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Plutella polaris Zeller, 1880 (Lepidoptera, Plutellidae) rediscovered at Svalbard, Norway, with comments on its taxonomic position

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Abstract. After 142 years, *Plutella polaris* Zeller, 1880 was rediscovered at Svalbard, Norway, in 2015. The locality and its vegetation are described. The specimen is the first female ever recorded, and its genitalia are illustrated. The taxonomic position of *P. polaris* relative to other *Plutella* Schrank, 1802 species in the Northern hemisphere is discussed.

Introduction

In 1873, seven specimens of an unknown microlepidopteran species were collected by the entomologist Reverend A.E. Eaton at Wide Bay, Svalbard, Norway, between 21st July and 24th July. The specimens were subsequently handed over to Henry Tibbats Stainton, who at the time was Britain's leading authority on Microlepidoptera. Stainton sent two of the males to his German colleague Philipp Christoph Zeller for his opinion. In a letter to Stainton dated May 29th 1874, Zeller described the species and named it *Plutella polaris*. Stainton (1880) later quoted Zeller's original description and made it clear that the description was Zeller's despite the fact that Stainton himself was the author of the paper (Stainton 1880) and so Zeller's authorship retains the later date.

Since the species was first discovered in 1873, no further records had been reported until 9 July 2015, when a female was collected by Geir Søli at Ringhorndalen, Wijdefjorden, Svalbard. The Ringhorndalen specimen (Fig. 1) agrees well externally with illustrations of a type specimen of *P. polaris* that was given by Bengtsson and Johansson (2011), and certainly not with *P. xylostella* (Linnaeus, 1758), a vagrant species observed on Svalbard every three or four years (Peter Coulson, pers. comm.). Geir Søli's new specimen is preserved in the collection of the Natural History Museum, University of Oslo (NHMO).

In the present paper, we provide supplements to the description of the species and its habitat at Svalbard, along with an updated account of its taxonomic status.

The locality

Ringhorndalen is part of the Indre Wijdefjorden National Park and one of several valleys on the eastern side of the Wijdefjorden. Wijdefjorden is the longest fjord on Svalbard, being 108 km long and cutting deep into Spitsbergen from the north (Fig. 2). The vegetation around the inner part

Figure 1. *Plutella polaris* Zeller, 1880. The single female recorded from Wijdefjorden, Svalbard in July 2015 (Photo: Karsten Sund, NHMO).

