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Use of two distant nesting areas as a breeding strategy of Golden Eagles *Aquila chrysaetos* in Valdres, southeast Norway

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Abstract. Sixteen occupied nesting territories of Golden Eagle *Aquila chrysaetos* were studied between 2000 and 2020, in the southern part of the valley of Valdres, southeast Norway. Most of the study area consists of rolling hills dominated by spruce *Picea abies* with numerous clear-cuts. It was concluded that at least six (about 40%) of the eagle pairs in these territories move back and forth between two alternate, distant nesting areas 5.3 km apart (average). In two additional pairs, a second nesting area was considered possible. In the remaining eight, only one nesting area was found. The periods of one nesting area in use varied from 2–19 years, before moving to the other nesting area. This result was supported by panoramic mid-day surveillance of the air space between the two nesting areas during 2014–2020. The maintenance of a second core nesting area is most likely a strategy for moving to a more favourable hunting area and might be initiated by a new mate in the pair. The move might also be influenced by avoidance of a close neighbouring pair. A switch of nesting areas, as indicated by this study, could significantly affect results, when the number of eagle pairs in a certain area is counted.

Keywords: Golden Eagle, nesting areas, south Norway

INTRODUCTION

Raptors have various responses to prey abundance. Wintering birds may simply move to another area, but for territorial pairs, it is important not to abandon an established hunting area or territory. For Gyrfalcons *Falco rusticolus* the pair reportedly stays but does not breed when prey is scarce (Galushin 1974). Recent observations in Mongolia suggest that some Saker Falcon *F. cherrug* pairs regularly abandon a breeding effort if food is insufficient and try a second breeding effort in a distant area the same year (Ellis et al. 2011). Several different strategies and distances of movement should be considered as a response to prey scarcity and prey awareness with avoidance of predators. In the northern range of Golden Eagle *Aquila chrysaetos* populations (e.g. Alaska and north Canada), all age-groups move south in winter, while in Scandinavia the older eagles remain in the territory during winter.

Breeding performance and territoriality in the Golden Eagle is considered related to availability of the principal prey (Tjernberg 1983, Sulkava et al. 1984, Bates & Moretti 1994, Gjershaug 1996, Steenhof et al. 1997, McIntyre 2002, Nystrøm et al. 2006, Watson 2010), although there might be exceptions as exemplified by Walker (2017). Within the hunting range, the eagle pair probably has detailed knowledge about prey hotspots (H. Dunker, unpubl. data). In Norwegian inland areas, the principal prey are mountain hares *Lepus timidus* and grouse. However, smaller prey such as small rodents, thrushes, corvids or larger mammalian species, mostly as carrion, might also support breeding (Madders & Walker 2002, Watson 2010, Dunker 2015, Walker 2017). When food is scarce, several tactics seem to help eagles survive and breed. Recently, stealing from other predators and predation on predators have come into focus as important aspects of eagle feeding ecology (Ellis et al. 2000, Arim & Marquet 2004, Moehrenschläger et al. 2007, Dunker 2017, Newton 2017). When prey is depleted locally, the hunting area might be considerably expanded (Moss et al. 2014, Walker 2017). Eagles might even leave the home range completely for a period of time. It has been shown by GPS-tracking of Golden Eagles captured in the northern boreal zone of Sweden, that some eagle pairs left the home range in June and made long range directional movements to mountains with reindeer herding in the northern parts of Sweden, Norway and Finland, before they returned to the original home range in July - August (Moss et al. 2014). Ferrer (1993) showed that young Imperial Eagles *Aquila adalberti* left a hunting area because rabbits *Oryctolagus cuniculus* learned to avoid their hunting efforts. Pairs of eagles might leave the traditional hunting area as a response to both low prey numbers and increased predator avoidance behaviour. Other factors than prey availability may also affect pair movement, so that they will tend to leave their usual hunting range. Interactions with neighbouring pairs are common and can be lethal (Haller 1996). A change of one partner in a pair might result in a change of nesting area (Kochert & Steenhof 2012). Disturbances of breeding might occur from other predators, including intruding eagles which can kill nestlings (Haller 1996). Disturbances from humans

