MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

„Effects of Predation Risk, Human Disturbance and Reproductive Status on Vigilance behavior of Austrian Eurasian Curlews (*Numenius arquata*)"

verfasst von / submitted by

Janette Siebert, BSc

angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien, 2019 / Vienna 2019

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	A 066 831
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Masterstudium Zoologie
Betreut von / Supervisor:	Dipl.-Biol. Dr. Christian H. Schulze

Sweet sun-warmed summer came along
From green leafed days of spring
I soon forgot the lonesome song
I heard the curlew sing

Extract from Tommy Makem "The Curlew´s Song" 2006

Acknowledgements

I really want to thank my supervisor Christian Schulze for his time, equipment and constructive ideas during field work and writing progress. Also, thanks to Barbara Waringer for sharing field work, food as well as ideas and supporting me with the analysis. Special thanks to Nina Gallmetzer for all her time and help with GIS. Thanks to Christiane Medicus, Elisabeth Ortner (both Haus der Natur), Hans Uhl (Büro für Integration von Mensch und Tier) and Hans-Martin Berg (NHM Vienna) for providing species and habitat knowledge as well as literature. Thanks to Julia Paterno and Felix Meyer for all their time and commitment during field work and furthermore to Niko Helmer for providing car and time. Special thanks to Julia Wyhlidal, Dominik Rabl and Karin Schlechta for sharing their equipment with me and making the field work possible. I also want to thank my friends Sandra Kollmann-Povolny and Anna Pal for all your support, critics, motivation and good drinks. Very special thanks to my life mate Mario Gastegger for all his patience and good ideas when statistics didn´t work the way they were supposed to. Last but not least thanks to my mum Marina Siebert and my sister Sarah Siebert for always supporting me and my passion for birds and nature.

Thanks a lot!

Abstract

Eurasian Curlews (*Numenius arquata*) breed in various landscapes in Austria. In 2017, their vigilance behavior was studied in breeding territories in Salzburg, Upper Austria, Lower Austria and Burgenland. Considering habitat preferences of breeding Curlews, following questions were addressed: (I) Which habitat parameters affect vigilance behavior (scan rate), with a special focus on the impact of the distance to woody structures and the vegetation height on the scan rate? (II) Do potential predators influence vigilance behavior? (III) Is there a relationship between breeding success and vigilance? (IV) Are there any regional differences in territory size? A model selection approach was used to determine the most important predictors for the number of scans per minute. The average territory size in Eastern Austria of 12.52 ha was ~24% higher compared to Western Austria, indicating that the openness of landscapes in Eastern Austria is facilitating larger territories. Vegetation height, distance to woody structures and territory size emerged as most important predictors for variation in scan rates. Increasing vegetation heights and consequent visual obstructions lead to an increasing scan rate. Distances between 100-150 m to woody structures emerged as important predictors for the scan rate with lower scan rates closer to woody structures. Vigilance behavior of Eurasian Curlews seems to be more dependent on territory size, geographical differences and vegetational structures than on potential predators. The occurrence of potential avian predators did not prove affecting recorded scan rates. Nevertheless, effects of potential, mostly nocturnal mammalian predators could not be quantified and need to be further investigated.

Keywords: Eurasian Curlew, geographic distribution, vigilance, territory size, vegetation height, woody structures, predators

Zusammenfassung

Große Brachvögel (*Numenius arquata*) brüten in unterschiedlichen Landschaften in Österreich. 2017 wurde ihr Sicherungsverhalten in Brutrevieren in Salzburg, Ober- und Niederösterreich und Burgenland untersucht. Unter Beachtung der Habitatpräferenzen des Großen Brachvogels wurde folgende Fragestellungen untersucht: (I) Welche Habitatparameter beeinflussen das Sicherungsverhalten (Scanrate), mit besonderen Fokus auf den Einfluss von der Entfernung zu Gehölzstrukturen und Vegetationshöhe auf die Scanrate? (II) Beeinflussen potentielle Prädatoren das Sicherungsverhalten? (III) Gibt es einen Zusammenhang zwischen Bruterfolg und Sicherungsverhalten? (IV) Gibt es regionale Unterschiede in der Territoriumsgröße? Mittels Modelselektion wurden die einflussreichsten Faktoren auf die Sicherungsrate untersucht. Die mittlere Reviergröße lag in Ostösterreich mit 12,52 ha um ~24% höher als in Westösterreich. Dies lässt vermuten, dass die Offenheit der Landschaften in Ostösterreich Möglichkeiten zur Etablierung größerer Reviere bietet. Vegetationshöhe, Entfernung zu Gehölzstrukturen und Territoriumsgröße wurden als die wichtigsten Prädiktoren für die Scanrate ermittelt. Größere Vegetationshöhen und sich daraus ergebende visuelle Beeinträchtigungen führten zu einer gesteigerten Scanrate. Entfernungen zu Gehölzstrukturen zwischen 100-150 m wurden als wichtiger Prädiktor für die Scanrate ermittelt. Diese sank mit geringerer Entfernung zu Gehölzstrukturen. Das Sicherungsverhalten des Großen Brachvogels scheint vor allem von Territoriumsgröße, geographischen Eigenschaften und Vegetationsstrukturen abhängig zu sein anstatt von potentiellen Prädatoren. Die Verbreitung potenzieller aviärer Prädatoren scheint die Scanrate nicht wie angenommen zu beeinflussen. Ein Einfluss von Säugerprädatoren konnte nicht festgestellt werden, sollte aber weiterhin untersucht werden.

Schlüsselwörter: Großer Brachvogel, geografische Verbreitung, Sicherungsverhalten, Reviergröße, Vegetationshöhe, Gehölzstrukturen, Prädatoren

Table of content

1 Introduction

"Any factor that interferes with the acquisition of information to detect predators should lead to an increase in vigilance to compensate for the poorer information." (Beauchamp 2014).

Vigilance behavior is performed by animals, such as birds, scanning their environment for potential predators and disturbances (Fitzpatrick and Bouchez 1998; Probst et al. 2014; Treves 2000). Additionally to a 'simple' scanning of the vicinity, a more complex behavior containing alarm calls, aggressive or distraction behavior can be shown, particularly when potential predators are detected (e.g. Fletcher et al. 2010). Vigilance behavior is influenced by many factors, such as vegetation cover, distance to visual obstructions, presence of predators and human disturbance (Beauchamp 2009; Boschert 1990; Fitzpatrick and Bouchez 1998; Lima 1986). Moreover, conspecifics can influence vigilance behavior (Sexton 2017). Decreasing rates of vigilance behavior were also observed in relation to flock size (Abramson 1979; Lima 1986; Schütz and Schulze 2011) as well as with the reduced ability to recognize approaching predators (Metcalfe 1984). Nevertheless, aggregation of animals does not always have the same effects on vigilance behavior (Treves 2000). House Sparrows *Passer domesticus*, that normally fed in cover, decreased their level of vigilance nearby visual obstructions (Lima 1986). Recent studies on visual obstructions in Chaffinches *Fringilla coelebs* found neither variations in "head-up rate" as indicator for higher vigilance behavior nor in food-search periods (Whittingham et al. 2004).

Vigilance studies in waders are quite common. Studies on Oystercatchers *Haematopus ostralegus* revealed significant impacts of vigilance behavior on foraging resulting in reduced feeding time with increasing vigilance (Coleman et al. 2003). Fitzpatrick and Bouchez (1998) showed unaltered feeding rates in waders with increasing level of vigilance. However, studies on waders did not reveal any relationships between antipredator vigilance and increasing sward height (Macdonald and Bolton 2008). Moreover, an increasing vigilance in obstructed areas was interpreted as the result of a higher predation risk due to obstruction (Beauchamp 2015).

The Eurasian Curlew (*Numenius arquata*, Linné 1758; family Scolopacidae) is widely distributed with a breeding range from the British Isles across Central Europe to Russia, reaching Lake Baikal (BirdLife International 2016). The Pyrenees, the Alps and the northern part of the Caspian Sea represent the southern borders of the species' breeding distribution. Breeding areas in Austria can be found in five federal states: Salzburg, Vorarlberg, Upper Austria, Lower Austria and Burgenland (Glutz von Blotzheim et al. 1986). The Eurasian Curlew (hereafter Curlew) winters around the coasts of Northwestern Europe, through the Mediterranean into Africa as well as the Middle East, and from Southeast Asia into the Sunda Islands (BirdLife International 2016). Breeding Curlews of South Germany are known to winter at the Atlantic coastal shore of France as well as the Iberian Peninsula (Boschert and Fiedler 2009). The peak of its return to Austria is mostly in March (Firbas 1962; Laber 2003). Territories will be occupied by males few days after their arrival (von Frisch 1964; Glutz von Blotzheim et al. 1986). The territory size can vary between 7 and 200 ha (Berg et al. 1992; Busch and Jeromin 2013; Glutz von Blotzheim et al. 1986; Seelig and Seelig 2001; Valkama et al. 1999; Wenger et al. 1991). Moreover, the territory size can vary from the first days of establishment until territories have been finally occupied and eventually intraspecific competition acts as a limiting factor (Glutz von Blotzheim et al. 1986). The current conservation status for the Eurasian Curlew in Austria is classified as EN [Endangered] (Dvorak et al. 2017).

Differences in vigilance behavior also depend on the breeding status of birds (Grant et al. 1999). Curlews are being particularly vigilant once their chicks are hatched (Grant et al. 2000). As documented for Curlews and Northern Lapwings *Vanellus vanellus,* during the period of chick rearing potential predators are also more intensively attacked (Fletcher et al. 2010; Glutz von Blotzheim et al. 1986). Human disturbance is an important factor for behavioral reactions of birds often resulting in decreased food uptake and increased vigilance (Fitzpatrick and Bouchez 1998; Gill et al. 1999; Sexton 2017). However, increased vigilance does not always involve changes in the foraging rate. Waders possibly adjust their vigilance to varying levels of disturbance (Fitzpatrick and Bouchez 1998). Wintering Curlews are known being able to assess their level of vigilance in roosting and feeding flocks, e.g. by assessing their own vigilance to other members of the flock (Evans 1988). Only few studies dealt with habitat characteristics and predation pressure (Macdonald and Bolton 2008). Furthermore, most studies investigated vigilance behavior in Curlews within a limited geographical range (e.g. Evans 1988; Sexton 2017) but not on a broad scale with different geographical habitat characteristics.

The aim of this study was to investigate the relationships between vigilance behavior and predation risk, human disturbance and reproduction success of Curlews across different landscapes in Austria. Hence, vigilance behavior of Curlews was observed in different breeding areas in Austria ranging from mosaics of bogs and hay meadows situated at the northern margin of the Alps (in the federal states of Salzburg and Upper Austria) and meadows on airfields (Upper Austria), all characterized by a continental climate, to hay meadows in eastern Austria, which are facing a drier Pannonian climate (Engl et al. 2004).

In particular, we addressed the following questions:

(I) Which habitat parameters affect vigilance behavior (scan rate) of Curlews, with a special focus on the effects of the distance to woody structures and vegetation height?
We assume that Curlews will increase their amount of vigilance with decreasing distance to woody structures, e.g. due a higher risk of predation by ambush predators (Sachteleben 1993). Although a denser, more heterogenous vegetation can improve nest crypsis and therefore may decrease nest predation risk, it may also result in increased vigilance as predators can more easily sneak up unnoticed (Teunissen et al. 2008).

(II) Do potential predators influence vigilance behavior?
In general, we assume that the presence of potential predators will increase vigilance. However, this relationship may become stronger with progressing season and hence higher investment in offspring.

(III) Is there a relationship between breeding success and vigilance?
As a higher extent of vigilance may indicate an increased predation risk, we expect that reproduction success is negatively related to vigilance.

(IV) Are there any geographical differences in territory size?

Finally, we assume that in more open landscapes in eastern Austria Curlews can occupy larger territories with the benefit of an increased size of their foraging area. However, when occupying larger territories, such breeding pairs may be less familiar with their entire territory area, hence, they have to compensate for by an increased vigilance.

2 Material and Methods

2.1 Study Sites

Our study sites cover the vast majority of breeding areas of the Curlews in Austria, only excluding the breeding population at Rheindelta (Voralberg). Breeding areas of the species in Austria are currently known from five federal states: Burgenland, Lower Austria, Upper Austria, Salzburg and Voralberg. No recent breeding records exist from Styria, Carinthia, Vienna and Tyrol (Bauer 1955; Glutz von Blotzheim et al. 1986). The last possible breeding of Curlews in Tyrol was in the 1970s (Gstader 1987). Curlews are only known as migratory birds in Styria since 1900 (Halbe 1979) and sometimes as visitors at the Danube river in Vienna (Donnerbaum et al. 2007). No evidence of former or current breeding is documented for Carinthia.

2.1.1 Burgenland

The four study sites in Burgenland belong to the Special Protection Areas (SPAs) of Austria: the SPA "Neusiedler See-Seewinkel" (with the study sites "Zitzmannsdorfer Wiesen" and "Sandeck-Illmitz"), the SPA "Parndorfer Platte-Heideboden" (study site "Leitha-Auen") and the SPA "Hanság" (study site "Hanság-Waasen") (Uhl and Denner 2015) (Fig. 1).

The study site "Zitzmannsdorfer Wiesen" is also part of the Important Bird Area (IBA) "Südlicher Seewinkel und Zitzmannsdorfer Wiesen" (Dvorak 2009). The study site encompasses about 740 ha, about 500 ha belong to the National Park Neusiedler See-Seewinkel. The boundary of the study site resembles the study area of Dvorak et al. (2011). We just slightly expanded the study site and included the western reed belt and pastures beside the "Seedamm". Dry and wet grassland, moor grass meadows, sandy soils as well as lime bogs and reed characterize the vegetation at the study site (Dvorak et al. 2011). A few vineyard acreages exist at the eastern margin of the study site. Woody plants are predominant in the northern part of the study site.

The study site "Hanság-Waasen" (hereafter "Hanság") is limited by the "Einserkanal" at its southeastern/eastern margin (representing the Austrian-Hungarian border) and by intensively used farmland at its northern and western margin. The area is characterized by extensively used farmland and remaining fens inside the conservation area "Bewahrungszone Waasen-Hanság" (Fally et al. 2015) as well as reeds. Few shelter belts, the "Hottergraben" ditch and drains are crossing the study site.

The study site "Sandeck-Illmitz" is characterized by common pastures (Euller et al. 2014) and extensive areas of hay meadows. The area is terminated by the village Illmitz, as well as vineyards and flooded areas.

The study site "Leitha-Auen" is dominated by intensively used farmland as well as wet meadows and wet fallows (Berg et al. 2011). The "Wiesgraben" and "Kleine Leitha" rivers with flanking shelter belts cross the study site that is terminated by forests, connected farmland areas and a major road.

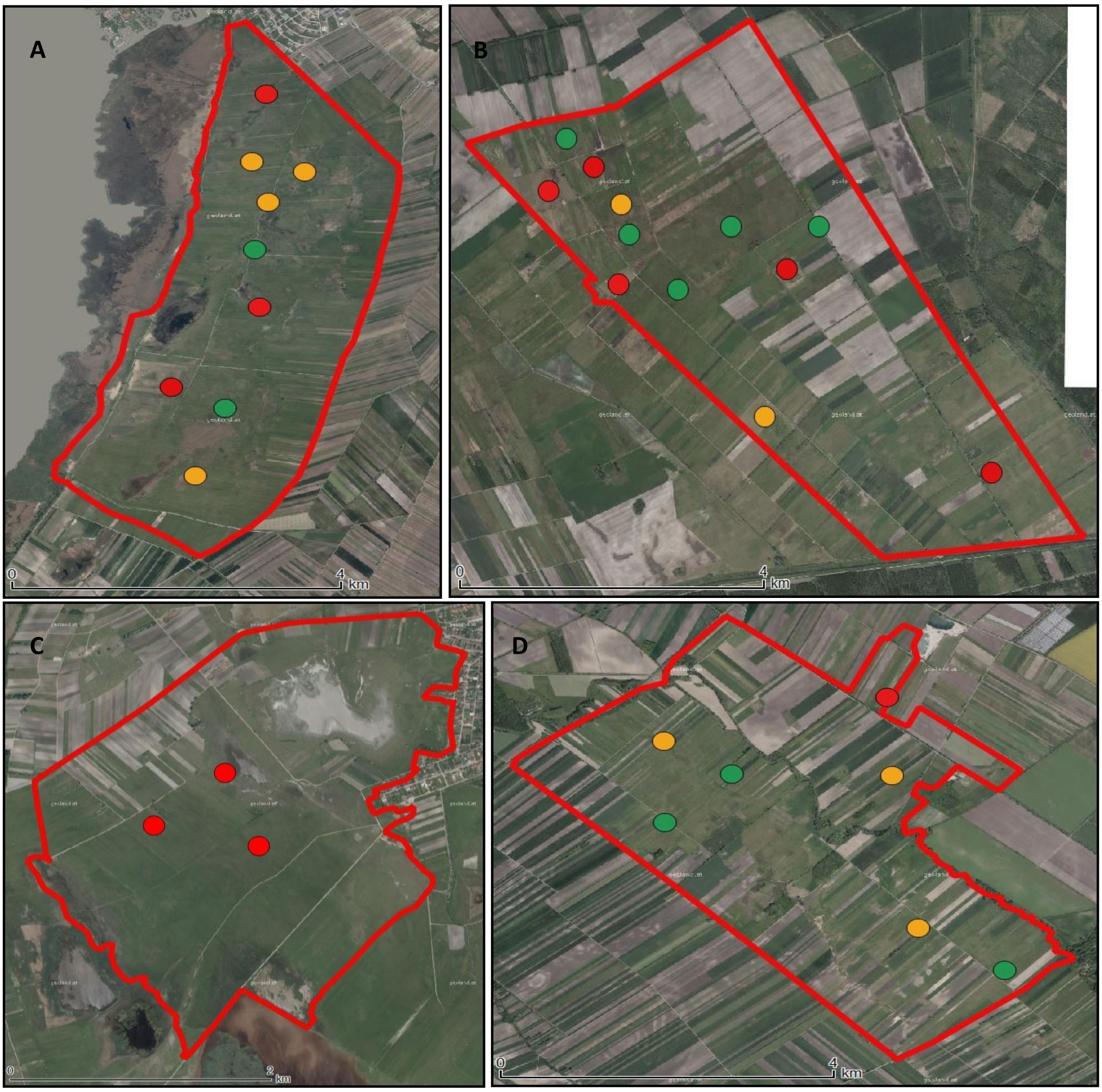


Fig. 1: Territories of the Eurasian Curlew (*Numenius arquata*) at the study sites in the federal state of Burgenland: (A) Zitzmannsdorfer Wiesen, (B) Hanság, (C) Sandeck-Illmitz and (D) Leitha-Auen. Circles indicate territory centers. Red circles: unknown reproductive status/no nest; orange circles: potential clutch(es); green circles: hatchling(s). The red lines indicate the borders of the study sites. Background map: altered after basemap.at and oriented northward. For coordinates of study sites compare Appendix Table 3.