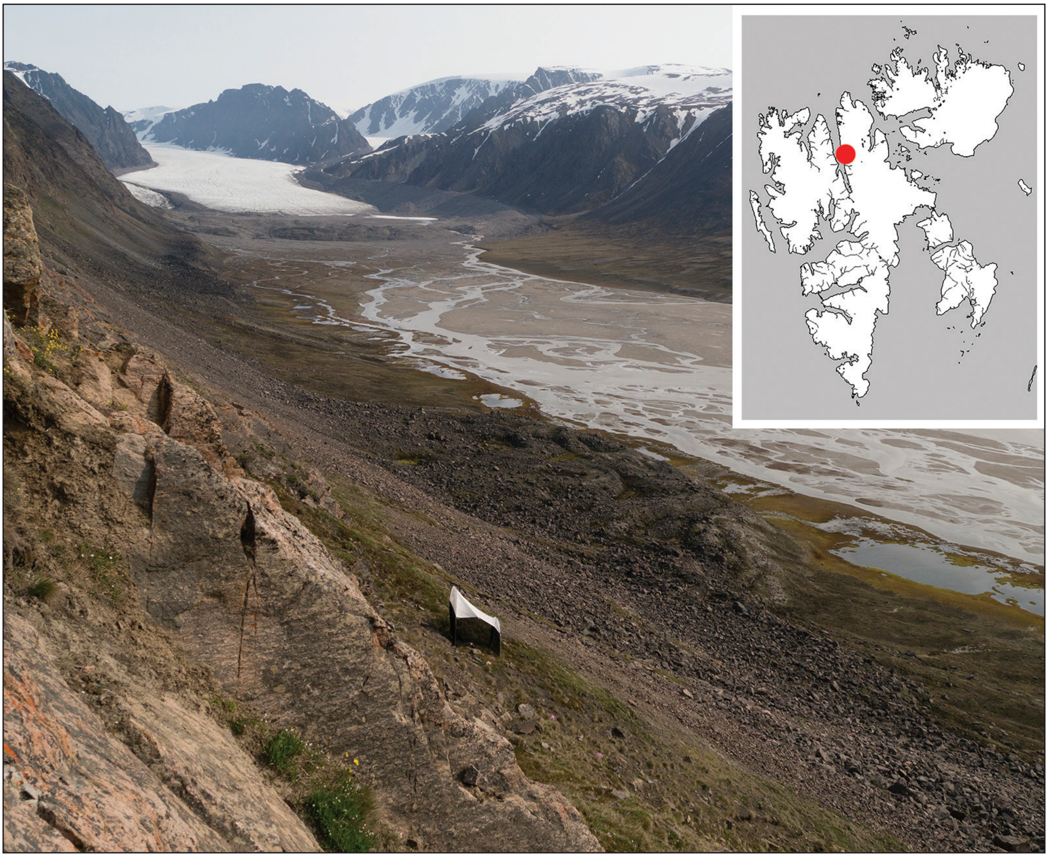

Figure 2. Ringhorndalen in Indre Wijdefjorden National Park where *Plutella polaris* was rediscovered in 2015. The inserted map shows Svalbard with the exact position of the locality (red circle). (Photo: G. Søli).

of the fjord has been characterized as high arctic steppe with several very rare plant species (e.g. Elvebakk and Nilsen 2016 and references therein). Very low precipitation and saline soils are the main reasons for the formation of this extremely rare and unique vegetation type found nowhere else in Europe. The inner, less exposed parts of the Ringhorndalen valley are less arid and locally the summer temperatures can be quite high.

As Wijdefjorden is not easily accessible during summer months, its flora has just recently been more thoroughly investigated (e.g. Elvebakk and Nilsen 2002). These studies have documented a unique vegetation with several rare and thermophilic plant species, some of them new to Svalbard (e.g. Elvebakk and Nilsen 2011, 2016; Eidesen et al. 2013). Based on these findings, the rich flora of Ringhorndalen may hold species of relict character from a warm postglacial period.

The single specimen of *P. polaris* was found on a south facing slope in the inner part of the valley (79.3358°N 16.1289°E) (Fig. 2). These slopes have rich vegetation with several species of Brassicaceae that are possible food plants for the larvae, e.g. *Draba alpina* L., *Braya glabella* Richardson or *Coclearia groenlandica* L. (as suggested by Bengtsson and Johansson (2011)).

The Lepidoptera fauna of Svalbard is very poor, with three resident species only: *P. polaris*, *Apamea exulis* (Lefèbvre, 1836) and *Pyla fusca* (Haworth, 1811) (Coulson et al. 2014). Interestingly, all three species were collected at Ringhorndalen in July 2015, of which *P. fusca* was even very common at the site.

Plutella in the Northern hemisphere

Presently 26 species of *Plutella* Schrank, 1802 are recognised worldwide, of which a few must still be regarded as dubious (see Robinson and Sattler (2001) Baraniak (2007), Landry and Hebert (2013)). Eleven species have been recorded from the northern hemisphere north of 30°N (Table 1). Three of these species have a wide distribution, including the nearly cosmopolitan *P. xylostella*, the Holarctic *P. porrectella* (Linnaeus, 1758) and the circumpolar *P. hyperboreella* Strand, 1902 (Landry et al. 2013). The two species *P. armoraciae* Busck, 1912 and *P. notabilis* Busck, 1904 are restricted to north-western North America, while the remaining six species are Palaearctic, seemingly with a rather restricted distribution confined to montane (*P. geniatella* Zeller, 1839, *P. haasi* Staudinger, 1883*, P. huemerella* (Baraniak, 2007) and *P. kyrkella* (Baraniak, 2007)) or arctic regions (*P. polaris* and *P. mariae* Rebel, 1923) (see also Bengtsson and Johansson 2011). *P. polaris* is among the most enigmatic of these species, as it has been known by only the original syntypes.

