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TAXONOMY OF ARCTIC LEMMINGS: A REVIEW OF CURRENT DEVELOPMENTS

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The role of lemmings in ecosystems of the Arctic tundra is well known. However, until now researchers have not reached agreement about the number of lemming species inhabiting the current tundra landscape, the limits of their ranges, the origin and relationship between species, and whether their populations follow the same or different cycles. This review is aimed at acquainting ornithologists with the results of the latest studies of lemming taxonomy and zoogeography as well as with the most controversial issues in this field of research. As more studies are required to clarify these issues and new data are likely to modify our understanding of lemming taxonomy, the information presented below should not be viewed as definitive.

To start with, the specific names of lemmings, like many widespread animal names, do not correspond to the formal definition of the taxon. Simpson (1945) distinguished four genera in the tribe Lemmini: *Dicrostonyx* Gloger – collared lemmings, *Synaptomys* Baird – bog lemmings, *Myopus* Miller – wood lemmings and *Lemmus* Link – true lemmings. However, further research revealed that despite a number of common external characteristics, collared lemmings did not share a common ancestry with the three other genera. The latter represented an independent phylum in the subfamily Arvicolinae and, from the second half of the 20th century, most researchers considered lemmings from the family Arvicolidae (or subfamily in some systems) to be two independent taxa of subfamily rank - Lemminae and Dicrostonychinae (Chaline 1972), or as two tribes (Gromov & Polyakov 1977), or as the tribe Lemmini and sub-tribe Dicrostonychina (Pavlinov & Rossolimo 1998).

The first remains of true lemmings are known from the late Pliocene in Eurasia (Simbugino, south Urals), and already they had formed characteristic morphological features. This is one of the few groups of herbivorous mammals whose diet comprises mainly low-calorie mosses and grasses. Such unique dietary specialization was associated with typical features of their dentition (Abramson 1993), allowing easy identification of their remains in the pellets of predators, even from small fragments of molars and lower jaw. Morphology and geography of true lemming remains from the late Cenozoic era indicate that the group evolved in wet marshy habitats of the boreal zone of Eurasia (Kowalski 1980, 1995), and these lemmings still live in such habitats. It is noteworthy that among three of the current genera (*Synaptomys, Myopus, Lemmus*), comprising the taxon Lemmini, only lemmings of the *Lemmus* genus inhabit the Arctic tundra of both the New and Old World, where their distribution is associated with low patches of polygonal marshes and does not expand as far north as that of collared lemmings. However, unlike the latter, certain species of true lemmings (*L. amurensis*) extend into forest-tundra and taiga. The only current genus of collared lemmings, *Dicrostonyx,* in contrast to true lemmings, inhabits exclusively drier elevated areas of the Arctic and Subarctic tundra. According to paleonthological data, the evolution of *Dicrostonyx* was associated from the very beginning with crioxerophylous landscapes of tundra-steppe, resembling its environment in the current tundra (Kowalski 1980, 1995).

Thus, Arctic lemmings belong to two genera of different origin, and accordingly two different phyletic branches of the subfamily Arvicolinae. Currently, both collared and true lemmings have a circumpolar distribution, but occupy different ecological niches and differ in their food specialization and optimal habitats (e.g. Batzli & Pitelka 1983, Rodgers & Lewis 1985). Collared and true lemmings are sympatric within nearly the whole tundra zone, with the exceptions of Scandinavia and the Kola Peninsula (only *Lemmus* is present), Greenland and some islands of the Arctic basin (e.g. Severnaya Zemlya - only *Dicrostonyx* is present). Lemmings are absent from Svalbard, Franz Josef Land and Kolguev Island. Interestingly, even attempts to acclimatise lemmings on Kolguev were unsuccessful. This island represents a mystery in this respect for zoologists, because few other Arctic islands that have no lemmings also have no suitable conditions for them. On Kolguev it seems that all necessary conditions for both collared and true lemmings exist, but the absence of rodents was reported by researchers back in the 19th century.

