Barnacle Goose *Branta leucopsis* abundance on Kolguev Island – current status and history of population growth

ALEXANDER KONDRATYEV[1]*, ELMIRA ZAYNAGUTDINOVA[2] & HELMUT KRUCKENBERG[3]

[1]Institute of Biological Problems of the North, FEB RAS, Portovaya str. 18, Magadan, Russia.
[2]St-Petersburg State University, Universitetskaya emb. 7/9, St-Petersburg, Russia.
[3]Institute for Waterbird and Wetlands Research (IWWR) e.V. Germany, Am Steigbügel 3, D-27283 Verden (Aller), Germany.
*Correspondence author. E-mail: akondratyev@mail.ru

Abstract

Barnacle Geese *Branta leucopsis* first colonised the Russian arctic island of Kolguev in the early 1980s, since when their numbers have steadily grown. Initial colonies were founded on fox-free coastal sand spits, but by the mid-1990s large colonies (> 5,000 breeding pairs) had become established in the Peschanka River delta, reaching 45,000 breeding pairs by the mid-2000s. Subsequently, numerous new smaller colonies (mean ± s.d. = 12 ± 6 nesting pairs, range = 1–54, n = 18 colonies) started to increase in numbers in the central part of the island, initially associated with *c.* 30% of all known Peregrine Falcon *Falco peregrinus* nests in the study area. The overall population size and number of inland colonies continued to grow, and by 2011–2012 all 24 known Peregrine Falcon nests had Barnacle Goose colonies (mean colony size = 54 ± 40 pairs, range = 1–133, n = 13 colonies). White-fronted Geese *Anser albifrons* and Tundra Bean Geese *Anser fabalis rossicus* formerly recorded nesting in dense colonies around Peregrine Falcon nests no longer did so, apparently having been expelled from core areas by the earlier nesting and more aggressive Barnacle Geese. The hatching success of Barnacle Geese nesting in the open sedge-moss bogs of central Kolguev (first occupied in 2011–2012) was no different to those associating with Peregrine Falcons (73% and 75% respectively). During brood rearing and moulting, Barnacle Geese share feeding habitats with other goose species. Should their numbers continue to grow on the island, further overgrazing of foraging habitats may increase competition between Barnacle Geese and White-fronted Geese for food, both in brood-rearing and in moulting habitats.

Key words: Barnacle Geese, nesting success, population growth.

The Barnacle Goose *Branta leucopsis* has increased dramatically in numbers in the Western Palearctic from the mid-1970s onwards (Madsen *et al.* 1999), and the exponential growth of the Russian-breeding population continues into the 21st century (Fox *et al.* 2010). In the late 1970s, the only known breeding colonies in Russia were confined to Novaya Zemlya and Vaigach Island. The increase in population size has been associated with a prominent westward shift in breeding range, with new colonies established on Kolguev Island (Ponomareva 1990; Gavrilo 1991), the western Kanin Peninsula (Filchagov & Leonovich 1992), and later along the southeast Barents Sea coast between the Kanin Peninsula and Vaigach Island (Syroechkovsky 1995). These new colonies were no longer associated with traditional nesting habitats (typically steep bluffs inaccessible to terrestrial predators), but were also situated on the flat expanses of the coastal salt marshes and adjacent sand and gravel spits (Syroechkovsky 1995).

In 1994, the biggest known Barnacle Goose colony in the Russian arctic (estimated at *c.* 5,000 pairs) was found at the mouth of Peschanka River on the east of Kolguev Island. The colony was distributed across various delta habitats, including coastal sandy spits, peat hummocks within sedge-moss bogs, flat drained open willow-moss tundra along river banks and many other open flat habitats, all potentially accessible to terrestrial predators (Morozov & Syroechkovsky 2004). Despite the presence of Arctic Foxes *Alopex lagopus* and Red Foxes *Vulpes vulpes* on this lemming-free island, predator abundance did not seem to be high in the mid-1990s (especially in the river delta and on the coastal spits)(Morozov & Syroechkovsky 2004), and so their impact did not prevent a rapid increase in nest numbers within these colonies. The colony in the Peschanka River delta continued to grow to an estimated 20,000 breeding pairs by the early 2000s (Anufriev 2005).

We studied the geese breeding on Kolguev Island in summers of 2006, 2007, 2008, 2011 and 2012, with the aim of estimating their numbers, habitat distribution, breeding biology and factors affecting their breeding success. Kolguev is famous for its large numbers of breeding Barnacle Geese, Tundra Bean Geese *Anser fabalis rossicus* and White-fronted Geese *Anser albifrons*, particularly the latter species (Morozov & Syroechkovsky 2004; Kondratyev & Zaynagutdinova 2008; Kruckenberg *et al* 2008; Mooij *et al.* 2011; Kondratyev *et al.* 2012). The Barnacle Goose population on Kolguev has received comparatively less attention, although estimates of total numbers, breeding biology and habitat distribution in 2006–2008 have been published elsewhere (Kruckenberg *et al* 2008; Kondratyev & Zaynagutdinova 2008; Mooij *et al* 2011; Kondratyev *et al* 2012). This paper provides further information on the dramatic expansion of Barnacle Geese across the island from the mid-2000s onwards (including new data from 2011 and 2012), describes the nature of this expansion, and assesses the potential for further population growth in this key breeding area.

