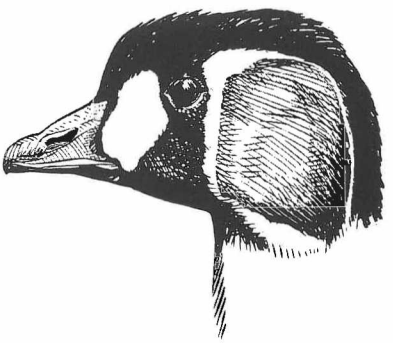
Influence of weather conditions and other factors on the reproductive cycle of Red-breasted Geese *Branta ruficollis* on the Taymyr Peninsula.



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In the course of research into Red-breasted Goose biology, up to 40 colonies of redbreasts in the Pyasina basin on the Taymyr Peninsula (Russia) were checked every year between 1977 and 1983. One of the aims of the programme was to analyse the influence of annual weather conditions on their population dynamics. It was found that temperature influences the date of arrival in the breeding area, as well as the start of incubation and the main hatching period of the goslings. The percentage of breeding birds and the number of nests per colony (on cliffs) seem to be determined by temperature, precipitation and the snow cover of the cliffs. The percentage of breeders is also influenced by the the physiological condition of the birds, which also influences clutch size. Clutch size, together with climatic parameters influence the number of goslings per nest as well as the embryonic and post-embryonic mortality. Reproductive success depends mainly on the physiological condition of adult Red-breasted Geese upon arrival in the breeding area, as well as on the weather of the breeding range during the reproductive period. Success is further influenced by the level of predation by the Arctic Fox and the population and reproductive success of Peregrine Falcons, Rough-legged Buzzards and Herring Gulls.

Keywords: Red-breasted Goose, Population Dynamics, Reproductive Success, Mortality, Weather Conditions, Predation.

Red-breasted Geese *Branta ruficollis* have a relatively limited breeding range in northern Siberia in the southern regions of the Taymyr, Gydan and Yamal Peninsulas (**Figure 1**). The main breeding grounds are found in the typical tundra zone of the Taymyr Peninsula, especially along the Pyasina, Agapa, Pura, Mokoritto, Verkhnyaya Taymyra, Luktakh, Logata, Gorbita, Bol'shaya Balakhnya, Novaya, Zakharova Rassokha, Bikada and Popigay Rivers. As nest habitat, Red-breasted Geese prefer areas of dry elevated tundra near water, in particular steep river banks and cliffs. Here they usually prefer sites near the nests of birds of prey. Some of the geese favour breeding on islands in the neighbourhood of breeding gulls (Cramp & Simmons 1977, Kostin 1981, 1985, Krivenko *et al.* 1982, Vinokurov 1982, 1990).

The northernmost known important staging area of Red-breasted Geese south of the breeding range is the floodplains of the Lower Ob river in the area around Khanty-Mansijsk town, especially Elizarovsky Temporary Nature Reserve (Khanty-Mansijski Autonomous Region) (Skokova & Vinogradov 1986), but it is possible that further staging areas are used in or near the breeding range.

At the end of the 1970s, the total population of the species was estimated at 22,000–27,000 birds (Vinokurov 1982), between 17,000 and 20,000 of them were breeding on the Taymyr Peninsula (Krivenko *et al.* 1982, Kostin 1985) (i.e. about 75% of the redbreast population at that time). At the end of the 1980s the wintering population was estimated at 35,000 birds (Vinokurov 1990, Madsen 1991) and during winter 1992–93 about 68,000 Red-breasted Geese were counted at the wintering grounds of Bulgaria and Romania (Rose & Taylor 1993).

