Ornis Norvegica

BirdLife NORWAY

Characteristics of cliff nest sites of Golden Eagles in forested hills of southeast Norway

Henning Dunker

Rennaveien 7, 2930 Bagn, Norway
e-mail: henningdunker1@gmail.com

Cite this article
Dunker H. 2023. Characteristics of cliff nest sites of Golden Eagles in forested hills of southeast Norway *Ornis Norvegica* **46**: 22–27. doi: 10.15845/on.v46.3698

Keywords
Aquila chrysaetos
cliff nesting
forested hills
Golden Eagle
nest site selection

Received 05 September 2022
Accepted 26 April 2023
Published 25 June 2023

Abstract
The characteristics of cliff nest sites of the Golden Eagle *Aquila chrysaetos* were evaluated from a sample of 57 nests, located during 2000–2020 in the forested valley of Valdres in southeast Norway. About 80% of nests were facing to the south and east, but availability of nest ledges seemed largely a consequence of cliff structure and orientation. Among the 57 nest sites, 4% were placed in a corner with vertical walls, 33% on a ledge with overhang, 10% on a ledge with a vertical back wall, 2% on a ledge with a reclining wall, 49% within a cavity and 2% within a cave. Thus, about 83% of the nest sites were sheltered by an overhang, a cavity or a cave in the cliff within 0.5–2 meters from the nest, and only 16% of sites lacked shelter from above. Heavy snowfall in early spring, torrential rain or strong winds in spring and summer may increase mortality among the nestlings unless the nest site is well sheltered. Moreover, a dry and snowless nest may allow the eagles to start early incubation in late March, thereby increasing fledgling survival. Cavity-nests are sheltered sites with less visibility that might protect from attacks from other raptors and Ravens *Corax corax*.

INTRODUCTION

Population studies of Golden Eagles *Aquila chrysaetos* have reported that a majority of nest sites are located in cliffs (Watson 2010). In studies of such nest sites, it has been customary to focus on the cliff height and orientation. The smaller scale nest environment, however, has been somewhat neglected. Standardized data are difficult to collect because most nest sites are inaccessible without climbing equipment and even more because of the rock irregularity which defies proper measurements. Accordingly, it has been common to describe nest sites with categories such as "ledge", "overhang", or "sheltered". For example, "nests of eagles were mostly located on ledges and potholes of cliffs" (Stahlecker et al. 2022).

In the extensive study of Golden Eagles by Tjernberg (1983), it is briefly stated that most of nests in cliffs had "overhanging mountain sides". Similarly, Bergo (1984) stated that more than half of the nests were "sheltered" and some were "well sheltered". According to Watson (2010), the preferred cliff nest sites of the Golden Eagle in Scotland are preferably sheltered from above, depending on the degree of shelter available. In cliffs, the irregular rock structures immediately surrounding the nest clearly influence the micro-climate to which nestlings and adults of raptors are exposed during vulnerable life stages (Mearns and Newton 1988, Fast et al. 2007, Anctil et al. 2014, Henderson et al. 2021). However, although the height of the cliff and its compass orientation has usually been recorded, the nest site shelter has only been roughly described for eagles (Willgohs 1961, Tjernberg 1983, Bergo 1984, Stahlecker et al. 2022, Watson 2010). However, recently nest site shelter has been reported as 'degrees of exposure' (Henderson et al. 2021).

