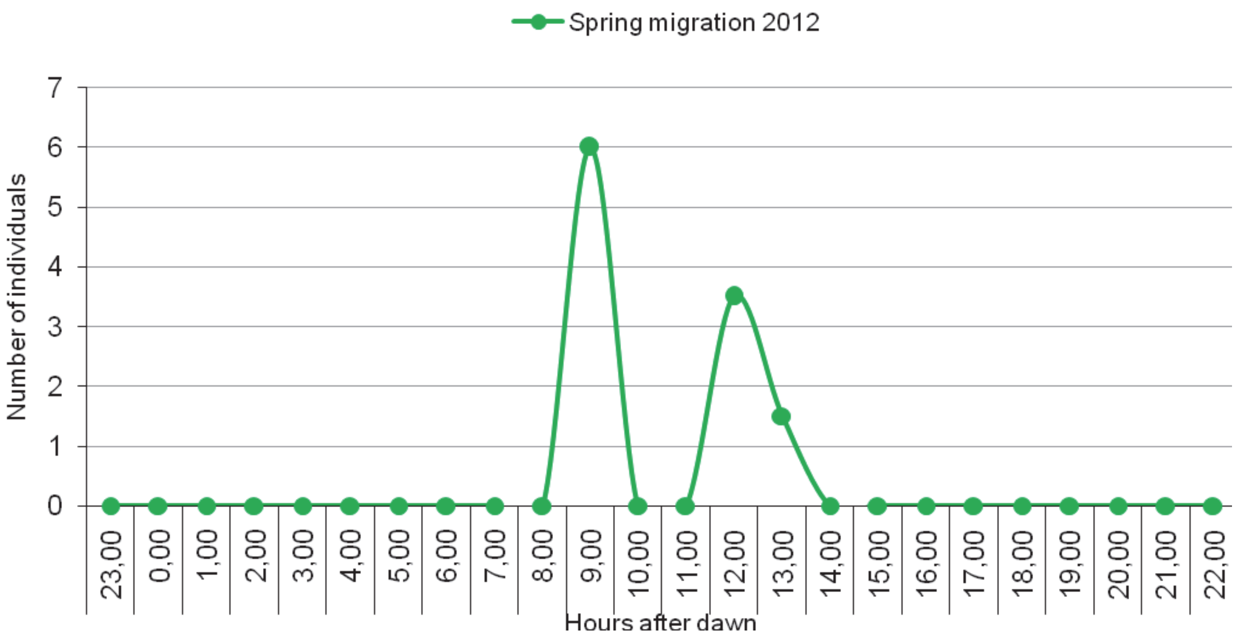


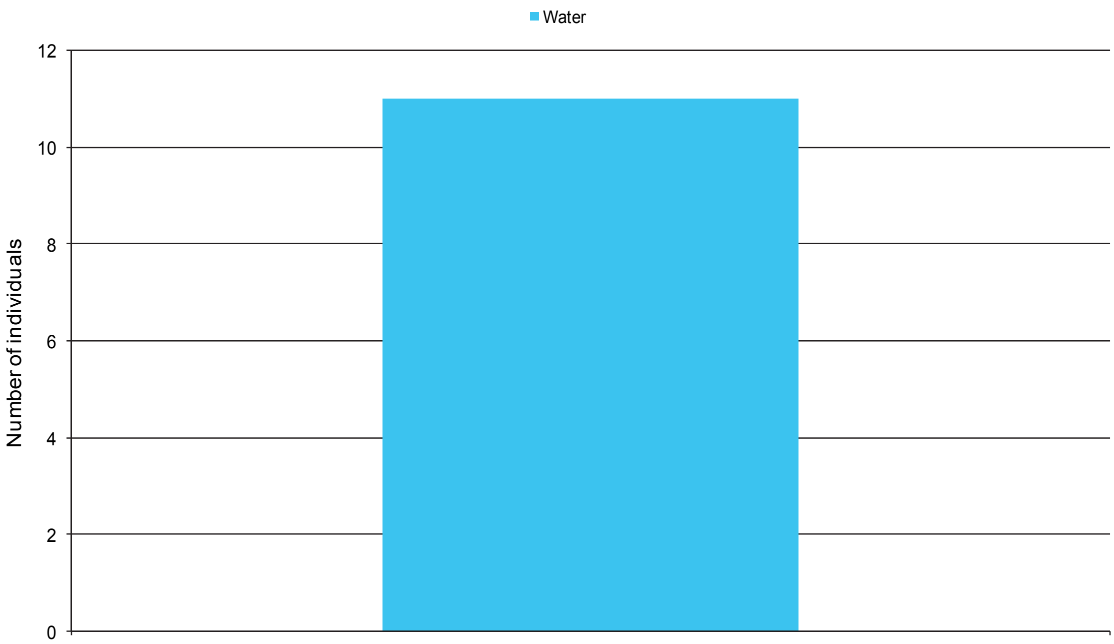
Group 8 – Small seabirds



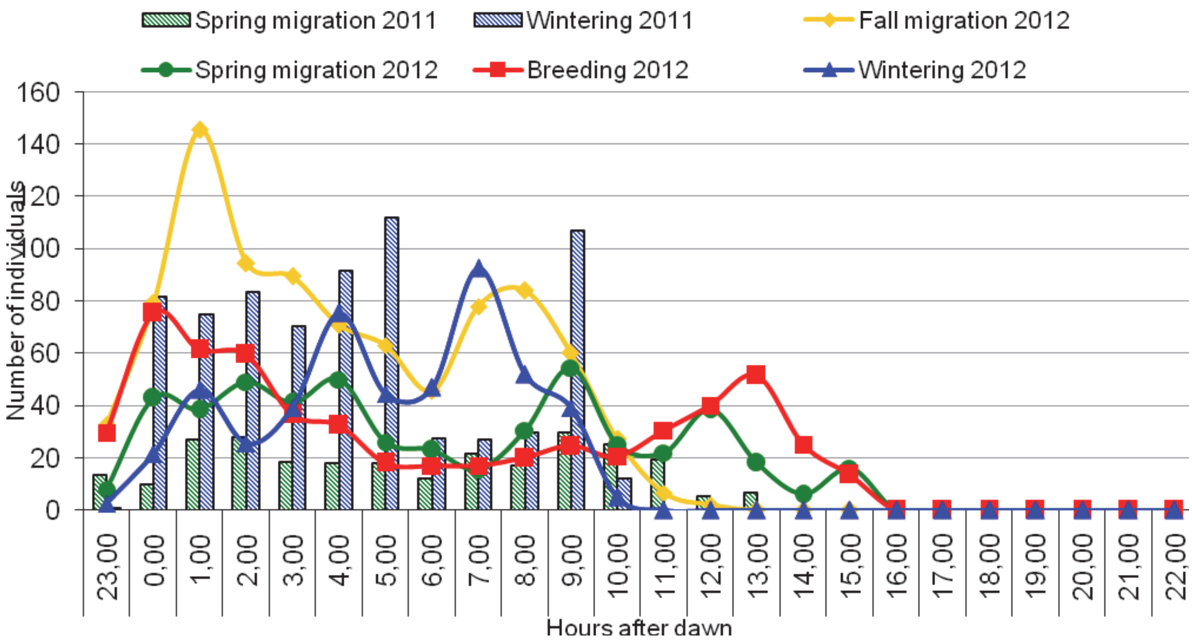


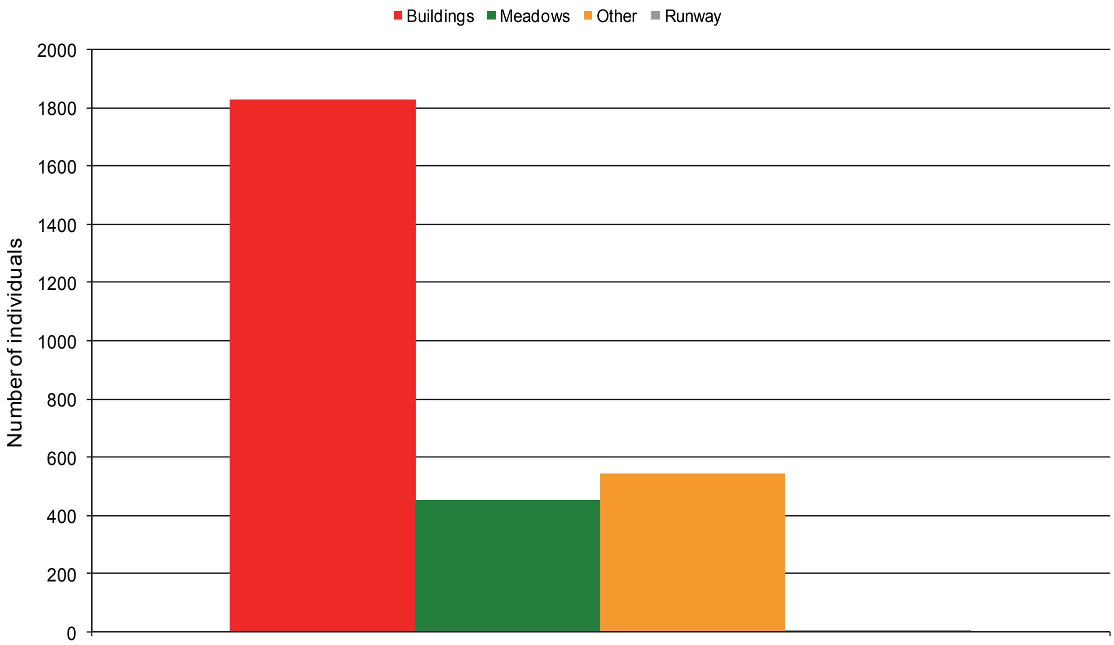
Group 9 – Waders



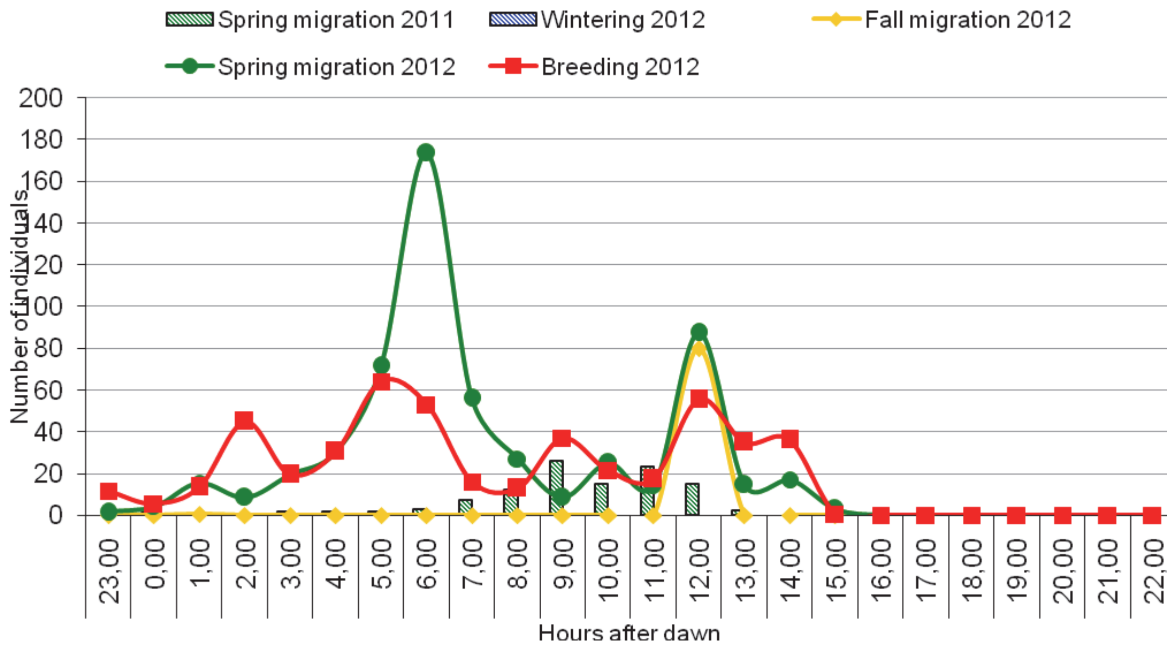


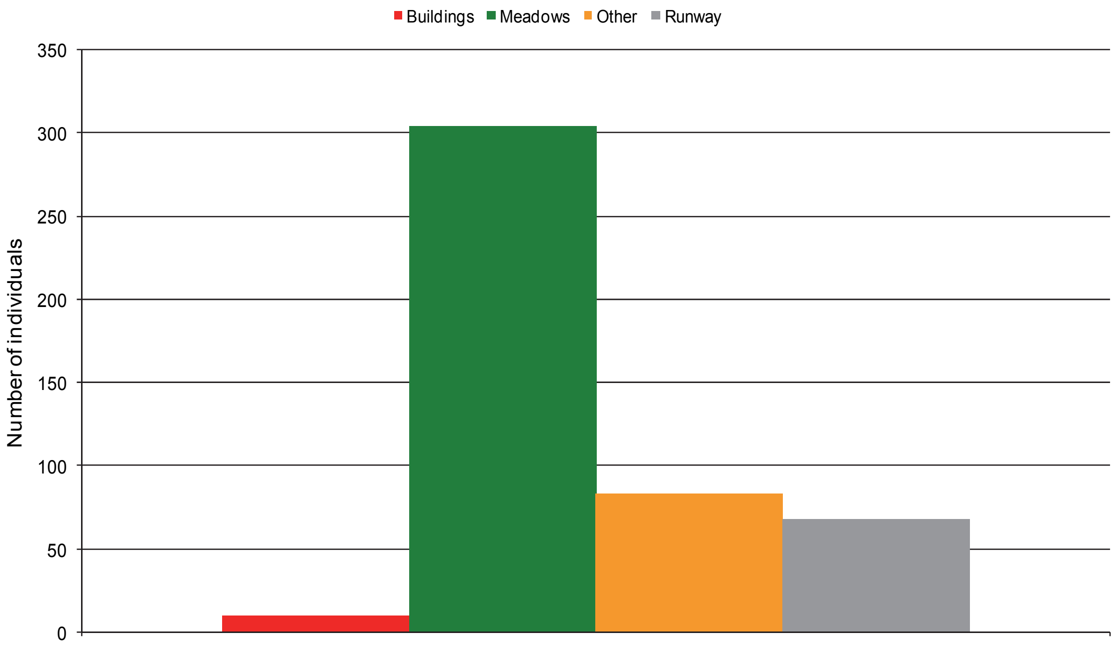
Group 10 – Doves



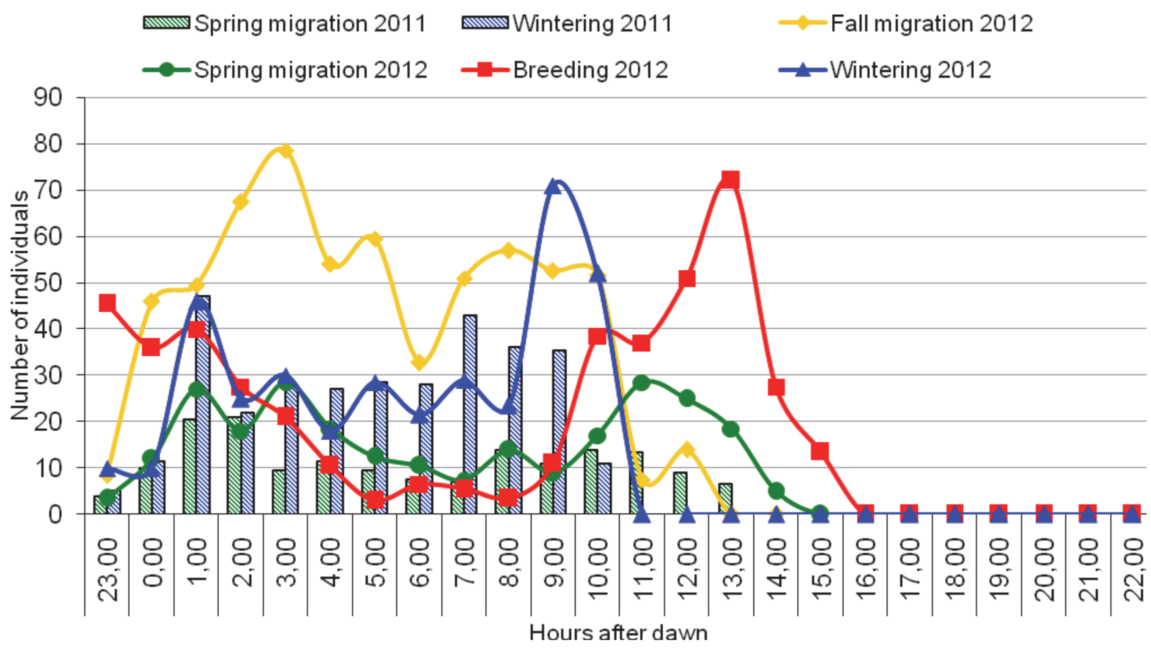


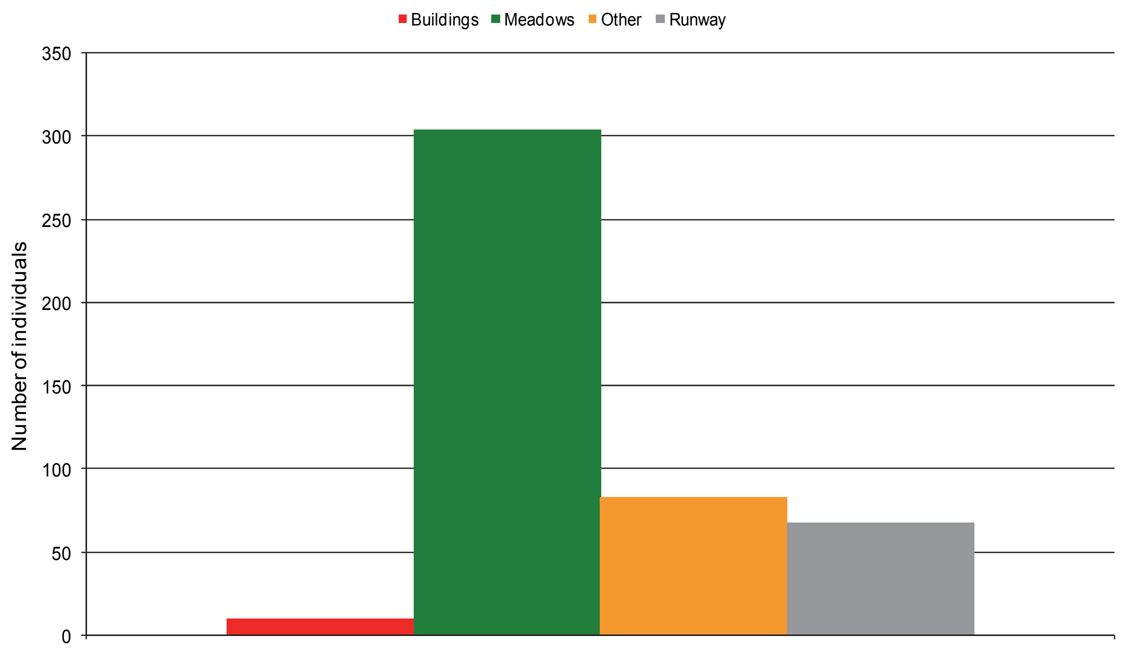
Group 12 – Swifts and swallows



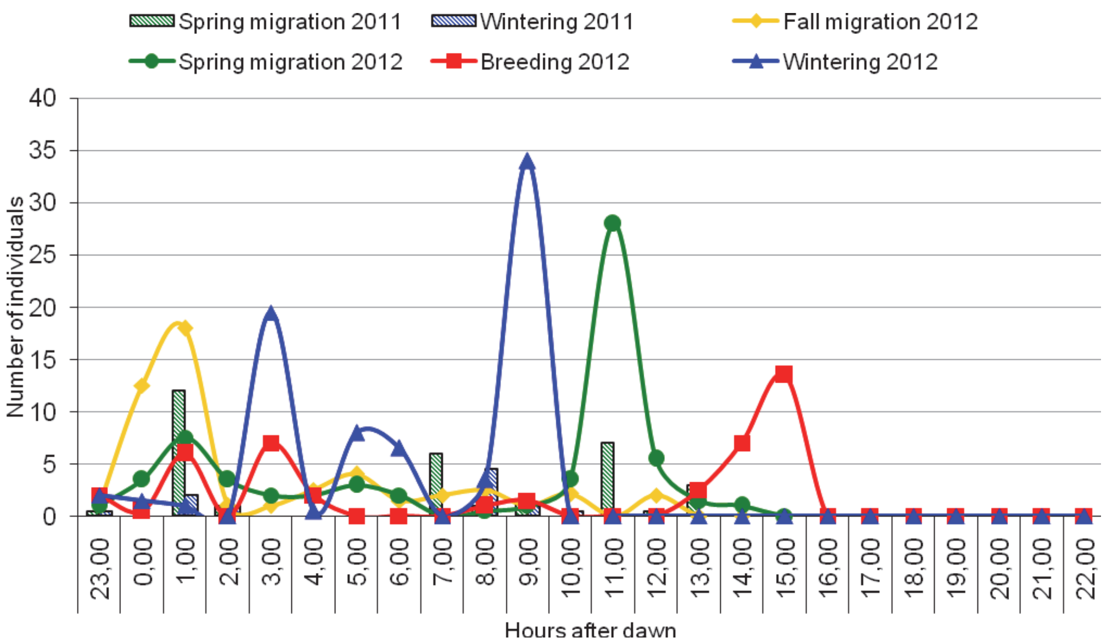


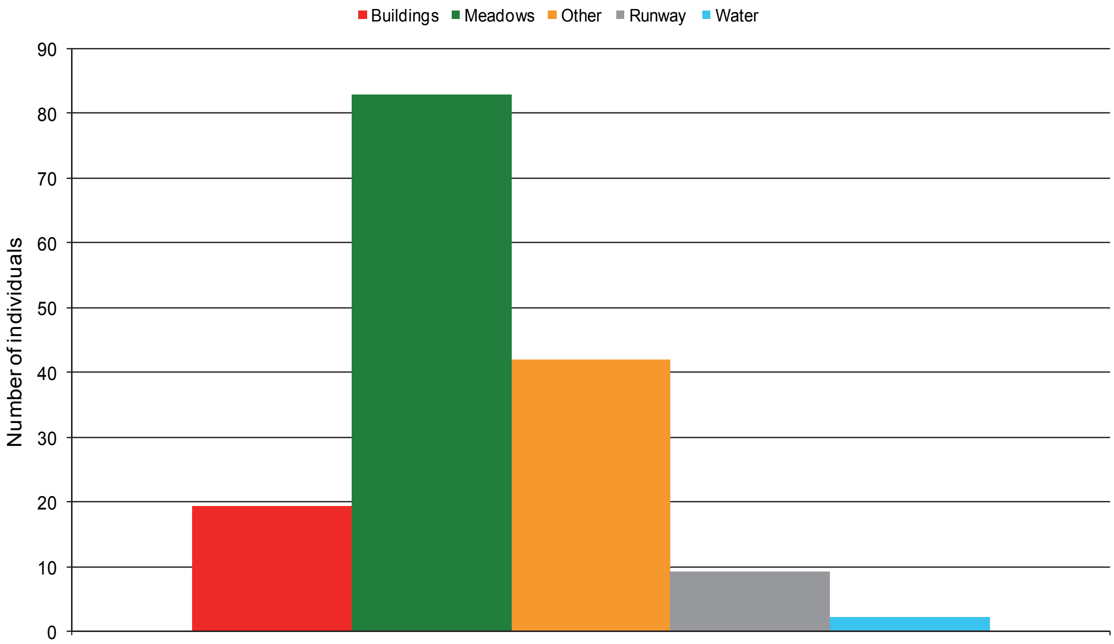
Group 13 – Corvids



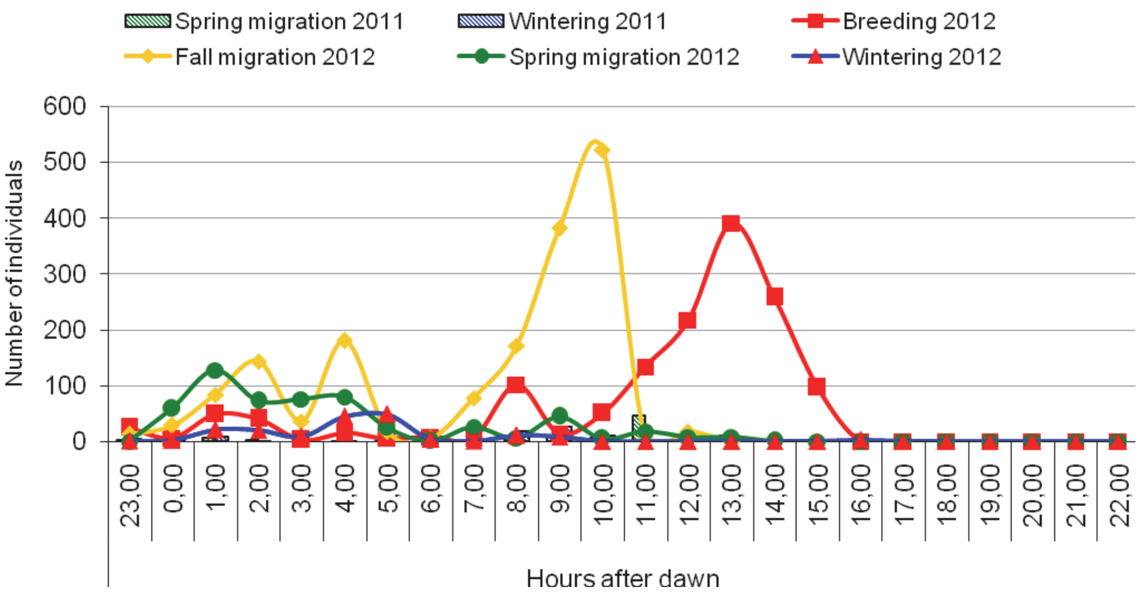


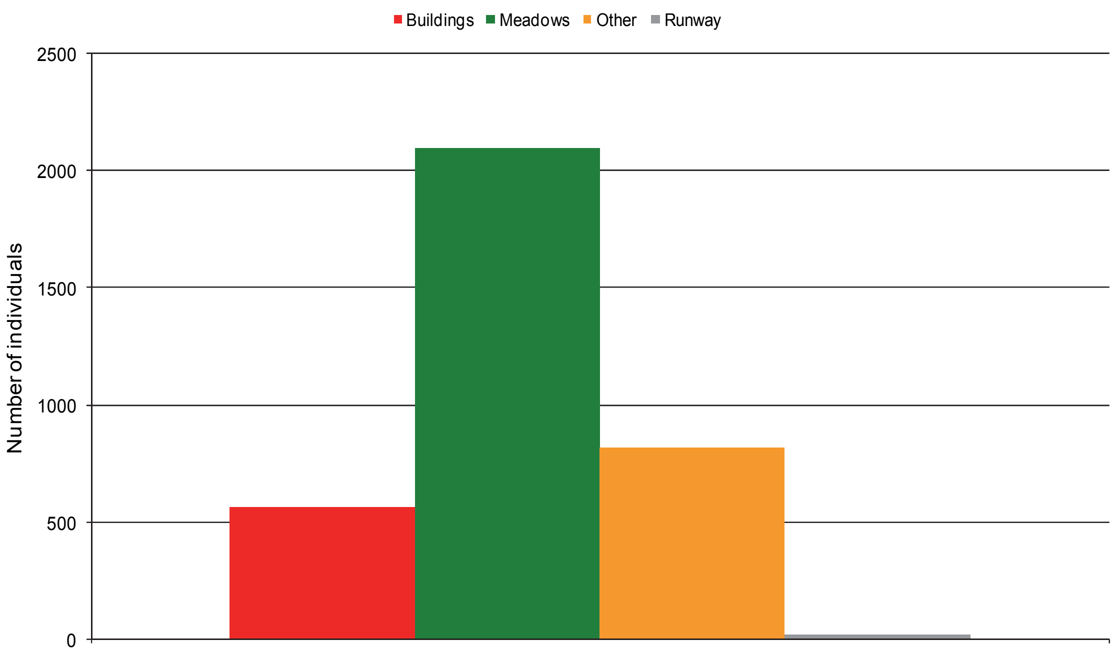
Group 14 – Non flocking passerines and bats