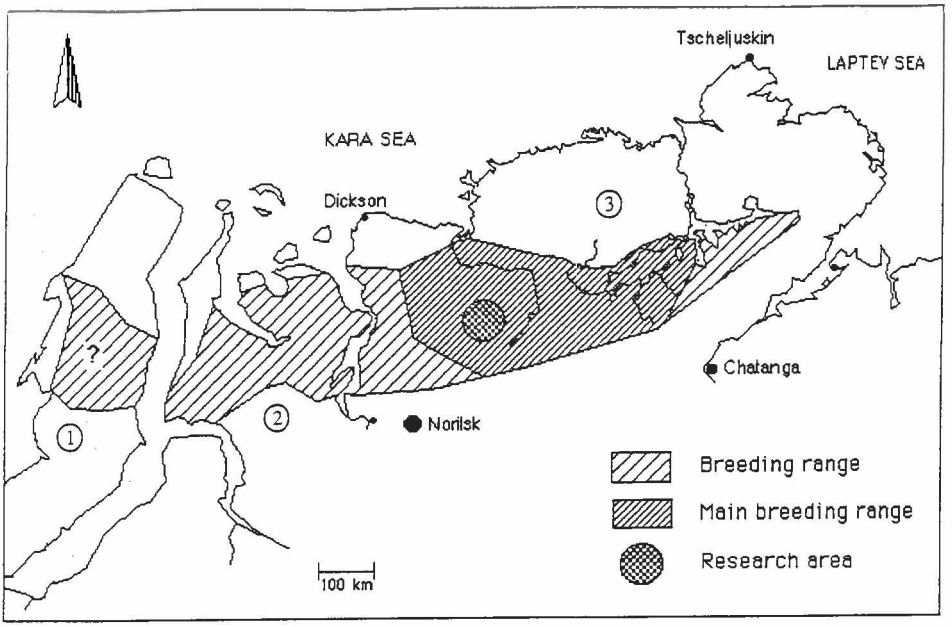

Figure 1. Distribution of the Red-breasted Goose *Branta ruficollis* in summer in Russia, at Yamal (1, may be extinct), Gydan (2) and Taymyr Peninsula (3)

The distribution of redbreasts within the breeding range, the number and size of the breeding colonies and the reproductive success varies from year to year, and it seems evident that climatic factors play an important role in most events in the arctic breeding area.

Several authors have tried in different ways to estimate the influence of climatic factors on the arctic breeding geese of the Taymyr Peninsula. Leonovich & Uspenski (1965) reported that weather changes have a great influence on reproduction. Such changes can lead to a partial or complete end to breeding, to a decrease in clutch size and a shift of nest sites. Kishinsky (1959) stated that weather conditions are the most important factors influencing reproduction and survival of birds in the tundra. According to Krechmar (1965), the numbers of breeding and moulting birds in the arctic are determined by the conditions the birds meet in winter, as well as during migration. This view was supported by the observations of Isakov (1940) and Mikheev (1953), who reported that the extreme cold in the Caspian Sea area in the winters of 1924–25 and 1949–50 caused high mortality in geese and led to a sharp decrease in numbers on the breeding grounds. Sdobnikov (1959) stated that the variations in reproductive success in arctic birds from year to year depend on the amount of body fat of the birds before the beginning of the annual reproductive cycle and these reserves depend again on conditions at the wintering as well as staging areas. This hypothesis is supported by a number of other authors (e.g. Boyd 1982, Ebbinge 1992, Ebbinge *et al.* 1982, Prokosch 1984). Since the 1950s, wintering Red-breasted Geese have shifted gradually to the west from their traditional sites in the territory of the former USSR and now mainly winter on the west coast of the Black Sea in the coastal areas of Rumania and Bulgaria (Madsen 1991, Michev *et al.* 1991, Munteanu *et al.* 1991). This development made it difficult for scientists of the former Soviet Union to study how climatic factors of these new wintering grounds influence yearly reproductive success as well as population dynamics. Observations in the breeding area also indicated that, not only the body condition of the breeding birds, but also the weather conditions in the breeding area, influenced reproductive success (Kostin 1986). These facts resulted in a stronger Russian focus on the influence of the

annual weather conditions in the breeding area on the reproductive success of Red-breasted Geese.

Besides climatic parameters, it seems that the Arctic Fox *Alopex lagopus* can be an important factor influencing the reproductive success of arctic breeding geese (e.g. Kostin 1982, Fox & Stroud 1988, Birks & Penford 1990, Ebbinge 1992).

The purpose of this publication is to present data on the nesting chronology of the Red-breasted Goose and to make preliminary analyses of the influence of weather conditions and fox predation on the reproductive cycle of the goose on the Taymyr Peninsula.

Study area and methods

In the course of a research programme on Red-breasted Goose biology between 1977 and 1983, up to 40 colonies of Red-breasted Geese were checked several times every year in the Pyasina basin (71°23'N, 90°14'E) on the Taymyr Peninsula (**Figure 1**) and data about their breeding biology gathered. Over the same period, the number of geese in the study area and the date of their arrival (arrival period, arrival peak) were recorded. Weather data were obtained from the daily measurements of a local meteorological post of Aeroflot in the breeding area as well as from the meteorological station at the Pyasina River (Kostin 1985).

