ARTIFICIAL NESTS—A REMEDIAL ACTION IN MAINTAINING VIABLE GYRFALCON POPULATIONS?

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ABSTRACT.—The Gyrfalcon (*Falco rusticolus*) faces several threats from environmental changes on its breeding and foraging grounds. In Finnmarksvidda, human activity has increased during recent decades in terms of numbers of residents, roads, use of fossil fuel, hunting for game birds, domesticated Reindeer (*Rangifer tarandus*) numbers, and eco-tourism. There also is increased forestation, and the Golden Eagle (*Aquila chrysaetos*) has become a regular breeder in the area.

Breeding Gyrfalcons are largely dependent on protected stick nests of Ravens (*Corvus corax*). Lack of suitable nest sites is an observed limiting factor both for the nesting density and breeding success of Gyrfalcons. There is longstanding evidence that, for many species of raptors, including the Gyrfalcon, providing artificial nests can increase breeding success in a given area. Artificial nests have also been suggested as a means of moving Gyrfalcons away from nest sites exposed to human disturbance. Artificial nests might thus counteract some of the threats to Gyrfalcons mentioned above. However, there has been no systematic study of this remedial action. In this study, we report nesting performance at nine artificial nests in Finnmark, northern Norway. They were constructed by improving cliff ledges or by making firm platforms for artificial Raven nests.

During the period 2000–2010, we recorded 94 Gyrfalcon nestings in the study area. Of these, 17 were in artificial nests. 77 nestings occurred in natural nests, of which 66 were built by Ravens, four by Golden Eagles, three by Rough-legged Buzzards (*Buteo lagopus*), three were on grassy ledges without stick nests, and one on unknown substrate. There were 61 (79%) successful nestings in natural nests, producing an estimated 168 young (2.76 young per successful nesting). Gyrfalcons attempted to breed in all of the nine artificial nests during the period 2000–2010. Of 17 nestings, 14 were successful (82%). Two of the artificial nests were unproductive during the study period. In total, artificial nests produced an estimated 45 young (3.2 young per brood), not statistically significantly different from the observed production of natural nests (P = 0.29). One artificial nest, placed in a location with no history of Gyrfalcon occupancy, was used in the year of construction by a pair of Gyrfalcons which successfully reared three young.

The study confirms that Gyrfalcons readily make use of artificial nests for breeding, that they accept a variety of nest constructions, and that reproduction is comparable with that at natural nests. It further suggests that artificial nests may initiate breeding in areas with no history of Gyrfalcon occupation, and stabilize breeding at active eyries. *Received 5 March 2011, accepted 28 June 2011*.

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MANY RAPTOR SPECIES live in areas where a shortage of suitable nest sites limits nesting density (Newton 1976, 1979). The Gyrfalcon (*Falco rusticolus*) is an early nester with laying dates differing throughout its breeding range from March to May when it is still winter in the Arctic. Nest site selection might occur even earlier (Cade et. al 1998), in January-February, and snow-free eyries seem to be favored (Platt 1976). The early laying and incubation period makes it crucial for the birds to choose a nest site protected from harsh weather and the effect of wind convection. The Gyrfalcon utilizes various types of nest sites on cliff ledges or in cavities, usually in old stick nests of other species, in particular the Raven (*Corvus corax*) (Cade 1960, Nielsen 1986, Tømmeraas 1990, Cade et al. 1998, Koskimies 2005). Gyrfalcon nesting in trees has been described from many regions (e.g., Kuyt 1962, 1980, Voronin 1987, Morozov 1991, Tømmeraas 2003, Obst 1994, Mela and Koskimies 2006). Gyrfalcons not only prefer nests that provide protection from adverse weather, but also from predators and falling debris (Figure 1) (Barichello 1983, Newton 1979). The most characteristic feature of Gyrfalcon cliff nests is some kind of projecting cover, usually an overhanging rock (Cade 1960, White and Roseneau 1970).

Shortage of suitable nest sites has been proposed as a limiting factor for the Gyrfalcon in parts of its range (Cade 1960, White and Cade 1971, Tømmeraas 1978, Kalyakin 1988, Shank and Poole 1994, Koskimies 1999, 2005, Furuseth and Furuseth 2009). Also, poorly-built nests can fall down during the nesting period (Knoff and Nøkleby 2011) or result in low nesting success (Figure 2) (Tømmeraas 1993b, Poole and Bromley 1988, Steen pers. comm. in Hansen 1994, Furuseth and Furuseth 2009, Knoff and Nøkleby 2011).

