RESEARCH ON CONSERVATION BIOLOGY OF THE GYRFALCON *FALCO RUSTICOLUS* IN NORTHERN FENNOSCANDIA: PRESENT STATUS AND FUTURE PROSPECTS

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Recent research and future research needs of the Fennoscandian Gyrfalcon populations for conservational purposes are reviewed. At present we have a much better knowledge on population size, annual fluctuations in pair numbers and breeding productivity in large study areas than in former decades, because the national monitoring projects have been intensified considerably in northern Finland, Sweden and Norway. Although many aspects of the ecology of the Gyrfalcon are better understood than 10–15 years ago, there remains still serious gaps in our knowledge especially on the viability of the populations, and on the key environmental factors related to the natality, mortality and dispersal of the Gyrfalcons in different parts of northern Fennoscandia. Preliminary re-evaluation of old data sources from the 19th century indicate a probable exaggeration of the decline of the Gyrfalcon´s population in former studies. The article presents also a new integrated project for more intensive monitoring and conservation of the Fennoscandian Gyrfalcon populations.

Key words: Gyrfalcon, conservation, population changes, Fennoscandia.

ИССЛЕДОВАНИЯ ПРИРОДООХРАННОЙ БИОЛОГИИ КРЕЧЕТА *Falco rusticolus* В СЕВЕРНОЙ ФЕННОСКАНДИИ: СОСТОЯНИЕ И ПЕРСПЕКТИВЫ. П. Коскимиес. Кирkконумми, Финляндия.

В статье дан обзор исследований последних лет и обоснована необходимость дальнейших исследований популяций кречета в Фенноскандии в природоохранных целях. В последнее время все более активно ведутся национальные проекты по мониторингу вида на севере Финляндии, в Швеции и Норвегии. Многие аспекты экологии кречета стали нам более понятны, чем 10-15 лет назад, но осталось немало серьезных пробелов в наших знаниях, особенно в том, что касается жизнеспособности популяций и основных факторов окружающей среды, обуславливающих рождаемость, смертность и расселение кречетов в различных частях северной Фенноскандии. Представлены последние данные о размере, межгодовых колебаниях численности и продуктивности популяций. Предварительная оценка литературных источников по 19 веку говорит о том, что в прежних исследованиях сокращение популяции кречета, вероятно, преувеличивалось. Кроме того, в статье представлен новый комплексный проект по более интенсивному мониторингу и охране популяций кречета в Фенноскандии.

Ключевые слова: кречет, природоохранная биология, Фенноскандия.

INTRODUCTION

The Gyrfalcon has a long and exceptional history in connection with man. It was the most valued raptor species among falconers at least since the beginning of the second Millennium. In his famous book, *De Arte Venandi cum Avibus*, Frederick II of Hohenstaufen (ca. 1248) praised the bird as follows (translated by Wood & Fyfe 1943): "Out of respect for their size, strength, audacity, and swiftness, the gerfalcons shall be given first place in our treatise". He continued that the Gyrfalcon "…holds pride of place over even the Peregrine in strength, speed, courage, and indifference to stormy weather". The falcons came from "… a certain island lying between Norway and Gallandia, called in Teutonic speech Yslandia", and "… in our experience the rare white varieties from remote regions are the best". Olaus Magnus (1555) tells the Gyrfalcon to be so strong and furious that it rushes to hunt up to five Common Cranes *Grus grus*, and it does not stop until it has killed them all.

From the 14th to the 18th century Denmark ruled northeastern Atlantic with varying success. With the help of Dutch falconers, the Danish court organized an effective trade of Gyrfalcons from Iceland and northern Scandinavia to Copenhagen especially in the 17th and 18th century (Oorschot 1974, Vaughan 1992, Christensen 1995). Gyrfalcons, and especially the Greenlandic white morph birds migrating to Iceland for winter, became gifts of the first rank from Danish kings to other European courts, for making peace and other diplomatic purposes. Russian tsars had a similar monopoly of falcon trade in northwestern Russia.

From 1664 to 1806, for example, much over 6 200 Gyrfalcons were exported from Iceland to Copenhagen, less than 10% of them of the white morph (Oorschot 1974, Christensen 1995). The number of falcons fluctuated considerably, with peaks ca. every tenth year. This cyclical fluctuation most probably reflected population changes of the main prey in Iceland, the Ptarmigan *Lagopus mutus* (Nielsen & Pétursson 1995). This statistics is the oldest time-series of mutual fluctuations of a prey and a predator documented in a scientifically accurate manner.

In addition to falconers, egg-collectors valued Gyrfalcons over other northern birds in the early decades of the scientific ornithology (e.g. Newton 1864–1907). In northern Fennoscandia, in the late 19th and early 20th century, hundreds of falcon clutches were taken by tens of collectors who employed local people for intensive "egg-hunting" of all northern birds (e.g. Wibeck 1960).

Long-lasting and large-scale trapping of Gyrfalcons and collecting of their eggs are thought to have caused a serious population decline since the 19th century in northern Fennoscandia (e.g. Cade et al. 1998). In addition, Willow Grouse *Lagopus lagopus* and Ptarmigan populations are possibly markedly smaller nowadays than decades ago, which is said to have a negative effect on falcons´ food supply (e.g. Tømmeraas 1994, Holmberg & Falkdalen 1996).

Because of these and many other threats, the Gyrfalcon has been classified as endangered all over the European range (Koskimies 1999, 2006, BirdLife International 2004). The European Union regards the Gyrfalcon as a priority species in need of special conservation concern (listed in Annex I of EU Birds Directive).

In recent years, research on the Fennoscandian populations has given much new data to re-evaluate the conservational status of the Gyrfalcon, as well as to plan more effective management methods than previously. In this article I discuss the present status of the Fennoscandian Gyrfalcon population and its long-term changes. I also review recent studies and future research needs.

Experience and results from monitoring studies in Finland, Norway and Sweden can be applied also in northwestern Russia to widen our knowledge of this top-predator, one indicator on the status of the Subarctic and Arctic food webs and ecosystems. For a modern review of the general ecology of the Gyrfalcon, the reader should look especially for Clum & Cade (1994), Cade et al. (1998) and Potapov & Sale (2005).

MONITORING PROJECTS IN NORTHERN FENNOSCANDIA

Finland

Long-term quantitative changes of bird populations have been monitored in Finland with a comparable methodology since the beginning of the 20th century (e.g. Merikallio 1958, Koskimies 1989a, Väisänen et al. 1998). The Finnish bird monitoring system (Koskimies 1987, 1989b, Koskimies & Väisänen 1991) has been founded on long-lasting, representative and nation-wide censuses of all bird groups, including a special mapping project for birds of prey (e.g. Honkala & Saurola 2006, Saurola 2006).

