Conservation success or increased crop damage risk? The Natura 2000 network for a thriving migratory and protected bird

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ABSTRACT

Protected areas are important to support biodiversity and endangered species. However, they are often too small to fulfill the resource requirements of many large and mobile wildlife species, especially when congregating in large numbers. In such cases, wildlife may overflow onto surrounding human-dominated land and cause impacts. The aim of the EU Natura 2000 network is to increase supranational connectivity between protected areas for migratory and protected species such as the common crane (*Grus grus*). The crane population along the Western European flyway has been increasing rapidly in recent decades, with peaks of 200,000 cranes at specific Natura 2000 sites. We studied 32 GPS-tagged cranes over four migration periods, to test the use of the network by cranes and the potential for impacts on adjacent farmland. During the nighttime, the probability that roosting cranes were located on Natura 2000 sites was 97%. During daytime, the probability of foraging cranes being located on arable land was 68%. The probability of foraging cranes occurring on agricultural fields close to Natura 2000 sites decreased with distance. Such foraging patterns may fuel conflicts between conservation and agricultural objectives. To resolve these conflicts we suggest improved cross-boundary collaboration and policy development among involved states, combined with stakeholder participation to implement effective compensation and damage prevention strategies which are focused upon networks of protected areas.

1. Introduction

The protection of important habitats is one of the most common measures to preserve biodiversity globally. However, protected areas are often too small to fulfill resource requirements of large and mobile wildlife species and connectivity of protected areas along wildlife pathways is often deficient (Runge et al., 2015). As a consequence, wildlife frequently utilize human-dominated lands outside protected areas, causing conflicts between conservation and other land use objectives (Balme et al., 2010; Nilsson et al., 2016; Redpath et al., 2013; Runge et al., 2015). Thus, the conservation of mobile and migratory wildlife species is challenging due to their extensive space use, seasonal resource needs and impact on human land use (Runge et al., 2015).

Large-scale conservation agreements have been initiated to protect migratory species at a supranational level, e.g., Convention on the Conservation of Migratory Species (EEC, 1992), Agreement on the Conservation of African-Eurasian Migratory Waterbirds (UNEP, 2016)

and the Convention on the Conservation of European Wildlife and Natural Habitats (Council of Europe, 1982; Kark et al., 2015). Except for the European Union Natura 2000 network (hereafter N2K) (EC, 2016; Orlikowska et al., 2016) the coordinated implementation of these initiatives is generally lacking. The N2K is the world's largest network of protected areas and covers 18% of the 28 EU member states' land (EC, 2016). To ensure functional habitat connectivity and long-term population viability of migratory and rare species listed in the EU Birds Directive and Habitats Directive (EC, 2016), the aim of the network is to halt biodiversity loss by protecting important breeding and staging sites. Its effectiveness in reaching these aims has been debated and criticized due to low connectivity between N2K sites caused by insufficient coordination between member states during implementation (Gruber et al., 2012; Opermanis et al., 2012). The N2K is not a network of strict protection, but includes human land use, such as sustainable agriculture and forestry (EC, 2016). Conflicts between conservation and other land use are still common due to land use restrictions such as
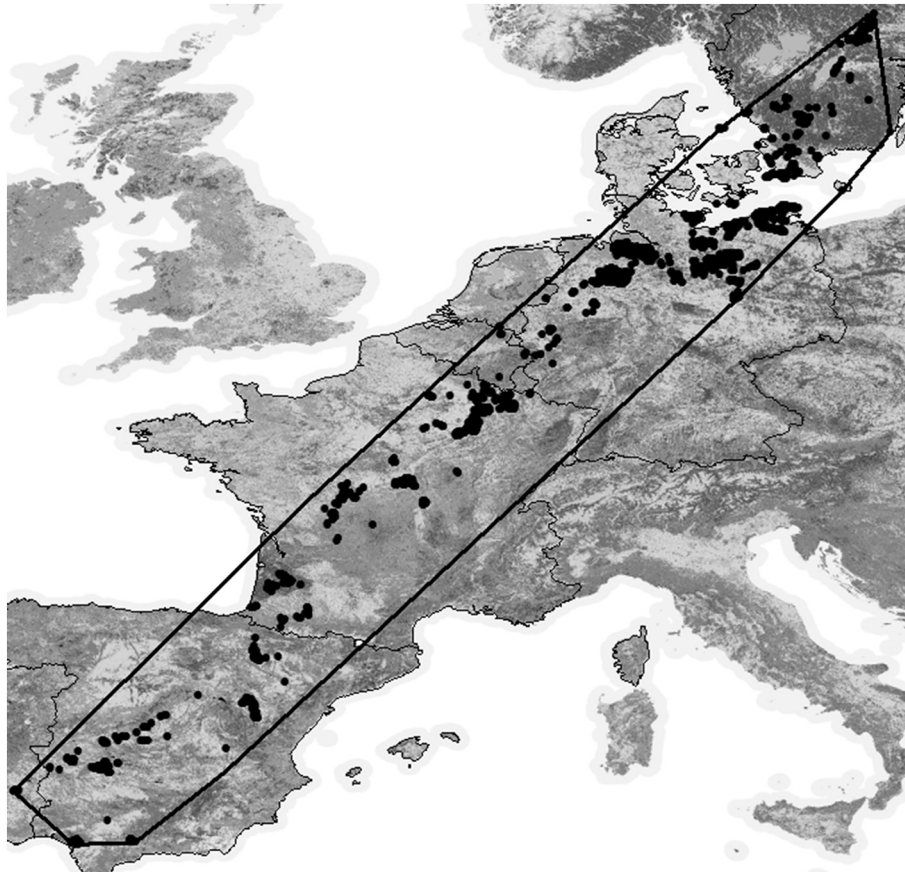

