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Wildlife Camera Monitoring Revealed the Northern Goshawk as a Predator on Gyrfalcon Nestlings

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Gyrfalcons (*Falco rusticolus*) inhabit alpine and tundra ecosystems in the northern hemisphere, primarily above 60°N (Booms et al. 2020). They are year-round residents within most of the breeding range, and ptarmigan (*Lagopus* spp.) are generally their most important prey (Booms and Fuller 2003, Koskimies and Sulkava 2011, Nielsen 2011, Robinson et al. 2019). Gyrfalcons normally hold their territories throughout the year and often use the same cliff for nesting across several breeding seasons. In the Nordic countries, the female usually lays 3–4 eggs in mid-April and nestlings reach fledging age in June or early July (Nielsen and Cade 1990, Johansen and Østlyngen 2011, Booms et al. 2020).

Documented observations of predation on Gyrfalcon nestlings, including intraguild predation, are almost absent from the scientific literature. However, there is a report from Sweden of a pine marten (*Martes martes*) killing a brood of three half-grown Gyrfalcon nestlings (Falkdalen 1997), and also a report from Russia of Peregrine Falcons (*Falco peregrinus*) killing a subadult Gyrfalcon feeding on their nestling (Pokrovsky et al. 2010). The absence of reports of depredation of Gyrfalcon nests may be largely explained by the low number of sympatric avian predators throughout much of the Gyrfalcon's breeding range. The Gyrfalcon can share habitat with the Common Raven (*Corvus corax*) in most of its breeding range and the Golden Eagle (*Aquila chrysaetos*) in parts of its breeding range (Boarman and Heinrich 2020, Booms et al. 2020, Katzner et al. 2020). Those two species can be considered potential predators on Gyrfalcon nestlings, but no direct evidence for this has been published to our knowledge. However, anecdotal evidence suggests that Gyrfalcons are at least occasionally consumed by hetero- and conspecifics. For example, Nielsen and Cade (1990) reported two occasions in which a yearling Gyrfalcon was found as food remains in a Common Raven nest, but the authors suggested that the remains were picked up as carrion. According to Platt (1977), the Golden Eagle is a potential predator of Gyrfalcons, and the remains of a dead Gyrfalcon were documented in a Golden Eagle nest in Norway (Hagen 1952). In central-west Greenland, Booms and Fuller (2003) found remains of juvenile Gyrfalcons in two pellets in a Gyrfalcon nest, but it is unclear whether this was a result of intraspecific predation or cannibalism following filicide or nestling death by another cause.

We used wildlife cameras to monitor a total of 11 Gyrfalcon nests in the Lierne municipality (approximately 64.4°N, 13.6°E) in central Norway during the nesting seasons from 2018 to 2022. Cameras were installed when the oldest nestling was approximately 18 d old. At each nest site, we used two motion-triggered cameras (Minox DTC 550; Wetzlar, Germany) set to take one picture with intervals of 15 s and 30 s, respectively. During monitoring of one of the nests, we recorded a Northern Goshawk (*Accipiter*

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gentilis recently renamed as Eurasian Goshawk [Chesser et al. 2023]; hereafter goshawk) that attacked and killed three Gyrfalcon nestlings.

Wildlife camera monitoring began on 31 May 2021 at a nest located on a cliff at 642 masl in the low-alpine vegetation zone, close to the climatic tree limit. On 4 June at 2306 H, the female Gyrfalcon was recorded at the nest feeding four seemingly healthy nestlings (Fig. 1). Subsequently, neither parent was recorded at the nest before the female returned at 0612 H on 5 June. During this interval, a subadult goshawk visited the nest at least two times between 0214 H and 0235 H, and killed three of the four nestling Gyrfalcons. Based on the plumage development, the oldest nestling was approximately 23 d old when the brood was predated (Moen 2023), and at that age nestling Gyrfalcons weigh approximately 1000 g (Poole 1989).

The first attack by the goshawk occurred at 0214 H, which was approximately 30 min prior to sunrise. Between 0214 H and 0222 H the goshawk killed and started to eat one of the Gyrfalcon nestlings (Fig. 1). At 0222 H the goshawk killed a second nestling. The goshawk left the nest at 0223 H, and at that time, the recording shows two live nestlings and one carcass in the nest. At 0227 H one of the nestlings began to scavenge its dead sibling, and the carcass disappeared from the nest at 0230 H, but no photos revealed how that happened. The goshawk was recorded at the nest again between 0232 H and 0235 H and the third nestling was killed during that period. After the second attack, the goshawk did not return to the nest. At 0612 H the female Gyrfalcon arrived at the nest with a prey item and began feeding the only surviving nestling (Fig. 1). This nestling reached fledging age and left the nest on 29 June.