Due to the low breeding density and uneven distribution, the Gyrfalcon can not be monitored either by ordinary bird census methods or those used for common raptors, with voluntary bird ringers and bird-watchers looking for all raptor nests in 10x10 km sample grids (e.g. Saurola 2006). To get reliable results of the Finnish Gyrfalcon population of only 20–35 pairs (Koskimies 1999), annual monitoring must cover all territories and nest-sites.

In the beginning of the 1990s I started a special project to search for and monitor Gyrfalcon´s nest-sites, and to study the ecology of the species for conservational purposes. The Finnish population was poorly known up to that time. For years I collected data on nest-sites from various sources and checked hundreds of cliffs. It took nearly ten years to localize most of the nest-sites in Finland by walking and skiing, and to learn details on the ecology and ethology of the Gyrfalcon necessary for effective monitoring. It was necessary to learn also geology, geography as well as history of Lapland and its fauna.

In the late 1990s also Metsähallitus, responsible governmental authority for conservation and monitoring of threatened animals and plants in state-owned lands in Lapland, started to map Gyrfalcon´s nest-sites for site-specific conservation activities (Mela & Koskimies 2006). Since then, it was possible to join our efforts and resources to control all nest-sites several times a year and look for new ones in a more intensive way.

Since the year 2000 I have worked systematically also in northernmost Sweden (north of the River Lainio–Lake Råstojavri), and in eastern Finnmark, which were not covered by Swedish and Norwegian monitoring projects, respectively. In addition to enlarge my study area for more reliable results, an important reason was the fact that many "Finnish pairs" have alternative nest-sites beyond our borders.

Sweden

In Sweden, ornithologists became more interested in systematic population monitoring locally in the 1980s (e.g. Lindberg 1983). The free hunting of *Lagopus sp*. and other small game raised worries on its possible impact on Gyrfalcons´ prey base (Holmberg & Falkdalen 1996).

The longest ongoing project for monitoring Gyrfalcons in Sweden started in the counties of Jämtland, Härjedalen and Dalarna, Central Sweden, in the year 1994 by the Sveriges Ornitologiska Förening (the Swedish Ornithological Society). The population is estimated at 24–37 breeding pairs, monitored annually by 20 voluntary bird-watchers (Falkdalen 2004, Falkdalen et al. 2005).

Further north in Norrbotten, covering half of the Swedish fjell area and Gyrfalcon range, a monitoring project began in 1996, funded by private funds and environmental authorities (Ekenstedt 2004, 2006a, 2006b, Falkdalen et al. 2005). During the first four years birds were monitored in two subareas, one with free access for hunters, the other including vast national parks where hunting is forbidden. Since 2000, the whole county has been covered up to the River Lainio in the north. In total, 42–51 pairs have been estimated to breed in Norrbotten.

The remaining part of the Swedish Gyrfalcon range, Västerbotten, has been covered since 2000 in a monitoring project run by the local environmental administration (Danielsson 2004, Falkdalen et al. 2005). The number of occupied territories varied from 12 to 21 in 2000–2004, but many breeding pairs have probably remained unnoticed so far due to the short time span of the project.

Norway

As in Finland and Sweden, many egg-collectors and local ornithologists collected information on the occurrence of the Gyrfalcon in various parts of Norway in the 1800s and early 1900s (e.g. Collett 1921). Special studies of the species were started by Hagen (1953) in southern Norway. Since the late 1960s, Per J. Tømmeraas (e.g. 1993, 1998) specialized on the species especially in northernmost Norway. His field studies have been continued in Alta and Kautokeino, western Finnmark, by Kenneth Johansen and Arve Østlyngen with co-workers (Johansen & Østlyngen 2004).

A very active monitoring project has also been started in recent years in Troms county, west of Alta–Kautokeino study area (Johnsen 2004, Karl-Birger Stann & Trond Johnsen unpublished). A major contribution of the project, also for widening knowledge on the general ecology and conservation status of the Gyrfalcon, is the inventory of nest-sites in the archipelago and along the coast of the Atlantic Ocean from Troms county to Finnmark. Seaside habitats, providing high numbers of seabirds as prey for falcons the year round, have not been studied before in such a large scale and with similar intensity.

Regional monitoring has been started also in Nordland, south of Troms county. Tømmeraas (1998) estimated the population in Nordland as 48–65 pairs, in Troms county 29–53 pairs, and in Finnmark 60–81 pairs. Karl-Birger Strann (unpublished) estimated the average numbers in autumn 2005 similarly as 50 pairs in Nordland and 70 pairs in Finnmark, but 100 pairs in Troms county. According to the newest data these estimates may be too low.

As my study area covers inland of eastern Finnmark, and the inventories by Strann, Johnsen, Østlyngen, Johansen and their co-workers cover the rest of Finnmark, Troms county and Nordland, we will have the whole population of northern Norway monitored in a comparable manner within the coming years. Further south in Norway, there has been some local monitoring projects of more limited scale. One of the longest and most intensive has been running in Telemark (Frydenlund-Steen 1998, Frydenlund-Steen & Sørli 2005).

FIELD METHODS OF GYRFALCON MONITORING IN FINLAND

Monitoring of population size and productivity

All the Fennoscandian projects aim to monitor primarily the annual numbers of territorial Gyrfalcon pairs, and the numbers of nestlings produced. These parameters are meant to measure the size, trend, conservational status and productivity of the populations. As they are in central focus in most raptor studies all over the world, general methods for raptor field studies have been applied (e.g. Postupalsky 1974, Pendleton et al. 1987).

In detail, however, field work must be suited for the ecology, behavioural traits, observability and other species-specific properties, as well as environmental factors of the study areas. A few methodological details applied in Finland will be discussed briefly. Similar methods in controlling of nest-sites have been used in Sweden and Norway to guarantee comparability of our results (e.g. Ekenstedt 2006a, 2006b). In the following chapters I will present also the methods I use for documenting the quality of nest-sites, collecting prey remains, and measuring availability of food.

Controls of nest-sites

Gyrfalcon nest-sites and potentially suitable cliffs with Raven *Corvus corax* nests have been looked for and controlled all the year round. Observations from other people have been useful for continuous up-dating of the data base of available nest-sites (c.f. Mela & Koskimies 2006).

The falcons visit nest-sites throughout the year. Occupied territories can be identified from signs left by the birds. In addition to falcons, special interest has been paid to human traces in the neighbourhood of the nest-sites. If visitors are supposed to come to a site intentionally, for the sake of the Gyrfalcon, at any time of the year, their motives have been inspected.

In recent years, regularly occupied nest-sites and home ranges have been visited several times in February and March, to get information on both breeding and non-breeding pairs and lone birds, either territorial or wandering individuals ("floating population").