Fig. 1. The migratory route of the 32 cranes equipped with GPS transmitters, defined as a minimum convex polygon (MCP 100%) of the migratory and staging locations.

grazing regimes and water rights (Blicharska et al., 2016) and damage caused by protected species in surrounding farmlands (Nilsson et al., 2016). This may risk the intended goals of socio-economic sustainability. The majority of previous scientific studies of the effectiveness of the N2K network has been limited to regional or national scales and only a few studies have covered several EU member states or the range of migratory species (Orlikowska et al., 2016).

The common crane (*Grus grus*, hereafter crane) is an iconic species of conservation importance and is included in Annex I of the Birds Directive since 1979. At the time of protection, cranes were rare due to hunting and wetland degradation, but numbers have recovered rapidly since 1979 and the most recent population estimate along the Western European flyway is ~500,000 individuals (Harris and Mirande, 2013). Currently, large numbers of cranes congregate at protected staging sites, including N2K sites such as Lac du Der-Chantecoq, France, where peaks of 200,000 cranes have been reported ("Grus-grus.eu," 2016). Similar to other large herbivorous birds (e.g. geese (*Anser* and *Branta* spp.) and swans (*Cygnus* spp.)), cranes divide their time between wetland sites where they roosts at night and adjacent arable land where they forage during daytime (Alonso et al., 1983). Increasing populations of cranes, geese and swans often cause damage to crops by foraging, probing and trampling on pre-harvest grasslands, cereals, maize and potatoes, leading to conflicts between agricultural and conservation objectives (Frank et al., 2018; Nowald, 2010; Salvi, 2010). However, cranes commonly also forage on post-harvest remains on stubble fields, where they do not cause crop losses (Nilsson et al., 2016). Following the increase in crane numbers, costs for damage compensation and preventive measures have increased in Europe. For example, the compensation for harvest losses, due to cranes, to farmers around Lac du Der-Chantecoq in France totalled 190,000 € over 2005–2008 (Salvi, 2010) and 400,000 € in Sweden in 2017 (Frank et al., 2018).

The goal of this study was to evaluate both the use of N2K network in providing important habitat for migratory large herbivorous birds and the probability of birds utilizing adjacent farmland along the flyway. We used cranes as a model species and used location data from GPS-tagged individuals from 2012 to 2015 to address the following questions: 1) Does the probability of crane presence differ between areas within and outside N2K sites and across habitats? 2) Does the probability of crane presence at a landscape level decrease with increasing distance to N2K sites?, and 3) is the probability of crane presence higher in N2K sites that were specifically initiated for crane conservation?