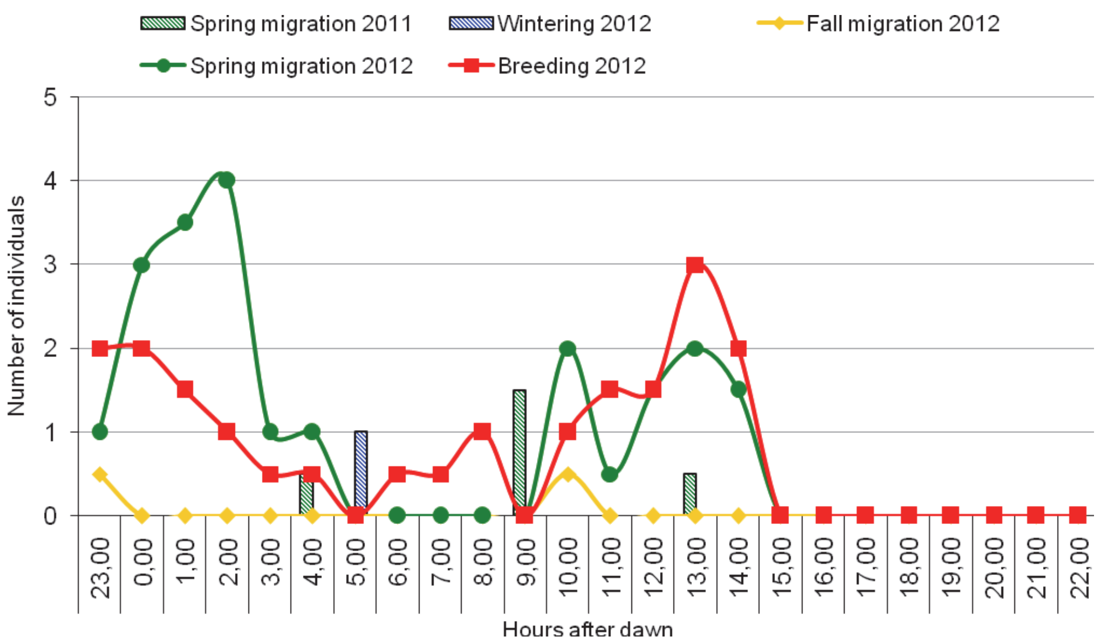


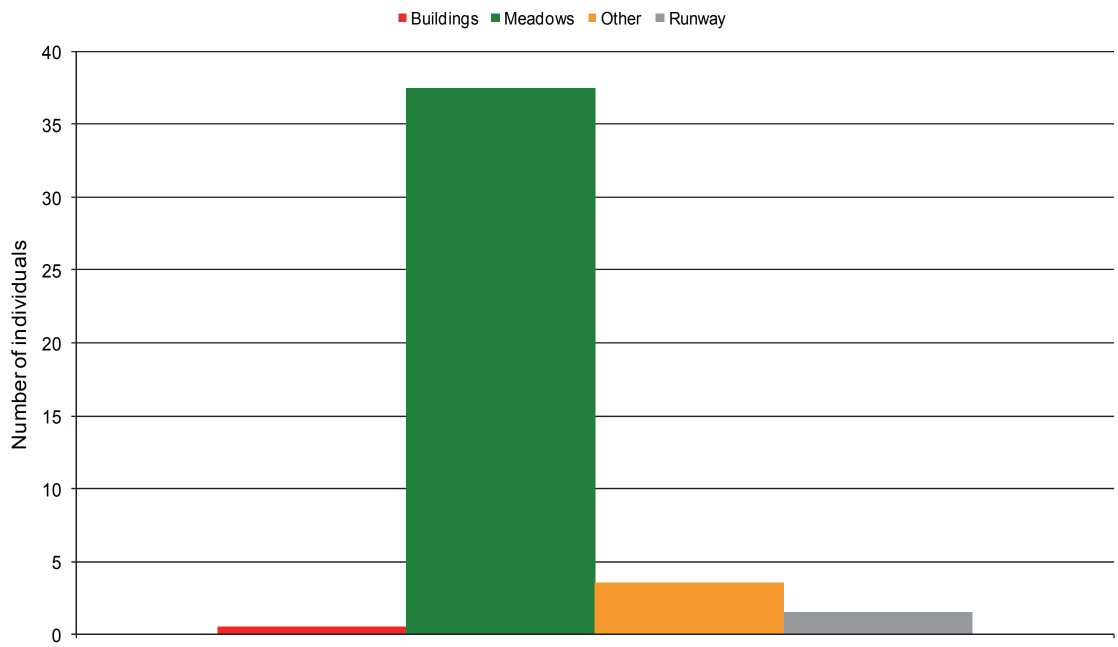
Group 15 – Flocking passerines



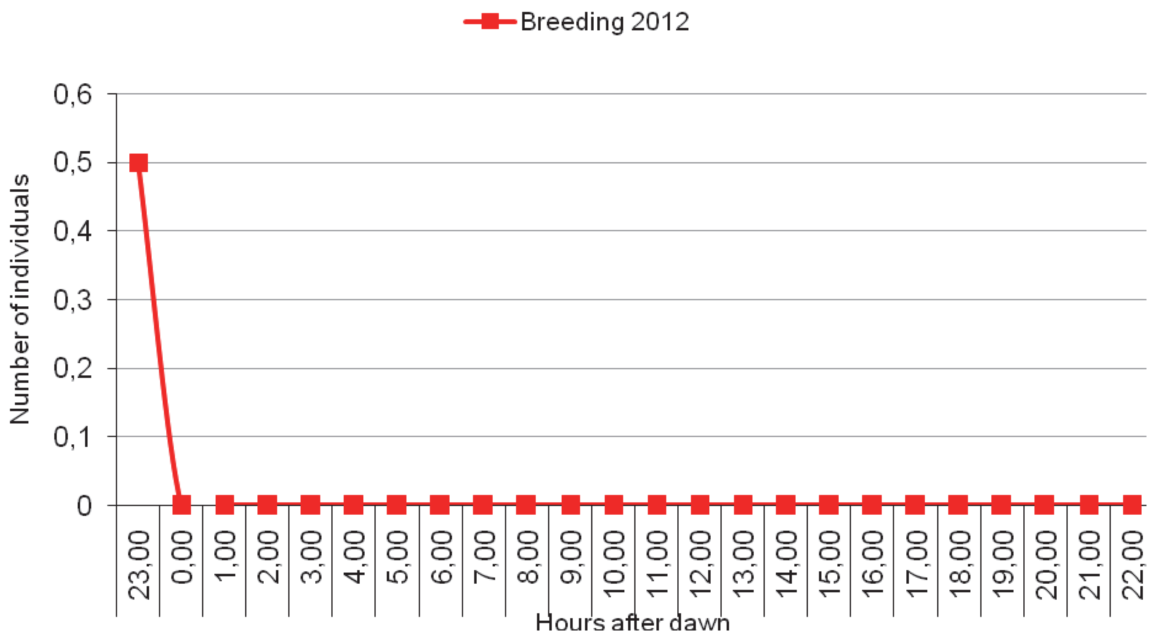


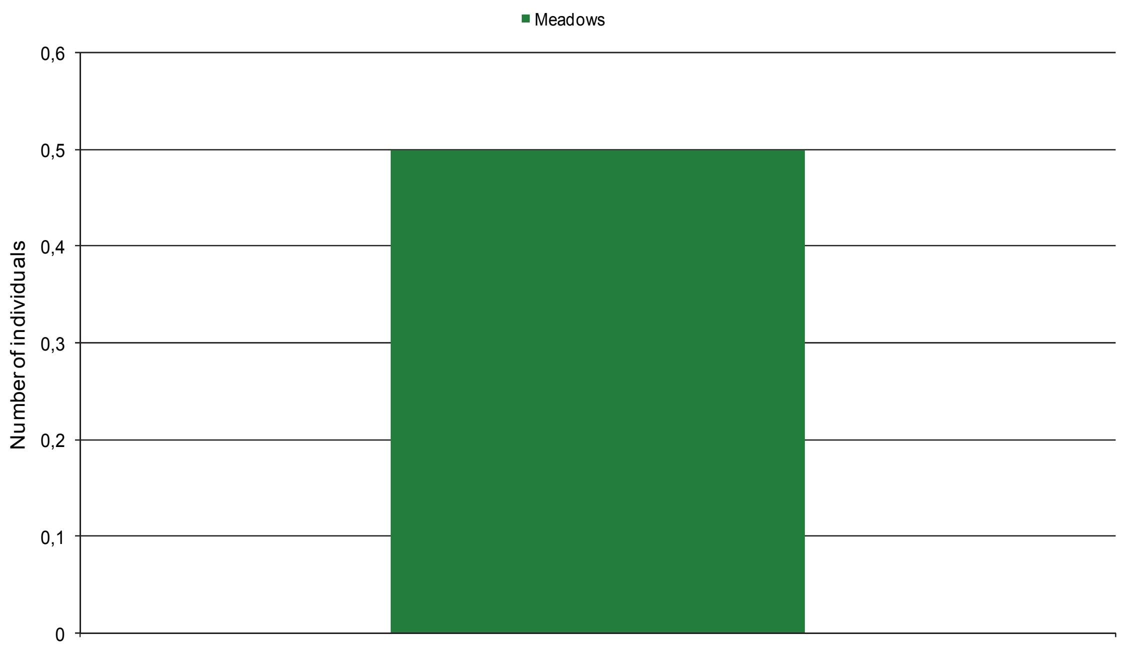
Group 16 – Small mammals (<10 Kg)





Group 17 – Large mammals (>10 Kg)

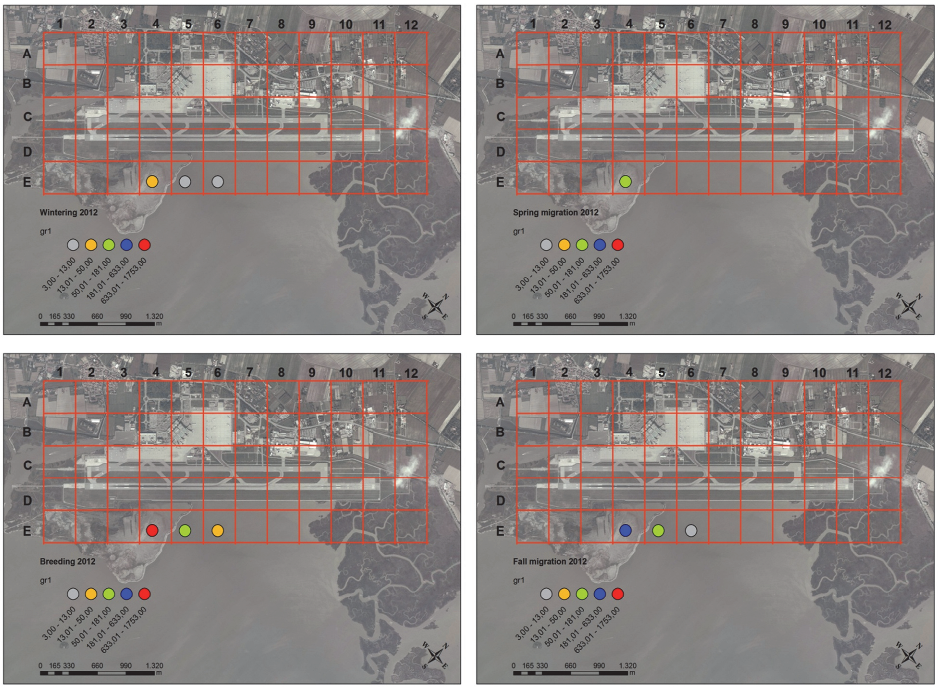




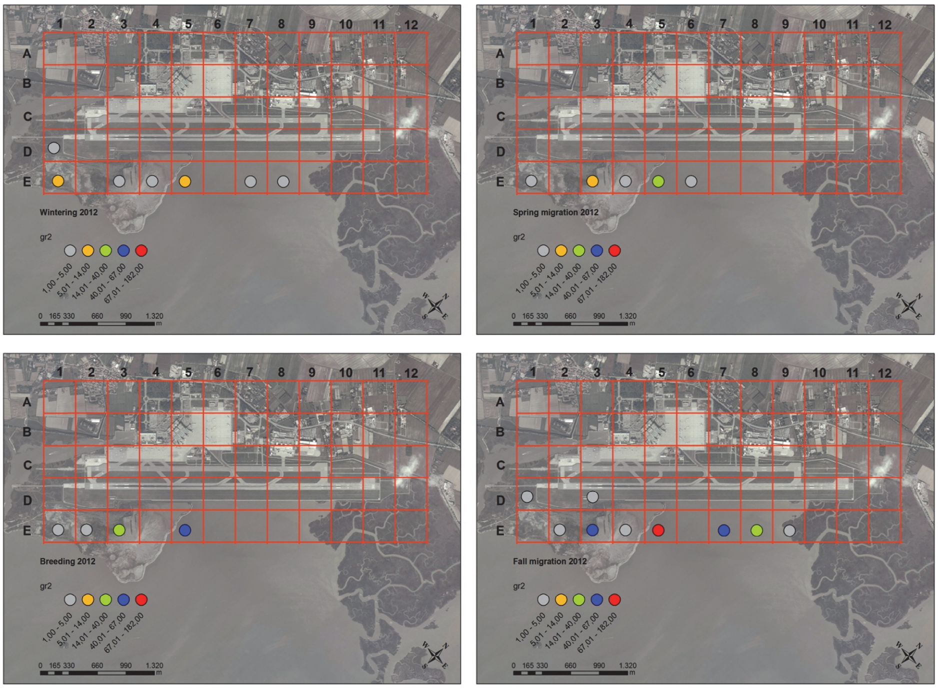
Annex II – Seasonal distribution of the functional groups of species

Venice Marco Polo airport

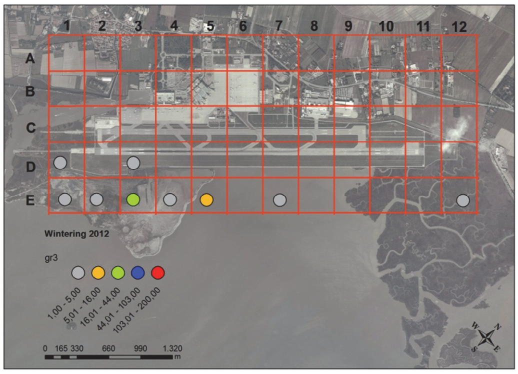
Group 1 – Grebes and divers

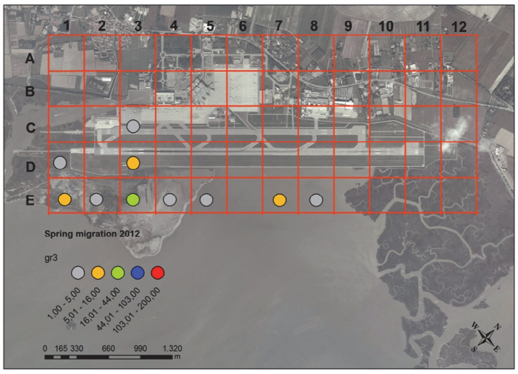


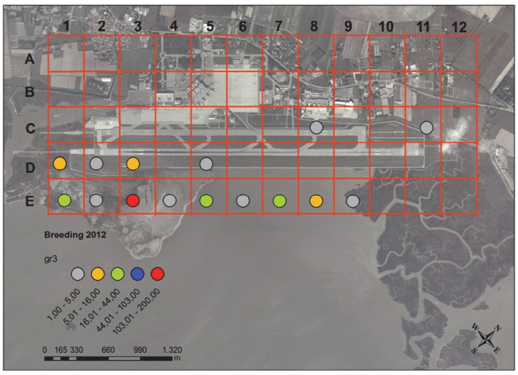
Group 2 – Cormorants, pelicans, swans and geese