All territories have been controlled systematically in the first standard visit in mid or late April, during egg-laying or early incubation, to confirm the number of pairs starting to nest (see Postupalsky 1974). The nests have been checked by binoculars or telescopes further away to avoid disturbance. If birds are not present, alternative nest-sites have been visited. Faeces, prey remains, down, traces in snow, and all other kind of signs of the presence of falcons have been recorded according to a detailed protocol. Active nest-sites have been controlled at irregular time-table also later from April to June especially to warden them against intentional or un-intentional disturbance, and both authorities and local people monitor moving of people in nesting areas to prevent disturbance.

The second standard visit to active nest-sites has been made in mid or late June, to count the nestlings, which are then usually 5–7 weeks old, and will fledge with high certainty within 0,5–2 weeks. If climbing does not take a long time and disturb the birds too much, the nestlings have been ringed with ordinary metal rings and special colour rings, the codes of which could be read with telescope from longer distance.

Parent birds at site during controls have been photographed and video-filmed, and their behaviour and appearance have been described in detail for individual recognition. This material is used to monitor site-tenacity and pair fidelity of nesting adults, and to get a rough estimate of population turnover. Recording voices is also under consideration as a non-invasive technique for separating individuals from each other. Moulted feathers have been collected at nest-sites for a forthcoming DNA analysis on individual identity, started by Johan Ekenstedt in Umeå University (unpublished). Nest-controls give also data on timing of nesting, quality of nest-sites, cause of unsuccessful nesting, and other topics on breeding biology.

Successful nest-sites have been visited in late summer or early autumn to confirm fledging of young, by inspecting signs left by them. At the same time, the neighbourhood of the nest-sites have been checked thoroughly for looking for prey remains and possible human traces.

Estimating quality of nest-sites

Availability of high-quality nest-sites is a necessary prerequisite for successful breeding of the Gyrfalcon (Koskimies 1999). Falcons prefer twig-nests built by Ravens, on ledges of abrupt cliff walls safe from mammalian predators. Almost all nests have a rocky overhang for protecting the nest from snowfalls and rain.

If optimal Raven nests are not available in a territory, some pairs have accepted Rough-legged Buzzard *Buteo lagopus* and Golden Eagle *Aquila chrysaetos* nests. Those nests usually do not have an overhang, and they are easier for land predators to access. Some Finnish pairs breed also more or less regularly in twig-nests in pines, especially in eastern Lapland (Cade et al. 1998, Mela & Koskimies 2006).

In spite of the importance of old twig-nests for the Gyrfalcons, no detailed studies have been published so far to describe their availability and quality in an extensive scale in Fennoscandia. In Finland, eastern Finnmark and northern Sweden, I have measured ca. 20 parameters from occupied nest-sites, as well as those Raven nests which have not been used by the Gyrfalcon. In the 1990s I used a simpler method by Barichello (1983), but in recent years I have applied a more sophisticated methodology by Wightman (2001).

According to my preliminary results, quality and safeness of available nests varies considerably. In many parts of the Finnish range there are not very many optimal nest-sites, which has a negative effect on the density and dispersion of the Gyrfalcons. Nest-site distribution may have a stronger effect on Gyrfalcon's distribution than on other cliff-nesting raptors with less strict nest-site requirements (e.g. Newton 1979).

Collecting and analysing of prey remains

Prey remains have been collected in an effective and standard manner both in June, when nestlings are close to fledging, and in early September, when fledglings have left the natal territory (Koskimies & Sulkava 2002). All bones, feathers and other remnants of prey animals have been picked from the nest, from nearby cliff ledges and below them.

Prey remains have been looked for also on top of cliff above the nest, and on cliffs and high terrain opposite to it. Parent birds prefer to sit and guard their nest in those kinds of sites, as well as eat and pluck prey animals before taking it to the nest. Near many nests there are also dead trees, horizontal tree trunks and other kinds of popular sitting places, under which remnants have been searched for. These methods are similar to those used in Icelland in the most thorough study of Gyrfalcon´s food in the world (Nielsen 2003, 2004).

All prey remains have been dried and stored for further analysis. A Finnish expert of the art, Prof. emer. Seppo Sulkava, has identified the specimens and counted the number of individuals (Koskimies & Sulkava 2002).

Monitoring availability of prey

Abundance of the Willow Grouse seem to be a key factor for successful breeding of the Gyrfalcon, in addition to undisturbed nest-sites (e.g. Cade et al. 1998, Koskimies 1999, Potapov & Sale 2005). On average, *Lagopus sp*. form generally over 90% of the Gyrfalcon´s diet throughout the breeding season in many parts of the European range (Koskimies & Sulkava 2002, Nielsen 2004, Nyström et al. 2005). The grouse are almost the only prey for half of the year in Lapland, and at least in Iceland their availability is the most critical factor regulating the proportion of falcon pairs which start to breed in early spring (Nielsen 2003). A similar relationship most probably exists in Fennoscandia.

The total population of the Willow Grouse in Finland has been estimated recently at 60 000–150 000 pairs, and that of the Ptarmigan at 3 000–6 000 pairs (Koskimies 2005). The Willow Grouse is supposed to be much more important prey for the Finnish Gyrfalcons compared to the Ptarmigan, but in higher mountain areas in Sweden and Norway the Ptarmigan is naturally very important (Nyström 2005).

Finnish grouse populations have been monitored annually by special censuses in late summer since the mid-1960s, and with the so called wildlife triangle censuses since the late 1980s (Lindén et al. 1996). Density estimates based on nation-wide line transect censuses exist from the 1940s (Merikallio 1958, Väisänen et al. 1998). Although the Willow Grouse population fluctuates cyclically, in the longer run it has declined in recent decades (Väisänen et al. 1998). During the first years of the 21st century, however, the population in northern Finland recovered locally to the highest level for decades (Helle et al. 2005).

A basic problem with grouse monitoring data for my research purposes is that there are too few census routes in northern Lapland. For that reason I have estimated relative fluctuations of the Willow Grouse population from year to year by recording all grouse seen or heard along my permanent routes to and from the falcon nests. Because I ski during winter and spring, and walk in summer and autumn, I can freely observe all birds the day round. I visit the same falcon territories from year to year, and several times a year in the same manner and along the same routes.

Because weather and time of the day may vary, however, and because these factors have effect on the observability of grouse, the total number of individuals can not be taken as such to indicate the real density of grouse. My statistics, however, can be used to classify each breeding season into categories of abundance (e.g. peaks and lows, as well as years with increasing or declining populations).

Other kind of data may be found to indicate the relative abundance of Willow Grouse in recent decades in northern Lapland. There are still many professional or semi-professional hunters, and they will be interviewed to get additional information on the changes of grouse populations in former years. Northernmost line transects and local bird censuses also give extra knowledge to evaluate fluctuations of grouse populations (Väisänen et al. 1998).