2.1.2 Lower Austria

The study site "Feuchte Ebene" in Lower Austria belongs to the SPA "Feuchte Ebene-Leitha Auen" (Uhl and Denner 2015) and was divided into three study sites: "Brunnlust", "Moosbrunn-Herrngras" and "Bachlüsse-Lange Mahden" (after Grinschgl 2015) (Fig. 2). The study site "Brunnlust" is characterized by moor grass and lime bogs with reed strips and scattered agricultural land and fallows. Furthermore, a high potential of leisure activities (e.g. pedestrians with free running dogs, cyclists) was noticed by

Grinschgl (2015). The study site is bordered by intensively used farmland. Remaining low moor, hay meadows and intensively used agricultural land characterize the study site “Moosbrunn-Herrngras”. Two fenced transmitter masts are located within the study site that is crossed by an asphalt road causing a relatively high disturbance (Grinschgl 2015). The study site is bordered by intensively used farmland and a human settlement. The study site “Bachlüsse-Lange Mahden” is characterized by a mixture of farmland as well as hay meadows and fallows. Rows of trees demarcate the northern and eastern margin of the study site. A riding school and tracks flank the northwestern and western border of the area. Intensively used grass land characterizes the southern border.

Fig. 2: Territories of the Eurasian Curlew (*Numenius arquata*) at the three study sites in the federal state of Lower Austria. From left to right: Brunnlust, Moosbrunn-Herrngras and Bachlüsse-Lange Mahden. Circles indicate territory centers. Red circles: unknown reproductive status/no nest; green circles: hatchling(s). Red lines indicate the borders of the study site. Background map: altered after basemap.at and oriented north. For coordinates of study sites compare Appendix Table 3.

2.1.3 Upper Austria

The study sites in Upper Austria include the two airports “Linz-Hörsching” and “Welser Heide”, the SPA “Ibmer Moor-Pfeiferanger”, “Irrsee” and “Zeller Ache”, that partly contain Important Bird Areas (IBA) (Uhl and Denner 2015) (Fig. 3 & 4). Uhl and Wichmann (2012) mentioned that Upper Austria contains with about 44 breeding pairs of Eurasian Curlews the largest population density in Austria.

The airport “Welser Heide” is a private glider airfield with a neighboring military airport in the north. This area is classified as SPA (Uhl and Denner 2015) and is located 11 km west of the airport “Linz-Hörsching” in Upper Austria. The airport is surrounded by human settlements and an industrial zone. The meadows within the airport are free from fertilizers since 1998 and, except the grass runaways, are only mowed once in mid-June. About 70 ha of the entire 100 ha airport area are nutrient poor grassland (Schuster et al. 2006). The airport “Linz-Hörsching” is a public airport with a neighboring military airport in the south located nearby the Danube river in central Upper Austria. The meadows between the tarmacs are mostly fertilized meadows. A 30 m wide meadow belt flanking the tarmacs is mowed four times per year. The 1st mowing takes place in mid-May, the 2nd at the end of June (Uhl and Wichmann 2013), which occurs right during the breeding season of the Curlew (Boschert 1990; von Frisch 1964). That belt covers up to ca. 70 ha of the complete 250 ha airport area. Furthermore, a year-round waterbody next to the airport will offer resting sites for Curlews and Lapwings during the breeding season (Uhl and

Wichmann 2013). The study site “Linz-Hörsching” is bordered by farmland and industrial zones. Both airports are free from woody vegetation and enclosed by a fence (Uhl and Wichmann 2013).

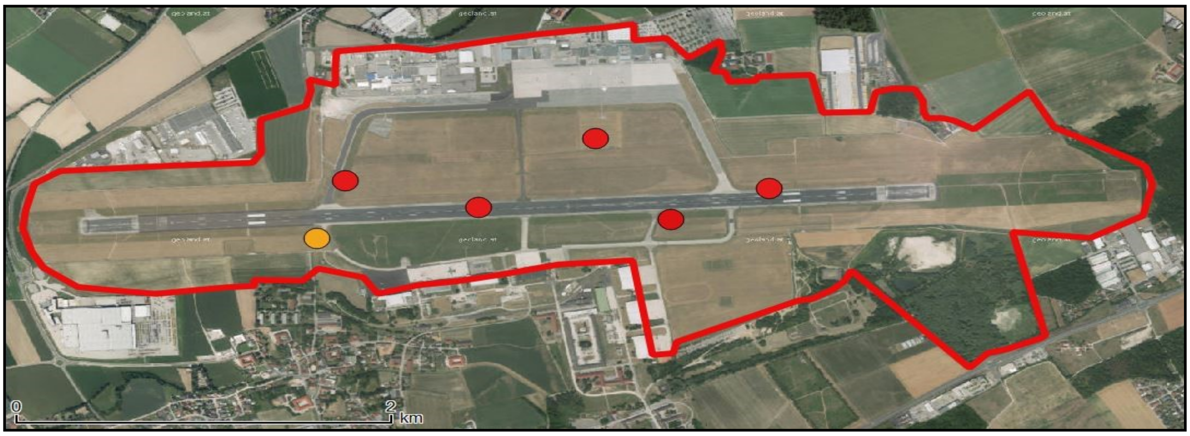


Fig. 3: Territories of the Eurasian Curlew (*Numenius arquata*) at the study site Linz-Hörsching in the federal state of Upper Austria. Circles indicate territory centers. Red circles: unknown reproductive status/no nest; orange circles: potential clutch(es). The red line indicates the border of the study site. Background map: altered after basemap.at and oriented northward. For coordinates of study sites compare Appendix Table 3.

The SPA “Ibmer Moor-Pfeiferanger” encompasses about 590 ha (Uhl and Denner 2015; Uhl and Wichmann 2013). The “Pfeiferanger” (140 ha, Uhl and Denner 2015) is composed of bog meadows with an increasing number of shrubs. The study site “Ibmer Moor” is delimited by fertile meadows and farmland towards the east. The southern meadows of the SPA “Ibmer Moor-Pfeiferanger” are characterized by intensively used agricultural land (Uhl and Wichmann 2013).

The study sites “Irrsee” and “Zeller Ache” are part of the IBAs “Wiesengebiete- und Seen im Alpenvorland” (Uhl and Denner 2015). Despite disturbances by leisure activities and pedestrians passing the territories of breeding Curlews, an increase of the local breeding population of Curlews could be recognized at the study site “Irrsee”. Two bathing places are located at the southern shore of lake Irrsee. The study site “Zeller Ache” encompasses about 20 ha of bog meadow and is on three sites surrounded by human settlement and industrial zones. The study site “Grabensee” encompasses about 25 ha. Bedding meadows and forest area can be found in the center surrounded by intensively used farmland (Werndl and Slotta-Bachmayer 2004). A lake-site camping area borders the study site in the west, the lake Grabensee represents the southern border. The predominant part of lake Grabensee belongs to Upper Austria and is designated as “Europaschutzgebiet” (Uhl et al. 2005).

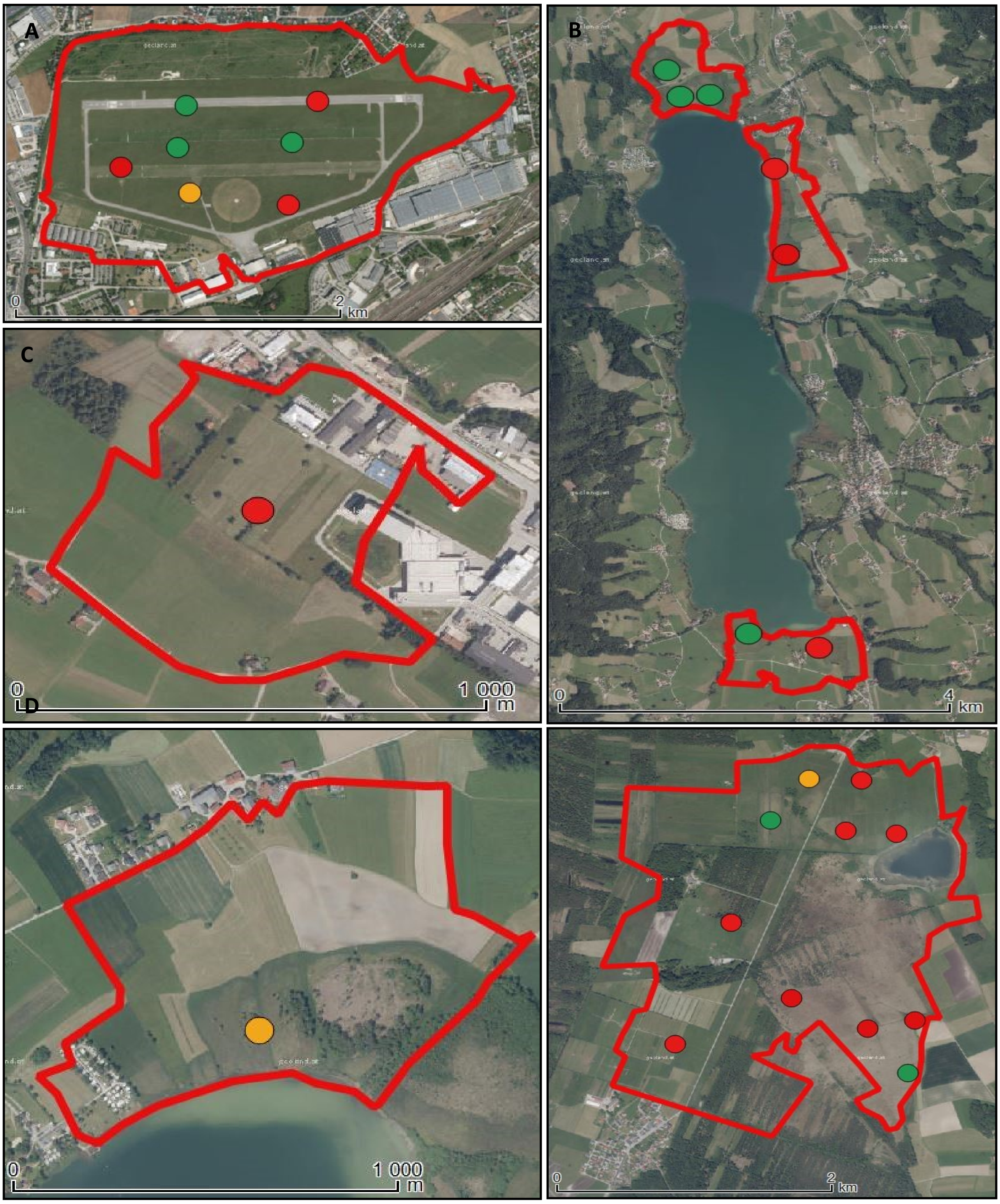


Fig. 4: Territories of the Eurasian Curlew (*Numenius arquata*) at the study sites in the federal state of Upper Austria: (A) Welser Heide, (B) Irrsee north, middle and south, (C) Zeller Ache, (D) Grabensee and (E) Ibmer Moor. Circles indicate territory centers. Red circles: unknown reproductive status/no nest; orange circles: potential clutch(es); green circles: hatchling(s). Red line: border of the study site. Background map: altered after basemap.at and oriented northward. For coordinates of study sites compare Appendix Table 3.

2.1.4 Salzburg

A total of seven study sites in Salzburg were considered in this study: “Oichtenriede”, “Obertrumer See” north and south, “Wallersee-Wengermoor”, “Wallersee-Bayerhamer Spitz”, “Wallersee-Fischtagginger Spitz”, “Weidmoos” and Lake Fuschl (Fig. 5). All are located between 420 and 665 m above sea level within the range of the Limestone Alps at the northern margin of the Alps (Pöhacker et al. 2014).

The SPA “Oichtenriede” (Uhl and Denner 2015) borders at Upper Austria. The southern area is characterized by intensively used grass land (Pöhacker et al. 2014). The Oichten river with branching drains crosses the northern and southern part of the study site “Oichtenriede”.

The two study sites at the Lake Obertrum belong either to the conservation area “Trumer Seen” (northern study site) or to the conservation area “Obertrumer See” (southern study site) (Pöhacker et al. 2014). The southern study site encompasses a size of about 50 ha and is flanked by private and public baths. Drains and intensively used meadows characterize the eastern part of the study site “Obertrumer See” south. A forest borders the western part of the study site. The northern study site “Obertrumer See” north is characterized by drains as well. Furthermore, increasing shrub growth at the drains, which may will end up in a patchy pattern of bedding meadows and woodland, can be recognized (Pöhacker et al. 2014).

The study site and conservation area “Egelseen-Schleedorf” encompasses three lakes, one of them is intensively used by fishery. The lakes are connected by drains. Intensively used meadows compose the major part of the study site, followed by the lake area and woodland. The lakes are bordered by reed belts and bedding meadows. A small part of a previously large raised bog is also part of the study site “Egelseen-Schleedorf” (Eichberger et al. 2014).

The conservation area “Wallersee” can be divided into three main parts: the northern “Europaschutzgebiet” (ESG) as well as the SPA “Wallersee-Wengermoor” (about 300 ha), the southwestern “Wallersee-Bayerhamer Spitz” (about 48 ha) and the southeastern “Wallersee-Fischtagginger Spitz” (about 46 ha) (Pöhacker et al. 2014; Uhl and Denner 2015). A raised bog with bordering begging and wet meadows in the center and around the “Wallerbach” river characterize the study site “Wallersee-Wengermoor” (Moritz 2006). Begging meadows with crossing drains characterize “Wallersee Bayerhamer Spitz” and “Wallersee-Fischtagginger Spitz”.

The “EU-Vogelschutzgebiet Weidmoos” encompasses a size about 170 ha, divided into ~140 ha of previously bog area and ~30 ha raised bog. The former bog area had been transformed and new water bodies as well as reed structures with a size of 35 ha were created. Begging meadows and reed belt become managed by mowing to prevent them from abandonment and bush growth (Pühringer et al. 2010).

The conservation area “Fuschlsee” encompasses a size of about 100 ha. Fen represents the main vegetation structure (Pöhacker et al. 2014), whereas a mixed forest and bedding meadows built the central part of that area (Werndl and Slotta-Bachmayer 2004). A soccer field borders the study site in the east and the Lake Fuschl flanks the study site in the southeast. The Fuschler Ache river crosses the study site that is surrounded by main streets and human settlement in the west and north.

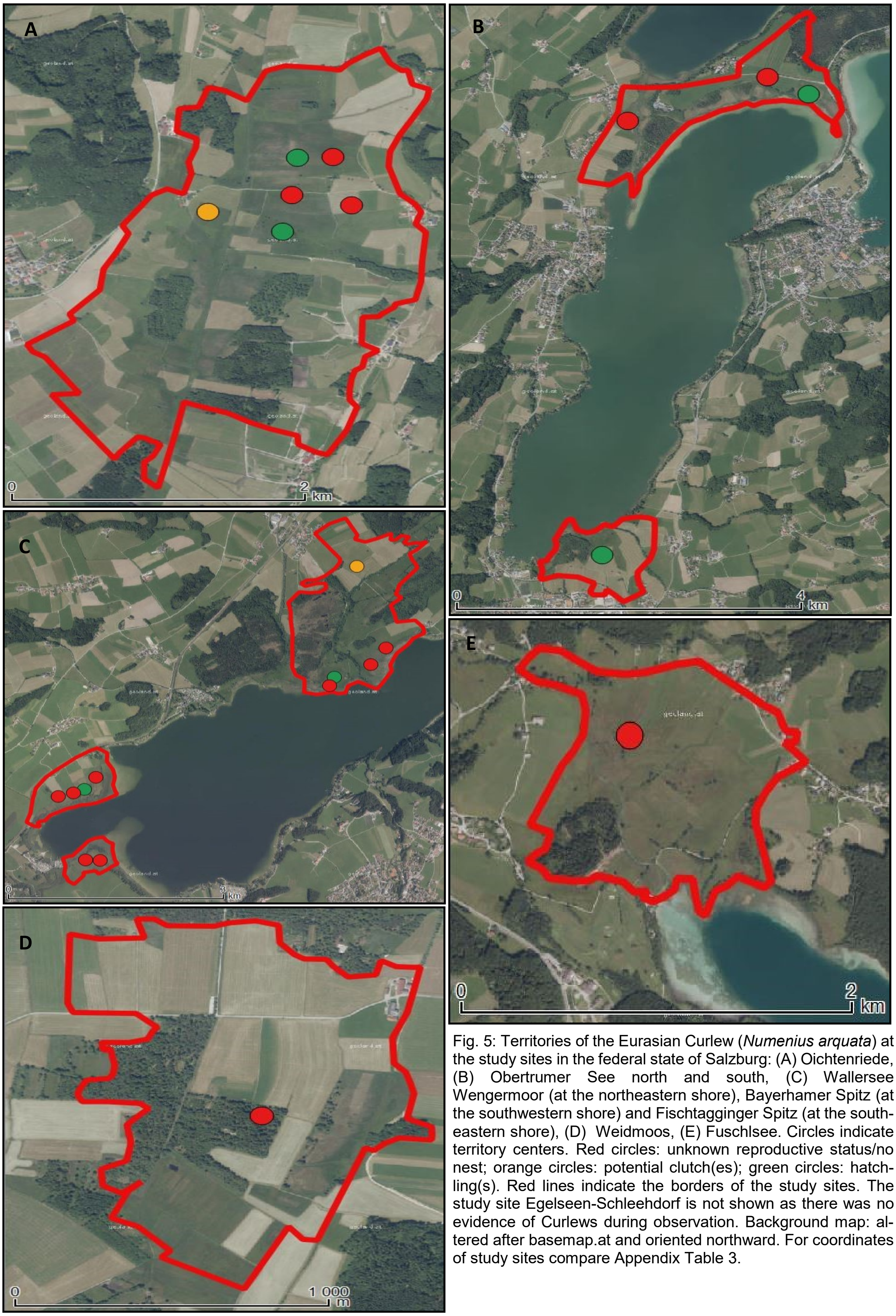


Fig. 5: Territories of the Eurasian Curlew (*Numenius arquata*) at the study sites in the federal state of Salzburg: (A) Oichtenriede, (B) Obertrumer See north and south, (C) Wallersee Wengermoor (at the northeastern shore), Bayerhamer Spitz (at the southwestern shore) and Fischtagginger Spitz (at the south-eastern shore), (D) Weidmoos, (E) Fuschlsee. Circles indicate territory centers. Red circles: unknown reproductive status/no nest; orange circles: potential clutch(es); green circles: hatchling(s). Red lines indicate the borders of the study sites. The study site Egelseen-Schleehdorf is not shown as there was no evidence of Curlews during observation. Background map: altered after basemap.at and oriented northward. For coordinates of study sites compare Appendix Table 3.