Table 1. Nesting territories (1–16) of Golden Eagles as related to recorded breeding within five-year periods (last period 2015–2020: 6 years), during 20 years of study. Surveillance statistics are given as the number of eagle observations, compared to the total number of hours with surveillance during 2014–2020. Territories 1–6 are those where the eagle pair has moved their breeding attempts back and forth between two nesting areas. Territories 7–8 are considered to possibly have two nesting areas, while 9–16 have no indications of more than one nesting area. Open spaces are formerly unknown territories together with nesting areas unvisited during the five-year period. Question marks are nesting areas with uncertainty about possible breeding attempts.

		Study period No. of recorded breedings in nesting areas				Surveillance statistics	
Territory number	Distance (km) between two nesting areas	2000–2004	2005–2009	2010–2014	2015–2020	No. of eagle observations	No. of obs. hours
1	5	0–?	0–?	0–1	4–2	19	58
2	4	1–0	1–3	2–0	3–0	19	45
3	10	?–1	2–0	1–0	1–0	26	131
4	4			1–0	0–2	20	62
5	5	1–?			0–1	6	35
6	4	0–1		1–?	5–0	12	27
7	4			1–0	3–0	14	16
8	4				1 – ?	5	8
9		2	1	2	3	27	33
10			1		2	4	10
11					4	13	24
12					1	1	5
13		1				4	25
14				1	2	26	110
15		2	2	2	1	15	52
16					1	10	13
TOTAL						221	654

(photographers, ornithologists, skiers, cottages etc.) are also relevant. Many eagle pairs tend to build a second nest close to the first one, even within 10 metres. The possible reasons for this seem, however, unknown. Some nests fall from cliffs; this might result in breeding failure or the pair moving to another nesting area. Nesting in trees, where cliffs are scarce, might involve a snow-covered nest at the onset of breeding. Such a case was suggested by Birkö (2018), where the snow-covered tree nest was abandoned and apparently the pair bred successfully in a cliff 5 km away.

In the Golden Eagle, the territory or hunting range has generally been assumed to contain only one core area with one and up to 18 alternative nests (Kochert & Steenhof 2012, Millsap et al. 2014). Here, the hunting range is considered equal with the home range, while the core area with nests is the area defended. Breeding Golden Eagles may have home or hunting ranges covering hundreds of square kilometres (Tjernberg 1983), up to 600 km^2 (Moss et al. 2014). The size of the core area, where the pair spend more than 50% of the time when breeding, might be related to the proportion of clear-cuts in their hunting range (Moss et. al 2014). Within this core area, the eagles will easily spot an intruding unfamiliar eagle or neighbouring individual and fly directly to meet this bird with subsequent circling, chasing and even fatal encounters, which seems frequent in a dense population (Haller 1996). However, the size and borders of the territory and home range might vary both between pairs and years. The extent of this is little known within a mostly homogenous landscape. However, within more rugged alpine landscapes, ridges and high-altitude peaks may serve as natural borders (Haller 1996). Evidence that the same pair uses different and distant nesting areas will, however, be difficult to obtain, because such a shift may occur only once in many years or even after 1–2 decades. This paper presents observations from two decades that support the hypothesis that some eagle pairs move back and forth between two distant nesting areas within the same hunting range, with a discussion of possible reasons for this behaviour.

