Global situation in Polar ecology and challenges in science we are dealing with at present

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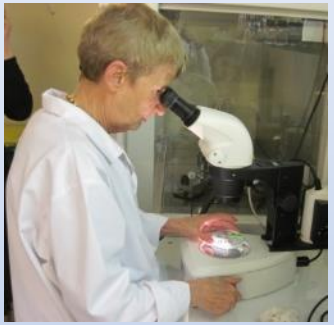

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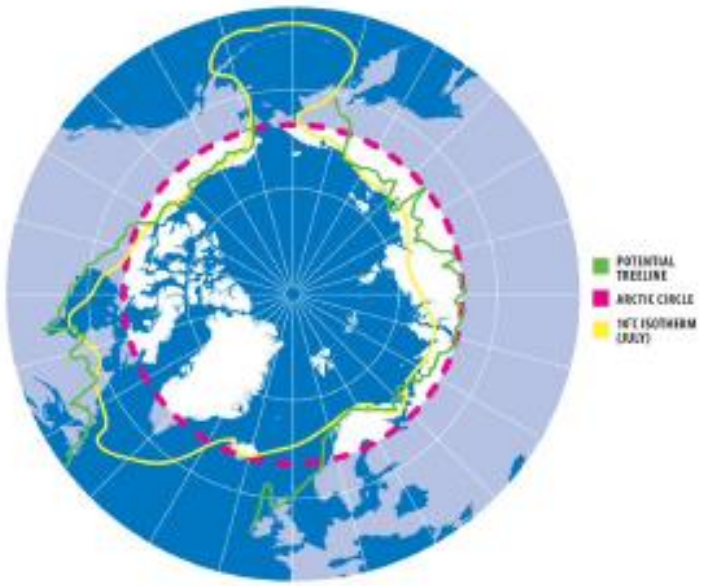
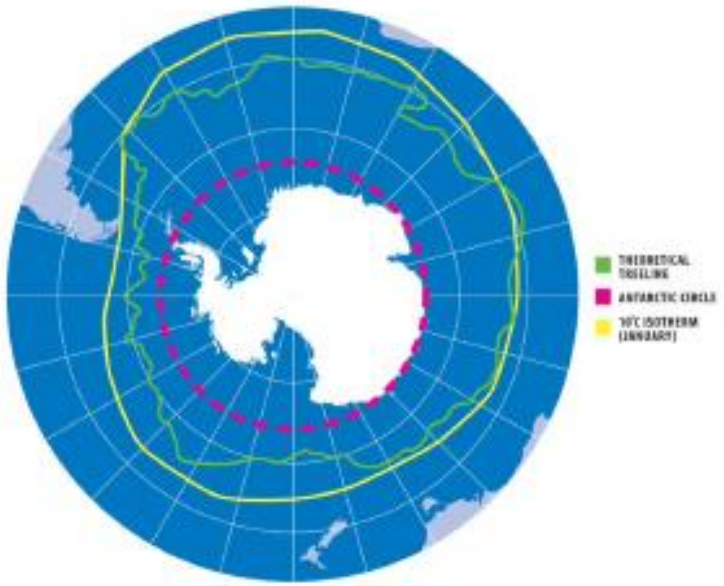




Arctic		Antarctic
2,218	Vascular plants	2
900	Mosses and Liverworts	125
1,750	Lichens	350
766	Algae and cyanobacteria	700

FIGURE 1 | Extent of contemporary Arctic and Antarctic habitats for polar photoautotrophs. Red line: Arctic/Antarctic Circle; Yellow line: 10°C summer isotherm; Green line: treeline. Arctic treeline calculated as extent of summer mean temperature at or above 6.4°C, with the growing season defined as the sum of days with a daily mean temperature of 0.9°C and not falling below 94 such days (blue line; Paulsen and Körner, 2014). Biodiversity data shows number of species, and was collated from the National Snow and Ice Data Center (https://nsidc.org/cryosphere/frozenground/plants.html) and Arctic Biodiversity Assessment (http://www.arcticbiodiversity.is/the-report/chapters/plants) (Arctic), and British Antarctic Survey (http://www.antarctica.ac.uk/about_antarctica/wildlife/plants) and Australian Antarctic Division (http://www.antarctica.gov.au/about-antarctica/wildlife/plants) (Antarctic).