2.2 Bird Surveys

The first Curlews were observed between 22 March and 4 April 2017 (Salzburg: 22 March 2017; Upper Austria: 28/29 March 2017; Lower Austria: 24 March 2017; Burgenland: “Zitzmannsdorfer Wiesen” on 26 March 2017, “Leitha-Auen” on 31 March 2017, “Hanság/Sandeck-Illmitz” on 4 April 2017). Beside searching for Curlews, observation points from which the major part of the study sites could be scanned for Curlews were determined during that first study site visits. The boundaries of study sites were represented using natural structures (forest edges, rivers, etc.) and human-made structures (streets, settlements, etc.). The Eurasian Curlew as well as the selected “Co-species” and possible predators were repeatedly counted at a mean interval of 7 days between 22 March and 30 June 2017. Fieldwork took place between sunrise and sunset including hours of higher bird activity (Boschert 1990; Reed et al. 1985). In case of forecasted unfavorable weather conditions (heavy precipitation, strong wind) observations were conducted one day earlier or one day later. Observations were done afoot from publicly accessible paths and observation platforms to avoid further disturbances by the observers (Boschert 1990). To finally being able determining Curlew territories, all observed courtship and territorial behaviors were recorded and noted on aerial photographs of the study sites immediately in the field (after Südbeck et al. 2005). Only at the study site “Feuchte Ebene” all observations were done without getting out of the car to minimize disturbances in this particularly sensitive breeding area (Frank Grinschgl, pers. recommended). Each potential breeding pair was at least observed for 15 minutes. Birds were primarily observed with binoculars (Swarovski EL 8,5*42, Bresser Varilux 8*20x50) and with spotting scopes (Swarovski ATX 25-60x85, Swarovski ATS 65 HD 25-50X W), but also acoustic records were taken into account. All Curlew observations (visual or acoustic) were marked on aerial images of the study sites as precise as possible.

2.3 Weather conditions

According to information extracted from the internet (*https:/at.wetter.com/wetter_aktuell/rueckblick/oesterreich/* 20.8.2018) for the capitals of the federal states, in 2017 precipitation in April was highest in Salzburg with 74.6 mm/m^2 and lowest in Upper Austria with 3.2 mm/ m^2. For May the highest amount of precipitation was recorded in Lower Austria with 79.8 mm/m^2 and the lowest in Upper Austria with 34.6 mm/m^2. In June the highest amount of precipitation was recorded in Salzburg with 104.5 mm/m^2, the lowest amount with 17.4 mm/m^2 in Lower Austria (Fig. 6).

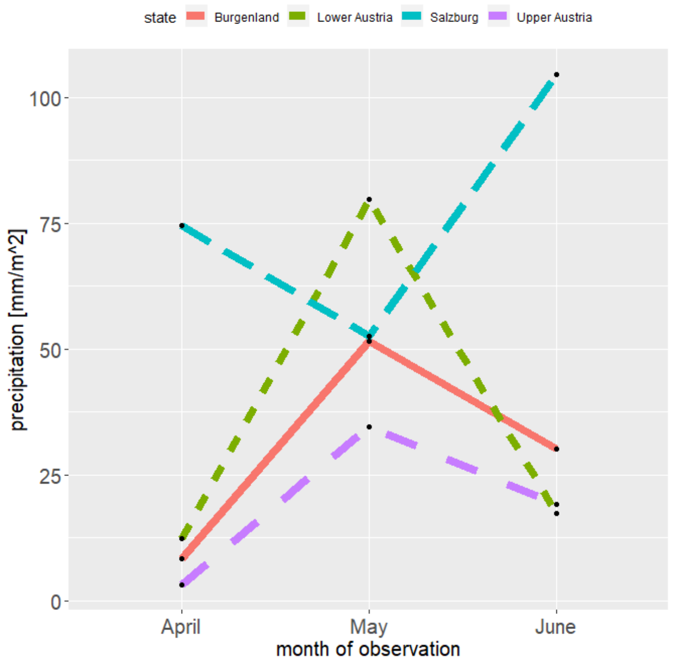


Fig. 6: Monthly precipitation in the federal states Burgenland, Lower Austria, Upper Austria and Salzburg during April-June 2017, based on precipitation data for the capitals of each state (according to *https:/at.wetter.com/wetter_aktuell/rueckblick/oesterreich/* 20.8.2018).

During study site visits the following weather parameters were recorded: cloudiness (0%, 1-25%, 26-50%, 51-75%, 76-100%), type of precipitation (hail, fog, rain, snow), strength of precipitation (none, weak, moderate, strong), temperature (°C) and wind force after Beaufort (Mather 2005). In case of strong rain and wind (>5 Beaufort) field work was interrupted because of inactivity of the Curlews as well as "Co-Species" and potential predators.

2.4 Disturbance

The numbers of humans on paths, observation platforms and directly in the breeding area were recorded and categorized ("1" = 0-10, "2" = 11-20, "3" = 21-30, "4" >30). Walkers without and with free running dogs have a high potential for disturbance in the early breeding season (Mammen et al. 2005). Motorized vehicles within the study sites (e.g. cars, tractors and airplanes) were recorded as well. All observations were marked on the aerial image for later digitalization and analyses.

2.5 Predators

Potential avian and mammalian predators of Eurasian Curlews were recorded during each visit of the study sites. Possible diurnally predators are mostly avian (e.g. raptors, gulls, corvids and herons) (Mason et al. 2018). Kestrels *Falco tinnunculus*, Common Buzzards *Buteo buteo*, Marsh Harriers *Circus aeruginosus*, Grey Herons *Ardea cinerea* and partially Carrion Crows *Corvus corone corone* were mentioned as the main avian predators of meadow birds (Bellebaum and Boschert 2003; Hönisch et al. 2008; Mason et al. 2018; Teunissen et al. 2006; Teunissen et al. 2008; Wallander et al. 2006). Beside their presence, all flight movements and directions as well as the behavior of possible avian predators were recorded. Nests of potential avian predators were also marked at an aerial image at early stage of field work before foliation.

Potential nocturnal and diurnal mammalian predators are e.g. Red Fox *Vulpes vulpes* and small mustelids like Stoats *Mustela erminea* or Weasels *Mustela nivalis* (Mason et al. 2018). Also Feral Cats *Felis silvestris catus*, which can be particularly important predators near human settlements (Hackländer et al. 2014), were recorded when observed during daytime.

We did not use nest cameras to identify nest predators as breeding Curlews proved being rather sensitive to disturbances (Fletcher et al. 2010; Mammen et al. 2005). Moreover, the likelihood of nest detection by predators such as Red Foxes may increase due to human activities at nests (von Frisch 1964; Teunissen et al. 2008). This study did not investigate the influences of European Boars (*Sus scrofa*) but Pühringer at al. (2010) mentioned that these omnivores might be possible predators for clutches and chicks.

2.5.1 Predation Index

Number of predators might affect the amount of vigilance behavior more than the type of predator (Larsen et al. 1996). Therefore, we calculated the median of observed predatory birds for all territories within the study sites and multiplied them with their respective predatory relevance to get a predation index for the study sites. The predatory relevance was scaled in three categories (1 = minor predatory relevance, 2 = medium predatory relevance, 3 = major predatory relevance) according to literature about the estimated impact of potential predators of adult Curlews and chicks (e.g. Bellebaum and Boschert 2003; Hönisch et al. 2008; Mason et al. 2018; Seelig and Seelig 2001; Teunissen et al. 2006; Teunissen et al. 2008; Wallander et al. 2006). Potential predators outside a 200 m buffer around the analyzed particular Curlews were not included in calculations. That buffer was calculated with reference to mean distances of nests of neighboring Curlews between 384 and 477 m (min. 110 m) (Glutz von Blotzheim et al. 1986) and 150 m (Bauer et al. 2005).

2.6 Video Recording and Analysis of Vigilance Behavior

Videos were shot with two different types of cameras (Sony Cybershot DSC-HX400V and Panasonic Lumix DMC-FZ72). Curlews were filmed for 15 minutes per observation round. Distinctions between breeding and non-breeding pairs were not done because of the non-predictability of later breeding success.

A total of 297 Eurasian Curlews was filmed during observations. The number of available videos (n = 337) taken for the study per study site is shown in Figure 7. 36 videos were skipped due to shimmering of light and too great distances. Hence, 301 videos remained for further analyses. All videos were taken between 2 April and 30 June 2017.

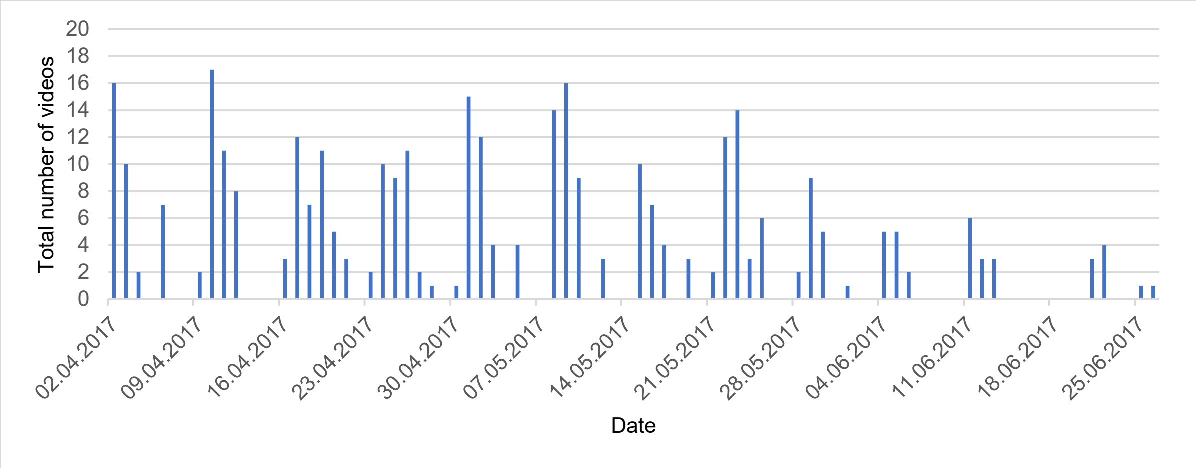


Fig. 7: Total number of videos (n = 337) taken during field season between 2 April and 30 June 2017.

A total of 281 (83.4%) videos were taken in later determined “Papierreviere”. The “Papierrevier” represents only an approximation of the true territory and may differ in size or shape to an unknown extent (Erdelen 1984). 57 videos (16.9%) were taken in non-determined “Papierreviere”. No videos could be taken in 25 territories (27.8%). In 16 territories (4.7%) Curlews could be only filmed once during observation rounds. No videos were taken at the study sites “Feuchte Ebene-Brunnlust” in Lower Austria and “Egelseen-Schleedorf” in Upper Austria due to a lack of breeding Curlews (Appendix Table 3).

The different sexes of the filmed Curlews were distinguished directly in the field after von Frisch (1964) and Boschert (1990) and later double-checked during video analyses. Video analyses were done by analyzing the first five minutes of the video recorded at the particular study site. If the filmed Curlew was not visible anymore within this timespan the time the bird was invisible was added to the first five minutes to get a total time of analysis of five minutes. Curlews that could be reliable distinguished (e.g. males due to particular mating behavior or territory flights; see here Boschert 1990; von Frisch 1964) got an individual Video ID. The Video ID was used for positioning the filmed Curlew on QGIS 2.18.9 (QGIS Development Team, 2016) to investigate the impact of disturbances and potential predators within a buffer of 200 m around the Curlew and to avoid augmented disturbances from conspecifics. Behavior was analyzed by an ethogram developed after von Frisch (1964) (see Appendix Table 4 for further details).

Vigilance behavior was investigated by counting the number of scans of Curlews during the first five minutes of video analysis. Scanning was defined as the head lifts from a foraging position with the bill above horizontal line (Boschert 1990; Evans 1988; von Frisch 1964). To reduce the number of variables we focused on scans at behavioral traits with the most frequency in Curlews: comfort, foraging and moving behavior (Boschert 1990). The number of scans in every video analysis was converted into scans per minute for a better comparison within the different study sites. The frequency of the investigated behavioral traits was calculated in percent. If the distinction of the sexes was too vague, the analyzed Curlews got the same Video ID to avoid double analysis. Every behavior, that occurred longer than one second, was classified as an independent behavior. Beginning and ending of every single behavior was noted. During each way of behaving we counted the number of scans. The number of birds presented in the video was noted for each analysis.

2.7 Delimitation of Territories

Male Curlews show display flights to defend their territory against conspecifics (von Frisch 1964). Hence, territories were defined as follows: One adult male Curlew had to be found in a potential territory for at least 3 observation rounds in a row, begun with the first evidence of presence. Additionally, one female Curlew must be observed in the same potential territory for at least one of the three observation rounds. Therefore, start and ending of movements in the air and on the ground were observed. A territory was defined as abandoned if no Curlew could be observed during three observation rounds in a row in the particular territory. If no Curlew could be observed at a study site/within a territory during three consecutive visits, the area/territory was not visited again, and territory size was delimited. The borders of the territories can become indistinct after hatching of offspring (Glutz von Blotzheim et al. 1986). Furthermore, non-breeding Curlews can be also observed in breeding territories after hatching (Wenger et al. 1991). The typical extreme alarm call of the parents indicating the presence of chicks was used as indicator for young hatchlings (von Frisch 1964; Glutz von Blotzheim et al. 1986). The loud and reedy staccato characteristics differentiates this call from other alarm calls (Glutz von Blotzheim et al. 1986). Thus, for delimitating territories only recorded Curlew locations till the date of the first recorded extreme alarm call or observed hatchlings were considered. Moreover, unsuccessful breeding Curlews form groups before leaving their territories (von Frisch 1964). Once those groups were observed at the potential territory, the size of the “Papierrevier” was not further extended.

2.8 Woody Structures and Vegetation Height

Single trees, closed forest and linear woody structures were summarized as woody structures to investigate their impact on the vigilance behavior of Curlews. Furthermore, potential differences of the distance to woody structures within the buffer of 200 m around the filmed Curlews at different study sites were analyzed. Therefore, we ranked the distance of the Curlew to woody structures in four categories: “1” = 0-50 m, “2” = 50-100 m, “3” = 100-150 m and “4” >150 m. Mean vegetation height was calculated with reference to the filmed Curlew (1 = toe joint, 2 = ankle joint, 3 = underbelly, 4 = half of the bird, 5 = end of neck, 6 = bird is not visible anymore) at beginning and end of each behavioral trait during analysis.

2.9 Breeding Success

Breeding pairs with successfully hatched chicks were determined from behavioral observations as following: (i) intensive and ongoing extreme alarm calling from one or both adults of the breeding pair, (ii) attempt of direct flights against potential predators and (iii) distraction displays (Glutz von Blotzheim et al. 1986; Fletcher et al. 2010; von Frisch 1964). Adults that didn´t show any of that behavioral traits were classified as non-breeders or unsuccessful breeders. A successful brood with fledglings was assumed if the chicks could be observed for a minimum of four weeks (Engl et al. 2004) or in case of observing fledglings at the end of June. For further analysis, breeding success was categorized in 0 = no or unknown nest status, 1= potential clutch and 2 = successful brood/fledglings.

2.10 Data Analysis

Spatial analysis as well as maps presented in this thesis were prepared with QGIS 2.18.9 "Las Palmas" (QGIS Development Team 2016). The shape of each "Papierrevier" was smoothed by use of the Convex hull algorithm and their size was calculated by use of the array processor of QGIS 2.18.9 (QGIS Development Team 2016). Vegetation was digitalized after direct observation and basemap.at (https://www.basemap.at/ visited March 2018) recommendation. The minimum distance to woody structures and streets was calculated with a distance matrix in QGIS 2.18.9. High and less frequented streets were summarized as roads. Curlews with territories within airport areas are known to show habituations to air traffic (Uhl et al. 2010). To avoid habituation effects, we excluded the study sites "Linz-Hörsching" and "Welser Heide" from distance measurements to roads.

Statistical analyses were made with R Studio (R Core Team 2018) using the following packages: lme4 (Bates et al. 2018), tidyr (Wickham et al. 2018), lubridate (Grolemund and Wickham 2011), date (Therneau et al. 2018), glmulti (Calcagno 2015), lmerTest (Kuznetsova et al. 2017) as well as ggplot2 (Wickham 2016) for visualization. We used Pearson and Spearman correlations to test for associations between all variables.