The orientation of Golden Eagle nests may not be related to climatic factors but simply reflect the orientation of available crags (Watson 2010). Generally, eagles show preference for south-oriented nest sites where available, because these sites may become snow free earlier in spring. It seems obvious that the great variation of cliff orientation of nest sites and cliff height in raptors, depends on the main cliff orientation, and the structure of cliffs and cliff height in general. Also, the choice of nest sites might be somewhat influenced by the prevalent wind direction and sun exposure. Eagles will normally prefer and use nests in vertical cliffs with a comparably high degree of safety from carnivorous mammals and also shelter from adverse weather and from being exposed to other raptors (Watson 2010). Furthermore, protruding and overhanging rocks sheltering the nests from adverse weather conditions might also improve breeding success in raptors (Anctil et al. 2014, Henderson et al. 2021). The Golden Eagle, as well as other species of eagles as the Spanish Imperial Eagle *Aquila adalberti* (Ferrer 2001) and the Wedge-tailed Eagle *A. audax* (Foster & Wallis 2010, Hatton et al. 2014) exist in habitats with few or no cliffs, where they breed almost exclusively in trees. It is therefore possible that the compass orientation of cliffs and their height have relatively little significance for nest site choice compared with nest shelter characteristics at a smaller scale. In this long-term study, I focused on the significance of shelter protecting nests of Golden Eagles located in cliffs, specifically on rock structures in the immediate nest surroundings (Anctil et al. 2014, Henderson et al. 2021).

METHODS

My main objective was to evaluate the hypothesis that nest shelter may be the most important parameter for nest site selection in cliffs by the Golden Eagle in my study area, a region with high levels of precipitation and snow cover in winter. Compared with all of the past studies focusing on the characteristics of nest cliffs, I focus more closely on conditions at the nest site itself. In recent years, the occurrence of torrential rain and other extreme weather conditions, has increased, possibly related to global warming (Christensen et al. 2013). A better understanding of the nest site characteristics of the Golden Eagle will help to understand whether nesting behaviour makes the species vulnerable to environmental change.

The present study was conducted in southeast Norway within the municipalities of Sør Aurdal, Nord Aurdal, southernmost Øystre and Vestre Slidre, and the valley of Etnedal within the region bounded by 60°30'–61°30' N and 9°5'–10°84' E. During the years 2000–2020, a total of 57 nests of Golden Eagles were located within 16 different territories, mostly in an 80 km distance of the north-south directed main valley of Valdres, with some nest sites situated in smaller valleys and canyons branching off from the main valley. Only three nests were found in trees, but the actual number of nests in trees was probably considerably higher. The study area covers about 2550 km² of mostly forested, undulating hills. The area is characterized by north-south oriented valleys, mostly with south and east facing cliffs. The hills lie mostly between 200 and 1000 m a.s.l. and are divided at intervals by valleys about 1–5 km wide and 200–500 m deep. The study area is covered mostly by forests of Norway spruce *Picea abies* with large clear-cuts, but also includes some small alpine areas at 1000–1500 m a.s.l. The total precipitation during the 5-month breeding season of Golden Eagles (March–July) averaged 364 mm (at Fagernes, Climate-Data.Org).

To evaluate the possibility that nest placement of eagles was determined by the local geology, which in Valdres and most of Norway is a manifestation of glacial movements, I compared the compass orientation of the 57 cliff nest sites, with the overall compass orientation of a random sample of 20 of the largest cliffs along 80 km of the main valley of Valdres. When evaluating the more detailed nest site characteristics, I focused on the structure of the cliff within 2 meters from the focal eagle nests. The nests were not climbed and I did not attempt to measure or evaluate the ledge sizes, which were mostly hidden from photographic view. However, as available refuge implies sheltering mostly by overhang, cave or crevice (Henderson et al. 2021), and as the eagle nestling sits mostly at the nest, rather than using an extended and often more exposed ledge, I focused on shelter structure at the nest site.

To evaluate shelter, I photographed each eagle nest, to show the protective structures within two meters from the nest. Each nest was scrutinized carefully on a computer image by zooming in for a close-up of the nest site. Four categories of nest sites were used: 1) a "corner" with mostly two, sometimes three approximately vertical sheltering walls at least 1 m tall, and without any significant overhead shelter. 2) a "ledge" with an approx. vertical or reclining back wall or an overhang. An overhang was defined as such, when it seemed to make more than 45 degrees with the horizontal surface of the nest. 3) a "cavity" with a ceiling and lateral structures as walls, usually with the nest touching the inner wall and being easily visible. A ceiling was defined as such, when it seemed to make less than 45 degrees with the horizontal surface of the nest. 4) a "cave", where the nest was completely hidden or only scarcely visible from the ground below the cliff wall. Vertical exposure was assessed by the degree of shelter from overhanging rocks whereas horizontal exposure was the shelter walls provided by laterally

Table 1. Sheltering rock structures as apparent from photos of 57 cliff nest sites of Golden Eagle in spruce forests of Valdres, southeast Norway, 2000–2021.

