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INVASION NOTE

Introduction of invertebrates into the High Arctic via imported soils: the case of Barentsburg in the Svalbard

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Abstract Forty six species of invertebrate were collected from the manure enriched imported soils below the abandoned cow sheds in the Russian mining town of Barentsburg, Svalbard. Of these, 11 (24 %) were new records for Svalbard, including Collembola, gamasid mites, Enchytraeidae and the first identified Lumbricidae. Many of the new records are species not frequently observed in the Arctic. It is hypothesized that these species arrived with the chernozem soils imported to Barentsburg for the greenhouses from central or southern European Russia, or with livestock. The observations presented here are the first records of human invertebrate introductions establishing in Svalbard outside of dwellings. It is not believed that the majority of new species records described present an immediate threat to the ecology of Svalbard but they may, especially *Deuteraphorura variabilis,* establish in the nutrient enriched floral communities beneath bird cliffs characteristic of Svalbard.

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Introduction

Few examples of human mediated introduction are documented from high northern latitudes. Nonetheless, in a period of rapid environmental change, and with expanding interest and activity in the Arctic, there is an increasing risk of the occurrence of such introductions. A recently observed example of human introduction of invertebrate species into the High Arctic via imported soils or livestock comes from the mining settlement of Barentsburg in Svalbard. The principal islands of the Svalbard archipelago lie in the European High Arctic between 74 and 81°N and 10–35°E, approximately 700 km north of mainland Norway. The inventory of the terrestrial and freshwater fauna of Svalbard records over 500 species of insects and soil invertebrates (Coulson 2007) of which very few are thought to have been introduced via human activity. Those that have been introduced are in general opportunistic species inhabiting human dwellings (Coulson and Refseth 2004; Coulson 2007). Approximately 60 species of alien vascular plants have been recorded in the settlements and 28–37 are believed to have been firmly established (Elven and Elvebakk 1996; Liška and Soldán 2004; Alsos et al. 2012) but, with the exceptions of the ecto and intestinal parasites of the introduced sibling vole (*Microtus levis*) restricted to the derelict mining town of Grumant, Isfjord (Krumpàl et al. 1991), there are no confirmed examples of human introductions of invertebrate species to the natural environment in Svalbard. There are generally comparatively few reports of introduced Collembola and soil mites to any region. In particular, there are no reports of introduced soil invertebrates into High Arctic regions. Here we report on the human introduction of terrestrial Annelida, Gamasida and Collembola to the Russian settlement of Barentsburg on the arctic island of Spitsbergen in Svalbard, most likely via imported soils for the greenhouse.

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Results and discussion

Soil samples were collected from the bottom and sides of a gully formed in the organic soils accumulated down a westerly facing slope under the abandoned cowsheds (78°04.3N, 014°12.09E) in Barentsburg in Grønfjord, Svalbard (Fig. 1). The soils formed layers several metres thick created from a mixture of discarded greenhouse soil and manure from the abandoned cow sheds. From these soils a total of 46 species of invertebrate were identified. Of these, 11 (24 %) were new species records to Svalbard (Table 1). Specimens of the Annelida are lodged at the Department of Biology and Environmental Sciences, University of Gothenburg, Sweden (Oligochaeta) and in the personal collection of R. M. Schmelz (Department of Animal Biology, University of A Coruña, Spain) (Enchytraeidae). The identified mites are deposited at the Department of Forest Protection, University of Life Sciences, Poznan, Poland and UNIS, Department for Arctic Biology, UNIS, Longyearbyen, Svalbard, Norway. Collembola are deposited at UNIS.

Four species of Annelida not previously recorded from Svalbard were collected; two enchytraeids, *Cognettia glandulosa* (Michaelsen, 1888) and *Enchytraeus dichaetus* Schmelz and Collado, 2010 and two lumbricids, *Dendrodrilus rubidus* (Savigny, 1826) sensu Sims and Gerard (1985) and *Dendrobaena hortensis* (Michaelsen, 1890) (Table 1). More than 30 species of enchytraeids have been recorded from all types of soil habitat in Svalbard (Dózsa-Farkas 1999) but the two species collected here are likely to have been recently introduced. *Enchytraeus dichaetus* was originally described from Mediterranean soils.