Other prey species do not have such a marked impact on the percentage of breeding pairs, and the number of nestlings they produce (e.g. Nielsen 2003, Nyström et al. 2005). Fledged young, on the contrary, probably hunt commonly other birds like waders, waterfowl, gulls and terns. Information on their abundance in different parts of the range, and in different habitats, are available from general bird censuses. As we do not have good knowledge on prey selection of young and immature Gyrfalcons, however, there remains a problem to evaluate the impact of abundance of various bird species on the survival of falcons.

GYRFALCON POPULATIONS IN NORTHERN FENNOSCANDIA

Number of pairs

I review shortly the recent status of the Gyrfalcon populations in northern Finland, Sweden and Norway, according to the results of the national monitoring projects described above (e.g. Falkdalen et al. 2005, Ekenstedt 2006a, 2006b, Mela & Koskimies 2006, Karl-Birger Strann unpublished). The present population in northern Fennoscandia, from Nordland and Jämtland–Härjedalen in the southwest to Finnmark in the northeast, is estimated at about 330 pairs. A general impression is that earlier population estimates have been too low, especially in poorly inventoried regions.

Comparable data on the number of pairs is available at the moment from Finland and Sweden, from the year 2000 to 2005 (table 1, fig. 1). Except in Västerbotten, field work effort has been at the same general level in all study areas during those years. Thus, the annual variation reflects mostly true natural fluctuations in Gyrfalcon populations. The proportion of successful nests has varied from about 40% to about 70% (fig. 2).

I have also compared preliminarily the density of the Willow Grouses in Finnish Lapland with the number of Gyrfalcon pairs (fig. 3). Grouse densities are based on wildlife triangle censuses in August (Lindén et al. 1996, Helle & Wikman 2006). Most of the data, however, comes from southern Lapland, south of the breeding range of the Gyrfalcon. But also in the north grouse population reached its peak in 2002–2004. Fig. 3 tends to indicate that good grouse years are followed by an increasing number of occupied territories and successfully breeding pairs 2–3 years later, probably when the nestlings raised in good years mature. In Iceland, the number of occupied Gyrfalcon territories was correlated with Ptarmigan density with a 3-year time-lag (Cade et al. 1998). A more critical analysis of our data will be made later.

Table 1. The number of occupied Gyrfalcon territories in Finland and in the three northernmost counties of Sweden in 2000–2005.

Year	2000	2001	2002	2003	2004	2005
Finland	16	23	23	22	31	32
Norrbotten	33	32	35	27	42	37
Västerbotten	12	12	14	15	21	?
Jämtland–Härjedalen	14	19	24	30	26	?
Total	75	86	96	94	120	?

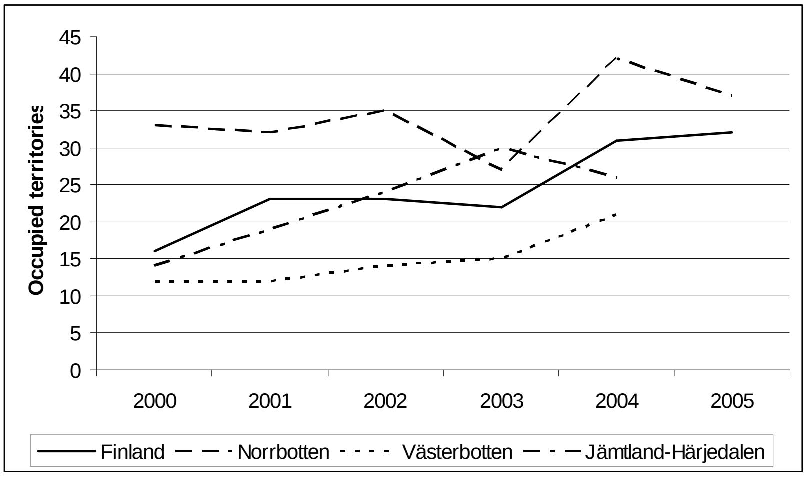

Figure 1. The number of occupied Gyrfalcon territories in Finland and in the three northernmost counties of Sweden in 2000–2005 (for Sweden, in 2005 data available only from Norrbotten).

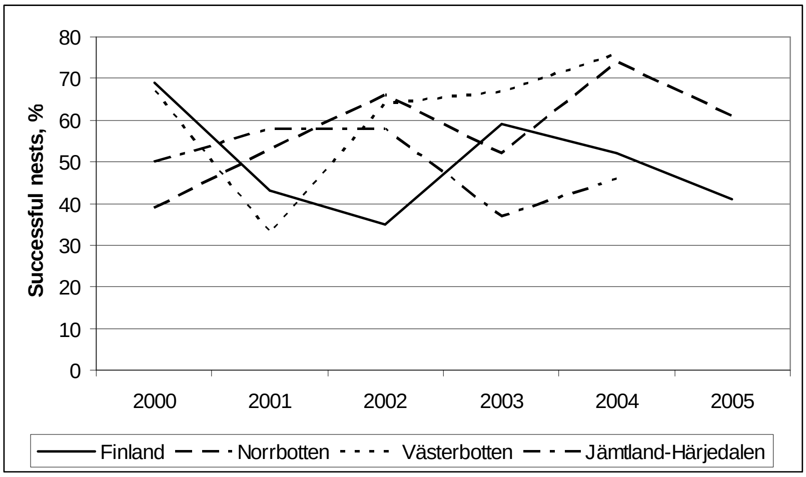

Figure 2. The percentage of successful nests of the occupied Gyrfalcon territories in Finland and in the three northernmost counties of Sweden in 2000–2005 (for Sweden, in 2005 data available only from Norrbotten).

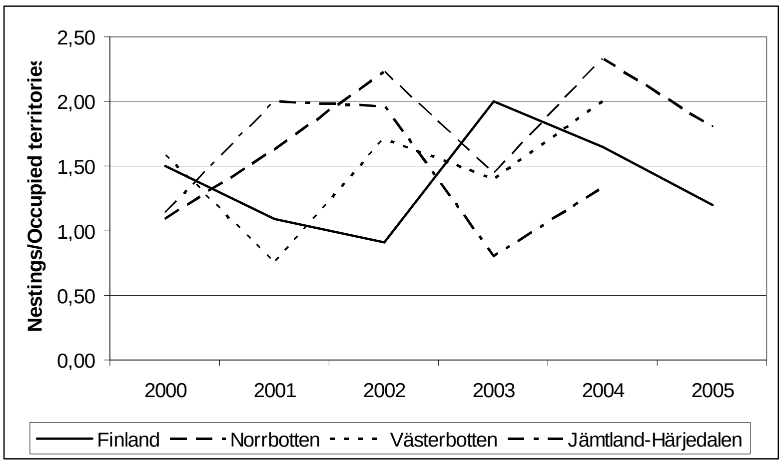

Figure 3. The mean number of big nestlings per occupied Gyrfalcon territory in Finland and in the three northernmost counties of Sweden in 2000–2005 (for Sweden, in 2005 data available only from Norrbotten).

