Antarctic Science 33(6), 605–623 (2021) © Antarctic Science Ltd 2021 doi:10.1017/S0954102021000328

Eukarya biodiversity in the Thala Hills, East Antarctica

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Abstract: Knowledge of the biodiversity of the Thala Hills oasis (Enderby Land, East Antarctica) is very limited. Here, we integrate all information available since 1962, when the Russian 'Molodyozhnaya' station was established in the western part of the oasis. The published data on local eukaryote diversity (lichens, embryophytes, metazoans) include records of 90 species. Since 2008, Belarusian Antarctic Expedition researchers have worked in the eastern part of the oasis, accessible from the Belarusian station 'Vechernyaya Mount'. This research revealed 95 species, including 44 species not recorded in the earlier published literature. The level of available information is uneven across major taxa. Lichens are the better-known group, with 51 species recorded in total, including 13 species recently recorded for the first time in the oasis. New records were also obtained for rotifers. Thala Hills biodiversity is consistent with wider patterns of Antarctic biogeography, with a high proportion of regionally endemic species (especially metazoans), the occurrence of both endemic and bipolar species of lichens and generally low numbers of cosmopolitan species (largely limited to aquatic rotifers, with the caveat that up-to-date taxonomic studies are required). The lack of data on marine macrobenthos, soil nematodes and terrestrial rotifers emphasizes the need for studies focusing on these groups.

Received 1 April 2021, accepted 15 June 2021

Key words: Enderby Land, invertebrates, lichens, moss, parasites, zooplankton

Introduction

The Antarctic flora and fauna are well adapted to the continent's harsh conditions (Convey 1996, Rogers *et al.* 2012). However, today they face increasing threats from both direct human impacts and climate change (Convey 2010, Chown *et al.* 2012, Convey & Peck 2019). Limited to typically small and often extremely isolated areas of ice-free land (oases), the Antarctic terrestrial biota is typified by high levels of regional endemism, surviving through the multiple and extensive glacial cycles of the Miocene, Pliocene and Pleistocene (Convey & Stevens 2007, Convey *et al.* 2008, 2020, Fraser *et al.* 2012). Even today, many of the isolated ice-free oases across Antarctica have yet to receive even basic surveys of their terrestrial biodiversity (Convey 2010, Convey *et al.* 2014).

Thala Hills is a coastal oasis located in Enderby Land, East Antarctica. Although there is a history of research in the area, this has focused on geological, geocryological and pedological studies (Dolgikh *et al.* 2015), and very little is known of its terrestrial biology and diversity. Most published studies are in the Russian-language literature, describing work that was carried out between the 1960s and the 1990s, and they are not widely accessible. The area of study within the oasis was also restricted in this period, mostly in the immediate vicinity of the Russian 'Molodyozhnaya' ('Youth') station in the western part of the oasis.

Since 2008, members of the Belarus Antarctic Expedition (BAE) have conducted multidisciplinary studies in the eastern part of the Thala Hills oasis during each summer season in the vicinity of the Belarus station 'Vechernyaya Mount' ('Evening Mount'). One of the primary goals of these studies has been to assess terrestrial (including freshwater) biodiversity, along with aspects of marine coastal diversity, in this poorly studied region, and to provide a baseline against which to assess any future evidence of human impacts and the consequences of global and regional environmental change.

https://doi.org/10.1017/S0954102021000328 Published online by Cambridge University Press

Fig. 1. Characteristic landscapes of the eastern part of the Thala Hills oasis (photographs by Dzmitry A. Lukashanets).

In this study, we present the most thorough overview of the biodiversity of the Thala Hills oasis yet achieved. The information presented focuses on the Eukarya and is based on both the available literature and our recent surveys and collections. These data allow for an initial assessment of native terrestrial biodiversity of the Thala Hills oasis, and they are discussed in the wider context of Antarctic terrestrial biogeography.

Materials and methods

Study area

The Thala Hills oasis was first mapped in 1960 using aerial photography taken in 1956–1958 under the auspices of the Antarctic Names Committee of Australia. A more detailed map was completed in 1962 by Russian (Soviet Union) surveyors when Molodyozhnaya station was

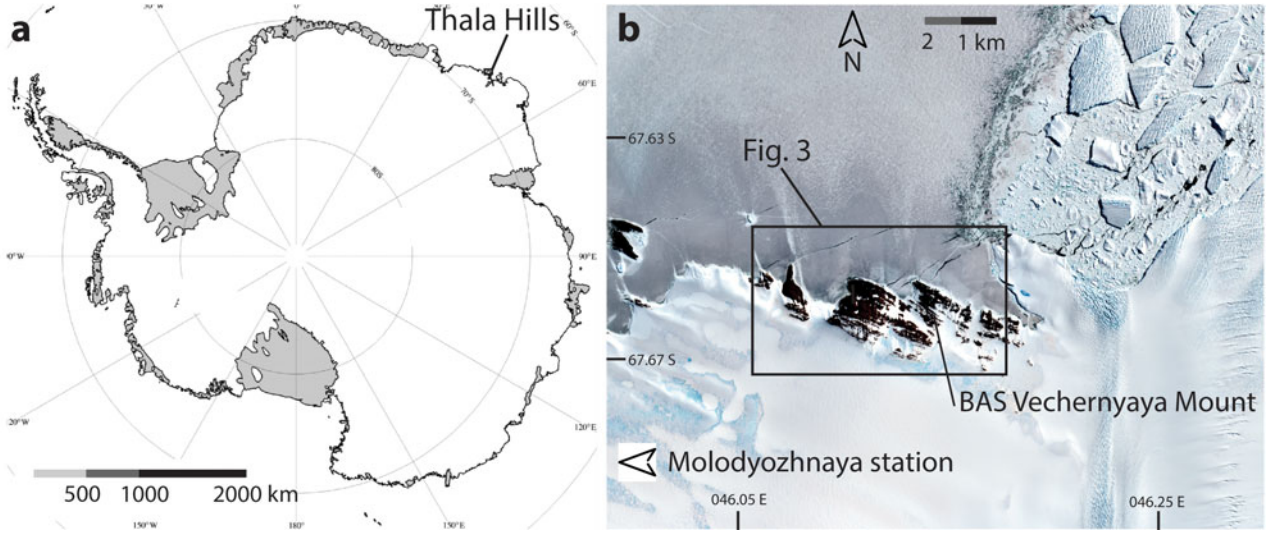

Fig. 2. Study area. **a.** The location of the Thala Hills oasis on the coast of East Antarctica. **b.** Satellite image of the eastern part of the Thala Hills oasis (Vechernyaya Mount). BAS = Belarus Antarctic Station.

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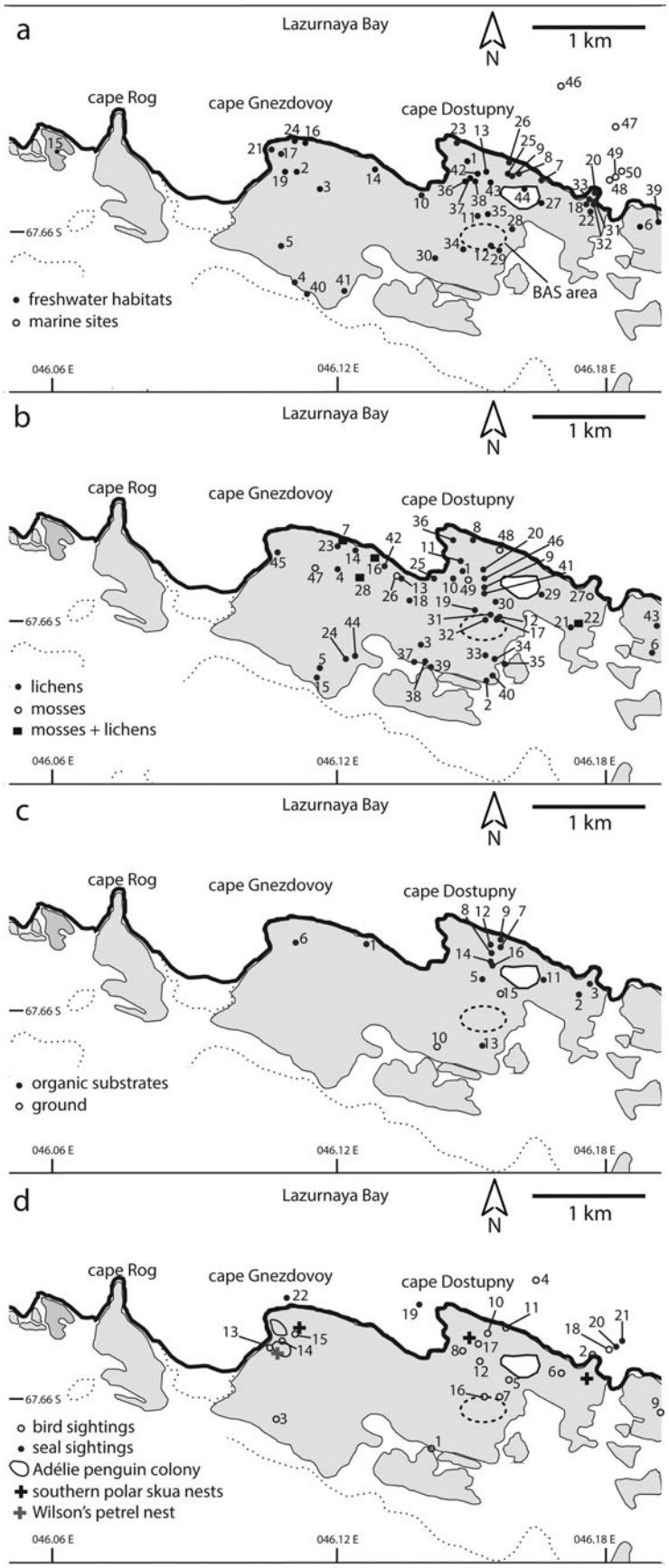