Study area

Kolguev Island (68°41'–69°30'N, 48°12'–50°18'E) is 83 km west–east, 93 km south–

north and lies 80 km offshore in the southeast Barents Sea, separated from the mainland by the 80 km Pomor Strait (Atlas of Arkhangelsk Region 1976; Fig. 1). The eastern, southern and southeast coasts of the island are surrounded by shallows, bordered with sandy and gravel spits. Altitudes in the central part of the island are generally between 20–60 m, but in the central hilly region the highest hills range up to 140–173 m a.s.l. and the southern part is a flat boggy plateau, 4–6 m a.s.l.. The coastline is even and rather straight with 40–70 m bluffs in the east and north (Atlas of Arkhangelsk Region 1976).

Winter is relatively mild for this latitude and the summer is cool. Average ambient temperature exceeds zero degrees from late May – early June. The coldest month is January (average temperature = –12.2°C), and the warmest is July (+7.4°C). The permafrost layer is at 1 m depth. Precipitation is mostly in winter, typically averaging 155 mm *per annum*. Snow melt commences around mid-May on southward-facing hills, about 1–2 weeks earlier on flat plains and river banks than in the hilly uplands of the central part of the island, and the land is generally clear of snow by early June on the plains, or by mid-June in the central uplands. In deep gullies, deep late snow patches persist until mid-July, but have mostly gone by early August. Winds are mostly from the northeast in spring and summer, mostly eastern in autumn, and mostly from the southwest and northwest in winter. The island usually has snow cover and frozen lakes from mid-September onwards. The sky is almost always cloudy (Atlas of Arkhangelsk Region 1976).

The western and central parts of the island comprise typical tundra vegetation, while southern tundra vegetation types dominate in the east and south (Gribova 1980). Due to the flat relief *c.* 38% of the island is bog vegetation, which is especially extensive in the south of the island (Bogdanovskaya-Gienef 1938). Of the tundra vegetation types, hummock lichen-moss tundra is most prevalent. Creek and river banks are overgrown with willow bushes (mostly *Salix glauca* and *S. lanata)* 1–2 m tall. The longest river on the island (Peschanka River), which crosses the island from west to east, is about 150 km in length (Koreisha 2000), and forms a large delta in its lower reaches with boggy habitats between the two main river channels.

Neither rodents nor small ground predators such as mustelids occur on the island, but Arctic Fox and Red Fox are common. Although Polar Bears *Ursus maritimus* visit the northeast coast for short periods each spring and sometimes stay along the coastline, they have never been recorded inland during summer. Some 8,000–10,000 domestic Reindeer *Rangifer tarandus* range freely over the whole of the island.

Methods

Fieldwork was undertaken from 29 May–13 August 2006, 24 May–16 August 2007, 29 May–10 September 2008, 29 May–16 August 2011 and 1 June–2 August 2012. In 2006, constant observations were made in the eastern part of the island in the Peschanka River delta, while central parts were visited for a short period once every 2–4 weeks. In 2007–2008 and 2011–2012,

major studies were undertaken in the centre of the island and eastern parts were visited for short periods. In 2011–2012 the field camp was situated in the upper Peschanka River catchment, 10 km upstream from the camp position in 2007–2008.

Estimates of total colony size, extent, structure, nesting success and nesting densities in various parts of the Peschanka River delta colony were based on the data published in Anisimov (2007). For the colonies situated in the central part of Kolguev (*i.e.* > 5 km from the coast) surveys were made on foot and by boat along predetermined census routes. The same boat routes were followed in each year; walking routes extended each year as new colonies were discovered, and previously found colonies were visited and surveyed in the same way in all years. Checks were made of all lakes and creeks in the 200 km^2 study area in 2008 and 2011 to determine flock distribution in the region. Peregrine Falcons are most active in defending a territory of 150–300 m around the nest (Kharitonov 2007) and this defensive behaviour makes these "protected" areas attractive to several goose species for establishing nesting colonies. Dense nesting aggregations therefore were defined as "colonies" on the basis of their distance from the nest of a protecting falcon, and also on the *c.* tenfold increase in goose nesting densities around falcon nests, in comparison with nesting densities elsewhere on central Kolguev Island. During the surveys we counted the number of all Barnacle Goose nests located (sites illustrated in Fig. 1), mapped them with GPS and subsequently checked the hatching success of all mapped nests during visits to the colonies in the second half of July. Nests where at least one egg membrane was present, indicative of hatching, were considered to have been successful. During 2006–2012, we found and described 1,194 Barnacle Goose nests at 43 inland colonies (23 different colony sites). The fate of 1,029 nests was estimated for the 28 colonies found in the central part of the island. Counts of broods and moulting groups were made for all geese species in late July – early August, both on predetermined and on arbitrarily-selected routes along the rivers and in the lake areas. These route censuses, of 1,666 km (summed for all seasons in the central part of Kolguev), found 4,600 Barnacle Geese broods and 27,600 moulting individuals.

Results

Transect counts conducted in 2006 enabled Anisimov (2007) to estimate the Barnacle Goose colony size in the Peschanka River delta. The number of paired individuals recorded in the delta (ranging from 1,600 geese in 1989 to 90,000 in 2006) comprised up to 18% of the entire Russian-breeding population (Table 1). Nesting density, calculated on the basis of transect counts made in different part of the colony, gave values varying from 750–6,000 nests/km^2, with the most common nesting densities being of 1,500 nests/km^2 (Anisimov 2007). Our own more general observations of the colony in subsequent years found no obvious changes in nesting densities for areas occupied by the colony during Anisimov's study, but it was noticeable that the overall area covered by the colony had expanded. Whereas in 2006 there had been