Taxonomy of *Lemmus* genus: brief history and current state of the issue

The composition of this genus was fundamentally revised several times during the 20th century, based on species concept, applied methods, and sometimes just because of an author's personal fancy to split or combine species. Three stages can be distinguished in the studies of lemming taxonomy based on the methods used.

The first stage (1920s – mid 70s) of research was based on analyses of variation in fur colour, body measurements and some cranial characteristics (e.g. Vinogradov 1925, Ognev 1948, Krivosheev & Rossolimo 1966). The results were controversial because the number of species varied from two (*L. lemmus* and *L. sibiricus*) to five (*L. lemmus, L. sibiricus, L. amurensis, L. trimucronatus, L. nigripes*) with different numbers of subspecies recognised. An extreme point of view that has not received recognition was formulated by Sidorowicz (1964), who believed in the existence of one polytypic species *L. lemmus* with 3 subspecies.

The second stage (mid 70s – end of 80s) was related to the invention of cytogenetic methods and experimental hybridisation (Raush & Raush 1975, Pokrovski et al. 1984, Gileva et al. 1984). The main and most striking result of these studies was that there were not the expected profound genetic differences between generally recognized "good" species – Norwegian (*L. lemmus*) and Siberian (*L. sibiricus*) lemmings, nor between true lemmings of the New and Old World. Lemmings from the Chukotsky Peninsula, in many systems considered to be subspecies of *L. s. chrysogaster*, had a karyotype identical to North American *L. trimucronatus*, but were different from all other Eurasian lemmings (*L. lemmus*, *L. amurensis* and *L. sibiricus*, including *L. s. portenkoi* from Wrangel Island and *L. s. flavescens* from Kamchatka) in karyotype and having reproductive isolation. All the latter Eurasian forms hybridised readily in experiments and have an identical karyotype (Pokrovski et al. 1984). Subsequent research has shown that there is a boundary between the two karyological forms along the Kolyma River (Fredga et al. 1999). However, the proposal to consider the genus as containing two species, *L. trimucronatus* and polytypic *L. lemmus* (Kuznetsova 1995) did not receive support, and the current practice of most reviewers continues to split the genus into three (*L. lemmus*, *L. sibiricus* and *L. amurensis* – Musser & Carleton 1993) or four (*L. lemmus*, *L. sibiricus*, *L. amurensis* and *L. trimucronatus* – Gromov & Erbaeva 1995, Jarell & Fredga 1993) separate species.

The novelty of the latest stage studies (i.e., through 1990s, by Chernyavski et al. 1993, Abramson 1999a, 1999b, Frega et al. 1999, Fedorov et al. 1999) is related to attempts to synthesise data from palaeontology, paleogeography, cytogenetics, classical morphology, and, finally, the now popular analysis of mitochondrial (mt) DNA, together with obtaining additional material from poorly surveyed regions of the Arctic. These studies have shown, in particular, that Siberian Lemmings from Wrangel Island and Kamchatka Peninsula and Amur Lemmings, despite substantial differences in size and fur colour, share characteristics of dentition in the lower jaw with true lemmings of the late Pleistocene (Chernyavski et al. 1993). Interestingly the relatedness of these forms was later confirmed by analysis of variability of mtDNA (cytochrome b, Fedorov et al. 1999). Molecular-genetic data confirmed the previous results of cytogenetic and hybridisation studies in demonstrating the large genetic divergence between *L. trimucronatus* from Chukotka and Alaska and other Eurasian true lemmings. Also, these studies provided the basis for species-level recognition of some previously suggested taxa: *L. lemmus*, *L. s. novosibiricus* from New Siberian Islands and *L. s. portenkoi* from Wrangel Island. The application of molecular-genetic and morphological methods to the same material has revealed genetic separation of continental Palearctic populations of *L. sibiricus* into western and eastern groups with the boundary most likely to be along the Lena River. In this case the genetic distance was the next largest after that between *L. trimucronatus* and Eurasian true lemmings, while the level of morphological differences was low. This separation previously was not reflected in lemming taxonomy, and recalled the subspecies *L. sibiricus bungei Vinogr.*, 1925, described from a small sample on the Lena River delta, which failed to receive recognition. Currently little controversy exists about the number of taxa within the genus, but opinions of researchers about the rank and status of the *bungei* race have split. Fredga et al. (1999) assign most importance to differences obtained by analyses of mtDNA and consider *bungei* to be a separate species, and thus distinguish five species within the genus. From my point of view, the morphological characteristics favour its status only as a subspecies, while making inferences for taxonomy directly from a quantitative evaluation of divergence obtained during sequencing of separate fragments of mtDNA is bound to serious bias (Hendry et al. 2000). Besides, material from the Lena River delta (*terra typica* of *L. s. bungei*) was not studied, and without that no clear answer can be given as to the status and precise western distribution border of *bungei*. Both points of view on genus composition are provided in Table 1, together with the main diagnostic characteristics and ranges (see also Fig. 1).