Breeding productivity

The number of big nestlings per occupied territory has varied considerably between study areas and years, from ca. 1.0 in poor years to ca. 2.2 in best years (table 2, fig. 4). The time-series in fig. 4 is too short to make any firm conclusions, but it shows that in such a vast area the best and the worst years are not identical. In addition, the amplitude of annual variation is of the same order of magnitude from region to region. The same holds true also for the average number of big nestlings per successful nest, varying typically from ca. 2.1 to 3.5 (fig. 5).

The density of the Willow Grouse may have some effect on the number of nestlings. The preliminary data from Finland shows a similar time-lag in this respect than in the number of pairs (fig. 6). The same reservations concerning the grouse data must be taken into account than said above.

Table 2. The mean number of big nestlings per occupied Gyrfalcon territory in Finland and in the three northernmost counties of Sweden in 2000–2005.

Year	2000	2001	2002	2003	2004	2005
Finland	1.50	1.09	0.91	2.00	1.65	1.22
Norrbotten	1.09	1.63	2.23	1.44	2.33	1.86
Västerbotten	1.58	0.75	1.71	1.40	2.00	?
Jämtland–Härjedalen	1.44	2.00	1.96	0.80	1.34	?

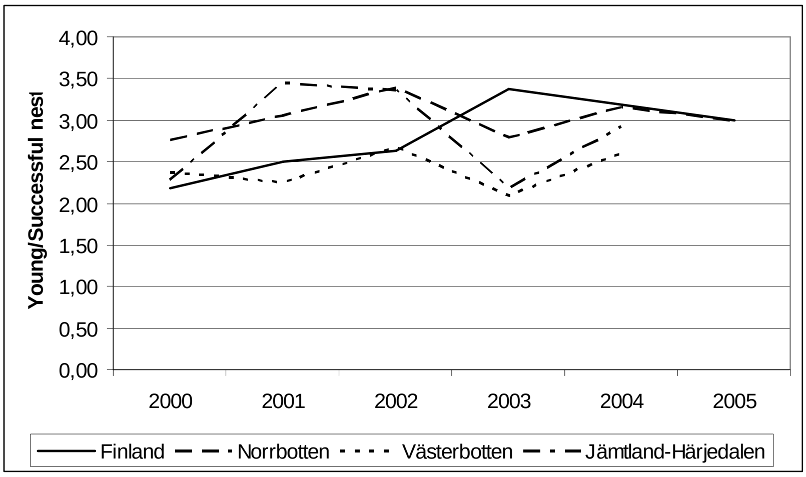

Figure 4. The mean number of big nestlings per successful Gyrfalcon nests in Finland and in the three northernmost counties of Sweden in 2000–2005 (for Sweden, in 2005 data available only from Norrbotten).

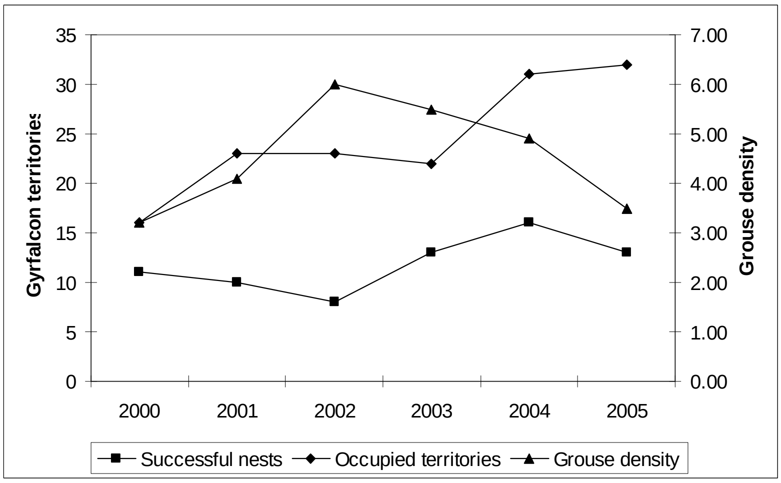

Figure 5. The number of occupied territories and successful nests of the Gyrfalcon in Finnish Lapland in 2000–2005 compared to the mean density of the Willow Grouse (individuals/km^2).

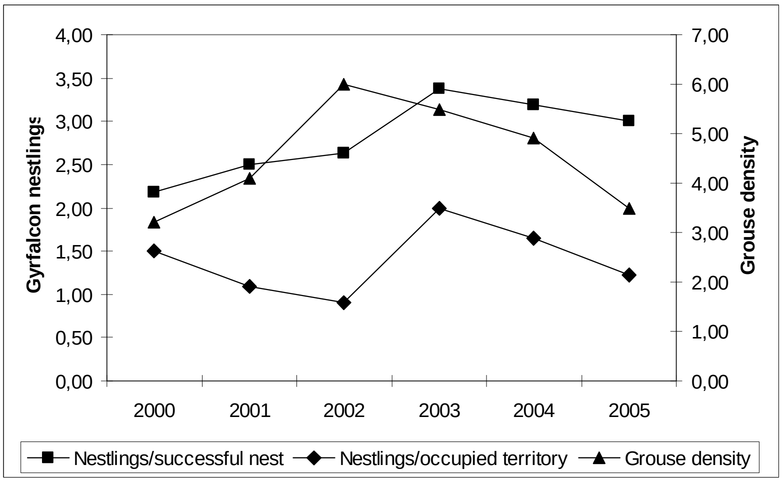

Figure 6. The mean number of big nestlings per occupied territory and successful nest of the Gyrfalcon in Finnish Lapland in 2000–2005 compared to the mean density of the Willow Grouse (individuals/km^2).

LONG-TERM TRENDS OF THE GYRFALCON POPULATIONS

Data sources from past decades

Due to intensive egg-collecting, in parts of northern Fennoscandia the size and density of Gyrfalcon populations can be estimated at some certainty back to 150 years ago (e.g. Newton 1864–1907, Sjölander 1946). For other bird species, quantitative data exist not earlier than in the 1910s and 1920s (Väisänen et al. 1998).