2. Methods

2.1. Data collection

We used location data from 32 juvenile cranes equipped with backpack-GPS-transmitters (Vectronics GPS-plus and Cellular Tracking Technologies (CTT)) captured during 2012–2015 in the surroundings of Tranemo (57°29′N/13°25′E) (*n* = 9) and Grimsö (59°43′N/15°28′E) (*n* = 23), Sweden. The territories and available juvenile cranes were first identified from a car during a fixed route. The juvenile cranes were then captured by hand after a fast run from a car or a hide (Månsson et al., 2013). The juveniles were tagged in July to early August, just before fledging, at an estimated age of 6–8 weeks and weighed 2800–4350 g. No separation between parents and chicks was seen following capture and release. The family groups (i.e., the fledged juvenile crane, parental pair and occasionally one other sibling) migrated southwards in late August or early September. The capture procedure fulfilled ethical requirements and was approved by the Animal Ethics Committee of central Sweden (C104/10 and C53/13).

We used a resource selection function to explore whether N2K sites were selected by individual cranes during migration and wintering (1st September to 31st March 2012–2016). We compared used locations with randomly distributed locations (hereafter; available locations) within the flyway (i.e., relative probability of habitat use in relation to availability; Lele & Keim 2006). The flyway was defined as the minimum convex polygon of all terrestrial locations (Fig. 1). Less precise locations, i.e., locations derived from only two satellites (2D) and locations with dilution of precision (DOP) > 7, were excluded to assure high precision (D'eon and Delparte, 2005). The mean number of used locations per individual was 508, although it ranged from 114 to 4986 due to varying lifetime of GPS transmitters. The lifetime of the GPS transmitters allowed us to follow all the individuals during parts of (n_{ind} = 32) or their complete first migration and winter period (n_{ind} = 22) and for some individuals also during the second (n_{ind} = 6) and the third period (n_{ind} = 4). The family group normally separates at the wintering sites during the first migration period, as the parents usually head northwards earlier than the juveniles (Alonso et al., 1984). Following juveniles and their family groups may limit generality as behavior may differ between different age groups (Alonso et al., 2004). However, juveniles, family groups and pairs without chicks congregate in larger flocks during the non-breeding period, i.e., during the first fall migration (Aviles, 2003). Family groups constitute of about 30% of the population at staging sites in Sweden (Nilsson, 2016).

We programmed Vectronic transmitters to send locations at 0700, 1100, 1500 and 2300 UTC time. The CTT transmitters had recharging solar panels and could thus position continuously during daytime. To match the time intervals of the Vectronic transmitters, the closest time to 0700, 1100, 1500, 2300 UTC time was also used for the CTT transmitters. To study differences between daytime activities and night roosting, we defined daytime and roost locations from the time of sunrise and sunset at each site respectively. To ensure correct classification, we excluded locations within 30 min before and after sunrise and sunset, as the majority of cranes depart and arrive to the roost during this time frame (Alonso et al., 1985). Remaining locations between sunset and sunrise were assigned as 'night roost' (27% of locations) and the rest as 'day' (73% of locations). We also removed locations for which we could assume that cranes were in migratory flight between staging sites based on a maximum step length between consecutive locations of > 20 km. The step length definition was based on visual observations of daily flights from roost to adjacent foraging sites in ArcGIS (version 10.3.1).

To assure representative sampling of variability in the available locations within the migration corridor, we used twice as many available locations (n_{avail} = 37,096), compared to used locations (n_{used} = 18,548), as recommended by Northrup et al. (2013). Cranes normally fly the shortest distance between staging sites, but the migratory route may vary due to factors such as wind direction (Mingozzi et al., 2013). We thus aimed to be liberal in sampling available habitats for the individual cranes during migration. One underlying assumption of resource selection functions is that the randomly distributed locations should be available at every point of time for the respective individual. To fulfill this assumption, the available locations were derived by randomly generating locations within the flyway (Fig. 1) in ArcGIS but were stratified across countries in proportion to the used locations for each respective individual. Moreover, the available locations were also randomly defined as roost and daily locations in proportion to the sample of used locations for each individual.

The Natura 2000 network is comprised of Special Protection Areas (SPAs) for species listed in the Birds Directive and Special Areas of Conservation (SACs) and Sites of Community Importance (SCIs) for species and habitats listed in the Habitats Directive. As cranes are listed in the Birds Directive, we excluded sites that were exclusively assigned under the Habitats Directive, i.e., SACs and SCIs, in this study. Habitat characteristics for all locations were derived from the Corine Land Cover data (0.1 × 0.1 km) (EEA, 2006) and were lumped into the

habitat categories arable, wetland/water and other land (Table S1). The locations were classified as inside or outside N2K sites (binomial) (EEA, 2016a) and for locations within N2K sites also site type (SPA or SPA & SAC/SCI) and if cranes were listed as targeted species in the site-specific management plan was noted (binomial) (EEA, 2016b). For daytime locations outside N2K sites, distance to the nearest N2K site was assessed in ArcGIS (version 10.3.1).