Nest sites	Shelter	Number
Corner	Vertical walls	2
Ledge	Overhang	19
	Vertical back wall	6
	Reclining back wall	1
Cavity	Ceiling with lateral walls, nest easily visible	28
Cave	Nest mostly hidden	1
Total number of cliff nests		57

protruding rocks following Henderson et al. (2021). The depths of the cavities were assumed to be equal to the diameter of the nest.

Four nests were excluded from further analysis, because the category could not be determined from the photo. Thus, a total of 57 nests were evaluated (Table 1). Also, it was recorded if the nest was more or less hidden behind vegetation. A few of the nest sites within the presented numbers of cliff categories may be subjectively or visually biased, due to a few cases with difficulties of distinguishing among a vertical back wall, a slightly reclining back wall or a slight overhang. However, the overall numbers are considered to indicate main features and trends of nest sites in the different areas (Table 1).

RESULTS

The main wall direction of all of the 20 major cliffs along the main valley in the study area, were oriented towards either the south (n = 8) or east (n = 12). Of the 57 nests, 44 (77%) were oriented towards south and east, 8 (14%) towards west and 5 (9%) towards north.

Among the total of 57 evaluated nests, 4% were in a corner, 33% on a ledge with overhang, 10% on a ledge with a vertical back wall, 2% on a ledge with a reclining wall, 49% were placed in a cavity, and 2% in a cave (Table 1). Overall, 83% of nest sites had overhead shelter from a cave, a cavity or with overhang (Figure 1).

All of the nests were more or less difficult to spot, even from different vantage points. Several nests had decomposed, due to moisture by frequent rain and winter snow. In Valdres, 8 (14%) nests fell down during my two-decade study period. The largest of the irregular cavities ranged from about 2 × 3 m² opening space, the smallest from about 1.5 × 1.5 m² which equals the approximate diameter of the nest. In about 10 cases (18%), the cavities were extended into a deeper crevice.

DISCUSSION

Nest orientation and cliff heights

In the study area in southeast Norway, virtually all of the major cliff habitats, as well as about 80% of the Golden Eagle nest sites were oriented towards south and east. Thus it seems probable that the height and orientation of cliffs used for nesting in Golden Eagles, simply reflect the general availability of cliff habitats within the study area, not necessarily a preference. However, northward orientated nest-sites with more snow in early spring were mostly avoided. The immediate nest surroundings may protect some nests from falling down, as well as resulting in less snow cover and more melting by the sun in early spring.

The occurrence of more eagle nests in the periphery of cliff walls was reported by Ellis (2020), and suggested as a strategy to reduce interference from other raptors, but may result from the geological occurrence of more ledges, crevices and cavities at the periphery rather than at the center of many cliff walls.

Shelter

In the present study, about 85% of the nests in cliffs were more or less sheltered from above because they were situated in a cave, a cavity or below an overhang. Watson (2010) emphasized the importance of overhead shelter, but the occurrence of shelter at Golden Eagle nest sites seems only to be quantified by Bergo (1984) in western Norway. He classified 58 nest sites as exposed (33%), sheltered (53%) and well-sheltered (14%). In Bergo's study, 53% of the nests were more or less hidden behind bushes, herbs or grass, while only two nests (4%) were partly hidden by vegetation in the present study. However, these two nests were detected comparably to other nests. Bergo (1984) did not distinguish between a ceiling and an overhang, and his category for well-sheltered included "overhanging and laterally protruding rocks" (14%) which fits partly with what I have termed caves and cavities in the present study (51%). Clearly a horizontally inclined ceiling provides the nest with more shelter than an overhang.