Artificial nest sites have been provided for a great number of raptor species, and can increase breeding density of raptors (Steenhof and Newton 2007). Where parts of a Gyrfalcon territory are disturbed, providing an artificial nest may be a method of moving breeding activity away from the disturbance (Tømmeraas 1978, Johansen and Østlyngen 2004, Koskimies 2005). There are several observations of Gyrfalcons accepting artificial nest sites (Tømmeraas 1978, Hansen 1994, Johansen and Østlyngen 2004, Steen and Sørli 2005) or using nests built on man-made structures (e.g., White and Roseneau 1970, Kalyakin 1988, Voronin and Kochanov 1989, Ritchie 1991, Morozov 2011). In the 1930s, a Sami named Saarenpaa from northern Finland was probably the first to make an artificial nest for Gyrfalcons. He placed two old stick nests of Rough-legged Buzzards (*Buteo lagopus*) on a cliff ledge, and supported the nest with two birches (*Betula pubescens*). The Gyrfalcons laid eggs in the nest, and, as was common at that time, Saarenpaa collected and sold them to an egg collector (Sjölander 1946). From 1978,

P. Tømmeraas experimented with building or enhancing nests for Gyrfalcons, using various constructions such as excavated nesting cavities, nesting boxes, and rock shelf nests. The best results were achieved by fastening mats made of steel reinforcement rods to which imitations of Ravens' nests were tied (Tømmeraas 1993). Of 52 observed nestings in northern Norway in the period 1982–1990, 9.6% took place in artificial nests (Tømmeraas 1990). In Hardangervidda, Norway, Hansen (1994) constructed an artificial nest at a Gyrfalcon location to secure a Raven's nest that tended to fall after a short time. The production of young Gyrfalcons there increased from two to eight per three-year period prior to and after the stabilization of the nest. From the same area, Steen (1998) reported an artificial nest where Gyrfalcons bred successfully each year for seven consecutive years with a minimum annual production of three young. In Hedmark, Norway, a Gyrfalcon nest site was restored and secured in the autumn of 2005, and during the following four years, the falcons raised four young each year (Carl Knoff pers. comm. in Furuseth and Furuseth 2009).

Even though there is evidence that Gyrfalcons may utilize artificial nests, to our knowledge there has been no quantitative study of this remedial method. As part of a Gyrfalcon monitoring program in Finnmark, northern Norway, we monitored nine artificial nests during the period 2000–2010 with the aim of comparing Gyrfalcons' use and productivity in artificial and natural nests. Furthermore, we wanted to find out whether providing artificial nests could establish the Gyrfalcon at sites with no previous history of occupancy.

Study Area

The study area consists of c. 10,000 km^2 in Alta and Kautokeino municipalities in the county of Finnmark, northern Norway (Figure 3), between 68°37´ and 70°08´ N and 21°58´ and 24°12´ E.

Figure 1. Well-protected nest site for Gyrfalcon in an old Raven nest.

Figure 2. Pile of old stick nests of Raven below Gyrfalcon nest.

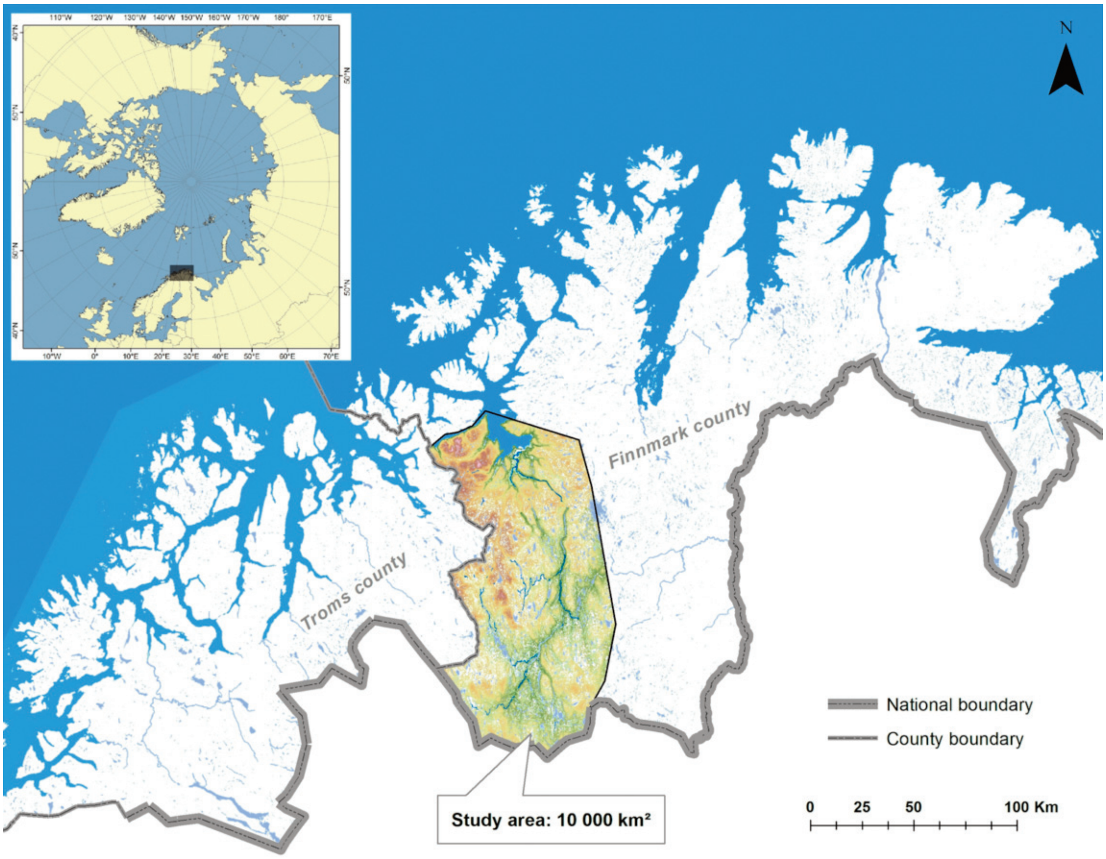

Figure 3. Map of the study area in Finnmark, northern Norway.