We ran a generalized linear mixed model (GLMM, fit by maximum likelihood (Laplace Approximation) using the function "glmer" (R-package lme4, Bates et al. 2015). Scans per minute were set as predictor variable, distance to woody structures, foraging and moving behavior, territory size (log), vegetation height as well as the number of Curlews and date of observation were sat as response variables. The territory ID was nested inside the study site and both was set as random effect. Date was converted with the function "as_date" (R-package lubridate, Grolemund and Wickham 2011). For further confirmation, we run an automated model selection (level 1, criterion AIC) with the function "glmulti" from the R package glmulti (Calcagno 2015). The model-averaged relative importance of terms showed the proportion of the best calculated models where the predictor variables were included. For better visualization, predicted values of the scans per minute for the respective predictor variables, were calculated with the "predict" function (R Core Team 2018). In advance, territory size was log transformed to achieve a normal distribution. The distance to roads was not included in the model because the vast majority of birds was observed in >150m distance from roads. Additionally, we excluded comfort behavior and reproduction success from further analyses due to the possibility of false correlations based on observation difficulties.

3 Results

3.1 Territory Size

A total of 88 territories were determined, distributed across all of our study sites (n = 24) (Appendix Table 1). 34 territories (38.20%) were found in Eastern Austria and 55 territories (61.80%) were found in our western study sites (incl. "Welser Heide" and "Linz-Hörsching"). The amount of territories fluctuated between 12 territories ("Hanság"; Burgenland) and one territory ("Moosbrunn-Herrngras", "Bachlüsse-Lange Mahden"; Lower Austria; "Grabensee", "Zeller Ache"; Upper Austria and "Obertrumer See" south, "Weidmoos", "Fuschlsee"; Salzburg). 32.35% of all territories in Eastern Austria and 90.91% of all territories in Western Austria encompasses a size <7 ha. 10 territories encompass a size <1 ha. The largest average territory size with 18.17 ha was found at “Zitzmannsdorfer Wiesen” (Burgenland). The smallest average territory size with 0.14 ha was found at the study site “Wallersee Fischtagginger Spitz” (Salzburg).

The average territory size in Eastern Austria (including Lower Austria and Burgenland) was with 12.52 ha ~24% higher than in Western Austria (including Upper Austria and Salzburg) with 2.98 ha (Fig. 8).

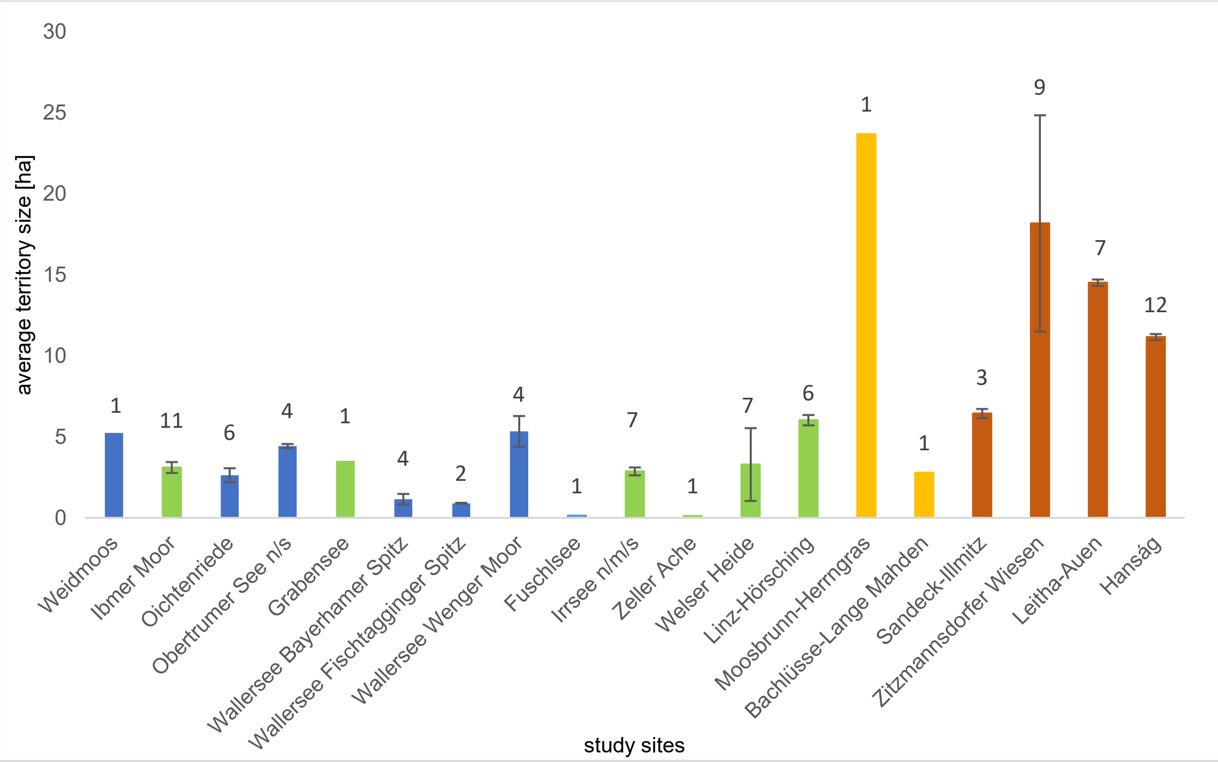


Fig. 8: Average territory size (± Std.dev.) (n=88) within the study sites (n=24). The number of territories is written above the bars, respectively. Colors represent the four study states: Lower Austria (yellow), Burgenland (brown), Upper Austria (green) and Salzburg (blue). Study sites are ordered by longitude from Western to Eastern Austria. For coordinates of study sites compare Appendix Table 3.

3.2 Scan Rate

Territory size (log) and foraging behavior both were significantly positively correlated with the number of scans per minute (“spm”) (Tab. 2). Date of observations emerged with a positive correlation close to the significance threshold. Vegetation height showed a positive but non-significant correlation with the number of spm. Comfort behavior emerged with a significant negative correlation to the number of spm. Distance to woody structures showed a significant positive correlation to the number of spm. Moving behavior, reproduction success, number of Curlews and distance to roads emerged with a negative but non-significant correlation to the number of spm.

Tab. 2: Spearman and Pearson correlations of scans per minute with territory size (log), the behavioral traits foraging, moving and comfort, date of observation as well as the categories reproduction success, distance to woody structures, number of Curlews, distance to roads and vegetation height, respectively. Green values show positive effects; red values show negative effects. Significant *p* values <0.05 are bold printed. df = degrees of freedom.

Variables	Pearson´s *r*	Spearman´s *rho*	df	*t*	Lower 95% CL	Upper 95% CL	*p*
Territory size (log-transformed)	0.236		271	3.999	0.12	0.35	**0.0001**
Foraging behavior	0.148		271	2.469	0.03	0.26	**0.0142**
Moving behavior	-0.025		271	-0.404	-0.14	0.09	0.6867
Comfort behavior	-0.194		271	-3.257	-0.31	-0.08	**0.0013**
Date of observations	0.117		271	1.935	0.00	0.23	0.0541
Reproduction success		-0.019					0.7567
Distance to woody structures		0.203					**0.0007**
Number of Curlews		-0.101					0.0968
Distance to roads		-0.017					0.7800
Vegetation height		0.032					0.6094

The distance to woody structures between 100-150 m turned out as the most important predictor for the scans per minute (positive effect, Tab. 3). Distances to woody structures between 50-100 m and > 150 m emerged with significant positive effects as well. The number of Curlews emerged as a significant negative predictor. Territory size (log), foraging and moving behavior, date of observation and the categories of vegetation height had no significant effects on the scans per minute.

Tab. 3: GLMM evaluating effects of different habitat and behavioral variables on the rate of scans per minute. Green values show positive effects; red values show negative effects. Categories of the distance to woody structures: (1) 0-50 m, (2) 50-100 m, (3) 100-150 m, (4) >150 m. Categories of vegetation height: (1) toe joint, (2) ankle joint, (3) underbelly, (4) half of the bird, (5) end of neck of the Curlew. Significant p values <0.05 are bold printed. df = degrees of freedom.

Variables	*Estimate*	*df*	*t*	*p*
Territory size (log)	1.274	44, 9	1.578	0.1225
Foraging behavior	0.019	246, 7	1.108	0.2689
Moving behavior	-0.002	231, 9	-0.143	0.8861
Number of Curlews	-1.449	232, 9	-2.028	**0.0437**
Date of observations	0.028	253, 6	1.478	0.1406
Distance to woody structures cat 2	3.279	246, 3	2.926	**0.0038**
Distance to woody structures cat 3	6.142	232, 4	4.663	**0.0001**
Distance to woody structures cat 4	2.497	175, 8	2.190	**0.0298**
Vegetation height cat 2	-0.454	248, 8	-0.311	0.7563
Vegetation height cat 3	0.082	255, 9	0.055	0.9558
Vegetation height cat 4	-1.116	251, 4	-0.701	0.4842
Vegetation height cat 5	1.954	248, 9	0.665	0.5066

According to the model selection, vegetation height and distance to woody structures were included in all 150 best models (AIC = 1746.10; $\tilde{x}$ AIC = 1778.02). The log-transformed territory size was included in almost all models (Fig. 9). The best six models selected automatically by “glmulti” ranked after the AIC criterion were shown in Appendix Table 5.

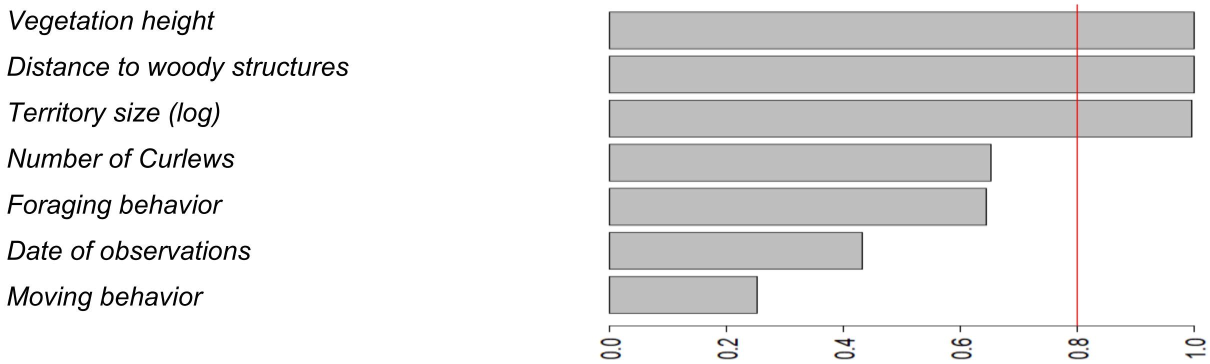
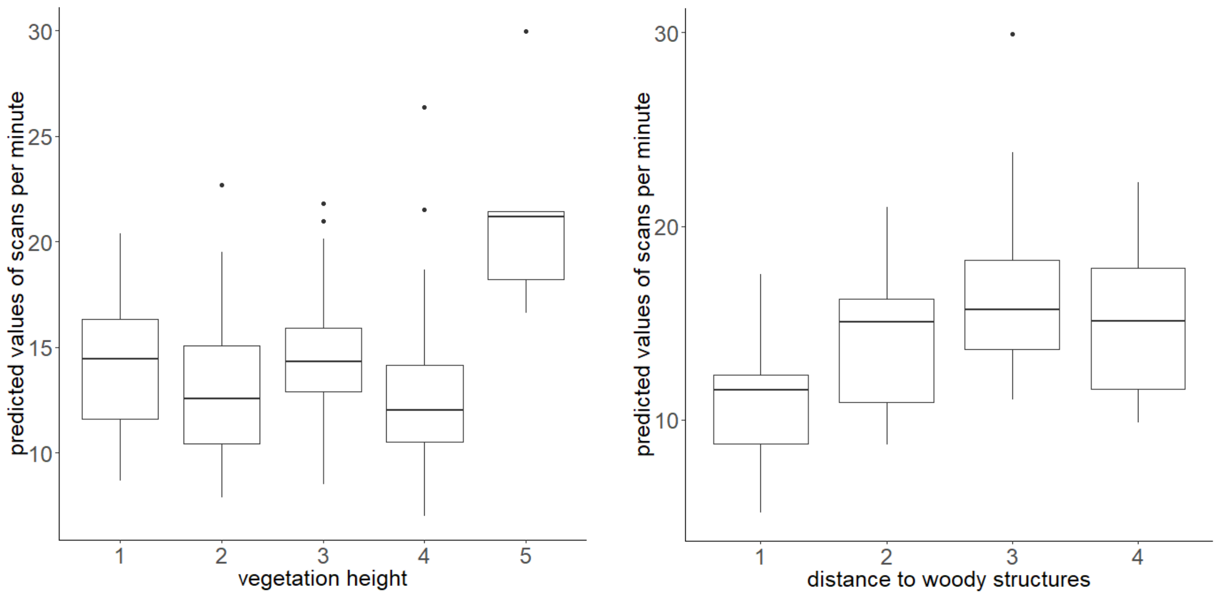


Fig. 9: Model-averaged importance of terms; red line at 80%.

Only when in high vegetation (category 5) Curlews increased their spm (Fig 10). Further, lower spm was observed in Curlews closer to woody structures and spm increased significantly with increasing territory size (Fig. 10).



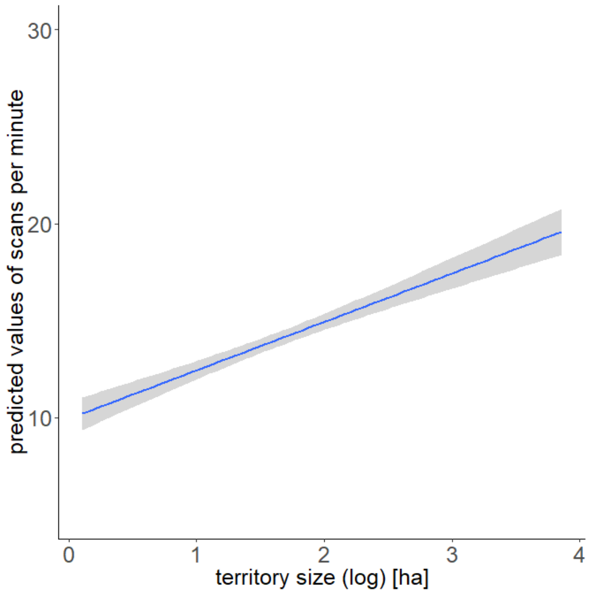
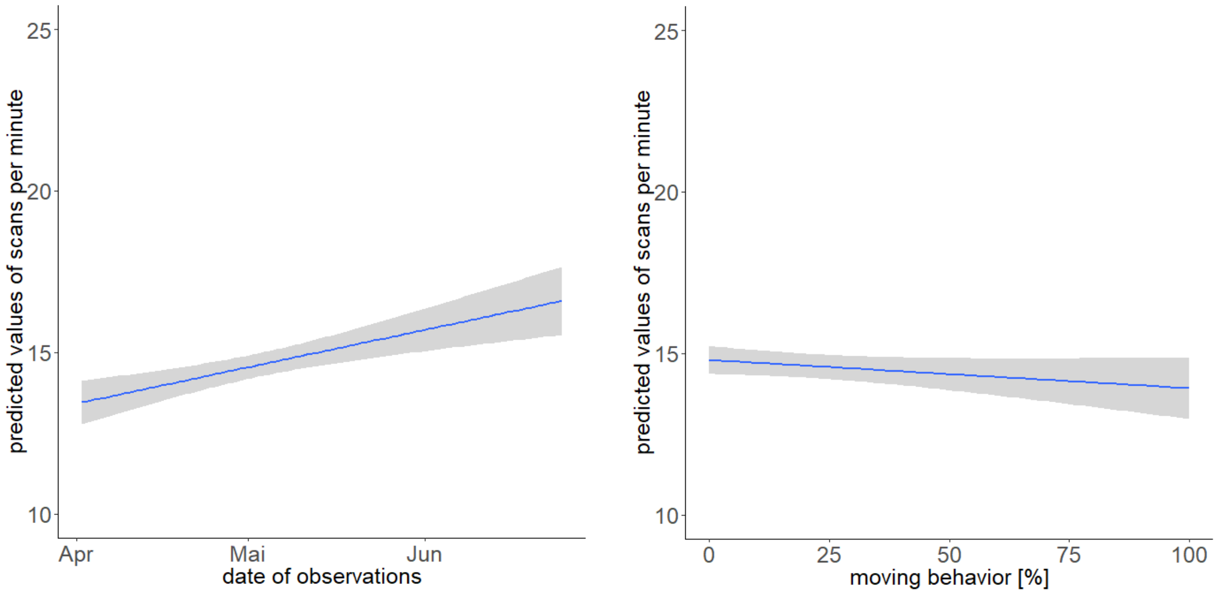


Fig. 10: Relationship between number of predicted scans per minute and predictor variables according to model-average relative importance of terms: vegetation height, distance to woody structures and log transformed territory size (n = 273). Regression line with included confidence interval of 95%. Categories of the distance to woody structures: (1) 0-50 m, (2) 50-100 m, (3) 100-150 m, (4) >150 m. Categories of vegetation height: (1) toe joint, (2) ankle joint, (3) underbelly, (4) half of the bird, (5) end of neck of the Curlew. Boxplots with including median, maxima/minima of distribution and residuals.

Spm increased in the course of the observation period. An increased proportion of moving behaviour had a weak negative effect on spm. In contrast, predicted spm was increasing with the amount of foraging behavior. Furthermore, Curlews decreased their spm with an increasing number of surrounding conspecifics (Fig. 11).