Fig. 3. Sampling and observing sites in the area of the Belarus Antarctic Station (BAS) 'Vechernyaya Mount' in the eastern part of the Thala Hills oasis. **a.** Aquatic habitats: freshwater and marine (for details, see Supplemental Table S1). **b.** Vegetation sampling sites (for details, see Supplemental Table S2). **c.** Terrestrial substrates sampled for micrometazoans (for details, see Supplemental Table S3). **d.** Birds and mammals (for details, see Supplemental Table S4).

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constructed. This low-lying coastal oasis is typical of such habitats in East Antarctica (Fig. 1). It is surrounded by glacial formations of different types. Although coastal, the nearshore area is normally covered with sea ice. The relief is rocky and undulating, reaching a maximum altitude of ~260 m above sea level (a.s.l.). Numerous riegels and depressions characterize the ground surface, indicating the influence of very strong geomorphological and periglacial processes. The main rock types are granitoids, primarily charnockites (including enderbites) (Simonov 1971).

The climate is harsh even in comparison with other East Antarctic oases (MacNamara 1969, Simonov 1971, Dolgikh *et al.* 2015). Blizzards are experienced on ~190 days each year (cf. 88 days at Schirmacher Oasis and 70 days at Bunger Hills). The average wind speed is ~10.2 m s^{-1}. Katabatic winds occur frequently, along with frequent cyclone intrusion. Maximum solar irradiance is high, with total irradiance of ~100.6 kcal cm^{-2}, ground-absorbed irradiance of 70.5 kcal cm^{-2} (four times greater than that of ice cover) and the irradiance balance being 30.5 kcal cm^{-2}. The average annual air temperature is -11.1°C, with the warmest monthly mean being -1.0°C in January and the coldest being -18.8°C in August. The instantaneous temperature of the ground surface ranges from -38°C in winter to +36°C in summer, with an annual average of -9.3°C. Annual precipitation is 484 mm water equivalent.

Water bodies are present in the inter-ridge depressions and several larger lakes are present in the western part of the oasis, including Lakes Glubokoe, Lagernoe and Ovalnoe. These have surface areas of 280, 53 and 40×10^3 m^2 and average depths of 11.6, 3.3 and 1.0 m, respectively (Simonov 1971).

Data collection

To collate all available information relating to Thala Hills biodiversity, the available literature was carefully examined. We referred to 21 sources that contain information on biodiversity records from the western and eastern parts of the Thala Hills oasis specifically, as well several atlases with information on species distribution (mainly for marine fauna) and multiple works addressing overall East Antarctic diversity.

The new studies reported here were conducted in the eastern part of the Thala Hills oasis (Enderby Land, East Antarctica) near the Belarusian station 'Vechernyaya Mountain', ~12 km from Molodyozhnaya station (Fig. 2). Studies took place during the II, III, V, VI, VIII, IX and XI BAE, in the summer periods between 2008–2009 and 2018–2019.

Marine biota were surveyed at Lazurnaya Bay in the Cosmonaut Sea. Marine macrobenthos were collected using several approaches, including benthic traps and grabs, direct collection by divers and using remotely operated underwater vehicles. The latter were also used to obtain video and photographic records. Fish were collected using standard line-and-hook collection methods following bioethical and ecological standards. Marine mammals and birds were observed using binoculars from the maximum possible distance. On land, lichens and mosses were collected by hand from rocks and the soil surface. Terrestrial invertebrates were extracted from some of these samples. Samples of freshwater zooplankton were collected by means of standard hydrobiological procedures (Andrews 1972, Schwoerbel 1972) using plankton nets (mesh size 45 or 20 µm). Both qualitative and quantitative plankton samples were taken, the latter filtering 50, 150, 200 or 400 l of water and expressing abundances as number of individuals per 100 l. Plankton samples were fixed using 4% formalin solution. The locations of all sample sites are illustrated in Fig. 3, and summary information about the sampled locations and habitats (freshwater bodies, sites of vegetation, etc.) is given in Supplemental Tables S1–S4.

All sampling and observations strictly followed the guidance of Annex II to the Protocol on Environmental Protection to the Antarctic Treaty (Conservation of Antarctic Fauna and Flora 2009) and the guidelines of the Scientific Committee on Antarctic Research (SCAR 2018), ensuring the minimum possible impact on the environment.

Sample processing

Initial sample processing took place at the Belarus Antarctic station, with subsequent studies on return of preserved material to Belarus. Processing techniques were appropriate to each of the groups examined. Microscopic metazoans (e.g. zooplankton, terrestrial invertebrates, etc.) were examined using Petri dishes or counting chambers under dissection and light microscopy. Appropriate reagents were used to dissolve the soft parts of rotifer individuals in order to make the details of sclerotized jaws visible, with morphometric analyses performed as described by Iakovenko *et al.* (2013). Micrographs of rotifers, parasitic nematodes and acanthocephalans were obtained using AxioCAM and NIKON E200 cameras with *AxioVision* and *NIS Elements BR* analysis 5.10.00, respectively. To isolate fish parasites, we followed procedures described by Buchmann (2007). For different taxonomic groups, we relied on appropriate taxonomic literature as follows. Lichens: Øvstedal & Smith (2001), Speilmann & Pereira (2012); rotifers: Donner (1965), Kutikova (1970, 2005), Dartnall & Hollowday (1985), Nogrady *et al.* (1995), De Smet & Pourriot (1997), Iakovenko *et al.* (2015); tardigrades: Ramazzotti & Maucci (1983), Pilato & Binda (2010), Bingemer & Hohberg (2017); mites:

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Table I. Checklist of the biota recorded from the Thala Hills oasis, with notes on wider distribution and biogeography.