Another important assumption of resource selection functions is independency between locations, which may be complex to fulfill, especially when using GPS locations derived from individuals. The complexity is mainly due to two aspects; the variability in number of locations per individual and a risk that individuals select for the same sites (i.e., inter-individual correlation) as well as autocorrelation in consecutive locations for an individual (i.e., intra-individual correlation) (Boyce, 2006; Fieberg et al., 2010). Autocorrelation between locations (i.e., inter-individual and intra-individual) may cause underestimation of variance around the model estimates. The potential inter-individual correlation is accounted for by including ID as random effect (see next section). Commonly used correlation structures in modelling to address concerns of intra-individual autocorrelation (e.g. corARMA in R) are not suitable for resource selection functions due to the use-availability design where only the used locations may be autocorrelated (Fieberg et al., 2010). Therefore, to address the potential issue of intra-individual autocorrelation, the data in our study was subsampled to include only three daytime locations (~4 h fix rate) and one night location. By doing so we achieved a step length of in average 2.9 km (95% CI: 2.4–3.0, excluding migratory flights > 20 km) between two consecutive locations. That is ~30 times the length of the raster pixel size of our used habitat data (0.1 × 0.1 km). We assumed that this allows individuals to have time to select an alternative and independent site between two consecutive locations (Gillies et al., 2006). To address whether inter-individual correlation, i.e., that cranes may have been part of the same flock, was a potential issue, we calculated distances between individuals for the GPS locations taken within 15 min. We found that only 1.7% of the locations of the GPS tagged individuals was within 0.3 km from other tagged individuals. The median distance between the tagged individuals was 348 km (range 0–2984 km). We therefore concluded that there was a very low probability of dependence when selecting for foraging and roost sites.

2.2. Statistical analysis

Site selection was analyzed by using a resource selection function, where used locations were compared to the randomly stratified 'available' locations, i.e., looking for disproportional use in comparison to availability in the landscape (Lele and Keim, 2006). As we could not exclude the possibility that available locations were actually used by cranes (Lele et al., 2013; Lele and Keim, 2006), we assessed relative resource selection estimates (i.e., RSF scores). Relative RSF scores do not give the absolute probability of crane use of a given site type, but rather a relative probability of use in relation to the sites that are available in the landscape (i.e., predictions of absolute probability of crane presence to other localities might be misleading, but predictions about general site selection patterns are still viable (Lele et al., 2013; Lele and Keim, 2006)). The resource selection functions used were generalized linear mixed models with binomial error structures and logit link functions (R package lme4; Bates et al., 2015), according to the logistic model formula;

$$y_i(0,1) = \frac{\exp(\beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \varsigma_{x(i)})}{1 + \exp(\beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \varsigma_{x(i)})}$$

where y is the mean probability of presence (i.e., proportional use in relation to availability) and $\beta_{0,1\ldots}$ are the explanatory variables of interest (see below for each model setup 1–3), and ς is the random intercept for each respective individual *i*. We generated three model

setups to answer the defined questions;

Model 1 included all used and available locations (n_{used} = 18,548, n_{avail} = 37,096) as a binomial response variable; explanatory variables were the main effect of whether a location was inside or outside N2K (binomial), the interaction effects of N2K and whether the location was a roost site or not (binomial) and N2K and habitat (three-level categorical), as well as the interaction of roost or not and habitat. Crane identity was included as random effect to account for interindividual variability.

Model 2 was based on daytime locations outside N2K sites (n_{used} = 10,821, n_{avail} = 24,155), to test what habitat cranes selected for during foraging activities and if there was a spillover of cranes from N2K sites. Used versus available locations was used as a binomial response variable, distance to nearest N2K site (km) and habitat were added as explanatory variables and crane identity as a random effect. Distance to N2K site was log-transformed as it violated the model criteria for a normal distribution.