Antarctica unique biodiversity

Threats to the Antarctic environments and biodiversity

Science and policy tools

Historical biogeography of Polar Regions

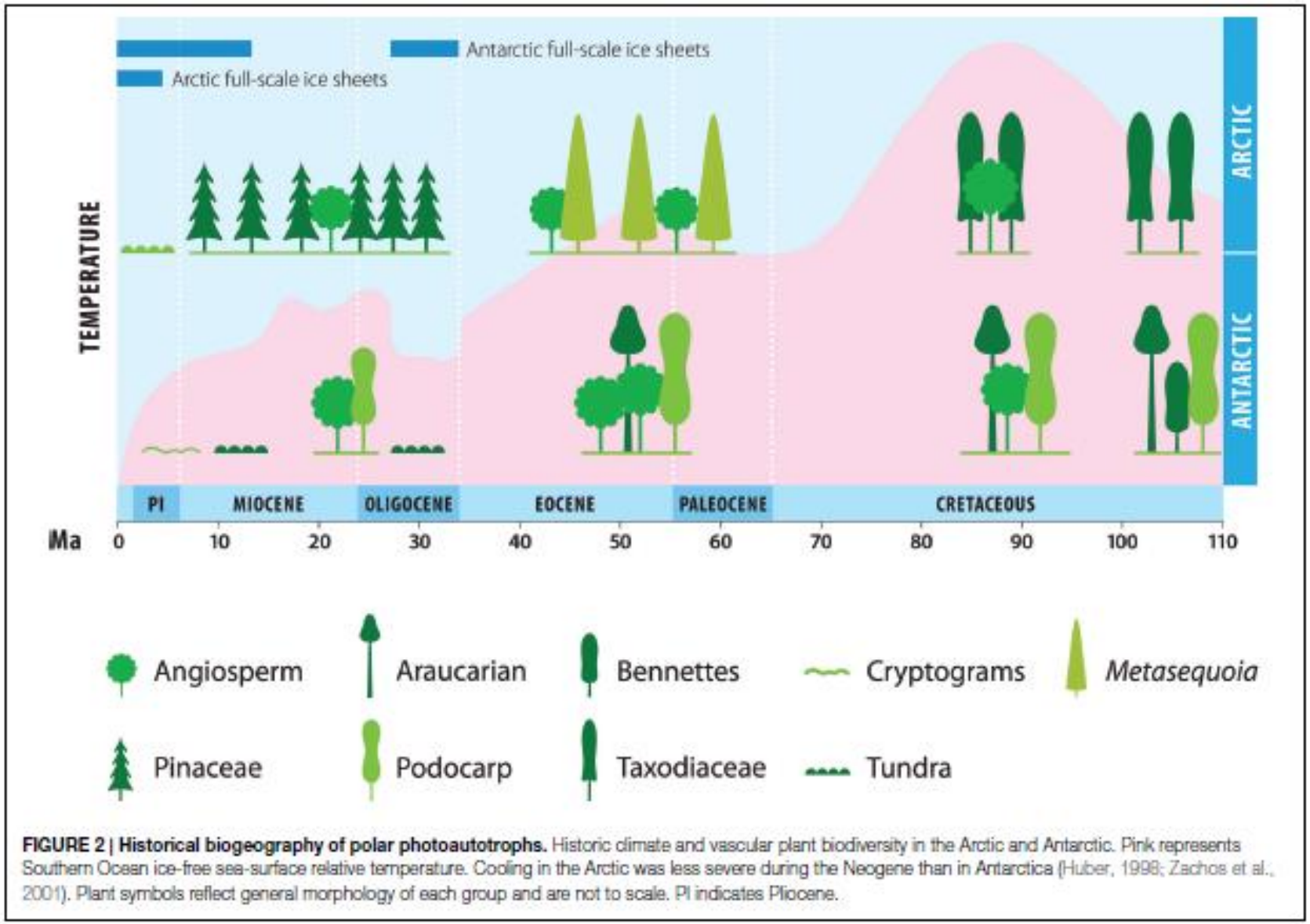


FIGURE 2 | Historical biogeography of polar photoautotrophs. Historic climate and vascular plant biodiversity in the Arctic and Antarctic. Pink represents Southern Ocean ice-free sea-surface relative temperature. Cooling in the Arctic was less severe during the Neogene than in Antarctica (Huber, 1998; Zachos et al., 2001). Plant symbols reflect general morphology of each group and are not to scale. PI indicates Pliocene.

Who is living on the Antarctic continent?

Non permanent inhabitants of the continent

Animals feeding in the sea

www.coolantarctica.com www.hu.mtu.edu http://www.ontwerpatelier.nl/

Who is living on the Antarctic continent?

Two species of higher plants:

Colobanthus quitensis

Deschampsia antarctica

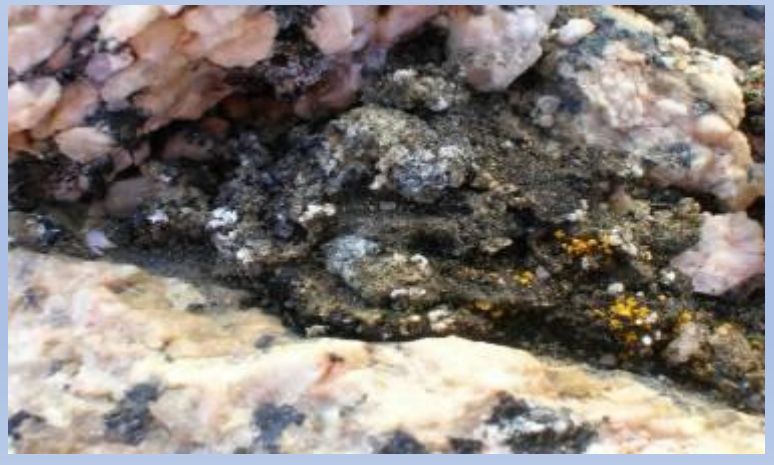
Photos: © Ron Lewis Smith, British Antarctic Survey

Mosses

www.coolantarctica.com

Lichens

Damien Ertz, Jardin Botanique de Belgique



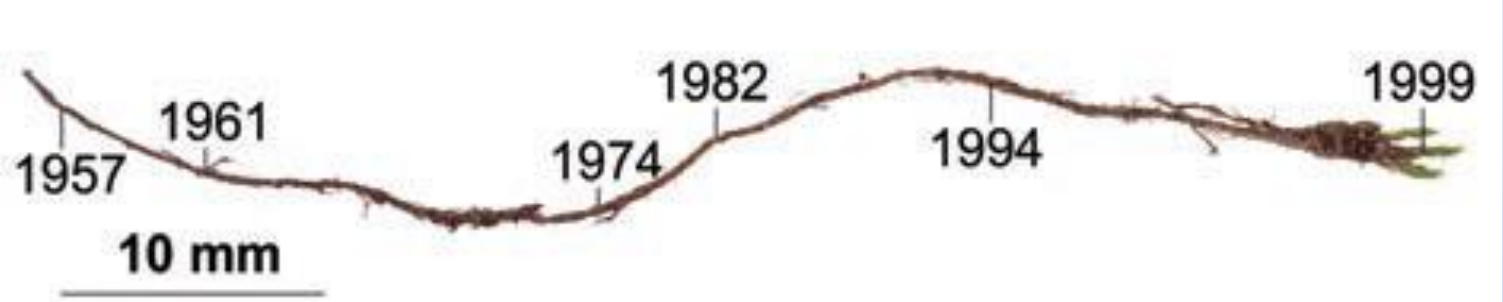
Damien Ertz, Jardin Botanique de Belgique

Australian Antarctic Magazine 14: 2008

A typical moss turf from Antarctic Specially Protected Area 135 near Casey station.

The undulations are caused by frost heaving. Most of the moss shown here is the endemic *Schistidium antarctici* (olive green in colour), which is the dominant moss species in the area. The bright green mosses at the front of the image are *Bryum pseudotriquetrum* and the red patches on the ridge tops are likely to be *Ceratodon purpureus.*

Growth rate?