Taxa	Habitat	Distribution	Present study	Previous records			Reference for TH
				Ant	EA	TH	
KINGDOM PLANTAE HAECKEL							
DIVISION **CHLOROPHYTA** REICHENBACH							
Order **Prasiolales** Schaffner							
Family Prasiolaceae F.F. Blackman et A.G. Tansley							
Prasiola crispa (Lightfood) Kützing	Ter	BP	+				Starmach 1995
DIVISION **BRYOPHYTA** SCHIMP.							
Class **Bryopsida** (Limpr.) Rothm.							
Order **Bryales** Limpr.							
Family Bryaceae Schwägr.							
Bryum archangelicum Bruch et Schimp.	Ter	BP	-				Kurbatova *et al.* 2014
Bryum argenteum Hedw.	Ter	Cosm	+				Kurbatova *et al.* 2014
Bryum pseudotriquetrum (Hedw.) P.Gärtn., B.Mey.et Scherb.	Ter	Cosm	+				Kurbatova *et al.* 2014
Order **Dicranales** H. Philib. ex M. Fleisch.							
Family Ditrichaceae Limpr.							
Ceratodon purpureus (Hedw.) Brid.	Ter	Cosm	+				Kurbatova *et al.* 2014
Order **Funariales** M. Fleisch.							
Family Funariaceae Schwägr.							
Funaria hygrometrica Hedw.	Ter	Cosm	+				-
Order **Grimmiales** M. Fleisch.							
Family Grimmiaceae Arn.							
Coscinodon lawianus (J. H. Willis) Ochyra	Ter	End	-				Kurbatova *et al.* 2014
Orthogrimmia sessitana (De Not.) Ochyra et Żarnowiec	Ter	BP	-				Kurbatova *et al.* 2014
Schistidium antarctici (Card.) L. I. Savicz et Smirnova	Ter	End	-				Kurbatova *et al.* 2014
Order **Pottiales** M. Fleisch							
Family Pottiaceae Schimp.							
Hennediella heimii (Hedw.) R. H. Zander	Ter	BP	-				Kurbatova *et al.* 2014
KINGDOM FUNGI (L.) R. T. MOORE							
DIVISION **ASCOMYCOTA** CAVALIER-SMITH							
Class **Arthoniomycetes** O.E. Erikss. et Winka							
Order **Arthoniales** Henssen ex D. Hawksw. et O.E. Erikss.							
Family Arthoniaceae Rchb.							
Arthonia molendoi (Heufl. ex Frauenf.) R. Sant.	Ter	BP	+				-
Class **Dothideomycetes** O.E. Erikss. et Winka							
Order **Capnodiales** Woron.							
Family Cystocoleaceae Locq. ex Lücking, B.P. Hodk. et S.D. Leav.							
Cystocoleus ebeneus (Dillwyn) Thwaites	Ter	BP	+				Andreev 2013
Class **Lecanoromycetes** O.E. Erikss. et Winka							
Order **Acarosporales** Reeb, Lutzoni et Cl. Roux							
Family Acarosporaceae Zahlbr.							
Acarospora gwynnii C.W. Dodge et E.D. Rudolph.	Ter	SH	+				Andreev 2013
Pleopsidium chlorophanum (Wahlenb.) Zopf	Ter	BP	+				-
Order **Caliciales** Bessey							
Family Caliciaceae Chevall.							
Amandinea punctata (Hoffm.) Coppins et Scheid.	Ter	Cosm	-				Andreev 2013
Buellia frigida Darb.	Ter	End	+				Andreev 2013
Buellia geophila (Flörke) Lynge	Ter	BP	-				Andreev 2013
Buellia soredians Filson	Ter	End	+				-
Buellia subfrigida May, Inoe	Ter	End	-				Andreev 2013
Family Physciaceae Zahlbr.							
Physcia caesia (Hoffm.) Hampe ex Fürnr.	Ter	Cosm	+				Andreev 2013
Rinodina olivaceobrunnea C.W. Dodge et G.E. Baker	Ter	BP	+				Andreev 2013
Order **Candelariales** Miadl., Lutzoni et Lumbsch							
Family Candelariaceae Hakul.							
Candelaria murrayi Poelt	Ter	End	+				Andreev 2013
Candelariella flava (C.W.Dodge et G.E.Baker)Castello et Nimis	Ter	End	+				Andreev 2013
Order **Lecanorales** Nannf.							
Family Lecanoraceae Körb.							

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TABLE I. (*continued*).

Taxa	Habitat	Distribution	Present study	Previous records			Reference for TH
				Ant	EA	TH	
Carbonea vorticosa (Flörke) Hertel	Ter	BP	-				Andreev 2013
Lecanora fuscobrunnea C. W. Dodge et G. E. Baker	Ter	End	-				Andreev 2013
Lecanora physciella (Darb) Hertel	Ter	End	+				Andreev 2013
Lecanora polytropa (Ehrh.) Rabenh.	Ter	Cosm	+				-
Lecidella cf. antarctica Ertz, Aptroot et Ovstedal	Ter	End	-				Andreev 2013
Lecidella cf. greenii U. Ruprecht et Türk	Ter	End	-				Andreev 2013
Lecidella siplei (C. W. Dodge et G. E. Baker) May. Inoue	Ter	End	-				Andreev 2013
Lecidella stigmatea (Ach.) Hertel et Leuck.	Ter	BP	+				-
Polyozosia expectans (Darb.) S.Y. Kondr., Lőkös & Farkas Darb.	Ter	End	+				Andreev 2013
Family Parmeliaceae Zenker							
Pseudephebe minuscula (Arnold) Brodo et D. Hawksw.	Ter	BP	+				Andreev 2013
Pseudephebe pubescens (L.) M. Choisy	Ter	BP	+				-
Rhizoplaca macleanii (C. W. Dodge) Castello	Ter	End	-				Andreev 2013
Rhizoplaca melanophtalma (DC.) Leuckert	Ter	BP	+				Andreev 2013
Usnea antarctica Du Rietz	Ter	SH	-				Andreev 2013
Usnea sphacelata R. Br.	Ter	BP	+				Andreev 2013
Family Stereocaulaceae Chevall.							
Lepraria alpina (de Lesd.) Tretiach et Baruffo	Ter	≈BP	+				Andreev 2013
Lepraria caesioalba (De Lesd.) J. R. Laundon	Ter	BP	-				Andreev 2013
Stereocaulon antarcticum Vain.	Ter	SH	-				Andreev 2013
Order **Lecideales** Vain.							
Family Lecideaceae Chevall.							
Lecidea andersonii Filson	Ter	End	-				Andreev 2013
Lecidea cancriformis C.W. Dodge et G.E. Baker	Ter	End	+				Andreev 2013
Lecidea lapicida (Ach.) Ach.	Ter	Cosm	+				-
Lecidea cf. polypycnidophora U. Ruprecht et Türk	Ter	End	-				Andreev 2013
Porpidia crustulata (Ach.) Hertel et Knoph	Ter	Cosm	+				-
Order **Petigerales** Walt. Watson							
Family Collemataceae Zenker							
Leptogium puberulum Hue	Ter	End	+				-
Order **Rhizocarpales** Miądl. et Lutzoni ex Miądl. et Lutzoni							
Family Rhizocarpaceae M. Choisy ex Hafellner							
*Rhizocarpon adarens*e (Darb.) I.M. Lamb	Ter	SH	+				-
Rhizocarpon flavum C.W. Dodge et G.E. Baker	Ter	End	+				-
Rhizocarpon geographicum (L.) DC.	Ter	Cosm	-				Andreev 2013
Order **Teloschistales** D. Hawksw. et O.E. Erikss.							
Family Teloschistaceae Zahlbr.							
Blastenia ammiospila (Wahlenb.)Arup, Søchting & Frödén(Ach.)H. Olivier	Ter	BP	+				Andreev 2013
Caloplaca lewis-smithii Søchting et Øvstedal	Ter	End	-				Andreev 2013
Caloplaca saxicola (Hoffm.) Nordin	Ter	BP	-				Andreev 2013
Flavoplaca citrina (Hoffm.) Arup, Frödén & Søchting (Hoffm.) Th. Fr.	Ter	Cosm	+				Andreev 2013
Polycauliona candelaria (L.) Frödén, Arup & Søchting (L.) Th. Fr.	Ter	BP	+				-
Xanthoria elegans (Link) Th. Fr.	Ter	BP	+				Andreev 2013
Xanthoria mawsonii C.W. Dodge	Ter	End	+				Andreev 2013
Order **Umbilicariales** J.C. Wei et Q.M. Zhou							
Family Umbilicariaceae Chevall.							
Umbilicaria africana (Jatta) Krog et Swinscow	Ter	SH	+				-
Umbilicaria aprina Nyl.	Ter	BP	+				Andreev 2013
Umbilicaria cristata C. W. Dodge et G. E. Baker	Ter	End	-				Andreev 2013
Umbilicaria decussata (Vill.) Zahlbr.	Ter	BP	+				Andreev 2013
KINGDOM ANIMALIA L.							
PHYLUM **PORIFERA** GRANT, 1836							
Class **Demospongiae** Sollas, 1885							
Order **Polymastiida** Morrow & Cárdenas, 2015							
Family Polymastiidae Gray, 1867							
Sphaerotylus antarcticus Kirkpatrick, 1907	Mar	End	+				Sirenko *et al.* 2017

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TABLE I. (*continued*).