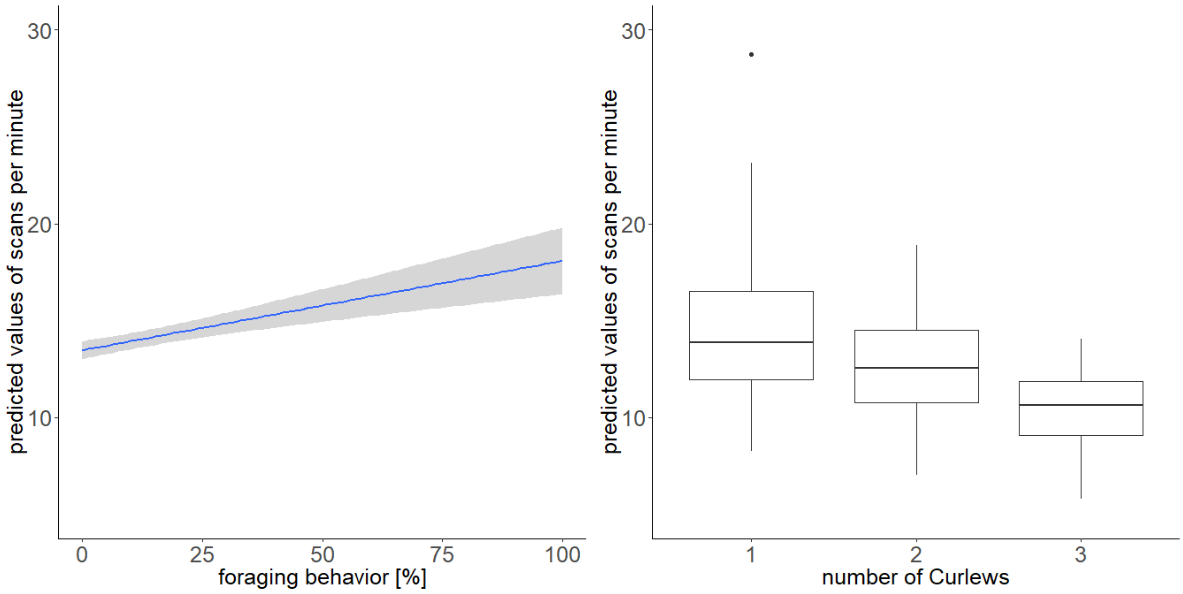


Fig. 11: Relationship between number of predicted scans per minute compared to the date of observations, moving and foraging behavior [%] as well as number of Curlews. Regression line shown with 95% confidence interval. Boxplots with including median, maxima/minima of distribution and residuals.

3.3 Breeding Success

Breeding success was observed in 21.59% of all territories (Tab. 4). Seven successful territories were found at Burgenland, six successful territories could be found in Upper Austria and Salzburg. No breeding success could be noticed in Lower Austria. Size of successful territories varied between 0.69 ha ("Irrsee" north/Upper Austria) and 31.33 ha ("Hanság"/Burgenland). The extreme alarm call of adults could be noticed in all successful territories except "Obertrumer See" south/Salzburg. Fledglings could be observed in 42.12% of all successful territories.

3.3.1 Effects of Predators on Breeding Success and Behavior

Carrion Crows were observed in 28% of all territories, followed by Kestrels in 24% of all territories (Fig. 12). All other potential avian predators were observed in less than 10% of all territories. Feral Cats were only observed in 2% of all territories.

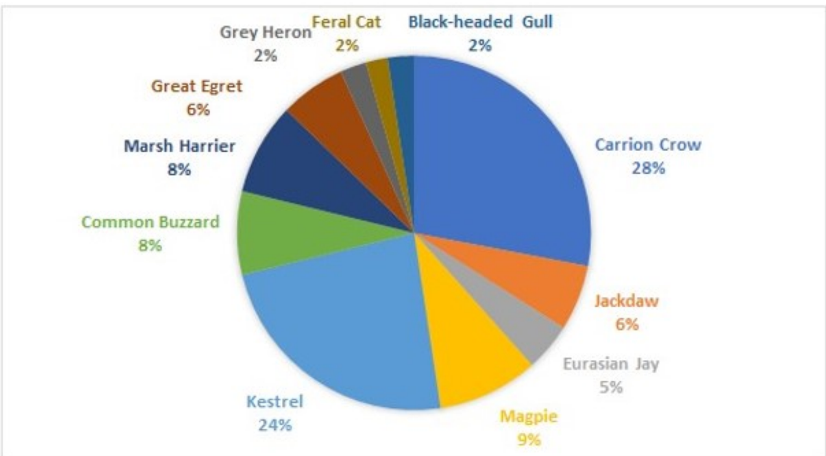


Fig. 12: Most frequently observed potential predators (n = 11) of clutches and fledglings of Eurasian Curlews (*Numenius arquata*) within territories (n = 89) at all study sites (n = 24).

Defense behavior, extreme alarm calls and warning behavior of Curlews against potential predators (compare Fig. 12) or humans were observed in 50% of all study sites (n = 24) (Fig. 13). Defense and warning behavior as well as extreme alarm calls caused by Kestrels, Common Buzzards, Marsh Harriers, Montagu´s Harriers and Eastern Imperial Eagles were observed at several study sites at Burgenland. Warning behavior of Curlews against potential predators and humans was most observed in Upper Austria and Salzburg. No extreme alarm calls of Curlews against potential predators or humans were observed in Salzburg.

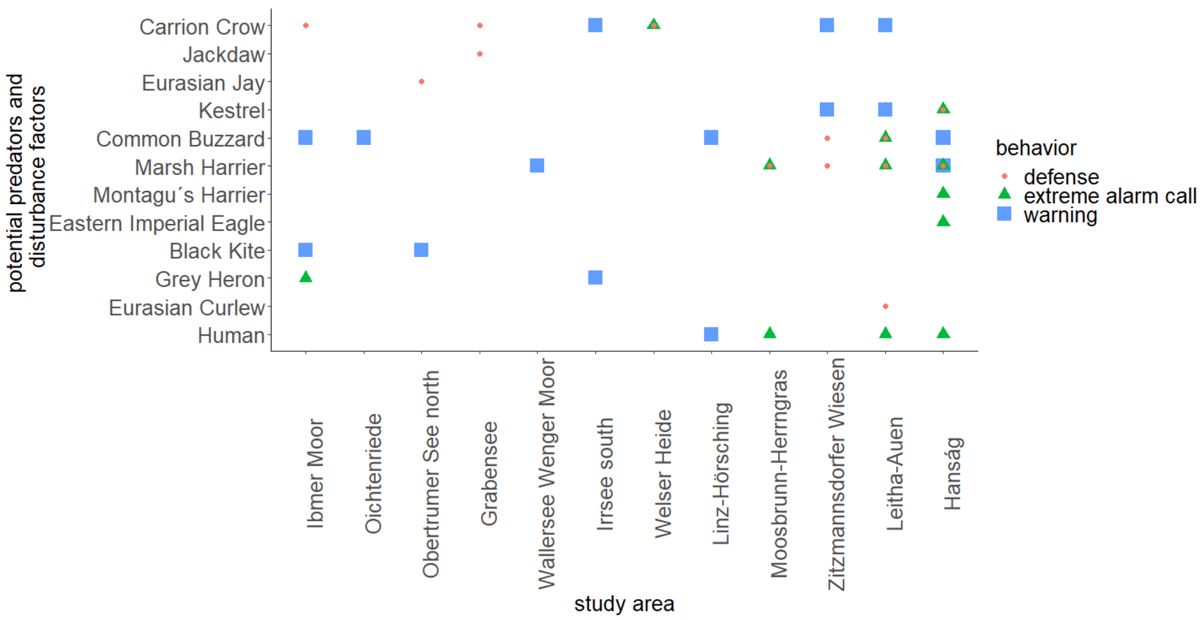


Fig. 13: Response of Curlews against potential predators and humans at the different study sites. Colors represent the different behavioral reactions of Curlews. Study sites ordered by longitude from western to eastern Austria. For coordinates of study sites compare Appendix Table 3.

Five different corvid species, Kestrels, Common Buzzards, three harrier species, Black Kites, two heron species, Black-headed Gulls as well as mustelids and Feral Cats could be observed at the successful territories. Lapwings (*Vanellus vanellus*) could be found in 84.21% of successful territories (n = 19; Tab: 4).

Tab. 4: Territory size, breeding success, presence of fledglings/extreme alarm call and “Co-species” at the documented successful study sites (n = 19). A successful brood with fledglings was assumed if the chicks could be observed for a minimum of four weeks (Engl et al. 2004) or in case of observing fledglings at the end of June.

State	Study site	Territory size ha	Breeding success	Fledglings/extreme alarm call	Potential observed predators within the territory	“Co-species”
Burgenland	Zitzmannsdorfer Wiesen	14.60	+	+/+	Carrion Crow Rook *Corvus frugilegus* Magpie Kestrel Common Buzzard Marsh Harrier Great Egret	Lapwing Redshank *Limosa limosa* Whimbrel *Numenius phaeopus*
	Hanság	5.86	+	+/+	Carrion Crow Kestrel Common Buzzard Marsh Harrier Montagu´s Harrier Great Egret Mustelids	Lapwing Great Bustard *Otis tarda*
		8.98	+	-/+		
		27.22	+	+/+		
		31.33	+	-/+		
	Leitha-Auen	11.59	+	-/+	Carrion Crow Kestrel Marsh Harrier Hen Harrier Great Egret Grey Heron Black-headed Gull	Lapwing
		15.19	+	+/+		
Upper Austria	Welser Heide	3.99	+	+/+	Carrion Crow Jackdaw Kestrel	Lapwing
	Irrsee north	0.69	+	+/+	Carrion Crow Kestrel	Lapwing
		2.67	+	-/+		
		3.72	+	-/+		
	Irrsee south	2.18	+	+/+	Carrion Crow Jackdaw Kestrel Common Buzzard Grey Heron Feral Cat	None observed
	Ibmer Moor	4.55	+	-/+	Carrion Crow Jackdaw Eurasian Jay Kestrel Common Buzzard Black-headed Gull Mustelids	Lapwing Common Snipe *Gallinago gallinago*
Salzburg	Oichten-riede	1.17	+	-/+	Carrion Crow Jackdaw Kestrel Common Buzzard	Common Snipe Lapwing
		3.92	+	-/+		
	Obertrumer See north	1.05	+	-/+	Carrion Crow Jackdaw Magpie Kestrel Black Kite Grey Heron Black-headed Gull	None observed
	Obertrumer See south	8.49	+	+/-	Carrion Crow Magpie Eurasian Jay Great Egret Grey Heron	Lapwing

Wallersee Wengermoor	4.42	+	-/+	Carrion Crow Jackdaw Eurasian Jay Kestrel Common Buzzard Great Egret Grey Heron Black-headed Gull	None observed
Wallersee Bayer-hamer Spitz	0.82	+	-/+	Carrion Crow Rook Magpie Kestrel Common Buzzard Marsh Harrier Black Kite Grey Heron Feral Cat	Lapwing

3.3.2 Predation Index

The calculated values of the predation index (“pri”) of potential predators of adult Curlews and their chicks summarized for each study site were highest at “Wallersee Wenger Moor” (pri = 30.5; Salzburg; Fig. 14). The study sites “Ibmer Moor” (Upper Austria) and “Zitzmannsdorfer Wiesen” (Burgenland) showed similar values (pri = 26). No values could be calculated for the study sites “Fuschlsee” (Salzburg) and “Irrsee” middle (Upper Austria) as no potential predators were observed (Appendix Table 2).

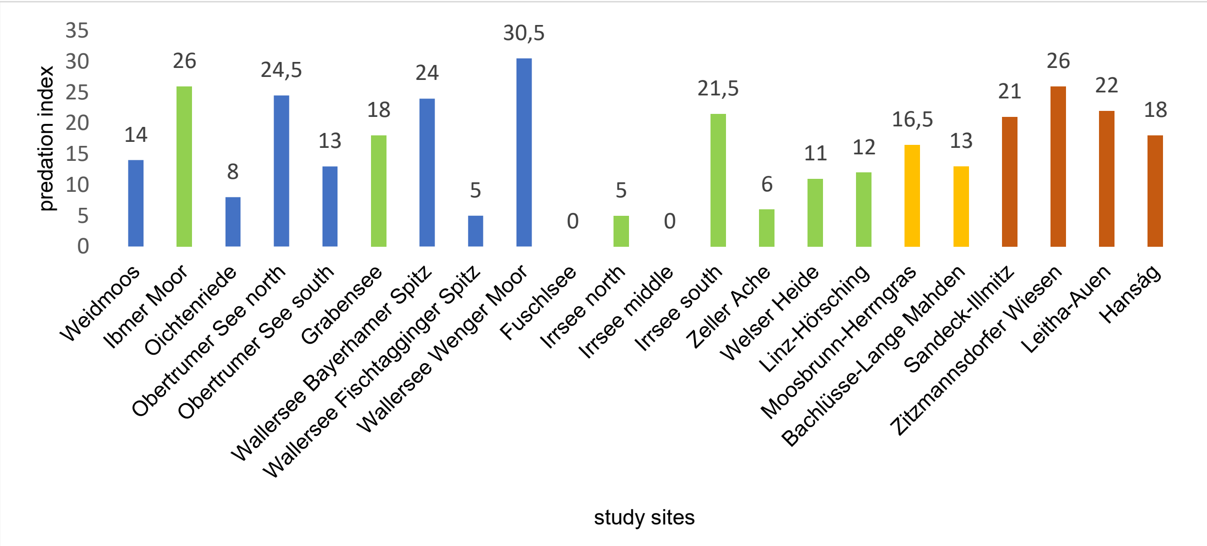


Fig. 14: Relationship between calculated predation index of potential predators summarized over the particular study sites (n = 24) along the longitude from Western to Eastern Austria. Colors represent the four study states: Lower Austria (yellow), Burgenland (brown), Upper Austria (green) and Salzburg (blue). For coordinates of study sites compare Appendix Table 3.

4 Discussion

4.1 Territory Size

The major part of territories in Western Austria encompasses a size <7 ha. Other studies reported territory sizes between 7 and 200 ha (Berg et al. 1992; Busch and Jeromin 2013; Glutz von Blotzheim et al. 1986; Seelig and Seelig 2001; Valkama et al. 1999; Wenger et al. 1991). Wenger et al. (1991) mentioned a mean territory size of 54 ha for particular territories in Lower Austria with no recognizable influence of varying proportions of grassland and agricultural land on territory size. According to Berg (1992), habitat quality is a major factor to determine the territory size. The small area of some protected meadows in Upper Austria (Uhl and Wichmann 2013) might be a reason for general smaller territory sizes in Western Austria. Furthermore, the variety in territory size could be caused by the high pressure of leisure activities in Upper Austria and Salzburg (Pöhacker et al. 2014; Pühringer et al. 2010; Uhl et al. 2005). Such human disturbances can force Curlews to forage outside their territories (Boschert 1990), hence affecting the size of the delineated territories. This may also explain small territory sizes (<1 ha). However, Tubbs and Tubbs (1996) found five breeding pairs with successful hatched chicks within 3 ha of bog. According to the fact that territories can become indistinct after hatching of offspring (Glutz von Blotzheim et al. 1986) the observations of Tubbs and Tubbs (1996) might be not comparable. Prolonged afforestation, human settlements and agricultural land use might be a further reason for the philopatric birds (Engl et al. 2004) to breed in smaller territories in Western Austria compared to Eastern Austria. Other studies mentioned no specific habitat associations of Curlews (Żmihorski et al. 2018). Nevertheless, they are capable to adapt on changing landscapes (Vliet et al. 2010).

4.1.1 Geographical Differences

Intensively used agricultural land or meadows, earlier mowing operations, reforestation, drains, ongoing expansion of industrial areas, nearby settlements, bathing jetties, runners apart from roads, straying dogs and the developing wood represent the most important disturbance factors and causes for habitat fragmentation at almost all study sites in Salzburg, Upper Austria and Lower Austria (Dvorak 2009; Grinschgl 2015; Pöhacker et al. 2014; Pühringer at al. 2010; Uhl et al. 2005). Curlews in Salzburg and Upper Austria were often found nearby human settlements or industrial areas. No Curlews were found at the study site "Egelseen-Schleehdorf" during our field work in 2017. This could be associated with habitat loss due to increasing abandonment of extensively agricultural land, fertilization, wood growth, fishery as well as human disturbance (Eichberger et al. 2014; Glutz von Blotzheim et al. 1986; Pöhacker et al. 2014). The lack of breeding pairs at the study site "Brunnlust" could be caused by human disturbance as well as agricultural field with tall crop (Grinschgl 2015).

In contrast, the study sites at Burgenland provided larger open landscapes with far distances to woody structures. Few meadows at the study sites "Hanság" and "Sandeck-Illmitz" were used for extensive grazing (Dvorak 2009) and provide suitable short meadows for foraging Curlews (Uhl and Wichmann 2013). Dvorak et al. (2011) also mentioned positive effects of managing the access of visitors to sensitive breeding areas of the Curlew at the study site "Zitzmannsdorfer Wiesen". Bikers, cars as well as birdwatchers are restricted to stay on paths at all study sites (Dvorak 2009; Tiefenbach 1998). However, high numbers of visitors on paths surrounding and crossing Curlew territories should not be underestimated. The study site “Leitha-Auen” is shaped by intensively used agricultural land as well as abandoned areas (50%) (Berg et al. 2011). Land use and vegetation structure provide a higher amount of disturbances and habitat fragmentation.

We assume that landscape conditions in Eastern Austria enable Curlews to establish larger territories. Higher population densities in Upper Austria (especially “Ibmer Moor”, “Welser Heide” and “Linz-Hörsching”; Uhl 2009) and Salzburg (especially “Oichtenriede”, “Obertrumer See”, “Grabensee” and “Wallersee”; Pöhacker et al. 2014) may force breeding pairs to breed with minor distances to each other. The fenced and treeless meadows at the study sites “Welser-Heide” and “Linz-Hörsching” provide open breeding places with less perching sites for potential avian and mammalian predators (Schuster et al. 2006; Uhl 2009). Furthermore, the periodic meadow operations at both airports favor the search for food of Curlews (Uhl and Wichmann 2013) resulting in colony-like breeding situations (Uhl 2009).