Model 3 included a subset of the data with day and roost locations within N2K sites (n_{used} = 5608, n_{avail} = 3593). The aim was to test whether the type, SPA or SPA & SAC/SCI N2K sites, or sites where cranes are listed in the site-specific management plans are more likely selected by cranes. Used versus available locations was used as a binomial response variable and type of protected area (two-level categorical; SPA or SPA & SAC/SCI N2K site) and if listed as target species in the site-specific management plans (binomial) were added as explanatory variables, with crane identity as a random effect.

Models from each set up (model 1–3) were ranked based on AIC according to principles described by Burnham and Anderson (2002). The function 'dredge' (R package MuMIn: Barton, 2013) was used to assess the associated fitted values and 95% confidence intervals after 1000 simulations (R package 'arm': Gelman et al., 2014). R version 3.2.3 was used for all statistical computing (R Core Team, 2015).

3. Results

The probability of cranes being located within N2K sites was higher than expected across habitats and both at day and night (Table 1, Fig. 2). Overall, almost one third (30%) of used locations were within N2K sites, compared to 10% of available locations. During nighttime, the probability of cranes roosting on wetland N2K sites was 97%, whereas during the day, the probability of cranes on arable land was 68% (Fig. 2). In total, the 32 GPS-tagged cranes visited 98 different N2K sites, with each individual visiting on average 6.2 ± 5.8 (SD) N2K sites (range = 0–22). The probability of cranes occurring on arable land close to N2K sites was also high but decreased with distance to N2K sites in the landscape (i.e., 63% at 0 km and 27% at the maximum distance 89.3 km) demonstrating a spillover of cranes to adjacent areas during daytime (Table S2, Figs. 2, 3 & S1). Cranes were more likely to be located on N2K sites where they are listed as a species of concern in the management plan (e.g., 77% when listed versus 6% when not listed in SPA's). However, there was no difference in presence between sites

assigned as SPAs & SAC/SCIs compared to sites assigned as merely SPAs (Fig. 4).

4. Discussion

The N2K network successfully targets cranes along their flyway, especially for wetland night roosting, and conclude that N2K sites protect important habitats for cranes as expected (EC, 2016). However, our study also highlights that the majority of the cranes' daytime activity (70% of daytime locations) along the migration route, occurs on arable land outside N2K sites. Increasing numbers and congregations of cranes foraging on arable land can lead to increased crop damage around staging sites, and thus increased conflicts between conservation and agricultural objectives and reluctance towards wetland restorations as also reported from for example Spain and Israel (Austin et al., 2018; Frank et al., 2018; Nowald, 2010; Salvi, 2010; Montrás Janer et al., in prep.). Thus, conservation conflicts in connection to N2K sites are likely to emerge and increase over time due to continued growth in the population and a lack of effective strategies for crop damage prevention. The increased risk of crop damage and the potential for conservation conflicts around protected wetland areas is likely to apply to other migratory large herbivorous birds, such as sandhill cranes (*Grus canadensis*), several goose species and swans. These species also forage on agricultural land and have increased over the last three decades across Europe and North America (Fox and Madsen, 2017; Lacy et al., 2015; Pearse et al., 2010).

The N2K sites mainly provided cranes with wetland roosts but also arable land for foraging, as shown by prior studies on crane behavior (Alonso et al., 1983). The probability of crane presence in wetland night roosts was high regardless of Natura 2000 designation, which may indicate that wetlands, rather than arable land, is a limiting factor along the migratory route (Harris and Mirande, 2013; Kanai et al., 2002; Vegvari and Tar, 2002). Similar to geese and swans, cranes generally select foraging sites close to roosts to lower energetic costs of movement (Jensen et al., 2017; Nilsson et al., 2016), which explains the relatively high probability of cranes at arable land within N2K sites. The equivalent probability of cranes in N2K sites assigned as SPAs and SAC/SCIs and in sites assigned as only SPAs, suggests that the attractiveness of N2K sites is independent of site type. Cranes are more likely to occur on N2K sites where they are listed as species targeted for conservation in the management plan, which may result from either site use by cranes during implementation or by successful on-site habitat improvement. From our study, we cannot address whether implementation of N2K sites will have any effect on the viability of the crane populations or if it solely will affect movement patterns. However, a study in the Hula Valley in Israel has suggested that protected wetlands in combination with productive agricultural land affect crane migration in terms of a northwards shift in migration and prolonged staging periods in such areas, which potentially may benefit population growth (Shanni et al., 2018). However, the background of the establishment of the site-specific management plans for the N2K sites and species lists may vary
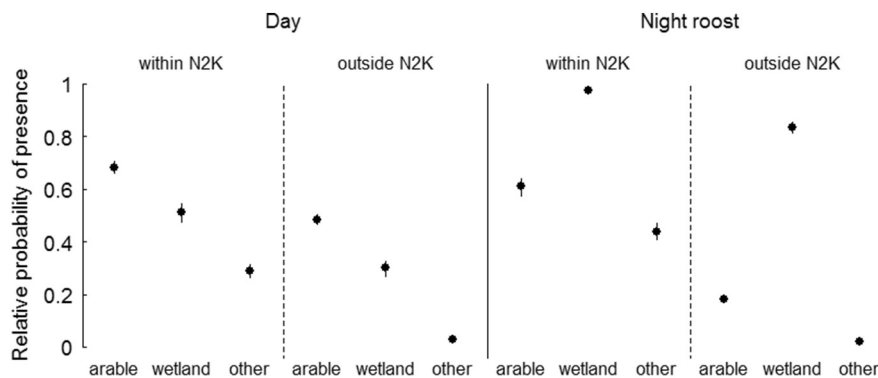