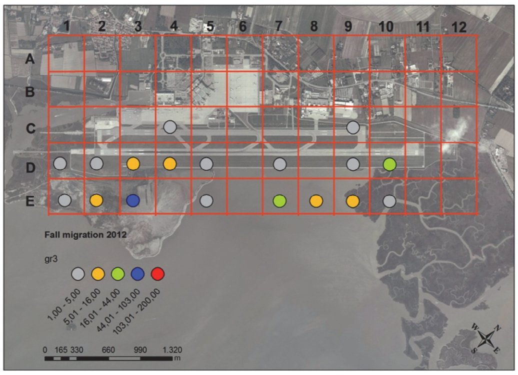


Group 3 – Herons, storks, flamingos

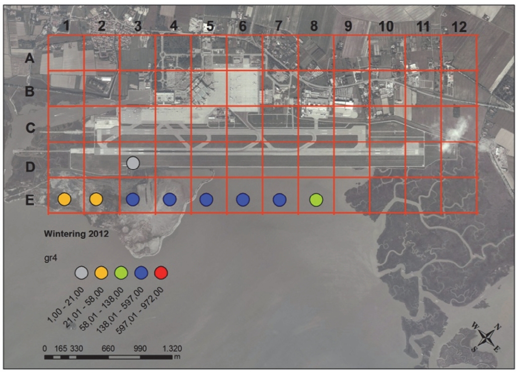


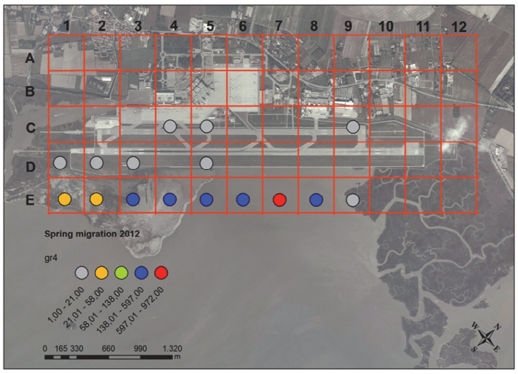


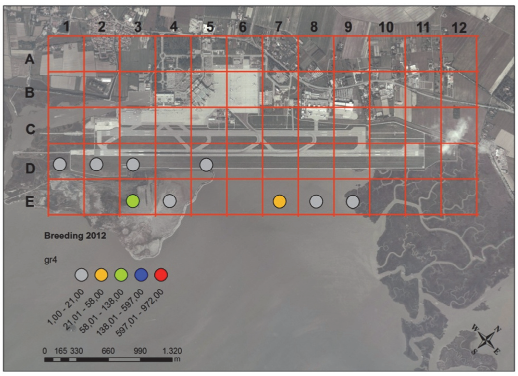


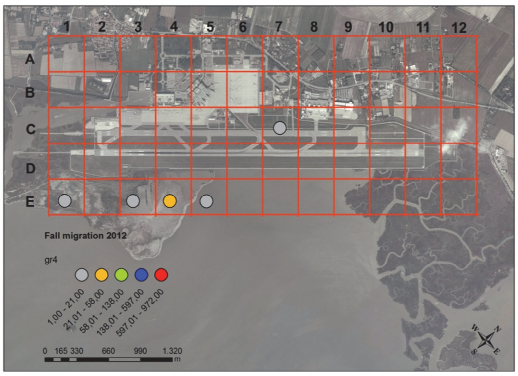


Group 4 – Ducks, pheasants, rallids

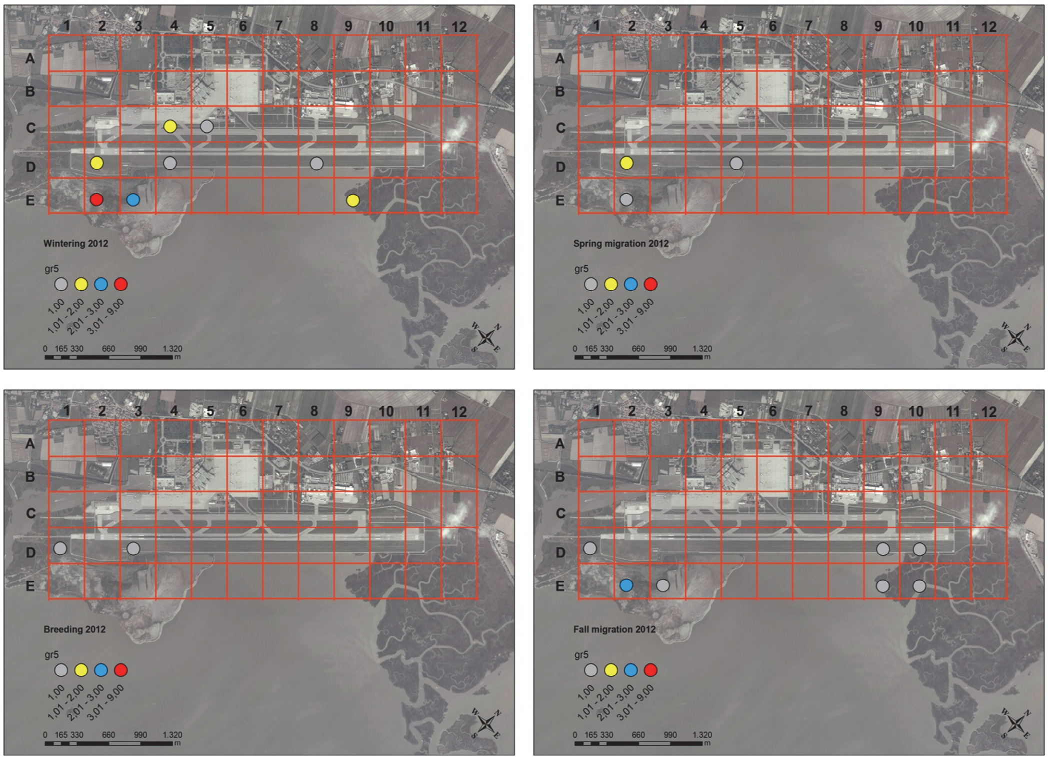




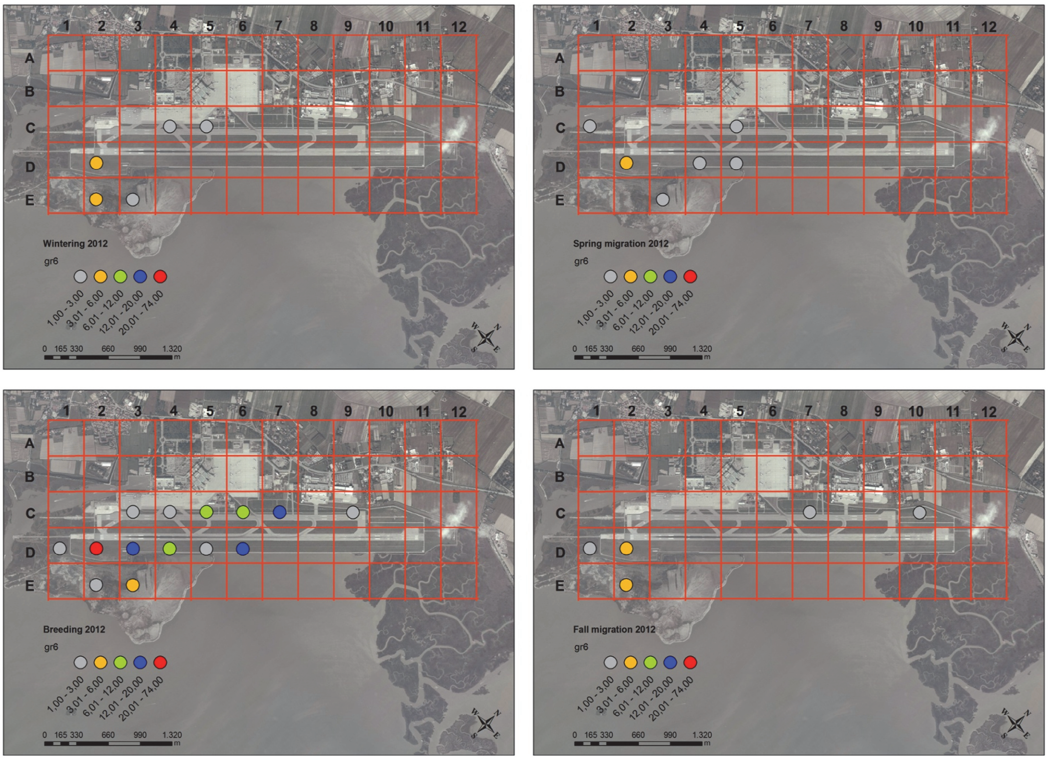




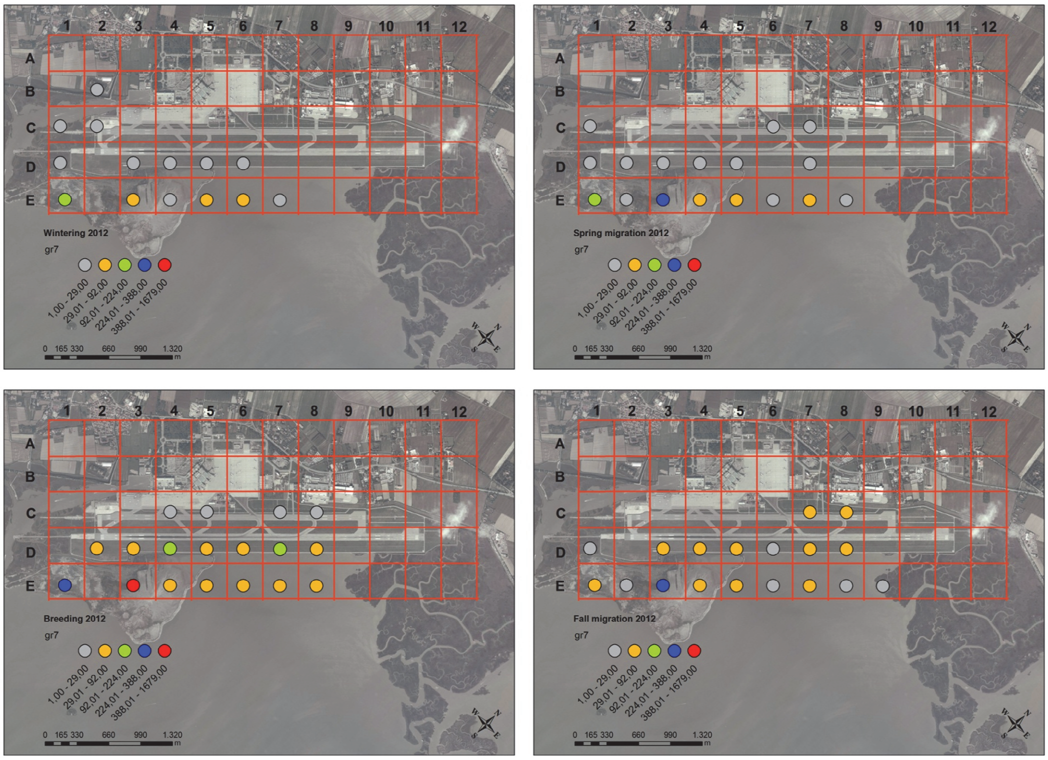
Group 5 – Birds of prey large



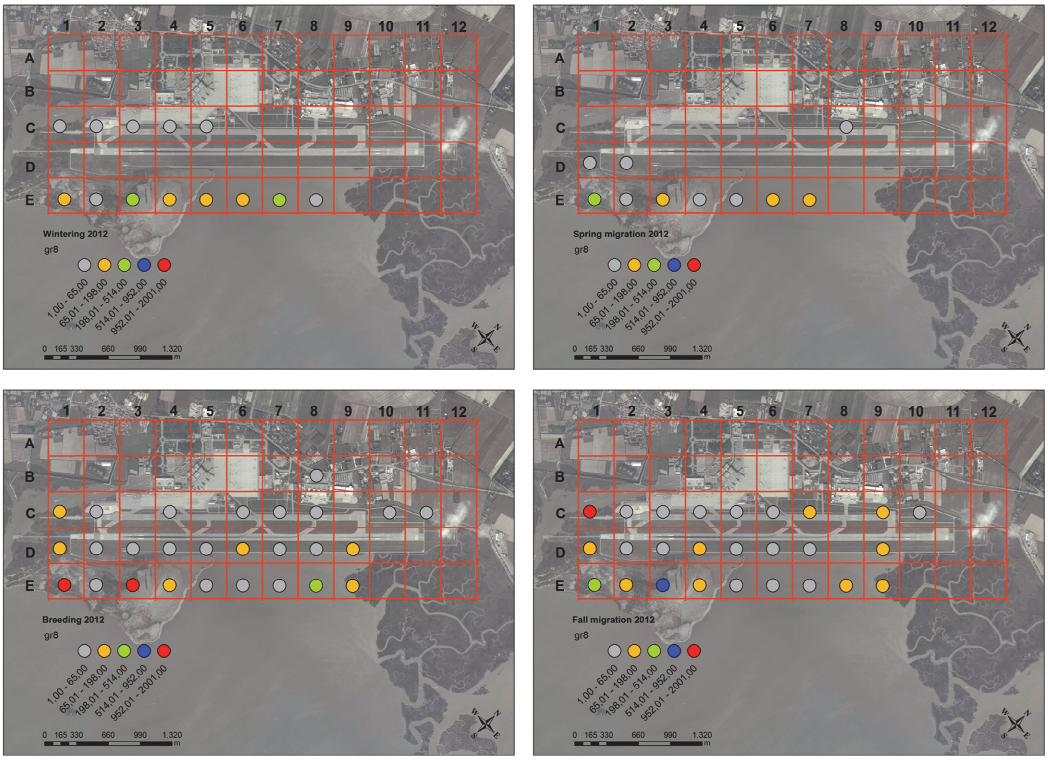
Group 6 – Birds of prey small



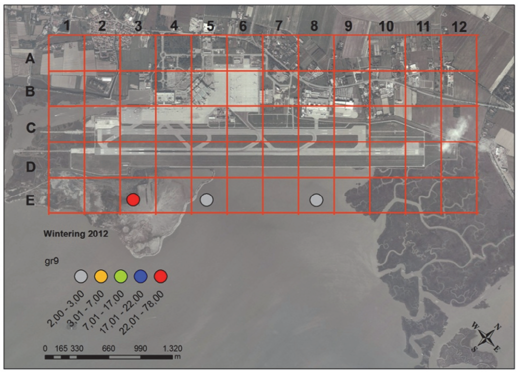
Group 7 – Large seabirds

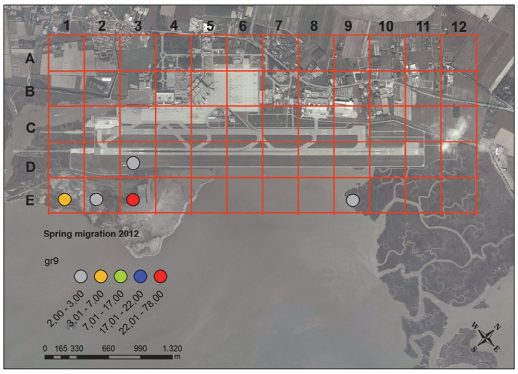


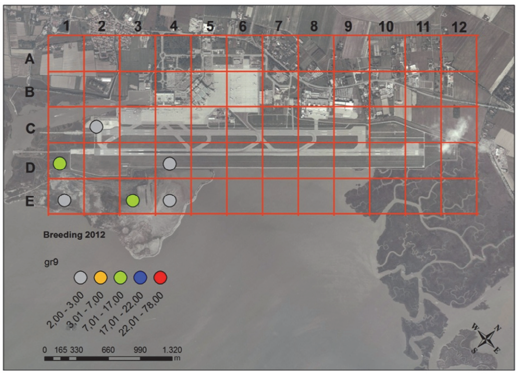
Group 8 – Small seabirds

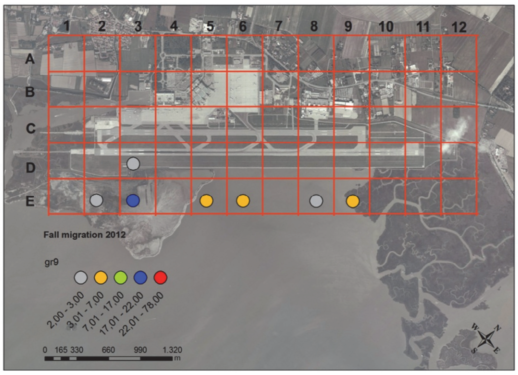


Group 9 – Waders

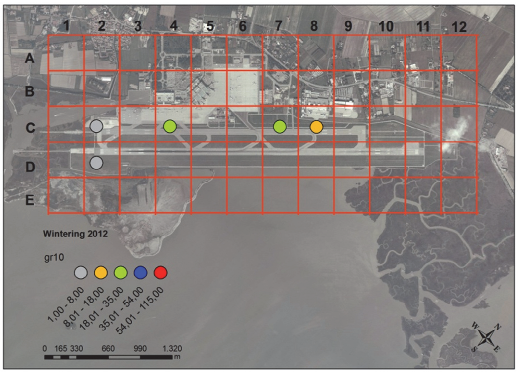


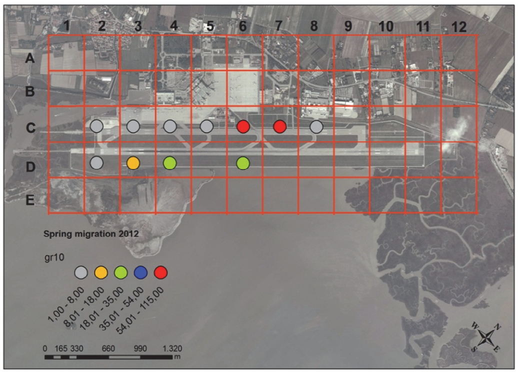


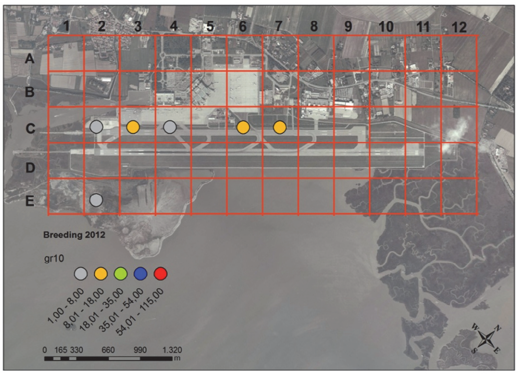


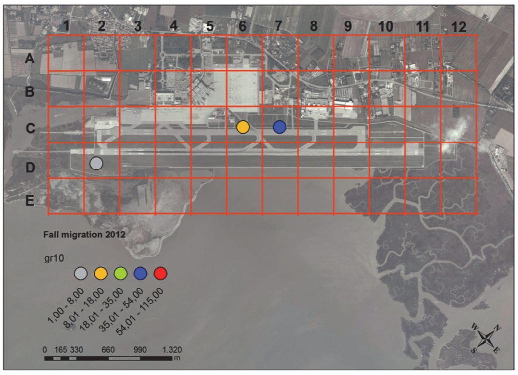


Group 10 – Doves

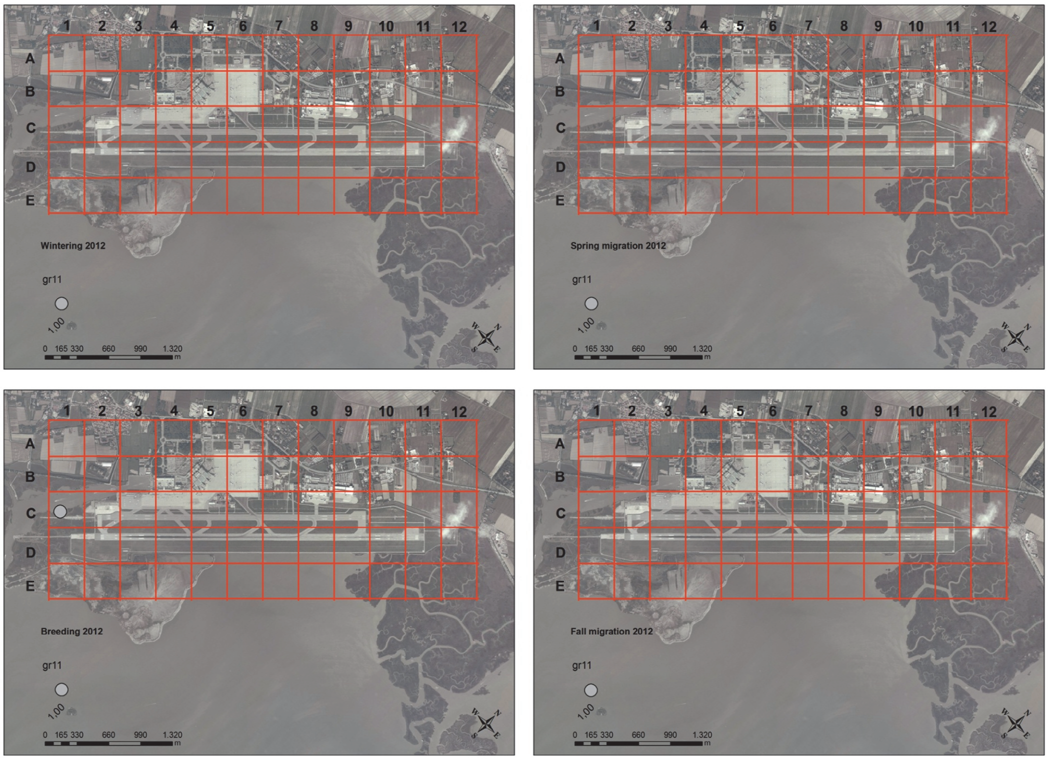




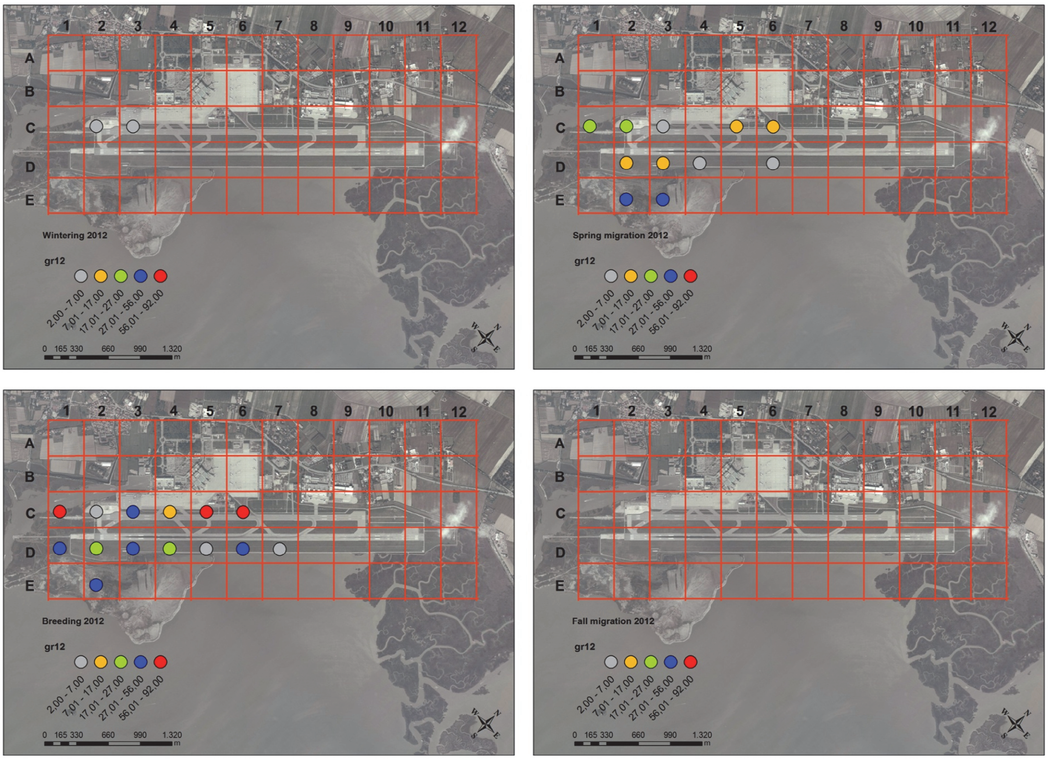




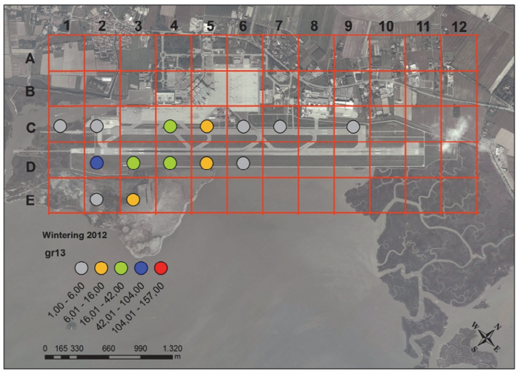
Group 11 – Owls

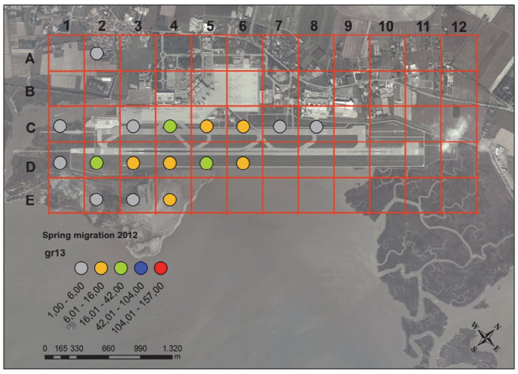


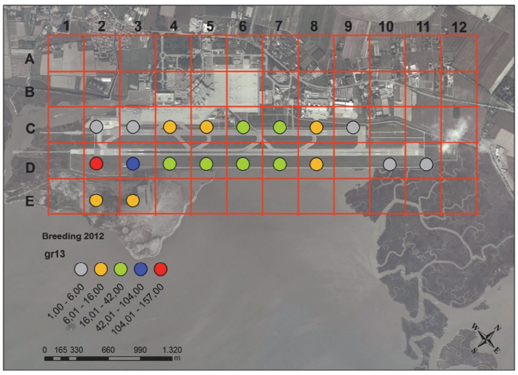
Group 12 – Swifts and swallows

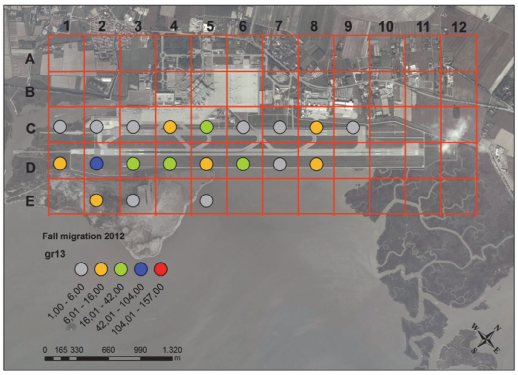


Group 13 – Corvids

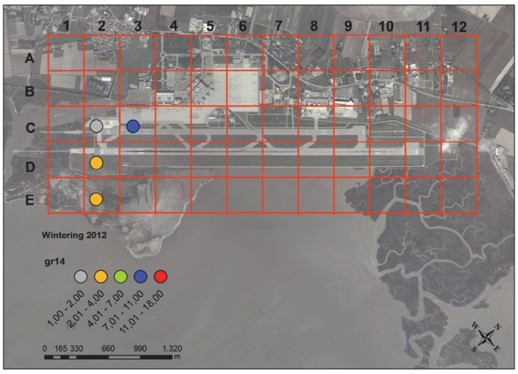


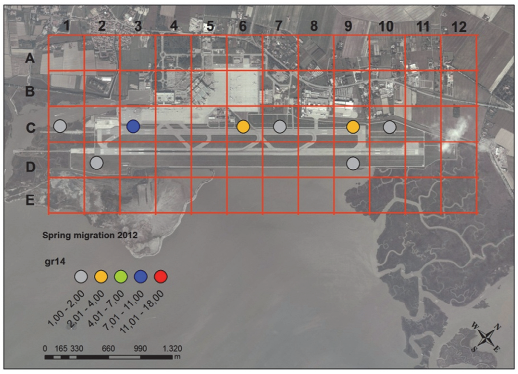


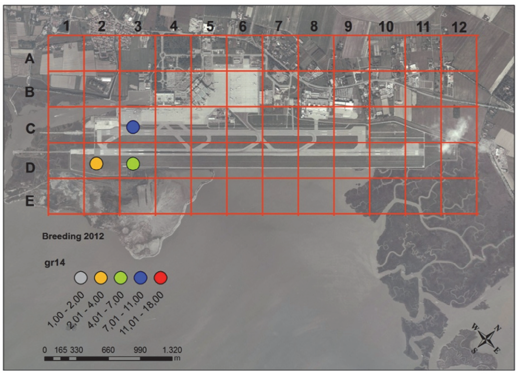


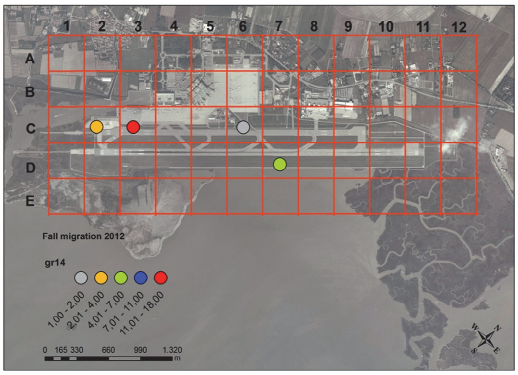


Group 14 – Non flocking passerines and bats

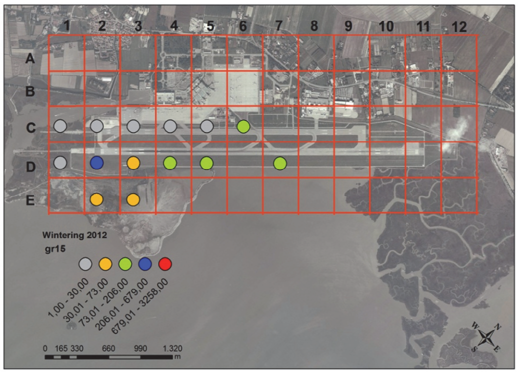


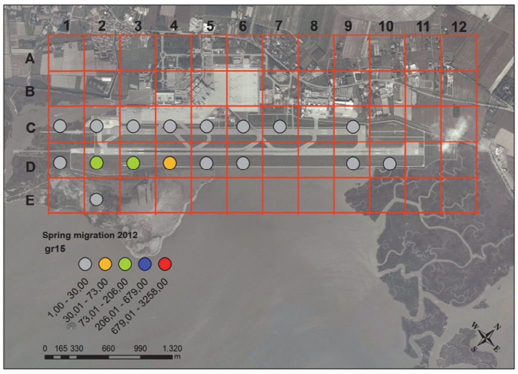


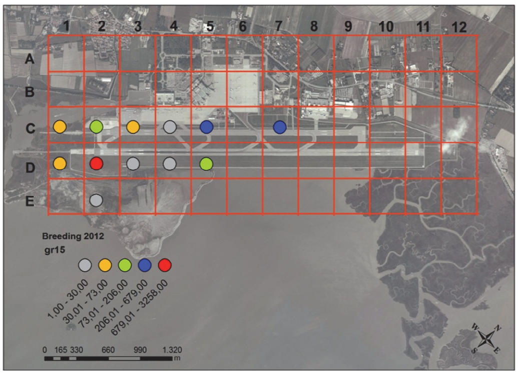


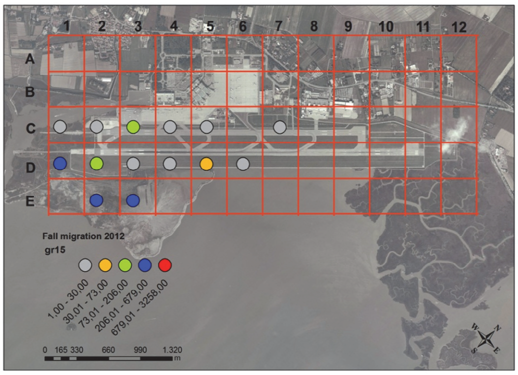


Group 15 – Flocking passerines

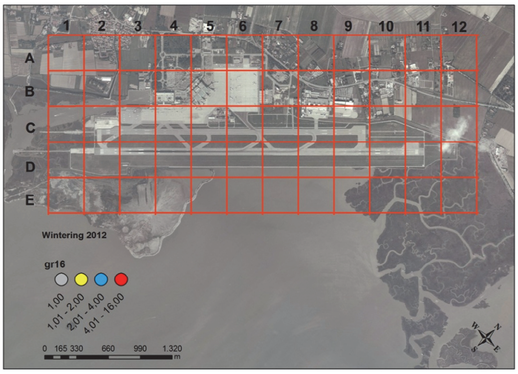


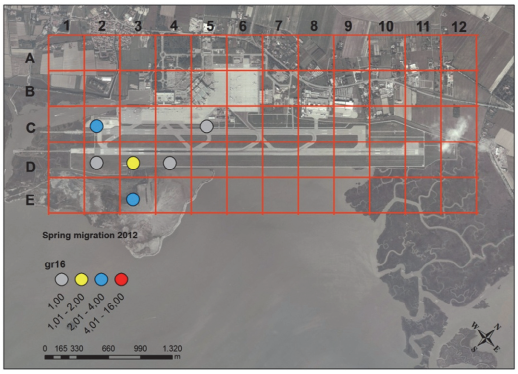


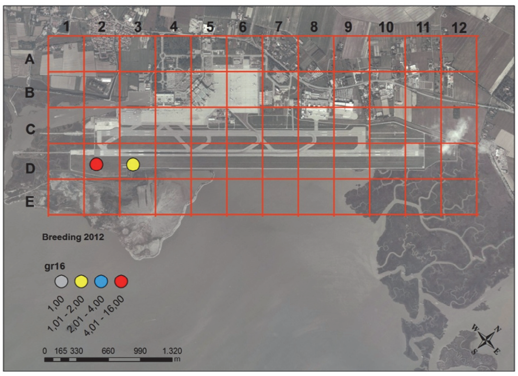


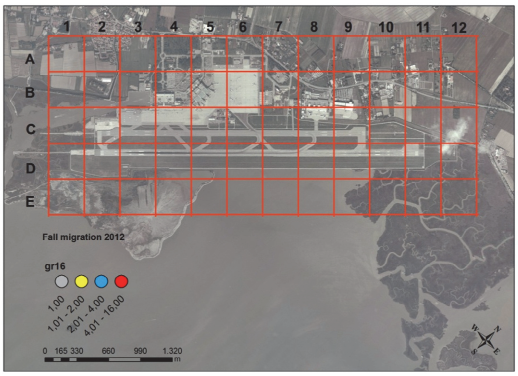


Group 16 – Small mammals (<10 Kg)