To estimate the reproductive success the following parameters were chosen: the average number of breeding birds as a percentage of the total population, the average number of nests per colony, the average clutch size, the average brood size after leaving the colony and the juvenile mortality (embryonic and post-embryonic), calculated from the difference between the average clutch and average brood size.

The date of arrival of the majority of the birds in the breeding area (arrival peak), the start of incubation by the majority of the breeders, the hatching period, i.e. the length of the period in which the majority of the goslings hatch and the date of the appearance of the majority of goslings were also recorded. Weather data consisted of: the temperature and moisture of the air, the temperature at the ground surface, the date air temperatures rose above the 0°C threshold, the snow cover of the cliffs (estimated by a 5 point system: 5=closed snow cover), cloud cover, the duration of precipitation in hours (solid, liquid and total sum) per month, the light intensity, and the speed and direction of the wind.

To estimate the influence of predators, some of the colonies were checked and the percentage of colonies attacked by predators and the percentage of nests destroyed by predators were established.

The relationship between the weather factors, fox predation and reproductive success was analysed by means of correlation analyses, using computer analyses based on standard formulae (Sachs 1970, Kreyzig 1965), on the assumption of the interdependence of chance selections from a biometric normal distribution. For the general analyses, only the average data per month and per ten-day period of May, June and July were used. For the analyses of anomalies, the average day temperatures of these months were used.

The 95% contour and the correlation coefficient (r)_± 0.75 was used to decide whether a correlation was to be accepted as being significant (Ivanter 1979). For lesser levels of significance, following levels were set: 90%, r=± 0.67; 80%, r=± 0.55; 70%, r= ± 0.46.

In this publication only the parameters that showed significant correlations of at least 90% are discussed.

Results

Relation between the reproductive parameters

Before the influence of weather factors on the reproductive success can be analysed, it is necessary to examine the relationship between the parameters chosen for the estimation of the reproductive success (**Table 1**). Several correlations were found.

The Red-breasted Geese arrived at the breeding sites within a period of about one week and showed an arrival peak in the middle of this period. The date of the arrival of the majority of the birds in the

Table 1. Reproductive data of Red-breasted Geese at the Taymyr Peninsula 1977-1983

	Date of the arrival of the majority of the geese (June)	Date of the start of incubation of the majority of the geese (June)	Average number of breeding birds as a percentage of the total population	Average number of nests per colony	Average clutch size	Duration of the hatching period in days	Date of the appearance of the majority of goslings (July)	Average number of goslings per breeding pair after leaving the colony	Embryonic and early post-embryonic mortality
1977	7	15	12.0	5.2	5.0	10	10	4.4	12
1978	10	22	54.0	7.5	6.0	11	18	5.7	5
1979	11	23	30.0	4.1	5.7	11	17	4.5	20
1980	12	25	13.0	5.2	5.3	15	19	3.6	32
1981	12	26	9.5	3.9	5.1	13	21	4.4	14
1982	13	23	45.0	7.5	6.2	9	19	5.6	10
1983	17	28	7.0	3.6	3.9	16	24	3.3	15
Total	12	23	24.4	5.3	5.3	12	18	4.5	15.4

breeding area showed a significant correlation with the date of the start of incubation by the majority of the breeders (r=0.89) and the date of the appearance of the majority of goslings (r=0.92). This means that the Red-breasted Geese try to start their reproductive cycle within one or two weeks (m=11.4 ± 3 days) after their arrival in the breeding area, and that the goslings hatch after an average incubation period of 25 ± 1 days (m=25.5).

There is no correlation between the date of arrival or the start of incubation and the percentage of breeding birds, the number of nests per colony, the average clutch size, the average number of goslings or juvenile mortality.

The percentage of breeding birds showed a positive correlation with the number of nests per colony (r=0.85), the average clutch size (r=0.83) and the average number of goslings (r=0.90); this means that in years with a small breeding population there were few nests per colony, with small clutch sizes and a low output of goslings per nest, and that if a high percentage of the birds were breeding the number of nests per colony, the number of eggs per clutch and the output of goslings per nest was high.