The higher prevalence of protected nest sites among Golden Eagles with overhangs, cavities, or cave-like characteristics (85%) versus ledges with a vertical or sloping back wall or a corner with vertical walls (16%), suggests that shelter from precipitation is important, together with concealment from overflying raptors and Ravens. Similarly, Henderson et al. (2021) found that early breeding Gyrfalcons *Falco rusticolus* in Alaska had higher productivity and tended to select more protected nest sites, which in the present study corresponds to 85% overhang-cavity-caves.

Nest sites with more protection seem to be important in a northern climate with a risk of snowstorms or heavy rain at the onset of breeding. A significant number of eagle pairs abandon their nesting attempt early in the breeding season, which may be partly explained by adverse weather conditions, as shown for Peregrine Falcons *Falco peregrinus* (Anctil et al. 2014). Henderson et al. (2021) also found that nest attendance of breeding birds increased with less shelter. Thus, a well-sheltered nest may allow adults more time for hunting during the latter part of the nestling period and thus may result in more fledged young.

Moisture, snow and heat

Moisture may be a problem for nests on exposed cliff ledges. In the Norwegian study area, areas of the cliff exposed to precipitation are characterized by a grey or blackish colour, often with dark vertical stripes resulting from downward running water. In contrast, the dry parts of vertical cliff walls with some overhang are light coloured. As a result of glacial friction, most of the cliffs in Norway will have reclining walls with a dark colour, whereas more restricted parts of the wall are vertical or with some overhang predicting a light, sometimes

Figure 1. An example of a typical sheltered cavity nest in Valdres, Norway.

faintly yellow colour. Accordingly, the eagle nests are most often found in restricted parts of the cliffs with a light colour (Dunker 2014). Nest site colouration likely indicates a preference for shelter against precipitation and moisture. In their study of Peregrine Falcons, Anctil et al. (2014) found no deaths of nestlings attributed to wind alone, but 38% of chick mortality was caused by the direct effects of frequent heavy rain (> 8 mm/day). The frequency of heavy rain also showed an increasing trend, possibly due to global warming.

Multiple days with extremely hot temperatures (>30 °C) can be fatal to eagle nestlings but are virtually non-existent in Norway. On the other hand, multiple days with heavy rain and late snowfalls in March-April can cause eagles to abandon breeding or can be fatal to the nestlings. The importance of the orientation of the cliff and cliff height seems not evident so far, whereas nest shelter may be significant to protect the content of the nest from exposure to harsh weather conditions. Thus, with the long duration of the breeding season combined with the short summer season in Norway, it could be important for eagles to start the breeding season as early as possible in March, when late snowfalls still commonly occur. Nests in trees and on cliffs with a sloping floor, will be increasingly susceptible to sliding and falling down during inclement weather with frequently stronger winds and more torrential rain, as predicted by global warming (Christensen et al. 2013). With a change in climate, more eagle nests may be at risk of falling down, both within and outside the breeding season. The response of the breeding population of Golden Eagles to global warming at least in parts of Norway may thus depend on the availability of suitable and more protected nest sites.

Nest predation

It has been claimed that in birds in general, nest predation is the primary cause of nest failure (Ricklefs 1969, Martin 1993). In many populations of the Golden Eagle, more than 50% of the pairs do not produce offspring each year. Thus, the risk and occurrence of nest predation have to be considered. However, nest predation is difficult to observe and may easily be under-estimated without extensive camera surveillance. Carnivores such as brown bear *Ursus arctos* (Masterov et al. 2018) and lynx *Felis lynx* (Warensjø 2000) are known to kill eagle nestlings from nests in trees. Marten *Martes martes* and wolverine *Gulo gulo* may also attack and kill eagle nestlings, but to my knowledge, losses to these predators has not been documented. Cavities and deep cracks may serve to hide both whitewash from nestling faeces and the nestling(s) to reduce predation risk.