By the beginning of 21st century the taxonomy of true lemmings, at least in the Palearctic, had developed satisfactorily compared with other wide-ranging taxa. The following issues of the genus taxonomy require clarification in future. (1) The systematic position and taxonomic status of the Yellow-bellied Lemming (*L. s. chrysogaster* Allen, 1903) described from the northern coast of the Sea of Okhotsk (Gizhiginskaya Bay) and yet not studied karyologically. (2) The southern limits of distribution of all races listed above remain unclear. (3) The taxonomic status of lemmings from the Lena River delta (*terra typica* of *L. s. bungei*) requires further investigation, as no data from this region were available for mtDNA analysis. (4) The taxonomic status of lemmings from Novaya Zemlya is unknown. (5) Differentiation of true lemmings in North America is poorly investigated in comparison with the Palearctic. The taxonomic status of *L. nigripes* and some island taxa remain debateable. A full-scale taxonomic revision of Nearctic true lemmings requires new data on geographical variability of craniometrical characteristics and fur coloration, as well as analyses of mtDNA variability.

Table 1. Taxonomy of genus *Lemmus*.

<table>
<tr><th colspan="2">Fredga et al. (1999)</th><th colspan="2">Abramson (1999b)</th><th>diagnostic characteristics</th></tr>
<tr><td>Species</td><td>Subspecies</td><td>Species</td><td>Subspecies</td><td>after Fredga et al. (1999) with additions</td></tr>
<tr><td>L. lemmus L., 1758
Norwegian Lemming
North of Norway, Finland, Kola Peninsula</td><td>Not described</td><td>L. lemmus L., 1758
Norwegian Lemming
North of Norway, Finland, Kola Peninsula</td><td>Not described</td><td>Brightly coloured black and yellow. Characterized by a black patch on the head and anterior part of the back</td></tr>
<tr><td>L. sibiricus
Kerr, 1792
Siberian Lemming
Continental tundra from the eastern coast of the White Sea up to the Lena River delta</td><td>Not described</td><td rowspan="6">L. sibiricus
Kerr, 1792
Siberian Lemming
From the eastern coast of the White Sea to the western bank of the Kolyma River, including islands of the Arctic basin</td><td>L. s. sibiricus
Continental tundra from the eastern coast of the White Sea up to the mouth of the Lena River</td><td>Rusty-brown back with longitudinal black stripe, ventral surface yellow or whitish, borderline between the dorsal and ventral parts quite distinct. Of average size. Black patch on rump is not well defined and, as a rule, is found only in old animals</td></tr>
<tr><td rowspan="5">L. bungei
Vinogr., 1925
Black-rumped Lemming
From the eastern coast of the Lena River up to the western bank of the Kolyma River, including islands of the Arctic basin and Kamchatka Peninsula</td><td>L. b. bungei