No correlation was found between the percentage of breeding birds and the percentage juvenile mortality. In the two years with the highest proportion of the population breeding (1978: 54% and 1982: 45 %) as well as in three years with a small breeding population (1977: 12%, 1981: 9.5% and 1983: 7%), there was low juvenile mortality (1977: 12%, 1978: 5%, 1981: 14%, 1982: 10% and 1983: 15%). In one year with a small breeding population (1980: 13%) as well as in one year with high number of breeding birds (1979: 30%), a high juvenile mortality (1980: 32%, 1979: 20%) was recorded. These results suggest that factors other than the mentioned parameters influence juvenile mortality.

The timetable of breeding seems to be more or less fixed, but reproductive success depends on factors other than the date of arrival or the start of incubation.

Relation between climatic parameters

Analyses showed (**Table 2**) that there is a relation between the average air temperatures during the first ten-day period of May and June, and between the date the air temperatures pass the 0°C threshold and the average air temperatures during the first ten day period of May.

Clear correlations were found between the date that the air temperatures rise above the 0°C threshold and the average ground temperatures in May (r=-0.76) and the average air temperature during the first ten-day period of June (r=-0.97) as well as between precipitation in June and the snow cover of the cliffs (r=0.93).

Table 2. Weather data from the Taymyr Peninsula 1977–1983.

	Average temperature at the ground surface in May	Average temperature at the ground surface in June	Average temperature at the ground surface in July	Temperature sum of May, June and July	Date the temperatures pass through the 0°C threshold	Duration of precipitation in hours per month (May)	Duration of precipitation in hours per month (June)	Duration of precipitation in hours per month (July)	Snow cover of the cliffs in points
1977	–5	7	11	13	27 May	121	117	137	3
1978	– 10	–5	9	–6	2 June	167	71	59	2
1979	– 9	10	24	25	5 June	135	119	18	3
1980	– 8	1	14	7	2 June	154	156	59	4
1981	– 10	3	11	4	5 June	165	126	39	4
1982	– 9	3	12	6	10 June	70	73	47	2
1983	– 10	4	11	5	12 June	63	120	65	3
Total	– 8.7	3.3	13.0	7.7	4–5 June	125	112	61	3

No correlation was found between the other climatic parameters.

Relation between the reproductive parameters and temperature

The date the air temperatures passed the 0°C threshold showed a positive correlation with the date of arrival of the majority of the birds in the breeding area (r=0.93), the date of the start of incubation by the majority of the breeders (r=0.81) and the date of the appearance of the majority of goslings (r=0.86). Further analyses showed that the annual average air temperatures of May, June and July do not influence the reproductive timetable nor reproductive success.

The average ground temperature of May showed a tendency to be correlated with the date of arrival (r=–0.68) and a correlation to the date of the start of incubation (r=–0.83) and to the date of the appearance of the majority of goslings (r=–0.87). Further analyses showed that the average air temperature data of the first ten-day period of May tended to be correlated to the date of the arrival of the majority of the geese (r=–0.68) and correlated to the date of the start of incubation (r=–0.79), as well as to the date of the appearance of the majority of goslings (r=–0.73).

There is also a tendency for the average air temperature during the first ten-day period in May to influence the number of nests per colony (r=0.67).

The average air temperature data during the first ten-day period in June showed a clear correlation to the date of the arrival of the majority of the geese (r=–0.93), to the date of the start of incubation (r=–0.82) and to the date of the appearance of the majority of goslings (r=–0.87), i.e. a cold start of June delays the reproductive time table.

Relation between reproductive parameters and precipitation

The duration of precipitation in June is correlated to the percentage of breeding birds (r=–0.84), the number of nests per colony (r=–0.74), the number of goslings per nest (r=–0.87) and the percentage of embryonic and post-embryonic mortality (r=0.87).

Relation between reproductive parameters and snow cover

There is a correlation between the snow cover on the cliffs and the percentage of breeding birds (r=–0.83), the number of nests per colony (r=–0.74), the number of goslings per nest (r=–0.74) and the percentage of embryonic and post-embryonic mortality (r=0.73).

Relation between the reproductive and other parameters

The Arctic Fox was the most important predator of the colonies that were

Table 3. Influence of predation by Arctic Foxes on breeding colonies of Red-breasted Geese.