The Gyrfalcon was one of the most highly prized and intensively sought birds among egg-collectors in Lapland. Most Fennoscandian clutches were collected in western Lapland and Finnmark. Collecting was an international business and field of interest, and the eggs taken were dispersed into tens of museums and private collections. Much fewer clutches were collected in eastern and northern Lapland and eastern Finnmark. The majority of the clutches known to me from various sources have been taken from the 1850s to the 1930s. To relocate the origin of them reliably one needs versatile professional knowledge. In addition to abundance of Gyrfalcons, egg-collections give data on clutch size, egg-size and timing of breeding.

Additional data on the occurrence of the Gyrfalcon in Lapland from the late 1800s to the mid-1900s can be found from tens of regional bird faunas, which were based mostly on non-systematic and non-quantitative observations by local or travelling naturalists. The information on all birds breeding in Lapland increased considerably from the 1960s to the 1980s because of markedly increased number of bird watchers. The two atlas projects in 1974–1979 (Hyytiä et al. 1983, Koskimies 1989a), and in 1986–1989 (Koskimies & Väisänen 1991, Väisänen et al. 1998), provided some new information on the occurrence of the Gyrfalcon in Lapland.

Earlier interpretation of population changes

Earlier authors have published more or less anecdotal information indicating a negative trend of both Gyrfalcons and their prey (e.g. Sjölander 1946, Tømmeraas 1993, Cade et al. 1998, Väisänen et al. 1998, Koskimies 1999). I have preliminarily re-thought old data sources more critically, and compared them with my modern knowledge. I doubt that especially Tømmeraas (1993, 1994) exaggerated the population decrease due to invalid methodology and non-representative sampling.

In the early 1990s Tømmeraas (1993) controlled 29 Gyrfalcon nesting sites, which were occupied in western Lapland and Finnmark in the mid-1800s according to egg-collections. Because he found a pair nesting in only three of those cliffs in a single year, and older traces of Gyrfalcon´s in another three sites, he concluded that there were only 19% of the pairs left. He repeated this statement in later publications (Tømmeraas 1994, 1998).

Gyrfalcon pairs do not breed every year, however, especially if the densities of Willow Grouse and Ptarmigans are under a certain limit. In Iceland, for example, the amplitude of variation of the Ptarmigan population has been 4.2, while the amplitude of the Gyrfalcon territorial population has been 1.5, and that of the of Gyrfalcon breeding population 3.6, respectively (Cade et al. 1998). This same data by Ólafur K. Nielsen from 1981 to 1996 shows that, of the 804 observation years for occupied territories, 355 (44%)had no sign of breeding, 72 (9%) had failed breeders, and 377 (47%) had successful breeders. Every year a significant part of the territorial birds remain non-breeding, as confirmed by myself also in Lapland. In addition, during the last 15 years I have found several territories with a breeding pair in only one or two years. They have found a better territory further away, or remained non-breeding, or a lone bird has remained un-paired at the site for years for many possible reasons. Some territories, occupied in the early 1990s, remained without a single sign of a visit by a Gyrfalcon, and then abruptly a pair appeared and started to breed in successive years.

It is common that breeding pairs change often nest-sites, which makes it difficult to monitor the true number of pairs if all suitable nest-sites in the study area are not controlled annually. A high number of pairs have up to 3–5 alternative nest-sites, in many cases up to 10–17 kilometres away (Cade et al. 1998). Those nest-sites used in the mid-1800s may have become unsuitable for several reasons during the past 150 years. Only a thorough search for all available nest-sites within the territories under control could verify whether falcons were breeding in other nest-sites of the same territories or not.

A serious flaw of the straightforward comparison between old data and a single-year check of the traditional nest-sites is also the fact that not all territories within a coherent study area were controlled by Tømmeraas (1993). The nest-sites from old sources were distributed in western Lapland and Finnmark in a region which have more breeding pairs than those inspected; egg-collectors did not find every nest in a certain geographical area. It is possible that the locations of occupied territories have changed during decades for several reasons, and checking only the classical ones does not give reliable information of the total population. Actually, I and the present Norwegian colleagues (Arve Østlyngen, Karl-Birger Strann et al. unpublished) have found that there really exist many other active territories than those controlled by Tømmeraas (1993) in the same area. In addition, for many of the pairs which he did not find 15 years ago, an alternative active nest-site has been found in the very same territories later on. Thus, the Gyrfalcon population has been markedly higher in the early 1990s than suggested by Tømmeraas (1993).

Further methodological aspects for trend re-evaluation

In order to make a methodologically valid and more reliable evaluation of the long-term population trends, a critical researcher must study all available old data sources (egg-collections, archives, literature etc.) from various parts of the Fennoscandian range. Comparison of a group of single nest-sites does not give reliable results, if for some reason or other, a number of nest-sites have changed over the decades. A multi-year data base from both old times and the present is needed to estimate the probable number of breeding pairs and their density in the same geographical areas during several periods in the history, to counterbalance impact of short-term fluctuations on the long-term trend.

One example of a questionable interpretation of the long-term, permanent population decline is based on a comparison of the present densities with those published by Sjölander (1946) from northern Sweden a century ago. His highest densities were recorded in fairly small areas in a peak year of the Norwegian lemming *Lemmus lemmus*. In general, during those years populations of *Lagopus sp*. and other grouse species are also at their peak, because predators concentrate to prey on abundant vole populations. Gyrfalcon populations were probably exceptionally dense during the exceptional lemming years, when, for example, Suomalainen (1912) saw 29 falcon clutches at one dealer in Karesuando, Sweden (see also Cade et al. 1998).

To make a reliable density estimate of the Gyrfalcon, a long study period is necessary. In parts of the study area of Tømmeraas (1993), for example, we have recently found markedly more pairs with a higher density than he found about 15 years ago. Part of the reason is our better knowledge and coverage of the study area and population (see above). In addition, very many new pairs have settled to territories which were unoccupied for years or even decades. Neighbouring pairs have nested in several occasions from five to ten kilometres from each other. The density of the Gyrfalcon has not been higher than that in many parts of the species' range without any human threats and plausible population declines (Clum & Cade 1994, Cade et al. 1998, Potapov & Sale 2005). Tømmeraas (1994) most probably exaggerated also the long-term decline of the Willow Grouse populations. In northern Finland, for example, in 2002–2004 the density of grouse reached temporary peaks comparable to those in the mid-1900s (Helle & Wikman 2002, 2006).

PROSPECTS FOR FUTURE RESEARCH

Research topics

Most researchers of the Gyrfalcon in northern Fennoscandia have focused on the number of nesting pairs and breeding success. This kind of monitoring projects are necessary for conservation and management, but a more versatile research programme is needed to implement effective conservation measures in the future (Koskimies 1999).

When preparing the Action Plan, the world experts of the Gyrfalcon recognized many topics with inadequate knowledge (Koskimies 1999). I have listed those and some additional research needs in table 3, as well as proposed some species-specific management techniques in relation to the same themes (see also Koskimies 2006).

