RESEARCH/REVIEW ARTICLE

The alien terrestrial invertebrate fauna of the High Arctic archipelago of Svalbard: potential implications for the native flora and fauna

Stephen J. Coulson

Department of Arctic Biology, University Centre in Svalbard, P.O. Box 156, NO-9171 Longyearbyen, Norway

Keywords
Introduced; microarthropod; enchytraeid; Acari; biodiversity.

Correspondence
Stephen J. Coulson, Department of Arctic Biology, University Centre in Svalbard, P.O. Box 156, NO-9171 Longyearbyen, Norway.
E-mail: steve.coulson@unis.no

Abstract

Experience from the Antarctic indicates that the establishment of alien species may have significant negative effects on native flora and fauna in polar regions and is considered to be amongst the greatest threats to biodiversity. But, there have been few similar studies from the Arctic. Although the terrestrial invertebrate inventory of the Svalbard Archipelago is amongst the most complete for any region of the Arctic, no consideration has yet been made of alien terrestrial invertebrate species, their invasiveness tendencies, threat to the native biology or their route of entry. Such baseline information is critical for appropriate management strategies. Fifteen alien invertebrate species have established in the Svalbard environment, many of which have been introduced via imported soils. Biosecurity legislation now prohibits such activities. None of the recorded established aliens yet show invasive tendencies but some may have locally negative effects. Ten species are considered to be vagrants and a further seven are classified as observations. Vagrants and the observations are not believed to be able to establish in the current tundra environment. The high connectivity of Svalbard has facilitated natural dispersal processes and may explain why few alien species are recorded compared to isolated islands in the maritime Antarctic. The vagrant species observed are conspicuous Lepidoptera, implying that less evident vagrant species are also arriving regularly. Projected climate change may enable vagrant species to establish, with results that are difficult to foresee.

To access the supplementary material for this article, please see supplementary files under Article Tools online.

The Arctic ecosystem is often described as undisturbed, or even pristine. However, this region is currently subject to extremely rapid environmental change and is experiencing faster changes, and of greater magnitude, than many other global regions (AMAP 2012; IPCC 2014). Environmental change is resulting in dramatic widespread alterations in species distribution. Human activities are also introducing alien species to polar regions (Frenot et al. 2005; Chown et al. 2012; Coulson et al. 2013a). The establishment of such alien species often has complicated effects on the resident ecology (Ricciardi et al. 2013), including species loss and disruption of key ecological processes (Richardson & Ricciardi 2013). Because invasive species are considered among the main threats to biodiversity in Antarctic terrestrial ecosystems (Hughes & Convey 2010; Hughes et al. 2010; Kennicutt et al. 2015) it is important to develop a fuller understanding of the current alien fauna of the Arctic.

The archipelago of Svalbard lies in the European High Arctic and is centred around 78°N, 15°E (Fig. 1). Attempts have been made to document the introduced flora and fauna of the archipelago (Gjertz & Lønø 1998; Liška & Soldán 2004; Belkina et al. 2013; Governor of Svalbard 2014). However, there has been no consideration of the

Citation: *Polar Research* 2015, *34*, 27364, http://dx.doi.org/10.3402/polar.v34.27364