Of the seven syntypes originally designated for *Plutella polaris*, only two males are still extant in the Natural History Museum, London. What has happened to the remaining five syntypes is not known. In addition to our rediscovery of *P. polaris* in Wijdefjorden, we were recently informed of another specimen identified as *P. polaris*. This specimen, a single male, was found during an expedition by Austrian and Russian lepidopterists to the Republic of Altai in Russia in 2016 at a considerably lower latitude of 49.5°N, 88.08°E (Huemer et al. 2017; BOLD), and is commented on below.

Compared to other species of *Plutella* that occur in northern Europe, the forewing pattern of *P. polaris* (Fig. 1) resembles that of *P. haasi* in having the brownish grey ground colour with a paler broad band along the posterior margin that is widened in the tornal area. The posterior margin is marked with a row of dark dots. The costal half of the forewing is paler than in the medial area. The two species *P. hyperboreella* and *P. mariae* differ externally from *P. polaris* by their strongly contrasted forewing pattern.

Table 1. Species of *Plutella* recorded in the Northern hemisphere north of 30°N.

Species	Distribution
Plutella armoraciae Busck, 1912	Nearctic: North-western North America
Plutella geniatella Zeller, 1839	Palaearctic: Central Europa
Plutella haasi Staudinger, 1883	Palaearctic: Norway, Sweden, Scotland
Plutella huemerella (Baraniak, 2007)	Palaearctic: France: Alpes-Maritimes
Plutella hyperboreella Strand, 1902	Holarctic: Norway, Sweden, Finland, Canada, Alaska
Plutella kyrkella (Baraniak, 2007)	Palaearctic: Russia: SW Altai
Plutella mariae Rebel, 1923	Palaearctic: Novaya Zemlya
Plutella notabilis Busck, 1904	Nearctic: North-western North America.
Plutella polaris Zeller, 1880	Palaearctic: Norway and Russia (Altai)
Plutella porrectella (Linnaeus, 1758)	Holarctic: North America and Eurasia
Plutella xylostella (Linnaeus, 1758)	Cosmopolitan

The female genitalia of *Plutella polaris*

Baraniak (2007) studied the two syntypes of *P. polaris* kept in the Natural History Museum, London, figured the wings and the male genitalia, and designated a lectotype. Bengtsson and Johansson (2011) also figured the male genitalia and presented a water colour painting of the moth.

As the female of *P. polaris* is found for the first time, a short description and illustration of the female genitalia (Fig. 3) are presented: apophyses anteriores longer than apophyses posteriores; tergite 8 forming sub-rectangular plate, about 2,5 times wider than long; sternite 8 formed by two slender sclerites that are narrowed laterally and fused with apophyses anteriores, at touching point with spines on posterior edges; ostium boat-shaped with curved "roof"; sternite 7 with concave posterior edge; ductus bursae narrow in posterior half, curved before middle, anterior portion wide, small sclerite present before widening; corpus bursae oval, without signa; bulla seminalis also oval, smaller than corpus bursae. The genitalia differ from those of *P. haasi* in having the ductus bursae divided in a narrow posterior part and a broad anterior one. They appear to be more similar to those of *P. hyperboreella*, but differ by the concave posterior edge of sternite 7.

Genetic analyses

In order to confirm the species identity of *P. polaris*, and derive more information about its taxonomic position relative to other *Plutella* species in the Northern hemisphere, we performed an analysis based on DNA barcoding. One leg was sampled from the Wijdefjorden specimen and sent for DNA extraction, amplification and sequencing at the Canadian Centre for DNA Barcoding in Guelph. The DNA barcoding fragment of the mitochondrial cytochrome c oxidase subunit 1 (CO1) was sequenced, using standard primers and bi-directional Sanger sequencing. The DNA sequence and original trace-files of the *P. polaris* specimen from Svalbard are publicly available in the dataset '*Plutella polaris* Svalbard, Norway' (DS-PPSN) (doi: dx.doi.org/ 10.5883/DS-PPSN) in the Barcode of Life Data System (BOLD) (Ratnasingham and Hebert 2007). Both the Wijdefjorden and Altai specimens of *P. polaris* belong to the same Barcode Index Number (BIN), BOLD:ADB0013, with 1.32% pairwise divergence between them (609 bp in common).