The highest priority in the future research needs should be set to topics which are connected to identifying limiting environmental factors and density regulation of Gyrfalcon populations, and to their ability to renewal. The poorly known parameters include, for example, habitat use, home range and dispersal ecology, genetics of a population and genetic relationships between neighbouring populations, wintering ecology, energetics, pair formation, and integration of immatures into breeding populations.

Table 3. Threats, conservation measures and research needs of the Gyrfalcon (importance in parenthesis according to Koskimies 1999: I = high, II = medium, III = low). This list includes only the most important threats in the Nordic countries and special research needs to study them more properly than at present. In addition, population dynamics of the Gyrfalcon (population size, natality, mortality, movements) should be an integral part of research and monitoring.

Threats	Conservation measures	Research needs
• **Reduced prey numbers** (I) - hunting - degradation of habitat - disturbance - mammalian predators - reindeer fences	* **Grouse conservation** - hunting regulations - protected areas - land use planning - trapping of other predators	* **Food availability** - grouse abundance - effects of hunting - food of falcons
• **Disturbance of nest sites** (I) - snow mobile traffic - ecotourism - hiking - bird watching and photographing - rock climbing	* **Land use planning** - snow mobile routes - tracks, skiing routes - cottages, huts - photography licenses - education - artificial nests	* **Susceptibility to dist.** - quality of nest sites - use of artificial nests
• **Habitat destruction** (II) - new roads - snow mobile routes - tourism infrastructure - cottages - reindeer fences - powerlines	* **Habitat protection** - protected areas - management of other areas	* **Habitat quality** - use of habitat - critical habitat needs
• **Robbing of nests** (II) - egg-collecting - falconry - falcon production in captivity (incl. hybrids)	* **Concealing of nests** - wardening - education - artificial nests	* **Falcon trade** - captive breeding - DNA-identification
• **Shooting adults, destroying nests** (III) - game keeping	* **Education** - wardening	* **Attitudes by public**
• **Reduced Raven nest numbers** (III) - decline of Raven population	* **Artificial nests** - feeding of Ravens	* **Artificial nests** - Raven monitoring - availability of nat. nests
• **Collisions** (III) - reindeer fences - powerlines	* **Land use planning**	* **Susceptibility**
• **Chemical contamination** (III) - long-distance fallout - waterfowl (esp. coastal in winter)	* **Reducing of chemicals**	* **Analysis of chem.**

Intensifying monitoring of natality and mortality, and factors influencing them is of basic importance. One of the most important gaps in our knowledge is the almost total lack of data on survival rates of both adults and young. As changes in mortality have more direct and stronger effect on the number of breeding pairs than changes in natality, information on mortality is essential to analyse more securely the viability of the Fennoscandian populations. Dispersion and site-fidelity, also poorly studied, are closely connected to survival and population turnover, as well as recruitment of new birds into a population.

It seems that the present reproduction will counter the mortality, but we cannot prove it adequately. In addition to demographic factors, there also exist geographic, genetic, habitat-specific, food-specific and other environmental factors, whose impact on the viability of populations we cannot evaluate adequately.

Research on the Gyrfalcon is not solely biology. As many types of human activities have effect on the habitat, food, nest-sites and other key factors in the life of falcons, studies should include also non-biological objects, methods and expertise.

Availability of food

The Gyrfalcon is totally dependent on Willow Grouse and Ptarmigan populations for food during most of the year. Knowledge on grouse population dynamics is very important for Gyrfalcon research and conservation (Koskimies 1999). In Sweden and Norway, ecology of these key prey species has been studied actively for decades (e.g. Steen 1989, Hörnell-Willebrand 2005), but in Finland data is more scanty.

We should know more especially on the critical habitat requirements of grouse in various parts of the Gyrfalcon´s range. Natural and human-caused factors affecting on natality, mortality and dispersal should be studied more carefully. Hunting has at least in some circumtances negative effects on grouse populations (Brøseth et al. 2005, Hörnell-Willebrand 2005), but this problem must be studied more extensively to get truly representative results. Unfortunately, there is only limited information on the possibilities of increasing the density of grouse populations.

Although there is no precise, comparable and quantitative data on the long-term trends of *Lagopus sp*. populations in northern Fennoscandia, some indirect data point to higher peak densities in the late 1800s and the early 1900s (Tømmeraas 1994, Koskimies unpublished). Local and regional variation has been typical for population fluctuations of grouse, and there are both natural and human-induced factors affecting on them. Low densities have been recorded also decades ago.

As Tømmeraas (1994), Holmberg & Falkdalen (1996), Cade et al. (1998), Koskimies (1999), Nielsen (2003), Nyström et al. (2005), Potapov & Sale (2005) and other authors stress, the density of *Lagopus sp*. is of critical importance of the viability of Gyrfalcon populations all over the range. We do not know, however, what is the critical regional grouse density, below which Gyrfalcons have significant difficulties to find enough food for starting to breed and to feed young. Partly this problem is due to poor data on the size of the home range in various habitats. In Iceland, Nielsen (2003) has data on the density level of Ptarmigans needed for successful breeding of the Gyrfalcon, but in Fennoscandia hunting habitat of the falcons is different from his area.

Food choice

Prey selection has been studied in many parts of the Gyrfalcon´s range (e.g. Clum & Cade 1994, Cade et al. 1998, Koskimies & Sulkava 2002, Nielsen 2003, Nyström et al. 2005, Potapov & Sale 2005). The most popular method has been collecting prey remains at and near nest-sites. There are some sources of error in this method, and it should be compared with more accurate and precise methods like video-filming and observations from a hide to get a better idea of the reliability and representativity of the results. Modern camera technology allows monitoring via camera set even in as arctic conditions as in Greenland (Booms & Fuller 2003).

Almost all information on food of Gyrfalcons comes from the breeding period. Automatic cameras, telemetry and other innovative techniques should be developed to study food also outside the breeding season. These techniques also help to study behaviour of the Gyrfalcon, e.g. related to feeding and other behaviour at nest-sites (e.g. Tømmeraas 1989, Booms & Travis 2003)

Availability of nest-sites

In addition to food, availability of safe twig-nests built by Ravens is another critical factor having effect on the viability of Gyrfalcon populations. Monitoring of Raven populations is an important part of a valid Gyrfalcon monitoring and conservation project. Recently, worries have been expressed on the viability of wintering Raven populations especially in Finland and Sweden where there might be lack of winter food for Ravens due to new EU legislation forbidding slaughter of reindeers outside of a few central slaughterhouses (Koskimies 1999).

Unintentional disturbance of nest-sites is a growing problem for Gyrfalcons. Ecotourism and other outdoor activities have led to a growing number of people who visit wilderness and high cliffs especially in the most critical period in late winter and early spring which pose a threat of high importance to Gyrfalcons (table 3, Koskimies 1999, Mela & Koskimies 2006).