4.1.2 Weather Conditions

The cold April with snowfall changed the territory situation, most notably in Salzburg and Upper Austria. It can be assumed, that a unknown proportion of clutches suffered due to low temperatures and snowfall (Hönisch et al. 2008; Liebel 2015; Robson 1998). The dry month May and June, especially at Lower Austria and Burgenland, might have caused larger territories in Eastern Austria (wetter.com 2018, https:/at.wetter.com/wetter_aktuell/rueckblick/oesterreich/ 20.8.2018; pers. observations). Dryness of former wet meadows is known as cause for food shortage (Engl et al. 2004). Adult Curlews might be forced to forage within a larger range resulting in larger territories.

4.2 Factors influencing Scan Rate

4.2.1 Vegetation Height

The number of scans per minute was significantly affected by vegetation height. A relationship between increasing vegetation height and scan frequency was mentioned by Boschert (1990). We could observe Curlews on areas with vegetation heights >40 cm that overtop the birds. Curlew chicks prefer taller vegetation (O’Brien 2001), e.g. for protection (Valkama et al. 1998). Furthermore, O´Brien (2001) mentioned positive associations between vegetation height and nest position. Contrarily, no significant differences between nest site and vegetation height was found by Robson (1998). We assume that Curlews compensate the decreasing visibility with increasing vegetation height with an increased vigilance. An adaptation on different vegetation heights is likely considering that Curlews have a preference for habitats with a high vegetational heterogeneity and complexity (Buchanan et al. 2017; Franks et al. 2017; Pearce-Higgins and Grant 2006).

4.2.2 Woody Structures

The distance to woody structures between 100-150 m turned out being an important predictor for the scans per minute. The scan rate of Curlews increased with increasing distance to woody structures. According to Glutz von Blotzheim et al. (1986) Curlews breed in glades of open woodlands in exceptional cases. More recent studies mentioned that Curlews tend to avoid woody structures within distances between 20–200 m depending on the type of woody structure (Weiß 2016; Wenger et al. 1991). The observed Curlews in Eastern Austria were observed at a mean distance to woody structures between 98.46 m (Lower Austria) and 214.48 m (Burgenland). Mean distances of Curlews to woody structures in Western Austria ranged between 123.81 m (Salzburg) and 135.97 m (Upper Austria) (see Fig. 15 for examples). Increasing vigilance behavior in waders can be caused by visual obstructions (Beauchamp 2015; Whittingham and Evans 2004). However, we could not detect a greater amount of vigilance behavior of Curlews neither in Western Austria nor in Lower Austria. Adaptations of the duration of scans in case of visual obstruction were mentioned by Whittingham et al. (2004). Therefore, it might be possible that Curlews in regions with less visibility adapt number and duration of scans per minute (Metcalfe 1984). As the later was not considered in our study, this has to remain untested.

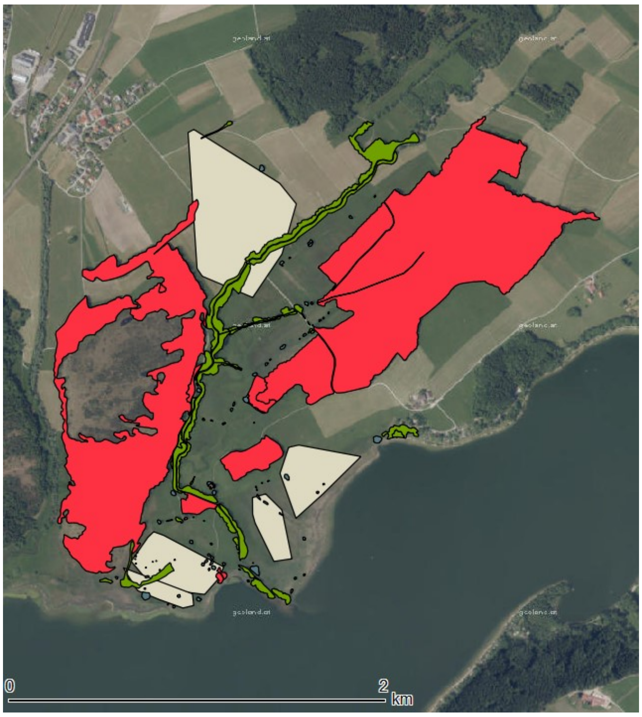


Fig. 15: Examples of two study sites, “Wallersee Wenger Moor” (left) and “Zitzmannsdorfer Wiesen” (right), with different amounts of woody vegetation. Both study sites contain territories with breeding success. Red areas: closed forests and woody structures, Green areas: linear woody structures, Blue areas: single trees and clumps of trees. Delineated Curlew territories are indicated in gray-white. Background map: altered after basemap.at and oriented northward. For coordinates of study sites compare Appendix Table 3.

4.2.3 Territory Size

Territory size emerged as an important predictor for the scan rate resulting in higher scan rates of Curlews with larger territories. Larger territories might be more difficult to overview, and conspecifics breed more apart. Therefore, we assume that Curlews will increase their scan rate to detect potential predators and disturbances in time.

4.2.4 Date

The increasing number of scans per minute shows a weak (non-significant) increase with progressing season. First breeding attempts usually are at the end of April (Glutz von Blotzheim et al. 1986), followed by an incubation period of 27-29 days (von Frisch 1964). The intensity of vigilance behavior in breeding Curlews depends on the current reproductive status at the moment of disturbance caused by humans (Fletcher et al. 2010; Uhl et al. 2010). Therefore, distraction behavior of flying Curlews during the later breeding season could point to fledglings. Non-breeders or unsuccessful breeding pairs did not show an intensive vigilance behavior (Fletcher et al. 2010).

4.2.5 Influence of Behavioral Traits

No significant effects of the amounts of foraging or moving behavior on the number of scans per minute were detected. Curlews are able to continue foraging while increasing their scan rate, by integrating short scans into their foraging techniques (Fitzpatrick and Bouchez 1998). Boschert (1990) mentioned that foraging is indiscernible from scanning behavior. Habituation on disturbances to a certain extent may facilitate continuing feeding, e.g. in the presence of humans (Fitzpatrick and Bouchez 1998). Different types of moving behavior were observed that were not investigated in detail, e.g. returning in crouching posture to the nest, moving during courtship behavior, moving between different foraging sites etc. Therefore, our results indicating a slightly decreased scan rate with increasing amount of moving should be interpreted carefully.

4.2.6 Effect of Conspecifics on Vigilance Behavior

Vigilance behavior is also known to be decreasing with increasing number of conspecifics (Abramson 1979). Also in our study vigilance, measured as scans per minute, was negatively correlated with the number of surrounding conspecifics. In breeding Curlews both partners contribute to egg incubation and raising the offspring, but mostly males are supposed to ensure the territory. They also tend to react with threatening behavior on conspecifics during that time (Glutz von Blotzheim et al. 1986). Overflying or fighting and calling Curlews can lead on to an increasing scan rate of neighboring Curlews (Boschert 1990). Moreover, surrounding Curlews sometimes join other Curlews in mutually attacking avian predators. Contrarily to current literature we could not observe mutual guarding of chicks of two or more Curlew families (Glutz von Blotzheim et al. 1986). In contrast, one Curlew male with two approximately three weeks old chicks reacted aggressively against approaching conspecifics. An increasing aggressiveness in males was also noticed by Currie et al. (2001).

4.3 Distance to Roads

The vast majority of Curlews was observed >150 m apart from roads. Therefore, our data correspond with the current literature. Weiß (2017) observed minimum distances to highly frequented roads of 110 m, mostly >260 m to the potential territory centers. Boschert (1993) reported for the vast majority (76.6%) of clutches distances to nearest roads between 51-300 m. Only few (5.9%) clutches were situated <50 m to nearest roads. However, as disturbance-relevant distances of meadow birds to streets are associated with the disturbance intensity (Vliet et al. 2010), these observations can hardly be generalized.

4.4 Relationship between Scan Rate and Breeding Success

Differences in vigilance behavior of adult Curlews were not related to their breeding success. Glutz von Blotzheim et al (1986) mentioned that Curlews tend to show distraction behavior against avian predators with greater intensity during hatching of chicks. Moreover, vigilant behavior is strongly connected with the reproductive status (Fletcher et al. 2010; Uhl et al. 2010). Fledglings could be only observed in 8 out of 19 successful territories. It can be assumed that not all successful breeding territories with fledglings could be detected during field work. Unfavorable weather conditions (shimmering of light, too great distances) made it difficult to verify breeding success, e.g. by recording hatched chicks. Similar problems were mentioned by Meyer and Jeromin (2016).

4.5 Influences of potential Predators and Disturbances

Marsh Harriers could be observed regularly in all territories of Curlews according to the median of the most frequent observed potential predators in all study sites (Appendix Table 3). According to literature, the "Neusiedler See-Seewinkel" is known as the main area of Marsh Harriers at Burgenland (Gamauf 1992). Marsh Harriers, Common Buzzards and Kestrels occupy larger territories compared to Curlews (Haindl 2013; Norrdahl et al. 1995; Sim et al. 2001). Furthermore, Marsh Harriers are known as reason for collaborative defense behavior of Curlews (von Frisch 1964; Glutz von Blotzheim, et al. 1986). Due to their unique hunting technique of patrolling less than five meters above ground (Altenburg et al. 1982), Marsh Harriers might not be affected by strong wind blows in open landscapes like it is observed in other raptors (Quinn and Cresswell 2004). We assume that Curlews might be more sensitive to hunting Marsh Harriers based on their hunting technique. Carrion Crows densities are often higher in landscapes with a mixture of agricultural areas and forests whereas Jackdaws and Magpies show higher preferences for agricultural landscapes (Andrén 1992). According to Wenger et al (1991), Curlews did not react to approaching Carrion Crows in larger territories. Moreover, the author mentioned regional differences in reactions of Curlews against Carrion Crows. These observations are partially congruent with our data. Curlew did not always react in the same way against approaching Carrion Crows. Burtscher et al. (2011) observed attacks of Curlews against Carrion Crows as well as Curlews unimpressed by Crows in close proximity or overflying.

Cats, dogs and Red Foxes as potential mammalian predators were only observed at a few study sites. Most cats were observed straying nearby farm houses and settlements in Salzburg and Upper Austria. Many studies revealed foxes and mustelids as the main predators of wader nests (Bellebaum and Boschert 2003; Grant et al. 1999; Hönisch et al. 2008; Teunissen et al. 2006; Teunissen et al. 2008). Cats are known to cause an increased aggressive behavior in Lapwings (Puchta et al. 2009). Furthermore, they are known to prey on adult Lapwings as well as on their chicks (Schie et al. 2011). Unfortunately, we could not allocate any amount of vigilance behavior to potential mammalian predators, but we assume that remaining unexplained variance in vigilance behavior can be attributed to an unknown extent to diurnal mammalian predators.

Differences in scan rates were also not related to our calculated predation index. Hence, we assume that territory size may play a greater role for vigilance behavior than the abundance of potential (avian) predators. Human disturbance is often mentioned as a reason for an increased scan rate (Coleman et al. 2003; Fitzpatrick and Bouchez 1998) and cause of prolonged scanning time (Boschert 1990). Curlews may remain in potential suboptimal habitats despite human disturbance due to the absence of more suitable habitats nearby (Beale and Monaghan 2004; Gill et al. 1999). Nevertheless, habituation to human disturbance might by possible (Fitzpatrick and Bouchez 1998; Gómez-Serrano and López-López 2014).

5 Synopsis

Vigilance behavior in Eurasian Curlews seems to depend on various factors including habituation to different types of disturbances and surrounding conspecifics. The most important predictors for the scan rate in breeding Eurasian Curlews appeared to be vegetation height, distance to woody structures and territory size. Curlews may be able to compensate visibility difficulties due to changing vegetation heights by adapting their vigilance behavior. The openness of landscapes in Eastern Austria provide the possibility for Curlews to establish larger territories resulting in increasing scan rates. An increasing vigilance may also compensate the complexity of larger territories. The relationship between breeding success and vigilance behavior might be underestimated in this study because of insufficient data. The occurrence of potential avian predators did not influence the scan rate as expected. Nevertheless, the influence of potential mammalian predators should be further investigated.

6 References

Abramson, M. 1979. *Vigilance as a factor influencing flock formation among Curlews. Ibis* 121: 213–16.

Altenburg, W., S. Daan, J. Starkenburg, and M. Zijlstra. 1982. *Polygamy in the Marsh Harrier, Circus aeruginosus: individual variation in hunting performance and number of mates*. *Behavior* 79: 272–311.

Andrén, H. 1992. *Corvid density and nest predation in relation to forest fragmentation : A landscape perspective*. *Ecology* 73: 794–804.

Bates, D., M. Maechler, B. Bolker, and St. Walker. 2018. "Fitting linear mixed-effects models using lme4." *Journal of Statistical Software*: 1–48. https://github.com/lme4/lme4/.

Bauer, K. 1955. *Die Brutvorkommen des Grossen Brachvogels (Numenius arquata L.) in Österreich*. *Vogelkundliche Nachrichten aus Österreich* 142: 1–6.

Beale, C.M., and P. Monaghan. 2004. *Behavioural responses to human disturbance: A matter of choice? Animal Behaviour* 68: 1065–69.

Beauchamp, G. 2009. *How does food density influence vigilance in birds and mammals? Animal Behaviour* 78: 223–31.

———. 2014. *Social predation: how group living benefits predators and prey.* 1st ed. ed. G Beauchamp. Academic Press.

———. 2015. *Visual obstruction and vigilance: A natural experiment*. *Journal of Avian Biology* 46: 476–81.

Bellebaum, J., and M. Boschert. 2003. *Bestimmung von Predatoren an Nestern von Wiesenlimikolen*. *Vogelwelt* 124: 83–91.

Berg, A. 1992. *Factors affecting nest - site choice and reproductive success of Curlews Numenius arquata on farmland*. *Ibis* 134: 44–51.

Berg, A., T. Lindberg, and K. Gunnar. 1992. *Hatching success of Lapwings on farmland: Differences between habitats and colonies of different sizes*. *Journal of Animal Ecology* 61: 469–76.

Berg, H.M., M. Dvorak, and A. Ranner. 2011. *Die Bedeutung der Leithaniederung (Nordburgenland) als Brut- und Rastgebiet für Limikolen*. *Vogelkundliche Nachrichten aus Ostösterreich* 22: 1–60.

BirdLife International. 2016. *Numenius arquata. The IUCN Red List of Threatened Species 2016: e.T22693190A90101437*. http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22693190A90101437.en.

Boschert, M. 1990. "Brutbiologie und Nahrungsökologie des Großen Brachvogels (Numenius arquata LINNÈ, 1758) in einem Brutgebiet am südlichen Oberrhein." Thesis. Eberhard-Karls-Universität, Deutschland.

Boschert, M., and W. Fiedler. 2009. *Zug in den Süden – Wohin fliegen Große Brachvögel vom badischen Oberrhein nach der Brutzeit? Osnabrücker Naturwissenschaftliche Mitteilungen* 35: 85–90.

Boschert, M. 1993. *Auswirkungen von Modellflug und Straßenverkehr auf die Raumnutzung beim Grossen Brachvogel (Numenius arquata)*. *Zeitschrift für Ökologie und Naturschutz* 2: 11–18.

Buchanan, G.M., J.W. Pearce-Higgins, D.J.T. Douglas, and M.C. Grant. 2017. *Quantifying the importance of multi-scale management and environmental variables on moorland bird abundance*. *Ibis* 159: 744–56.

Calcagno, V. 2015. "*Package glmulti 1.0.7. Model selection and multimodel inference made easy*." *Community Ecology Package*: 1–20.

Coleman, R.A., N.A. Salmon, and S.J. Hawkins. 2003. *Sub-dispersive human disturbance of foraging Oystercatchers Haematopus ostralegus*. *Ardea* 91: 263–68.

Currie, D. et al. 2001. *Sex roles, parental effort and offspring desertion in the monogamous Eurasian Curlew Numenius arquata*. *Ibis* 143: 642–50.

Donnerbaum, K., M. Dvorak, O. Samwald, and W. Pfeifhofer. 2007. *Beobachtungen zu Frühjahrszug, Brutzeit und Herbstzug 2007 sowie Winter 2007/2008 in Ostösterreich Wien, Niederösterreich, Burgenland) und in der Steiermark*. *Vogelkundliche Nachrichten aus Ostösterreich* 18: 1–4.

Dvorak, M. 2009. *Important Bird Areas. Die wichtigsten Gebiete für den Vogelschutz in Österreich*. Wien: Verlag des Naturhistorischen Museums Wien, Wien.

Dvorak, M., A. Landmann, N. Teufelbauer, and G. Wichmann. 2017. *Erhaltungszustand und Gefährdungssituation der Brutvögel Österreichs: Rote Liste (5. Fassung) und Liste für den Vogelschutz prioritärer Arten (1. Fassung)*. *Egretta* 55: 6–42.

Dvorak, M., B. Wendelin, and H. Lehner. 2011. *Die Brutvögel der Zitzmannsdorfer Wiesen in den Jahren 1991 bis 2011 - Auswirkungen von Wiesenrückführungen und Managementmaßnahmen*. Wien.

Eichberger, Ch. et al. 2014. *Landschaftspflegeplan Naturschutzgebiet (NSG) Egelseen unter Einbeziehung eines erweiterten Untersuchungsgebietes in den Gemeinden Mattsee und Schleedorf (Flachgau, Salzburg) - Kurzfassung.* Salzburg.

Engl, M., F. Leibl, and K. Mooser. 2004. *Bestandsentwicklung, Brutbiologie und Reproduktionserfolg des Großen Brachvogels Numenius arquata im Mettenbacher und Grießenbacher Moos, Landkreis Landshut*. *Ornithologischer Anzeiger* 43: 217–35.

Erdelen, M. 1984. *Bird communities and vegetation structure: I. Correlations and comparisons of simple and diversity indices*. *Oecologia* 61: 277–84.