METHODS

The present study was conducted in the southern part of the valley of Valdres, within the municipalities of Sør-Aurdal, Nord-Aurdal, Etnedal and southernmost Øystre and Vestre Slidre in southeast Norway, within 60 30' - 61 30' latitude and 9 5'–10 10' longitude, during the years 2000–2020 The study area covers about 2550 km^2 of mostly forested, rolling hills. This part of Norway is characterised by north-south oriented glaciated valleys. The hills lie mostly between 200 and 1000 m a.s.l. and are divided at intervals by glacier valleys about 1–5 km wide and 500 m deep. The study area is covered mostly by Norway spruce *Picea abies* forest, but also includes some small alpine areas 1000–1500 m a.s.l. Within the studied 16 nesting territories, Golden Eagles have their main hunting-areas related to many small and a few extensive clear-cuts (vegetation height 0–2 m). The most important prey species are mountain hare, Capercaillie *Tetrao urogallus*, Black Grouse *Lyrurus tetrix* and Willow Grouse *Lagopus lagopus*. Carrion from wild cervids in winter and sheep in summer is obviously important for survival and breeding.

It is apparent that tagging of the individual eagles and GPS-monitoring, or DNA samples from blood or feathers is necessary to obtain direct evidence of the use of two different nesting areas. This was not done in the present study. For this study, I have used an indirect approach, monitoring breeding attempts within the two nesting areas and surveillance of the eagles' use of the air space between the two assumed nesting areas during 2014–2020. Prior to 2014, field effort concerned localising 16 territorial pairs, finding nests and recording some breeding attempts. Sustained surveillance of nest sites was initiated in 2014. The 16 pairs were evaluated with respect to whether there were one or two nest sites within each territory (Table 1). It is assumed that the pair will have much of their activity concentrated in the nesting area where breeding occurs. The records of breeding attempts were defined as observations of nestlings in May–July or a begging fledgling in vicinity of the nest in July–September. As the study was initiated in 2000, there was a gradual build-up of knowledge about nests and breeding attempts (Table 1). After 2013, the overall picture of pairs and nests was considered fairly complete. This completion was further confirmed in 2018, when 80–90% of the eagle pairs were breeding (Dunker unpubl. data). Among the 16 nesting territories of eagles, five were added during extension of the study area after 2015. The number of nests with recorded breeding was 23, including 50 cases of verified breeding attempts. Because two distant nesting areas might easily be interpreted as belonging to two different pairs, two decades (2000–2020) of observations were evaluated to be confident that two different pairs were not involved. All distances were measured to the nearest kilometre (Figure 1). All the 1–2 nests in each nesting area were close (within 200 m), except one case where the nesting area included 6 nests in an extended cliff wall of 2 km distance. To support the claim that two nesting areas were in use by one pair of eagles, I surveyed the air space between the two nesting areas with 10 x 40 and 20 x 80 binoculars. Individual recognition was not possible because of large distances. The observation range was 6–8 km with 20 x 80. This was done at 1–3 km distance from the main core area, with about 180 degree view from about 30 vantage points. Each surveillance bout was 2–5 hours, mostly between 1100–1400 CET, as the eagles most often soar around noon, when wind tends to increase and when the air warms up creating thermal lift (Haller 1996). The horizon and most of the terrain was scanned every 2–3 minutes. This surveillance covered a total of about 650 hours with about 220 eagle sightings. Two nests were hidden in cavities, barely visible, so a disproportionately large number of hours were spent finding these (Table 1, territory 3 and 14). The nests with a small number of observation hours, were known only after the expansion of the study area after 2015. Most of the surveillance (about 85%) occurred during the breeding season (March–July) with a peak in May. Where 3–4 eagles were seen soaring together, this obviously concerned hostile encounters with unknown individuals or neighbouring pairs.

RESULTS

During the study period, only one nesting territory seems to have been abandoned, and this occurred after 2015. One possibly new-established territory was found in 2020 (territory 16). In the other territories, eagle pairs were seen all years during the two-decade study, although some individuals may have died and been replaced by another individual without this being known. The claim that two different nesting areas were used by the same pair was supported by observations of neighbouring pairs breeding mostly more than 10 km away, and the fact that the two assumed nesting areas were never recorded to be used simultaneously for a breeding attempt the same year. All nests but two were situated in the numerous, mostly south- or east-facing cliffs in the study area. Among the about 40 eagle nests, 11 have decayed almost completely during the study period. Among these some may have been built or used by Rough-legged Buzzards *Buteo lagopus*. Five nests have fallen from the cliff, and two have been partially transformed into anthills. The number of eagle nests used is considered known, but of course, some old nests may remain undetected.