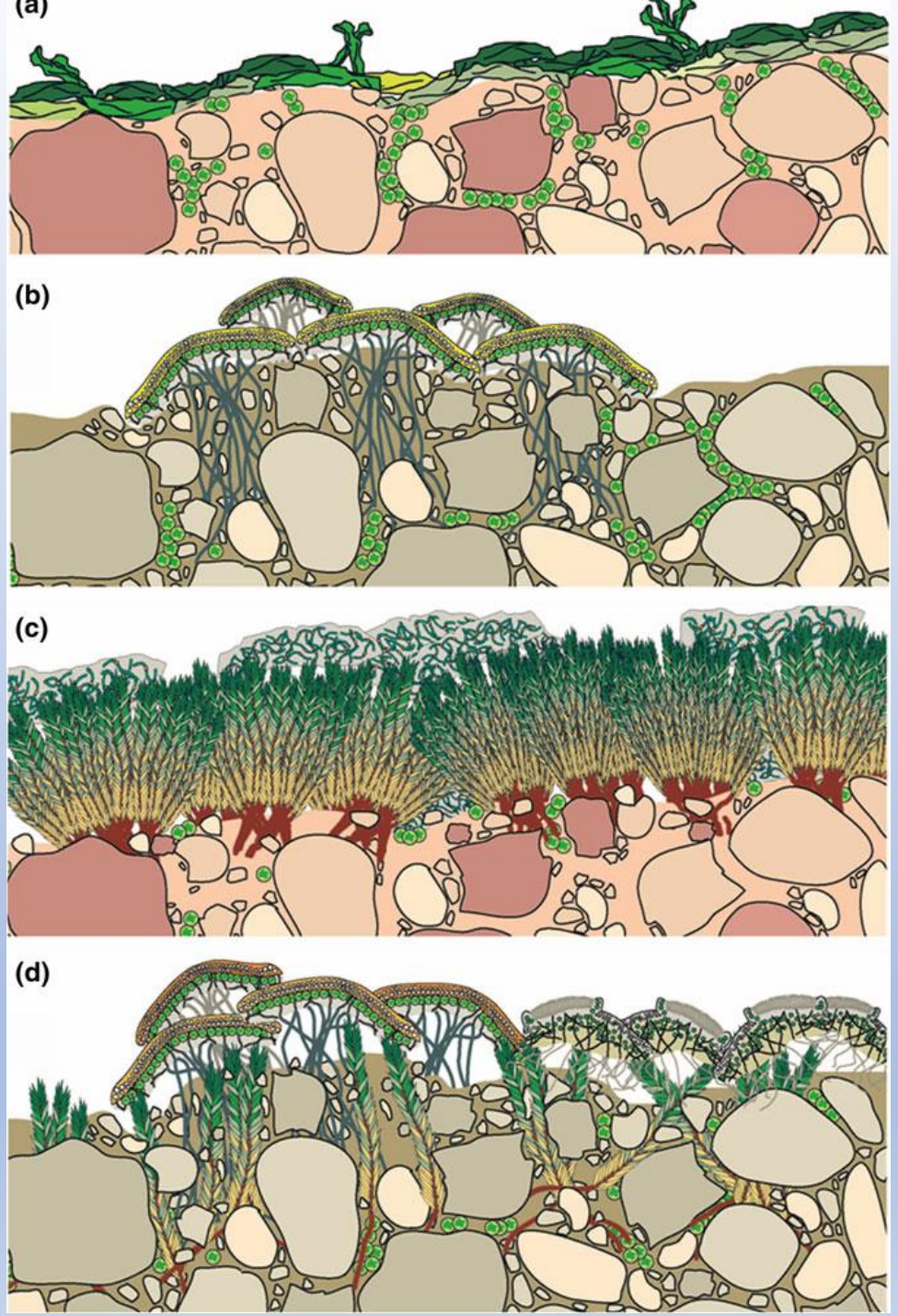


Radiocarbon isotope analysis has allowed researchers to determine the age and growth rate of moss shoots.

→ average growth rates between 0.4 and 1.6 mm per year.

Schemes of typical Antarctic **biological soil crusts**

a P. crispa—green algae crust.
b Lichen—green algae crust.
c Bryophyte—cyanobacterial crust,
d Bryophyte—lichen crust



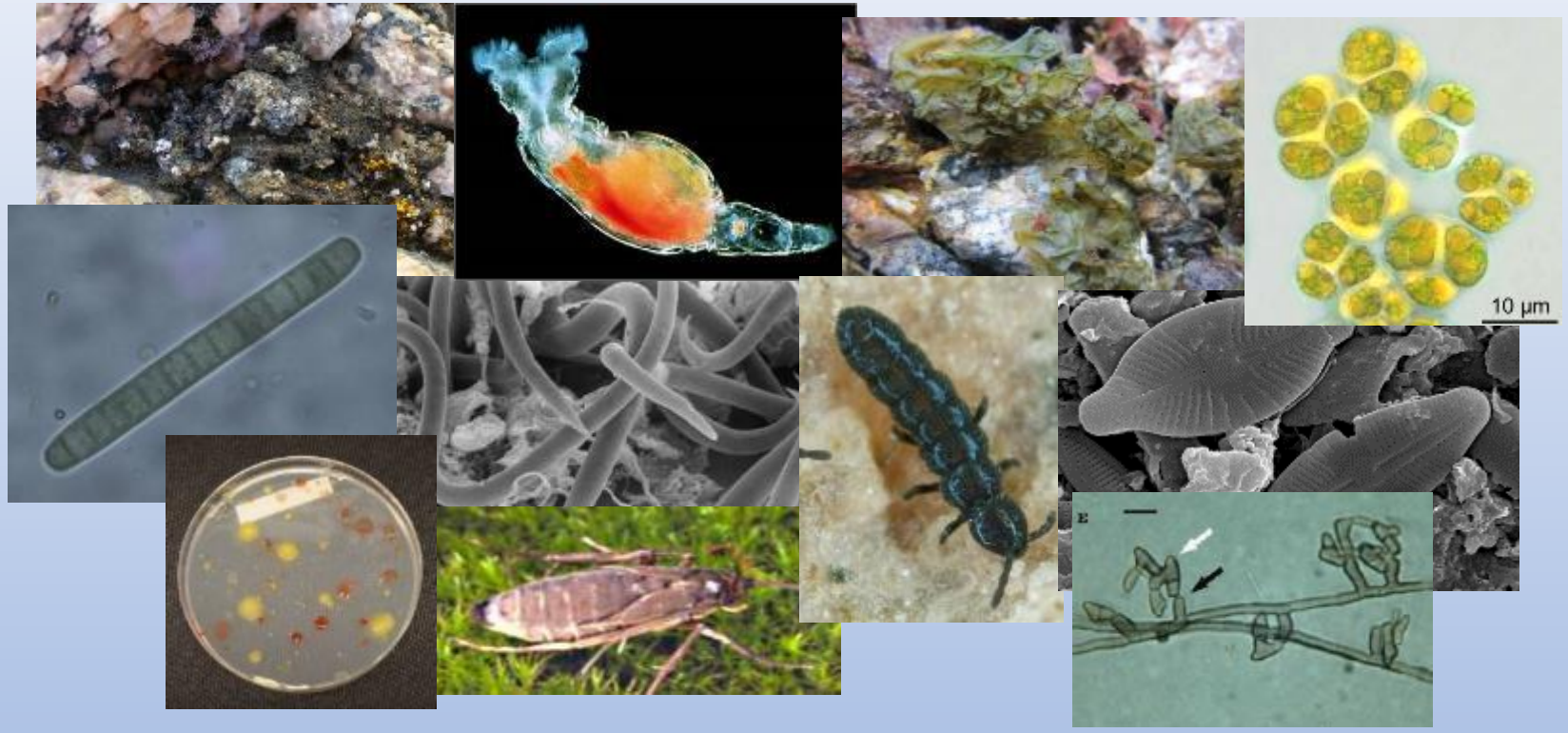
Buedel et al. 2014

Microbial colonization in hyperarid deserts.