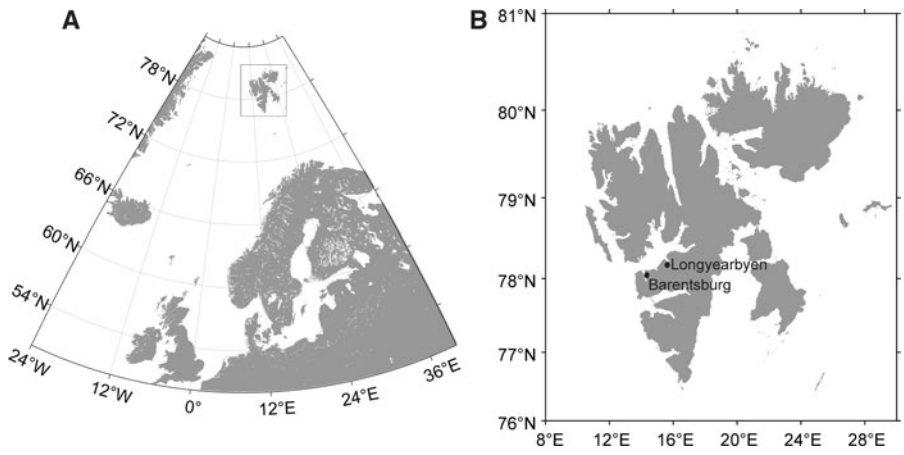

Fig. 1 The location of Svalbard (**a**) and the two settlements of Barentsburg and Longyearbyen (**b**)

Table 1 Invertebrate species previously unrecorded in Svalbard collected from the anthropogenic soils at the abandoned cowsheds in Barentsburg

Class	Order	Family	Species	Distribution
Oligochaeta	Haplotaxida	Enchytraeidae	*Cognettia glandulosa* (Michaelsen, 1888)	Holarctic
			Enchytraeus dichaetus Schmelz & Collado 2010 (=*E. minutus* ssp. *bisetosus* Rota & Healy, 1994)	Holarctic
		Lumbricidae	*Dendrodrilus rubidus* (Savigny, 1826)	Holarctic (common throughout the Norwegian mainland). Records from the southern hemisphere
			Dendrobaena hortensis (Michaelsen, 1890)	Holarctic but rarely observed in Scandinavia. Records from the southern hemisphere
Arachnida	Parasitiformes	Parasitidae	*Paragamasus (Aclerogamasus) insertus* (Micherdziński, 1969)	Palaearctic
			Vulgarogamasus remberti (Oudemans, 1912)	Palaearctic
Collembola	Poduromorpha	Hypogastruridae	*Hypogastrura purpurescens* (Lubbock, 1868)	Cosmopolitan
			H. assimilis Krausbauer, 1898	Cosmopolitan
		Onychiuridae	*Deuteraphorura variablis* (Stach 1954)	Palaearctic
	Entomobryomorpha	Isotomidae	*Folsomia fimetaria* (Linnaeus, 1758)	Holarctic
			Desoria grisea (Lubbock, 1869)	Holarctic

The species has been found frequently in samples from agricultural soils and organically enriched sites in the temperate Northern hemisphere. The semiaquatic *C. glandulosa* is a common element in non-acid moist to wet soils, the northern Norwegian mainland included. With generally low local dispersal rates and long lifecycles of at least 1 year in the high north (Birkemoe et al. 2000), it is unlikely that the introduced enchytraeids, *E. dichaetus* and *C. glandulosa,* will spread far from Barentsburg in the foreseeable future. Climatic conditions in Svalbard may have prevented previous invasions of *C. glandulosa*, a species common in the Holarctic, to the natural environment in Svalbard. *Enchytraeus dichaetus* is associated with agricultural soils and organically enriched sites. Therefore, the new enchytraeid species are not considered to pose an immediate threat to the resident flora and fauna of Svalbard.

Both species of Lumbricidae are widespread, including records from the southern hemisphere. *Dendrodrilus rubidus* can be considered as resident in large parts of the Holarctic and could, in some areas, be a natural component of the sub-Arctic and Arctic terrestrial fauna. It may establish but is not likely to become invasive. *Dendrobaena hortensis* has only been occasionally found in Scandinavia but is known to be a widely distributed ubiquitous anthropochorous opportunist but which has not become a fierce invader anywhere. *Dendrodrilus rubidus* commonly occurs in wet moss and thin layers of litter and decomposing plant material at high-altitudes in Norway but this species cannot survive exposure below −13.5 °C (Holmstrup 1994). Considering the harsh winter conditions in Svalbard, it will probably be restricted to areas with local organic enrichment and with sufficient accumulation of winter snow to provide protection against low air temperatures, for example under bird cliffs.