During surveillance, eagles were spotted and followed with binoculars as far as possible in 221 cases, including 41 cases with two eagles together, presumably a pair, eight cases with three eagles

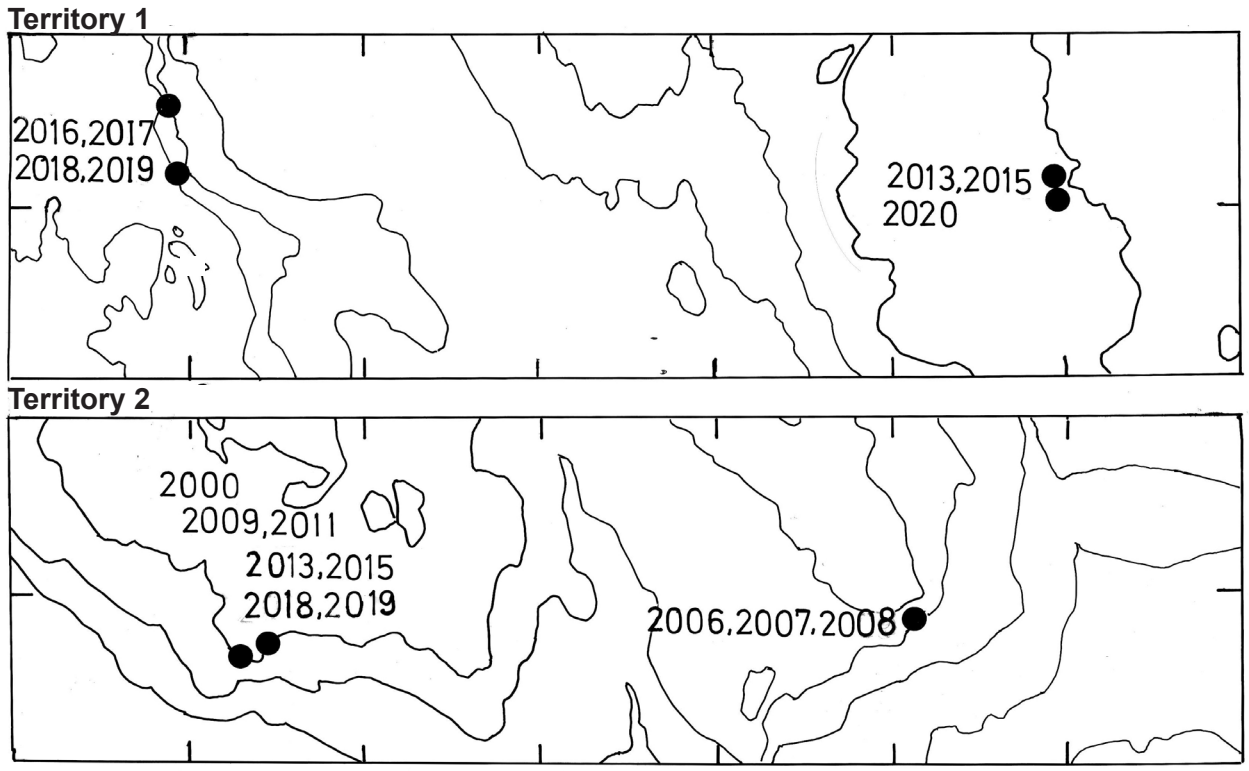

Figure 1. Two examples showing change from one nesting area to a second one in Golden Eagles. Nests are indicated by black dots with years of recorded breeding. Territory numbers refer to Table 1. Both maps cover 2 × 7 km with 100 m contour intervals.

together and three cases with four eagles soaring together. I concluded that among the 16 Golden Eagle breeding territories, six pairs (about 40%) used two distant nesting areas, with distances varying from 4 to 10 km with an average of 5.3 km. The period of one nesting area being continually in use varied from 2–19 years, before moving to the other nesting area. In territory 1 and 2, these periods were 4 and 2, and 10 and 3 years, respectively (Figure 1). In two additional pairs, two nesting areas were considered possible, while in the remaining eight pairs, no observations or nests indicated another distant nesting area.