Vinogr., 1925
From the Lena River up to the western bank of the Kolyma River</td><td>L. s. bungei
Vinogr., 1925
From eastern coast of the Lena River up to western bank of the Kolyma River</td><td>Characterized by a black patch on the rump and by a contrasting rufous-coloured area around vibrissae and ears. The borderline between rusty-brown dorsal and light-grey ventral sides is distinct. Of average size</td></tr>
<tr><td>L. b. novosibiricus
Vinogr., 1925
New Siberian Islands</td><td>L. s. novosibiricus
Vinogr., 1925
New Siberian Islands</td><td>Significantly larger than mainland forms. Distinguishable by dark grey coloration of ventral side.</td></tr>
<tr><td>L. b. portenkoi
Chernyavsky, 1980
Wrangel Island</td><td>L. s. portenkoi
Chernyavsky, 1980
Wrangel Island</td><td>Similar to L. s. novosibiricus in size and coloration, but with more pronounced ash-grey tints.</td></tr>
<tr><td>L .b. flavescens
Brandt, 1845
Kamchatka Peninsula</td><td></td><td>Small sized, dorsal stripe not well defined, flanks yellow. Black patch on rump is small and less prominent than in other subspecies, back dark-brown</td></tr>
<tr><td>L. b. ognevi*
Vinogr., 1933
Verkhoyanski Range</td><td></td><td>Single specimen is close to Amur and Kamchatka lemmings in size, colour intermediate between nominal bungei and flavescens</td></tr>
<tr><td rowspan="2">L. amurensis
Vinogr., 1925
Amur Lemming
South of Yakutia, Amur Region.</td><td rowspan="2">Not described</td><td rowspan="2">L. amurensis
Vinogr., 1925
Amur Lemming
South of Yakutia, Amur Region, Kamchatka Peninsula</td><td></td><td>The smallest lemming, dark, deep rusty-brown dorsal side with rufous flanks. Dorsal black stripe is distinct from head to tail.</td></tr>
<tr><td>L. a. flavescens
Brandt, 1845
Kamchatka peninsula</td><td>Small sized, dorsal stripe is less well-defined than in typical L. amurensis, flanks yellow.</td></tr>
<tr><td>L. trimucronatus
Richardson, 1825
Brown Lemming
North America and Chukotsky peninsula</td><td>Not described</td><td>L. trimucronatus
Richardson, 1825
Brown Lemming
To the east of the Kolyma River, Chukotka, North America</td><td>Not described</td><td>Compared with other forms, the coloration is more monochromatic, with prevailing rufous-brown tints on dorsal side. No dorsal stripe. Differs from all other forms by yellow-ochre ventral side.</td></tr>
<tr><td colspan="5">* – L. b. ognevi Vinogr., 1933 is known by a single subadult specimen, captured at the south of Verkhoyanski Range and initially described as subspecies of L. amurensis. In my view, the taxonomic position of this form can be clarified only after obtaining additional material from that region.</td></tr>
</table>