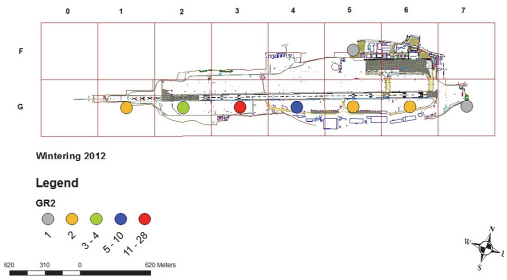


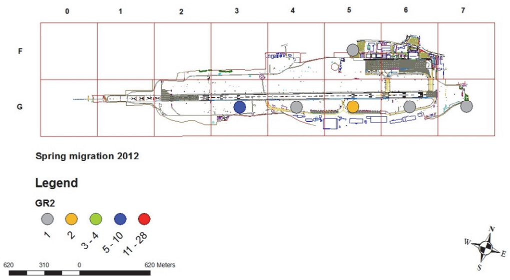


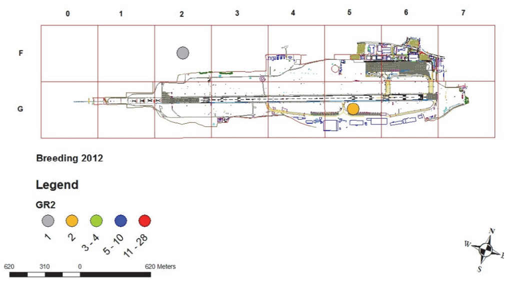


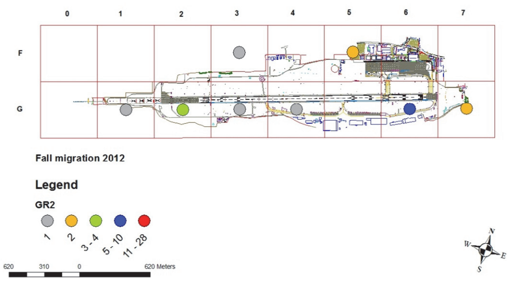
Treviso Antonio Canova airport – TSF

Group 2 – Cormorants, pelicans, swans and geese

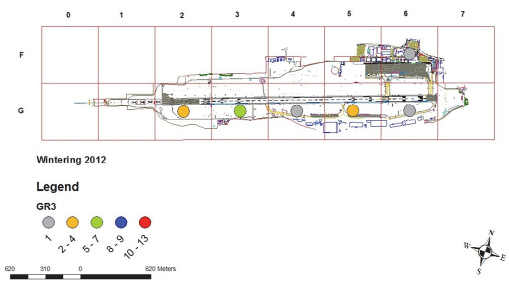


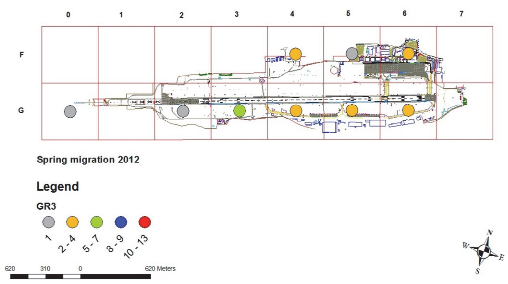


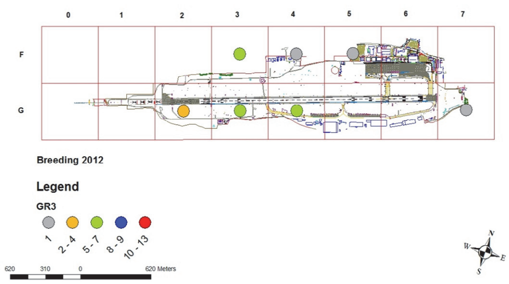


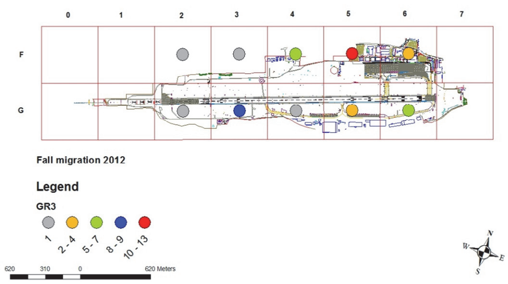


Group 3 – Herons, storks, flamingos

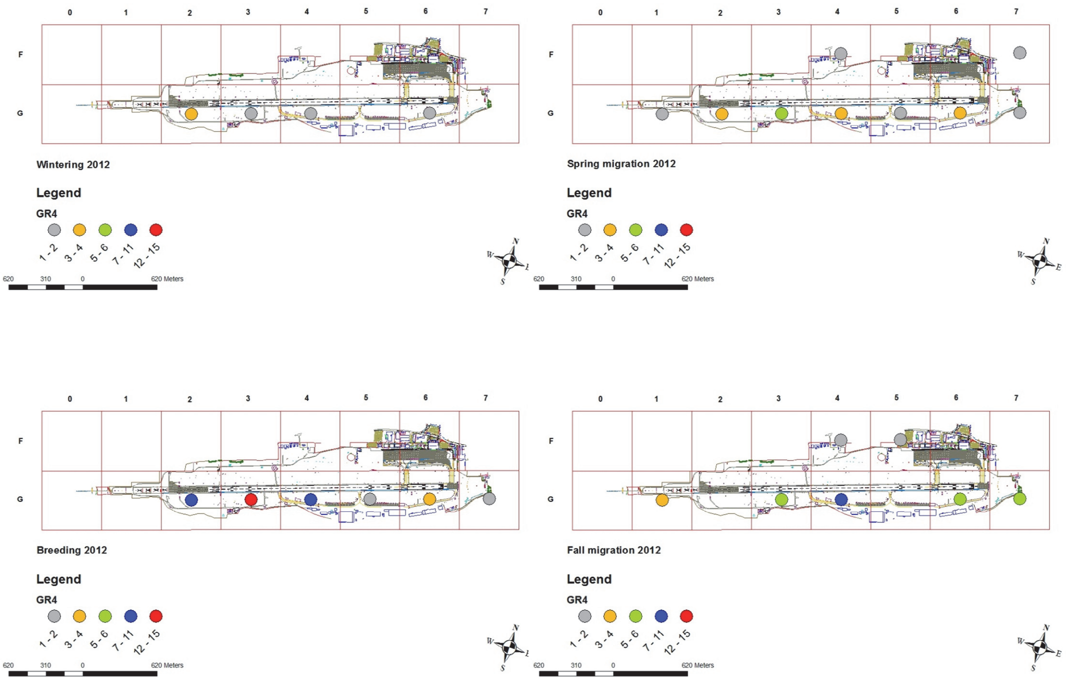




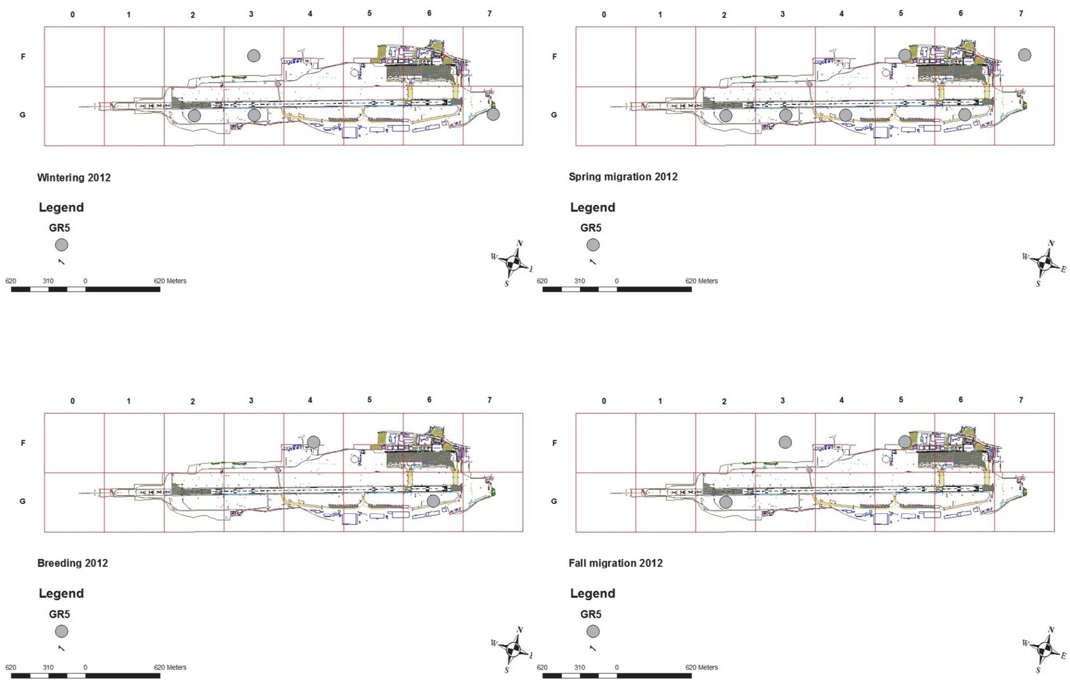




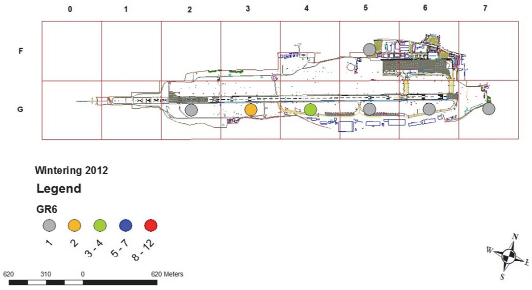
Group 4 – Ducks, pheasants, rallids

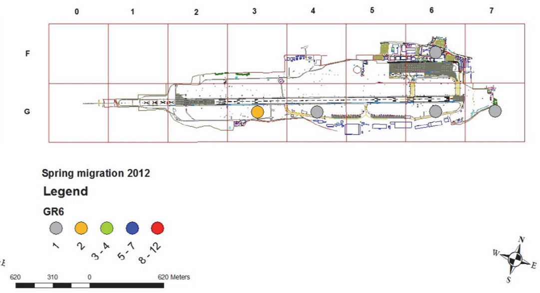


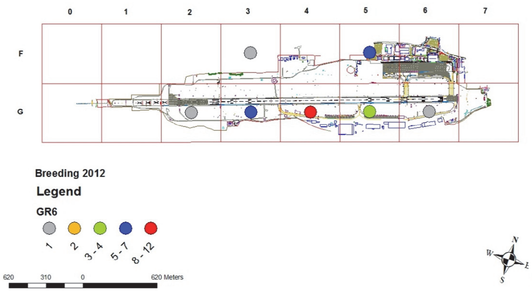
Group 5 – Birds of prey large

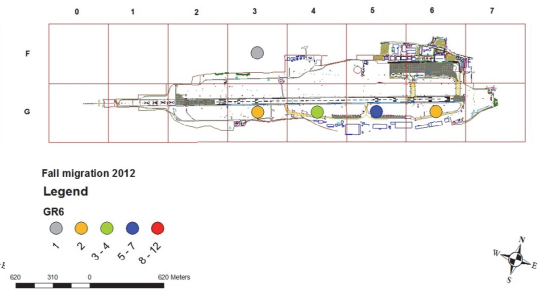


Group 6 – Birds of prey small

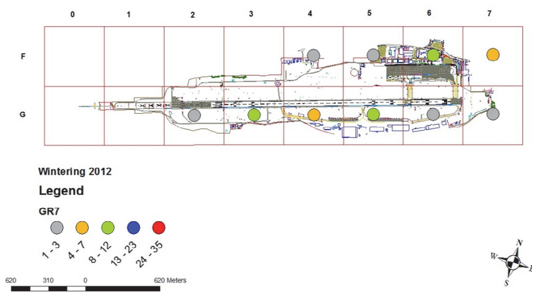


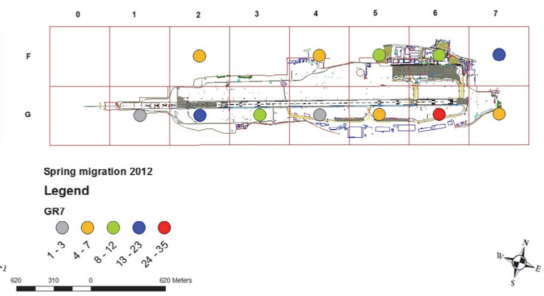


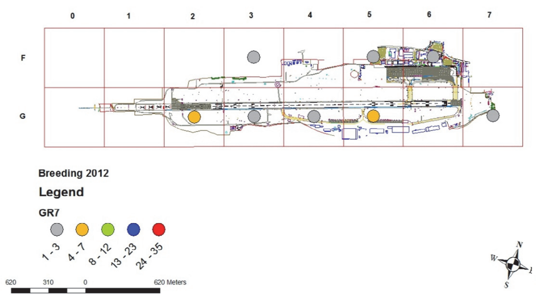


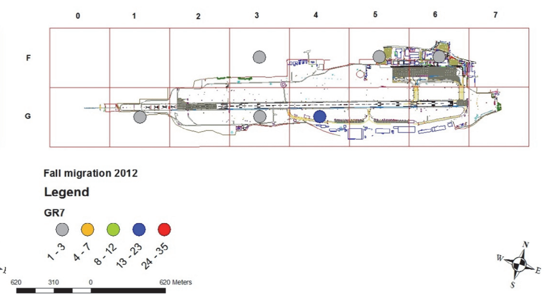


Group 7 – Large seabirds

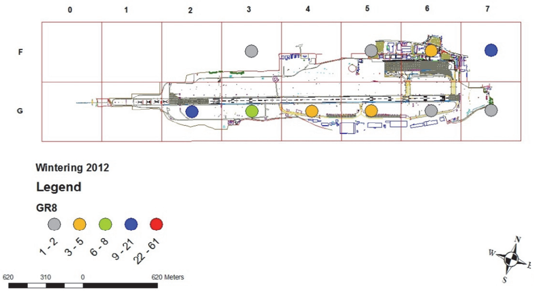


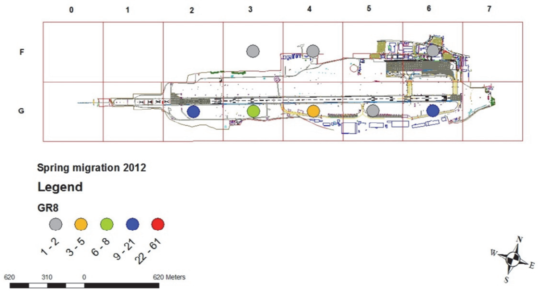


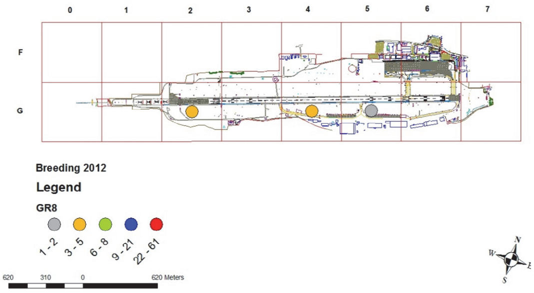


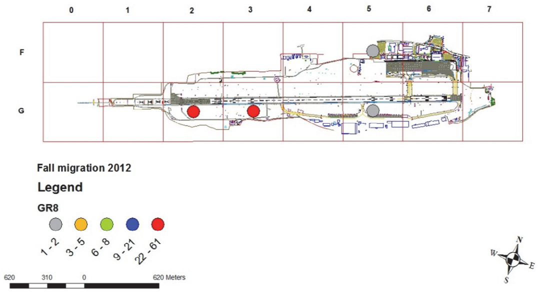


Group 8 – Small seabirds

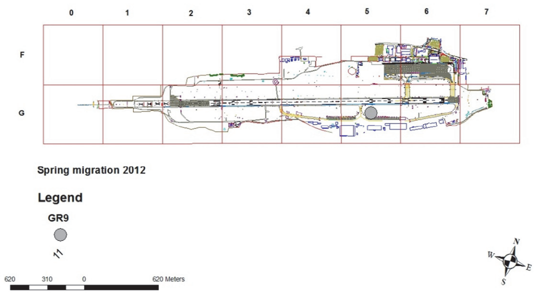


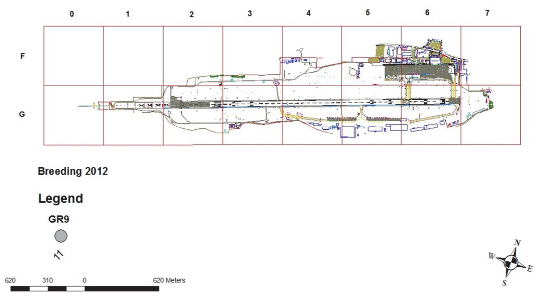


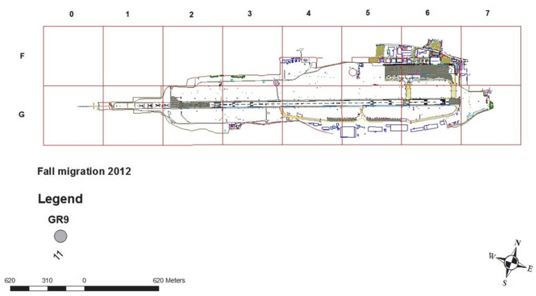




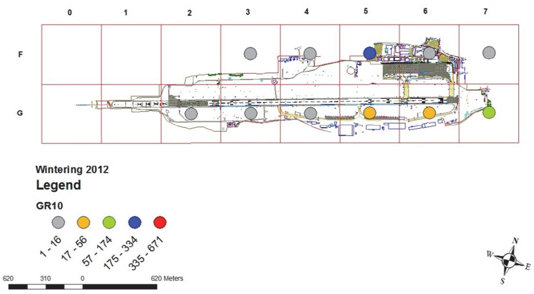
Group 9 – Waders

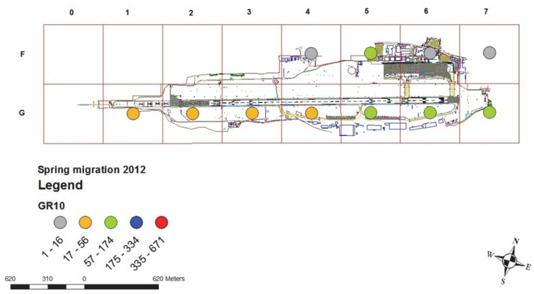


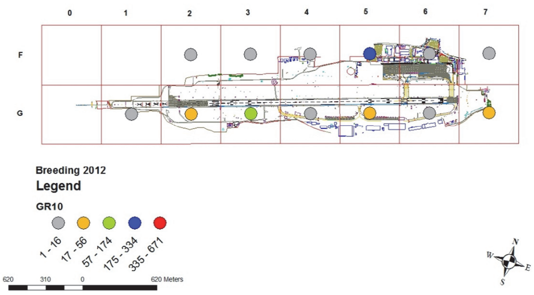


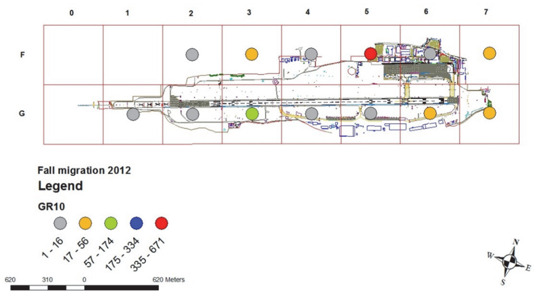


Group 10 – Doves

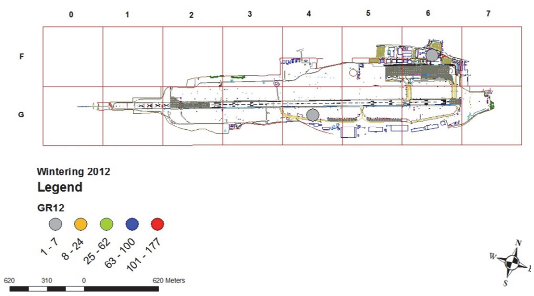


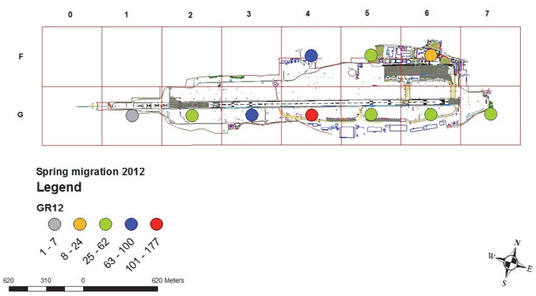


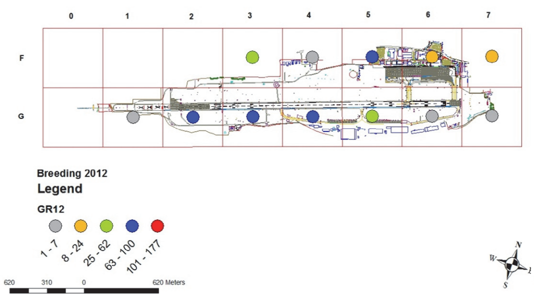


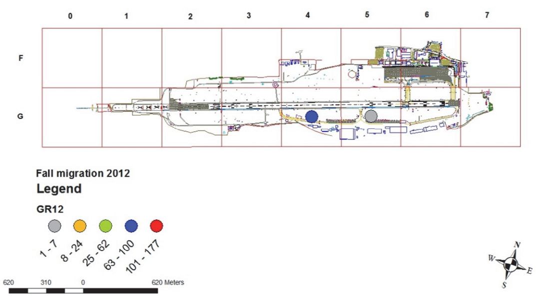


Group 12 – Swifts and swallows

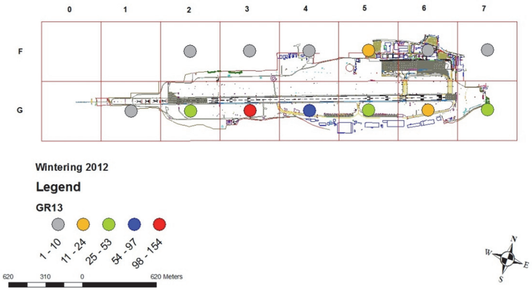


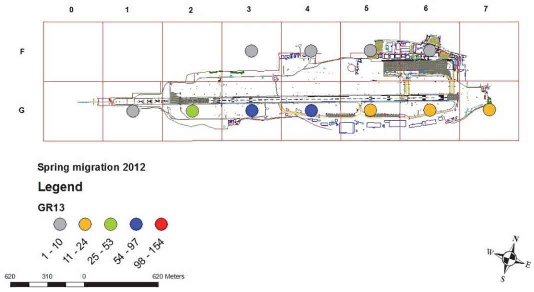


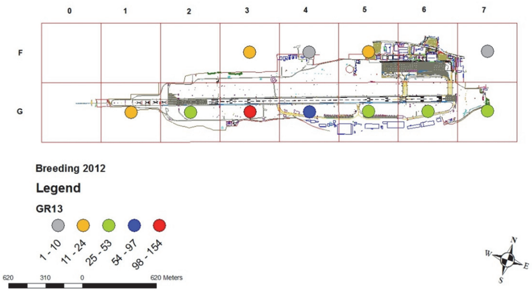


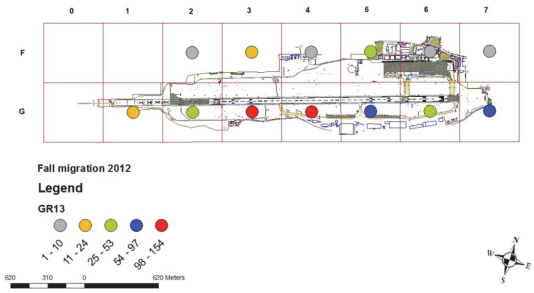


Group 13 – Corvids

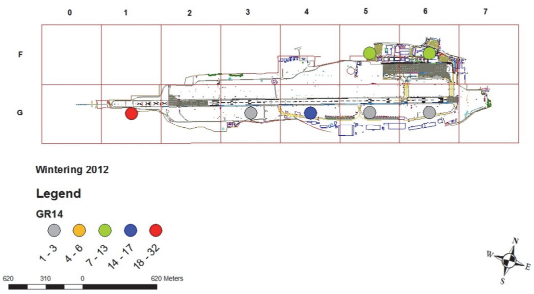


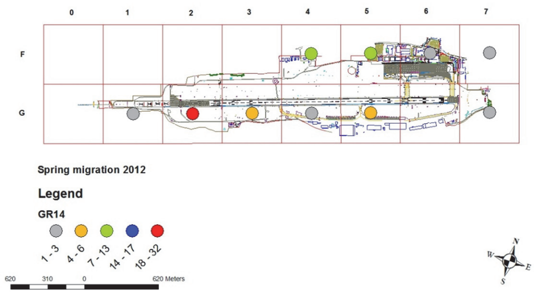


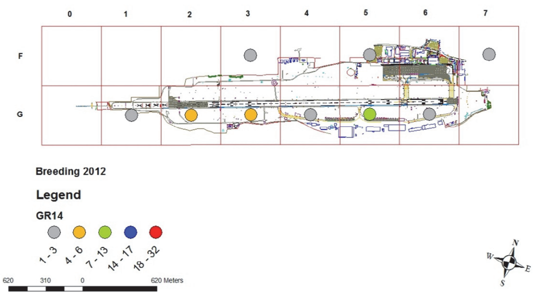


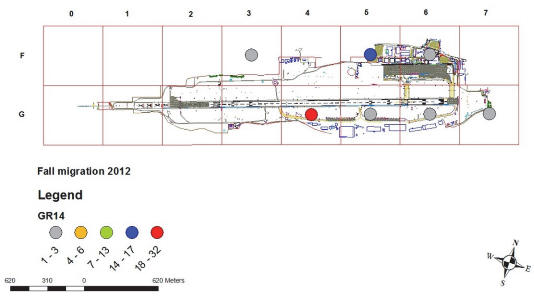


Group 14 – Non flocking passerines and bats

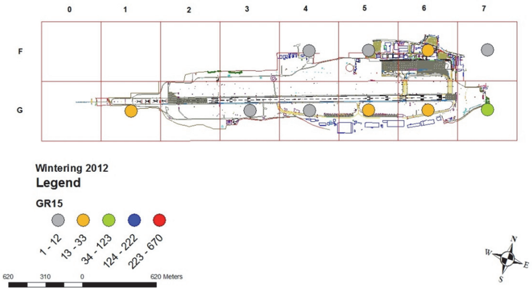


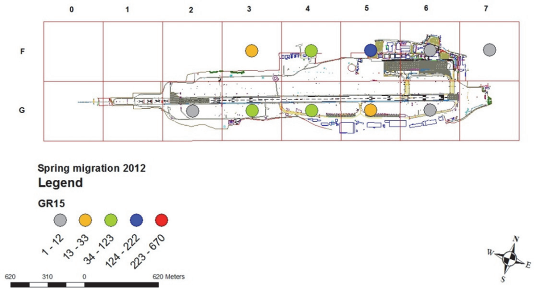


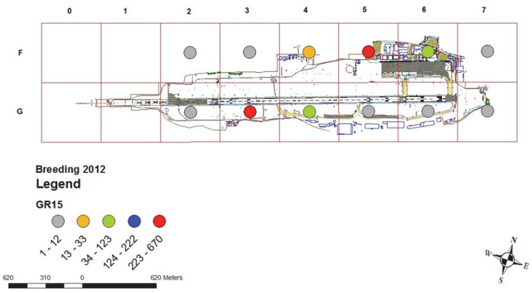


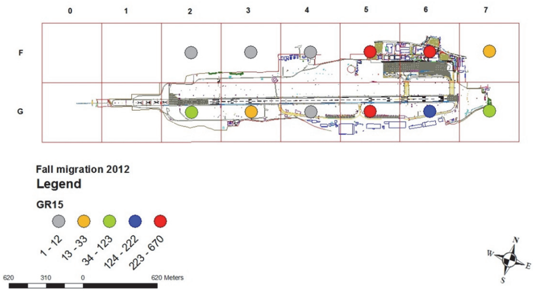


Group 15 – Flocking passerines

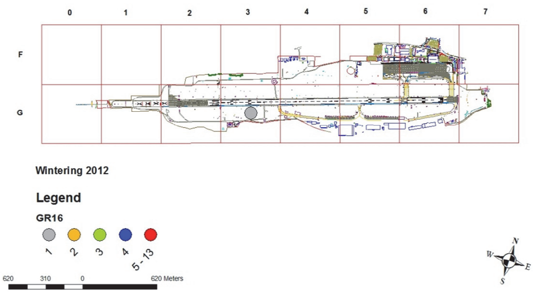


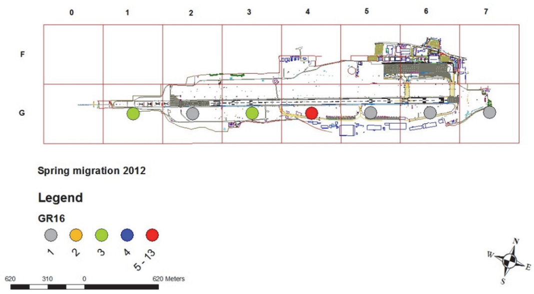


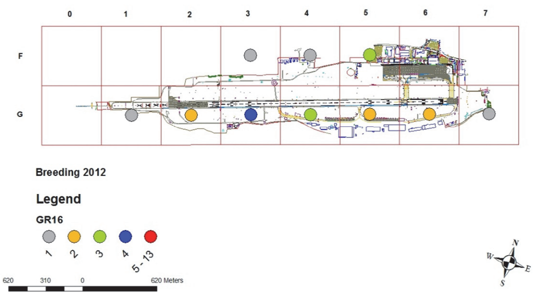


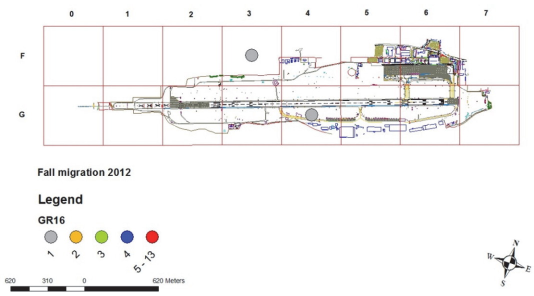


Group 16 – Small mammals (<10 Kg)

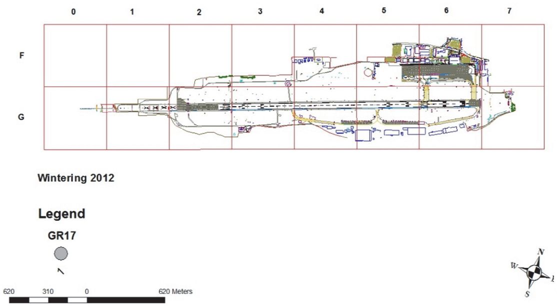


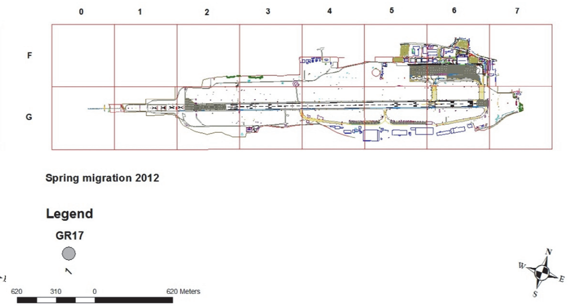


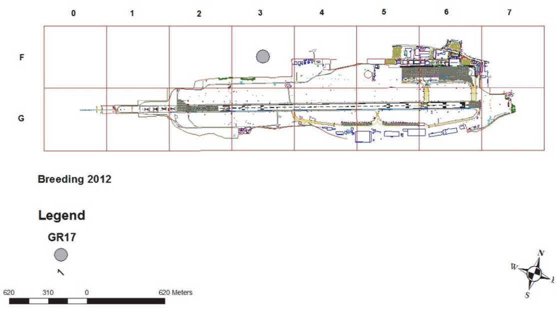


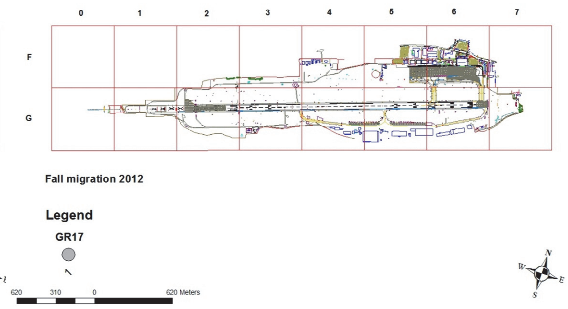


Group 17 – Large mammals (>10 Kg)









Annex III – Analysis of wildlife community at the airports' habitats

Venice Marco Polo airport - VCE

ANOSIM- Analysis of Similarities

One-Way Analysis

Resemblance worksheet
Name: Resem1
Data type: Similarity
Selection: All

Factor Values
Factor: airport habitat
Water
Other
Buildings
Meadows
Runway

Factor Groups

Sample	airport habitat
1	Water
2	Water
3	Water
4	Water
5	Water
6	Water
7	Water
8	Water
9	Water
10	Water
11	Water
12	Water
13	Water
14	Water
15	Water
16	Water
17	Water
18	Water
19	Water
20	Water
21	Water
22	Water
23	Water
24	Water
25	Water
26	Water
27	Water
28	Water
29	Water
30	Water
31	Water
32	Water
33	Water
34	Water
35	Water
36	Water
37	Water
38	Water
39	Water
40	Water
41	Water
42	Water
43	Water
44	Water
45	Water
46	Water
47	Water
48	Water
49	Water
50	Water
51	Water
52	Water
53	Water
54	Water
55	Water
56	Water
57	Water
58	Water
59	Water
60	Water
61	Water
62	Water
63	Water
64	Water
65	Water
66	Water
67	Water
68	Water
69	Water
70	Water
71	Water
72	Water
73	Water
74	Water
75	Water
76	Water
77	Water
78	Water
79	Water
80	Water
81	Water
82	Water
83	Water
84	Water
85	Water
86	Other
87	Other
88	Other
89	Other
90	Other
91	Other
92	Other
93	Other
94	Other
95	Other
96	Other
97	Other

98	Other
99	Other
100	Other
101	Other
102	Other
103	Other
104	Other
105	Other
106	Other
107	Other
108	Other
109	Other
110	Other
111	Other
112	Other
113	Other
114	Other
115	Other
116	Other
117	Other
118	Other
119	Other
120	Other
121	Other
122	Other
123	Other
124	Other
125	Other
126	Other
127	Other
128	Other
129	Other
130	Other
131	Other
132	Other
133	Other
134	Other
135	Other
136	Other
137	Other
138	Other
139	Other
140	Other
141	Other
142	Other
143	Other
144	Other
145	Other
146	Other
147	Other
148	Other
149	Other
150	Other
151	Other
152	Other
153	Other
154	Other
155	Other
156	Other
157	Other
158	Other
159	Other
160	Other
161	Other
162	Other
163	Other
164	Buildings
165	Buildings
166	Buildings
167	Buildings
168	Buildings
169	Buildings
170	Buildings
171	Buildings
172	Buildings
173	Buildings
174	Buildings
175	Buildings
176	Buildings
177	Buildings
178	Buildings
179	Buildings
180	Buildings
181	Buildings
182	Buildings
183	Buildings
184	Buildings
185	Buildings
186	Buildings
187	Buildings
188	Buildings
189	Buildings
190	Buildings
191	Buildings
192	Buildings
193	Buildings
194	Buildings
195	Buildings
196	Buildings
197	Buildings
198	Buildings
199	Buildings
200	Buildings
201	Buildings
202	Buildings
203	Buildings
204	Buildings
205	Buildings
206	Buildings
207	Buildings
208	Buildings
209	Buildings
210	Buildings
211	Buildings
212	Buildings
213	Buildings
214	Buildings
215	Buildings
216	Buildings
217	Buildings
218	Buildings
219	Buildings
220	Buildings
221	Buildings
222	Buildings
223	Buildings
224	Buildings
225	Buildings
226	Buildings
227	Buildings
228	Buildings
229	Buildings
230	Buildings
231	Buildings
232	Buildings
233	Buildings
234	Buildings
235	Buildings
236	Buildings
237	Buildings
238	Buildings
239	Buildings
240	Buildings
241	Buildings
242	Buildings
243	Buildings
244	Buildings
245	Buildings
246	Buildings
247	Buildings
248	Buildings
249	Meadows
250	Meadows
251	Meadows
252	Meadows
253	Meadows
254	Meadows
255	Meadows
256	Meadows
257	Meadows
258	Meadows
259	Meadows
260	Meadows
261	Meadows
262	Meadows
263	Meadows
264	Meadows
265	Meadows
266	Meadows
267	Meadows
268	Meadows
269	Meadows
270	Meadows
271	Meadows

272	Meadows
273	Meadows
274	Meadows
275	Meadows
276	Meadows
277	Meadows
278	Meadows
279	Meadows
280	Meadows
281	Meadows
282	Meadows
283	Meadows
284	Meadows
285	Meadows
286	Meadows
287	Meadows
288	Meadows
289	Meadows
290	Meadows
291	Meadows
292	Meadows
293	Meadows
294	Meadows
295	Meadows
296	Meadows
297	Meadows
298	Meadows
299	Meadows
300	Meadows
301	Meadows
302	Meadows
303	Meadows
304	Meadows
305	Meadows
306	Meadows
307	Meadows
308	Meadows
309	Meadows
310	Meadows
311	Meadows
312	Meadows
313	Meadows
314	Meadows
315	Meadows
316	Meadows
317	Meadows
318	Meadows
319	Meadows
320	Meadows
321	Meadows
322	Meadows
323	Meadows
324	Meadows
325	Meadows
326	Meadows
327	Meadows
328	Meadows
329	Meadows
330	Meadows
331	Meadows
332	Meadows
333	Meadows
334	Runway
335	Runway
336	Runway
337	Runway
338	Runway
339	Runway
340	Runway
341	Runway
342	Runway
343	Runway
344	Runway
345	Runway
346	Runway
347	Runway
348	Runway
349	Runway
350	Runway
351	Runway
352	Runway
353	Runway
354	Runway
355	Runway
356	Runway
357	Runway
358	Runway
359	Runway
360	Runway
361	Runway
362	Runway
363	Runway
364	Runway
365	Runway
366	Runway
367	Runway
368	Runway
369	Runway
370	Runway
371	Runway
372	Runway
373	Runway
374	Runway
375	Runway
376	Runway
377	Runway
378	Runway
379	Runway
380	Runway
381	Runway
382	Runway
383	Runway
384	Runway
385	Runway
386	Runway
387	Runway
388	Runway
389	Runway
390	Runway
391	Runway
392	Runway
393	Runway
394	Runway
395	Runway
396	Runway
397	Runway
398	Runway
399	Runway
400	Runway
401	Runway
402	Runway
403	Runway
404	Runway
405	Runway
406	Runway
407	Runway
408	Runway
409	Runway
410	Runway
411	Runway
412	Runway
413	Runway