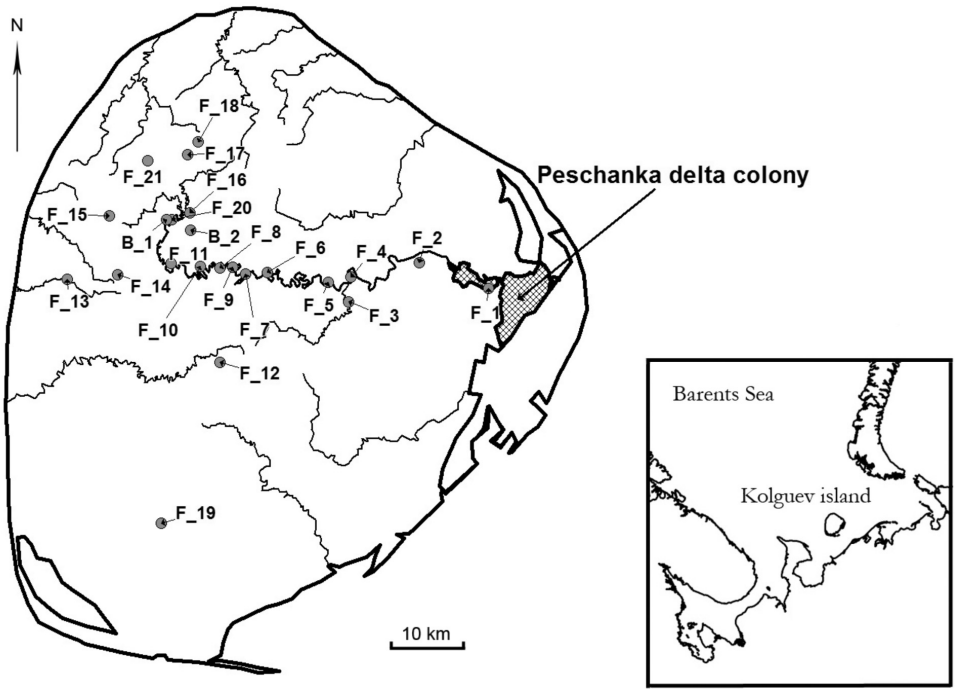

Figure 1. Map of Kolguev Island with Barnacle Goose colonies (grey dots). Abbreviations correspond to colony names shown in Table 2.

unoccupied areas in the upper reaches of the Peschanka River delta, (especially in low-lying riparian habitats), or there had been some isolated sub-colonies several hundred metres from the main colony, by 2011–2012 all these vacant sites within the delta had been completely occupied by nesting Barnacle Geese, linking all previously isolated sub-colonies to the main colony. Nevertheless, the borders of this very large colony, which now stretches almost 12 km along the lower channel of the Peschanka River, are still clearly delineated by low-lying riparian habitats, and we rarely observed Barnacle Geese nesting uphill on the slopes of the river terrace or on the upper plateau (the only exception being one falcon-associated colony F_1; Fig. 1). The growth of this main colony, which commenced prior to the start of our study in 2006 (when colony size was estimated most thoroughly), continued in 2007–2008 (when only some parts of the colony were monitored) and has continued thereafter, has only taken place within the low-lying riparian habitat between the steep banks of the river terraces which border the Peschanka River delta. There was still space unoccupied by geese between the east bank of Peschanka River and the terrace slope in 2006, in a band ranging from 100–1,000 m in width, but these gaps had become occupied by

Table 1. Number of geese recorded in the Peschanka River delta colony, in relation to the whole of the Russian-breeding Barnacle Goose population.

Year	Population size[1]	Colony size (no. of individuals)	% of Russian population	Data source for colony size
1989	100,000	1,600	1.6	Gavrilo 1991
1995	250,000	10,000	4.0	Morozov & Syroechkovsky 2004
2001	300,000	50,000	16.0	Anufriev 2005
2006	500,000	90,000	18.0	Anisimov 2007

[1]Total population size from Fox *et al*. 2010.

nests in 2011 and 2012. Overall, however, these newly-colonised areas would not have added >10% to the area of covered by the delta colony.

By 2006, the Barnacle Goose nesting distribution was no longer restricted to the coastal zone. Transects undertaken in central Kolguev found at least 23 "inland" colonies, most associated with Peregrine Falcon nesting territories and one with a Gyr Falcon *Falco rusticolus* nest (Fig. 1). Not all colonies were monitored every year, but those inspected during two or more seasons show that colony size varied across years (Kruskal-Wallis test: $H_4 = 22.2$, $P < 0.001$), with a general tendency for the colony size to be greater in more recent years (2011–2012) than at the start of the study (2007–2008) (Mann-Whitney U test: $W = 611.5$, $n1 = 32$, $n2 = 21$, $P < 0.001$, Table 2). Nesting success also varied, with the mean proportion of clutches hatched per colony ranging from 59% (s.d. = 34%, $n = 5$ colonies) in 2007 to 92% (s.d. = 8.6%, $n = 3$ colonies) in 2006 (Table 2), but the substantial variation in hatching success between colonies within years (particularly in 2007) meant that the difference between years was not significant (Kruskal-Wallis test: $H_4 = 4.15$, n.s.).

In 2006–2008, Barnacle Geese were mainly associated with Peregrine Falcons that nested on steep slopes in the upper reaches of the Peschanka River and its major tributaries; they were seldom found around falcon pairs nesting in the watershed hills. Thus, in 2007–2008 only two out of five Peregrine Falcon nests in the hills of central Kolguev Island were known to have Barnacle Goose colonies around them (territories F_17 and F_18 in Table 2), compared with 13 out of 14 Peregrine Falcon nests along the river systems with associating Barnacle Geese in these years. The other three colonies in the hills (F_12, F_14 and F_15) had 5–25 nests of White-fronted Geese and Bean Geese associating, with minimal distances of 3–5 m and a maximum of up to 100 m between the falcon and goose nests, irrespective of

Table 2. Patterns of Barnacle Goose colony growth in the central part of Kolguev. Colony names correspond to those shown on Fig. 1. Falcon-associated colonies are listed as "F", bog colonies – as "B". Cases when Peregrine falcons were nesting are shown in bold. Colony size is given in number of nests. Blank cells correspond to data absence. Zero values correspond to definite absence of Barnacle Geese nests at the site in a given season. Falcon territories where no colonies were recorded during the study were not allocated a colony code.