	Colonies checked	Colonies attacked by Arctic foxes		Nests found	Nests destroyed by Arctic fox	
Years	*n*	*n*	%	*n*	*n*	%
1977	2	1	50.0	24	3	12.5
1978	19	5	26.0	104	9	8.6
1979	8	2	25.0	41	3	7.3
1980	3	2	66.7	27	16	59.0
1981	8	4	50.0	43	14	32.6
1982	10	–	0.0	68	–	0.0
1983	6	2	33.3	36	5	13.9
Total	56	16	28.6	343	50	14.6

checked. The data on fox predation in **Table 3** show that there is a correlation between the number of nests destroyed by Arctic Foxes and the percentage of embryonic and post-embryonic mortality (r=0.79).

Discussion

Relation between the reproductive parameters and temperature

An important requirement for the return of the Red-breasted Geese to their breeding grounds is the availability of food, i.e. their arrival must be related to the rate of snow melt and the clearing of snow from the tundra. Snow melt starts when air temperatures rise above 0°C. The date that air temperatures in the breeding area rise above the 0°C threshold is influenced by the ground temperatures in May, as well as by air temperature at the beginning of May. Air temperatures in May influence the thawing rate in June, i.e. low air temperatures in May seem to delay snow melt and therefore the beginning of reproduction of the geese. Air temperatures at the beginning of June are most important in determining the conditions that the geese meet upon arrival on the breeding grounds; i.e. mild air temperatures in this period allow early snow melt, early arrival of the geese and an early start of the reproductive cycle. It seems that Red-breasted Geese try to start their reproductive cycle within one or two weeks (m=11.4 ± 3 days) after their arrival in the breeding area, and that the goslings hatch after an average incubation period of 25 ± 1 days. Because of this fixed timetable of reproduction and the correlations found, the date the air temperatures rise above the 0°C threshold seems to determine the date of the arrival as well as of the start of incubation in Red-breasted Geese and therefore the date of appearance of the majority of goslings.

Comparable periods between the arrival of the geese and the beginning of incubation were reported for Cackling Geese *Branta canadensis minima* and Brent Geese *Branta bernicla hrota* (Raveling 1978) as well as for the Greenland White-fronted Geese *Anser albifrons flavirostris* (Fox & Madsen 1981, Fox & Stroud 1981, Fox & Ridgill 1985). According to Raveling (1978), this period is needed for yolk production to complete the ova maturation process before egg-laying. This author suggested that the process of rapid yolk production is stimulated by the final migration to the nesting grounds or is triggered by arrival. Based on the correlations found in this study, we suggest that in Red-breasted Geese the process of rapid yolk production is influenced rather strongly by weather conditions on the breeding grounds as the geese arrive.

Therefore it seems that the ground temperatures in May and at the beginning of June, or the date at which the air temperatures in the breeding area rise above the 0°C threshold, can be used to predict the main hatching period of the goslings.

Relation between the reproductive parameters and precipitation as well as snowcover

Because of the short summer, arctic bird species try to nest as soon as possible after arrival in the breeding area. Observations showed that Red-breasted

Geese arrived at the breeding sites ready for egg-laying; several times we found eggs in the snow before nests were built. This fact could mean that, in part, the birds' yolk production was triggered elswhere before arrival at the actual breeding site, maybe during a last staging between the area around Khanty-Mansijsk and the actual breeding site. Successful reproduction is only possible if there is enough snow free space for feeding and breeding, especially on the cliffs where the colonies are situated. If the birds cannot breed within 14 days after arrival, they leave the breeding sites and move to the moulting sites (Kostin 1985).

The analyses showed that the percentage of the birds that can actually start breeding and the number of nests per colony seem to be determined by air temperatures at the beginning of June, the duration of precipitation in June and the snow cover on the cliffs. Low air temperatures, a long period of precipitation and snow cover on the cliffs at the beginning of June lead to a low number of breeding pairs and a small number of nests per colony, while high air temperatures, a short duration of precipitation and almost snow-free cliffs result in a high number of breeding pairs and relatively big colonies.

These facts support the hypothesis that, in general, not only the start of the reproductive cycle, but also the number of breeding birds depends of weather conditions of the breeding area and that, in Red-breasted Geese, the process of rapid yolk production is stimulated by the weather conditions in the breeding area at the time of the arrival.