Global Test
Sample statistic (Global R): 0,764
Significance level of sample statistic: 0,1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Water, Other	0,972	0,1	Very large	999	0
Water, Buildings	0,892	0,1	Very large	999	0
Water, Meadows	0,99	0,1	Very large	999	0
Water, Runway	0,836	0,1	Very large	999	0
Other, Buildings	0,758	0,1	Very large	999	0
Other, Meadows	0,712	0,1	Very large	999	0
Other, Runway	0,453	0,1	Very large	999	0
Buildings, Meadows	0,823	0,1	Very large	999	0
Buildings, Runway	0,541	0,1	Very large	999	0
Meadows, Runway	0,552	0,1	Very large	999	0

SIMPER- Similarity Percentages - species contributions

One-Way Analysis

Data worksheet
Name: Data2
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90,00%

Group Water
Average similarity: 52,13

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chroicocephalus ridibundus	29,44	14,55	2,45	27,91	27,91
Larus michahellis	29,01	12,88	2,49	24,70	52,61
Tadorna tadorna	17,69	7,57	1,27	14,53	67,14
Podiceps cristatus	11,58	4,47	1,00	8,57	75,71
Recurvirostra avosetta	13,76	2,73	0,49	5,23	80,94
Anas platyrhynchos	7,28	2,64	0,74	5,07	86,01
Ardea cinerea	5,16	2,32	1,41	4,44	90,45

Group Other
Average similarity: 40,94

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Phalacrocorax carbo	4,38	14,84	1,54	36,24	36,24
Falco tinnunculus	2,12	6,59	1,25	16,11	52,35
Sturnus vulgaris	7,91	5,94	0,65	14,50	66,85
Pica pica	1,83	5,87	1,14	14,34	81,19

Corvus cornix	1,40	3,49	0,82	8,53	89,73
Larus michahellis	2,24	1,44	0,32	3,53	93,25

Group Buildings
Average similarity: 39,97

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chroicocephalus ridibundus	8,16	17,94	0,82	44,87	44,87
Motacilla alba	1,65	7,85	1,23	19,63	64,49
Sturnus vulgaris	2,75	7,42	0,78	18,55	83,05
Columba livia	1,43	2,46	0,38	6,15	89,20
Passer italiae	1,00	1,85	0,42	4,62	93,82

Group Meadows
Average similarity: 47,58

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Sturnus vulgaris	18,90	19,79	1,60	41,60	41,60
Corvus cornix	7,17	10,84	2,47	22,79	64,39
Larus michahellis	4,63	3,88	0,89	8,16	72,54
Pica pica	2,41	2,87	1,28	6,03	78,57
Alauda arvensis	2,21	2,07	0,77	4,35	82,92
Columba livia	3,03	1,83	0,58	3,85	86,77
Ardea cinerea	1,64	1,68	0,81	3,53	90,29

Group Runway
Average similarity: 24,14

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corvus cornix	1,33	8,03	0,72	33,28	33,28
Columba livia	1,56	3,81	0,41	15,79	49,07
Alauda arvensis	0,85	3,16	0,40	13,08	62,15
Falco tinnunculus	0,73	2,82	0,44	11,67	73,82
Pica pica	0,59	1,71	0,36	7,09	80,91
Larus michahellis	1,07	1,61	0,33	6,68	87,59
Sturnus vulgaris	1,46	1,34	0,23	5,55	93,14

Groups Water & Other
Average dissimilarity = 92,43

Species	Group Water Av.Abund	Group Other Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chroicocephalus ridibundus	29,44	1,05	16,95	2,44	18,34	18,34
Larus michahellis	29,01	2,24	15,58	2,02	16,85	35,19
Tadorna tadorna	17,69	0,11	10,80	1,50	11,69	46,88
Recurvirostra avosetta	13,76	0,00	7,48	0,76	8,09	54,97
Podiceps cristatus	11,58	0,00	7,32	1,20	7,91	62,88
Anas platyrhynchos	7,28	0,03	5,19	0,89	5,61	68,50
Sturnus vulgaris	0,34	7,91	4,04	0,49	4,37	72,87
Ardea cinerea	5,16	0,25	3,17	1,40	3,43	

						76,31
Egretta garzetta	3,75	0,06	2,41	1,34	2,61	78,92
Phalacrocorax carbo	2,81	4,38	2,36	1,27	2,55	81,47
Cygnus olor	2,17	0,00	1,54	0,83	1,66	83,13
Falco tinnunculus	0,17	2,12	1,40	1,27	1,52	84,65
Pica pica	0,11	1,83	1,21	1,37	1,31	85,96
Anatre nn id	1,98	0,00	1,20	0,38	1,30	87,26
Calidris alpina	2,46	0,03	1,17	0,29	1,26	88,52
Corvus cornix	1,11	1,40	0,97	1,08	1,05	89,57
Tringa nebularia	1,41	0,00	0,96	0,76	1,04	90,61

Groups Water & Buildings
Average dissimilarity = 89,15

Species	Group Water Av.Abund	Group Buildings Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Larus michahellis	29,01	0,30	16,97	2,32	19,03	19,03
Chroicocephalus ridibundus	29,44	8,16	13,62	1,71	15,28	34,31
Tadorna tadorna	17,69	0,00	11,20	1,52	12,56	46,88
Recurvirostra avosetta	13,76	0,00	7,69	0,76	8,63	55,50
Podiceps cristatus	11,58	0,00	7,55	1,21	8,47	63,98
Anas platyrhynchos	7,28	0,02	5,38	0,90	6,03	70,01
Ardea cinerea	5,16	0,02	3,38	1,46	3,80	73,80
Egretta garzetta	3,75	0,02	2,52	1,36	2,82	76,63
Sturnus vulgaris	0,34	2,75	1,95	0,91	2,19	78,81
Phalacrocorax carbo	2,81	0,00	1,68	0,92	1,89	80,70
Cygnus olor	2,17	0,00	1,59	0,83	1,79	82,49
Anatre nn id	1,98	0,00	1,24	0,38	1,39	83,88
Calidris alpina	2,46	0,00	1,18	0,28	1,32	85,20
Motacilla alba	0,03	1,65	1,16	1,57	1,30	86,50
Columba livia	0,08	1,43	1,01	0,70	1,14	87,64
Tringa nebularia	1,41	0,00	1,00	0,76	1,12	88,76
Podiceps nigricollis	1,51	0,02	0,89	0,51	1,00	89,76
Corvus cornix	1,11	0,18	0,70	0,80	0,78	90,54

Groups Other & Buildings
Average dissimilarity = 85,59

Species	Group Other Av.Abund	Group Buildings Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chroicocephalus ridibundus	1,05	8,16	19,09	1,13	22,30	22,30
Sturnus vulgaris	7,91	2,75	12,74	0,86	14,89	37,19
Phalacrocorax carbo	4,38	0,00	11,98	1,57	13,99	51,18
Falco tinnunculus	2,12	0,10	5,74	1,24	6,71	57,89
Larus michahellis	2,24	0,30	4,93	0,57	5,76	63,64
Motacilla alba	0,02	1,65	4,84	1,46	5,65	69,30
Pica pica	1,83	0,60	4,26	1,25	4,97	74,27
Columba livia	0,04	1,43	3,86	0,70	4,51	78,78
Corvus cornix	1,40	0,18	3,65	1,10	4,26	83,04

Passer italiae	0,30	1,00	2,94	0,78	3,43	86,48
Buteo buteo	0,56	0,00	1,57	0,71	1,83	88,31
Turdus merula	0,06	0,31	1,05	0,57	1,23	89,54
Delichon urbicum	0,00	0,37	0,90	0,28	1,06	90,60

Groups Water & Meadows
Average dissimilarity = 88,44

Species	Group Water Av.Abund	Group Meadows Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chroicocephalus ridibundus	29,44	1,96	13,75	2,21	15,54	15,54
Larus michahellis	29,01	4,63	11,69	1,63	13,21	28,76
Sturnus vulgaris	0,34	18,90	9,59	1,37	10,84	39,59
Tadorna tadorna	17,69	0,45	8,84	1,48	9,99	49,59
Recurvirostra avosetta	13,76	0,01	6,35	0,76	7,18	56,77
Podiceps cristatus	11,58	0,02	6,04	1,21	6,83	63,60
Anas platyrhynchos	7,28	0,60	4,07	0,89	4,61	68,20
Corvus cornix	1,11	7,17	3,40	1,68	3,85	72,05
Ardea cinerea	5,16	1,64	2,08	1,20	2,35	74,40
Egretta garzetta	3,75	0,70	1,76	1,22	1,99	76,39
Columba livia	0,08	3,03	1,59	0,74	1,80	78,18
Phalacrocorax carbo	2,81	0,19	1,37	0,91	1,55	79,74
Pica pica	0,11	2,41	1,26	1,46	1,43	81,17
Cygnus olor	2,17	0,00	1,25	0,85	1,41	82,58
Alauda arvensis	0,06	2,21	1,18	1,08	1,33	83,91
Anatre nn id	1,98	0,00	1,00	0,39	1,13	85,05
Calidris alpina	2,46	0,00	1,00	0,28	1,13	86,18
Falco tinnunculus	0,17	1,50	0,79	0,81	0,90	87,07
Tringa nebularia	1,41	0,00	0,78	0,77	0,89	87,96
Podiceps nigricollis	1,51	0,00	0,72	0,50	0,82	88,78
Lepus europaeus	0,02	1,32	0,69	0,91	0,79	89,56
Passer italiae	0,00	1,11	0,55	0,55	0,63	90,19

Groups Other & Meadows
Average dissimilarity = 76,81

Species	Group Other Av.Abund	Group Meadows Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Sturnus vulgaris	7,91	18,90	21,41	1,44	27,87	27,87
Corvus cornix	1,40	7,17	8,15	1,71	10,61	38,48
Larus michahellis	2,24	4,63	6,44	1,01	8,38	46,87
Phalacrocorax carbo	4,38	0,19	6,00	1,52	7,81	54,68
Columba livia	0,04	3,03	3,81	0,80	4,96	59,64
Chroicocephalus ridibundus	1,05	1,96	3,03	0,69	3,95	63,59
Alauda arvensis	0,12	2,21	2,98	1,04	3,88	67,47
Falco tinnunculus	2,12	1,50	2,76	1,14	3,59	71,06
Ardea cinerea	0,25	1,64	2,33	1,02	3,03	74,09
Pica pica	1,83	2,41	2,20	1,16	2,87	76,96
Lepus europaeus	0,00	1,32	1,68	0,95	2,19	79,15
Passer italiae	0,30	1,11	1,47	0,66	1,91	81,06
Anthus pratensis	0,00	0,67	0,96	0,48	1,25	82,31
Egretta garzetta	0,06	0,70	0,96	0,63	1,25	83,56
Phasianus colchicus	0,00	0,62	0,89	0,67	1,16	84,71
Buteo buteo	0,56	0,21	0,88	0,79	1,15	85,86
passeriformi	0,03	0,65	0,83	0,42	1,07	86,94
Anas platyrhynchos	0,03	0,60	0,78	0,53	1,02	87,96
Hirundo rustica	0,02	0,80	0,72	0,27	0,94	88,89
Tadorna tadorna	0,11	0,45	0,70	0,40	0,91	89,80
Carduelis carduelis	0,00	0,56	0,62	0,33	0,81	90,61