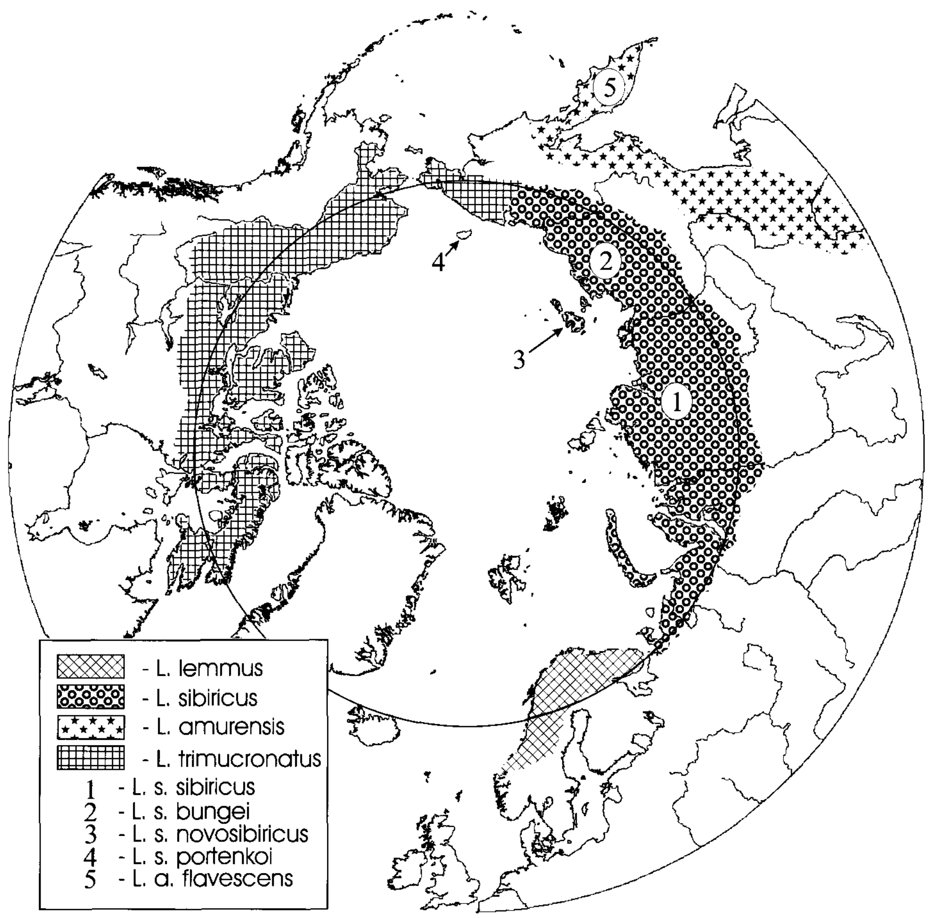

Figure 1. Range of genus *Lemmus*.

Taxonomy of *Dicrostonyx* genus: brief history and current state of the issue

Research of the taxonomy of collared lemmings followed the same logic as that for true lemmings in respect to there being three stages distinguishable, on the basis of the methods applied. An important difference is found in the contrasting lack of similarity between the two genera, both in the speed of evolution of the chewing surface of the molars and in the karyotype. While in true lemmings the pattern of the molar chewing surface is astonishingly stable both in space and time, in collared lemmings this character evolved at the highest rate among the Arvicolinae. True lemmings have a stable karyotype throughout their circumpolar range, the only difference between Eurasian and North American populations is the number of chromosome arms ($2n$ = 50, NF = 50 and 52, respectively). In contrast, collared lemmings are unusually polymorphic in respect to their chromosomes (Gileva 1983). This leads to a wider variation in the number of species distinguished within the genus, from 1 to 11. External characteristics and fur coloration are subject to pronounced seasonal and age changes in collared lemmings. Seasonal dimorphism of collared lemmings is well known as they acquire white fur colour in winter and enlarged and split third and fourth claws on the hind legs, which is reflected in the Russian species name, literally translated as "hoofed" lemming. The English name, collared lemming, originated from the presence in summer of a distinct collar. However, there is less variability in fur colouration geographically than seasonally, and collared lemmings from different areas of the circumpolar range are so close phenotypically that generally only one holarctic species has been distinguished within the genus, *D. torquatus* Pallas, 1778 (Ognev 1948, Corbet 1978), or one species for the Palearctic (*D. torquatus)* and another for the Nearctic (*D. groenlandicus* Traill, 1823) (Hall 1981). *D. hudsonius* Pallas, 1778, described from the Ungava Peninsula (north-east Canada) is often considered as a separate species, and it differs from other recent forms in having a primitive molar pattern, which is similar to that of the extinct *D. simplicior* from the mid Pleistocene.