The duration of precipitation in June and the snow cover on the cliffs also influence the number of goslings per nest and juvenile mortality. This relation seems understandable, because the cooling effect of precipitation can reduce the effectiveness of incubation and kill goslings, especially in the first days of life, whereas prolonged snow cover can have a negative influence on breeding and feeding conditions. Although the clutch size showed clear correlations to the percentage of breeding birds and the number of goslings per nest, no clear correlation was found between clutch size and climatic parameters. This could be explained by the fact that the percentage of breeding birds is influenced not only by climatic parameters in the breeding area, but also by the the physiological condition of the birds upon arrival, which also affects clutch size. The mainly physiologically induced clutch size for its part influences, together with climatic and other parameters, the number of goslings hatched per nest, as well as the juvenile mortality.

Good physiological condition upon arrival could result in a short egg-laying period and bigger clutch sizes which, together with favourable weather conditions during incubation, induce a short hatching period and a bigger number of goslings per nest. Although we found only weak evidence of a relationship between the duration of the hatching period and embryonic and post embryonic mortality (r=0.56), from field observations we have the impression that a prolonged hatching period increases mortality, e.g. late clutches could suffer increased fox predation because group defence and/or predator protection of the colony by that time has decreased.

General remarks

The search for correlations between temperature and reproductive success is rendered difficult by the fact that the temperature data are generalised. The breeding situation of local birds will be more influenced by local microclimate than by the general temperature of a region. Walter & Breckle (1986) stated that on the tundra, air temperatures are highest close to the ground surface and that temperatures on sun-exposed slopes can reach a level more than 10°C higher than the standarized local temperature recorded 2 m above the ground. Romanova (1978) found that cliffs are the most favourable breeding sites of tundra because of their good microclimate; in July cliffs get 50% more solar radiation than flat tundra areas. According to Romanova's data temperatures can vary from 5 to 18°C between the base and the top of cliffs used as nest habitat by Red-breasted Geese. We assume that these temperature differences, as well as other

parameters, are the reason for our difficulties in finding clear correlations between temperature and reproductive success of Red-breasted Geese as we had expected.

Relation between reproductive and other parameters

Red-breasted Geese usually prefer nest sites near the nests of birds of prey and gulls (Kostin 1985). Ninty percent of the colonies observed were situated on cliffs. Forty eight percent of these colonies were situated near the nest of a Peregrine Falcon *Falco peregrinus*, 14% near the nest of a Rough-legged Buzzard *Buteo lagopus* and 14% near the nests of both species. In the remaining 14% of the cliff-colonies observed, there was no nest of a bird of prey in the neighbourhood, but in most cases a single bird of prey or the remnants of a fresh nest were found, which could mean that one of the breeding partners died or the nest was deserted. Such colonies showed a below-average number of Redbreast nests. Several times the shift of nesting site by a bird of prey resulted in a shift of the Red-breasted Goose colony in the following years. Ten percent of the colonies observed were situated on islands and in the neighbourhood of breeding gulls, mainly Herring Gull *Larus argentatus*. We can state that there is a clear connection between the selection of nesting sites by Red-breasted Geese and the presence of breeding birds of prey on cliffs or gulls on islands. This relationship is based on the need of breeding Red-breasted Geese for protection against predation by the Arctic Fox. On the other hand, the breeding bird of prey profits from the vigilance of the geese (Kostin 1985).

In spite of this protection, in some years there is considerable predation of Redbreast nests by foxes. In order to estimate the influence of Arctic Fox predation on reproductive success, a variable number of Red-breasted Goose colonies were specially observed to determine the number of nests destroyed (**Table 3**). The years 1973, 1976, 1979, 1982, 1985, 1988 and 1991 were peak years for the lemming population *Lemmus sibericus* and *Dicrostonyx torquatus* of the Taymyr Peninsula. During this research programme (1977–1983), an above-average number of attacks on Red-breasted Goose colonies and the highest number of nests destroyed by foxes were recorded in the years 1977, 1980, 1981 and 1983 (**Table 3**), i.e. in three of four years, this was one year after a lemming peak year. These years, just as 1986, 1989 and 1992, were bad breeding years for the Red-breasted Goose.

The reason could be that a decrease in the number of lemmings after a peak year forces the foxes to shift to alternative food resources, e.g. small birds and eggs as well as carrion. This assumption is supported by similar data gathered by Ebbinge (1992) as well as the observations of Birks & Penford (1990) that on the tundra of western Greenland, where lemmings are absent, the main food of the Arctic Fox is of small (nesting) birds, eggs and carrion.