Figure 4. Gyrfalcon site on a small cliff in the southern part of the study area.

Figure 5. Large river valley with high cliffs typical of the northern part of the study area.

The southern part is a mountainous plateau 300–500 meters above sea level, with birch forests, marshes, lakes and a few major watercourses reaching the sea in Alta. The cliffs are generally small, located in river valleys or in steep parts of rounded hills (Figure 4).

Further north the landscape changes and the river valleys are large, with extended high cliff formations (Figure 5). The valleys are surrounded by mountainous areas. In the richer valleys, birch forests dominate in the higher parts and are gradually replaced by pine trees (*Pinus sylvestris*) in the lower regions closer to the coast.

The altitude of the study area varies from 0–1,000 m above sea level. The climate of the coastal part of the study area in Alta (elevation 3 m) is of an inland type, with cold winters and relatively warm, dry summers. The temperature norm for January is –8.7°C, and 13.4°C in July. Precipitation is 400 mm per year. In Kautokeino in the southern part of the study area, with an elevation of 307 m, the temperature norm for January is –16°C, and for July is 12.4°C. Precipitation is 325 mm/year (Norwegian Meteorological Institute 2010).

About 130 avian species breed in the area, including many species of gulls, ducks, raptors, waders and passerines. Twenty-four species of terrestrial mammals regularly occur (The Norwegian Zoological Society 2002), including domesticated Reindeer (*Rangifer tarandus*). There are about 21,000 human residents in the study area, and most of them live in the urban settlements of Alta (c. 16,000 inhabitants) and Kautokeino (c. 1,300 inhabitants).

Methods

Artificial Nests.—Nine artificial nests were constructed under overhanging rocks on cliffs to give shelter from snow and rain. We chose places high up in the cliffs to protect the nests from terrestrial predators. We aimed for a southern orientation to exploit earlier snow melting in the spring, although this was not achievable at all locations (Table 1). We constructed most of the nests at active Gyrfalcon sites in localities with a suspected shortage of suitable nest sites. We based this on previous observations of frequent breeding failures in suboptimal nesting sites or a total lack of available nest sites at the time of expected egg-laying (i.e. late March-early April).

Five Gyrfalcon territories were known either from historical data from the mid-19th century or from geographical names pointing to a long history of Gyrfalcon occupancy. Three of these territories seemed abandoned and showed no signs of Gyrfalcon occupancy at the time we built the artificial nests.

In addition to active or historical Gyrfalcon sites, in 2008 we provided artificial nests at two different cliffs with no history of Gyrfalcon occupancy. At one of them, droppings and moulted body feathers from Gyrfalcons were found the previous winter, but there were no signs of stick nests in the small gorge comprising the locality. After constructing the artificial nest, however, we found evidence of former Gyrfalcon nestings in the form of old prey remains of ptarmigan and old stick nests that had fallen from a slick ledge a few meters up the face of the cliff.

At the other cliff we found no signs of Gyrfalcon occupancy. We had observed lone Gyrfalcons in the surrounding area several times during the previous five years. Also, the area was known to be a good habitat for Willow Ptarmigan (*Lagopus lagopus*). Consequently, we thought that shortage of suitable nest sites could be a limiting factor preventing Gyrfalcons from breeding in the area.

Improving a Cliff Ledge.—A minimal-intervention method of making an artificial nest is to improve a suboptimal ledge already used by Ravens and/or Gyrfalcons. We constructed two nest sites this way, using somewhat different techniques. We restored one historical Gyrfal-

Table 1. Characteristics of the nine artificial nests.

Orientation (°/360)	0–297 (mean 171, SD 88)
Elevation (m)	330–520 (mean 417, SD 70)
Height nest-ground (m)	4–45 (mean 11, SD 13)
Height of nest cliff (m)	7–50 (mean 18, SD 14)
Former Gyrfalcon site	8 of 9 sites
Historical Gyrfalcon site	5 of 9 sites