Colony code	2006		2007		2008		2011		2012	
	Colony size	Hatching success (%)	Colony size	Hatching success (%)	Colony size	Hatching success (%)	Colony size	Hatching success (%)	Colony size	Hatching success (%)
F_1	**12**	**83**	0		0		**38**	**81**	**53**	**28**
F_2	**16**	**94**	**0**							
F_3	**4**	100			>20					
F_4			**9**							
F_5			**11**						**40**	
F_6					**23**					
F_7					**25**		**35**			
F_8			24	16						
F_9			**3**	**30**	**16**	**58**				
F_10			**5**	**80**	**22**	**71**				
F_11			**54**	**91**	0		2		**2**	
F_12			**0**		**1**	100				
F_13			**9**	**80**						
F_14			**0**		**2**	100			16	25
F_15			**0**		**2**		46	43	**4**	**100**
F_16					**0**		**6**		77	89
F_17					13				**41**	**97**
F_18					**13**				47	64
F_19					**8**					
F_20					**0**		48	74	87	73
F_21							**56**	**91**	133	94
B_1					0		49	76	76	67
B_2			0		0		37	80	>40	

species. In 2011–2012 not only did all 11 inspected falcon nests (including all nests in the watershed habitats) have Barnacle Goose colonies within the falcon protected area (*c.* 0.075 ± 0.05 km^2 around the falcon nest, n = 12 nests), but the number of *Anser* species nests within the area protected by falcons had drastically decreased (Table 3). In 2007, colony F_14 had 18 nests of *Anser* geese species and no Barnacle Goose nests, in 2008 the first two Barnacle Goose nests were recorded (along with 13 *Anser* goose nests) and in 2012 we found 16 Barnacle Goose nests but no *Anser* goose nests in the area protected by the falcon.

Colony occupancy also became more consistent over time. In 2006–2008, when falcon pairs skipped nesting, the Barnacle Geese abandoned nesting in the absence of the raptor protection (3 of 6 cases where the falcons skipped nesting), whereas in 2011–2012, geese continued to nest in all 8 cases where the falcons skipped nesting on their territories (Table 2). Moreover, we found no significant difference in breeding success between Barnacle Goose colonies nesting in the presence of falcon pairs (91%) and those nesting without (69%) in 2011 and 2012, though sample sizes were small (Mann Whitney U test: W = 39.0, $n1$ = 5, $n2$ = 6, P = 0.12, n.s., Table 2). Two of these colonies (F_16 and F_23) increased markedly in size in 2012 and pairs in both colonies bred very successfully, despite the falcon pairs skipping nesting in both cases (Table 2). The opposite was true for another colony (F_15), which had a larger colony when the falcon pair was not nesting in 2011 than when they were breeding in 2012 (Table 2).

In addition to the colonies formed around falcon nesting areas, two colonies of a new type were found in 2011–2012 in the central part of Kolguev Island. Both of these colonies (B_1 and B_2 in Fig. 1 and Table 2) were situated on sedge-moss bogs formed at the bottoms of dried-out lakes in areas, where there was no sign of a colony in 2007–2008. Nests were mostly placed on the tops of peat hummocks protruding from wet moss mats flooded by spring melt waters, and neither colony was associated with any raptors. These two colonies were highly successful (hatching success 67–80%) in both seasons and colony size increased from 49 in 2011 to 76 in 2012 in one of them, and from 37 to >40 (nests were not mapped; only counted from a distance in 2012) in the other (Table 2). Indeed, the hatching success of Barnacle Geese nesting in the two bog colonies in 2011–2012 (*c.* 73% of 162 clutches where breeding success was monitored were thought to have produced at least one gosling) was similar to that of geese associating with Peregrine Falcons in the same years (75% of 192 monitored clutches hatched; χ^2_1 = 0.02, n.s.). The areas available for the two bog colonies are relatively constant, being restricted by the outer borders of dry lakes (0.11 and 0.24 km^2 respectively). At colony B_1, the nesting density increased from 440 nests/km^2 in 2011 to 680 nests/km^2 in 2012; at colony B_2, however, nesting density was much lower and did not exceed 200 nests/km^2, possibly due to the wetter nature of the habitat with fewer peat hummocks protruding from the wet moss bog. Moreover, these two new colonies were situated in the vicinity of two other falcon-

Table 3. Some parameters associated with Barnacle Goose colonies monitored in the central part of Kolguev Island in 2006–2012.