Fig. 2. Relative probability of crane presence at arable, water/wetlands, and other habitat, inside vs. outside N2K sites, during daytime and at night roost site, respectively. The predicted estimates and their 95% confidence intervals are produced from 1000 model simulations based on the estimates from the top-ranked mixed effects model (Tables 1 & S2).
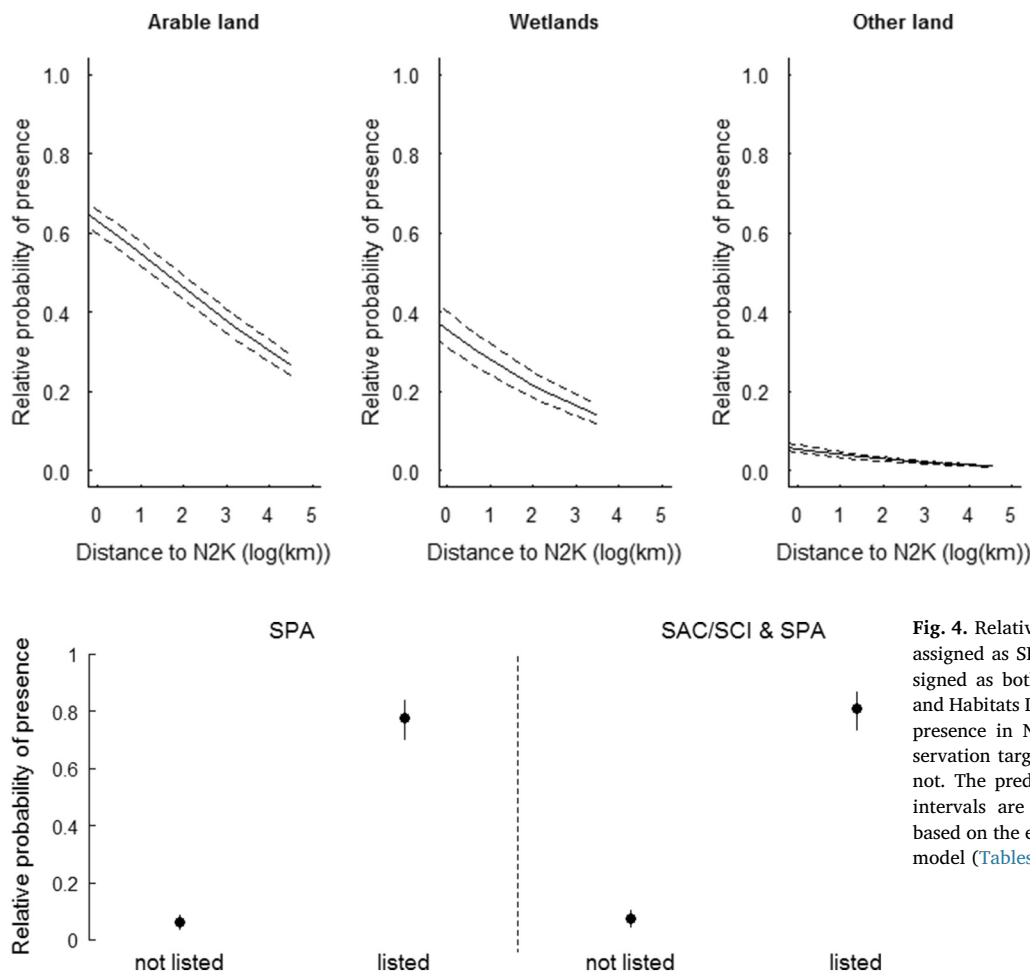
Fig. 3. Relative probability of crane presence during daytime as a result of distance to nearest N2K site ($\log_e$(km)) on arable land, water/wetlands and other land. The solid lines are predictions with their 95% confidence intervals as dashed lines from the top-ranked mixed effects model (Tables 1 & S2). Predictions are only plotted for the range of available data on the x-axis.
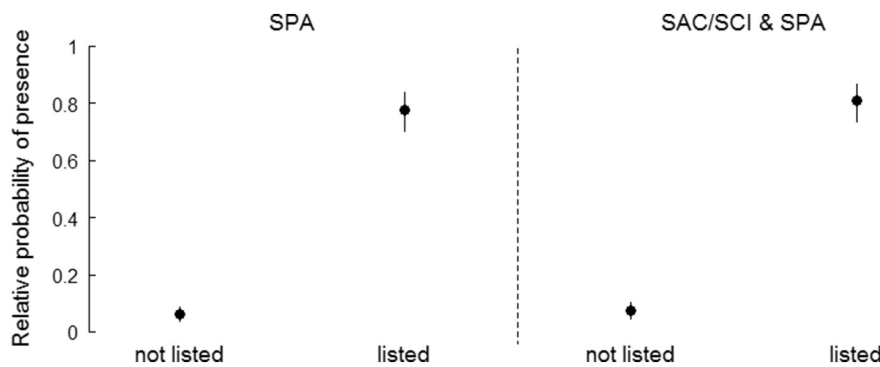