Taxa	Habitat	Distribution	Present study	Previous records			Reference for TH
				Ant	EA	TH	
PHYLUM **CNIDARIA** HATSCHEK, 1888							
Class **Anthozoa** Ehrenberg, 1831							
Order **Actiniaria** Hertwig, 1882							
Family Actiniidae Rafinesque, 1815							
Urticinopsis antarctica (Verrill, 1922)	Mar	End	+				Sirenko *et al.* 2017
PHYLUM **ROTIFERA** CUVIER, 1798							
Class **Eurotatoria** De Ridder, 1957							
Subclass **Bdelloidea** Hudson, 1884							
Order **Adinetida** Melone et Ricci, 1995							
Family Adinetidae Hudson et Gosse, 1886							
Adineta coatse Iakovenko *et al.*, 2015	FW	End	+				-
Adineta grandis Murray, 1910	FW	End	+				-
Adineta editae Iakovenko, 2015	Ter	End	+				-
Adineta cf. *vaga vaga* (Davis, 1873)	Ter	≈BP	+				-
Adineta cf. *vaga minor* Bryce, 1893	Ter	Cosm	+				-
Adineta steineri Bartoš, 1951	Ter	≈Cosm	+				-
Order **Philodinida** Melone et Ricci, 1995							
Family Philodinidae Ehrenberg, 1838							
Macrotrachela kallosoma (Schute, 1954)	Ter	≈BP	+				-
Philodina alata Murray, 1910	FW	End	+				-
Philodina gregaria Murray, 1910	FW, Ter	End	+				-
Pleuretra lineata Donner, 1962	FW	BP	+				-
Subclass **Monogononta** Plate, 1889							
Order **Collothecaceae** Harring, 1910							
Family Collothecidae Harring, 1910							
Collotheca ornata (Ehrenberg, 1832)	FW	Cosm	+				-
Order **Ploima** Hudson et Gosse, 1886							
Family Brachionidae Ehrenberg, 1832							
Kellicottia longispina (Kellicott, 1879)	FW	≈Cosm	+				-
Keratella cochlearis (Gosse, 1851)	FW	≈Cosm	+				Kutikova 1991, Sharov *et al.* 2015
Keratella quadrata (Müller, 1786)	FW	≈Cosm	-				Kutikova 1991
Keratella tecta (Gosse, 1851)	FW	≈Cosm	+				-
Family Dicranophoridae Harring, 1913							
Encentrum lutra Wulfert, 1936	FW	≈BP	-				Kutikova 1991
Encentrum saundersiae (Hudson, 1885)	FW	≈BP	+				-
Family Epiphanidae Harring, 1913							
Epiphanes senta (Müller, 1773)	FW	Cosm	+				-
Rhinoglena cf. *frontalis* Ehrenberg, 1853	FW	≈BP	+				-
Family Lepadellidae Harring, 1913							
Lepadella patella (Müller, 1773)	FW	Cosm	+				Opaliński 1972, Kutikova 1991, Sharov *et al.* 2015
Family Notommatidae Hudson et Gosse, 1886							
Cephalodella sterea (Gosse, 1887)	FW	≈Cosm	+				-
PHYLUM **ACANTHOCEPHALA** KOELREUTER, 1771							
Class **Palaeacanthocephala** Meyer, 1931							
Order **Echinorhynchida** Southwell et Macfie, 1925							
Family Heteracanthocephalidae Petrochenko, 1956							
Aspersentis megarhynchus (von Linstow, 1892)	Mar	End	+				-
Family Rhadinorhynchidae Travassos, 1923							
Metacanthocephalus campbelli (Leiper et Atkinson, 1914)	Mar	End	+				-
Metacanthocephalus johnstoni Zdzitowiecki, 1983	Mar	End	+				-
PHYLUM **ANNELIDA** LAMARCK, 1809							
Class **Polychaeta** Grube, 1850							
Order **Sabellida** Latreille, 1825							

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TABLE I. (*continued*).

Taxa	Habitat	Distribution	Present study	Previous records			Reference for TH
				Ant	EA	TH	
Family Sabellidae Latreille, 1825							
Perkinsiana magalhaensis (Kinberg, 1867)	Mar	SH	+				-
Family Serpulidae Rafinesque, 1815							
Serpula narconensis Baird, 1865	Mar	SH	+				-
Order **Terebellida** Dales, 1962							
Family Flabelligeridae de Saint-Joseph, 1894							
Flabegraviera mundata (Gravier, 1906)	Mar	End	+				-
PHYLUM **MOLLUSCA** LINNAEUS, 1758							
Class **Bivalvia** Linnaeus, 1758							
Order **Anomalodesmata** Dall, 1889							
Family Laternulidae Hedley, 1918							
Laternula elliptica (P. P. King, 1832)	Mar	End	+				Sirenko *et al.* 2017
Class **Gastropoda** Cuvier, 1795							
Order **Neogastropoda** Wenz, 1938							
Family Buccinidae Rafinesque, 1815							
Neobuccinum eatoni (E. A. Smith, 1875)	Mae	End	+				Sirenko *et al.* 2017
PHYLUM **NEMATODA** RUDOLPHI, 1808							
Class **Chromadorea** Inglis, 1932							
Order **Rhabditida** Chitwood, 1933							
Family Anisakidae Railliet et Henry, 1912							
Contracaecum osculatum (Rudolphi, 1802)	Mar	BP	+				-
Contracaecum radiatum (Linstow, 1907)	Mar	End	+				WoRMS 2021b
Pseudoterranova decipiens (Krabbe, 1878)	Mar	BP	+				-
Family Cystidicolidae Skrjabin, 1946							
Ascarophis nototheniae Johnston et Mawson, 1945	Mar	SH	+				-
PHYLUM **TARDIGRADA** DOYÈRE, 1840							
Class **Eutardigrada** Richters, 1926							
Order **Apochela** Schuster, Nelson, Grigarick & Christenberry, 1980							
Family Milnesiidae Ramazzotti, 1962							
Milnesium tardigradum Doyère, 1840	FW, Ter	Cosm	+				Dastych 1984, Utsugi & Ohyama 1991
Order **Parachela** Schuster, Nelson, Grigarick & Christenberry, 1980							
Family Hypsibiidae Pilato, 1969							
Acutuncus antarcticus (Richters, 1904)	FW, Ter	End	+				Utsugi & Ohyama 1991
Diphascon chilenense Plate, 1888	Ter	Cosm	-				Utsugi & Ohyama 1991
Diphason langhovdense (Sudzuki, 1964)	Ter	End	-				Dastych 1984
Isohypsibius improvisus Dastych, 1984	Ter	End	-				Dastych 1984
Family Macrobiotidae Thulin, 1928							
Mesobiotus blocki (Dastych, 1984)	Ter	End	-				Dastych 1984
Mesobiotus coronatus (de Barros, 1942)	FW, Ter	≈Cosm	-				Utsugi & Ohyama 1991
Mesobiotus montanus (Murray, 1910)	Ter	≈Cosm	-				Utsugi & Ohyama 1991
Minibiotus weinerorum (Dastych, 1984)	Ter	End	-				Dastych 1984
Family Ramazzottiidae Sands, McInnes, Marley, Goodall-Copestake, Convey & Linse, 2008							
Hebesuncus conjungens (Thulin, 1911)	FW, Ter	BP	-				Utsugi & Ohyama 1991
Hebesuncus schusteri (Dastych, 1984)	Ter	End	-				Dastych 1984
Class **Heterotardigrada** Marcus, 1927							
Order **Echiniscoidea** Richters, 1926							
Family Echiniscidae Thulin, 1928							
Echiniscus kerguelensis Richters, 1904	FW, Ter	BP	+				Utsugi & Ohyama 1991
Echiniscus pseudowendti (Dastych, 1984)	Ter	End	-				Dastych 1984
Pseudechiniscus suillus (Ehrenberg, 1853)	Ter	Cosm	-				Dastych 1984
PHYLUM **ARTHROPODA** LATREILLE, 1829							
Class Arachnida Lamarck, 1801							
Order Trombidiformes Reuter, 1909							

(*Continued*)

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TABLE I. (*continued*).

Taxa	Habitat	Distribution	Present study	Previous records			Reference for TH
				Ant	EA	TH	
Family Penthalodidae Thor, 1933							
Stereotydeus meyeri Strandtmann, 1967	Ter	End	-				Strandtmann 1967
Class **Collembola** Lubbock, 1871							
Order **Poduromorpha** Börner, 1913							
Family Neanuridae Börner, 1901							
Friesea eureka Greenslade, 2018	Ter	End	-				Wise 1971, Greenslade 2018
Class **Malacostraca** Latreille, 1802							
Order **Amphipoda** Latreille, 1816							
Family Pontogeneiidae Stebbing, 1906							
Paramoera walkeri (Stebbing, 1906)	Mar	End	-				Rakusa-Suszczewski 1972b, Klekowski *et al.* 1973, Rakusa-Suszczewski & Klekowski 1973, Opaliński 1974
PHYLUM **ECHINODERMATA** BRUGUIÈRE, 1791							
Class **Asteroidea** de Blainville, 1830							
Order **Valvatida** Perrier, 1884							
Family Ganeriidae Sladen, 1889							
Cuenotaster involutus (Koehler, 1912)	Mar	End	+				Sirenko *et al.* 2017
Family Odontasteridae Verrill, 1899							
Odontaster validus Koehler, 1906	Mar	SH	+				Gruzov & Pushkin 1973, Sirenko *et al.* 2017
Class **Echinoidea** Leske, 1778							
Order **Camarodonta** Jackson, 1912							
Family Echenidae Gray, 1825							
Sterechinus neumayeri (Meissner, 1900)	Mar	End	+				Sirenko *et al.* 2017
Class **Ophiuroidea** Gray, 1840							
Order **Ophiurida** Müller et Troschel, 1840							
Family Ophiuridae Müller et Troschel, 1840							
Ophionotus victoriae Bell, 1902	Mar	End	+				Sirenko *et al.* 2017
Ophiura rouchi (Koehler, 1912)	Mar	End	+				Sirenko *et al.* 2017
Ophiurolepis gelida (Koehler, 1901)	Mar	End	+				Sirenko *et al.* 2017
Family Ophiopyrgidae Perrier, 1893							
Ophioplinthus relegata (Koehler, 1922)	Mar	End	+				Sirenko *et al.* 2017
Ophiosparte gigas Koehler, 1922	Mar	End	+				Sirenko *et al.* 2017
PHYLUM **CHORDATA** BATESON, 1885							
Class **Actinopterygii** Klein, 1885							
Order **Perciformes** Bleeker, 1859							
Family Bathydraconidae Regan, 1914							
Gymnodraco acuticeps Boulenger, 1902	Mar	End	+				Jakubowski & Rembiszewski 1974, Jakubowski 1975
Family Nototheniidae Günther, 1861							
Trematomus bernacchii (Boulenger, 1902)	Mar	End	+				Jakubowski 1970, Dewitt *et al.* 1990
Trematomus borchgrevinki (Boulenger, 1902)	Mar	End	+				Rakusa-Suszczewski 1972a
Trematomus hansonii Boulenger, 1902	Mar	End	+				-
Trematomus nicolai (Boulenger, 1902)	Mar	End	+				Jakubowski 1970
Trematomus newnesi Boulenger, 1902	Mar	End	+				Jakubowski 1970
Trematomus pennellii Regan, 1914	Mar	End	+				-
Class **Aves** L., 1758							

(*Continued*)

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TABLE I. (*continued*).