Euller, K. et al. 2014. *Auswirkungen der Beweidung in der Bewahrungszone des Nationalparks Neusiedlersee-Seewinkel - eine statistische Analyse der Vegetationsdaten des Dauerflächenmonitorings*. *Acta ZooBot Austria* 150/151: 41–62.

Evans, A.D. 1988. “Individual differences in foraging behaviour, habitat selection and bill morphology of wintering Curlew, Numenius arquata.” Thesis. University of Edinburgh, Scotland.

Fally, J. et al. 2015. “*Die Landschaften des Burgenlandes mit besonderer Berücksichtigung der botanisch bemerkenswerten Stellen.* – In: Fischer M. A. & al., Burgenlandflora – Die Pflanzenwelt des Burgenlands online. - Eisenstadt: Naturschutzbund Burgenland.” http://burgenlandflora.at/landschaften/#Leithaboden/ downloaded 14.05.2018.

Firbas, W. 1962. *Die Vogelwelt des Machlandes*. *Naturkundliches Jahrbuch* 19: 1–49.

Fitzpatrick, S., and B. Bouchez. 1998. *Effects of recreational disturbance on the foraging behaviour of waders on a rocky beach*. *Bird Study* 45: 157–71.

Fletcher, K. et al. 2010. *Changes in breeding success and abundance of ground-nesting moorland birds in relation to the experimental deployment of legal predator control*. *Journal of Applied Ecology* 47: 263–72.

Franks, S.E., D.J.T. Douglas, S. Gillings, and J.W. Pearce-Higgins. 2017. *Environmental correlates of breeding abundance and population change of Eurasian Curlew Numenius arquata in Britain*. *Bird Study* 64: 393–409.

von Frisch, O. 1964. *Der Große Brachvogel (Numenius arquata L.)*. 2nd ed. Magdeburg.

Gamauf, Anita. 1992. *Status und Verbreitung der Greifvögel in Österreich*. *Egretta* 35: 4–8.

Gill, J.A., K. Norris, and W.J. Sutherland. 1999. *Why behavioural responses may not reflect the population consequences of human disturbance. Biological Conservation* 97: 265–68.

Glutz von Blotzheim, U.N., K.M. Bauer, and E. Bezzel. 1986. *Handbuch der Vögel Mitteleuropas, Band 7: Charadriiformes (2. Teil)*. Wiesbaden Verlag für Wissenschaft und Forschung: AULA-Verlag GmbH.

Gómez-Serrano, M.A., and P. López-López. 2014. *Nest site selection by Kentish Plover suggests a* *trade-off between nest-crypsis and predator detection strategies*. *PLoS ONE* 9: 1–10.

Grant, M.C. et al. 1999. *Breeding success and causes of breeding failure of Curlew Numenius arquata in Northern Ireland*. *Journal of Applied Ecology* 36: 59–74.

———. 2000. *Estimating the abundance and hatching success of breeding Curlew Numenius arquata using survey data*. *Bird Study* 47: 41–51.

Grinschgl, F. 2015. *Artenschutzprogramm Wiesenbrüter in der zentralen Feuchten Ebene Bearbeitungsjahr 2014*. Wien.

Grolemund, G., and H. Wickham. 2011. “Dates and times made easy with lubridate.” *Journal of Statistical Software* 40: 1–25. http://www.jstatsoft.org/v40/i03/.

Gstader, W. 1987. Tiroler Vogelwarte *Vogelkundliche Berichte und Informationen aus Tirol*. Mutters.

Hackländer, K., S. Schneider, and J.D. Lanz. 2014. *Gutachten - Einfluss von Hauskatzen auf die heimische Fauna und mögliche Managementmaßnahmen*. Wien.

Haindl, H. 2013. “Die Rohrweihe - Untergang für die Hasenpopulation !?” Thesis. Universität für Bodenkultur Wien, Österreich.

Halbe, E. 1979. *Eine steirische Zentralkartei ornithologischer Daten*. *Mitteilungen der Abteilung für Zoologie am Landesmuseum Joanneum* 8: 43–68.

Hönisch, B., Ch. Artmeyer, J. Melter, and R. Tüllinghoff. 2008. *Telemetrische Untersuchungen an Küken vom Großen Brachvogel Numenius arquata und Kiebitz Vanellus vanellus im EU-Vogelschutzgebiet Düsterdieker Niederung*. *Vogelwarte* 46: 39–48.

Kuznetsova, A., P.B. Brockhoff, and R.H.B. Christensen. 2017. “lmerTest Package: Tests in linear mixed effects models.” *Journal of Statistical Software* 82: 1–26.

Laber, J. 2003. *Die Limikolen des österreichisch/ungarischen Seewinkels*. *Egretta* 46: 1–91.

Larsen, T., T.A. Sordahl, and I. Byrkjedal. 1996. *Factors related to aggressive nest protection behavior: A comparative study of Holarctic waders*. *Biological Journal of the Linnean Society* 58: 409–39.

Liebel, H. 2015. *6. landesweite Wiesenbrüterkartierung in Bayern 2014/2015: Bestand, Trends und Ursachenanalyse*. Augsburg.

Lima, S.L. 1986. *Distance to cover, visual obstructions, and vigilance in House sparrows*. *Behaviour* 102: 231–37.

Macdonald, M.A., and M. Bolton. 2008. *Predation on wader nests in Europe*. *Ibis* 150: 54–73.

Mammen, U. et al. 2005. 141. BfN-Skripten *Grundlagen und Maßnahmen für die Erhaltung des Wachtelkönigs und anderer Wiesenvögel in Feuchtgrünlandgebieten*. Bonn.

Mason, L.R., J. Smart, and A.L. Drewitt. 2018. *Tracking day and night provides insights into the relative importance of different wader chick predators*. *Ibis* 160: 71–88.

Mather, J.R. 2005. “Beaufort Wind Scale.” In *Encyclopedia of World Climatology*, ed. John E. Oliver. Dordrecht: Springer Netherlands, 156–57.

Metcalfe, N.B. 1984. *The effects of habitat on the vigilance of shorebirds: Is visibility important?* *Animal Behaviour* 32: 981–85.

Meyer, N., and H. Jeromin. 2016. *Gelegeschutzmaßnahmen beim Großen Brachvogel 2016*. Bergenhusen.

Moritz, U. 2006. *Ornitho-ökologische Untersuchung im Naturschutzgebiet / natura 2000 - Gebiet „Wallersee-Wenger Moor" mit besonderer Berücksichtigung der Wiesenbrüter, der Brutvögel des Eis- und Wallerbachs sowie des Wenger Hochmoores (*)*. *Salzburger Vogelkundliche Berichte* 11: 1–13.

Norrdahl, K., J. Suhonen, O. Hemminki, and E. Korpimäki. 1995. *Predator resence may benefit :*

Kestrels protect Curlew nests against nest predators. *Oecologica* 101: 105–9.

O'Brien, M. 2001. "Factors affecting breeding wader populations on ipland farmland in Northern Britain." University of Edinburgh, Scotland.

Pearce-Higgins, J.W., and M.C. Grant. 2006. *Relationships between bird abundance and the composition and structure of moorland vegetation*. *Bird Study* 53: 112–25.

Pöhacker, J., Chr. Medicus, and R. Lindner. 2014. *Wiesenvögel in der Kulturlandschaft-Zeiger für Biödiversität und Nachhaltigkeit*. Salzburg.

Probst, R. et al. 2014. *Literaturstudie Prädation & Vogelschutz*. Wien.

Puchta, A., J. Ulmer, A. Schönenberger, and B. Burtscher. 2009. *Zur Situation des Kiebitzes Vanellus vanellus im Vorarlberger Alpenrheintal*. *Der Ornithologische Beobachter* 106: 275–96.

Pühringer, N., M. Brader, and Chr. Ragger. 2010. *Ornithologische Erhebung Weidmoos*. Salzburg.

QGIS Development Team. 2016. "QGIS user guide Release 2.18." *QGIS Geographic Information System. Open Source Geospatial Foundation Project*. https://www.qgis.org/de/.

Quinn, J.L., and W. Cresswell. 2004. *Predator hunting behaviour and prey vulnerability*. *Journal of Animal Ecology* 73: 143–54.

R Core Team. 2018. "R: A language and environment for statistical computing." https://www.r-project.org/.

Reed, T. M. et al. 1985. *Diurnal variability in the detection of waders on their breeding grounds*. *Bird Study* 32: 71–74.

Robson, G. 1998. "*The breeding ecology of Curlew Numenius arquata on north Pennine moorland*." Ph.D. dissertation. University of Sunderland.

Sachteleben, J. 1993. *Jagdstrategie und Habitatnutzung bei Mäusebussard Buteo buteo und Turmfalke Falco tinnunculus - Konkurrenzvermeidung zweier Greifvogelarten*. *Ornithologischer Anzeiger* 32: 37–43.

Schie, T. van, A. Kant, and R. Messemaker. 2011. 1 *Weidevogels*. Roodbont Publishers B.V.

Schuster, A., M. Strauch, and M. Plasser. 2006. *Die wiedergewonnene Welser Heide! - Der Welser Flugplatz vor dem Hintergrund der Landschaftsentwicklung im Unteren Trauntal (Oberösterreich)*. *ÖKO-L* 28: 3–14.

Schütz, C., and C. Schulze. 2011. *Scanning behaviour of foraging Ruffs Philomachus pugnax during spring migration: is flock size all that matters?* *Journal of Ornithology* 152: 609−616.

Sexton, C. 2017. "*Influence of the disturbance on shorebird behaviour*." Thesis. University College Cork, Ireland.

Sim, I.M.W., A.V. Cross, D.L. Lamacraft, and D.J. Pain. 2001. *Correlates of Common Buzzard Buteo buteo density and breeding success in the West Midlands*. *Bird Study* 48: 317–29.

Südbeck, P. et al. 2005. 1 *Methodenstandards zur Erfassung der Brutvögel Deutschlands*. Vogelwarte Radolfzell: Max-Planck-Insitut für Ornithologie.

Teunissen, W., H. Schekkerman, and F. Willems. 2006. *Predation on meadowbirds in the Netherlands – results of a four-year study*. *Osnabrücker Naturwissenschaftliche Mitteilungen* 32: 137–43.

Teunissen, W., H. Schekkerman, F. Willems, and F. Majoor. 2008. *Identifying predators of eggs and chicks of Lapwing Vanellus vanellus and Black-tailed Godwit Limosa limosa in the Netherlands and the importance of predation on wader reproductive output*. *Ibis* 150: 74–85.

Therneau, T., Th. Lumley, K. Halvorsen, and K. Hornik. 2018. "date: Functions for handling dates." https://cran.r-project.org/package=date.

Tiefenbach, M. 1998. *Naturschutz in Österreich - Monographien Band 91*. Wien.

Treves, A. 2000. *Theory and method in studies of vigilance and aggregation*. *Animal Behaviour* 60: 711–22.

Tubbs, C.R., and M. Tubbs. 1996. *Breeding waders and their habitat in the New Forest, Hampshire, England*. *Wader Study Group Bulletin* 79: 82–86.

Uhl, H. et al. 2005. *Meadow birds in Upper Austria in 2004 - Population trends and importance for nature conservation on the basis of province-wide mapping*. *Vogelkundliche Nachrichten aus Ostösterreich* 13: 117–62.

———. 2009. *Wiesenvögel in Oberösterreich 2008 - Ergebnisse der landesweiten Bestandserhebungen 1994 bis 2008 und Naturschutzbezüge*. Wien.

Uhl, H., and M. Denner. 2015. *Vogelschutzgebiete nach EU-Richtlinie in Österreich: Umsetzungsstand und Handlungsbedarf, speziell für ÖPUL-Förderungen. Studie von BirdLife Österreich im Rahmen eines Projektes für BirdLife International und MAVA Foundation.* Wien.

Uhl, H., M. Plasser, and M. Pollheimer. 2010. *Wissenschaftliche Begleituntersuchung der Auswirkungen des Rockkonzertes der Gruppe AC-DC am Flugplatz Wels - Fachliche Grundlagen für die Erklärung des Gebietes zum Naturschutzgebiet*. Krems/Donau.

Uhl, H., and G. Wichmann. 2013. *Wiesen- und Kulturlandschaftsvögel in Oberösterreich 2011-2013*. Wien.

Valkama, J. et al. 1998. *Habitat selection by breeding Curlews (Numenius arquata) on farmland: The importance of grassland*. *Annales Zoologici Fennici* 35: 141–48.

Valkama, J., D. Currie, and I. Korpimaki. 1999. *Differences in the intensity of nest predation in the Curlew Numenius arquata: A consequence of land use and predator densities? Ecoscience* 6: 497–504.

Vliet, R.E. van der, J.van Dijk, and M.J. Wassen. 2010. *How different landscape elements limit the breeding habitat of meadow bird species*. *Ardea* 98: 203–9.

Wallander, J., D. Isaksson, and Th. Lenberg. 2006. *Wader nest distribution and predation in relation to man-made structures on coastal pastures*. *Biological Conservation* 132: 343–50.

Weiß, I. 2016. UmweltSpezial *Ermittlung der Toleranz von Wiesenbrütern gegenüber Gehölzdichten, Schilfbeständen und Wegen in ausgewählten Wiesenbrütergebieten des Voralpenlandes*. Augsburg.

Wenger, A. et al. 1991. *Artenschutzprogramm Großer Brachvogel im westlichen Niederösterreich 1991 - Bericht 4/1991 Forschungsbericht WWF Österreich*. Wien.

Werndl, M.A., and L. Slotta-Bachmayer. 2004. *Bewertung ausgewählter Wiesengebiete Salzburgs anhand des Vorkommens und der Dichte von Wiesenvögeln*. *Salzburger Vogelkundliche Berichte* 10: 2–35.

wetter.com. 2018. “Jahresrückblick.” https://at.wetter.com/wetter_aktuell/rueckblick/oesterreich/ visited 20.08.2018.

Whittingham, M.J., S.J. Butler, J.L. Quinn, and W. Cresswell. 2004. *The effect of limited visibility on vigilance behaviour and speed of predator detection: Implications for the conservation of granivorous passerines*. *Oikos* 106: 377–85.

Whittingham, M.J., and K. Evans. 2004. *The effects of habitat structure on predation risk of birds in agricultural landscapes*. *Ibis* 146: 210–20.

Wickham, H. 2016. *ggplot2: Elegant graphics for data analysis.* New York: Springer-Verlag New York. http://ggplot2.org.

———. 2018. “A grammar of data manipulation.” https://dplyr.tidyverse.org/.

Wickham, H., L. Henry, and RStudio. 2018. “Easily tidy data with ‘spread()’ and ‘gather()’ functions.” : 1–22. http://tidyr.tidyverse.org/.

Żmihorski, M. et al. 2018. *Habitat characteristics associated with occupancy of declining waders in Polish wet grasslands*. *Agriculture, Ecosystems & Environment* 251: 236–43.

7 Appendix

Appendix Table 1: Study sites with corresponding territory size (ha), territory ID, location of territory within protected area, existence timespan of the territory, presence of chicks/extreme alarm call and respective number of analyzed videos.

State	***Study site***	***Territory size (ha)***	***Territory ID***	***Location of territory within protected area***	***Existence of the Territory***	***Chicks/ Extreme alarm call***	***Analyzed videos***
				Inside + outside -			
Burgenland	Zitzmannsdorfer Wiesen	6.09	3	+	25.03.2017-28.05.2017		1
		6.25	15	+	18.04.2017-05.06.2017		0
		8.54	5	+	25.03.2017-21.05.2017		2
		11.21	4	+	25.03.2017-05.06.2017		5
		14.41	9	+	03.04.2017-05.06.2017	-/+	1
		14.59	7	+	25.03.2017-26.06.2017	+/+	0
		21.15	6	+	25.03.2017-12.06.2017		0
		34.87	8	+	25.03.2017-12.06.2017	-/+	0
		46.42	10	+	25.03.2017-21.05.2017		1
	Hanság	3.03	25	+	21.04.2017-19.05.2017		0
		3.33	24	+	04.04.2017-23.06.2017	-/+	3
		5.22	27	+	13.04.2017-12.05.2017		3
		5.86	21	+	04.04.2017-23.06.2017	+/+	3
		6.34	16	+	04.04.2017-21.04.2017		0
		7.52	18	+	04.04.2017-01.06.2017		0
		8.59	17	+	04.04.2017-12.05.2017		0
		8.98	23	+	04.04.2017-16.06.2017	-/+	2
		11.38	26	+	04.04.2017-08.06.2017	-/+	1
		15.08	22	+	13.04.2017-16.06.2017		2
		27.22	20	+	04.04.2017-23.06.2017	+/+	2
		31.33	19	+	04.04.2017-16.06.2017	-/+	1
	Sandeck-Illmitz	4.99	13	+	28.04.2017-01.06.2017		0
		6.88	11	+	21.04.2017-25.05.2017		0
		7.42	12	+	05.05.2017-16.06.2017		1
	Leitha-Auen	8.08	30	+	10.04.2017-22.05.2017	-/+	0
		8.53	33	+	31.03.2017-22.05.2017		8
		10.68	32	+	31.03.2017-01.05.2017		1
		11.59	28	+	31.03.2017-11.06.2017	-/+	2
		15.19	31	+	02.04.2017-25.06.2017	+/+	1
		17.23	34	+	31.03.2017-11.06.2017		0
		30.22	29	+	02.04.2017-15.05.2017		0
Lower Austria	Moosbrunn-Herrngras	23.67	1	+	24.03.2017-04.06.2017	-/+	9
	Bachlüsse-Lange Mahden	2.79	2	+	24.03.2017-22.05.2017		3
Upper Austria	Welser Heide	1.94	90	+	02.05.2017-13.06.2017	-/+	0
		2.02	46	+	06.04.2017-22.05.2017		0
		2.13	41	+	06.04.2017-30.05.2017		2
		3.79	44	+	28.03.2017-21.06.2017	-/+	0
		3.99	45	+	06.04.2017-26.06.2017	+/+	1
		4.48	43	+	06.04.2017-10.05.2017		6
		4.68	42	+	28.03.2017-10.05.2017		7
	Linz-Hörsching	2.51	38	-	06.04.2017-10.05.2017		1
		3.98	40	-	28.03.2017-10.05.2017		2
		4.95	39	-	12.04.2017-02.05.2017		2
		5.30	37	-	28.03.2017-30.05.2017		0
		7.73	35	-	06.04.2017-22.05.2017		4
		11.68	36	-	06.04.2017-30.05.2017		0
	Ibmer Moor	1.07	53	+	21.03.2017-25.04.2017		1
		1.11	56	+	02.05.2017-30.05.2017		1
		1.27	59	+	21.03.2017-30.05.2017		0
		1.31	55	+	25.04.2017-23.05.2017		6
		2.10	57	+	25.04.2017-05.06.2017		2
		2.45	87	+	25.04.2017-23.05.2017	+/-	0
		2.79	89	+	02.05.2017-23.05.2017		0
		3.19	88	+	02.05.2017-12.06.2017		0
		4.55	54	+	03.04.2017-12.06.2017	-/+	6
		6.66	58	+	21.03.2017-16.05.2017		5
		7.66	60	+	11.04.2017-30.05.2017		2
	Irrsee north	0.69	86	+	10.05.2017-21.06.2017	+/+	4
		2.67	48	+	29.03.2017-21.06.2017	-/+	5