Cytogenetic and hybridisation experiments indicate that *D. torquatus* is a holarctic superspecies, while the rank of the most cytologically-studied subspecies in the Nearctic was subsequently raised to species level (Corbet & Hill 1991, Musser & Carleton 1993). Cytogenetic and hybridisation studies of Palearctic collared lemmings gave unexpected results. Collared lemmings from Wrangel Island turned out to be karyologically very different from lemmings of continental populations, and attempts at hybridization always led to resorbtion of embryos (Chernyavski & Kozlovski 1980). This research allowed the distinction of lemmings from Wrangel Island as a separate species, Vinogradov's Lemming *D. vinogradovi* Ognev, 1948.

Table 2. Principal current views on the composition of the genus *Dicrostonyx*.

Musser & Carleton (1993)	Jarell & Fredga (1993)	Fedorov (1998)
D. hudsonius Pallas, 1778 **Ungava Lemming** Labrador and north Quebec, Canada	*D. hudsonius* Pallas, 1778 **Ungava Lemming** Labrador and north Quebec, Canada	*D. hudsonius* Pallas, 1778 **Ungava Lemming** Labrador and north Quebec, Canada
D. groenlandicus Traill, 1823 **Greenland Lemming** North Greenland, St. Elizabeth Island, north-east Canada. Range borders undefined	*D. groenlandicus* Traill, 1823 **Greenland Lemming** North America, Bering Sea islands, Wrangel Island	*D. groenlandicus* Traill, 1823 **Greenland Lemming** Bering Sea islands, Wrangel Island, North Greenland, St. Elizabeth Island, north-east Canada
D. torquatus Pallas, 1778 **Collared Lemming** Arctic Eurasian tundra from eastern coast of the White Sea to Chukotsky Peninsula, Kamchatka, incl. Novaya Zemlya, Severnaya Zemlya and Newsiberian Island	*D. torquatus* Pallas, 1778 **Collared Lemming** Mainland tundra of Siberia	*D. torquatus* Pallas, 1778 **Collared Lemming** Mainland tundra of Siberia
D. richardsoni Merriam, 1900 Western coast of the Hudson Bay, Mackenzie River area, Canada		*D. richardsoni* Merriam, 1900 Western coast of the Hudson Bay, Mackenzie River area, Canada
D. exsul Allen, 1919 St. Lawrence Island		
D. kilangmiutak Anderson & Rand, 1945 Victoria and Banks Islands, adjacent mainland tundra of Canadian coast		
D. nelsoni Merriam, 1900 Western Alaska		
D. nunatakensis Youngman, 1967 Yukon, Canada		
D. rubricatus Richardson, 1889 Northern Alaska		
D. unalascensis Merriam, 1900 Aleutian Islands		
D. vinogradovi Ognev, 1948 **Vinogradov's Lemming** Wrangel Island		

It is noteworthy, that unlike the situation with true lemmings on the island, karyotype structure of *D. vinogradovi* is similar to that of collared lemmings from Alaska, and their hybridization, as believed by Jarrell & Fredga (1993), is likely to result in fertile hybrids. The latter authors consider *D. vinogradovi* along with other Nearctic forms as a subspecies of *D. groenlandicus* based on karyological data.

Additional cytogenetic studies of collared lemmings from new localities within the Palearctic range of the genus and analysis of mtDNA variability carried out in recent years showed the existence of four chromosomal races and five phylogeographic groups (Fredga et al. 1999). However, these findings did not stimulate alterations to the generic taxonomy. Similar studies of mtDNA of collared lemmings from the Nearctic support the distinction of three species: *D. groenlandicus, D. hudsonius* and *D. richardsoni* (Fedorov 1998), while mtDNA variability in *D. groenlandicus* indicated the presence of two phylogeographic groups with an approximate separation along the Mackenzie River (Ehrich et al. 2000). Current views of different researchers on the composition of the genus *Dicrostonyx* are provided in Table 2, with ranges shown in Fig. 2.