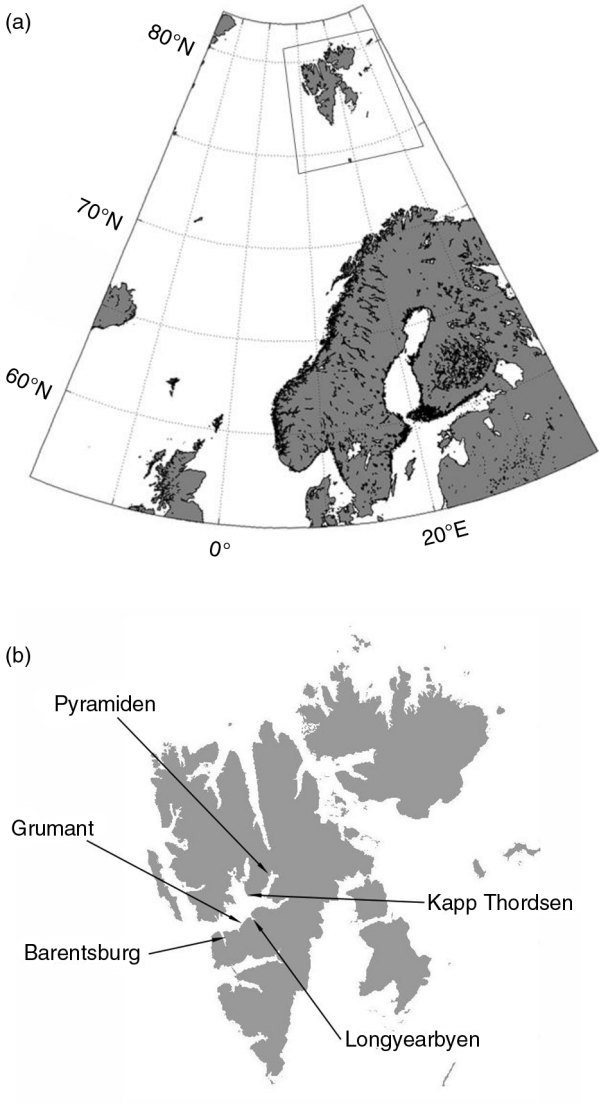

Fig. 1 (a) The Svalbard Archipelago (box) and (b) locations in Svalbard referred to in the text.

alien species element of the invertebrate community, even though the invertebrate fauna of Svalbard is considered to be amongst the best known for any region in the Arctic (Hodkinson 2013) and the invertebrate fauna comprises a fundamental component of the tundra ecosystem. The unique governance status of Svalbard and its limited commercial history has resulted in one of the least disturbed regions in the Arctic. This status has been further supported by the Norwegian government with recent legislation—the Svalbard Environmental Protection Act of 2002—created to manage and conserve this environment, including provision for climate change science.

Natural dispersal to Svalbard is an ongoing process and results in new species establishing in the terrestrial environment (Coulson et al. 2002; Alsos et al. 2007; Ware et al. 2012; Coulson et al. 2014; Governor of Svalbard 2014). The current inventory of the terrestrial and freshwater fauna of Svalbard includes close to 600 microarthropod species names (Coulson 2007a), although some care must be taken with exact numbers because of the large number of potential synonyms, misidentifications and other taxonomic confusion (Coulson et al. 2014). All are considered to have colonized the archipelago since the retreat of the ice after the last glacial maximum approximately 11 000 years ago (Coulson et al. 2014). It is difficult to assess the rate at which invertebrate species arrive and colonize the archipelago since direct observation is impossible. Estimates of the rate of establishment of plant species, and the subsequent arrival of further individuals, have been made using sequencing techniques (Alsos et al. 2007; Eidesen et al. 2013), but this approach remains to be applied to the invertebrate fauna.

The environment of Svalbard is now under strict management and the Svalbard Environmental Protection Act forbids deliberate introduction of new species. However, in the past several vertebrate species were introduced as attempts to conserve species (muskox [*Ovibos moschatus*]), improve sport hunting and fishing (e.g., Arctic hare [*Lepus arcticus*] and trout [*Salmo trutta*]; Gjertz & Lønø 1998), or greening of the tundra initiatives via the deliberate introduction of plants (Belkina et al. 2013). Accidental introduction of alien species has also occurred, for example, the sibling vole (*Microtus levis*; Fredga et al. 1990), which now forms an established population centred on the abandoned mining town of Grumant (Fig. 1). Moreover, 78 species of alien plant are now recorded in Svalbard (Governor of Svalbard 2014), the majority believed to be accidental introductions.