Taxa	Habitat	Distribution	Present study	Previous records			Reference for TH
				Ant	EA	TH	
Order **Charadriiformes** Huxley, 1867							
Family Stercorariidae Gray, 1871							
Stercorarius maccormicki (Saunders, 1893)	Mar	SH	+	■	■	■	Ropert-Coudert *et al.* 2014
Order **Procellariiformes** (Fürbringer, 1888)							
Family Procellariidae Leach, 1820							
Pagodroma nivea (Forster, 1777)	Mar	SH	+	■	■	■	Ropert-Coudert *et al.* 2014
Family Hydrobatidae Mathews, 1912							
Oceanites oceanicus (Kuhl, 1820)	Mar	SH	+	■	■	■	Ropert-Coudert *et al.* 2014
Order **Sphenisciformes** Sharpe 1891							
Family Spheniscidae Bonaparte, 1831							
Aptenodytes forsteri Gray, 1844	Mar	End	+	■	■	□	-
Pygoscelis adeliae (Hombron et Jacquinot, 1841)	Mar	End	+	■	■	■	Ropert-Coudert *et al.* 2014
Class **Mammalia** L., 1758							
Order **Carnivora** (Bowdich, 1821)							
Family Phocidae Gray, 1821							
Leptonychotes weddellii (Lesson, 1826)	Mar	End	+	■	■	■	Ropert-Coudert *et al.* 2014

Dark grey boxes indicate previous records; light grey boxes indicate no previous record.
Ant = Antarctica (including the Maritime Antarctic and sub-Antarctic islands); BP = bipolar distribution; Cosm = cosmopolitan; EA = East (Continental) Antarctica; End = endemic to Antarctica (including Continental Antarctica, the Maritime Antarctic and the sub-Antarctic islands); FW = freshwater; Mar = marine; SH = Southern Hemisphere; Ter = terrestrial; TH = Thala Hills (within the Cosmonaut Sea coastal area).

Strandtmann (1967); springtails: Wise (1971), Greenslade (2018a); marine macrobenthos: Brueggeman (1998), Hibbert & Moore (2009), Rauschert & Arntz (2015), Sirenko *et al.* (2017); fish: Fischer (1985), Gon (1990), McMillan *et al.* (2014).

Data analysis and presentation

Following identification to the lowest taxonomic level practicable, for each taxon we assessed whether it had previously been recorded 1) in Antarctica generally (including Maritime Antarctic and sub-Antarctic regions, 2) in Continental Antarctica (from Dronning Maud Land to the Ross Sea) or 3) in the Thala Hills region specifically. The relatively limited spatially explicit data available in the literature from the latter region, in particular from the marine environment, meant that assessment of 3) was sometimes problematic (commonly the lack of precise location information meant that we considered taxa previously recorded from the 'Cosmonaut Sea' to be potentially present in the Thala Hills area). We extracted known distributional information primarily from the *Biogeographic Atlas of the Southern Ocean* (De Broyer *et al.* 2014) and the published literature, as well as open-access databases (Australian Antarctic Data Center (AADC n.d.), AlgaeBase, BirdLife International, Global Biodiversity Information Facility (GBIF) and The World Register of Marine Species (WoRMS)).

Results

Our search of the available literature and open-access data sources identified that the previously recorded eukaryotic terrestrial and marine biodiversity of the Thala Hills area included 90 species. In the new surveys reported in the current study, a total of 95 species were found. However, only 51 of these species (54%) were previously recorded from this area. A full list of all species that have now been reported from the Thala Hills oasis is given in Table I.

Voucher specimens are stored in the collections of the Scientific and Practical Center of the National Academy of Sciences of Belarus for Bioresources (SPC for Bioresources), Minsk, Belarus. Lichen specimens are also stored in the lichen herbarium (MSK-L) at the V.F. Kuprevich Institute of Experimental Botany of the National Academy of Sciences of Belarus (IEB), Minsk, Belarus. All data on specimens collected during the 2018/2019 season are available at http://boldsystems.org/index.php/MAS_Management_DataConsole?codes=GDBAE (the project in Barcode of Life Data System 'GDBAE', Genetic Diversity of East Antarctica). Supplemental

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Table II. Comparison of lichen assemblages between Vechernyaya Mount, eastern Thala Hills, obtained in recent surveys, and Molodyozhnaya, western Thala Hills (extracted from Andreev 2013).

Characteristic	Locality	
	Vechernyaya Mount	Molodyozhnaya
Total number of species	33	38
Biogeography		
Endemic to Antarctica	10 (30%)	17 (45%)
Distributed in Southern Hemisphere	3 (9%)	2 (5%)
Bipolar	15 (45%)	13 (34%)
Cosmopolitan	5 (15%)	6 (16%)
Thalli form		
Crustose	18 (55%)	23 (61%)
Filamentous	1 (3%)	1 (3%)
Foliose	10 (30%)	9 (24%)
Fruticose	3 (9%)	4 (11%)
Leprose	1 (3%)	1 (2%)
Type of substrata		
Saxicolous	25 (76%)[a]	29 (76%)[a]
Terricolous	5 (15%)	5 (13%)
Epiphytic on bryophytes	10 (30%)	12 (32%)
Species diversity distance		
Similarity (Sørensen-Dice coefficient)	56.3%	

[a] The sum is more than 100% because some species occurred on more than one substratum.

Table S5 contains general information on voucher specimens. Photographs and video records confirming other records of species (without voucher specimens) are also available at the SPC for Bioresources.

Below, we provide brief overviews of the main groups of Eukarya recorded from the oasis.

Terrestrial diversity

Lichens. The only published synthesis of lichen diversity from Thala Hills is that of Andreev (2013), which includes some recently obtained data (2010–2011) and a collation of earlier fragmentary reports (Golubkova *et al.* 1969, Andreev 1990). These reports document material from the vicinity of Molodyozhnaya station in the western part of the oasis and a small number of other locations (Cape Kosisty and the McMahon Islands). A total of 38 species were reported, representing mostly crustose growth forms and saxicolous species. No closed lichen communities were present, and lichens were present only in very small clusters or as individual thalli, mostly in cryptic locations. *Candelariella flava*, *Rinodina olivaceobrunnea*, *Amandinea punctata*, *Xanthoria mawsonii* and *Flavoplaca citrina* were the dominant lichens in moss-algae-lichen associations growing on gravel substrata in sheltered locations around rocks and hollows and in rock crevices. The species *Buellia frigida*, *Umbilicaria decussata*, *Umbilicaria aprina* and *Pseudephebe minuscula* were present in moist sites such as lotic waterbeds and near the edges of melting snow patches and glacier edges. Small patches of *P. minuscula* and *Lecidea* spp. were also infrequently present on more exposed rock surfaces on the hills of the western part of the oasis.

Collections in the Vechernyaya Mountain locality in the eastern part of the oasis initiated in 2009 now allow for a more complete description of the lichen diversity of Thala Hills. The lichen flora of this part of the oasis consists of 32 species, and one species of lichenicolous fungus was also recorded (Table I). Twenty of the 33 species are present in both the western and eastern parts of the oasis, and the remaining 13 species were newly recorded only from the eastern part. In the eastern part of the oasis, lichens were recorded at altitudes of 15–256 m a.s.l., and again no continuous cover was present. Most species (25; 75.8%) were saxicolous. Ten species were epiphytic on mosses and five were terricolous (some species can grow

Table III. Rotifers obtained from freshwater lakes (n = 18) and temporary ponds (n = 27) in the Thala Hills oasis.