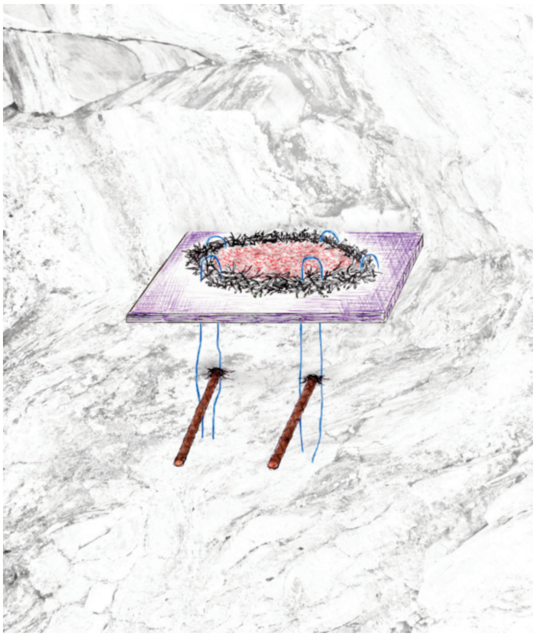

Figure 6. Method of constructing an artificial nest for Gyrfalcons.

con site in 1993. The ledge was shallow, and stick nests tended to fall down. We dug the ledge out with a climbing axe to increase its depth and improve the shelter from the overhanging cliff. No stick nest was placed upon the ledge, but we provided some substrate for the nest scrape by crushing the inner part of an old Crow's (*Corvus corone cornix*) nest.

We made one more artificial nest in a similar fashion. We built an imitation of a Raven's nest upon a large cliff ledge, used for several consecutive years by breeding Gyrfalcons. At the time of restoration, the original stick nest had been worn down by several broods of Gyrfalcons being raised there. We fixed a ring of fresh sticks to the cliff using wire and steel bolts. Then we wove numerous more sticks into the ring to make an imitation of a Raven's stick nest. Finally we filled the center of the nest with bark grit, a substrate proven suitable for a nest scrape.

Platforms for Imitation Raven Nests.—For the other seven artificial nests, the first step was to build a safe platform. We always placed the platform beneath an overhanging part of the cliff. Secondly we placed and fastened an imitation of a Raven's nest on the platform, using steel bolts and wire. We made the platforms in different ways, using mats made of steel reinforcement rods, concave concrete shapes, or water-resistant veneer plates, all mounted to the cliff by steel bolts, or mounted on steel reinforcement rods drilled horizontally into the rock (Figure 6). We also filled the centers of these nests with bark grit as substrate for a nest scrape.

Field Study.—We have carefully surveyed the Gyrfalcon population in the study area for the last 20 years (Østlyngen and Johansen unpublished). The study area holds 33 territories with confirmed nesting by Gyrfalcons after 1990. In the field-study period 2000–2010, we surveyed as many identified nest sites as possible each year. We checked the nest sites for incubating birds and nest characteristics during late April or first days of May when most Gyrfalcon pairs had completed egg-laying. In June, we surveyed breeding pairs for breeding success, i.e., number of large young observed on the nest, 5 weeks of age being minimum acceptable age for assessing success. We defined nest survival as the probability that a nesting attempt survives from initiation to completion and has at least one offspring that reaches 5 weeks of age (Steenhof and Newton 2007). We climbed all accessible nests and banded the young. Some nest sites were inaccessible; hence we had to determine brood size by observing the nest through a spotting scope from a distance.

From 2004, we used helicopters for the surveys, significantly enhancing the number of nest sites visited each year (Figure 7). We otherwise reached the nesting territories mainly by snowmobile, but also by skiing during winter and spring in some cases. After the first week of May, we visited most eyries on foot, though some were reached by helicopter or fixed-wing aircraft in late June or early July.

Statistical Methods.—As an outcome measure, we used mean number of young produced per breeding attempt in artificial and natural nests. We compared and analyzed means from the two categories of nests. Since the data set could not be considered normally distributed, we used a two-sample Wilcoxon rank-sum (Mann-Whitney) test. P-values of < 0.05 were considered significant.

RESULTS

During the period 2000–2010, we recorded a total of 94 initiated Gyrfalcon nestings in the study area (Table 2). The majority of Gyrfalcons bred in old stick nests of Ravens or imitation Raven nests. Seventy-seven nestings occurred in natural nests, of which 66 were built by Ravens, four by Golden Eagles (*Aquila chrysaetos*), three by Rough-legged Buzzards, three were on grassy ledges without stick nests, and one on unknown substrate

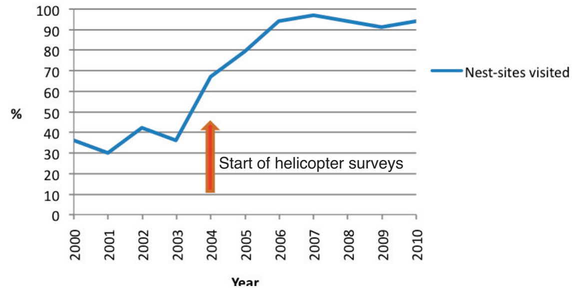

Figure 7. Percentage of total nest sites visited each year during 2000–2010.

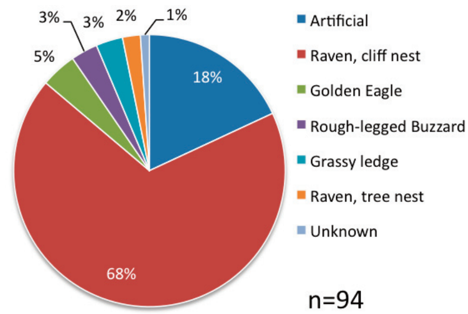

Figure 8. Gyrfalcon nest site selection 2000–2010.