The alien terrestrial invertebrate species of Svalbard have been assessed from reports in scientific and grey literature and are summarized here with comments on introduction routes, invasive risk and potential ecological consequences. Three categories of alien species have been defined: (i) established in natural environment; (ii) vagrant species occasionally seen naturally dispersing to Svalbard; and (iii) observations, those species with sporadic recordings associated with human activities, that is, synanthropic. Invasive potential is assessed based on food requirements, life history strategies and physiology to survive on the natural Arctic tundra.

Results and discussion

Only 15 alien invertebrate species are known to have established in the Svalbard environment (Table 1, Supplementary Table S1), while 10 species are considered as

Citation: *Polar Research* 2015, *34*, 27364, http://dx.doi.org/10.3402/polar.v34.27364

Table 1 Alien terrestrial invertebrates in Svalbard. Refer to Supplementary Table S1 for additional information concerning introduction route, distribution and invasive potential.

Species	Status in Svalbard[a]	References
Cestoda		
Echinococcus multilocularis Leuckart, 1863	Established	Henttonen et al. 2001
Oligochaeta		
Cognettia glandulosa (Michaelsen, 1888)	Established	Coulson et al. 2013a, b
Enchytraeus dichaetus Schmelz & Collado 2010	Established	Coulson et al. 2013a, b
Dendrodrilus rubidus (Savigny, 1826)	Established	Coulson et al. 2013a, b
Dendrobaena hortensis (Michaelsen, 1890)	Established	Coulson et al. 2013a, b
Acari		
Laelaps hilaris C.L. Koch 1836	Established	Krumpál et al. 1991
Paragamasus (*Aclerogamasus*) *insertus* (Micherdziński, 1969)	Established	Coulson et al. 2013a, b
Vulgarogamasus remberti (Oudemans, 1912)	Established	Coulson et al. 2013a, b
Dendrolaelaps foveolatus (Leitner, 1949)	Established	Coulson et al. 2015
Araneae		
Thanatus formicinus (Clerck 1757)	Observation	Aakra & Hauge 2003
Collembola		
Hypogastrura assimilis Krausbauer, 1898	Established	Coulson et al. 2013a, b; Coulson et al. 2015
H. purpurascens (Lubbock, 1868)	Established	Coulson et al. 2013a, b
Deuteraphorura variabilis (Stach 1954)	Established	Coulson et al. 2013a, b
Folsomia fimetaria (L. 1758)	Established	Coulson et al. 2013a, b
Desoria grisea (Lubbock, 1869)	Established	Coulson et al. 2013a, b
D. tigrina (Nicolet, 1842)	Established	Coulson et al. 2015
Insecta		
Cimex lectularius L. 1758	Observation	Coulson pers. obs.
Forficula sp.	Observation	Anonymous 2004
Periplaneta sp.	Observation	Anonymous 2006a
Coccinella septempunctata L. 1758	Observation	Anonymous 2006b
Reesa vespulae (Milliron 1939)	Observation	Coulson pers. obs.
Oryzaephilus mercator (Fauvel, 1889)	Observation	Coulson 2007b
Calliphora vicina Robineau-Desvoidy 1830	Observation	Summerhayes & Elton 1928
Plutella xylostella (L. 1758)	Vagrant	e.g., Coulson et al. 2002 and references therein; Coulson et al. 2014
Syngrapha interrogationis (L. 1758)	Vagrant	Sendstad et al. 1976; Laarsonen 1985
Nymphalis antiopa (L. 1758)	Vagrant	Sømme 1993
Vanessa cardui (L. 1758)	Vagrant	Lokki et al. 1978; Laarsonen 1985; Sømme 1993
Hofmannophila pseudospretella (Stainton 1849)	Vagrant	Kaisila 1973; Laarsonen 1985
Pieris sp.	Observation	Anonymous 2007
Pieris napi (L. 1758)	Vagrant	Kaisila 1973; Laarsonen 1985
Ephestia kuehniella Zeller 1879	Observation	Anonymous 2006c
Pempeliella dilutella (Denis and Schiffermüller 1775)	Vagrant	Kaisila 1973; Laarsonen 1985