The correlation between the mortality and the number of nests destroyed by foxes shows that predation can have a marked influence on the reproductive success of Red-breasted Geese. In some years, the influence of predation seems to surpass the influence of the weather, making it difficult to find a clear correlation between juvenile mortality and climatic parameters.

Besides predation by foxes, the clutches of Red-breasted Geese breeding on islands are also endangered by migrating Reindeer *Rangifer tarandus*. It was observed several times that migrating Reindeer crossed such colonies and destroyed a considerable number of nests (Kostin 1985).

The studies of Zyrjanov & Kokorev (1983) between 1966 and 1981 showed that, in spite of their smaller size and higher sensibility to climatic influences as well as fox predation, Red-breasted Geese had a lower rate of juvenile mortality than the White-fronted Geese in the same area (Red-breasted Goose: 15.3% and White-fronted Goose: 17.5%). This could indicate that, in spite of the observed destruction of nests, colony breeding under the cover of more quarrelsome species like birds of prey and gulls actually offers a rather good protection for breeding redbreasts.

Conclusions

As a result of the analyses of weather conditions and the reproductive cycle of Red-breasted Geese *Branta ruficollis* at the Taymyr Peninsula, a number of conclusions can be drawn. The date the temperatures rise above the 0°C threshold seems to influence the date of the arrival as well as the start of incubation and therefore the date of the appearance of the majority of goslings. The total ground temperature in May and the beginning of June, or the date that the temperatures of the breeding area passes the 0°C threshold, can be used to predict the main hatching period of goslings. The percentage of breeding birds and the number of nests per colony seem to be determined by the temperatures at the beginning of June, the amount of precipitation in June and the snow cover of the cliffs. The percentage of breeding birds is also influenced by their physiological condition, which also affects clutch size. In turn, clutch size, together with climatic parameters, influence brood size as well as juvenile mortality. Reproductive success depends mainly on the physiological condition of the birds upon arrival as well as on weather conditions at the breeding site at arrival and during the reproductive period. The reproductive success is also influenced by the level of predation by the Arctic Fox, the population level and reproductive success of the Peregrine Falcon, Rough-legged Buzzard and Herring Gulls as well as by the migratory routes of Reindeer.

References

Boyd, H. 1982. Influence of temperature on arctic-nesting geese. *Aquila* 89:259–269.

Birks, J.D.S. & Penford, N. 1990. Observations on the ecology of Arctic Foxes *Alopex lagopus* in Eqalummiut Nunaat, West Greenland. *Meddr Grønland, Biosci.* 32:1–26.

Cramp, S. & Simmons, K.E.L. 1977. *Handbook of the birds of Europe, the Middle East, and North Africa: the birds of the Western Palearctic. Vol. 1: Ostrich-Ducks*. Oxford Univ. Press, Oxford.

Ebbinge, B.S. 1992. Population Limitation in Arctic-breeding Geese. *Diss. R.U. Groningen*, Groningen.

Ebbinge, B., St.Joseph, A., Prokosch, P. & Spaans, B. 1982. The importance of spring staging areas for arctic-breeding geese, wintering in western Europe. *Aquila* 89:249–258.

Fox, A.D. & Madsen, J. 1981. The pre-nesting behaviour of the Greenland White-fronted Goose. *Wildfowl* 32:48–54.

Fox, A.D. & Stroud, D.A. (Eds.). 1981. Report of the 1979 Greenland White-fronted Goose Study Expedition to Eqalungmiut Nunaat, West Greenland. *Greenland White-fronted Goose Study*, Aberystwyth. 319pp.

Fox, A.D. & Stroud, D.A. 1988. The breeding biology of the Greenland White-fronted Goose *Anser albifrons flavirostris. Meddr Grønland, Biosci.* 27:1–14.

Isakov, Yu.A. 1940. Winter ecology of waterfowl in the southern Caspian region. *Periodical of the ornithological Reserve "Gasan-Kuli"*, Vol. 1. (in Russian).

Ivanter, E.V. 1979. Fundamentals of practical biometry. *Petrozavodsk*, Karelia. (in Russian).