Inland colonies	**2006**	**2007**	**2008**	**2011**	**2012**
Falcon territories inspected	6	14	15	8	10
Falcon territories with BG colonies around (including years when falcons skipped breeding)	3	7	11	7	10
Falcon territories with *Anser* colonies around	2	5	6	4	2
Number of *Anser* nests in monitored falcon associated colonies	46	40	50	10	7
% of falcon territories with BG colonies	50	50	73	87	100
Number of colonies monitored	3	7	11	9	11
Number of nests in monitored colonies	32	115	> 156	317	> 616
Mean colony size (± s.d.)	10.7 (6.1)	12.8 (17.1)	11.3 (9.0)	39.4 (15.2)	52.4 (39.2)
Per cent of successful nests in all checked inland colonies	91	69	71	74	70

associated colonies (F_16 and F_20, 0.6–2 km from the new colonies), which also increased in size markedly in 2012 (Table 2 and Fig. 2). Several solitary nests (*i.e.* without raptor protection, but which in four out of eight cases hatched successfully) were also recorded in 2011 and 2012 in the area between these four colonies (Fig. 2). Previously, two cases of solitary nesting by Barnacle Goose pairs, at distances > 2 km from a colony, were observed in 2008, but both of these breeding attempts were unsuccessful as a result of fox predation.

Barnacle Goose distribution over the island changes radically during the post-hatching period. During nesting, all central colonies typically support no more than 500–1,000 pairs (*i.e.* < 1% of all the nesting population of the island), yet late summer counts made in early–mid August indicate that one-third of all broods of this species move to central Kolguev after hatching, when all broods (including broods from late nesting pairs) leave their colony sites, when even the earliest-hatched goslings are not yet able to fly. These counts give densities ranging from 5–20 broods/km^2 across the different habitats. Given that the total area of prime Barnacle Goose brood-rearing habitats (*i.e.* where such high densities were observed) is at least 800 km^2, we roughly estimated that the habitats of central Kolguev could support up to 16,000 broods (Kondratyev *et al.* 2012). Non-breeders also

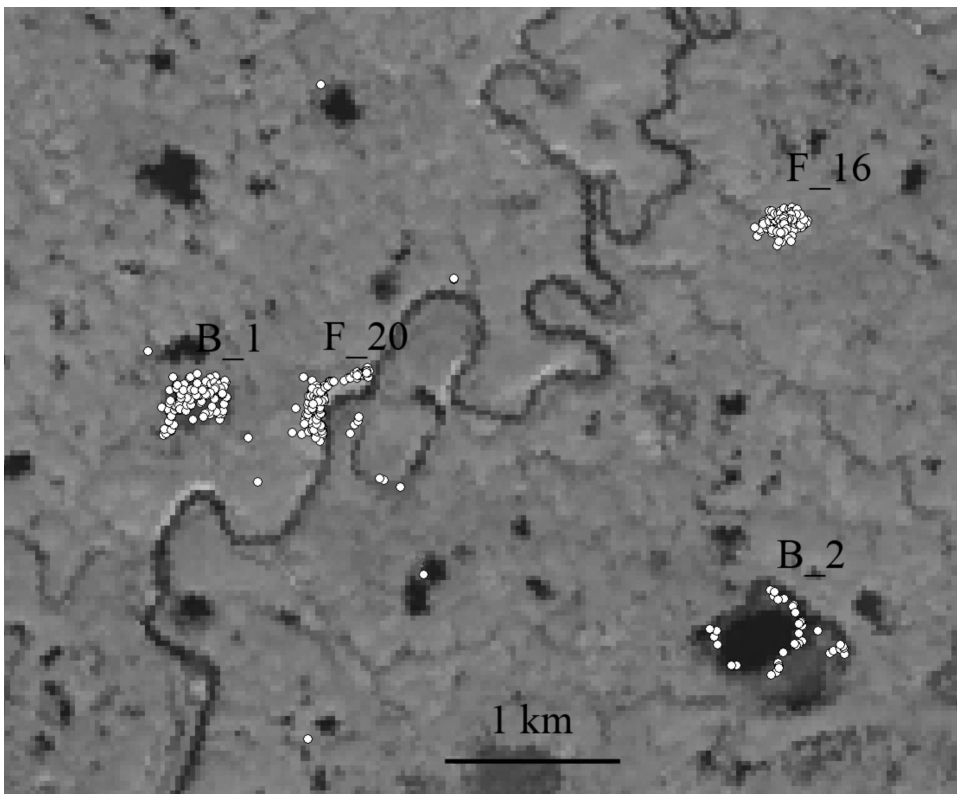

Figure 2. Barnacle Goose nest distribution pattern in the upper reaches of the Peschanka River. Colony abbreviations correspond with those on Fig. 1 and Table 2.

now concentrate in large numbers in the centre of the island (Kondratyev *et al.* 2012). Groups of 50–100 non-breeding Barnacle Geese are regularly observed along the river bluffs in the vicinity of each of the breeding colonies (several hundred metres from the nesting pairs) from the start of the incubation period, and these are augmented by new flocks of 20–40 individuals which continue to arrive, moving upstream from the Peschanka River delta. By the start of moulting period, during 4–10 July, flocks of > 400–600 individuals occur around some of the colonies, with the biggest concentrations of non-breeders seen mostly on the Peschanka River, under the colonies on its slopes. The largest group of non-breeding Barnacle Geese counted in the upper and middle reaches of the Peschanka River, seen on 24 July 2007, was of 1,935 individuals in a single flock (Table 4). In other seasons the flock sizes were smaller, but moulting groups of > 500 birds were observed near Peregrine Falcon eyries in the upper and middle reaches of Peschanka and some other rivers each year. Such large

Table 4. Flock sizes recorded for Barnacle Geese moulting near Peregrine Falcon eyries along the river bluffs (adjacent to Barnacle Goose breeding colonies) and in the lake areas of central Kolguev Island in 2008 and 2011.

	River bluff sites	Lake areas
Minimum flock size	16	2
Maximum flock size	1,935	300
Mean flock size	452	38
(± s.d.)	(519)	(40)
Number of flocks recorded (*n*)	29	358

moulting groups were always observed in areas < 2 km from the nearest Peregrine Falcon nesting territory. Flock sizes recorded for moulting non-breeders in the lake areas were significantly smaller than along the river ($t_{357} = 14.7$, $P < 0.001$); they never exceeded 300 moulting birds, and mostly varied in size between 20–50 individuals (Table 4).