[a]Established denotes in natural environment; vagrant denotes occasional natural dispersal to Svalbard; observation denotes sporadic recordings associated with human activities.

vagrants and a further seven classified as observations. No invertebrates have been deliberately introduced into the environment yet several species are believed to have been introduced with hosts or soils (Henttonen et al. 2001; Coulson et al. 2013a). Recently permission has been granted by the Governor of Svalbard after a risk assessment to import the earthworm *Eisenia fetida* (Savigny 1826) as part of a composting project but with strict conditions to avoid accidental release into the natural environment. The majority of the introduced alien invertebrate species have been accidentally introduced along with imported soils for either the greenhouse in Barentsburg or as a part of the greening project in Pyramiden (Coulson et al. 2013a; Coulson et al. 2015) (Fig. 1), including the only earthworms recorded in Svalbard (Coulson et al. 2013a). Two species of invertebrates—*Laelaps hilaris* and *Echinococcus multilocularis*—appear to have been introduced with their mammalian host. The host, the sibling vole (*M. levis*), is thought to have arrived in Svalbard along with foodstuffs for the horses working in the coal mines in Grumant (Fredga et al. 1990) or the farm animals in Barentsburg (Governor of Svalbard 2014). *Echinococcus multilocularis* has the potential to infect humans resulting in alveolar echinococcosis (Atanasov et al. 2013)

and suitable sanitary precautions should therefore be exercised when visiting locations where the vole is known to occur.

Few of these alien invertebrate species are considered to be invasive and none have been recorded far from beyond the probable point of entry. However, there is the potential for two Collembola, *Folsomia fimetaria* (L. 1758) and *Deuteraphorura variabilis* (Stach 1954), to spread beyond their current locations and they may represent a threat to the rich Collembola assemblages in similar nutrient enriched habitats beneath bird cliffs (Supplementary Table S1; Zmudczyńska et al. 2012) and which are considered characteristic of the Svalbard environment (Jónsdóttir 2005). In Iceland, *F. fimetaria* is often found in organic soils along seashores (Fjellberg 2007) and *D. variabilis* is common in enriched organic soils along the coasts of the White Sea (Pomorski & Skarżyński 2001).

Many of the observations here relate to individual recordings of invertebrates associated with imported fresh produce in the supermarket of the main settlement, Longyearbyen (Fig. 1), for example, *Coccinella septempunctata* L. 1758 (Insecta, Coleoptera). Other species may be observed infrequently in Longyearbyen or Barentsburg and represent synanthropic species such as *Ephestia kuehniella*. None of these appear to be able to establish in the natural environment and probably present little threat to the native biology. Few vagrants have been recorded. This is likely because of the difficulty with observing occasional and sporadic invertebrate visitors to the archipelago, especially in the absence of systematic monitoring programmes. However, seven species of vagrant Lepidoptera have been observed, with, for example, *Plutella xylostella* typically arriving with southerly winds (Supplementary Table S1; Coulson et al. 2002). This implies that considerable numbers of smaller and less obvious invertebrate species are likely to be arriving irregularly and, while the current environment hinders establishment of these species, projected environmental change may permit colonization of Svalbard by vagrant species.

The mosquito *Ochlerotatus nigripes* (Zetterstedt, 1838) (*Aedes nigripes*) is often cited as an imported species arriving in drinking water barrels with the phosphate miners working at Kapp Thordsen (Fig. 1) in 1918 (Hoel 1967). This theory of introduction is likely to be incorrect for two reasons. Firstly, this species was recorded in Isfjorden by both Boheman (1865) and Holmgren (1869) many years prior to the arrival of the phosphate miners and, secondly, this mosquito has a broad distribution throughout the Arctic region, including Greenland and the Norwegian mainland, suggesting an ability to disperse naturally to Svalbard. This mosquito therefore does not appear in the inventory presented here.