a Landscape of Miers Valleys, Antarctica illustrating **a desert pavement** covered with rocks supporting the development of b **hypolith** and c **endolith** communities.
(Photograph
credits: Don A. Cowan)

Cowan et al 2014)

The **permanent inhabitants** on the Antarctic continent are **tiny creatures or microorganisms**



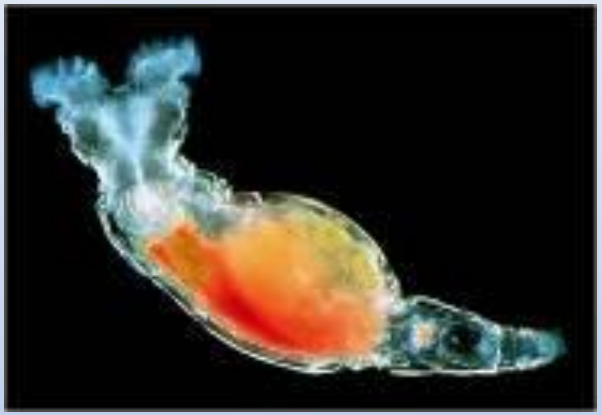
Microorganisms can even be found in the continental ice sheet or the deep subsurface!

The permanent inhabitants on the Antarctic continent are tiny creatures or microorganisms

The unsung heroes of Antarctica !

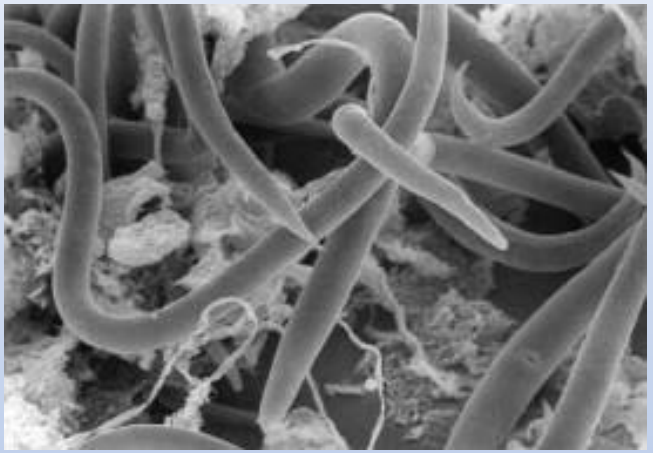
A few invertebrates: nematodes, tardigrades, rotifers, copepods, collembola and acarians

Rotifer : *Philodina gregaria*



Copepod

Nematode : *Panagrolaimus davidi*



Copyright: Uwe Kils

Collembola: *Gomphiocephalus hodgsoni*

Wingless mite: *Pringleophaga kerguelensis*

http://www.micrographia.com/
http://www.rsnz.org/funding/marsden_fund

http://www.aad.gov.au/default.asp?casid=1749
http://bio.waikato.ac.nz/staff/hogg_research.shtml

Acarian, Utsteinen

Collembola, Utsteinen

Acarian, Teltet

Rhagidia, an acarian, the antarctic ‘lion’

Its prey, the ‘antarctic antilope’ : the springtail

http://www.reuters.com/article/2009/01/13/us-antarctica-bugs-idUSTRE50C0B020090113

Belgica antarctica: the largest terrestrial insect!

Emile Racovitza, naturalist of the Belgica

2-6 mm de long

Wingless diptera

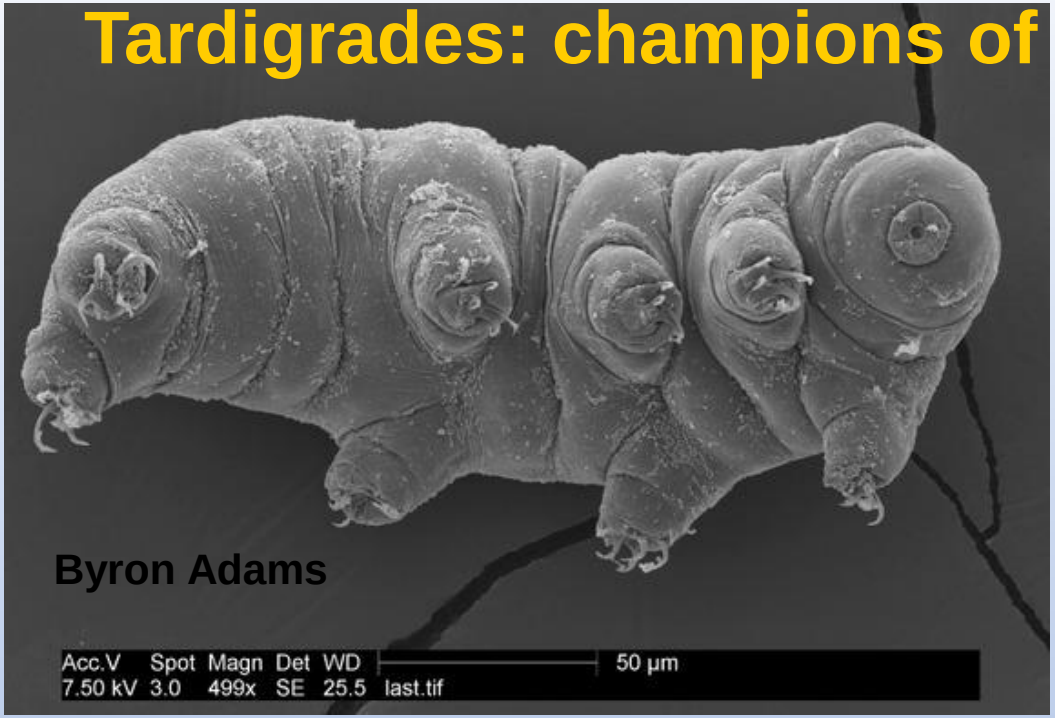
Larvae living 2 years and very resistant