Two species of gamasid mite previously unrecorded in Svalbard were collected, *Paragamasus (Aclerogamasus) insertus* (Micherdziński, 1969) and *Vulgarogamasus remberti* (Oudemans, 1912). *Paragamasus (Aclerogamasus) insertus* is a rare species known only from the Stolowe Mountains in Poland. Micherdziński (1969) found only one specimen (female) from which the species was described. Kamczyc and Gwiazdowicz (2009) recorded the species from the soil and leaf litter from the same region but no further observations are known. The second species of gamasid mite, *V. remberti,* is recorded from Europe, Iceland and Russia (western Siberia). It is not considered likely that the two new gamasid mite species will disperse far from the Barentsburg region or have significant impacts on the native ecosystem.

Five new species of Collembola were also found; *Hypogastrura purpurescens* (Lubbock, 168), *H. assimilis* Krausbauer, 1898, *Deuteraphorura variabilis* (Stach, 1954), *Folsomia fimetaria* (Linnaeus, 1758), and *Desoria grisea* (Lubbock, 1869). All, are typical members of a fauna associated with soils having a high organic content such as compost, garden soil and wrack beds along seashores and stream banks. *Hypogastrura purpurescens, H. assimilis, Desoria grisea* are commonly found associated with human activity in northern Europe while *Folsomia fimetaria* and *Deuteraphorura variabilis* are observed along coast lines or in ornigenic soils in northern Europe and Iceland but have not been previously been recorded at such high latitudes. Since in northern Europe, *H. purpurescens, H. assimilis, Desoria grisea* are rarely found outside organic soils associated with human activity, it is not considered likely that they will become established in the arctic habitats of Svalbard. The remaining two, *Folsomia fimetaria* and *Deuteraphorura variabilis,* may establish. In Iceland, *Folsomia fimetaria* is often found in organic soils along seashores. It may become resident in such habitats in Svalbard and also in ornigenic soils beneath bird cliffs. *Deuteraphorura variabilis* is a common species in enriched ornigenic soils along the coasts of the White Sea (Pomorski and Skarzynski 2001). It is very abundant in the Barentsburg cowshed soils and probably represents a threat to the rich Collembola assemblages in similar nutrient enriched habitats in Svalbard, for example under bird cliffs which are considered characteristic of the Svalbard environment (Jonsdottir 2005).

The scarcity of records of human introduced invertebrates into other High Arctic regions suggests that such importation may not yet be a significant problem in contrast to many other regions. The lack of obviously recently introduced invertebrate species may be due to the relatively great connectivity with mainland populations enabling natural dispersal and colonisation processes to dominate. But increasing human access to the Arctic may result in new introductions from distant source populations. Ware et al. (2011) found a great number of alien seeds on the shoes of travelers passing through Svalbard airport, an average of 3.9 seeds per traveler. 26 % of these seeds germinated under simulated Svalbard conditions indicating at least the possibility of potential establishment. Similar studies for the invertebrate fauna have yet to be undertaken.

The lack of knowledge concerning the current fauna of the archipelago is a significant problem when evaluating new records of invertebrate species to Svalbard (Ávila-Jiménez et al. 2011). Nonetheless, our observation of a significant number of previously unrecorded species of invertebrate to Svalbard occurring in anthropogenic nutrient rich soils in the town of Barentsburg strongly suggests that these have been recently introduced.

It has proved difficult to determine the origin of the soils imported to Barentsburg but it is a chernozem type from the central or southern European regions of Russia. It is unusual that soil for use in a greenhouse is transported such long distances but soils used as dry

ballast are known to, or speculated to, have introduced soil invertebrates into other regions, for example North America (Majka and Klimaszewski 2008), Iceland (Rundgren 2007) or the sub-Antarctic islands (Majka et al. 2008).

Here we have focused on introduction of invertebrates via import with the soils. But, these rich anthropogenic soils may also act as a favorable habitat enabling the establishment of invertebrates introduced by other means, for example via fodder or on the hooves of the animals, activities in the town or by migrating birds nesting in, and around, the settlement. Few of the introduced species discussed here are likely to represent serious threats to the natural ecology of Svalbard. The unusually rich anthropogenic soils in Barentsburg, combined with the ameliorated winter conditions under the snow accumulated in the gully, may be the main factors enabling this unusual soil community to persist. However, there is at least the potential for such species to colonise the nutrient enriched and floristically diverse communities beneath bird cliffs are considered characteristic of the High Arctic environment (Jonsdottir 2005). Finally, introduction to Barentsburg may have provided the advance guard of these invertebrate species with a beachhead from which to colonise Svalbard should environmental conditions alter in their favour.

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