Among the six territories with two nesting areas, only one nest was found in five of the possibly secondary nesting areas, and two nests in the sixth. All of the pairs with two nesting areas have been surveyed for at least 10 years, with no cases of simultaneous breeding in both nesting areas.

The individual eagles in these six pairs have repeatedly been seen to use the air space between the two areas. In two cases, the probability of two nesting areas was supported by another observer (P. Furuseth, pers. comm.). When breeding occurred at one of the nesting areas, there were very few or no observations of eagles close to the nests at the other nesting area.

DISCUSSION

The present study suggests that some eagle pairs switch from one nesting area to another distant nesting area within the home range, and that this behaviour may concern up to half of the population. The present sample also suggests that the distance between the two nesting areas may vary from 4–10 km. However, the extent of this phenomenon seems unrecognised, as well as the causes of this behaviour. The use of two distant nesting and breeding areas by some pairs does not seem to have been previously suggested in the Golden Eagle, although alternative nests are well known at distances from 0-8 km (Fisher 1976, Gjershaug 1981, Fremming 1982, Slater et al. 2017). Presently, it is suggested that some eagle pairs move back and forth between two distant nesting areas, while other pairs have a cluster of alternative nests which seem to be used randomly within a single nesting area, mostly within less than 500 metres distance (Kochert & Steenhof 2012). Bergo (1984) recorded distances between the alternative nests from 1 m–2.5 km, with a mean of 600 m, in Hordaland, western Norway. Some distant alternative nests may never be used for breeding, as when breeding failure usually results in nest-building that is often outside the usual nest group (Walker 2017). Gargett (1990) claimed that alternate nests of the same pair of Black Eagles *Aquila verreauxi* can be as far apart as the nests of neighbours. In Gargett's study, also about 40% of distances between alternate nests were more than 1 km apart, and nearest neighbour distances were from 1–2.5 km. Nearest neighbour distances varies from 8–17 km in the Golden Eagle (Watson 2010). In

western Norway, Bergo (1984) recorded 10–20.5 km neighbour distances. Gargett's interpretation of distant alternate nests might parallel the present interpretation of distant alternate nesting areas. Watson (2010) noted that pairs of Golden Eagle generally use a favourite nest but «will intermittently use a site at the opposite end of the hunting range from the favoured eyrie». These observations seem to support similar alternative nesting areas as I discuss here. The impression of one of the two nesting areas being secondary and less used, was supported by the finding of only one nest in all but one of six alternative nesting areas. This one nesting area has two nests.

Watson (2010) suggested that moving regularly between several nests might be a response to disturbance. In the present study, there were no observations to support this. However, D. Ellis (pers. comm.) reported an experiment in Montana to introduce a minor disturbance in the nest used in 1970, to induce the pair to move to another nest about 100 m away. Instead, the pair built a new nest 2.5 km away. All that was done to encourage the move was to place a plastic bag with a stone inside in the previously used nest. In the Black Eagle, disturbance associated with human visits in the nesting area, climbing the nest for ringing (banding) and collecting of prey remnants did not seem to cause movements of the pair in the following season (Gargett 1990). Watson (2010) suggested that periodic use of an alternate but nearby eyrie may be a means of reducing parasites. Dudek (2017) found that Golden Eagles reuse less parasitized nests in successive years. It has been suggested that eagles tend to change nests, i.e. move to another but nearby nest, after the turnover of at least one member of the pair (Kochert & Steenhof 2012). Among 10 territories recorded by Haller (1996), the duration of paired eagles in an area was from 3–23+ years. New and distant nests might be related to extension of the hunting range in the Black Eagle (Gargett 1990). Presence of a nearby nesting area in use by a neighbouring pair, might possibly also cause a pair to breed at the other more distant nesting area (P. Furuseth pers. comm.). In a few cases, nests with a sloping foundation may fall down, and thus force the pair to find another nest site. However, in the present study area, almost all nests are situated in cliff cavities or caves with roof or overhang as well as a somewhat horizontal floor. Only two tree-nests have been found in this study area, possibly because cliff nesting sites were sufficiently abundant.