		3.72	47	+	29.03.2017-21.06.2017	-/+	5
	Irrsee middle	0.98	50	+	12.04.2017-17.05.2017		6
		2.24	49	+	29.03.2017-29.05.2017		0
	Irrsee south	2.19	51	+	29.03.2017-21.06.2017	+/+	13
		7.59	52	+	29.03.2017-19.04.2017		4
	Grabensee	3.50	63	-	22.03.2017-05.06.2017		16
	Zeller Ache	0.11	61	-	04.04.2017-03.05.2017		5
Salzburg	Oichtenriede	1.09	80	+	22.03.2017-02.05.2017		1
		1.17	85	+	03.04.2017-12.06.2017	-/+	4
		3.05	82	+	22.03.2017-30.05.2017		6
		3.23	81	+	22.03.2017-12.06.2017		0
		3.35	83	-	11.04.2017-09.05.2017		2
		3.92	84	+	22.03.2017-27.06.2017	-/+	9
	Obertrumer See north	1.05	65	+	03.04.2017-05.06.2017	-/+	7
		4.04	64	+	22.03.2017-05.06.2017		10
		4.13	91	+	18.04.2017-12.06.2017		1
	Obertrumer See south	8.49	67	+	11.04.2017-27.06.2017	+/-	11
	Wallersee Wenger Moor	1.39	72	+	02.04.2017-04.06.2017		4
		2.05	70	+	22.03.2017-29.05.2017		7
		3.97	69	+	22.03.2017-11.06.2017		12
		4.42	71	+	10.04.2017-15.05.2017	-/+	2
		14.87	68	+	22.03.2017-04.06.2017		17
	Wallersee Bayerhamer Spitz	0.65	74	+	22.03.2017-15.05.2017		5
		0.82	73	+	22.03.2017-15.05.2017	-/+	1
		0.83	75	+	02.04.2017-17.04.2017		4
		2.29	76	+	10.04.2017-11.06.2017		10
	Wallersee Fischtagginger Spitz	0.82	78	+	02.04.2017-22.05.2017		1
		0.98	77	+	02.04.2017-11.06.2017		5
	Weidmoos	5.24	62	+	03.04.2017-30.05.2017		2
	Fuschlsee	0.14	79	+	12.04.2017-24.04.2017		2

Appendix Table 2: The calculated Median of the most frequent observed potential predators during field work in all study sites. Numbers in brackets represent the actual predation risk resulting from the multiplication of predation index and respective median of the potential predator. Sum of the calculated predation index summarized for the observed potential predators (n = 16) at the study sites (n = 24) is printed in bold.

state	***Studysite***	***Carrion Crow***	***Rook***	***Jack-daw***	***Eurasian Jay***	***Magpie***	***Kestrel***	***Common Buzzard***	***Marsh Harrier***	***Hen Harrier***	***Mon-tagus´s Harrier***	***Black Kite***	***Great Egret***	***Grey Heron***	***Black-headed Gull***	***Mus-telids***	***Feral Cat***	***Sum preda-tion index***
	Predation Index	**3**	**2**	**1**	**1**	**1**	**2**	**2**	**3**	**2**	**2**	**3**	**2**	**3**	**1**	**3**	**3**	
Burgenland	Zitzmanns-dorfer Wie-sen	2 (6)	2 (4)			1 (1)	1 (2)	1 (2)	1 (3)				1 (2)		5 (5)			**26**
	Hanság	1 (3)					1 (2)	1 (2)	1 (3)		1 (2)		1.5 (3)			1 (3)		**18**
	Sandeck-Illmitz	1 (3)	2 (4)				1 (2)	1 (2)	1 (3)				2 (4)		2 (2)			**21**
	Leitha-Auen	2 (6)					1 (2)	1 (2)	1 (3)	1.5 (3)			1 (2)	1 (3)	1 (1)			**22**
Lower Austria	Moosbrunn-Herrngras	1 (3)			2 (2)	1.5 (1.5)	1 (2)	1 (2)	1 (3)					1 (3)				**16.5**
	Bachlüsse-Lange Mahden	3 (9)					1 (2)			1 (2)								**13**
Upper Austria	Welser Heide	2 (6)		3 (3)			1 (2)											**11**
	Linz-Hörsching	1 (3)	1.5 (3)				1 (2)	1 (2)			1 (2)							**12**
	Ibmer Moor	1.5 (4.5)		5 (5)	1.5 (1.5)		1 (2)	1 (2)				1(3)		1(3)	2 (2)	1 (3)		**26**
	Irrsee north	1 (3)					1 (2)											**5**
	Irrsee middle																	**0**
	Irrsee south	1.5 (4.5)		3 (3)			1 (2)	2 (4)					1 (2)	1(3)			1 (3)	**21.5**
	Grabensee	2.5 (7.5)		5 (5)		1.5 (1.5)	2 (4)											**18**
	Zeller Ache	2 (6)																**6**
Salzburg	Oichten-riede	1 (3)		1 (1)			1 (2)	1 (2)										**8**
	Obertrumer See north	1 (3)			1 (1)	1.5 (1.5)	1 (2)					1 (3)		4 (12)	2 (2)			**24.5**
	Obertrumer See south	1.5 (4.5)			1 (1)			1.5 (3)						1.5 (4.5)				**13**
	Wallersee Wenger Moor	2 (6)		6 (6)	1 (1)	1 (1.5)	1 (2)	1 (2)	1(3)				2 (4)	1 (3)	2 (2)			**30.5**
	Wallersee Bayerham-er Spitz	1 (3)	1 (2)			2 (2)	1 (2)	1 (2)	1 (3)			1 (3)		1 (3)			1 (3)	**24**
	Wallersee Fischtag-ginger Spitz	1 (3)				2 (2)												**5**
	Weidmoos	3 (9)			1 (1)		1.5 (3)								1 (1)			**14**
	Fuschlsee																	**0**

Appendix Table 3: Observation dates, nearest reference location including coordinates (N/E) and altitude (m) of the study sites (n = 25). Furthermore, last evidence of Eurasian Curlews *(Numenius arquata)* at the particular study site and estimated number of territories. Estimated number of territories of Eurasian Curlew was defined after recommendation in Bibby (1995). Number in brackets suggests potential number of territories in total (including territories outside the study sites). The study sites "Irrsee" north, middle and south are summarized as "Irrsee". Altitudes and coordinates after mapcarta.com (visited 14.05.2018).

State	***Study area***	***Reference location***	***Coordinates (N/E)***	***Altitude (m)***	***Observations***	***Last evidence of Curlew***	***Est. no. of territories***
Burgen-land	Zitzmannsdorfer Wiesen	Neusiedler Wiesen	47.8919°/16.8697°	117	25.03.- 26.06.2017	26.06.2017	9
	Hanság	Kommassantenwiesen	47.7319°/ 17.0361°	113	25.03.- 30.06.2017	30.06.2017	12 (18)
	Sandeck-Illmitz	Illmitz	47.7615°/ 16.8002°	120	25.03.- 30.06.2017	30.06.2017	4
	Leitha-Auen	Leithawiesen	48.0167°/ 17.0603°	131	31.03.- 25.06.2017	25.06.2017	7
Lower Austria	Moosbrunn-Herrngras	Herrngras	48.0061°/ 16.4622°	181	24.03.- 25.06.2017	18.06.2017	(>)1
	Bachlüsse-Lange Mahden	Bachlüsse	48.0067°/ 16.4942°	176	24.03.- 11.06.2017	22.05.2017	1
	Brunnlust	Moosbrunn	48.0167°/ 16.45°	183	24.03.- 15.05.2017	-	?
Upper Austria	Welser Heide	Wels airport	48.1833°/ 14.0409°	317	28.03.- 25.06.2017	25.06.2017	7
	Linz-Hörsching	Linz airport	48.2332°/ 14.1875°	298	28.03.- 26.06.2017	26.06.2017	6
	Ibmer Moor	Hackenbuch	48.044°/ 12.9477°	423	21.03.- 27.06.2017	27.06.2017	11
	Irrsee	Zell am Moos	47.9° /13.3167°	574	29.03.- 26.06.2017	26.06.2017	3/2/2
	Grabensee	Rödhausen	48,0027°/ 13,0999°	520	22.03.- 27.06.2017	05.06.2017	1
	Zeller Ache	Mondsee	47.8565°/ 13.3491°	493	29.03.- 29.05.2017	10.05.2017	1
Salzburg	Oichtenriede	Michaelbeuern	48,0167°/ 13,0333°	422	22.03.- 27.06.2017	27.06.2017	6
	Obertrumer See north	Zellhof	47,9833°/ 13,1°	504	22.03.- 27.06.2017	12.06.2017	3
	Obertrumer See south	Obertrum am See	47,9372°/ 13,0772°	508	22.03.- 27.06.2017	27.06.2017	1
	Egelseen-Schleedorf	Obernberg	47,9667°/ 13,1167°	622	29.03.- 11.04.2017	-	?
	Wallersee-Wengermoor	Weng	47,9333°/ 13,1833°	510	22.03.- 26.06.2017	11.06.2017	5
	Wallersee-Bayerhamer Spitz	Bayerham	47,9167°/ 13,1457°	556	22.03.- 26.06.2017	21.06.2017	4
	Wallersee-Fischtagginger Spitz	Seekirchen am Wallersee	47,9°/ 13,1333°	510	22.03.- 26.06.2017	21.06.2017	2
	Weidmoos	Maxdorf	48,0167°/ 12,95°	425	03.04.- 22.06.2017	30.05.2017	1
	Fuschlsee	Hotel Schloss Fuschl	47.8086°/ 13.2562°	673	22.03.- 11.06.2017	15.05.2017	1

Appendix Table 4: Showing the correlation coefficients of different variables considered for the basic generalized linear mixed model evaluating effects of variables on scans per minute of the Eurasian Curlew. Critical values are marked red. Bold variables were included in the basic glmm. Abbreviations: Terrid = territory ID, Terrisize = territory size (log), Roads = distance to roads, Woody = distance to woody structures, Veg height = vegetation height, Numb Curl = numbers of Curlews, Foraging = foraging behavior, Comfort = comfort behavior, Moving = moving behavior, Spm = scans per minute, Reprosuc = reproduction success, Date = date of observation. Categories calculated as numerics (function “as.numerics”, R base Package, R Core Team 2018).

	Terri size	*Roads*	***Woody***	***Veg height***	***Numb Curl***	***Foraging***	*Comfort*	***Moving***	***Spm***	*Reprosuc*	***Date***
Terriid											
Terri size	1										
Roads	-0.06470677	1									
Woody	0.07259679	0.276967699	1								
Veg height	-0.03798944	0.028708950	0.110037910	1							
Numb Curl	-0.05645923	-0.072569375	0.023402280	-0.002043961	1						
Foraging	0.25945649	0.052969744	0.002026849	-0.092703822	0.008709158	1					
Comfort	-0.12768428	-0.025951715	0.002339552	-0.041310835	0.087996683	-0.325541623	1				
Moving	-0.04578606	-0.107002578	-0.083833944	-0.052942377	0.012628330	-0.163274068	-0.555361770	1			
Spm	0.23896669	0.087364866	0.124062347	0.051366948	-0.125159572	0.141761179	-0.192868652	-0.01538870	1		
Reprosuc	0.22820266	-0.082887080	-0.015168246	0.086711607	-0.050146915	0.012432284	-0.046338573	-0.03478446	0.0417810	1	
Date	0.05341272	-0.001337719	0.018500402	0.018500402	0.164348293	-0.046222591	0.019565411	-0.157991998	-0.02708803	0.12252911	1

Appendix Table 5: The best 6 models selected automatically by “glmulti” ranked after the AIC criterion within a range of 2 degrees AIC.

Ranking	***Model***	***AIC***	***Weights***
1	spm ~ 1 + distance_woody + catveg + foraging + logterrisize + number_of_curlews	1746.101	0.18544489
2	spm ~ 1 + distance_woody + catveg + foraging + logterrisize + date_of_observations + number_of_curlews	1746.765	0.13300162
3	spm ~ 1 + distance_woody + catveg + logterrisize + number_of_curlews	1747.437	0.09506439
4	spm ~ 1 + distance_woody + catveg + foraging + logterrisize	1747.536	0.09047006
5	spm ~ 1 + distance_woody + catveg + logterrisize + date_of_observations + number_of_curlews	1747.976	0.07262457
6	spm ~ 1 + distance_woody + catveg + foraging + logterrisize + date_of_observations	1747.995	0.07193951

Appendix Table 6: Behavioral traits of Eurasian Curlews recorded in the field. Altered after von Frisch (1964).

	Behavior	Subtypes		Definition
1.	**Vigilance**	"Scan"	-	head lifts from a foraging position
			-	bill above horizontal line (only if case 9B is not working)
			-	turning of head without change of direction
2.	**Sounds**	A - "Triller"	-	in case of landing
			-	welcoming of the partner
			-	attacks of conspecifics from other territories
			-	after expulsion of predators
		B - "Gugen"	-	during territory marking flights of ♂
		C - "Warnruf"	-	"Vorwarnruf" – "Gúig-gúig" in case of weak disturbance in the territory
			-	"Warnen" – "Guí-guíg" in case of approaching predators to nest/chicks, often in combination with circling flights around the nest
		D - "Kükenwarnruf"/extreme alarm call	-	shortly before or during hatching of chicks, very loud and percing – "Gügügügügügüg"
		E - "Begattungslaut"	-	during mating – "Gri-gri-gri"
		F - "Zärtlichkeitslaut"	-	nest take over or welcoming of the partner – "Gui" or "Bui"
		G – "Angstlaut"	-	broad and throaty "Kräău" or "Aääeuü"
		H – "Weinen"	-	in case of distraction – "Büüüüöööö-büüüüöööö"
		I – "Zugruf"	-	"Guui-güü" or "Gääiü"
3.	**Defense of territory – active and demonstrative**	A - "Revierflug" (♂)	-	flying up and down in combination with "Gugen"
		B – "Drohen" (♂)	-	protruding of the thorax
			-	bill is turned down
			-	tail feathers widespread
		C- "Scheinkampf"	-	biting of grass instead of attacking the rival
		D – "Fluchthaltung" (passive defense)	-	thorax upright
			-	neck vertical
			-	bill horizontal or lightly lifted up
		E – "Kampf"	-	wing beats
			-	bill beats
			-	leg kicks
4.	**Mating behavior**	A – "Aufforderung"	-	♂ rounds ♀
			-	"Zärtlichkeitslaut"
			-	♂ moves primaries if ♀ is waiting for him
		B – "Begattung"	-	♂ with "Begattungslaut", picking at ♀ tail feathers
			-	♂ jumping on back of ♀, picking at head and neck feathers, "Begattungslaut"
5.	**Nesting behavior**	A – "Nestbildung"	-	♂ pressing and turning its thorax at hollow on ground, leg kicks
		B – "Brüten"	-	♂/♀ with swinging movement while settling on nest
			-	♂/♀ with laying back
			-	♂/♀ with panting through the bill
			-	♂/♀ with short changes of position
6.	**Foraging behavior**		-	picking on the ground for food
			-	head and bill turned down
7.	**Comfort behavior**		-	preening
8.	**Resting**		-	head is laid back
9.	**Movement**	A – "Flug"		
		B – "Am Boden"		

<u>Appendix 7:</u> Exemplary pictures of the study sites across the federal states of Austria.

App. 1: Study site Zitzmannsdorfer Wiesen, Burgenland.

App. 2: Study site Leitha-Auen, Burgenland.

App. 3: Study site Hanság, Burgenland.

App. 4: Study site Sandeck-Illmitz, Burgenland.

App. 5: Study site Moosbrunn-Herrngras, Lower Austria.

App. 6: Study site Bachlüsse Lange-Mahden, Lower Austria.

App. 7: Study site Linz-Hörsching, Upper Austria.

App. 8: Study site Welser Heide, Upper Austria.

App. 9: Study site Irrsee south, Upper Austria.

App. 10: Study site Ibmer Moor, Upper Austria.

App. 11: Study site Grabensee, Upper Austria.

App. 12: Study site Wallersee Bayerhamer Spitz, Upper Austria.

App. 13: Study site Fuschlsee, Salzburg.

App. 14: Study site Obertrumer See south, Salzburg.

App. 15: Study site Obertrumer See north, Salzburg.

App. 16: Study site Oichtenriede, Salzburg.

Appendix 8:

Mit Unterstützung von Bund und Europäischer Union

Bundesministerium
Nachhaltigkeit und
Tourismus

LE 14-20
Entwicklung für den Ländlichen Raum

Europäischer
Landwirtschaftsfonds für
die Entwicklung des
ländlichen Raums:
Hier investiert Europa in
die ländlichen Gebiete.