Groups Buildings & Meadows
Average dissimilarity = 84,54

Species	Group Buildings Av.Abund	Group Meadows Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Sturnus vulgaris	2,75	18,90	21,39	1,56	25,30	25,30
Chroicocephalus ridibundus	8,16	1,96	11,17	1,06	13,21	38,51

Corvus cornix	0,18	7,17	10,43	2,16	12,33	50,84
Larus michahellis	0,30	4,63	6,16	1,02	7,28	58,13
Columba livia	1,43	3,03	4,30	0,95	5,09	63,21
Alauda arvensis	0,00	2,21	3,21	1,04	3,79	67,01
Pica pica	0,60	2,41	2,89	1,36	3,42	70,43
Ardea cinerea	0,02	1,64	2,50	1,02	2,95	73,38
Motacilla alba	1,65	0,16	2,45	1,44	2,90	76,28
Passer italiae	1,00	1,11	2,14	0,90	2,53	78,81
Falco tinnunculus	0,10	1,50	2,00	0,80	2,37	81,18
Lepus europaeus	0,00	1,32	1,78	0,96	2,10	83,28
Anthus pratensis	0,00	0,67	1,02	0,49	1,21	84,48
Egretta garzetta	0,02	0,70	0,99	0,62	1,17	85,66
passeriformi	0,11	0,65	0,94	0,44	1,12	86,77
Phasianus colchicus	0,00	0,62	0,94	0,67	1,11	87,89
Anas platyrhynchos	0,02	0,60	0,82	0,53	0,97	88,86
Hirundo rustica	0,05	0,80	0,78	0,29	0,93	89,78
Carduelis carduelis	0,04	0,56	0,70	0,35	0,83	90,61

Groups Water & Runway
Average dissimilarity = 96,11

Species	Group Water Av.Abund	Group Runway Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chroicocephalus ridibundus	29,44	0,65	18,64	2,56	19,39	19,39
Larus michahellis	29,01	1,07	17,25	2,23	17,94	37,34
Tadorna tadorna	17,69	0,01	11,76	1,52	12,23	49,57
Recurvirostra avosetta	13,76	0,00	8,03	0,76	8,35	57,92
Podiceps cristatus	11,58	0,19	7,93	1,20	8,25	66,18
Anas platyrhynchos	7,28	0,07	5,67	0,89	5,90	72,07
Ardea cinerea	5,16	0,15	3,49	1,42	3,63	75,70
Egretta garzetta	3,75	0,09	2,62	1,34	2,72	78,42
Phalacrocorax carbo	2,81	0,02	1,76	0,92	1,83	

						80,25
Cygnus olor	2,17	0,00	1,69	0,83	1,76	82,01
Anatre nn id	1,98	0,00	1,30	0,38	1,35	83,35
Calidris alpina	2,46	0,00	1,22	0,28	1,27	84,63
Columba livia	0,08	1,56	1,16	0,68	1,21	85,83
Sturnus vulgaris	0,34	1,46	1,16	0,49	1,20	87,04
Tringa nebularia	1,41	0,00	1,05	0,75	1,10	88,14
Corvus cornix	1,11	1,33	1,03	1,07	1,08	89,21
Podiceps nigricollis	1,51	0,00	0,93	0,51	0,96	90,18

Groups Other & Runway
Average dissimilarity = 82,10

Species	Group Other Av.Abund	Group Runway Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Phalacrocorax carbo	4,38	0,02	14,94	1,51	18,20	18,20
Sturnus vulgaris	7,91	1,46	14,76	0,85	17,97	36,17
Larus michahellis	2,24	1,07	7,06	0,71	8,60	44,77
Falco tinnunculus	2,12	0,73	6,16	1,11	7,51	52,28
Pica pica	1,83	0,59	5,49	1,21	6,69	58,97
Columba livia	0,04	1,56	5,02	0,69	6,11	65,08
Corvus cornix	1,40	1,33	4,66	1,07	5,68	70,76
Chroicocephalus ridibundus	1,05	0,65	4,16	0,72	5,07	75,83
Alauda arvensis	0,12	0,85	3,19	0,72	3,89	79,72
Buteo buteo	0,56	0,00	1,98	0,70	2,41	82,13
Passer italiae	0,30	0,33	1,67	0,44	2,03	84,16
Emberiza calandra	0,31	0,01	1,13	0,49	1,38	85,54
Ardea cinerea	0,25	0,15	1,07	0,42	1,31	86,85
Actitis hypoleucos	0,26	0,04	0,97	0,38	1,18	88,03
Hirundo rustica	0,02	0,34	0,87	0,24	1,06	89,09
Apus apus	0,09	0,19	0,74	0,21	0,90	89,99
Lepus europaeus	0,00	0,21	0,62	0,43	0,76	90,75

Groups Buildings & Runway
Average dissimilarity = 86,47

Species	Group Buildings Av.Abund	Group Runway Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chroicocephalus ridibundus	8,16	0,65	25,82	1,17	29,86	29,86
Sturnus vulgaris	2,75	1,46	11,36	1,09	13,14	43,00
Columba livia	1,43	1,56	7,86	0,91	9,09	52,09
Motacilla alba	1,65	0,12	6,80	1,33	7,87	59,96
Corvus cornix	0,18	1,33	5,40	0,96	6,25	66,21
Passer italiae	1,00	0,33	4,25	0,74	4,92	71,13
Larus michahellis	0,30	1,07	3,77	0,70	4,36	75,49
Alauda arvensis	0,00	0,85	3,50	0,69	4,05	79,54
Pica pica	0,60	0,59	3,18	0,89	3,68	83,22
Falco tinnunculus	0,10	0,73	3,08	0,72	3,56	86,78
Turdus merula	0,31	0,03	1,48	0,54	1,71	88,50
Delichon urbicum	0,37	0,04	1,27	0,30	1,47	89,96
Hirundo rustica	0,05	0,34	1,04	0,26	1,20	91,16

Groups Meadows & Runway
Average dissimilarity = 81,44

Species	Group Meadows Av.Abund	Group Runway Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Sturnus vulgaris	18,90	1,46	25,58	1,66	31,42	31,42
Corvus cornix	7,17	1,33	9,71	1,78	11,93	43,34
Larus michahellis	4,63	1,07	6,68	1,03	8,20	51,55
Columba livia	3,03	1,56	4,92	0,96	6,05	57,60
Alauda arvensis	2,21	0,85	3,31	1,07	4,07	61,66
Pica pica	2,41	0,59	3,31	1,34	4,07	65,73
Chroicocephalus ridibundus	1,96	0,65	3,14	0,65	3,85	69,58
Ardea cinerea	1,64	0,15	2,76	1,00	3,39	72,97
Falco tinnunculus	1,50	0,73	2,43	0,93	2,98	75,96
Lepus europaeus	1,32	0,21	1,96	1,00	2,41	78,36
Passer italiae	1,11	0,33	1,75	0,63	2,15	80,52
Hirundo rustica	0,80	0,34	1,21	0,35	1,48	82,00
Anthus pratensis	0,67	0,06	1,20	0,50	1,47	83,47
Egretta garzetta	0,70	0,09	1,16	0,62	1,42	84,89
Phasianus colchicus	0,62	0,01	1,06	0,67	1,31	86,20
passeriformi	0,65	0,06	0,99	0,44	1,21	87,41

Anas platyrhynchos	88,58	0,60	0,07	0,95	0,56	1,17
Carduelis carduelis	89,47	0,56	0,02	0,73	0,34	0,89
Tadorna tadorna	90,30	0,45	0,01	0,68	0,39	0,83

Treviso Antonio Canova airport - TSF

ANOSIM - Analysis of Similarities

One-Way Analysis

Resemblance worksheet
Name: Resem1
Data type: Similarity
Selection: All

Factor Values
Factor: airport habitat
Water
Other
Buildings
Meadows
Runway

Factor Groups

Sample	airport habitat
1	Water
2	Water
3	Water
4	Other
5	Other
6	Other
7	Other
8	Other
9	Other
10	Other
11	Other
12	Other
13	Other
14	Other
15	Other
16	Other
17	Other
18	Other
19	Other
20	Other
21	Other
22	Other
23	Other
24	Other
25	Other
26	Other
27	Other
28	Buildings
29	Buildings
30	Buildings
31	Buildings
32	Buildings
33	Buildings
34	Buildings
35	Buildings
36	Buildings
37	Buildings
38	Buildings
39	Buildings
40	Buildings
41	Buildings
42	Buildings
43	Buildings
44	Buildings
45	Buildings
46	Buildings
47	Buildings
48	Buildings
49	Buildings
50	Buildings
51	Buildings
52	Meadows
53	Meadows
54	Meadows
55	Meadows
56	Meadows
57	Meadows
58	Meadows
59	Meadows
60	Meadows
61	Meadows
62	Meadows
63	Meadows
64	Meadows
65	Meadows
66	Meadows
67	Meadows
68	Meadows
69	Meadows
70	Meadows
71	Meadows
72	Meadows
73	Meadows
74	Meadows
75	Meadows
76	Runway
77	Runway
78	Runway
79	Runway
80	Runway
81	Runway
82	Runway
83	Runway
84	Runway
85	Runway
86	Runway
87	Runway
88	Runway
89	Runway
90	Runway
91	Runway
92	Runway
93	Runway
94	Runway
95	Runway
96	Runway
97	Runway
98	Runway
99	Runway

Global Test
Sample statistic (Global R): 0,696
Significance level of sample statistic: 0,1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Water, Other	0,944	0,1	2925	999	0
Water, Buildings	0,985	0,2	2925	999	1
Water, Meadows	0,984	0,1	2925	999	0
Water, Runway	0,96	0,1	2925	999	0
Other, Buildings	0,671	0,1	Very large	999	0
Other, Meadows	0,58	0,1	Very large	999	0
Other, Runway	0,442	0,1	Very large	999	0
Buildings, Meadows	0,827	0,1	Very large	999	0
Buildings, Runway	0,872	0,1	Very large	999	0
Meadows, Runway	0,637	0,1	Very large	999	0

SIMPER - Similarity Percentages - species contributions

One-Way Analysis

Data worksheet
Name: Data2
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90,00%

Group Water
All the similarities are zero

Group Other
Average similarity: 31,96

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corvus cornix	1,46	6,88	1,19	21,52	21,52
Pica pica	1,67	6,17	1,03	19,29	40,82
Columba palumbus	3,40	5,52	0,80	17,26	58,08
Falco tinnunculus	0,97	2,85	0,94	8,91	66,99
Sturnus vulgaris	2,87	2,84	0,45	8,87	75,87
Phalacrocorax carbo	1,29	2,13	0,48	6,66	82,53
Streptopelia decaocto	0,85	1,97	0,61	6,17	88,70
Passer italiae	0,60	1,15	0,40	3,60	92,29

Group Buildings
Average similarity: 58,17

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Columba livia	9,26	39,58	3,66	68,03	68,03
Sturnus vulgaris	4,45	8,19	0,76	14,08	82,12
Streptopelia decaocto	1,42	4,98	1,29	8,55	90,67

Group Meadows
Average similarity: 49,25

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corvus cornix	7,90	16,04	2,07	32,57	32,57
Pica pica	5,35	11,77	2,81	23,89	56,46
Sturnus vulgaris	8,43	7,74	0,89	15,71	72,17
Columba livia	4,89	4,29	0,85	8,70	80,88
Hirundo rustica	3,71	1,66	0,35	3,36	84,24
Alauda arvensis	0,97	1,33	0,90	2,70	86,94
Columba palumbus	1,24	1,17	0,72	2,37	89,32
Falco tinnunculus	0,78	0,97	0,79	1,98	91,30

Group Runway
Average similarity: 42,02

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corvus cornix	3,63	25,98	2,07	61,83	61,83
Pica pica	1,33	6,07	0,94	14,44	76,27
Falco tinnunculus	0,98	3,31	0,67	7,87	84,14
Hirundo rustica	1,12	2,16	0,35	5,14	89,28
Columba livia	1,09	1,92	0,44	4,57	93,85

Groups Water & Other
Average dissimilarity = 98,33

Species	Group Water Av.Abund	Group Other Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Columba palumbus	0,00	3,40	12,71	0,93	12,93	12,93
Sturnus vulgaris	0,00	2,87	10,42	0,71	10,60	23,53
Pica pica	0,00	1,67	9,34	1,20	9,50	33,02
Corvus cornix	0,00	1,46	8,86	1,18	9,01	42,03
Columba livia	0,58	0,75	6,61	0,63	6,73	48,76
Phalacrocorax carbo	0,00	1,29	5,93	0,83	6,03	54,79
Calidris temminckii	0,82	0,00	5,83	0,51	5,93	60,71
Falco tinnunculus	0,00	0,97	4,72	1,12	4,80	65,51
Tringa glareola	0,75	0,00	4,43	0,56	4,51	70,02
Streptopelia decaocto	0,00	0,85	4,00	0,94	4,07	74,09
Hirundo rustica	0,00	0,64	3,27	0,37	3,33	77,42
Passer italiae	0,00	0,60	3,22	0,74	3,28	80,70
Motacilla alba	0,47	0,09	2,91	0,59	2,96	83,66
Turdus merula	0,00	0,35	1,94	0,56	1,97	85,63
Fringilla coelebs	0,00	0,44	1,76	0,37	1,79	87,42
Garrulus glandarius	0,00	0,15	1,47	0,34	1,49	88,91
passeriformi	0,00	0,39	1,44	0,45	1,46	90,37

Groups Water & Buildings
Average dissimilarity = 93,41

Species	Group Water Av.Abund	Group Buildings Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Columba livia	0,58	9,26	39,71	2,92	42,51	42,51
Sturnus vulgaris	0,00	4,45	17,17	1,08	18,38	60,89
Streptopelia decaocto	0,00	1,42	6,71	1,56	7,18	68,07
Passer italiae	0,00	1,01	4,47	1,14	4,79	72,86
Calidris temminckii	0,82	0,00	3,94	0,67	4,22	77,08

Tringa glareola	0,75	0,00	3,27	0,67	3,51	80,58
Motacilla alba	0,47	0,35	2,66	0,90	2,85	83,43
Corvus cornix	0,00	0,66	2,53	0,83	2,71	86,14
Pica pica	0,00	0,47	1,93	0,60	2,07	88,21
Hirundo rustica	0,00	0,43	1,72	0,36	1,84	90,05

Groups Other & Buildings
Average dissimilarity = 79,13

Species	Group Other Av.Abund	Group Buildings Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Columba livia	0,75	9,26	25,14	2,02	31,77	31,77
Sturnus vulgaris	2,87	4,45	12,79	1,10	16,16	47,93
Columba palumbus	3,40	0,18	7,55	0,82	9,54	57,47
Pica pica	1,67	0,47	4,22	1,34	5,34	62,80
Phalacrocorax carbo	1,29	0,00	3,21	0,83	4,06	66,86
Streptopelia decaocto	0,85	1,42	3,21	1,08	4,06	70,92
Corvus cornix	1,46	0,66	3,19	1,28	4,03	74,95
Passer italiae	0,60	1,01	2,74	1,12	3,47	78,41
Hirundo rustica	0,64	0,43	2,67	0,50	3,37	81,78
Falco tinnunculus	0,97	0,41	2,38	1,26	3,01	84,79
Turdus merula	0,35	0,24	1,38	0,74	1,75	86,54
Fringilla coelebs	0,44	0,00	1,04	0,37	1,32	87,86
passeriformi	0,39	0,06	1,02	0,52	1,29	89,15
Motacilla alba	0,09	0,35	1,02	0,64	1,28	90,43

Groups Water & Meadows
Average dissimilarity = 97,26

Species	Group Water Av.Abund	Group Meadows Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Corvus cornix	0,00	7,90	19,59	2,09	20,14	20,14
Sturnus vulgaris	0,00	8,43	15,73	1,22	16,18	36,32
Pica pica	0,00	5,35	13,27	2,36	13,65	49,96
Columba livia	0,58	4,89	8,45	1,34	8,68	58,65
Hirundo rustica	0,00	3,71	6,81	0,63	7,00	65,65
Bubulcus ibis	0,00	1,28	3,12	0,55	3,21	68,86
Columba palumbus	0,00	1,24	2,45	1,10	2,52	71,37
Alauda arvensis	0,00	0,97	2,33	1,04	2,39	73,76
passeriformi	0,00	0,76	2,16	0,55	2,22	75,99
Calidris temminckii	0,82	0,00	2,03	0,65	2,08	78,07
Passer italiae	0,00	1,05	1,92	0,74	1,97	80,04

Falco tinnunculus	0,00	0,78	1,87	1,12	1,92	81,96
Phasianus colchicus	0,24	0,89	1,79	1,18	1,84	83,80
Tringa glareola	0,75	0,00	1,76	0,65	1,81	85,61
Lepus europaeus	0,00	0,93	1,69	0,87	1,74	87,35
Motacilla alba	0,47	0,18	1,32	0,84	1,36	88,70
Larus michahellis	0,00	0,41	0,97	0,29	0,99	89,70
Anthus pratensis	0,00	0,27	0,93	0,37	0,95	90,65

Groups Other & Meadows
Average dissimilarity = 76,21

	Group Other	Group Meadows				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Sturnus vulgaris	2,87	8,43	12,32	1,22	16,17	16,17
Corvus cornix	1,46	7,90	11,97	1,80	15,70	31,87
Pica pica	1,67	5,35	6,92	1,63	9,08	40,96
Columba livia	0,75	4,89	6,83	1,23	8,96	49,92
Hirundo rustica	0,64	3,71	5,88	0,70	7,71	57,63
Columba palumbus	3,40	1,24	4,85	0,76	6,37	63,99
Bubulcus ibis	0,32	1,28	2,53	0,60	3,32	67,31
Phalacrocorax carbo	1,29	0,00	2,10	0,81	2,76	70,07
Passer italiae	0,60	1,05	1,83	0,94	2,41	72,48
passeriformi	0,39	0,76	1,83	0,66	2,40	74,88
Alauda arvensis	0,00	0,97	1,74	1,07	2,28	77,16
Phasianus colchicus	0,00	0,89	1,45	1,09	1,90	79,06
Streptopelia decaocto	0,85	0,11	1,42	0,98	1,87	80,93
Lepus europaeus	0,12	0,93	1,38	0,91	1,81	82,74
Falco tinnunculus	0,97	0,78	1,37	1,17	1,80	84,54
Larus michahellis	0,15	0,41	0,96	0,37	1,26	85,80
Buteo buteo	0,34	0,29	0,82	0,84	1,07	86,87
Turdus merula	0,35	0,17	0,78	0,66	1,03	87,90
Chroicocephalus ridibundus	0,14	0,30	0,77	0,57	1,01	88,91
Egretta garzetta	0,10	0,46	0,77	0,53	1,01	89,92
Fringilla coelebs	0,44	0,00	0,70	0,36	0,91	90,83

Groups Buildings & Meadows
Average dissimilarity = 74,07

	Group Buildings	Group Meadows				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Corvus cornix	0,66	7,90	12,55	2,11	16,94	16,94
Sturnus vulgaris	4,45	8,43	11,39	1,29	15,38	32,33
Columba livia	9,26	4,89	10,82	1,32	14,61	46,93
Pica pica	0,47	5,35	8,46	2,37	11,42	58,36
Hirundo rustica	0,43	3,71	5,43	0,69	7,33	65,68
Streptopelia decaocto	1,42	0,11	2,34	1,46	3,16	68,84
Bubulcus ibis	0,00	1,28	2,20	0,56	2,97	71,81
Passer italiae	1,01	1,05	1,98	1,12	2,67	74,48
Columba palumbus	0,18	1,24	1,79	1,15	2,41	76,89
Alauda arvensis	0,00	0,97	1,63	1,13	2,20	79,09

passeriformi	0,06	0,76	1,49	0,59	2,01	81,11
Phasianus colchicus	0,00	0,89	1,37	1,12	1,85	82,95
Falco tinnunculus	0,41	0,78	1,29	1,19	1,74	84,69
Lepus europaeus	0,00	0,93	1,28	0,86	1,73	86,42
Larus michahellis	0,13	0,41	0,87	0,36	1,18	87,60
Motacilla alba	0,35	0,18	0,73	0,77	0,98	88,58
Chroicocephalus ridibundus	0,14	0,30	0,71	0,59	0,96	89,54
Egretta garzetta	0,00	0,46	0,64	0,48	0,86	90,40

Groups Water & Runway
Average dissimilarity = 96,21

Species	Group Water Av.Abund	Group Runway Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Corvus cornix	0,00	3,63	28,41	2,37	29,53	29,53
Pica pica	0,00	1,33	9,39	1,33	9,76	39,29
Columba livia	0,58	1,09	8,82	0,96	9,17	48,45
Calidris temminckii	0,82	0,00	7,42	0,61	7,71	56,17
Hirundo rustica	0,00	1,12	7,27	0,68	7,56	63,73
Falco tinnunculus	0,00	0,98	6,15	1,07	6,39	70,11
Tringa glareola	0,75	0,00	5,61	0,63	5,84	75,95
Chroicocephalus ridibundus	0,00	0,74	4,40	0,51	4,57	80,52
Motacilla alba	0,47	0,23	4,26	0,74	4,43	84,95
Alauda arvensis	0,00	0,40	2,67	0,69	2,77	87,72
Sturnus vulgaris	0,00	0,42	2,06	0,35	2,14	89,86
Phasianus colchicus	0,24	0,03	1,90	0,65	1,97	91,83

Groups Other & Runway
Average dissimilarity = 74,90

Species	Group Other Av.Abund	Group Runway Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Columba palumbus	3,40	0,12	9,67	0,86	12,91	12,91
Corvus cornix	1,46	3,63	9,24	1,12	12,33	25,24
Sturnus vulgaris	2,87	0,42	8,56	0,72	11,43	36,67
Hirundo rustica	0,64	1,12	5,58	0,71	7,44	44,11

Pica pica	1,67	1,33	5,24	1,11	7,00	51,11
Columba livia	0,75	1,09	4,89	0,77	6,53	57,64
Phalacrocorax carbo	1,29	0,00	4,26	0,81	5,69	63,33
Falco tinnunculus	0,97	0,98	3,71	1,15	4,95	68,28
Streptopelia decaocto	0,85	0,11	2,96	0,96	3,96	72,23
Chroicocephalus ridibundus	0,14	0,74	2,81	0,51	3,75	75,98
Passer italiae	0,60	0,08	2,33	0,77	3,12	79,10
Alauda arvensis	0,00	0,40	1,46	0,66	1,95	81,05
Turdus merula	0,35	0,00	1,38	0,56	1,84	82,89
Fringilla coelebs	0,44	0,00	1,34	0,36	1,79	84,68
Bubulcus ibis	0,32	0,22	1,28	0,39	1,71	86,39
Larus michahellis	0,15	0,21	1,26	0,57	1,69	88,08
passeriformi	0,39	0,00	1,12	0,45	1,49	89,57
Buteo buteo	0,34	0,00	1,03	0,64	1,38	90,95

Groups Buildings & Runway
Average dissimilarity = 83,61

	Group Buildings	Group Runway				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Columba livia	9,26	1,09	28,54	2,11	34,14	34,14
Sturnus vulgaris	4,45	0,42	13,01	1,02	15,56	49,70
Corvus cornix	0,66	3,63	10,17	1,63	12,16	61,86
Streptopelia decaocto	1,42	0,11	4,71	1,44	5,64	67,49
Hirundo rustica	0,43	1,12	4,17	0,76	4,98	72,48
Pica pica	0,47	1,33	4,01	1,30	4,79	77,27
Passer italiae	1,01	0,08	3,29	1,12	3,94	81,21
Falco tinnunculus	0,41	0,98	3,00	1,14	3,59	84,80
Chroicocephalus ridibundus	0,14	0,74	2,43	0,53	2,91	87,70
Motacilla alba	0,35	0,23	1,49	0,71	1,78	89,48
Alauda arvensis	0,00	0,40	1,23	0,74	1,48	90,96