Our photo documentation represents the first detailed description of nestling Gyrfalcons being killed by another raptor species. By comparing the size of the goshawk with the female Gyrfalcon, we determined that the predator was a subadult female. Female Gyrfalcons are typically slightly larger than female goshawks, and both are substantially larger than male goshawks (Booms et al. 2020, Squires et al. 2020). The goshawk and the female Gyrfalcon on our video recording appear to be similar in size (Fig. 1).

Goshawks are powerful and opportunistic predators that prey on a large variety of birds and mammals (Squires et al. 2020), including other raptors such as Long-eared Owls (*Asio otus*), Tawny Owls (*Strix aluco*), nestling and adult Eurasian Sparrowhawks (*Accipiter nisus*), nestling and adult Common Buzzards (*Buteo buteo*), nestling European Honey-Buzzards (*Pernis apivorus*), and nestling Ospreys (*Pandion haliaetus*; Kostrzewa 1991, Squires et al. 2020, Anderwald et al. 2021). Based on our literature review, intraguild predation among goshawks and Gyrfalcons has not previously been documented, perhaps because the two species usually inhabit different habitats (Booms et al. 2020, Squires et al. 2020). In central Norway, though, boreal forests (inhabited by goshawks) and the subalpine to alpine areas (i.e., where Gyrfalcons breed) are often adjacent habitats, which may facilitate interactions of the two species. The Gyrfalcon nest described here was located approximately 800 m from suitable goshawk habitat comprising mature spruce (*Picea abies*) forest. Additionally, we note that we were not aware of a nearby goshawk territory, which may suggest that the predator was a non-territorial bird with a larger, less consistent foraging range.

Our nest monitoring data show that Gyrfalcon parents usually deliver prey to the brood 4–5 times per day when the nestlings are 20–25 d old (B. Moen unpubl. data). We were surprised that neither Gyrfalcon was recorded at the nest for a period of 7 hr during which time the predation event occurred. This may indicate that Gyrfalcons are adapted to low predation risk at the nesting stage and therefore do not actively guard their nest site, especially after their nestlings have become homeothermic. Although siblicide is widespread among raptors (Allen et al. 2020), we found no published descriptions of siblicide by Gyrfalcons, and Booms et al. (2020) state that inter-sibling conflict is not observed in this species. Here we recorded a nestling that began to scavenge on its dead sibling almost immediately after the predator left the nest, suggesting that the sibling's carcass triggered a feeding response.

Goshawks may negatively impact reproduction of other raptors by killing nestlings. For example, Kostrzewa (1991) showed that the proportion of nestling loss in Common Buzzards and honey-buzzards was highly negatively correlated with the distance to the nearest active goshawk nest, suggesting that nesting close to a goshawk nest imposes a higher predation risk. We believe that our photos of the goshawk attacking nestling Gyrfalcons represent a rare event. However, the possibility of goshawk predation introduces an additional variable that could affect the persistence of Gyrfalcons, given the existing challenges of an altered landscape and low juvenile survival rate (Booms et al. 2011, Nygård et al. 2011, Barraquand and Nielsen 2021). Climate change may promote interactions between the two species. Northern alpine areas and the Arctic tundra are among the biomes that are predicted to be most affected by global

Figure 1. Wildlife camera photos documenting a subadult Northern Goshawk as a predator on Gyrfalcon nestlings, central Norway, 2021. (A) The female Gyrfalcon feeding four healthy nestlings 3 hr before the goshawk attack; (B) and (C) a subadult goshawk attacks and kills two nestlings within a period of about 6 min; (D) shortly after the attack, one of the two surviving nestlings scavenges its dead sibling; (E) about 20 min after the first attack, the goshawk returns and kills the third nestling; (F) 4 hr after the goshawk attack, the female Gyrfalcon returns and feeds the surviving nestling.

warming (Post et al. 2009). A fundamental response is increased primary productivity that leads to "greening" of the tundra and an increase in the elevation of the tree line (Xu et al. 2013, Ims et al. 2019). Changing elevation of the tree limit can lead to an increase in the quantity of suitable habitat for opportunistic predators such as the goshawk and a decrease in suitable habitat for the Gyrfalcon. Changing habitats may also result in more frequent interactions between the two species, which may negatively affect the breeding success of Gyrfalcons in the future.

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