Fig. 4. Relative probability of crane presence in N2K sites assigned as SPAs (Birds Directive) compared to sites assigned as both SPA and SAC/SCI both (Birds Directive and Habitats Directive) as well as the probability of crane presence in N2K sites where cranes are listed as conservation target in the site-specific management plan or not. The predicted estimates and their 95% confidence intervals are produced from 1000 model simulations based on the estimates from the top-ranked mixed effects model (Tables 1 & S2).

Table 1
The four top-ranked models according to AIC criterion within each model category: model 1 – assessment of relative probability of crane presence within and outside N2K sites, model 2 – assessment of relative crane presence during daytime in relation to proximity to N2K sites, and model 3 – assessment of relative crane presence at N2K sites in relation to its type. See modelling details in method description.

Model		AIC	ΔAIC	Weight
1	Habitat + N2K + roost + N2K*habitat + N2K*roost + habitat*roost	51,647.3		1
	Habitat + N2K + roost + N2K*habitat + habitat*roost	51,912.5	265.2	0
	Habitat + N2K + roost + N2K*roost + habitat*roost	52,219.6	572.3	0
	Habitat + N2K + roost + habitat*roost	52,507.8	860.5	0
2	Habitat + dist to N2K$_{log}$	33,466.6		1
	Habitat	34,686.4	1219.8	0
	Dist to N2K$_{log}$	41,520.5	8054.0	0
	Null model	43,149.2	9682.6	0
3	Cranes listed + site type	8409.8		0.99
	Cranes listed	8418.1	8.3	0.01
	Site type	11,493.3	3083.5	0
	Null model	11,512.9	3103.1	0

between countries and sites and may range from just lists of present species to detailed plans for restoration measures for certain species. Improved knowledge of the implementation processes and the site-specific management measures is thus needed to fully understand the mechanisms behind our findings of higher probability of crane occurrence in N2K sites where cranes have been listed.

The overall ecological effectiveness of the N2K network has been criticized due to the low functional connectivity between sites (Opermanis et al., 2012; Popescu et al., 2014). The effectiveness however varies due to the protected species' movement abilities (Gruber et al., 2012). According to our findings, mobile species like the crane and European otter (*Lutra lutra*) are well served by the network,

whereas species with restricted mobility, such as the cricket (*Paracaloptenus caloptenoides*), are insufficiently protected by the network (Gruber et al., 2012).