There is an awareness that alien species in, or arriving to, Svalbard have the potential to be highly disruptive to the native flora and fauna. The Office of the Governor of Svalbard is taking active measures to eradicate four human introduced alien species in the archipelago because of their potential to cause negative environmental impacts: two rodents (*M. levis* and *Mus musculus*), the plant *Anthriscus sylvestris* (Apiaceae) and one invertebrate, the cestode *E. multilocularis*. Measures to control the intermediate host, the sibling vole (*M. levis*), will reduce the occurrence of the parasite but as yet there is no defined plan of action.

Overall, the current alien invertebrate fauna of Svalbard consists of relatively few species and none have yet displayed invasive tendencies. This is in contrast with the maritime Antarctic, where alien species, such as the carabid beetle (*Merizodus soledadinus* [Guerin-Meneville, 1830]), may have dramatic effects on the native flora and fauna (Convey et al. 2011; Greenslade & Convey 2012; Hidalgo et al. 2013). The relatively scarcity of alien species in Svalbard could possibly be a result of the greater connectivity in the Arctic, where extensive regions of continent and numerous islands facilitate natural dispersal. However, with projected climate change there is a likelihood that additional alien species will be able to establish, both those naturally dispersing to the archipelago and those imported accidently by humans. Current biosecurity measures prevent the deliberate import of alien invertebrates to Svalbard, but there remains the threat of species introductions by anthropochory.

Acknowledgements

The idea for the article resulted from a workshop on alien species in Svalbard held at the Norwegian Polar Institute, Tromsø. Two anonymous reviewers made valuable contributions to the manuscript.

References

Aakra K. & Hauge E. 2003. Checklist of Norwegian spiders (Arachnida: Araneae), including Svalbard and Jan Mayen. *Norwegian Journal of Entomology 50*, 109–129.

Alsos I.G., Eidesen P.B., Ehrich D., Skrede I., Westergaard K., Jacobsen G.H., Landvik J.Y., Taberlet P. & Brochmann C. 2007. Frequent long-distance plant colonization in the changing Arctic. *Science 316*, 1601–1608.

AMAP 2012. *Arctic climate issues 2011: changes in Arctic snow, water, ice and permafrost*. Oslo: Arctic Monitoring and Assessment Programme.

Citation: *Polar Research* 2015, *34*, 27364, http://dx.doi.org/10.3402/polar.v34.27364

Anonymous 2004. Ubuden gjest til middag. (Uninvited dinner guest.) *Svalbardposten*, 18 May, p. 28.

Anonymous 2006a. Ny inspeksjon av messa. (New inspection of the canteen.) *Svalbardposten*, 10 Mar., p. 7.

Anonymous 2006b. Marihønebesøk. (Ladybird visit.) *Svalbardposten*, 9 Mar., p. 5.

Anonymous 2006c. Møll i bakeriet. (Moths in the bakery.) *Svalbardposten*, 24 Jun., p. 5.

Anonymous 2007. Sommerbesøk. (Summer visit.) *Svalbardposten*, 5 Feb., p. 9.

Atanasov G., Benckert C., Thelen A., Tappe D., Frosch M., Teichmann D., Barth T.F.E., Wittekind C., Schubert S. & Jonas S. 2013. Alveolar echinococcosis-spreading disease challenging clinicians: a case report and literature review. *World Journal of Gastroenterology 19*, 4257–4261.

Belkina O., Borovichev E., Davydov D., Konoreva L., Koroleva N., Likhachev A., Petrova O. & Savchenko A. 2013. *The study of flora and vegetation of Pyramiden settlement and its vicinity*. Apatity: N.A. Avrorin Polar–Alpine Botanical Garden Institute, Russian Academy of Sciences.