Kishinsky, A.A. 1959. About the peculiar biology of tundra birds. In: *Proceedings of the second all-union ornithological congress 18–22 August 1959*, Vol. 3, Moscow University, Moscow (in Russian).

Kostin, I.O. 1981. On the ecology of Red-breasted Geese during and after the breeding period. In: *Ecology and protection of birds*, Kischinjow. Pp. 115–118. (in Russian).

Kostin, I.O. 1982a. On the factors that influence the size of the breeding population of Red-breasted Geese on Taymyr. In: *Increased productivity of hunting areas*, Moscow. Pp. 113–125. (in Russian).

Kostin, I.O. 1985. The biology of the Red-breasted Goose: problems of conservation. *Biol. Diss. USSR Institute for Nature Conservation*, Moscow. (in Russian).

Kostin, I.O. 1986. Influence of the climate at the status of the Red-breasted Goose population of Taymyr. In: *Questions of hunting ecology*. Moscow. Pp.81–94. (in Russian).

Krechmar, A.V. 1965. Anseriformes of the Pyasina river basin. In: *Geography of the waterfowl resources of the USSR*, Vol. 2., Moscow. (in Russian).

Kreyzig, E. 1965. *Statistische Methoden und ihre Anwendung*. Van den Hoeck & Ruprecht, Göttingen.

Krivenko, V.G., Ivanov, G.K. & Kostin, I.O. 1982. Survey of the Red-breasted Geese at Taymyr 1978-79. In: *Proceedings of the 18th International Ornithological Congress*, Moscow. Pp.182–183. (in Russian).

Leonovich, V.V. & Uspenski, S.M. 1965. Peculiarities of climate and bird life in the arctic. *Periodical of the Biological Institute of the UFAN*, Sverdlovsk, Vol. 38. (in Russian).

Madsen, J. 1991. Status and trends of goose populations in the Western Palearctic in the 1980s. *Ardea* 79:113–122

Michev, T.M., Pomakov, V.A., Nankinov, D., Ivanov, B.E. & Profirof, L., 1991. A short note on wild geese in Bulgaria during the period 1977 to 1989. *Ardea* 79:167–168.

Mikheev, A.V. 1953. Influence of frost on the wintering birds of the Caspian region. In: *Migratory birds of the European part of the USSR*, Riga. (in Russian).

Munteanu, D., Talpeanu, M., Weber, P. & Mircea, G. 1991. A note on the present status of geese in Rumania. *Ardea* 79:165–166.

Prokosch, P. 1984. Population, Jahresrhythmus und traditionelle Nahrungsplatzbindung der Dunkelbäuchige Ringelgans *Branta b. bernicla* im Nordfriesischen Wattenmeer. *Ökol.Vögel* 6:1–99.

Raveling, D.G. 1978. The timing of egg laying by northern geese. *Auk* 95:294–303.

Romanova, E.N. 1978. Micro- and macroclimate of Taymyr. In: *Structure and meganism of the biocenosis of the Taymyr tundra. Nauka*, Leningrad. (in Russian).

Rose, P.M. & Taylor, V. 1993. *Western palearctic and south-west asian waterfowl census 1993*. IWRB, Slimbridge.

Sachs, L. 1970. Statistische Methoden. *Springer*, Berlin- Heidelberg-New York.

Sdobnikov, V.M. 1959. Population size dynamics of mammals and birds of northern Taymyr during the period 1943-1950. *Zoological Jounal* 38 (11).

Skokova, N.N. & Vinogradov, V.G. 1986. Protection of waterfowl and wader habitats. *Agropromizdat Pub.*, Moscow, 240 pp. (in Russian).

Vinokurov, A.A. 1982. Present status of the *Branta ruficollis* population and measures for its protection. *Aquila* 89:115–122.

Vinokurov, A.A. 1990. *Branta ruficollis* in the USSR. In: Matthews, G.V.T. *Managing Waterfowl Populations. IWRB Special Publication* 12:197–198.

Walter, H. & Breckle, S.W., 1986. Ökologie der Erde. Band 3: Spezielle Ökologie der Gemäßigten und Arktischen Zonen Euro Nordasiens. *Fischer*, Stuttgart.

Zyrjanov, V.A. & Kokorev, J.I., 1983. Reproductive success of geese at Taymyr. *Sci.technical Bull. Siberian sect.Acad.Agri.Sci.* 23: 36–45 (in Russian).

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