(Figure 8). Of the total number of Gyrfalcon nestings, 75 (80%) were successful, resulting in a minimum of 177 and an estimated total of 213 young produced (i.e., 2.2–2.8 young per successful nesting). We estimated the brood size of verified successful nestings with unknown numbers of young by using the mean of observed brood sizes from the respective categories of nests (artificial or natural). For nestings that were observed in the incubation period only, we multiplied the estimated brood size by the expected nest survival (based on survival of nests observed both during the incubation and late-nestling periods) to adjust for the rate of nesting failure. There were considerable fluctuations in the annual number of Gyrfalcon nestings in the study period, i.e., from 2 to 18, which was also reflected in the annual number of young produced (Table 2).

Table 2. Overview of Gyrfalcon nestings in the study area 2000–2010.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Sum
Artificial nests												
Initiated nestings	1	1	0	1	1	2	0	3	5	1	2	17
Succeeded nestings	1	1	0	1	1	2	0	2	5	0	1	14
Number of young (observed minimum)	4	4	0	2	1	3	0	7	15	0	4	40
Number of young (observed and estimated)	4	4	0	2	3.2	5.2	0	7.2	15	0	4	44.6
Natural nests												
Initiated nestings	3	1	2	2	7	10	13	15	13	5	6	77
Succeeded nestings	3	1	2	2	6	9	10	10	10	3	5	61
Number of young (observed minimum)	8	0	6	8	18	11	25	23	21	4	13	137
Number of young (observed and estimated)	8	2.3	6.9	8	19.9	24.4	25.8	29.5	26.5	4	13	168.3

Artificial Nests.—All nine artificial nests held nesting Gyrfalcons during the study period. Seven nests had been placed before the start of the study, while two were constructed during the study period (2008). We recorded 17 nesting attempts in the nine artificial nests, of which 14 (82%) were successful. Two artificial nests did not have successful breeding of Gyrfalcons during the study period. In total, the nestings in artificial nests produced 45 young (3.2 fledglings per successful nesting).

Natural Nests.—We recorded 77 nesting attempts in natural nests, of which 61 (79%) were successful. These successful nestings produced a total of 168 young (2.76 young per successful nesting). The difference in mean number of young per successful nesting between artificial and natural nests was not statistically significant (Mann-Whitney, z = –1.57, P = 0.12).

A Remarkable Year.—In 2008, we examined 31 localities, of which eight were provided with an artificial nest. The number of confirmed Gyrfalcon nestings in the study area reached a peak of 18, five in artificial and 13 in natural nests. The probability for breeding in territories with artificial nests was about 10% higher than in territories without, even though natural nests by far outnumbered artificial nests. The mean number of young in the five artificial nests was 3.0, compared to 1.9 in the 13 natural nests, but small sample size still rendered this difference non-significant (Mann-Whitney test, z = –1.66, P = 0.098).

A Remarkable Territory.—One nesting territory provided with an artificial nest had successful nestings each year of the 11-year study period. Seven nestings were conducted in the same artificial nest, and four in different natural nests. For all years combined, the average annual production of young in the artificial nests was 3.5, compared to 2.5 in the natural nests. This difference was also not significant (Mann-Whitney test, z = –1.49, P = 0.14).

A New Territory.—On 17 February 2008, we constructed an artificial nest at a cliff site with no sign or knowledge of former Gyrfalcon occupancy. The same year, a pair of Gyrfalcons raised three young in the nest. The fledging date was estimated to be around 5 July, indicating a start of laying at about 7 April, less than two months after the construction of the nest. Occupancy of the nest cliff, pair bonding and courtship behavior prior to egg-laying must have happened very rapidly when a suitable nest site existed for the first time (Figure 9). Interestingly, a pair of Ravens nested for the first time on the same cliff the following year. The distance to the closest known Gyrfalcon location (also with successful nesting in 2008) was 14 km.

Nesting Failure at Suboptimal Nest Sites.—When there is a shortage of nest sites, Gyrfalcons may be forced to lay their eggs in unusual and suboptimal places. In 2007, we observed a Gyrfalcon pair breeding in a Raven's nest, freshly built upon a 60-cm-high snow drift on a cliff ledge. During the study, three nestings on grassy ledges and two in old Raven nests in trees also ended in early nesting failure. These six nest sites, unusual for Gyrfalcons in our study area, had one characteristic in common—the lack of an adequate overhang.

Discussion

We observed that about 80% of breeding attempts by Gyrfalcons in artificial nests were successful, which was similar to the yield in natural nests. Furthermore, the Gyrfalcons accepted a variety of nest constructions and performed successful breeding in an artificial nest in an area with no known history of Gyrfalcon occupation.

Utilization of Artificial Nests.—This study shows that Gyrfalcons quite readily accept artificial nests. We made them by various techniques, and all were accepted for breeding by Gyrfalcons during the study period.