Discussion

The progress colonisation and expansion of Barnacle Geese on Kolguev Island can be divided into several stages, each with its own specific features. The first stage was the initial appearance of the geese as a breeding species on the island in the early 1980s; subsequently the geese have started to play a more important role within the island ecosystem. During the early years, from 1980–2005, the first small breeding colonies appeared and increased along the coast, mostly on the spits and estuaries of the big rivers (Ponomareva 1990; Gavrilo 1991). The Arctic Fox was not particularly numerous on the island in the mid-1990s (probably because foxes were commercially hunted on the island until the early 1990s, which at least partly suppressed their population), but it seems likely that the first small colonies were established in fox-free areas, as observations suggest that even nowadays the spits are only rarely visited by foxes. Some wet parts of the vast and boggy Peschanka River delta are difficult for foxes to access, so small Barnacle Goose colonies also appeared there. The location of the colonies close to coastal marsh habitats suitable for brood-rearing provided potential for population growth; it therefore was not surprising that several small delta colonies, mentioned by Morozov & Syroechkovsky (2004) as separate colonies in 1994 and 1995, grew and combined so that by 2001 there was a large single colony (mentioned by Anufriev 2005) in the Peschanka River delta. Later, as the fox population of Kolguev Island increased markedly, the delta colony was big enough to survive, despite more intensive fox

predation. Thus, whereas in 1994–1995 Morozov and Syroechkovsky (2004) reported that they only "sometimes have seen Arctic Foxes in that area", by 2006 up to six Arctic Fox dens were recorded inside the colony, each with 4–7 pups each year (authors' pers. obs.). Despite Barnacle Geese being the main prey of foxes (pers. obs.), which placed their dens in and around the colony, overall nesting success for geese in the delta colony was still > 90% (Anisimov 2007). The colony therefore not only survived successfully but continued to grow.

Neither Syroechkovsky and Morozov (2004), during their extensive studies of the central part of the island, nor other authors (Glazov 1998; Anufriev 2005) who visited the island in the 1990s, reported cases of Barnacle Geese nesting in association with Peregrine Falcons in the centre of the island, though the falcons themselves were described as a rather common breeding species (Morozov & Syroechkovsky 2004). This strongly suggests that falcon-associated inland colonies have appeared more recently, but prior to the start of our work (presumably between 2000–2005) and the expansion to central parts of Kolguev should be considered to represent a second significant stage in Barnacle Goose colonisation of the island. This development also saw non-breeding Barnacle Geese move from the Peschanka River delta to congregate in the vicinity of the new colonies during the second half of June, prior to the start of moult. The largest concentrations of moulting non-breeders were invariably seen adjacent to these inland colonies of the upper Peschanka River.

A further development has been the use of new nesting habitat by the geese in the last two years of the study, when two colonies were recorded on dry lake beds disassociated from raptor nests. These habitats in themselves were not new for the species, as they are quite typical nesting habitats in the Peschanka River delta, though they might be considered as secondary for the species in general (Barnacle Geese having started to use them only in conjunction with the westward expansion of the breeding range), whereas their breeding habitats on steep river banks are more typical primary habitats (common for the species in the former core breeding areas on Novaya Zemlya and Vaigach Island; Syroechkovsky 1995). Prior to 2011, we never observed Barnacle Geese nesting in these habitats in the central parts of the islands, as in 2006–2008 all inland colonies were small and strongly associated with falcon nests for protection. Cases of skipped breeding, or breeding but with low hatching success in the cases when falcons have nested in a particular season, may serve as additional evidence that during the early stages of colony (and thus population) development Barnacle Geese may breed most successfully in areas inaccessible to terrestrial predators (such as bluffs, sandy spits or islands, or under the protection of breeding falcons), until the colony reaches a size of several thousands nests where the presence of foxes cannot prevent its further growth, as is now the case in the Peschanka River delta. Nesting on peat hummocks, protruding from the wet moss mats and on dry flat ground along the rivers and lakes banks, therefore appear to be secondary

nesting habitats, used by Barnacle Geese only after the population has reached a certain level, as these habitats are readily accessed by foxes. These nesting habitats were never mentioned as being exploited by Barnacle Geese at their primary breeding sites on Novaya Zemlya and Vaigach Island (Syroechkovsky 1995). That these habitats are now being used in central Kolguev Island, coupled with high nesting success both at these and at falcon-associated colonies (even when the falcons skipped breeding), might indicate that the inland-breeding Barnacle Geese on the Upper Peschanka River have now reached the stage when they are not as dependant on falcons for successful breeding as in 2006–2008, when all cases of successful breeding in the central part of the island were strongly associated with falcons. It is also worth noting that these two new colonies were not only situated close to each other (there were only 3 km between them), but they were also rather close (0.6 and 2 km respectively) to two large successful falcon-associated colonies, together comprising *c.* 400 nests (in four groups), with at least ten solitary nests spread out between them, thus providing an opportunity for the rapid growth and merging of these groups following increased hatching success in 2011–2012 (Fig. 2, Table 2). The entire upper Peschanka River area is likely to support further growth of Barnacle Goose colonies, with considerable potential for the establishment of large colonies through a process similar to that recorded for the Peschanka River delta colony in the 1990s.