Boheman C.H. 1865. Spetsbergens Insekt-Fauna. (Spitsbergen's insect fauna). *Öfversigt af Kongliga Vetenskaps-Akademiens Förhandlingar 22*, 563–577.

Chown S.L., Huiskes A.H.L., Gremmen N.J.M., Lee J.E., Terauds A., Crosbie K., Frenot Y., Hughes K.A., Imura S., Kiefer K., Lebouvier M., Raymond B., Tsujimoto M., Ware C., Van de Vijver B. & Bergstrom D.M. 2012. Continent-wide risk assessment for the establishment of non-indigenous species in Antarctica. *Proceedings of the National Academy of Science of the United States of America 109*, 4938–4943.

Convey P., Key R.S., Key R.J.D., Belchier M. & Waller C.L. 2011. Recent range expansions in non-native predatory beetles on sub-Antarctic South Georgia. *Polar Biology 34*, 597–602.

Coulson S.J. 2007a. The terrestrial and freshwater invertebrate fauna of the High Arctic archipelago of Svalbard. *Zootaxa 1448*, 41–58.

Coulson S.J. 2007b. On the occurrence of *Oryzaephilus mercator* in Svalbard, Norway. *Norwegian Journal of Entomology 54*, 21–22.

Coulson S.J., Convey P., Aakra K., Aarvik L., Ávila-Jiménez M.L., Babenko A., Biersma E., Boström S., Brittain J., Carlsson A.M., Christoffersen K.S., De Smet W.H., Ekrem T., Fjellberg A., Füreder L., Gustafsson D., Gwiazdowicz D.J., Hansen L.O., Holmstrup M., Kaczmarek L., Kolicka M., Kuklin V., Lakka H-K., Lebedeva N., Makarova O., Maraldo K., Melekhina E., Ødegaard F., Pilskog H.E., Simon J.C., Sohlenius B., Solhøy T., Søli G., Stur E., Tanaevitch A., Taskaeva A., Velle G., Zawierucha K. & Zmudczyńska-Skarbek K. 2014. The terrestrial and freshwater invertebrate biodiversity of the archipelagoes of the Barents Sea; Svalbard, Franz Josef Land and Novaya Zemlya. *Soil Biology and Biochemistry 68*, 440–470.

Coulson S.J., Fjellberg A., Gwiazdowicz D.J., Lebedeva N.V., Melekhina E.N., Solhøy T., Erséus C., Maraldo K., Miko L., Schatz H., Schmelz R.M., Søli G. & Stur E. 2013a. Introduction of invertebrates into the High Arctic via imported soils: the case of Barentsburg in Svalbard. *Biological Invasions 15*, 1–5.

Coulson S.J., Fjellberg A., Gwiazdowicz D.J., Lebedeva N.V., Melekhina E.N., Solhøy T., Erséus C., Maraldo K., Miko L., Schatz H., Schmelz R.M., Søli G. & Stur E. 2013b. The invertebrate fauna of anthropogenic soils in the High Arctic settlement of Barentsburg, Svalbard. *Polar Research 32*, article no. 19273, doi: http://dx.doi.org/10.3402/polar.v32i0.19273

Coulson S.J., Fjellberg A., Melekhina E.N., Taskaeva A.A., Lebedeva N.V., Belkina O., Seniczak S., Seniczak A. & Gwiazdowicz D.J. 2015. Microarthropod communities of industrially disturbed or imported soils in the High Arctic; the abandoned coal mining town of Pyramiden, Svalbard. *Biodiversity and Conservation 24*, 1671–1690.

Coulson S.J., Hodkinson I.D., Webb N.R., Mikkola K., Harrison J.A. & Pedgley D. 2002. Aerial colonisation of High Arctic islands by invertebrates: the diamondback moth *Plutella xylostella* (Lepidoptera: Yponomeutidae) as a potential indicator species. *Diversity and Distributions 8*, 327–334.