Henderson et al. (2021) considered the access of terrestrial predators to eagle nest sites, but risk of attacks from avian predators are also relevant. Other raptors and Ravens are also fully capable of killing eagle nestlings. Harassment from corvids, in particular by Ravens, may also distract and disturb breeding eagles. Ravens might occasionally eat eagle eggs as filmed at Bald Eagle *Haliaeetus leucocephalus* nests (youtube.com/results?search query = raven+eating+bald+eagle+egg) and kill eagle nestlings as filmed on an Osprey *Pandion haliaetus* nest in Finland (youtube.com/results? search query = raven+eating+osprey). Raptors which could potentially depredate Golden Eagle nests in Scandinavia include Goshawk *Accipiter gentilis*, Gyrfalcon, Eagle Owl *Bubo bubo* and possibly White-tailed Eagles, depending on region. In addition, intruding Golden Eagles may disturb breeding and even kill eagle nestlings (Haller 1996).

It is well known that immature eagles, in particular birds assumed to be yearlings, tend to intrude in the vicinity of Golden Eagle nests during the breeding season (Walker 2017). These raptors may be more successful by a rear attack which is possible from more directions in case of a nest in a tree than in case of a nest on a cliff with some shelter from the back. With a back cover, an eagle nestling will be able to maintain a claw-defense posture which may instinctively be used even towards their own parents when they deliver prey at the nest (Ellis 2013, Ellis & Schmitt 2017). Therefore, in addition to a means to avoid effects of bad weather conditions, cliff nesting in raptors is probably also an antipredator strategy, with specific sets of behaviour patterns developed (Cullen 1957). Back walls, or cavities behind the nest may facilitate defense both for adults and large nestlings, preventing attack from the rear (Mysterud & Dunker 1983).

Ellis (2020) found that 19% of the cliff nests of Golden Eagle in open habitats in Mongolia were accessible without climbing or rappelling. Similarly, the corresponding number was 26% of the cliff nests studied by Tjernberg (1983) in the forests of Sweden. However, neither they nor other authors seem to have evaluated if cliffs were preferred over trees as nest sites. Extreme weather increases, torrential rains and late heavy snow cause reduced breeding success among nesting raptors, at least in some areas and populations (Trenberth et al. 2003, Min et al. 2011, Mioduzewski et al. 2018). Thus the shelter provided by nesting in a rock cavity in a cliff, seems optimal for the Golden Eagle, and possibly for many other bird species, with special importance in northern regions with climatic changes in rainfall in summer and snow cover in winter.

Acknowledgements. I am most grateful to David H. Ellis for accompanying me and for his experienced evaluations of most of the nest sites in Norway, June 2018. My greatest thanks also to Tore Slagsvold and two anonymous referees for comments on a previous version of the manuscript which helped me to revise and improve the manuscript considerably.

REFERENCES

Anctil A, Franke A & Bety J. 2014. Heavy rainfall increases nestling mortality of an Arctic top predator: experimental evidence and long-term trend in Peregrine Falcons. *Oecologia* **174**: 1033–1043.

Bergo G. 1984. Habitat and nest-site features of Golden Eagles *Aquila chrysaetos* (L.) in Hordaland, West Norway. *Fauna Norvegica Series C., Cinclus* **7**: 109–113.

Christensen JH, Krishna KK, Aldrian E, An S.I, Cavalcanti IFA, de Castro M, Dong W, Goswami P, Hall A, Kanyanga JK, Kitoh A. et al. 2013. Climate phenomena and their relevance for future regional climate change. Pp. 1217–1308 in: Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V & Midgley PM (Eds.) *Climate change 2013*: *The physical science basis.* Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK.

Cullen E. 1957. Adaptations in the Kittiwake to cliff-nesting. *Ibis* **99**: 275–302.

Dunker H. 2014. Vad ar det som påverkar kungsørnens val av boplats? *Kungsørnen* **2014**: 48–53. (In Swedish, with English summary).

Ellis DH. 2013. *Enter the realm of the Golden Eagle.* Hancock House, WA U.S.A. & B.C. Canada.

Ellis DH, & Schmitt NJ. 2017. *Behaviour of the Golden Eagle, An illustrated ethogram.* Hancock House, WA U.S.A & B.C. Canada.

Ellis DH. 2020. Ecology of the Golden Eagle in Mongolia, part 1: breeding distribution and nest-site descriptions. *Journal of Raptor Research* **54**: 18–29.