The substantial increase in Barnacle Goose numbers in central Kolguev Island between early June and July–August, due to the westward movements of broods and flocks of non-breeders from the Peschanka River delta, has not been mentioned in any earlier studies (made in the 1980s and 1990s) of geese on the island. The growth in Barnacle Goose numbers in the central part of Kolguev over the last decade may have considerable consequences for the island's ecosystem as their brood-rearing habitats largely overlap with those of the White-fronted Geese, although Bean Goose brood-rearing habitats are more separate (Kondratyev *et al.* 2012). Elsewhere where Barnacle Goose numbers have expanded and come into close contact with White-fronted Geese, there have been indications of a shift in distribution of the latter, possibly as a result of competition for food (Zimin *et al.* 2007; Kruckenberg & Kowalik 2008). If Barnacle Goose numbers increase further, this will likely lead to elevated competitive interactions between the two species. As the preferred nesting habitats of Barnacle Geese and the two *Anser* goose species on Kolguev differ slightly (Kondratyev *et al.* 2012), there has been little evidence to date of serious adverse effects of the growing Barnacle Goose population on the *Anser* geese at the nesting stage. However, we have some local observations, such as the expulsion of *Anser* species from areas around some falcon nests, and slightly lower clutch size amongst *Anser* pairs breeding *c.* 500 m from the main Barnacle Goose colony in the Peschanka River delta (Kondratyev *et al.* 2012) that suggest some limited effects. The most serious competitive interactions between the Barnacle Goose and the *Anser* geese can be expected during the post-hatching period,

when they tend to share the same lakes and lake shores for feeding (A. Kondratyev unpubl. data).

Taking into account all of the above changes in Barnacle Goose numbers and distribution across the island, there are several future possibilities for the future of Barnacle Goose nesting on Kolguev Island. These include, firstly, stabilisation of the growth of the delta colony and coastal colonies in the near future, especially on the edges, as overall density in the central part of the colony no longer seems to be increasing. All remaining gaps within low-lying nesting habitats will probably soon be filled, and as the geese are not occupying the slopes of the delta, the remarkable growth of the main delta colony is expected to plateau. Secondly, a continued increase in nest numbers around raptor colonies can be expected elsewhere, with the extent of each colony limited to a 250–300 m protected radius around a raptor nest. Currently, based on the colony size and distances between the furthest nests, the nesting density does not exceed 1,500 nests/km^2, but this still permits a potential fourfold increase in nesting density to reach the maximum of 6,000 nests/km^2 sometimes observed in the delta colony (Anisimov 2007). Colonies around raptor nests therefore could reach 500–600 nests; 6,000–10,000 more nests in total, given the current raptor distribution. Thirdly, the new "sedge-moss bog" colony types that have appeared in the centre of the island seem to be limited by available suitable habitats. Colony size in these cases is limited by the availability of dry places protruding from the flooded lake bottom, so the potential for these specific colonies appear to be physically restricted to not more than 1,000 more nests over the entire island, due to low number of suitable dry lakes with peat hummocks protruding from spring-flooded wet boggy bottoms. Lastly, solitary nests that successfully fledge young in the areas between several closely placed and constantly growing colonies of the upper Peschanka River have the potential to attract other breeders, thus filling the gaps between these colonies and making the process of joining several colonies into one larger-sized colony even more rapid. As broods are free to move after hatching to any part of the island, the potential for this colony to grow might be limited only by the overall carrying capacity of the entire island ecosystem during the brood-rearing period.

To conclude it is suggested that the carrying capacity of the brood-rearing and moulting habitats need to be studied more thoroughly to assess the possible future impact of increased Barnacle Goose numbers on the breeding *Anser* species, and possibly also with regard to the vegetation types present on the island.

Acknowledgements

We would like to thank the many students and volunteers who supported us in our work on Kolguev Island during the five-year study. We are also grateful to the German Committee for Bird Protection (VsK, Hamburg) and the ECORA GEF Project for financial support of the expeditions made in 2006–2008. In 2011 and 2012 this study was part of a project of the Institute of Avian Research, the Department of Biology and Environmental Science, University of Oldenburg, the Institute for

Wetlands and Waterfowl Research (IWWR) e.V., the European White-fronted Goose Research Programme and the Wadden Sea National Park Administration of Lower Saxony, which was funded by the Federal Agency for Nature Conservation under the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (FKZ 3510 860 1000), the Niedersächsische Wattenmeerstiftung and the Committee for Bird Protection. J. Mooij, Ch. Zöckler, Y. Anisimov, F. Kasanski, J. Dierschke, C. Ketzer, N. Feige, P. Glazov, V. Buzun, Ye. Jatcuk, I. Lysansky, A. Dolgova, O. Pokrovskaya, D. Dorofeev, A. Dmitriev, S. Rozenfeld, F. Hillig, V. Chuiko, D. Ochinashko, V. Blüml, G. Reichert, H. Ernst, P. de Vries, G. Nikolaus, A. Fritzsch and E. Bünemann took part in our Kolguev expeditions and provided invaluable help with the fieldwork. For excellent technical assistance we would like to thank R. Bolshakov, who was ECORA project coordinator for Kolguev, A. Vokuev (Barents Secretariat, Naryan-Mar) and the Department of International Affairs at the Nenets Autonomous Okrug Administration (Naryan-Mar). We also thank colleagues from the Institute for Avian Research "Vogelwarte Helgoland" for collaboration in 2011 and 2012.

References

Anisimov, J.A. 2007. Colonies of Barnacle Geese on Kolguev Island. *In* J. Mooij *et al.* (eds.), *Tenth Meeting of the Goose Specialist Group of Wetlands International*, pp. 13–14. Wetlands International/IUCN Species Survival Commission Goose Specialist Group, Xanten, Germany.