Eidesen P.B., Ehrich D., Bakkestuen V., Alsos I.G., Gilg O., Taberlet P. & Brochmann C. 2013. Genetic roadmap of the Arctic: plant dispersal highways, traffic barriers and capitals of diversity. *New Phytologist 200*, 898–910.

Fjellberg A. 2007. *The Collembola of Fennoscandia and Denmark. Part II: Entomobryomorpha and Symphypleona*. *Fauna Entomologica Scandinavica 42*. Leiden: Brill.

Fredga K., Jaarola M., Ims R.A., Steen H. & Yoccuz N.G. 1990. The 'common vole' in Svalbard identified as *Microtus epiroticus* by chromosome analysis. *Polar Research 8*, 283–290.

Frenot Y., Chown S.L., Whinam J., Selkirk P.M., Convey P., Skotnicki M. & Bergstrom D.M. 2005. Biological invasions in the Antarctic: extent, impacts and implications. *Biological Reviews 80*, 45–72.

Gjertz I. & Lønø O. 1998. Innførte arter på Svalbard. (Introduced species in Svalbard.) *Fauna (Oslo) 51*, 58–67.

Governor of Svalbard. 2014. *Handlingsplan mot skadelige fremmede arter pa Svalbard. (Action plan for harmful alien species in Svalbard.)* Longyearbyen: Office of the Governor of Svalbard.

Greenslade P. & Convey P. 2012. Exotic Collembola on Subantarctic islands: pathways, origins and biology. *Biological Invasions 14*, 405–417.

Henttonen H., Fuglei E., Gower C.N., Haukisalmi V., Ims R.A., Niemimaa J. & Yoccoz N.G. 2001. *Echinococcus multilocularis* in Svalbard: introduction of an intermediate host has enabled the local life-cycle. *Parasitology 12*, 547–552.

Hidalgo K., Laparie M., Bical R., Larvor V., Bouchereau A., Siaussat D. & Renault D. 2013. Metabolic fingerprinting of the responses to salinity in the invasive ground beetle *Merizodus soledadinus* at the Kerguelen Islands. *Journal of Insect Physiology 59*, 91–100.

Hodkinson I.D. 2013. Terrestrial and freshwater invertebrates. In H. Meltofte (ed.): *Arctic Biodiversity assessment. Status and trends in Arctic biodiversity*. Pp. 194–223. Akureyri: Conservation of Arctic Flora and Fauna.

Hoel A. 1967. *Svalbards historie 1596–1965. (Svalbard's history 1596–1965.)* Oslo: Sverre Kildahl.

Holmgren A.E. 1869. Bidrag til kännodomen om Beeren Eilands och Spetsbergens insekt-fauna. (Contribution to our knowledge of the insect fauna of Bjørnøya and Spitsbergen.) *Kungliga Svenska Vetenskapsakademiens Handlingar 8*, 1–55.

Hughes K.A. & Convey P. 2010. The protection of Antarctic terrestrial ecosystems from inter- and intra-continental transfer of non-indigenous species by human activities: a review of current systems and practices. *Global Environmental Change 20*, 96–112.

Hughes K.A., Convey P., Maslen N.R. & Smith R.I.L. 2010. Accidental transfer of non-native soil organisms into Antarctica on construction vehicles. *Biological Invasions 12*, 875–891.

IPCC 2014. *Climate change 2014: synthesis report*. Geneva: Intergovernmental Panel on Climate Change.

Jónsdóttir I.S. 2005. Terrestrial ecosystems on Svalbard: heterogeneity, complexity and fragility from an Arctic island perspective. *Proceedings of the Royal Irish Academy 105*, 155–165.

Kaisila J. 1973. Notes on the arthropod fauna of Spitsbergen. III: 15. The Lepidoptera of Spitsbergen. *Annales Entomologici Fennici 39*, 60–63.