Taxa	Occurrence		*n* (ind. · (100 l)$^{-1}$)	
	Lakes	Temporary ponds	Lakes	Temporary ponds
Adineta coatsae Iakovenko *et al.*, 2015	-	4	-	n/d
Adineta grandis Murray, 1910	-	3	-	n/d
Adineta sp.	1	1	n/d	n/d
Bdelloidea sp.	16	26	0.25–1031.1	0.5–77 × 10^3
Cephalodella sterea (Gosse, 1887)	-	1	-	0.5
Collotheca ornata (Ehrenberg, 1832)	1	-	2	-
Encentrum saundersiae (Hudson, 1885)	-	1	-	n/d
Epiphanes senta (Müller, 1773)	2	-	0.5–5.3	-
Kellicottia longispina (Kellicott, 1879)	2	-	n/d	-
Keratella cochlearis (Gosse, 1851)	3	-	n/d	-
Keratella tecta (Gosse, 1851)	1	-	n/d	-
Lepadella patella (Müller, 1773)	2	-	0.5–31.8	-
Philodina alata Murray, 1910	3	4	0.5–8.5	0.9–19.0
Philodina gregaria Murray, 1910	-	6	-	n/d
Pleuretra lineata Donner, 1962	-	1	-	n/d
Rhinoglena cf. *frontalis* Ehrenberg, 1853	2	1	n/d	n/d

n/d = not determined.

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Table IV. Parasites associated with *Trematomus* spp. sampled in the Cosmonaut Sea (n_{fish} = 32; $n_{parasites}$ = 1512).

Taxon	EI %	I_{EI}	AI (ind.)	I_{AI}	II (ind.)		DI (%)
					Mean	Median	
Nematoda							
Contracaecum osculatum (Rudolphi, 1802)	100.00	89.11–100.0	32.44	23.88–46.81	32.44	23.00	68.65
Contracaecum radiatum (Linstow, 1907)	75.00	56.59–88.54	13.91	9.19–20.31	18.54	15.00	29.96
Pseudoterranova decipiens (Krabbe, 1878)	3.10	0.07–16.22	0.03	0.001–0.09	1.00	1.00	0.066
Ascarophis nototheniae (Johnston et Mawson, 1945)	12.50	3.51–29.0	0.22	0.03–0.05	1.75	1.50	0.46
Acanthocephala							
Aspersentis megarhynchus (von Linstow, 1892)	3.13	0.07–16.22	0.16	0.001–0.47	5.00	5.00	0.33
Metacanthocephalus campbelli (Leiper & Atkinson, 1914)	6.25	0.76–20.81	0.06	0.001–0.16	1.00	1.00	0.13
Metacanthocephalus johnstoni Zdzitowiecki, 1983	6.30	0.73–20.80	0.13	0.001–0.31	2.00	2.00	0.26

AI = abundance index (average number of parasite individuals per fish examined); DI = dominance index (relative abundance of each species); EI = proportion of contaminated fishes; I_{AI} = confidence interval of AI; I_{EI} = confidence interval of EI; II = intensity of invasion (number of parasite individuals per individual contaminated fish).

on more than one substratum). The most frequent growth forms were crustose (18 species) and foliose (10 species). These features are closely similar to those of the lichen community of the western part of the oasis (Andreev 2013).

The most abundant species were *Buellia frigida*, *Physcia caesia*, *Xanthoria elegans*, *Umbilicaria aprina*, *Umbilicaria decussata* and *Usnea sphacelata*. Moderately common species included *Candelariella flava*, *Lecanora polytropa*, *Polyozosia expectans* and *Pseudephebe minuscula*. Species only occurring rarely in the oasis included *Acarospora gwynnii*, *Lecidea cancriformis*, *Pleopsidium chlorophanum*, *Pseudophebe pubescens*, *Rhizocarpon adarense*, *R. flavum*, *Xanthoria candelaria*, amongst others. There was low similarity (as indicated by the Sørensen-Dice coefficient) between lichen species diversity in the vicinity of Vechernyaya Mountain and in the western part of Thala Hills (Table II).

Mosses. The bryophyte flora included nine species of moss, with no other groups of embryophytes represented. According to brief summaries (Savicz-Lyubitskaya & Smirnova 1972, Kurbatova *et al.* 2014), in the western part of the oasis only *Bryum pseudotriquetrum* and *Ceratodon purpureus* are common, with other species (*B. archangelicum*, *Hennediella heimii*, *Orthogrimmia sessitana*, *Schistidium antarctici* and *Coscinodon lawianus*) being rare.

In the eastern part of the oasis, *B. pseudotriquetrum* and *C. purpureus* are again the most common species, often growing together. Relatively large carpets of *B. pseudotriquetrum* are present (up to 60 m^2), especially in areas with ornithogenic influence from the local Adélie penguin colony. Two other newly recorded species had more limited occurrence as isolated clumps: *B. argenteum* and *Funaria hygrometrica* (Table I), the latter being limited to moist places.

Terrestrial and freshwater micro-invertebrates. Four species of planktonic rotifer have previously been recorded in the western part of the Thala Hills oasis (Opaliński 1972, Kutikova 1991, Sharov *et al.* 2015). Sampling of 50 water bodies in the eastern part of the oasis in the current study revealed five bdelloid (Bdelloidea) and nine monogonont (Monogononta) species (Table I). Other than *Lepadella patella* and *Keratella cochlearis*, all freshwater rotifer species identified from the samples examined in this study are new records for the oasis. Most of the species were characterized by low occurrence frequency, with only bdelloids (mostly unidentified) present in most water bodies (Table III). Six further bdelloid species, new for the oasis, were extracted from terrestrial samples (moss associations, algal mats).

Three tardigrade species were identified in the current study from moss and algal samples - *Milnesium tardigradum*, *Acutuncus antarcticus* and *Echiniscus kerguelensis* - confirming their presence in the oasis. Eleven other freshwater and terrestrial species have been reported in previous studies in the western (Utsugi & Ohyama 1991) and eastern parts of the oasis (Dastych 1984) (Table I).

Terrestrial micro-arthropods. The described micro-arthropod diversity of the Thala Hills oasis is very low, and samples examined in the current study did not include specimens of the one springtail (Collembola) recorded, previously known as *Friesea grisea* (Wise 1971). The taxonomy of Antarctic members of this genus has recently been extensively revised (Greenslade 2018a, Carapelli *et al.* 2020a, 2020b), and material from Thala Hills has been re-described as the new and oasis-endemic species *F. eureka* (Greenslade 2018b). The prostigmatid mite *Stereotydeus meyeri* was sometimes commonly associated with moss vegetation and lichens (Strandtmann 1967).

Marine diversity

Marine invertebrates. Very limited published information is available documenting marine benthos diversity in the

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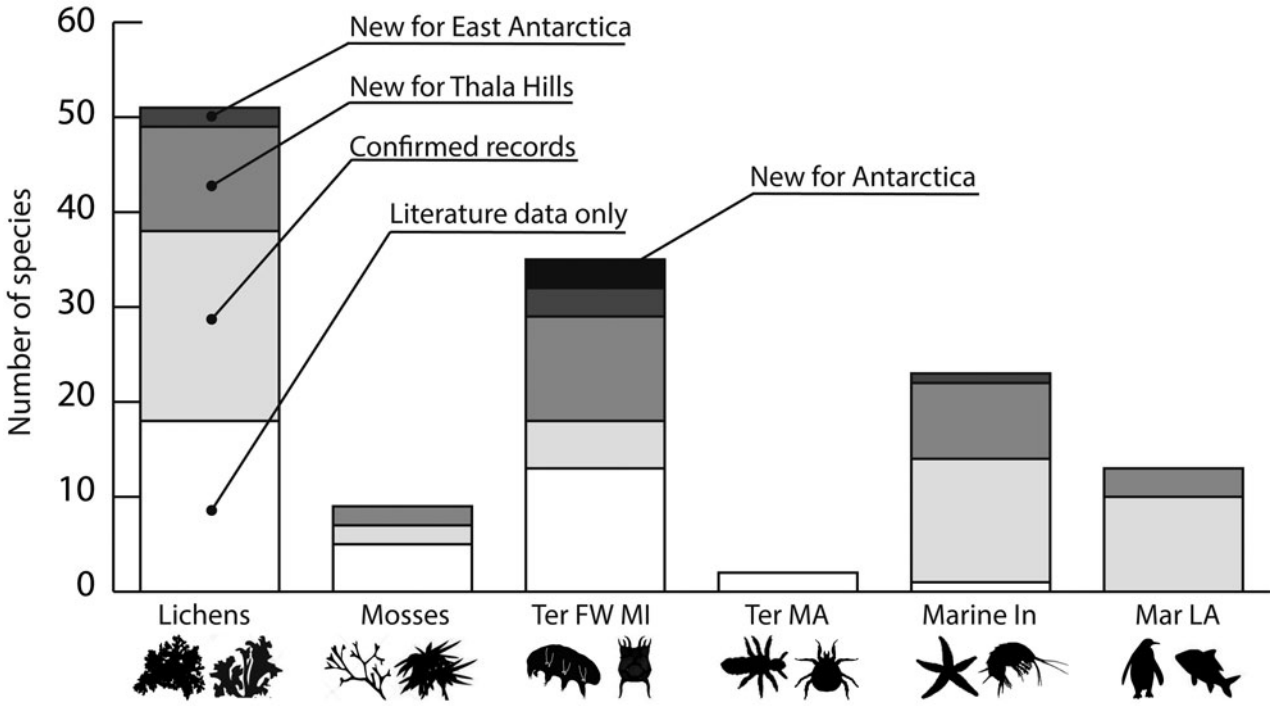

Fig. 4. All species records (lichens, embryophytes, metazoans) available from the Thala Hills oasis (literature data plus current study). Marine In = marine invertebrates; Marine LA = marine large animals (fish, seals, birds); Ter FW MI = terrestrial and freshwater micro-invertebrates; Ter MA = terrestrial micro-arthropods.