Anufriev, V.V. 2005. Number and interspecies relations of geese (Anseridae) on Kolguev island. *In* Gavrilo *et al.* (eds.), *Waterfowl in Northern Eurasia. Thesis of the Third International Symposium*, pp. 14–15. Publishing House of All-Russian Geological Institute, St-Petersburg, Russia. [In Russian.]

Atlas of the Arkhangelsk Region. 1976. *Atlas of the Arkhangelsk Region.* Head Division for Geodesy and Kartography under the Supreme Council of USSR, Moscow, Russia. [In Russian.]

Bogdanovskaya-Gienef, I.D. 1938. Natural conditions and reindeer pastures of Kolguev Island. *Materials of the Polar Agriculture, Animal Stock and Hunting Husbandry Research Institute* 2: 5–161.

Filchagov, A.V. & Leonovich, V.V. 1992. Breeding range expansion of Barnacle and Brent Geese in the Russian European North. *North Polar Research* 11: 41–46.

Fox, A.D., Ebbinge, B.S., Mitchell, C., Heinicke, T., Aarvak, T., Colhoun, K., Clausen, P., Dereliev, S., Faragó, S., Koffijberg, K., Kruckenberg, H., Loonen, M.J.J.E, Madsen, J., Mooij, J., Musil, P., Nilsson, L., Pihl, S. & van der Jeugd, H. 2010. Current estimates of goose population sizes in western Europe, a gap analysis and an assessment of trends. *Ornis Svecica* 20: 115–127

Gavrilo, M.V. 1991. Barnacle Goose on Kolguev Island. *Proceedings of 10th All-Union Ornithological Conference. Part 2, Vol. 1,* p. 128. Nauka, Minsk, Russia. [In Russian.]

Glazov, M.V. 1998. Breeding conditions of waders in Russian tundra in 1997. Kolguev Island. *Russian Wader Study Group Information Bulletin* 11: 29.

Gribova, S.A. 1980. Tundra. *In* S.A. Gribova *et al.* (eds.), *Vegetation of European part of USSR.* L., pp. 29–69. Nauka, St-Petersburg, Russia. [In Russian.]

Mooij, J., Kruckenberg, H., Kondratyev, A., Zaynagutdinova, E. & Zöckler, C. 2011.

Kolguev – island of geese. *Goose Specialist Group Bulletin* 13: 24–33.

Kharitonov, S.P. 2007. Colonies of Red-Breasted Geese around Peregrine Falcons: falcon activity as a factor, influencing the distribution of Red-Breasted Geese nests within the colony. *Study and conservation of raptors in Northern Eurasia. In* Galushin *et al.* (eds.), *Procedings of V International conference on raptors of Northern Eurasia. 2008. Ivanovo, 4–7 Feb 2008,* pp. 187–190. Ivanovo State University, Ivanovo, Russia. [In Russian.]

Kondratyev, A.V., Zaynagutdinova, E.M. & Kruckenberg, H. 2012. Recent status and biology of geese on Kolguev Island. *Casarca* 15 (2): 3–70. [In Russian.]

Kondratyev, A. & Zaynagutdinova, E. 2008. Greater White-fronted Geese *Anser albifrons* and Bean Geese *A. fabalis* on Kolguev Island – abundance, habitat distribution, and breeding biology. *Vogelwelt* 129: 326–333.

Koreisha, M.M. 2000. Kolguev Island. *Journal of Geocryology* 1: 69–91. [In Russian.]

Kruckenberg, H. & Kowallik, C. 2008. Verdrängen Weißwangengänse Branta leucopsis die Blässgänse Anser albifrons aus ihren Nahrungsgebieten am Dollart? – *Vogelkundliche Berichte aus Niedersachsen* 40: 417–426

Kruckenberg, H., Kondratyev, A., Mooij, J.H., Zöckler, C. & Zaynagutdinova, E. 2008. White-fronted Goose flyway population status – interim report of a preliminary study in 2006. *Angewandte Feldbiologie* 2: 1–63.

Litvin, K.E. & Syroechkovsky, E.V. 1996. Bean Goose (*Anser fabalis rossicus*) breeding biology in the North-East of European Russia. *Casarca*, 2: 138–167. [In Russian.]

Madsen, J., Cracknell G. & Fox A.D. (eds.). 1999. *Goose populations of the Western Palearctic. A review of status and distribution*. Wetlands International Publication No. 48. Wetlands International, Wageningen, the Netherlands and the National Environmental Research Institute, Rønde, Denmark.

Morozov, V.V. & Syroechkovsky Jr, E.E. 2004, Materials to our knowledge of bird fauna of Kolguev. *Ornitologia* 31: 9–50. [In Russian.]

Ponomareva, T.S. 1990. Barnacle goose. *In* Amirkhanov (ed.), *New breeding colony in the surroundings of Kolguev Island. Results of rare species study (Materials for the Red Data Book)*, pp. 81–84. Central Research Laboratory of Hunting Control Headquarter of Russian Federation, Moscow, Russia. [In Russian.]

Ponomareva, T.S. 1995. Breeding avifauna of the neighbourhood of Kolguev Island. *Ornitologia* 26: 92–96. [In Russian.]

Syroechkovsky, E.E. Jr. 1995. New data on breeding distribution of Barnacle Geese in Russia. *Casarca* 1: 39–46. [In Russian.]

Zimin, V.B., Artemjev, A.V., Lapshin N.V. & Tjulin A.R. 2007. *Spring bird concentrations on Olonetz fields: general characteristics. Geese*. Nauka, Moscow, Russia. [In Russian.]