In addition to the CO1 sequence obtained from *P. polaris*, 41 CO1 sequences from nine other species of *Plutella* were obtained from BOLD (Ratnasingham and Hebert 2007): *P. hyperboreella*,

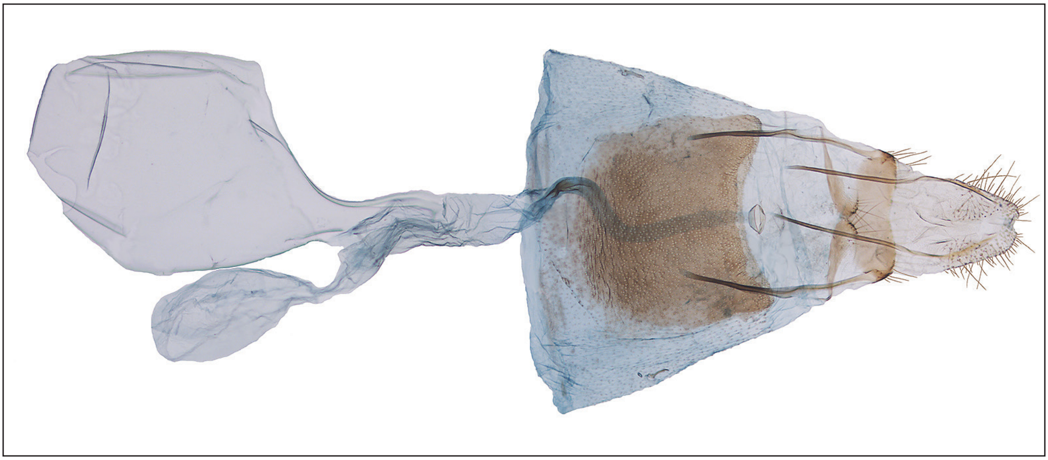

Figure 3. The female genitalia of *Plutella polaris*. (Photo: L. Aarvik).

P. haasi, *P. notabilis*, *P. huemerella*, *P. geniatella*, *P. porrectella*, *P. armoraciae*, *P. xylostella*, and *P. australiana* Landry & Hebert, 2013. We also got the opportunity to include the Altai-specimen of *P. polaris* mentioned above, as the CO1 sequence was kindly placed to our disposal by Peter Huemer. Based on the molecular phylogeny of Yponomeutoidea (Sohn et al. 2013), 15 CO1 sequences representing six species in the two genera *Eidophasia* Stephens, 1842 and *Rhigognostis* Zeller, 1857 were selected to root the gene tree. These species were *E. albidorsella* (Walsingham, 1881), *E. messingiella* (Fischer von Röslerstamm, 1840), *E. vanella* (Walsingham, 1900), *R. senilella* (Zetterstedt, 1839), *R. annulatella* (Curtis, 1832) and *R. schmaltzella* (Zetterstedt, 1839). The alignment was made in MEGA7 (Kumar et al. 2016), and checked manually.

The final dataset consisted of 52 nucleotide sequences, with 552 positions (Table 2). A phylogenetic analysis, using the Maximum likelihood method with the Kimura 2-parameter model (K2P) (Kimura 1980) was performed in MEGA7 (Kumar et al. 2016) with 1000 bootstrap replications. The Maximum likelihood tree was redesigned using Adobe Illustrator CS6.

As can be seen from the Maximum likelihood tree (Fig. 4), the two specimens of *P. polaris* appear in a common clade, separated by a K2P distance of 1.1 %. This clade has the North American *P. armoraciae* as its sister-group. In turn, these two species form a sister-group relationship to a much larger clade containing the six species, *P. porrectella*, *P. hyperboreella*, *P. notabilis*, *P. geniatella*, *P. huemerella* and *P. haasi*, all widely separated from the cosmopolitan *P. xylostella* and the Australian *P. australiana*.

Interestingly, the two specimens representing *P. haasi* appear widely separated in the tree, and undoubtedly represent two different species.

Discussion and conclusion

The present results clearly demonstrate that *P. polaris* is a valid species, well defined morphologically, and based on genetic distances, is clearly delimited from other species in the genus. The new record from the Altai mountains in Russia, also demonstrates that the species has a much wider distribution (albeit with strongly divergent haplotypes) than has been recognized up to present.