Groups Meadows & Runway
Average dissimilarity = 72,47

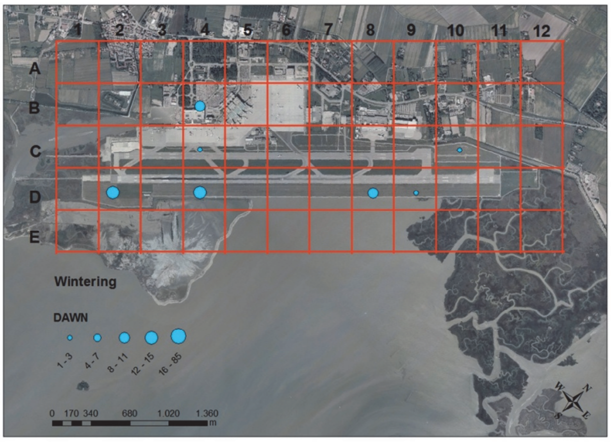
Species	Group Meadows Av.Abund	Group Runway Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Sturnus vulgaris	8,43	0,42	13,36	1,19	18,43	18,43
Corvus cornix	7,90	3,63	9,51	1,43	13,13	31,56
Pica pica	5,35	1,33	8,45	1,79	11,66	43,22
Columba livia	4,89	1,09	7,32	1,29	10,10	53,32
Hirundo rustica	3,71	1,12	6,74	0,79	9,30	62,61
Bubulcus ibis	1,28	0,22	2,81	0,58	3,88	66,49
Columba palumbus	1,24	0,12	2,08	1,13	2,87	69,36
Falco tinnunculus	0,78	0,98	1,80	1,28	2,49	71,85
passeriformi	0,76	0,00	1,76	0,55	2,43	74,28
Chroicocephalus ridibundus	0,30	0,74	1,73	0,60	2,39	76,67
Alauda arvensis	0,97	0,40	1,71	1,03	2,36	79,03
Passer italiae	1,05	0,08	1,70	0,76	2,34	81,37
Phasianus colchicus	0,89	0,03	1,59	1,12	2,19	83,56
Lepus europaeus	0,93	0,17	1,54	0,95	2,12	85,69
Larus michahellis	0,41	0,21	1,18	0,42	1,62	87,31
Ardea cinerea	0,32	0,06	0,76	0,51	1,05	88,36
Motacilla alba	0,18	0,23	0,75	0,61	1,03	89,39
Anthus pratensis	0,27	0,00	0,74	0,37	1,02	90,41

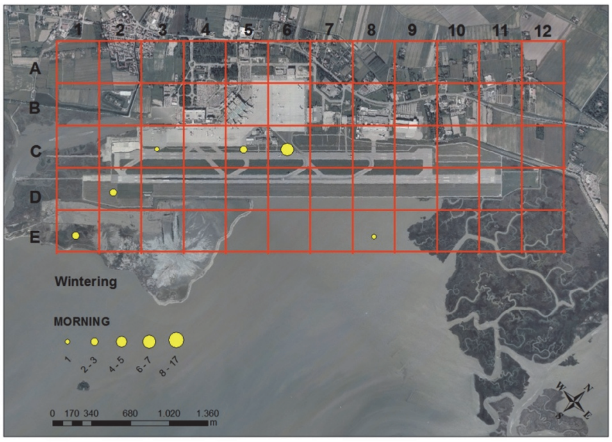
Annex IV – Air corridors of yellow-legged gulls and black-headed gulls through the airports during daytime and different biological periods

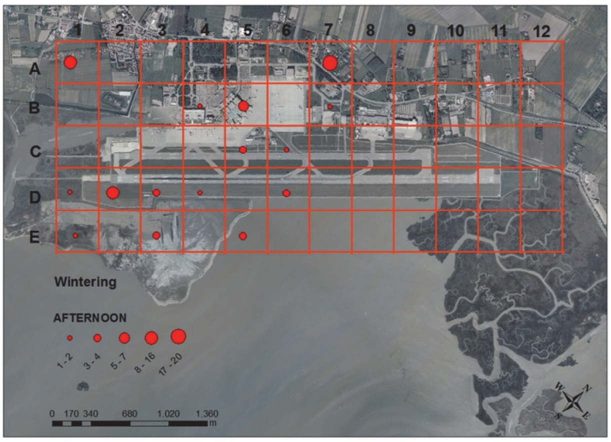
Venice Marco Polo airport

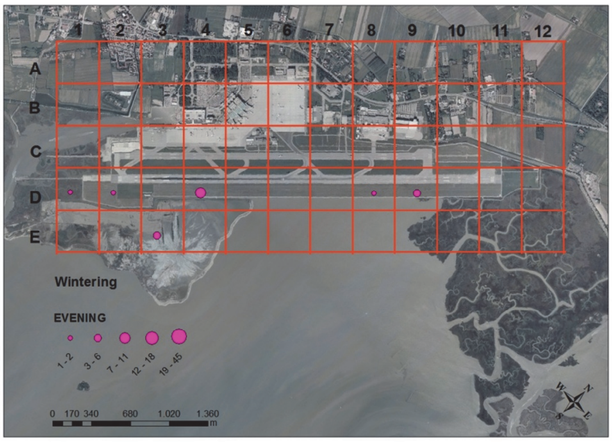
Larus michahellis – Yellow-legged gulls

1. Wintering

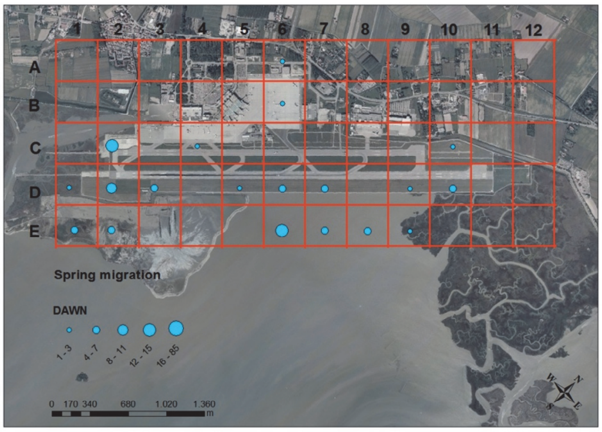


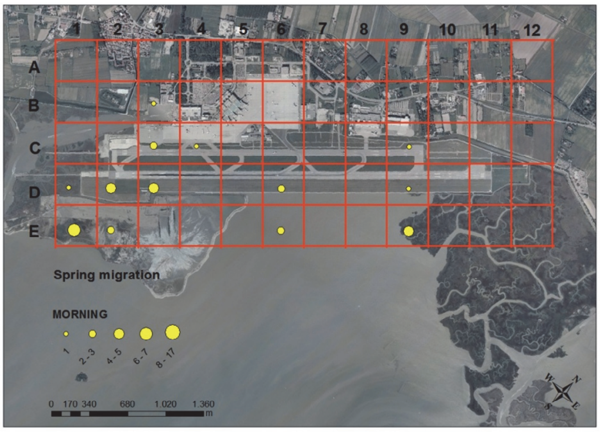


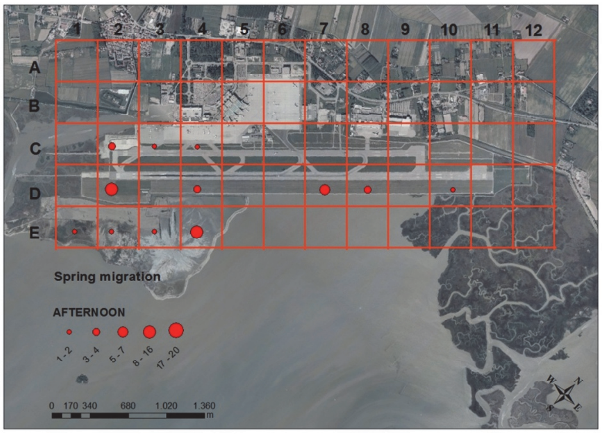


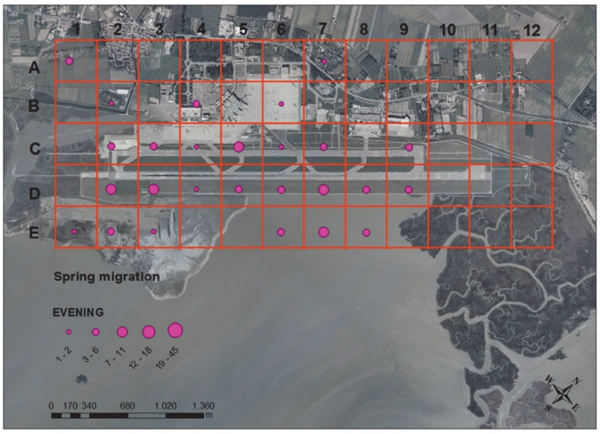


2. Spring migration

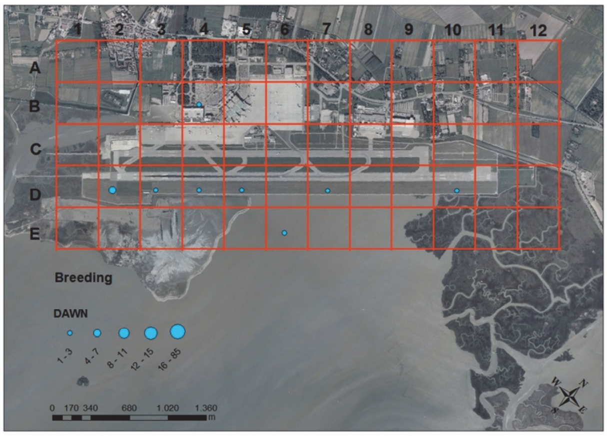


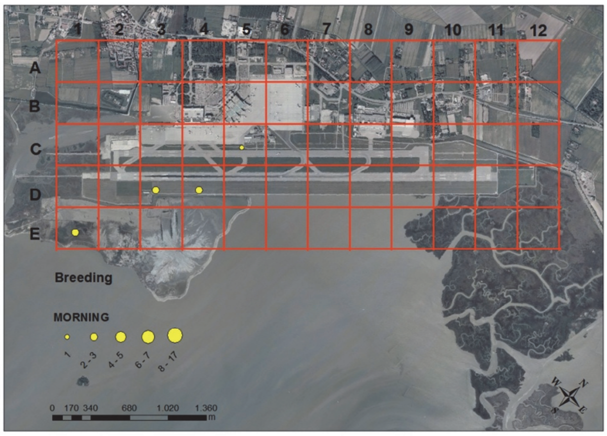


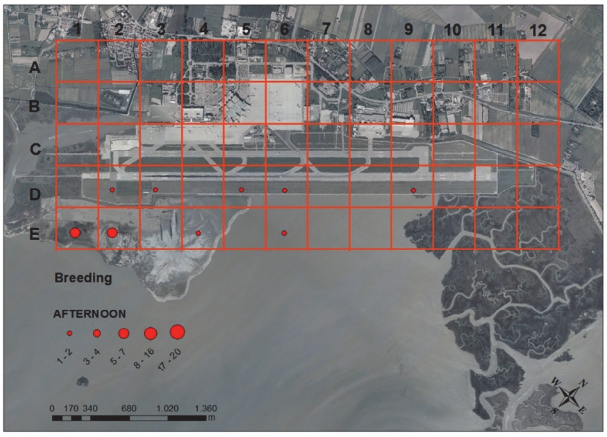


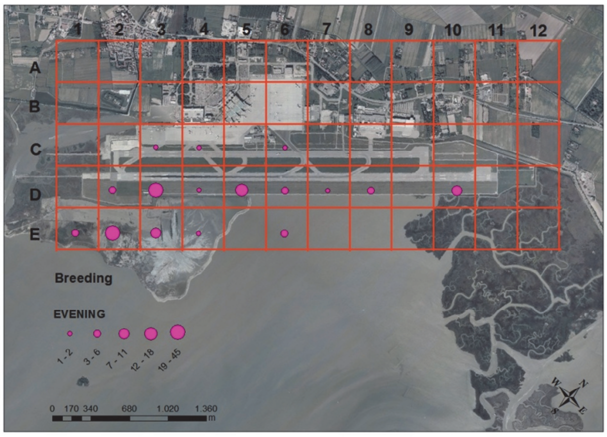


3. Breeding

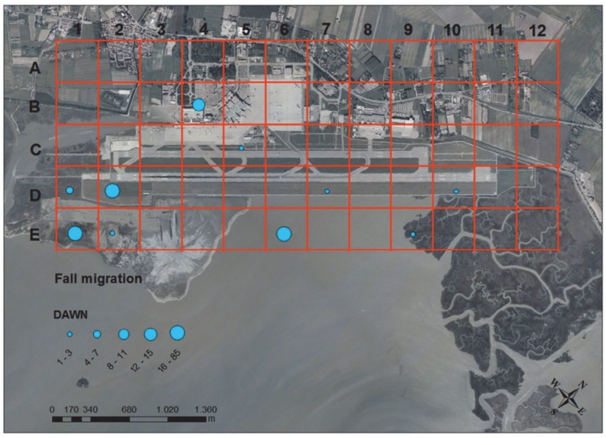

Breeding
DAWN
1 - 3
4 - 7
8 - 11
12 - 15
16 - 85
0 170 340 680 1.020 1.360 m

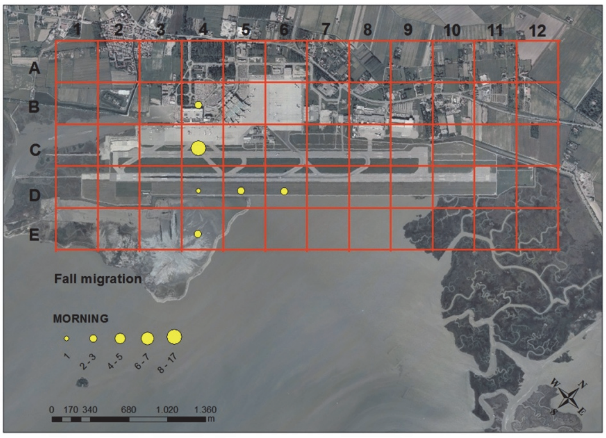

Breeding
MORNING
1
2 - 3
4 - 5
6 - 7
8 - 17
0 170 340 680 1.020 1.360 m

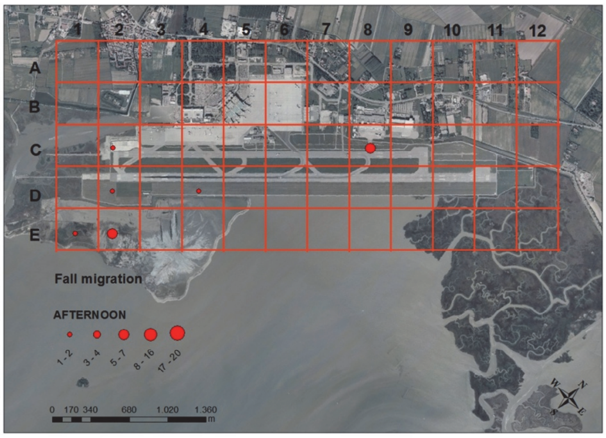

Breeding
AFTERNOON
1 - 2
3 - 4
5 - 7
8 - 16
17 - 20
0 170 340 680 1.020 1.360 m

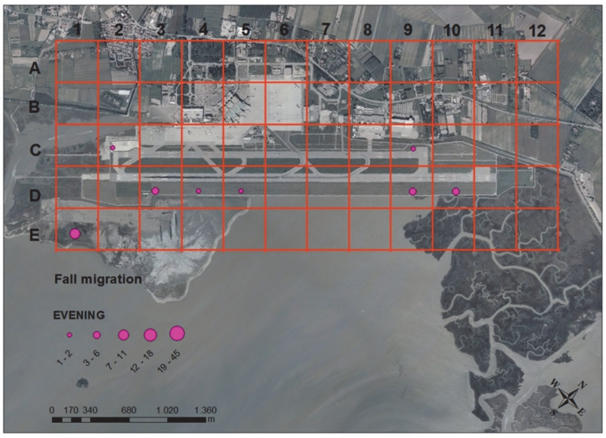

Breeding
EVENING
1 - 2
3 - 6
7 - 11
12 - 18
19 - 45
0 170 340 680 1.020 1.360 m

4. Fall migration



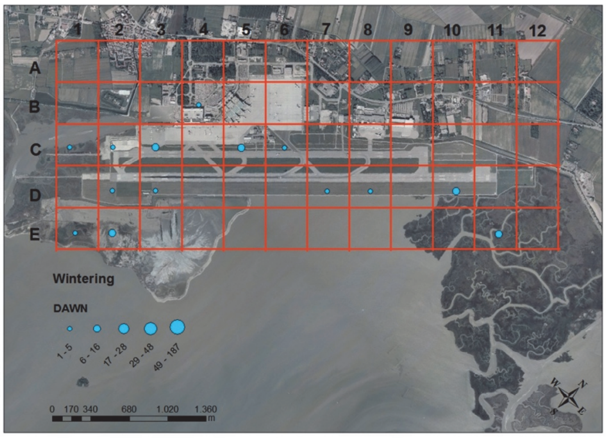


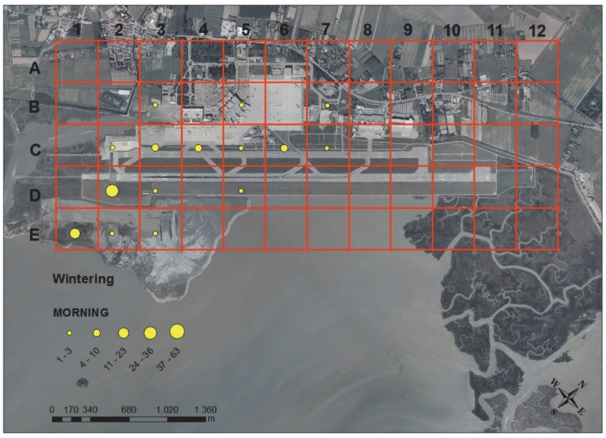


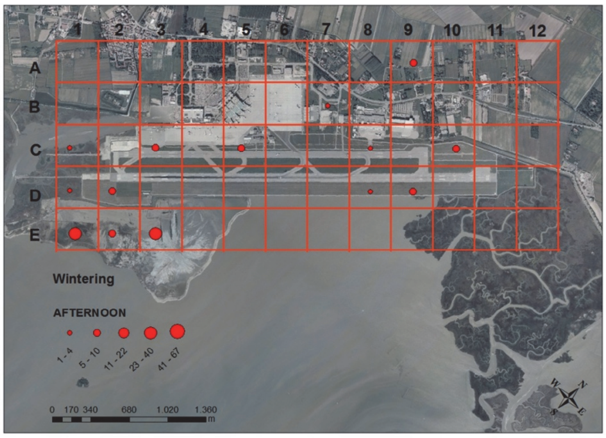


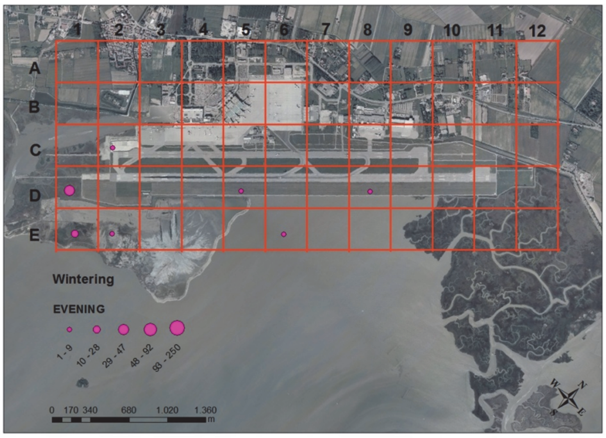
Croicocephalus ridibundus – **Black-headed gulls**

1. Wintering

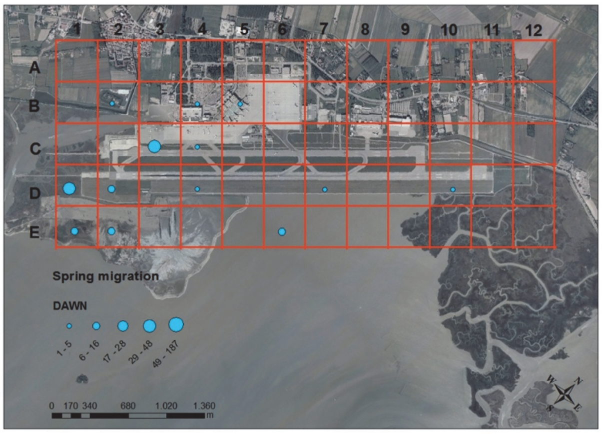


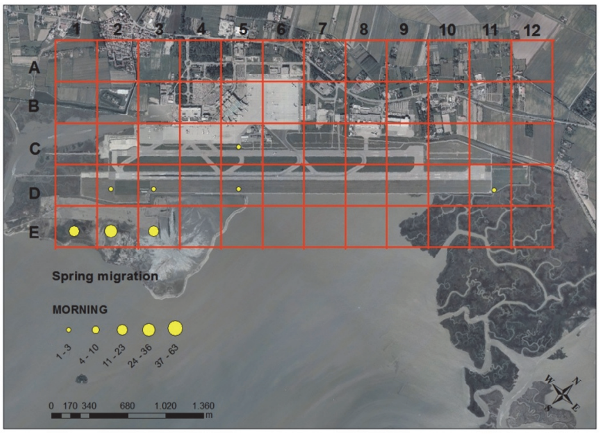


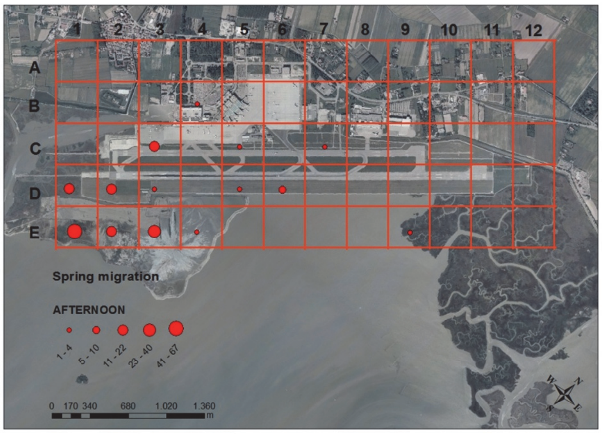


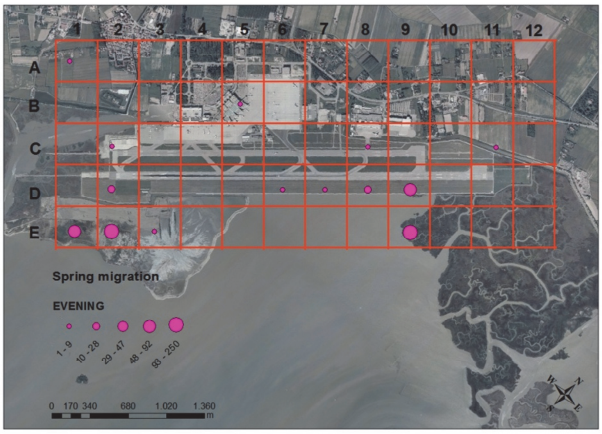


2. Spring migration

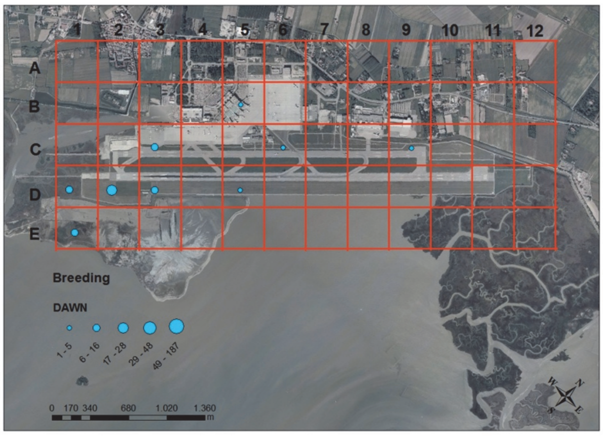


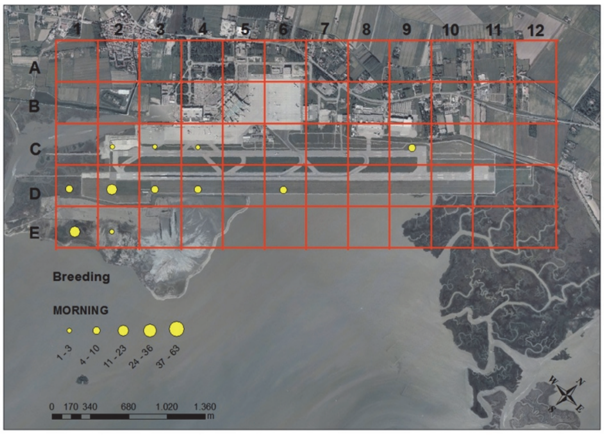


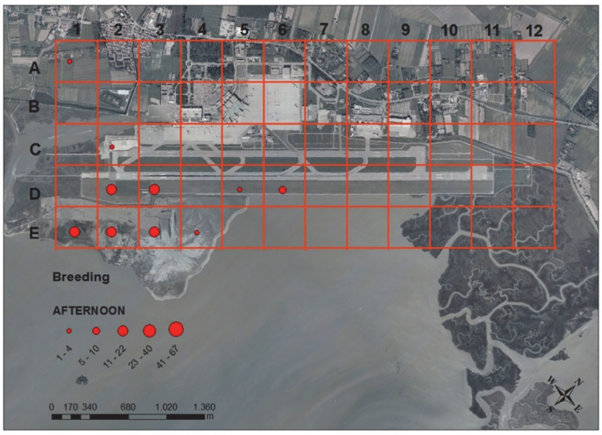


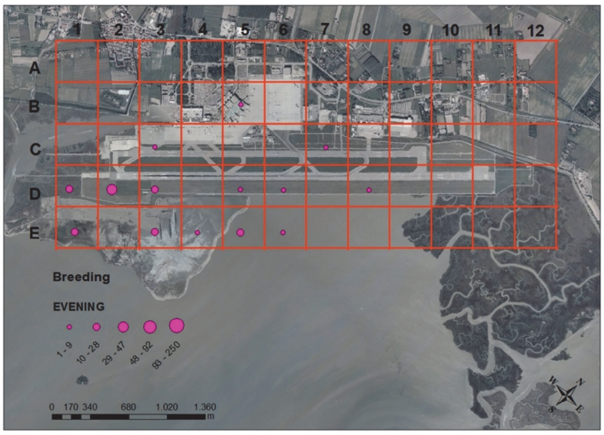


3. Breeding

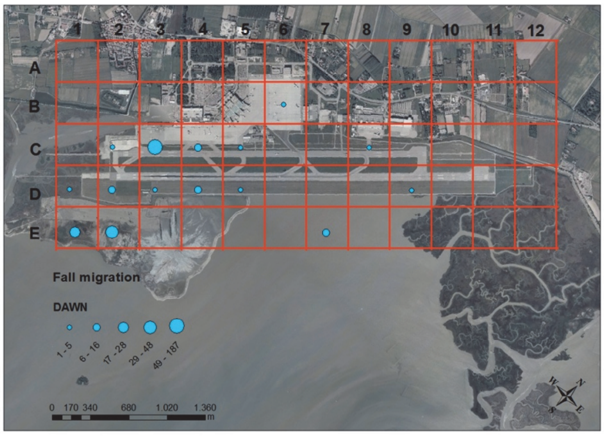

1 2 3 4 5 6 7 8 9 10 11 12
A B C D E
Breeding
DAWN
1 - 5
6 - 16
17 - 28
29 - 48
49 - 187
0 170 340 680 1.020 1.360
m