Adults living 10 days

Studied to elucidate its adaptation strategies (Rhinehart J, USDA, USA)

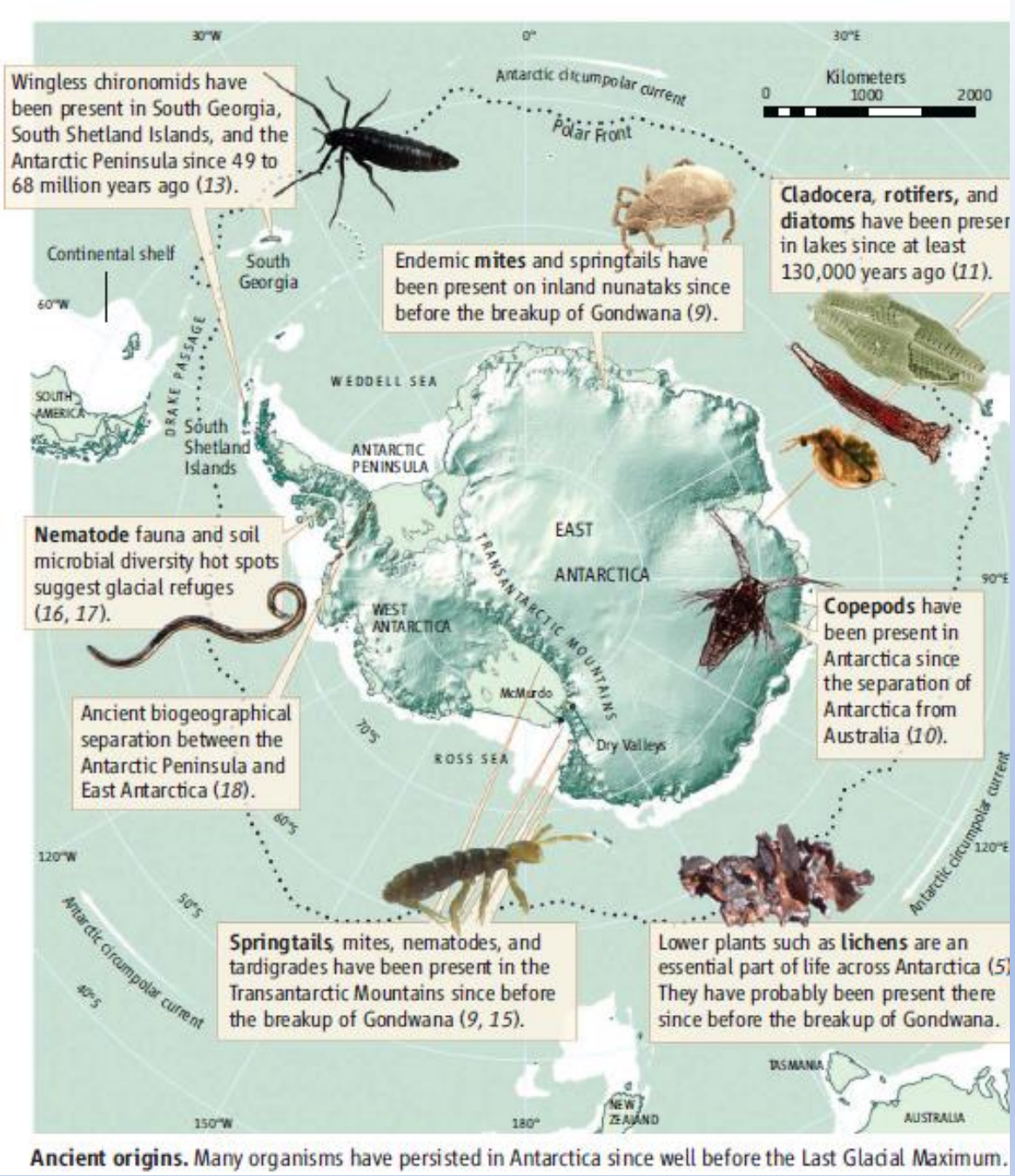
http://www.units.muohio.edu/cryolab/education/antarcticbestiary_terrestrial.htm#Belgica

Tardigrades: champions of anhydrobiosis



Like the nematodes, these algae-eaters alors called ‘water bears’ can enter a anhydrobiosis state where metabolism is stopped.

Mplecular evidences show that the present inhabitants of the continent are residing tere since much before the last glaciation and maybe even before the continent started to cool.



Ancient origins. Many organisms have persisted in Antarctica since well before the Last Glacial Maximum.

Terrestrial life forms that survived on the continent to the glaciation cycles since millions of years!

Convey & Stevens, Science, 2007

Antarctica is essentially a microbial continent

- Large biodiversity of adapted microorganisms lives permanently in the ice-free areas (about 44,000 km^2).

- Presence of potential endemic taxa

- Survival in glacial refugia since the continent moved away from Australia and South America

- They show biogeographic patterns

- Antarctic microorganisms may contain novel molecules with potentially pharmaceutical or biotechnological interest

Microorganisms are generally invisible to the humain eye

-Need a microscope and relevant expertise to see and characterize them

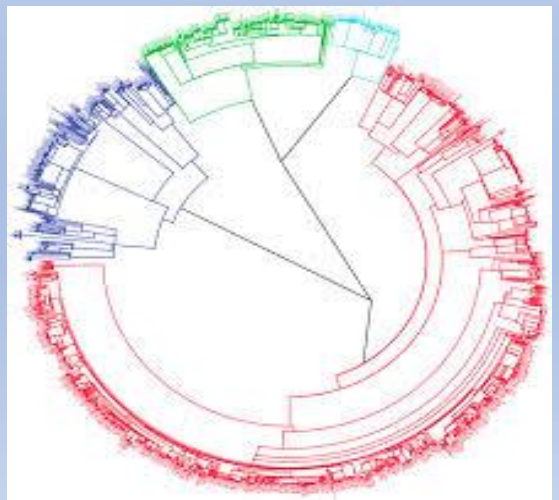
-Need molecular methods to determine their identity.