Fast PLF, Gilchrist HG & Clark RG. 2007. Experimental evaluation of nest shelter effects on weight loss in incubating Common Eiders *Somateria mollissima*. *Journal of Avian Biology* **38**: 205–214.

Ferrer M. 2001. *The Spanish Imperial Eagle.* Lynx Edicions, Barcelona, Spain.

Foster A & Wallis R. 2010. Nest-site characteristics of the Wedge-tailed Eagle *Aquila audax* in southern Victoria. *Corella* **34**: 36–44.

Haller H. 1996. Der Steinadler in Graubunden. Langfristige untersuchungen zur populationsökologie von *Aquila chrysaetos* im zentrum der Alpen. *Der Ornithologische Beobachter* **9**: 1–167. (In German, with English summary)

Hatton F, Mickan PH, Gruber B & Olsen J. 2014. Modelling the nesting habitat requirements of the Wedge-tailed Eagle *Aquila audax* in the Australian Capital Territory using nest site characteristics. *Corella* **38**: 63–70.

Henderson MT, Booms TL, Robinson BW, Johnson DL & Anderson DL. 2021. Direct and indirect effects of nesting site characteristics for a cliff-nesting raptor in Western Alaska. *Journal of Raptor Research* **55**: 17–32.

Martin TE 1993 Nest predation and nest sites: new perspectives on old patterns. *BioScience* **43**: 523–532.

Masterov V, Romanov M & Sale R. 2018. *Steller's Sea Eagle.* Snowfinch Publishing, Gloucestershire, UK.

Mearns R & Newton I. 1988. Factors affecting breeding success of Peregrines in south Scotland. *Journal of Animal Ecology* **57**: 903–916.

Min SK, Zhang X, Zwiers FW & Hegerl GC. 2011. Human contribution to more-intense precipitation extremes. *Nature* **470**: 378–381.

Mioduszewski J, Vavrus S & Wang S. 2018. Diminishing Arctic sea ice promotes stronger surface winds. *Journal of Climate* **31**: 8101–8119.
Mysterud I & Dunker H. 1983. Food and nesting ecology of the Eagle Owl, *Bubo bubo* (L.) in four neighbouring territories in southern Norway. *Swedish Wildlife Research* **12**: 71–113.
Ricklefs RE. 1969. An analysis of nestling mortality in birds. *Smithsonian Contributions to Zoology* **9**: 1–48.
Stahlecker DW, Wallace ZP, Mikesic DG, Boal CW, Murphy RK, Howe WH & Ruehmann MB. 2022. Golden Eagle nesting territory distribution in wind energy landscapes of the Southern Great Plains. *Journal of Raptor Research* **56**: 387–397.
Tjernberg M. 1983. Habitat and nest site features of Golden Eagle *Aquila chrysaetos* (L.), in Sweden. *Swedish Wildlife Research* **12**: 131–163.
Trenberth KE, Dai A, Rasmussen RM & Parsons DB. 2003. The changing character of precipitation. *Bulletin of the American Meteorological Society* **84**: 1205–1217.
Walker D. 2017. *A fieldworker's guide to the Golden Eagle.* Whittles Publishing Ltd. Scotland, U.K.
Warensjø B. 2000. Ørninventering – några minnesanteckningar. *Kungsørnen* **2000**: 16–24. (In Swedish with English summary).
Watson J. 2010. *The Golden Eagle.* T. and A.D. Poyser, London, U.K.
Willgohs JF. 1961. The White-tailed Eagle *Haliaetus albicilla albicilla* (Linné) in Norway. *Årbok for Universitetet i Bergen. Mat. Naturv. Serie No 12.:* 4–212.

Ornis Norvegica (ISSN 1892-9737) is a peer-reviewed, online and open access journal publishing original papers in all fields of ornithology. The geographical focus is on Fennoscandia. Descriptive articles documenting bird biology or populations are welcome. Articles dealing with faunistical material should be analytical. Both subscription and publishing are free of charge.

Read articles, submit papers, and more information about Ornis Norvegica at:
https://boap.uib.no/index.php/ornis/index