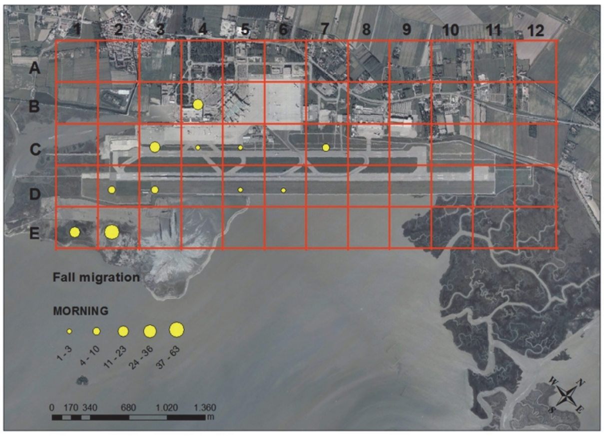

1 2 3 4 5 6 7 8 9 10 11 12
A B C D E
Breeding
MORNING
1 - 3
4 - 10
11 - 23
24 - 36
37 - 63
0 170 340 680 1.020 1.360
m

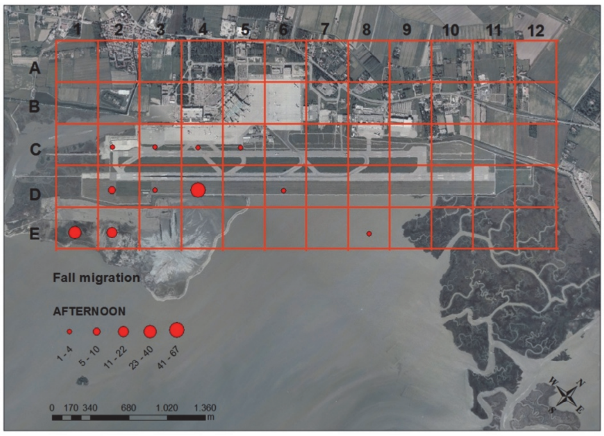

1 2 3 4 5 6 7 8 9 10 11 12
A B C D E
Breeding
AFTERNOON
1 - 4
5 - 10
11 - 22
23 - 40
41 - 67
0 170 340 680 1.020 1.360
m

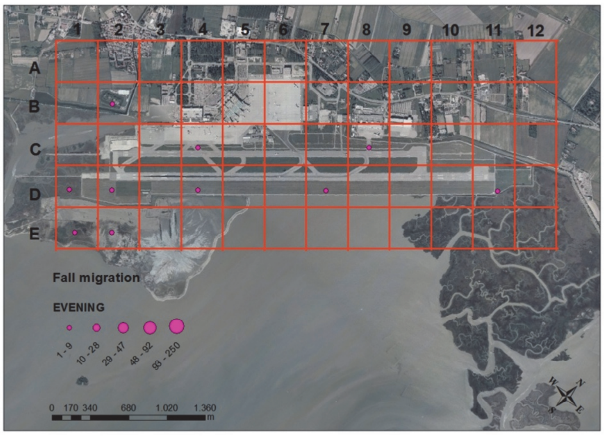

1 2 3 4 5 6 7 8 9 10 11 12
A B C D E
Breeding
EVENING
1 - 9
10 - 28
29 - 47
48 - 92
93 - 250
0 170 340 680 1.020 1.360
m

4. Fall migration





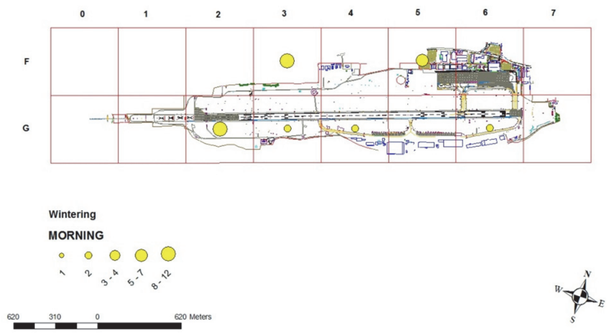


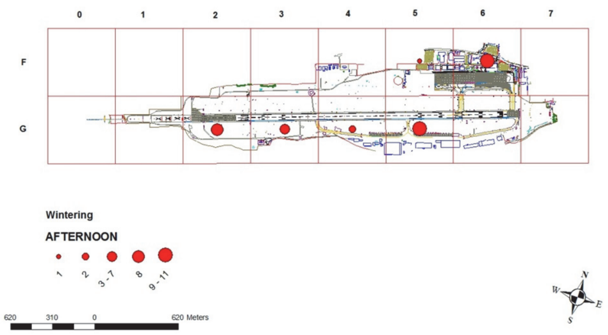


Treviso Antonio Canova airport

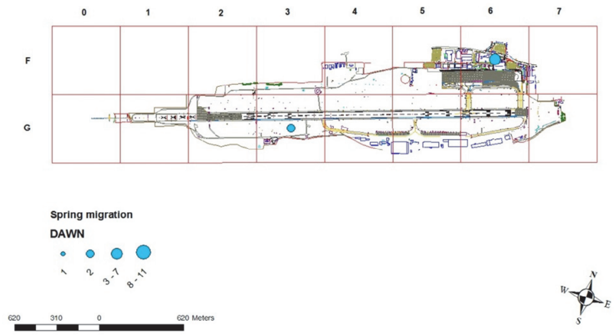
Larus michahellis – Yellow-legged gulls

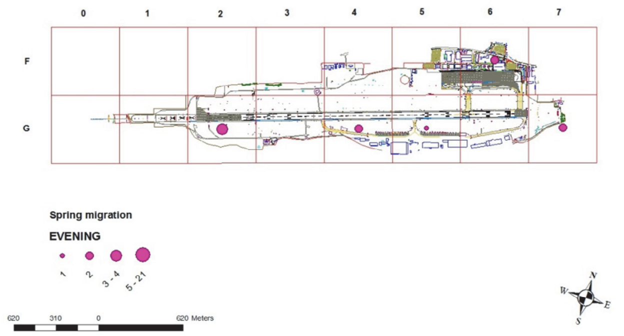
1. Wintering





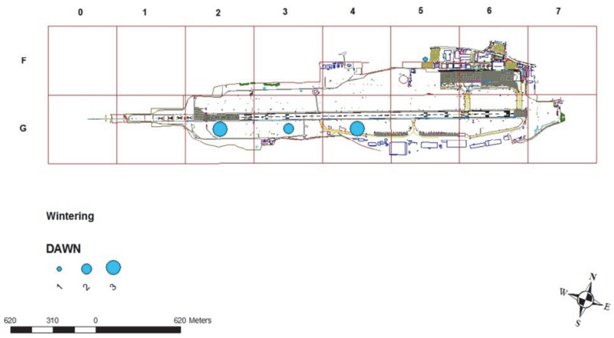
2. Spring migration

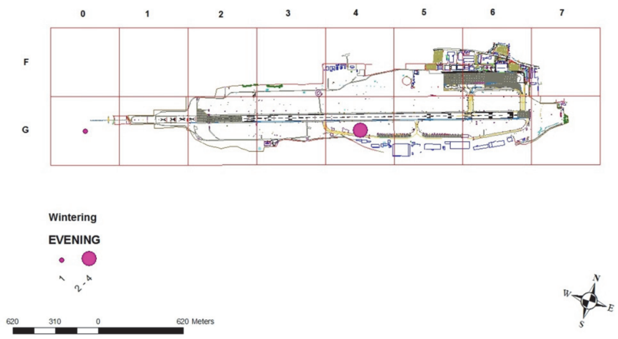




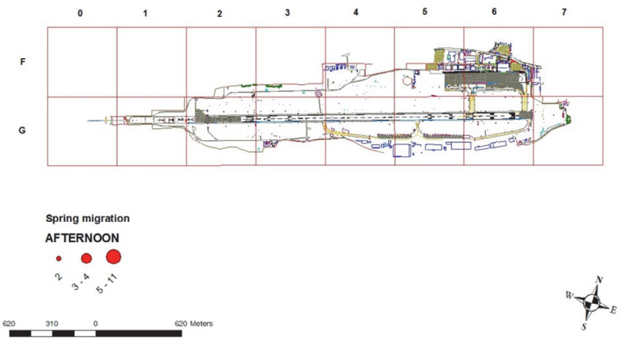
Croicocephalus ridibundus – Black-headed gulls

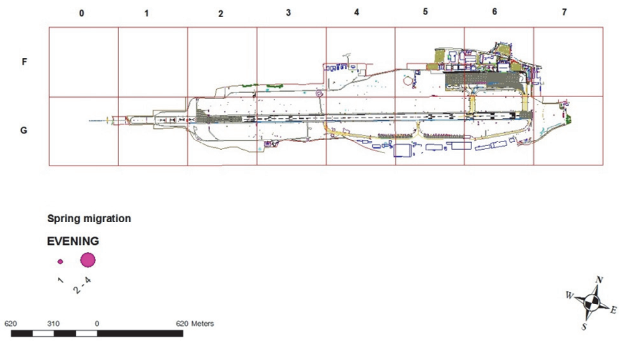
1. Wintering





2. Spring migration





Ringraziamenti

A conclusione di questo periodo di dottorato, che è stato talvolta travagliato ma anche ricco di soddisfazioni, mi sento di porgere i miei più sentiti ringraziamenti a coloro che, in questi tre lunghi anni, mi hanno seguito, spronato, stimolato e sostenuto.

Prima fra tutti, un sentito ed affettuoso ringraziamento va al mio Tutor, Prof.ssa Patrizia Torricelli, che, con la saggezza che la contraddistingue, mi ha supportato dandomi dei preziosi consigli, ma soprattutto le sono grata per aver sempre creduto in me e nelle mie capacità. Per questo la ringrazio dal profondo del mio cuore con la speranza di non aver disatteso le sue aspettative.

Un profondo ringraziamento va alla mia Co-tutor, Dott.ssa Cecilia Soldatini, che con costanza e dedizione mi ha seguito in questo percorso dottorale, introducendomi nell' interessante campo dell'analisi del rischio di birdstrike ed arrivando ad ottenere, insieme, soddisfacenti risultati.

Vorrei inoltre ringraziare calorosamente il Dott. Vyron Georgalas che, nonostante un inizio un po' diffidente, mi ha poi accolto nel gruppo con il calore che si riserva ad un amico.

Un caro ringraziamento va al Dott. Matteo Zucchetta per essere sempre stato disponibile nei miei riguardi nei momenti di bisogno e per aver cercato di trasmettermi la sua grande conoscenza, facendomi così avvicinare al mondo della modellistica. Vorrei inoltre ringraziare il Dott. Yuri Albores Barajas per aver collaborato allo sviluppo di questo progetto e Lucio Panzarin per il suo fondamentale aiuto nella raccolta dei dati sul campo.

Un sentito grazie va poi al Dott. Andrea Rosina, per i suoi preziosi insegnamenti e consigli relativi all'utilizzo del sistema informativo GIS. Colgo anche l'occasione per ringraziare il Dott. Wolfgang Goymann (Dept. Behavioural Neurobiology, MPI for Ornithology, Seewiesen) e il Dott. Wolfgang Fiedler (Dept. Behavioural Physiology, MPI for Ornithology, Radolfzell), per l'ospitalità con cui mi hanno accolta durante il mio periodo di permanenza in Germania.

Un ringraziamento speciale va ad Adriano Andreon, safety manager presso l'aeroporto Marco Polo di Venezia (Save S.p.A), che ha finanziato il progetto rendendo così possibile la realizzazione di questo studio.

Sono inoltre particolarmente grata ai miei commissari interni di dottorato, il Prof. Stefano Malavasi, il Prof. Claudio Agostinelli e il Prof. Stefano Soriani, per aver letto con attenzione la mia tesi e per i loro utili commenti e consigli.

Ci tengo a ringraziare alcuni cari amici tra cui Anna Salin e Carlotta Santi, per la disponibilità che mi hanno dimostrato nel correggere "il mio inglese" quando mi sorgevano dei dubbi, Fabio Da Forno che ha realizzato la copertina di questa tesi, Nicola Lotto per alcune delle fotografie presenti all'interno di questa tesi e Margherita Chiarot per essermi stata vicina in tutti questi anni.

Nella speranza di non aver dimenticato nessuno, ringrazio quindi le persone più importanti della mia vita, senza le quali non sarei mai riuscita a giungere al termine di questo lungo percorso di studio.
In primis ringrazio il mio ragazzo, Paolo Franceschetti, la cui energia, positività e genialità mi hanno sempre sostenuta e aiutata ad andare avanti. La tua presenza e il tuo sostegno sono stati per me fondamentale, non solo nella mia vita privata ma anche per la buona riuscita di questo lavoro.
Infine ringrazio i miei genitori, Attilio Coccon e Annamaria Romano, a cui dedico questa tesi, perché con il loro affetto, comprensione ed i valori che mi hanno trasmesso, sono diventata quella che sono. Spero di avervi reso orgogliosi ancora una volta.
Per ultimi, ma non ultimi nel mio cuore, ringrazio i miei adorati e fedeli cani, Argo e Stella, con cui ho condiviso gli ultimi undici anni della mia vita e la cui presenza è per me davvero indispensabile.

A tutti voi sono profondamente grata!

Acknowledgments

At the end of this period of doctorate, which has been sometimes troubled but also rich of satisfactions, I wish to thank all those people who have followed me, encouraged, motivated and psychologically supported in these three long years.

First of all, I would like to thank my Supervisor, Prof. Patrizia Torricelli, for her support and the wise advises she gave me, but above all for believing in me and my capabilities. I hope to have not dissatisfied her expectations.

I am deeply grateful to my Co-supervisor, Dr. Cecilia Soldatini, for her perseverance and dedication in following me during my PhD. Furthermore, I would like to thank Cecilia for having introduced me in the interesting field of the birdstrike risk assessment, obtaining together satisfying results.

I warmly thank Dr. Vyron Georgalas for his advices but, above all, for welcoming me within the research group as a friend.

A dear thank goes to Dr. Matteo Zucchetta for his helpfulness and the expert teachings with which he has introduced me to the modeling field. I wish also to thank Dr. Yuri Albores Barajas for his collaboration in developing this research project and Lucio Panzarin for his fundamental help in collecting data during the field sessions.

I sincerely thank Dr. Andrea Rosina, for his useful advices regarding the use of the Geographical Information System GIS.

I also thank Dr. Wolfgang Goymann (Dept. Behavioural Neurobiology, MPI for Ornithology, Seewiesen) and Dr. Wolfgang Fiedler (Dept. Behavioural Physiology, MPI for Ornithology, Radolfzell) for the hospitality they have given me during my permanence in Germany.

A special thank goes to Adriano Andreon, the safety manager of Venice Marco Polo International airport (Save S.p.A), for financing the project making the realization of this study possible.

I am also particularly grateful to my PhD internal commissioners, Prof. Stefano Malavasi, Prof. Claudio Agostinelli and Prof. Stefano Soriani, for having carefully read my thesis and for their helpful comments and advices.

I would like to thank some dear friends of mine, Anna Salin and Carlotta Santi for correcting my english when I had doubts, Fabio Da Forno for having realized the cover layout of this thesis, Nicola Lotto for some of the pictures reported in the theisis and Margherita Chiarot, for being always present in my life.

Hoping to have not forgotten anyone, I wish now to thank the most important people of my life, without which I would have never be able to reach the end of this long journey of study.

In primis I warmly thank my boyfriend, Paolo Franceschetti, whose energy, positivity and genius have always supported me and helped to keep on going. You have been fundamental, not only in my own private life but also for the success of this work.
Finally, I want to thank my parents, Attilio Coccon and Annamaria Romano, to whom I dedicate this thesis. It is for their love, understanding and moral values that I became what I am. I really hope to have made you proud.
Last, but not least in my heart, I thank my lovely and faithful dogs, Argo e Stella, for having shared with me the last eleven years of my life and whose presence and love are essential to me.

To you all, I am deeply and sincerely grateful!

Additional information

Participation to Congresses

VI European Conference on Behavioural Biology, ECBB 2012, Essen, Germany (19/07/2012 – 22/07/2012);

8th Conference of the European Ornithologists' Union, Riga, Latvia, (27/08/2011 – 30/08/2011);

II International Congress on the Problematic wildlife: Conservation and Mangement, University of Tuscia, Genazzano, Rome, Italy (03/02/2011 - 05/02/2011);

V European Conference on Behavioural Biology , ECBB 2010, Università di Ferrara, Italy (15/07/2010 – 18/07/2010);

ASAB Conference 2009, Association for the Study of Animal Behaviour, St. John College, Oxford, U.K. (02/09/2009 – 04/09/2009);

Contributions to Congresses

Coccon, F., Albores-Barajas Y.V., Torricelli, P., Soldatini, C., 2012, *Modelling the spatial movements of two hazardous species in relation to attractive sources to prevent Birdstrike risk*, VI European Conference on Behavioural Biology ECBB, Essen, Germany;

Coccon, F., Fusani, L., 2011, *Male manakins do not adapt their courtship display to spatial alteration of their court*, 8th Conference of the European Ornithologists' Union, Riga (Latvia);

Coccon, F., 2011, *Airport traffic increases, will Birdstrike increase too?*, II International Congress on the Problematic wildlife: Conservation and Management, University of Tuscia, Genazzano, Rome, Italy;

Soldatini, C., Georgalas, V., Albores-Barajas, Y.V., Montemaggiori, A., **Coccon, F.**, Torricelli, P., 2011, *Birds on runway: An ecological approach for a flight safety problem*, II International Congress on the Problematic wildlife: Conservation and Management, University of Tuscia, Genazzano, Rome, Italy;

Coccon, F., 2010, *Behavioural response of Manacus vitellinus to an alteration of the courtship arena*, V European Conference on Behavioural Biology ECBB, University of Ferrara, Italy;

Contributions to the Inauguration of the Doctoral School of Ca' Foscari University

Coccon, F., Soldatini, C., Albores-Barajas Y.V., Torricelli, P., 2012, *Spatial and temporal distribution of feral pigeons in an urban enironment: a preliminary analysis*, Inauguration of the Doctoral School of Ca' Foscari University of Venice, Italy;

Coccon, F., Fusani, L., Rojas, A., Goymann, W., 2012, *Effects of melatonin and food availability on nocturnal migration in free-living warblers*, Inauguration of the Doctoral School of Ca' Foscari University of Venice, Italy;

Coccon, F., 2011, *Analisi delle direttrici di movimento di due specie pericolose per il traffico aereo quale strumento gestionale per la sicurezza aeroportuale (Spatial movement analysis of two bird species hazardous for aviation as a tool to improve flight safety at airports)*, Inauguration of the Doctoral School of Ca' Foscari University of Venice, Italy;

Participation to Workshops

Ecotone GPS telemetry Workshop, Wierzba Conference Center, Wierzba Village, Masurian Lake District, Poland (5/04/2013-9/04/2013);

Ciso Day – Demography and distribution of birds in a changing world , University Ca' Foscari of Venice, Italy (14/12/2012-15/12/2012);

Fauna ornitica in città – esempi gestionali e prospettive future (Synanthropic bird species- examples of management and future prospects), Maremma Natural Science Museum, Tuscany, Italy (19/02/2011);

Urban Biodiversity, Circolo Agorà, Pisa, Italy (20/04/2012);

How to measure and conserve the biodiversity, Palazzo Franchetti, Venice, Italy (20/05/2011-22/05/2011);

Participation to technical courses

Biodiversity in the lagoon of Venice: modelling the species distribution, Ca' Foscari University of Venice (held by Dr. M. Zucchetta from 26/06/2012 to 29/06/2012;

GIS analysis: geoprocessing and raster analysis, Legnaro University of Padova (held by Dr. R. Rossi from 15/02/2012 to 17/02/2012);

Application of statistical and geostatistical techniques for the analysis of environmental data, Ca' Foscari University of Venice (held by Prof. C. Gaetan and C. Varin from 23/01/2012 to 27/01/2012);

Ecosystem Based Management: confronting trade offs, Ca' Foscari University of Venice (held by Prof. J. Link & F. Pranovi from 16/01/2012 to 20/01/2012);

Protection fundamentals of the industrial property and documentary research, Ca' Foscari University of Venice (held by Dr. E. Toniolo from 08/02/2011 to 10/02/2011);

GIS as a tool for the analysis of environmental data, Ca' Foscari University of Venice (held by Prof. G. Ciotoli from 24/01/2011 to 28/01/2011);

Scientific publications

Coccon, F., Bossi, G., Borrotti, M., Soldatini, C., under review, Attraction Risk Index: a new bio-geographic approach for birdstrike risk assessment at airports, Risk analysis;

Coccon, F., Albores-Barajas, Y.V., Zucchetta, M., Andreon, A., Torricelli, P., Soldatini, C., under review, Modelling the spatial movements of two hazardous bird species in relation to attractive sources for birdstrike risk prevention, Risk analysis;

Fusani, L., **Coccon, F.**, Rojas Mora, A., Goymann W., under review, Melatonin reduces migratory restlessness in Sylvia warblers during autumnal migration, Frontiers in Zoology;

Bon, M., Stival, E., Semenzato, M., Soldatini, C., **Coccon, F.**, Trabucco, R., 2013, Uccelli di laguna e di città. L'atlante ornitologico nel comune di Venezia 2006-2011 (Birds of the lagoon and the city. Birds atlas in the municipality of Venice 2006-2011), Marsilio Ed., Venezia;

Coccon, F., Schlinger, B., Fusani, L., 2012, Male Golden-collared Manakins *Manacus vitellinus* do not adapt their courtship display to spatial alteration of their court, IBIS (The International Journal of Avian Science) 154(1):173-176;

Scientific reports

Coccon, F., Baldaccini, E., Torricelli, P., Campostrini, P., Studio B.6.72 B/9, Attività di rilevamento per il monitoraggio degli effetti prodotti dalla costruzione delle opere alle bocche lagunari: I Rapporto di Valutazione, periodo Maggio – Agosto 2013;

Coccon, F., Soldatini C., Torricelli, P., 2013, Monitoraggio faunistico e Analisi del rischio di wildlife strike presso l'aeroporto Antonio Canova di Treviso, annual report 2012 (Wildlife monitoring and wildlife strike risk analyses at the Treviso Antonio Canova airport, annual report 2012) Department of Environmental Science, Informatics and Statistics, Ca' Foscari University of Venice;

Coccon, F., Soldatini C., Torricelli, P., 2013, Monitoraggio faunistico e Analisi del rischio di wildlife strike presso l'aeroporto Marco Polo di Venezia, annual report 2012 (Wildlife monitoring and wildlife strike risk analyses at the Venice Marco Polo airport, annual report 2012), Department of Environmental Science, Informatics and Statistics, Ca' Foscari University of Venice;

Coccon, F., Soldatini C., Torricelli, P., 2012, Analisi delle fonti attrattive per l'avifauna presso l'aeroporto Antonio Canova di Treviso (Analysis of the attractive sources for birds at the Antonio Canova International airport), Department of Environmental Science, Informatics and Statistics, Ca' Foscari University of Venice;

Coccon, F., Soldatini C., Torricelli, P., 2012, Analisi delle fonti attrattive per l'avifauna presso l'aeroporto Marco Polo di Venezia (Analysis of the attractive sources for birds at the Marco Polo International airport), Department of Environmental Science, Informatics and Statistics, Ca' Foscari University of Venice;

Extra scientific activities

Tutorial activities for supplementary teaching in the academic course titled: '*Laboratory of Biodiversity*' held by Dr. Brigolin (11/03/2013 – 15/06/2013);

Stage activity at the Max-Plank Institute fűr Ornithology in Radolfzell & Seewiesen, Germany, to work on the research project titled '*Physiology of long-distance migrants*' followed by Dr. W. Goymann, MPI Ornithology, Seewisen, in collaboration with Prof. L. Fusani, University of Ferrara (16/08/2012 – 30/09/2012);

Presentation of a two hours seminar titled "Behavioural responses of *Manacus vitellinus* to an alteration of their courtship arena" within the course of Ecology and Animal Biology held by Prof. Stefano Malavasi, Ca' Foscari University of Venice (23/04/2012);

Tutorial activities for supplementary teaching in the academic course titled: '*Laboratory of Biodiversity*' held by Prof. Torricelli (27/02/2012 – 29/03/2012);

Participation in a course of capturing and ringing of migratory birds at the ringing station in the island of Ponza (IT) within the project: '*Flexibility and constraints in animal movement patterns: ecology, evolution and annual cycles'* followed by Dr. M. Cardinale in collaboration with the Max Plank Insitute fűr Ornithology (Germany) and the University of Ferrara (23/04/2011 – 30/04/2011);

Participation in the annual census campaign of wintering waterbirds (IWC) in the province of Venice, Italy (09/01/2012 - 11/01/2012);