Kennicutt M.C., II, Chown S.L., Cassano J.J., Liggett D., Peck L.S., Massom R., Rintoul S.R., Storey J., Vaughan D.G., Wilson T.J., Allison I., Ayton J., Badhe R., Baeseman J., Barrett P.J., Bell R.E., Bertler N., Bo S., Brandt A., Bromwich D., Cary S.C., Clark M.S., Convey P., Costa E.S., Cowan D., Deconto R., Dunbar R., Elfring C., Escutia C., Francis J., Fricker H.A., Fukuchi M., Gilbert N., Gutt J., Havermans C., Hik D., Hosie G., Jones C., Kim Y.D., Le Maho Y., Lee S.H., Leppe M., Leitchenkov G., Li X., Lipenkov V., Lochte K., López-Martínez J., Lüdecke C., Lyons W., Marenssi S., Miller H., Morozova P., Naish T., Nayak S., Ravindra R., Retamales J., Ricci C.A., Rogan-Finnemore M., Ropert-Coudert Y., Samah A.A., Sanson L., Scambos T., Schloss I.R., Shiraishi K., Siegert M.J., Simões J.C., Storey B., Sparrow M.D., Wall D.H., Walsh J.C., Wilson G., Winther J.G., Xavier J.C., Yang H. & Sutherland W.J. 2015. A roadmap for Antarctic and Southern Ocean science for the next two decades and beyond. *Antarctic Science 27*, 3–18.

Krumpàl M., Cyprich D., Zejda J. & Ambros M. 1991. The occurrence of field vole (*Microtus arvalis* Pallas 1778) and its acarofauna on Spitsbergen (Svalbard). *Biológia 46*, 881–885.

Laarsonen E. 1985. Butterflies from Spitsbergen. *Baptria 10*, 69–72.

Liška J. & Soldán Z. 2004. Alien vascular plants recorded from the Barentsburg and Pyramiden settlements, Svalbard. *Preslia 76*, 279–290.

Lokki J., Malmstrom K.K. & Suomalainen E. 1978. Migration of *Vanessa cardui* new record and *Plutella xylostella* (Lepidoptera) to Spitsbergen in the summer 1978. *Notulae Entomologicae 58*, 121–123.

Pomorski R.J. & Skarżyński D. 2001. Springtails (Collembola) collected in Chupa Inlet region (N. Karelia, Russia). *Prace Zoologiczne 29*, 46–57.

Ricciardi A., Hoopes M.F., Marchetti M.P. & Lockwood J.L. 2013. Progress toward understanding the ecological impacts of nonnative species. *Ecological Monographs 83*, 263–282.

Richardson D.M. & Ricciardi A. 2013. Misleading criticisms of invasion science: a field guide. *Diversity and Distributions 19*, 1461–1467.

Sendstad E., Bergvik T. & Hegstad A. 1976. *Plusia interrogationis* new-record (Lepidoptera, Noctuidae) found at Svalbard, Norway. *Norwegian Journal of Entomology 23*, 91–92.

Sømme L. 1993. The terrestrial arthropod fauna of Svalbard. *Arctic Insect News 4*, 2–4.

Summerhayes V.S. & Elton C.S. 1928. Further contributions to the ecology of Spitsbergen. *Journal of Ecology 16*, 193–268.

Ware C., Bergstrom D.M., Müller E. & Alsos I.G. 2012. Humans introduce viable seeds to the Arctic on footwear. *Biological Invasions 14*, 567–577.

Zmudczyńska K., Olejniczak I., Zwolicki A., Iliszko L., Convey P. & Stempniewicz L. 2012. The influence of allochthonous nutrients delivered by colonial seabirds on soil collembolan communities on Spitsbergen. *Polar Biology 35*, 1233–1245.

Citation: *Polar Research* 2015, *34*, 27364, http://dx.doi.org/10.3402/polar.v34.27364