To conclude the review I would like to stress that unsolved issues are more numerous in the taxonomy of the *Dicrostonyx* genus compared with *Lemmus*. Karyotypes of collared lemmings from Kamchatka, Severnaya Zemlya, Newsiberian Islands and Novaya Zemlya are not known. At the current time variability of craniological characteristics have not been analysed for samples from the major part of the Palearctic generic range. Data on the number of subspecies are very controversial. An adequate taxonomic revision requires analysis of relationships between morphological variability, chromosomal races and phylogeographic groups, and whenever possible to collate these with well-traced paleonthological history of the genus. This is the intended aim of further research.

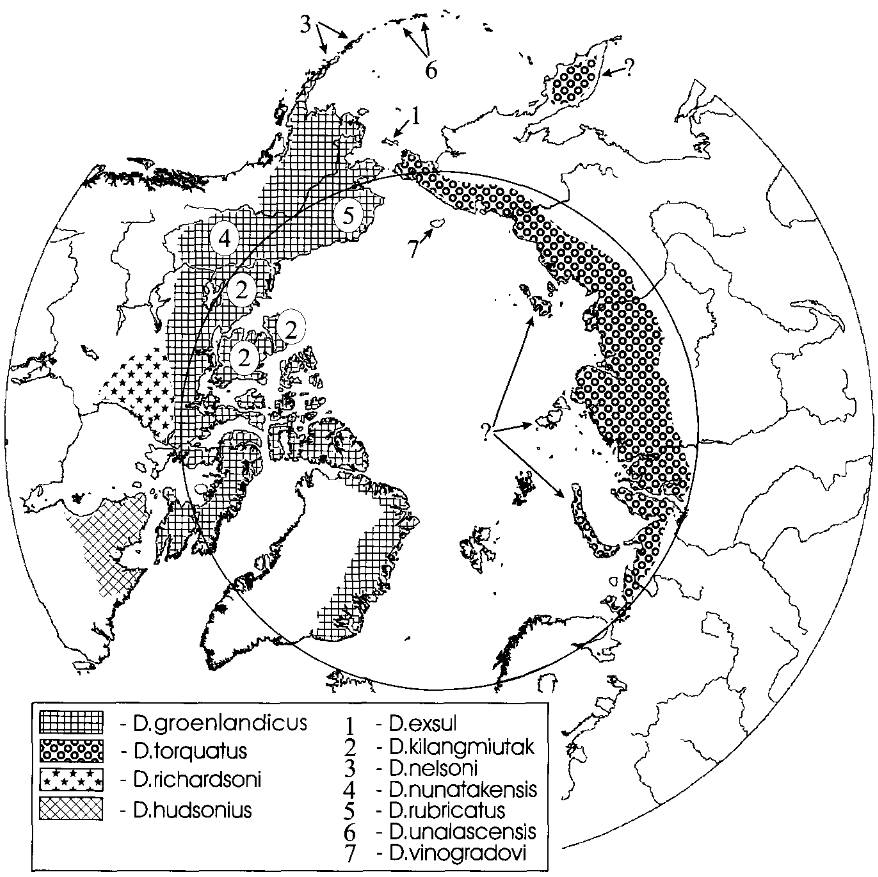

Figure 2. Range of genus *Dicrostonyx*. Numbers denote species following Musser and Carleton (1993), as in table 2 in the text. Question marks indicate areas from which collared lemmings were not studied karyologically, and hence have unclear taxonomic status.

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INDICATIONS OF YEAR 2000 ARCTIC BREEDING SUCCESS BASED ON THE PERCENTAGE OF FIRST YEAR BIRDS IN AUSTRALIA IN THE 2000/01 AUSTRAL SUMMER.

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The Victorian Wader Study Group and the Australasian Wader Studies Group have been attempting over the last 20 years to monitor the annual breeding success of migratory waders by measuring, in each austral summer, the proportion of juvenile/first year birds in the wader populations in south-east Australia (SEA) and north-west Australia (NWA) respectively. The results for the last year (i.e., estimated 1999 breeding success) were published in Issue Number 2 of the Arctic Birds Newsletter in April 2000.