Table 2. List of specimens included in the DNA barcode analysis together comprising 52 nucleotide sequences. Abbreviations used for depositories: ANIC – Australian National Insect Collection; BIOUG – Centre for Biodiversity Genomics; CNC – Canadian National Collection of Insects, Arachnids, and Nematodes; NHMO – Natural History Museum, University of Oslo; NTNU-VM – Norwegian University of Science and Technology – University Museum; TLMF – Tiroler Landes-museum Ferdinandeum; USNM – Smithsonian Institution National Museum of Natural History; ZMUO – University of Oulu Zoological Museum.

Species	BOLD Process ID	Country	Depository
Plutella hyperboreella	LEFIA800-10	Finland	ZMUO
Plutella hyperboreella	LEFIA801-10	Finland	ZMUO
Plutella hyperboreella	LEFIC108-10	Finland	ZMUO
Plutella hyperboreella	MNAG269-08	Canada	CNC
Plutella hyperboreella	MNAG268-08	Canada	CNC
Plutella haasi	LEFID118-10	Russia, N Ural	ZMUO
Plutella haasi	LON5958-17	Norway	NHMO
Plutella notabilis	MNAJ558-09	Canada	CNC
Plutella huemerella	PHLAB606-10	Italy	TLMF
Plutella geniatella	PHLAA575-09	Italy	TLMF
Plutella geniatella	PHLAA094-09	Italy	TLMF
Plutella geniatella	PHLAB255-10	Italy	TLMF
Plutella geniatella	PHLAB256-10	Italy	TLMF
Plutella geniatella	PHLAI835-13	Italy	TLMF
Plutella porrectella	LEFIJ911-10	Finland	ZMUO
Plutella porrectella	RRGCO094-15	Canada	BIOUG
Plutella porrectella	LEFIJ910-10	Finland	ZMUO
Plutella porrectella	LEFIK544-10	Finland	ZMUO
Plutella porrectella	LON5956-17	Norway	NHMO
Plutella polaris	LEALT906-16	Russia, Altai	TLMF
Plutella polaris	LON2736-16	Norway, Svalbard	NHMO
Plutella armoraciae	NGNAQ667-14	Canada	BIOUG
Plutella armoraciae	NGAAF282-14	Canada	BIOUG
Plutella armoraciae	SMTPI9177-14	Canada	BIOUG
Plutella armoraciae	MNAJ560-09	Canada	CNC
Plutella armoraciae	MNAK560-10	Canada	CNC
Plutella xylostella	LEFIB587-10	Finland	ZMUO
Plutella xylostella	LEFIB955-10	Finland	ZMUO
Plutella xylostella	LEFIJ1709-13	Finland	ZMUO
Plutella xylostella	LON1214-14	Norway	NHMO
Plutella xylostella	LEFIE003-10	Finland	ZMUO
Plutella australiana	PHSAU1390-12	Australia	ANIC
Plutella australiana	MCCAA2949-12	Australia	BIOUG
Plutella australiana	PHSAU1611-12	Australia	USNM
Plutella australiana	PHSAU1612-12	Australia	USNM
Plutella australiana	PHSAU1614-12	Australia	USNM
Plutella australiana	PHSAU1615-12	Australia	USNM
Eidophasia messingiella	LEFIG367-10	Finland	ZMUO
Eidophasia messingiella	LEFIG368-10	Finland	ZMUO
Eidophasia messingiella	LEFIE702-10	Finland	ZMUO
Eidophasia vanella	LNAUT964-14	United States	USNM
Eidophasia albidorsella	LNAUT960-14	United States	USNM

Eidophasia albidorsella	LNAUT959-14	United States	USNM
Eidophasia albidorsella	LNAUT961-14	United States	USNM
Eidophasia albidorsella	LNAUT962-14	United States	USNM
Eidophasia albidorsella	LNAUT963-14	United States	USNM
Rhigognostis senilella	LON1272-14	Norway	NHMO
Rhigognostis senilella	ABOLA921-15	Austria	TLMF
Rhigognostis annulatella	LON220-08	Norway	NHMO
Rhigognostis annulatella	PHLAB866-10	Italy	TLMF
Rhigognostis schmaltzella	LEPVM047-12	Norway	NTNU-VM
Rhigognostis schmaltzella	LEPVM048-12	Norway	NTNU-VM