New sensitive High-Throughput analyses accessible

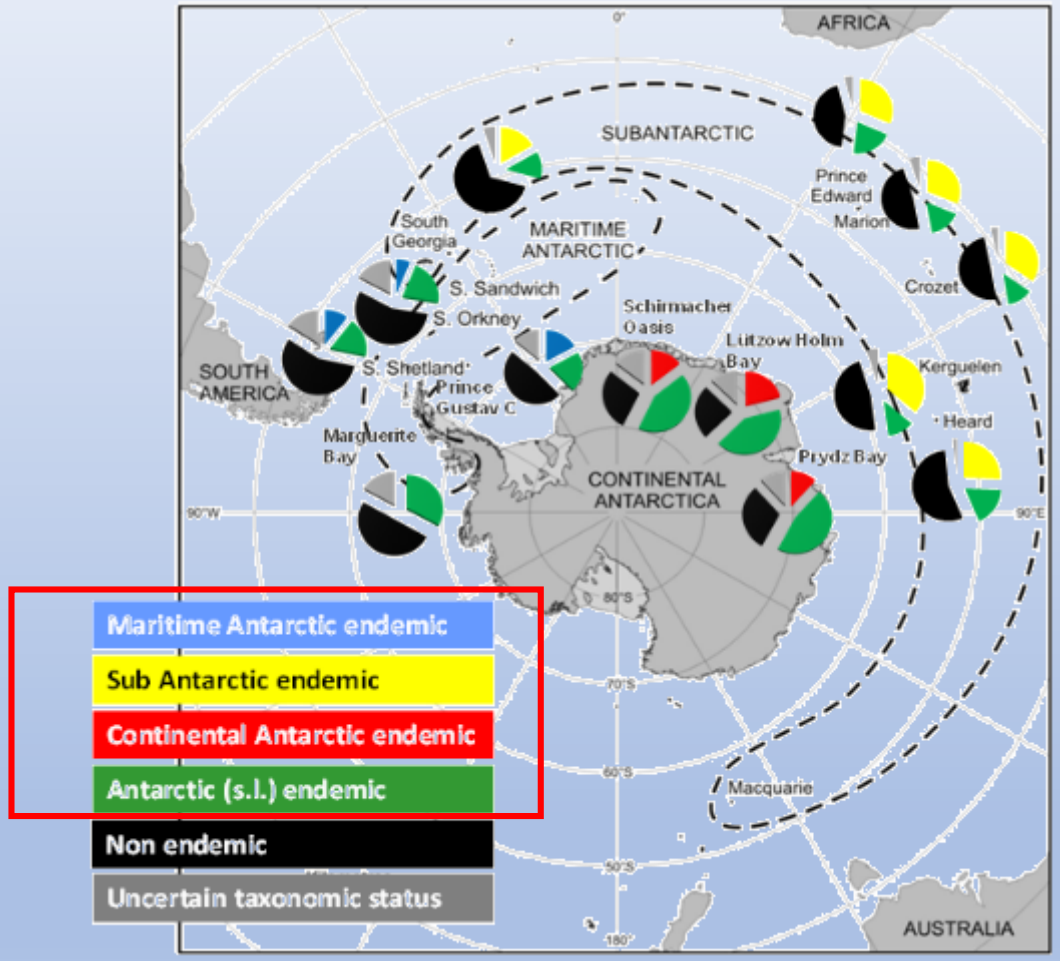
- Constant progresses in molecular methods (NGS)

- Potential to describe the microbial communities with unprecedented details without preconceived expectations

Will there still be pristine Antarctic areas to study the native microbial flora, its functioning and properties?

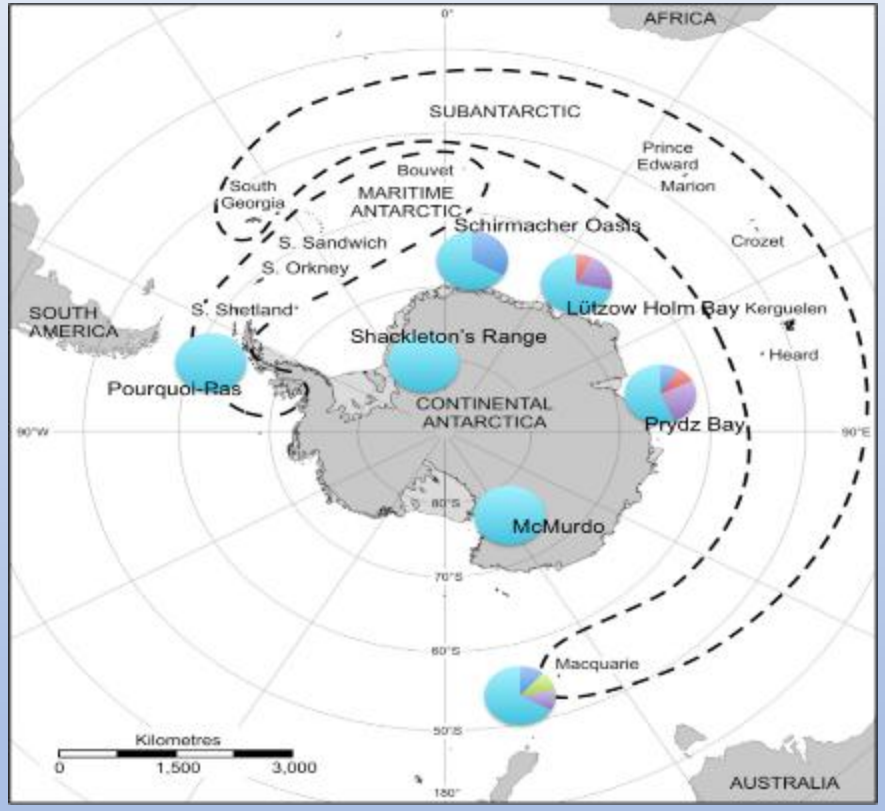


In freshwater diatoms, up to **60% of potential endemism** was observed in continental Antarctica

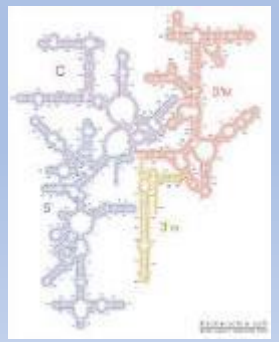


Pinseel E et al.