Reactions towards humans, and susceptibility to disturbance, varies between falcon pairs, but the information on reactions to various human activities is still too anecdotal and unsystematic. As we can not make scientifically controlled experiments with such a threatened species like the Gyrfalcon, all random experience collected in monitoring projects should be gathered and analysed thoroughly. A territory- and nest-site-specific evaluation of susceptibility to disturbance should be made, as a part of applying the general Action Plan regionally and locally.

Gyrfalcons accept artificial nests (e.g. Tømmeraas 1978, Hansen 1994, Johansen & Østlyngen 2004, Frydenlund-Steen 2005). Building of artificial nests as a method for transferring disturbed pairs to safer nest-sites should be studied in a systematic way.

Habitat quality

In addition to food and nest-sites, we should study also other key factors of Gyrfalcon´s habitat, and the use of home range by both breeding and non-breeding falcons. Better understanding of the habitat requirements of both the falcons and their main prey are essential to plan and implement effective management measures. We should study various types of human activities and their versatile effects on all types of habitat factors. Many kinds of construction, tourism and other activities deteriorate at least locally the quality of the habitat, and they pose serious threats to many pairs (Koskimies 1999).

One example of a poorly-documented threat are reindeer fences, totalling to tens of thousands of kilometres all over northern Fennoscandia. They might be detrimental directly to many Gyrfalcons, but especially to Willow grouse and Ptarmigans. They may kill hundreds of thousands of grouse in northern Fennoscandia every year (Bevanger & Brøseth 2000). Red foxes *Vulpes vulpes* patrol along the fences, which has considerably helped these animals to survive over the subarctic winter. In summer, an expanding and increasing fox population may have a growing negative effect on breeding success of Willow Grouse and other land birds.

The study of habitat use and evaluation of the most critical habitat needs requires telemetry. The Gyrfalcon, however, has been regarded as a very sensitive species to any extra disturbance, like a transmitter, especially in cold and dark wintertime. That is why researchers in Fennoscandia have retained from fitting transmitters on these birds living over winter in harsh conditions. Many successful studies in Greenland and Alaska, e.g. by the Peregrine Fund, however, point to possibilities of this technique, especially when the transmitters get smaller and lighter, and can be monitored via satellites. Because of controversial arguments over the suitability of this methodology to the Gyrfalcon, specialists on this technique must carefully plan a non-harmful study for Gyrfalcons.

Intentional destroy

Although illegal all over the Gyrfalcon´s European range, taking of eggs and young for collections and falconry still seems to continue (e.g. Frydenlund-Steen & Sørli 2005). True scale of robbing of clutches and broods shall be examined carefully in the field during the nest-site controls.

Recently, both environmental administration and non-governmental organizations have started to work together in Scandinavia and Finland to map the present scale of bird crime. At the same time, covering all nest-sites under monitoring and most susceptible nests under intensive wardening (Frydenlund-Steen & Sørli 2005), robbing business will become much more risky than before.

To evaluate the extent of robbing eggs and nestlings, as well as shooting of wild birds and the whole trade of living and dead falcons, conservationists should control falconry birds, captive breeding programmes, various collections etc. to study the origin of individuals, most effectively with modern DNA analysis (Cade et al. 1998, Koskimies 1999).

Chemical contamination and climatic warming

There are controversial results of the amount of chemical contamination in the eggs and tissues of the Gyrfalcon in northern Europe (e.g. Cade et al. 1998, Koskimies 1999, Potapov & Sale 2005). Although pesticides and other harmful contaminants probably do not pose as serious a threat to Gyrfalcon populations as to Peregrine Falcons *Falco peregrinus*, their levels and possible impacts should be monitored regularly and in different habitat types. Although DDT, PCB and other dangerous compounds are not allowed anymore at the same scale than during the past decades, new compounds like bromide flame retardants may become harmful to this kind of top predators.

Climatic warming may become the most extensive and serious environmental threat to Subarctic and Arctic Gyrfalcon populations, as well as whole northern ecosystems. Koskimies (1999) could not evaluate its future impact in any detail. Lately a growing number of studies has been published on the possible impact of warmer climate on many animal and bird species in the Arctic, where the climate is supposed to warm up by over five degrees centigrade by the year 2100. Recently, e.g. ACIA (2005) and Lovejoy & Hannah (2005) have reviewed the newest knowledge.

Long-time data sets of the Gyrfalcon have proved to be very valuable both for the research and conservation of the species itself, as well as indicating human-caused changes in the food web and environment in which falcons form an integral part. Museum specimens, egg-collections and other types of old data on the numbers, distribution and breeding biology can be used also for evaluating the effect of large-scale environmental changes like chemical contamination and climatic warming.

The Fennoscandian Gyrfalcon project

A co-Nordic research project planned by Pertti Koskimies (Finland), Karl-Birger Strann (Norway) and Johan Ekenstedt (Sweden) will be started in its full scale in 2007, after two preliminary years of development. The main aim is to standardize the long-term monitoring and management of Gyrfalcon populations in northern Fennoscandia. The study includes several special projects which are integrated to form a coherent work for collecting necessary information for effective and practical conservation of the total population, in lines with the need of further research delineated by Koskimies (1999) and reviewed above.

The main aims of the study include:

-Standardizing field work in detail and combining results in a very large, ecologically meaningful and versatile range, so that the results can be applied to other parts of the circumpolar breeding area.

-Intensive mapping of breeding pairs and measuring of breeding productivity for evaluating the absolute population size and its fluctuations, as well as the factors behind the changes.

-Measuring habitat requirements, home range and habitat use, nest-sites, food availability and other critical factors and threats of the species, and studying the use of habitats.

-Developing population model for estimating the viability of both national populations and the meta-population in the whole of northern Fennoscandia.

-Studying migration and dispersal patterns, site-tenacity, longevity, causes of death and population turnover, as well as gene flow and genetic relationships between different parts of the range, by ringing, telemetry, DNA analyses and other non-invasive methods.

-Measuring the levels of pollutants in Gyrfalcons, their eggs and young, and in food animals.

-Evaluating the impacts of conventional threats, and including proposed effects of climatic warming, for the population development and conservation status, and developing effective conservation measures against their influence.

The Gyrfalcon is a top predator, and the study aimed at effective conservation of viable populations must include the whole food chain on which the species is dependent. Our project will include a very interesting comparison between inland and coastal populations, whose habitats, prey selection and other ecological parameters differ in many respects. In spite of this, the populations and individuals interact with each other, because especially immature birds from Finland and Sweden migrate towards the Norwegian coast for winter (Koskimies unpublished).

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