Because of the high efficiency of the N2K network in targeting cranes, there was an apparent relationship between cranes and land adjacent to N2K sites predominantly into arable land during daytime when foraging, which create a potential risk of damage to arable crops (Frank et al., 2018; "Grus-grus.eu," 2016; Salvi, 2010). If true, crop damage within or adjacent to N2K sites would fuel a multi-faceted conservation conflict by adding to existing land use restrictions connected to site-specific conservation measures (Blicharska et al., 2016; Bouwma et al., 2010; Popescu et al., 2014). For example, managers

have experienced increased unwillingness by farmers to contribute to wetland restorations as it may lead to increasing numbers of cranes and geese that cause crop damage, but also due to increased administrative workload and restrictions for grazing regimes and water rights (Blicharska et al., 2016; J.M. Wikland, County Administrative Board Örebro, pers. comm). On the other hand, there are examples from North America where authorities have been successful in mitigating crop damage caused by sandhill cranes which have emphasized collaborative engagement of farmers in conservation in general (Barzen and Ballinger, 2018).

Based on Article 9 in the Birds Directive, member states are allowed to take actions 'to prevent serious damage to crops, livestock, forests, fisheries and water' (EC, 2009). For protected bird species such actions include non-lethal and lethal scaring, alternative feeding areas or compensation (Hake et al., 2010; Nilsson et al., 2016). There is currently no common policy for mitigation of conflicts related to crop damage caused by the increasing numbers of protected birds such as common cranes but also geese and swans (Austin et al., 2018; Fox and Madsen, 2017; Nilsson, 1997). Lack of conflict mitigation may lead to both lower acceptance for conservation of cranes and reluctance towards wetland restorations, among farmers and landowners since the wetlands attract birds causing crop damage. However, the effect of different conflict mitigation strategies on farmers acceptance for wetland and crane conservation needs to be studied further. The EC endorses economic compensation within N2K sites from CAP or LIFE projects (EC, 2014). However, general strategies for compensation to landowners within protected areas varies among countries; from lack of compensation to land use contracts and land purchase (Bouwma et al., 2010). Our results therefore illustrate the importance of increased efforts of conflict management within, and adjacent to, protected wetlands. This could include strategies with a combination of compensation, scaring, baiting of seeds to alternate foraging towards invertebrates on newly sown field and alternative and undisturbed feeding areas (Austin et al., 2018; Barzen and Ballinger, 2018; Nilsson et al., 2016). Such strategies will benefit from local stakeholder participation (Hake et al., 2010; Tuvendal and Elmberg, 2015).

We expect that conservation conflicts will become a growing problem if the populations of cranes, geese and swans in the Western Europe flyway continue to increase drastically, with up to several hundred thousand cranes and geese foraging at arable lands on specific staging sites that often are protected and designated as N2K sites (Fox and Madsen, 2017; "Grus-grus.eu," 2016). The mitigation of these conflicts will require long-term strategies at an international level. These strategies should preferably be based on scientific evidence and cross-boundary collaboration between range states, combined with a bottom-up process of local participation (Blicharska et al., 2016; Redpath et al., 2017) to set joint targets and to manage conflicts by increasing the acceptance and understanding for conservation measures (Kark et al., 2015; Maxwell et al., 2015). A promising example of a local strategy is used in Sweden, where groups with representatives of farmers, managers, ornithologists, hunters and researchers meet several times per year to share perspectives and to advice management on how to allocate resources for damage prevention, with the aim to increase stakeholder participation and adaptiveness in management (Hake et al., 2010).

At present there are no initiatives by EC to manage cranes or other protected species causing damage within and adjacent to N2K sites. Here, the evidence-informed flyway management plan for pink-footed goose (*Anser brachyrhynchus*) could provide an example of how to collaborate across national borders (Madsen and Williams, 2012). In this plan, range states and stakeholders have agreed on a population target with an adaptive management process of annual monitoring, population estimation and implementation of measures (Madsen and Williams, 2012). However, such initiatives raise the need for regularly revised EU directives, similar to the IUCN Red List. Such revisions would allow for more adaptive management of N2K sites and for improved agreement and coordination between policies (Orlikowska et al., 2016).

To mitigate conservation conflicts related to protected birds in connection to protected wetlands worldwide, we suggest that increased resources are allocated to improve cross-boundary collaboration and streamlined policy among involved states. Further, improved local participation is required to explore the usefulness of compensation and damage preventive measures, within and adjacent to protected areas to ensure socioeconomic sustainability of supranational networks of protected areas.

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