Some basic aspects, such as overhanging rock and protection from predators, still have to be taken into consideration when constructing an artificial nest for Gyrfalcons. It has been recommended that artificial stick nests be provided with bones, excrement, and feathers to stimulate the Gyrfalcons to breed (Tømmeraas 1978). We used none of these extras when con-

Figure 9. Incubating Gyrfalcon in a new territory.

structing the artificial nests in our study. Observations of Gyrfalcons taking over freshly built Raven nests (once in this study, see above) show that they may initiate breeding in stick nests without these additions (Brüll 1938, Poole and Bromley 1988, Nielsen and Cade 1990). Thus, Gyrfalcons do not seem to require signs of former use to initiate breeding.

The Gyrfalcon's overwhelming preference for old stick nests of Ravens in our study area still suggests a significant stimulating effect, although this might be a local tradition more than instinct (Newton 1979). The Gyrfalcon can use nest ledges with no former stick nest, even though in our study area this choice was rare (only 3% of the nestings in our 11-year study). In Iceland, Ó. K. Nielsen successfully restored a former Gyrfalcon nest ledge without the use of a stick nest (Ó. K. Nielsen., pers. comm.). Raven nests make up only 52% of Gyrfalcons' nest choices in Iceland (Ó. K. Nielsen, unpublished data). In our study, we found a stick nest more likely to attract Gyrfalcons than a bare ledge, as also suggested by Kuyt (1980). One of our artificial nests was merely a dug-out cliff ledge, and it took 16 years after restoration until Gyrfalcons nested there. The Gyrfalcons finally accepted the nest ledge when a pair of Ravens had built a large stick nest there.

Nesting Results in Artificial Nests.—Five of the artificial nests resulted in first-time observations of Gyrfalcon nestings in the respective territories since our first surveys in 1990. The lack of any signs of Gyrfalcon nestings in these localities at the time of the first surveys suggested that Gyrfalcons may have been absent from these territories since at least 1985, maybe even longer. These localities had only one to three small cliffs with few, if any, suitable nest ledges. The five artificial nests were the certain cause of the eight young produced in these localities during the study period, and even so for the total of 23 young produced since 1990.

Given that artificial nests offer the chance to control important features of the nest site, like protection from adverse weather and predators, one might expect that artificial nests would have a better chance of survival than natural nests. In our study, nest survival was 0.8 for both categories, implying that nest survival may be influenced by other factors than nest characteristics alone (e.g. food availability, disturbance, or others), or that natural and artificial nests give equally good protection from adverse weather and predators. Old Raven nests, being the Gyrfalcons' most common nest choice among natural nests in the study area, almost always had large overhangs and were well protected from predators, thus serving these requirements well. Some of the artificial nests were placed in areas marginal to Gyrfalcons. For example, we built two of the artificial nests at an altitude of 520 m, the highest known for Gyrfalcon nests in the study area. Furthermore, some artificial nests were placed in areas with no sign of Gyrfalcon occupancy for years or decades. Equal nest survival in spite of such potential disadvantages is consistent with the hypothesis that artificial nests are as least as good as natural ones.

Artificial Nests as Means to Increase the Breeding Range of the Gyrfalcon.—To the best of our knowledge, this study is the first to show that an artificial nest has resulted in the establishment of Gyrfalcons in a location with no history of Gyrfalcon occupation. A pair of Ravens nested in the same cliff the following year, suggesting that the presence of an artificial stick nest may stimulate breeding by this species. Thus, artificial nests might help to extend the Gyrfalcon's breeding range into areas of otherwise good habitats but where suitable nest sites are lacking. Finnmarksvidda is one such area, comprising prime Willow Ptarmigan habitat, but with hardly any suitable cliffs and only few Raven nests in trees (still a very unusual nest choice for Gyrfalcons in Finnmark). Also, in Russia there are large areas with high prey abundance but no nest sites. An example from Kolguev Island, where Gyrfalcons were found nesting for the first time in 2008 on an old drilling platform from oil exploitation, shows that lack of nest sites limits the species' breeding range there (Morozov 2011). Ritchie (1991) recorded two nestings of Gyrfalcons in consecutive years (1988 and 1989) in Ravens' nests along the Trans Alaska Oil Pipeline System, the distance to the closest traditional Gyrfalcon aerie being 15 km. Here, the oil pipeline caused an increased breeding density of Gyrfalcons by offering new nesting sites. Initiation of experiments with artificial nests on poles on the Russian tundra (Mechnikova et al. 2011) and nest boxes in northern Finland (P. Koskimies pers. comm.) will eventually provide further knowledge about the effect of artificial nests on breeding range and productivity.

Study Limitation.—Compared to earlier studies, the large study area, the high number of nest sites surveyed, and the extended observation period are main strengths of the present study. Nevertheless, the sample of artificial nests was relatively small, which limits the power to detect differences in breeding success between different nest types. Furthermore, the artificial nests were constructed in Gyrfalcon territories selected by us, rather than randomly allocated among the eligible territories. Due to small sample size and selective placement of the artificial nests, our findings should be interpreted with caution: we cannot be sure that they would apply in other study areas. In the first five years of the study period, less than half of the Gyrfalcon nest sites were visited annually. This should not introduce much bias, however, since the proportions of natural and artificial nests visited were similar.