Thala Hills region, with few species recorded (Gruzov & Pushkin 1973). Our recent observations of benthos close to the shoreline of Lazurnaya Bay in the eastern part of Thala Hills revealed eight echinoderm species (the starfish *Cuenotaster involutus* and *Odontaster validus*, the sea urchin *Sterechinus neumayeri* and five species of brittle stars), two mollusc species, three polychaete worms and a number of other species (anthozoans and sponges) (Table I). Most have previously been recorded in the Cosmonaut Sea, while the polychaetes appear to be the first formal records from the area.

All three parasitic acanthocephalan species and three of the four parasitic nematodes have been recorded for the first time in the recent sampling studies. All species were found in fish individuals (*Trematomus* spp.), with the parasite contamination levels being extremely high (Table IV). The most frequently encountered in rank order were *Contracaecum osculatum* larvae followed by *C. radiatum* larvae, *Ascarophis nototheniae* adults, the three acanthocephalan species and *Pseudoterranova decipiens* larvae.

Fish, birds and mammals. Fish species previously recorded close to the Thala Hills coastline include *Trematomus bernacchii*, *T. newnesi*, *T. nicolai*, *T. borchgrevinki* and *Gymnodraco acuticeps*, with new records of *T. hansoni* and *T. pennellii* obtained in our recent surveys (Table I). Similarly, the only mammal (*Leptonychotes weddellii*) and most marine birds have previously been noted in the area, with the exception of *Aptenodytes forsteri*, for which we provide the first formal record. *Pygoscelis adeliae*, *Stercorarius maccormicki* and *Oceanites oceanicus* breed within the oasis.

Discussion

Thala Hills biodiversity

Lichens are well known for their high levels of environmental stress tolerance (Singh *et al.* 2015) and they form the main component of continental Antarctic vegetation (Castello & Nimis 1997, Øvstedal & Smith 2001, Nayaka & Upreti 2005, Peat *et al.* 2007). The lichen diversity of Thala Hills is similar to that of Bunger Hills and Schirmacher Oasis, the Prince Charles Mountains and other continental Antarctic locations (Andreev 2013). Some of the species present (*Acarospora gwynnii*, *Buellia frigida*, *Candelariella flava*, *Rinodina olivaceobrunnea*, *Pseudephebe minuscula*) are widespread throughout the Antarctic continent (Øvstedal & Smith 2001). The data obtained in the current study have increased the known lichen species diversity of the Thala Hills oasis by almost 25%, from 38 to 51 species (Fig. 4). Most of the new species records are of species known from elsewhere in Continental Antarctica, although two have not previously

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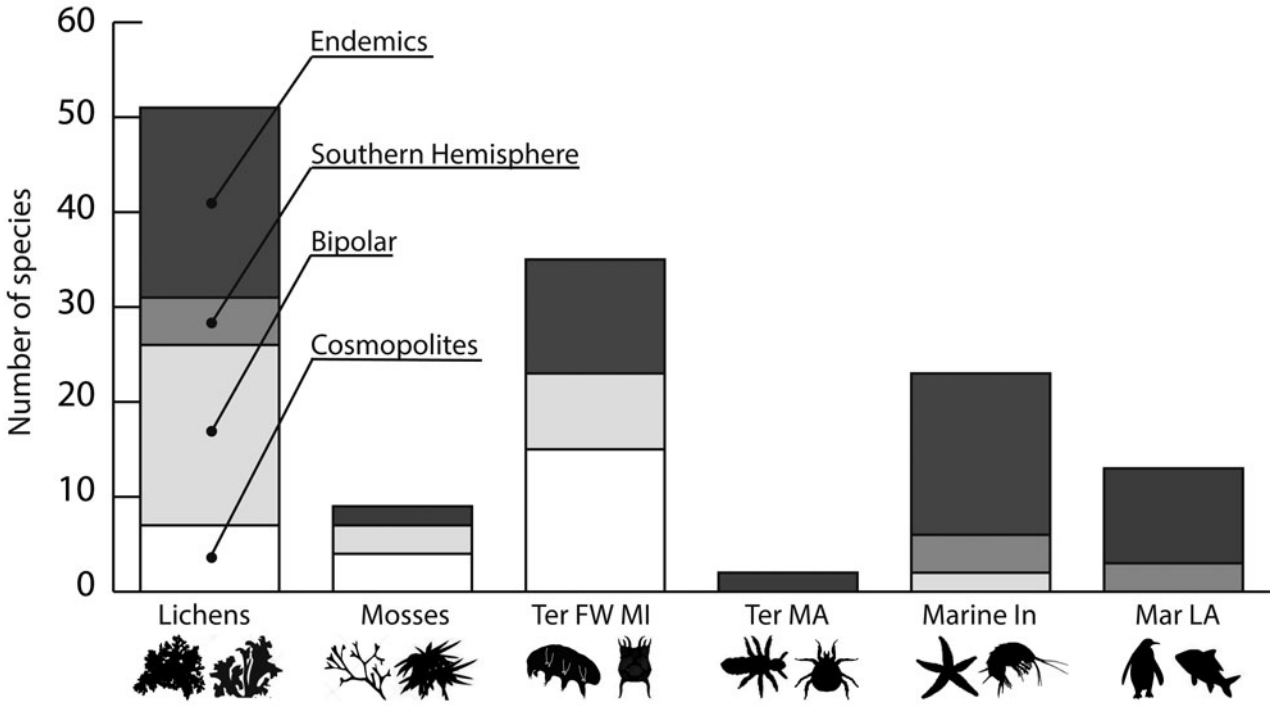

Fig. 5. Biogeographic analysis of all species (lichens, embryophytes, metazoans) known from the Thala Hills oasis. Marine In = marine invertebrates; Marine LA = marine large animals (fish, seals, birds); Ter FW MI = terrestrial and freshwater micro-invertebrates; Ter MA = terrestrial micro-arthropods.

been recorded in from this region (Filson 1975, Smith 1988, Kanda & Inoue 1994, Castello & Nimis 1995, Pandey & Upreti 2000, Nayaka & Upreti 2005, Singh *et al.* 2007, 2015, Rai *et al.* 2011, Smykla *et al.* 2011, Singh & Nayaka 2017). The two new records are of *Porpidia crustulata*, a cosmopolitan species known from the sub-Antarctic and Maritime Antarctic (AADC n.d., Singh *et al.* 2015) and *Leptogium puberulum*, which was previously known only from the Maritime Antarctic (AADC n.d.). Eleven species known from elsewhere in the Antarctic Conservation Biogeographic Region of East Antarctica are recorded specifically from Thala Hills for the first time: *Arthonia molendoi*, *Pleopsidium chlorophanum*, *Buellia soredians*, *Lecanora polytropa*, *Lecidea lapicida*, *Lecidella stigmatea*, *Pseudephebe pubescens*, *Rhizocarpon adarense*, *R. flavum*, *Umbilicaria africana* and *Polycauliona candelaria*.

The low similarity between lichen species diversity in the eastern and western parts of Thala Hills (Table II) is perhaps surprising as the ecological structure of these assemblages (in terms of growth form and growth substrate) as well as the wider biogeography of the component species are closely similar. However, at small scales, considerable patchiness is characteristic of many elements of Antarctic terrestrial diversity, even though at larger scale many factors that can strongly influence diversity are more predictable, such as overall climate, pedology and underlying geology and other environmental factors (Usher & Booth 1984, Green *et al.* 2011, Convey *et al.* 2014, 2018).

Of the nine moss species recorded, two are new for Thala Hills. The presence of a solitary clump of *Bryum argenteum* in our recent surveys (coll. O. Borodin) has already been reported (Kurbatova *et al.* 2014). This species is known from other locations in Continental Antarctica (Ochyra & Singh 2008, Ochyra *et al.* 2008b). However, the record of *Funaria hygrometrica* is striking, as the species is otherwise known in Antarctica only from sub-Antarctic South Georgia (Ochyra *et al.* 2008b) and a single record (presumed introduced) from one site in Wilkes Land in Continental Antarctica (Ochyra *et al.* 2008a). The species has previously been recorded from actively geothermally heated ground on Deception Island (South Shetland Islands) as a colonist soon after eruptions in 1967/1968 (Collins 1969). However, it only persisted at that location as long as the geothermal activity continued, then rapidly died out (Smith 1984, 2005), which suggests that the species does not have appropriate physiological abilities to support its survival in a Continental Antarctic location such as Thala Hills. The material identified here (and also reported from Wilkes Land) as *F. hygrometrica* may, therefore, require further taxonomic assessment.