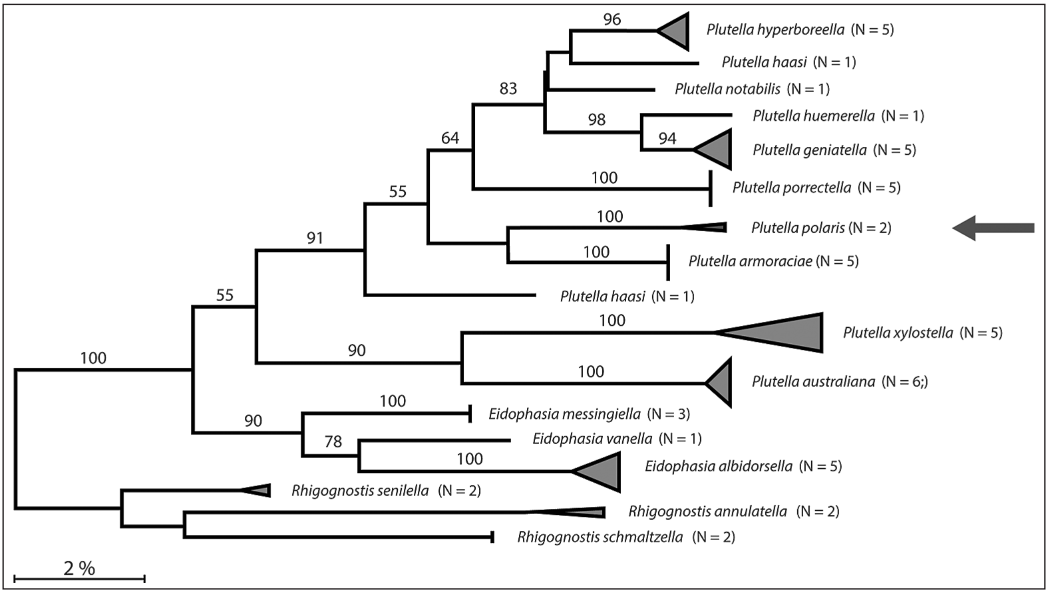

Figure 4. The Maximum Likelihood tree based on DNA barcoding of *P. polaris* (arrow) and 10 other nominal species in the genus *Plutella*. Six species representing the two genera *Eidophasia* and *Rhigognostis* were used as outgroup. Bootstrap support values (1000 replicates) are listed above the branches. Number of specimens is given in brackets after each species.

This solves the previous enigma of the existence of a prior endemic to Spitzbergen not collected for 142 years that existed close to the 80th parallel. More thorough collecting in northern Eurasia will most likely uncover new localities for the species. Another possibility is that *P. polaris* has a circumpolar distribution, as recently revealed for *P. hyperboreella* (Landry et al. 2013). According to Hodges et al. (1983) there are a few additional *Plutella* species in North America, but there is no modern taxonomic treatment of them. If future taxonomic work results in the synonymization of any of these species with *P. polaris*, the name *P. polaris* would still have priority.

The genetic analysis also revealed a conflicting interpretation of the species *P. haasi*. The specimen forming a sister-group to *P. hyperboreella* originates from the type locality (Norway: Dovre), while the specimen located further towards the root of the *Plutella* clade, was collected in North Ural, Russia, and undoubtedly represents a new species. Further studies are needed to elucidate the status of these species.

The exact locality for Eaton's first records of *P. polaris* in 1873 is not known, as the locality is simply referred to as "Wide Bay", an old, unofficial name for Wijdefjorden, used up to 1934. As previously mentioned, Ringhorndalen is just one of several valleys opening towards the fjord, and Eaton may well have disembarked elsewhere along the fjord. From our own observations in Flatøyrdalen, the first valley south of Ringhorndalen, it is likely that the neighbouring valleys also may offer favourable conditions for the species. Hopefully future expeditions in the region will reveal a more detailed knowledge about the present distribution of *P. polaris*.

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