Conclusion.—Not withstanding the limitations of our study, we conclude that the breeding success of Gyrfalcons in artificial nests was at least as good as in natural nests. Our observations suggest that construction of artificial nests may dampen the potentially negative effects of human and environmental changes in the breeding range of the Gyrfalcon.

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LITERATURE CITED

BARICHELLO, N. 1983. Selection of nest sites by Gyrfalcons (*Falco rusticolus*). M.S. thesis. University of British Colombia, Vancouver, Canada.

BRÜLL, H. 1938. Ergebnisse der Islandexpedition der Hermann-Göring-Stiftung 1937. [Results from the Hermann-Göring-Foundation's expedition to Iceland 1937, in German.] Zeitschrift für Deutscher Falkenorden 3:22–41.

CADE, T. J. 1960. Ecology of the Peregrine and Gyrfalcon populations in Alaska. University of California Publications in Zoology. 63:151–290.

CADE, T. J., P. KOSKIMIES, AND Ó. NIELSEN. 1998. *Falco rusticolus* Gyrfalcon. BWP Update 2(1):1–25.

FURUSETH, L. E., AND P. FURUSETH. 2009. Jaktfalk i Buskerud. Rapport fra kartleggingsarbeid i 2009. [Gyrfalcon in Buskerud County. Report 2009, in Norwegian.] Naturvernforbundet i Buskerud, Darbu, Norway.

HANSEN, R. E. 1994. Erfaringer med kunstige reir for Jaktfalk. [Experiences with artificial nests for Gyrfalcons, in Norwegian.] Vår Fuglefauna 17(1):31–34.

JOHANSEN, K., AND A. ØSTLYNGEN. 2004. Kunstig reirplass for Jaktfalk (*Falco rusticolus*)—et eksempel [Artificial nest site for Gyrfalcon—an example, in Norwegian.] Pages 37–41 *in* J. Ekenstedt (Ed.). Proceedings from the Gyrfalcon Workshop, Umeå, Sweden, September 28, 2004.

KALYAKIN, V. N. 1988. [Rare animal species in extreme northwest Siberia.] Pages 97–107 *in* Y. G. Shvetsov (Ed.). [Rare Terrestrial Vertebrates of Siberia.] Nauka, Novosibirsk, Russia (in Russian).

KNOFF, C., AND P. NØKLEBY. 2011. Erfaringer med kunstige reir for jaktfalk. [Experiences with artificial nests for Gyrfalcons, in Norwegian]. Vår Fuglefauna 34(2):76–79.

KOSKIMIES, P. 1999. International Species Action Plan. Gyrfalcon *Falco rusticolus*.

BirdLife International & European Commission, Brussels, Belgium.

KOSKIMIES, P. 2006. Research on conservation biology of the Gyrfalcon *Falco rusticolus* in northern Fennoscandia: Present status and future prospects. Pages 56–69 *in* P. Koskimies and N. V. Lapshin (Eds.). Status of Raptor Populations in Eastern Fennoscandia. Proceedings of the Workshop, Kostomuksha, Karelia, Russia, November 8–10, 2005.

KUYT, E. 1962. A record of a tree-nesting Gyrfalcon. Condor 64:508–510.

KUYT, E. 1980. Distribution and breeding biology of raptors in the Thelon River area, Northwest Territories, 1957–1969. Canadian Field-Naturalist 94:121–130.

MECHNIKOVA, S., M. ROMANOV, AND N. KUDRYAVTSEV. 2011. Change in numbers and nesting ecology of the Gyrfalcon in the Yamal Peninsula, Russia, from 1981 to 2010. *In* R. T. Watson, T. J. Cade, M. Fuller, G. Hunt, and E. Potapov (Eds.). Gyrfalcons and Ptarmigan in a Changing World. The Peregrine Fund, Boise, Idaho, USA. http://dx.doi.org/10.4080/gpcw.2011.0220

MELA, M., AND P. KOSKIMIES. 2006. Monitoring and conservation of the Gyrfalcon (*Falco rusticolus*) in Finland. Pages 97–100 *in* P. Koskimies and N. V. Lapshin (Eds.). Status of Raptor Populations in Eastern Fennoscandia. Proceedings of the Workshop, Kostomuksha, Karelia, Russia, November 8–10, 2005.

MOROZOV, V. V. 1991. Sapsan i krechet na krainem severo-vostoke Evropy. [Peregrine and Gyrfalcon in the extreme northeast of Europe, in Russian.] Byulletin Moskovskogo Obschestva Ispitatelyei Prirody Otdel Biologicheskii 96:57–65.