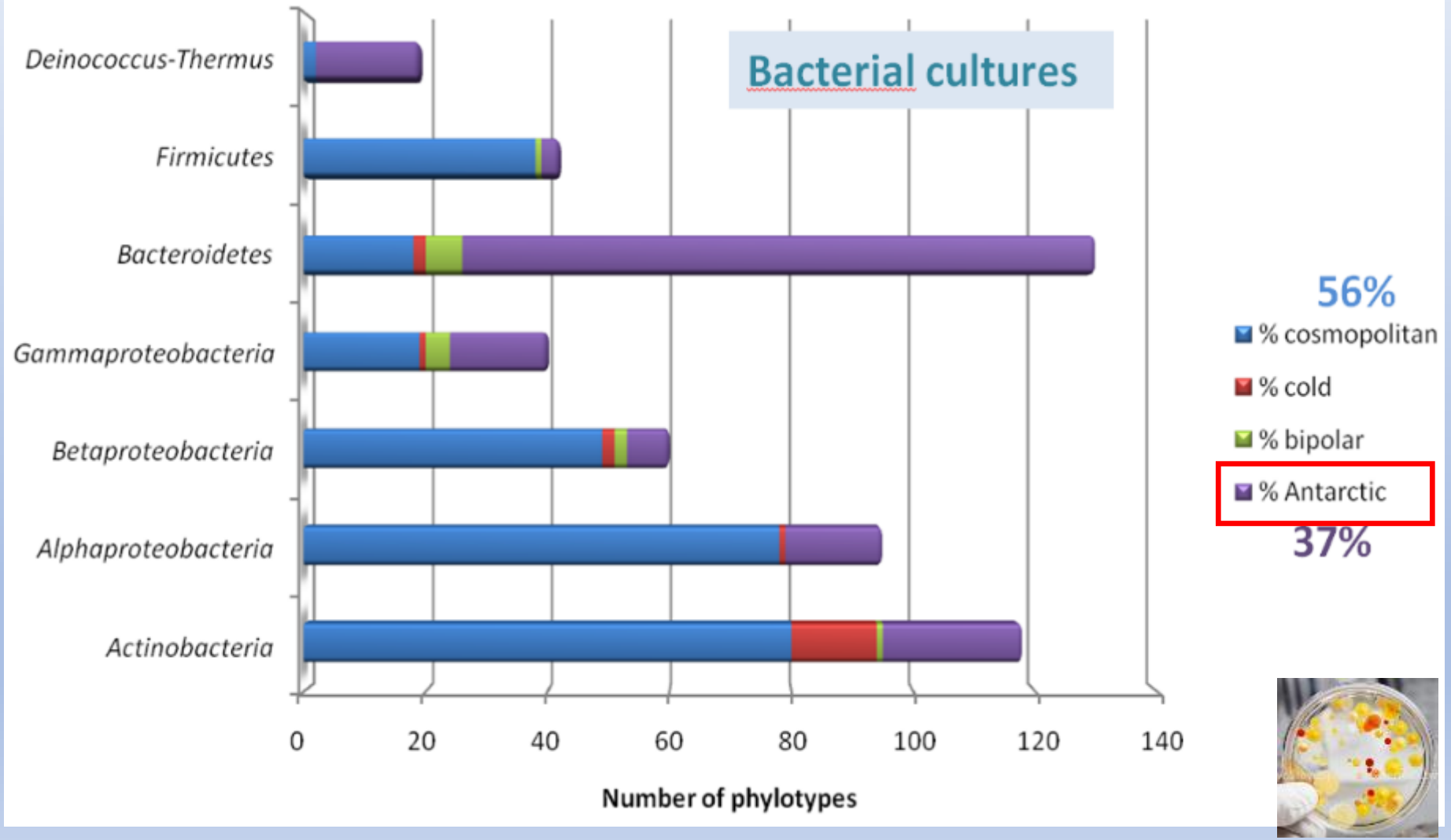
In aquatic cyanobacteria, **about 10-15 %** of the 16S rRNA sequences seem to be **endemic to Antarctica**



- Regional endemic
- Antarctic endemic
- Sub-polar
- Alpine-polar
- Cosmopolite



In bacteria, the isolation of strains from 9 aquatic and terrestrial samples : **37 % seemed to be restricted to Antarctica**, and **many were novel to science**



- Literature data : **endemism of microbial taxa is relatively high in all the biogeographical provinces**
- Depending on the studied regions, **the proportions of cosmopolitan and endemic taxa are variable**. In the case of Diatoms, the SubAntarctic province has a higher level of regional endemism than the Maritime province.

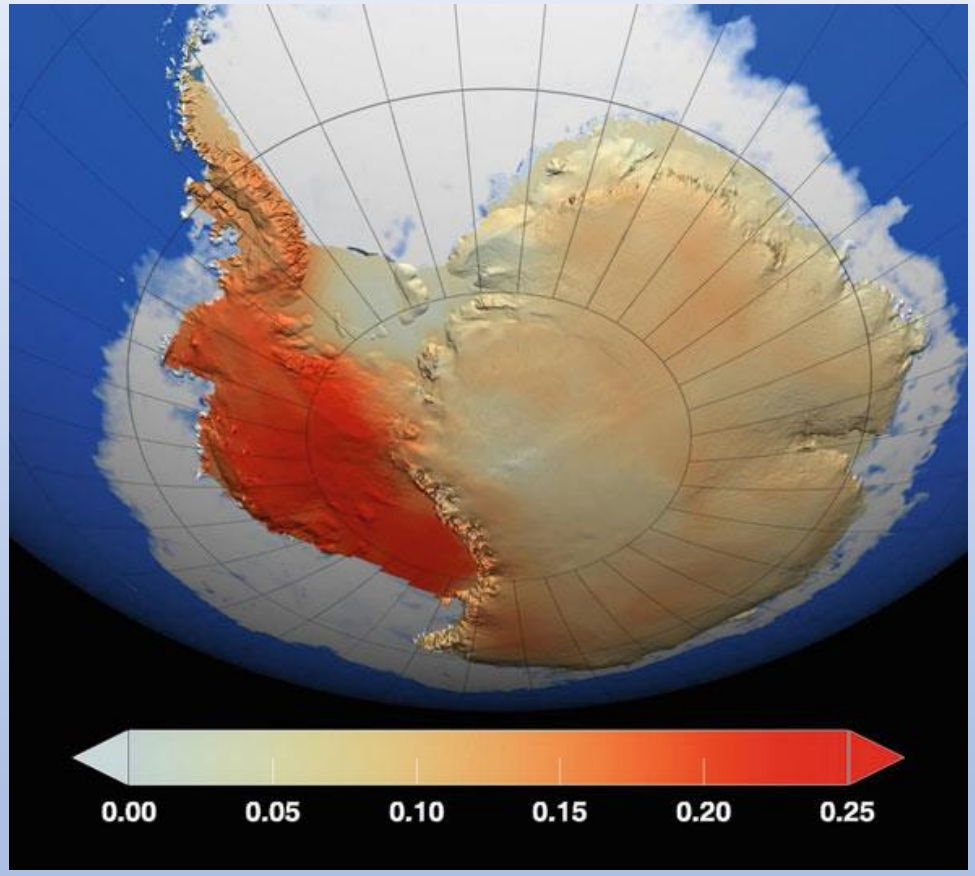
- In lakes situated along a limnological gradient, the microbial communities were **structured by the climate-related variables: salinity** (and related variables)**, lake water depth and nutrient concentrations**,
- **Molecular clock analyses** in diatoms and green algae revealed that some taxa have a long evolutionary history in Antarctica and that **long-term survival occurred in glacial refugia. This could explain the existence of province endemic taxa.**