The attached tables (Tables 1 & 2) show the results for the Arctic breeding year 2000 as measured during the 2000/01 austral summer. The figures for the previous year are also shown for comparison. Note that the number of catches which make up each species' total are also included, giving some indication of the spread of the sampling.

Overall the proportion of first year birds in wader populations in both SEA and NWA was lower in the 2000/01 austral summer than in the 1999/2000 summer. Specifically, for species where comparisons between the two years can be made, six out of eight species in SEA appeared to fare worse and five out of six species in NWA.

Based on the broad criteria given in the previous report Sanderling, Bar-tailed Godwit (Alaskan breeding population), Great Knot (but note small sample size), Curlew Sandpiper and Ruddy Turnstone which visit SEA had a poor (0-10% juveniles) breeding season in 2000. Red-necked Stint and Sharp-tailed Sandpiper appear to have had rather better, but still only moderate, breeding success with only Red Knot performing well (52% first year birds, i.e. exceptionally well). Although the Red Knot figure was based on just a single catch it was made at a principal site for this species without "twinkling" (which can cause the more experienced adults to leave the area) and significant numbers of other medium/large size waders were also present, all of which had low proportions of first year birds.

In NW Australia catches the percentage of first year birds was generally a little higher than in SE Australia.

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A WORD FROM THE COMPILERS

The third issue of the newsletter of the International Arctic Birds Breeding Conditions Survey (ABBCS) focuses on describing and analysing breeding conditions for birds in the Arctic during last summer 2000. Since publication of the last issue of the newsletter our main efforts as coordinators have been to raise the profile of the survey among members of the Arctic research community and improve access to accumulated data. The Survey website was re-designed and updated in January 2001, incorporating the following main changes:

◊ The site has a new, global address on the web, to facilitate access: http://www.arcticbirds.ru. However, support of the mirror site at the former address (http://www.soil.msu.ru/~soloviev/arctic) continues.

◊ The amount of information that can be accessed via clickable maps was expanded substantially, including most of the data from part 1 of the questionnaire and some data from part 2. In line with increasing weight of the data source, individual reports on breeding conditions are now supplemented by recommendations for citation.

◊ The download section was expanded by two issues of annual newsletters available for download in pdf format, and electronic publication of the current issue is planned soon after the printing of paper copies.

The project website is expected to become the main tool for quick dissemination of information from the database, and we will be grateful for pointers to any problems associated with access to the site or downloading data.

After three years of the project's full-scale operation, the following statistics can be presented on changes of geographic coverage between years, in terms of numbers of localities by region:

Region	1998	1999	2000
Alaska	1	6	6
Canada	0	8	5
Greenland	2	3	3
Russia	37	28	38

The coverage of Greenland and Alaska was constant for two last year and disappointingly low, in particular for Alaska, considering the high intensity of ornithological research carried out there.

Although information was received from fewer locations in Canada in 2000 compared with 1999, the quality and explanatory power of available data improved. In 1999 all the data for the Canadian north came from a report of the Tundra Northwest 1999 expedition, with sparse data, mainly restricted to rodent abundance. For the 2000 season, we received reports (including detailed information) from ornithologists, with the emphasis on birds, which better fits the Survey scope. Information from all but one of the Canadian sites in 2000 became available as a result of cooperation with Northwest Territories/Nunavut bird checklist survey (http://www.mb.ec.gc.ca/nature/migratorybirds/nwtbcs/index.en.html), and due to the personal efforts of its coordinator, Vicky Johnston from the Canadian Wildlife Service. We hope that this cooperation will develop further.

Geographic coverage of the Russian Arctic in 2000 improved compared with the previous year, partly as a result of the surveys by the International Arctic Expedition of Russian Academy of Sciences on the Chukotsky Peninsula, from where no reports were available in 1999. The above statistics indicate that there is still a lot to be done to really bring the survey to a circumpolar scale, which is necessary to address some of the "hot" issues in current Arctic science.

One such issue, hot not only in the figurative meaning, is a threat of global warming and climate change, which has been attracting increasing interest among ornithologists during recent years. An annual conference