MOROZOV, V. V. 2011. Ecological basis for the distribution and breeding of Gyrfalcons in the tundra of European Russia and preconditions for spreading to new grounds. *In* R. T. Watson, T. J. Cade, M. Fuller, G. Hunt, and E. Potapov (Eds.). Gyrfalcons and Ptarmigan in a Changing World. The Peregrine Fund, Boise, Idaho, USA. http://dx.doi.org/10.4080/gpcw.2011.0222

NEWTON, I. 1976. Population limitation in diurnal raptors. Canadian Field-Naturalist 90:274–300.

NEWTON, I. 1979. Population Ecology of Raptors. T. & A. D. Poyser, London, UK.

NIELSEN, Ó. K. 1986. Population ecology of the Gyrfalcon in Iceland with comparative notes on the Merlin and the Raven. Unpubl. Ph.D. thesis, Cornell University, Ithaca, New York, USA.

NIELSEN, Ó. K., AND T. J. CADE. 1990. Annual cycle of the Gyrfalcon in Iceland. National Geographic Research 6(1):41–62.

NORWEGIAN METEROLOGICAL INSTITUTE. 2010. Weather database (eKlima). Report.

OBST, J. 1994. Tree nesting by the Gyrfalcon (*Falco rusticolus*) in the western Canadian Arctic. Journal of Raptor Research 28(1):4–8.

PLATT, J. B. 1976. Gyrfalcon nest site selection and winter activity in the western Canadian Arctic. Canadian Field-Naturalist 90:338–345.

POOLE, K. G., AND R. G. BROMLEY. 1988. Natural history of the Gyrfalcon in the central Canadian Arctic. Arctic 41:31–38.

RITCHIE, R. J. 1991. Effects of oil development on providing nesting opportunities for Gyrfalcons and Rough-legged Hawks in northern Alaska. Condor 93(1):180–184.

SHANK, C. C., AND K. G. POOLE. 1994. Status of Gyrfalcon *Falco rusticolus* populations in the Northwest Territories, Canada. Pages 421–436 *in* B.-U. Meyburg and R. D. Chancellor (Eds.). Raptor Conservation Today. World Working Group on Birds of Prey, Pica Press, Berlin, Germany.

SJÖLANDER, D. 1946. Zoologiska Lapplandsminnen. [Zoological memories from Lapland, in Swedish.] Sveriges Natur's Årsbok Göteborg. 37:95–107.

STEEN, O. F. 1998. Jaktfalken på Hardangervidda. [The Gyrfalcon in Hardangervidda.] Blåfoten 5:1–2.

STEEN, O. F., AND B. SØRLI. 2005. Reirovervåking av Jaktfalk i Telemark i

2005. [Nest surveillance of Gyrfalcons in Telemark in 2005, in Norwegian.] Våre Rovdyr 19(4):92–95.

Steenhof, K., and I. Newton. 2007. Assessing nesting success and productivity. Pages 181–192 *in* D. M. Bird and K. L. Bildstein (Eds.). Raptor Research and Management Techniques. Hancock House, Surrey, British Columbia, Canada and Blaine, Washington, USA.

The Norwegian Zoological Society. 2002. Atlas of Norwegian Mammals.

Tømmeraas, P. J. 1978. Kunstige reirplasser for Jaktfalk *Falco rusticolus* og Vandrefalk *Falco peregrinus*. [Artificial nest sites for Gyrfalcons and Peregrines, in Norwegian.] Vår Fuglefauna 1(3/4):142–151.

Tømmeraas, P. J. 1990. Falkens reirbyggere. Utdrag fra rovfuglstudiene ved Alta-Kautokeino- og Reisavassdragene. [Nest-builders for the falcons, in Norwegian.] Vår Fuglefauna 13:205–214.

Tømmeraas, P. J. 1993. The status of Gyrfalcon *Falco rusticolus* research in northern Fennoscandia 1992. Fauna Norvegica Series C, Cinclus 16:75–82.

Tømmeraas, P. J. 2003. Jaktfalkens år 2003. [The year of the Gyrfalcon 2003, in Norwegian.] Våre Rovdyr 17(3/4):63–65.

Voronin, R. N. 1987. O biologii krecheta (*Falco gyrfalco* L.) na jugo-vostoke Bolshezemel'skoi tundry. [Biology of Gyrfalcon (*Falco gyrfalco* L.) in the south-east of the Bolshezemelskaya tundra, in Russian.] Byulletin Moskovskogo Obschestva Ispitatelyei Prirody Otdel Biologicheskii 92(6):10–15.

Voronin, R. N., and S. E. Kochanov. 1989. [New findings on the breeding sites of Peregrine and Gyrfalcon in the tundras of the NE European part of the USSR.] Pages 44–45 *in* X. X. Kuzyakin (Ed.). Proceedings of the Surveyed Characteristics, Results of Counts and Survey Materials of Non-commercial Birds, Reptiles, Amphibia and Fish. Bashkir Books, Ufa, Russia (in Russian).

White, C. M., and T. J. Cade. 1971. Cliff-nesting raptors and ravens along the Colville River in Arctic Alaska. Living Bird 10:107–150.

White, C. M., and D. G. Roseneau. 1970. Observations on food, nesting, and winter populations of large North American falcons. Condor, 72:113–115.