There might be several reasons for changing between two distant nesting areas. The most likely reason, however, seems to be a switch to more favourable hunting conditions in a distant part of the hunting range (Millsap et al. 2015). It is likely that the eagle pair by their year after year predation can deplete the local prey populations. If this is true, having two nesting areas, would allow for prey populations to recover and raptor awareness among prey to decline, while the other area is being used for breeding. Radio-tracked eagles in Scotland used their territories by 98% < 6 km of the centre (nesting site) and 50% < 2–3 km (McGrady et al. 2002, McLeod et al. 2002). Thus, moving to another distant area 5–6 km away might increase the most used hunting range by more than 50%. Imperial Eagles can abandon an area where hunting grows increasingly difficult because the prey becomes aware of the eagle (Ferrer 1993). As almost all of the eagle nests in the present study were well sheltered in cliffs with a roof or overhang (Dunker unpubl.), it does not seem likely that precipitation during the breeding period will influence change of nesting area. The use of carrion by breeding eagles is claimed as important by Abuladze & Shergalin (2002), Madders & Walker (2002) and Walker (2017). Long-range movements by eagles have been assumed to be related to alpine areas with reindeer husbandry (Moss et al. 2014). Similarly, long-range movements by a breeding pair within its hunting range might be related to carcasses of sheep, which might be a supplement of food when prey are scarce. Remnants of sheep have been found twice in one of the nests in the present study.

The monitoring of Golden Eagle populations is done in many countries, and extensively in Scandinavia by both scientists and amateurs. In Norway, the methods of monitoring are mostly standardized to minimise bias (Gjershaug et al. 2018). Active nests are easy to verify, but to be certain that an eagle pair is non-breeding will always remain a problem. This seems to be a cause for concern with monitoring of the Golden Eagle in Great Britain (Walker 2017). The use of two distant nesting areas by one eagle pair has important implications when the number of eagle pairs is counted in a specific area and when neighbouring distances are measured. Many eagle pairs seem not to breed every year, but could they possibly be breeding at an unknown location, perhaps many km away? A long-term study over several decades might be necessary to assess if two nesting areas are in use by one or two pairs of eagles. Extensive panoramic surveillance might support the hypothesis. Moulted feathers collected in the nest should tell if the female is the same bird at both sites. Feathers collected below roost sites could show the same for male adults. Systematic collection of feathers seems to hold substantial research potential (Smith et al. 2003). Blood from nestlings would also serve to identify parents (Wink et al.1999, Kenward et al. 2007). This method has recently been used in Norway (Torvmo et al. 2019).

Watson (2010) stated that «new nests appear to be built rarely», citing the findings by Kochert (Kochert et al. 2002) that only 9.5% of breeding pairs used new nests each year during a 20-year study. The distances from the old to the new nests are, however, not indicated. However, it is generally understood that these nests are

spread within at most a few hundred meters (D. Ellis pers. comm.) Studies that cover less than two decades could miss long-term changes. A future study of the frequency of breeding and breeding success before and after a switch of nesting area might reveal an advantage of the two nesting areas strategy. The present study suggests that a more complex picture of Golden Eagle breeding behaviour will emerge by closer studies over several decades.

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