Rotifer diversity has previously received very little attention in Thala Hills. Of the freshwater species listed

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in Table III, only *Lepadella patella* and *Keratella cochlearis* have previously been recorded from the oasis specifically, although most of the other species are recorded from other regions of Continental Antarctica (Chatey *et al.* 1981, Everitt 1981, Suren 1990, Kutikova 1991, Dartnall 1995a, 2000, Webster-Brown *et al.* 2010, Hansson *et al.* 2012). Exceptions include *Rhinoglena frontalis*, which is known from sub-Antarctic Heard Island, the Kerguelen archipelago and Macquarie Island (Dartnall 1993, 1995b, De Smet 2001, Dartnall *et al.* 2005), *Pleuretra lineata* known from the Maritime Antarctic (Iakovenko *et al.* 2015) and *Encentrum saundersiae* and *Keratella tecta*, which are new Antarctic records. There are no previous records of rotifers from terrestrial habitats at Thala Hills. Four of the species identified here are known from other parts of Continental Antarctica: *Adineta editae*, *A. vaga vaga*, *A. steineri* and *Philodina gregaria* (Sohlenius *et al.* 1995, Sohlenius & Boström 2005, Webster-Brown *et al.* 2010, Iakovenko *et al.* 2015). *Macrotrachela kallosoma* is a new record from Continental Antarctica, although it has been recorded from the Falkland Islands in the South Atlantic (Kutikova 1991). The subspecies *A. vaga minor* has not previously been recorded from Antarctica or the sub-Antarctic.

In the marine environment, all fish species identified excluding *Trematomus hansonii* and *Trematomus pennellii* have been recorded previously from the Thala Hills shoreline or the wider Cosmonaut Sea (Jakubowski 1970, 1975, Rakusa-Suszczewski 1972a, Jakubowski & Rembiszewski 1974, Dewitt *et al.* 1990).

Acanthocephalans have not been studied in the region of the Cosmonaut Sea. While all three parasitic acanthocephalan species are new records for the oasis, they have been noted previously from Antarctic waters, and members of the genus *Metacanthocephalus* have been noted widely around Continental Antarctica (Rocka 2006).

All marine nematode species recorded here are widely distributed around Antarctica and also sub-Antarctic South Georgia (Rocka 2006). However, only *Contracaecum radiatum* has explicitly been recorded from the Cosmonaut Sea (WoRMS 2021b). All of our records of Echinodermata, Mollusca and several other taxa confirm previous reports from the Cosmonaut Sea, while *Odontaster validus* and *Sterechinus neumayeri* have explicitly been reported from the coastal zone near Thala Hills (Gruzov & Pushkin 1973). New species records for the region are reported for Polychaeta. Overall, the macrobenthos communities present along the coast of Thala Hills show no distinct differences from the well-described communities of Prydz Bay (Commonwealth Sea, East Antarctica) (Saucede *et al.* 2014, Sirenko *et al.* 2017). Although no studies of the birds and mammals present around Thala Hills are available, all species present are well known from the wider region of East Antarctica (Del Hoyo *et al.* 1992, Ropert-Coudert *et al.* 2014).

Biogeographical patterns

The Thala Hills terrestrial biota includes a high proportion of endemic species (Fig. 5), a feature that is being increasingly strongly recognized across Antarctica (Pugh & Convey 2008, Convey *et al.* 2020). Most of the lichens present in Thala Hills are widely represented in polar vegetation and are either Antarctic endemics or have bipolar distributions. However, several species are cosmopolitan (e.g. *Amandinea punctata*, *Flavoplaca citrina*, *Physcia caesia*, *Lecanora polytropa*, *Lecidea lapicida*, *Porpidia crustulata*, *Rhizocarpon geographicum*) (Singh *et al.* 2015), with a small number having Southern Hemisphere distributions, including *Acarospora gwynnii*, *Umbilicaria africana*, *Usnea antarctica*, *Stereocaulon antarcticum* (Singh *et al.* 2015), *Rhizocarpon adarense* (Øvstedal & Smith 2001, McCarthy & Elix 2014). Moss diversity, while being lower overall, had a slightly greater proportion of Antarctic endemic and bipolar species, along with the cosmopolitan *Ceratodon purpureus*, *Bryum argenteum* and *B. archangelicum* (Ochyra *et al.* 2008b).

The relatively high number of cosmopolitan species apparently characterizing the terrestrial and freshwater rotifer faunas of Thala Hills may be a reflection of the lack of modern taxonomic analyses, including the application of molecular approaches, applied to material from this region. Where such studies have been applied (e.g. Iakovenko *et al.* 2015), the general conclusion is that Antarctic representatives are clearly distinct from other relatives globally, as is the case in other groups of terrestrial fauna (reviewed by Convey *et al.* 2020). There is a similar lack of up-to-date taxonomic reconsideration of tardigrades across much of Antarctica. Few tardigrades were directly recorded in the current study, with the majority of species records only being available in older literature. Of those records, five species are currently considered to be cosmopolitan and seven to be Antarctic endemics. The species *Echiniscus kerguelensis* and *Hebesuncus conjungens* currently have bipolar distributions. Endemic species recorded include *Acutuncus antarcticus*, considered to be one of the most widely distributed tardigrades in Antarctica (Tsujimoto *et al.* 2014). However, the latest research indicates that even this apparently well-known species most likely represents a species group with geographically distinct intra-Antarctic distributions, further highlighting the need for up-to-date taxonomic re-analyses (Short 2021). *Diphascon langhovdense* is also an Antarctic endemic, along with five other species originally described from this study area but not apparently subjected to subsequent study.

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In the marine communities assessed here, most recorded species are typical of and only known from Antarctic and sub-Antarctic waters (Danis *et al.* 2014, Saucede *et al.* 2014, Sirenko *et al.* 2017, Stöhr *et al.* 2020). However, the benthic *Odontaster validus* and *Serpula narconensis* have been reported from the southern Pacific and south-west Atlantic Oceans (Blom & Moriarty 2021, Mah 2021, Orrell 2021, Read & Fauchald 2021) and *Perkinsiana magalhaensis* from South America (Häussermann & Försterra 2009, Bigatti 2015). All recorded fish species are widely distributed in the Southern Ocean (Andriyashev 1964, Dewitt *et al.* 1990, Gon 1990, Duhamel *et al.* 2014). The fish parasites, acanthocephalans and nematode worms show both restricted and globally widespread distributions (Rocka 2006, Bezerra *et al.* 2021a, 2021b, WoRMS 2021a, 2021b).

Acknowledgements

We are grateful to Igor S. Smirnov, Boris I. Sirenko, Sergey Yu. Gagaev and Alexey V. Neelov from the Zoological Institute, Russian Academy of Sciences, for their help in identifying marine benthos and fish. We thank all members of the Belarus Antarctic Expeditions for their assistance in sampling and return of material to Belarus, as well as the officers and crew of the Russian scientific vessels for logistic support in the transfer of samples. We acknowledge Alex Borisenko and Maria Kuzmina from Center of Biodiversity Genomics (Guelph, Canada) for their promotion in creating the reference library in Barcode of Life Data System. In addition, we thank two anonymous reviews for their helpful comments.

Author contributions

DL combined all literature data as well as field data, including those collected by himself (2018–19), and prepared the text, figures and supplemental materials. PC made significant contributions in preparing the text and interpreting the data. OB, VM and YH have been the main implementers of the surveys on site throughout the BAEs (2008–2018). AG, the chief of the expedition, facilitated the logistic and transport support for sampling during all seasons. Several authors identified species in specific taxonomic groups: VV and NM - rotifers (with DL in case of bdelloids); AY - lichens; and TS - fish parasites.

Financial support

This study was conducted in the framework of the Belarus National Antarctic Program's projects 'Monitoring of the Polar Regions of the Earth and Ensuring the Activities of Arctic and Antarctic Expeditions' (2007–2015) and 'Monitoring of Polar Regions of the Earth, Creation of the Belarusian Antarctic Station and Support of the activities of Polar Expeditions' (2016–2020). This paper also contributes to the SCAR 'State of the Antarctic Ecosystem' programme. Peter Convey is supported by NERC core funding to the British Antarctic Survey's 'Biodiversity, Evolution and Adaptation' Team.

Supplemental material

Five supplemental tables will be found at https://doi.org/10.1017/S0954102021000328.

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