Antarctica unique biodiversity

Threats to the Antarctic environments and biodiversity

Science and policy tools

Climate change !



Colour image of Antarctica showing temperature changes that have occurred within the past 50 years.

Hogg et al. 2014

Threats to Soil Communities: Human Impacts !

Kevin A. Hughes

a **Quarrying activities** leading to the destruction of lichen habitat and storm petrel breeding ground (Photo: H.-U. Peter).
b **Vehicle tracks** over vegetated ground away from the designated road network (Photo: O. Mustafa).
c Open **dumping of waste** near a; Photo: C. Buesser).
d An **oil spill** on snow-covered ground, with station personnel attempting to remove the oil-impregnated snow (Photo: Bellingshausen)

REVIEW

doi:10.1038/nature14505

The changing form of Antarctic biodiversity

Nature 2015

Steven L. Chown[1], Andrew Clarke[2], Ceridwen I. Fraser[3], S. Craig Cary[4], Katherine L. Moon[1,3] & Melodie A. McGeoch[1]

Antarctic biodiversity is **extensive**, ecologically **diverse** and biogeographically **structured**. Understanding of how this diversity is **distributed** in marine and terrestrial systems, the mechanisms underlying its **spatial variation**, and **the significance of the microbiota** is growing rapidly.

Broadly recognizable **drivers** of diversity variation include **energy availab**ility and **historical refugia**. The impacts of local **human activities** and global **environmental change** nonetheless pose challenges to the current and future understanding of Antarctic biodiversity.

Life in the Antarctic and the Southern Ocean is surprisingly **rich**, and as much **at risk** from environmental change as it is elsewhere.

Biological Conservation 232 (2019) 253–257

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

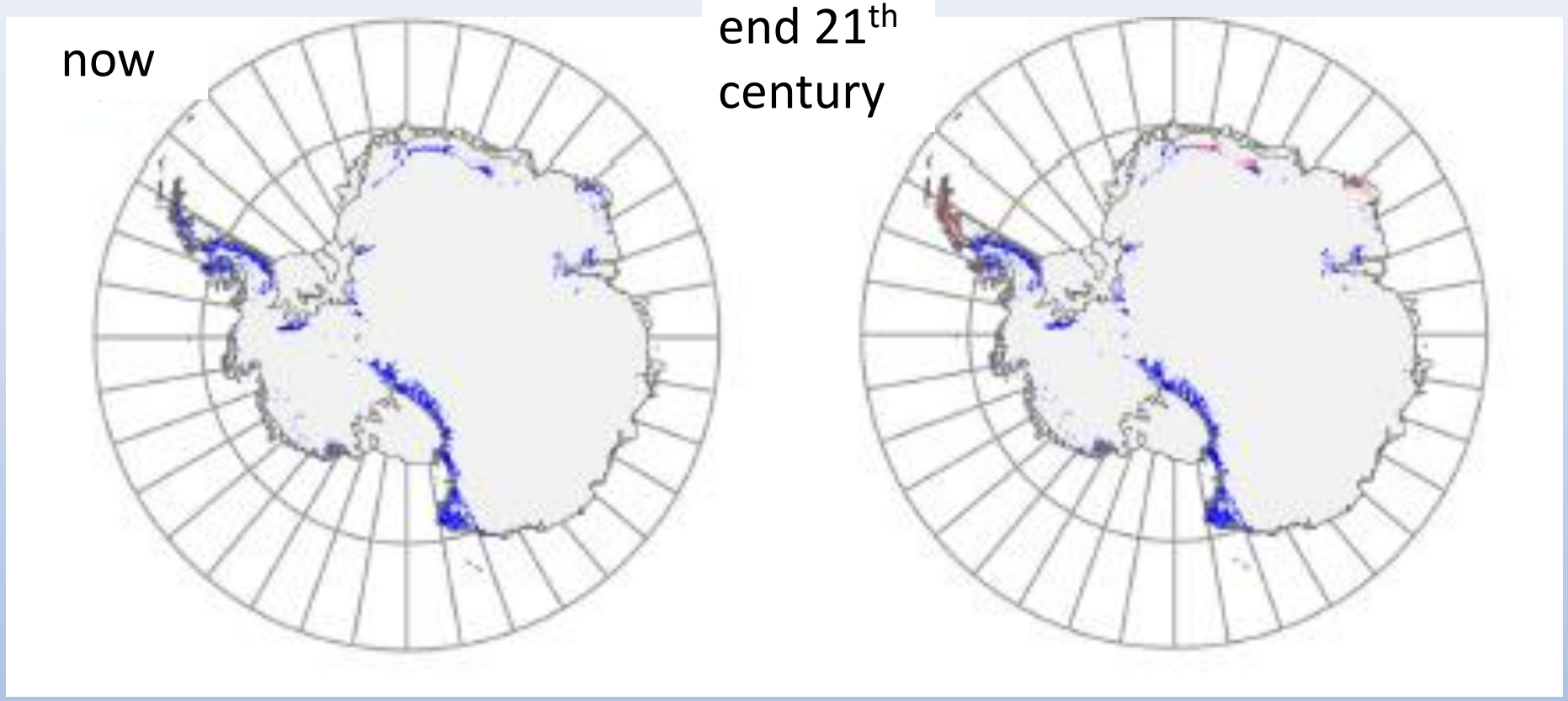
Short communication

Ice-free area expansion compounds the non-native species threat to Antarctic terrestrial biodiversity

Grant A. Duffy[a,*], Jasmine R. Lee[a,b]

Warming across ice-covered regions will result in changes to both the physical and climatic environment, revealing **new ice-free** habitats and **new climatically suitable habitats** for non-native species establishment

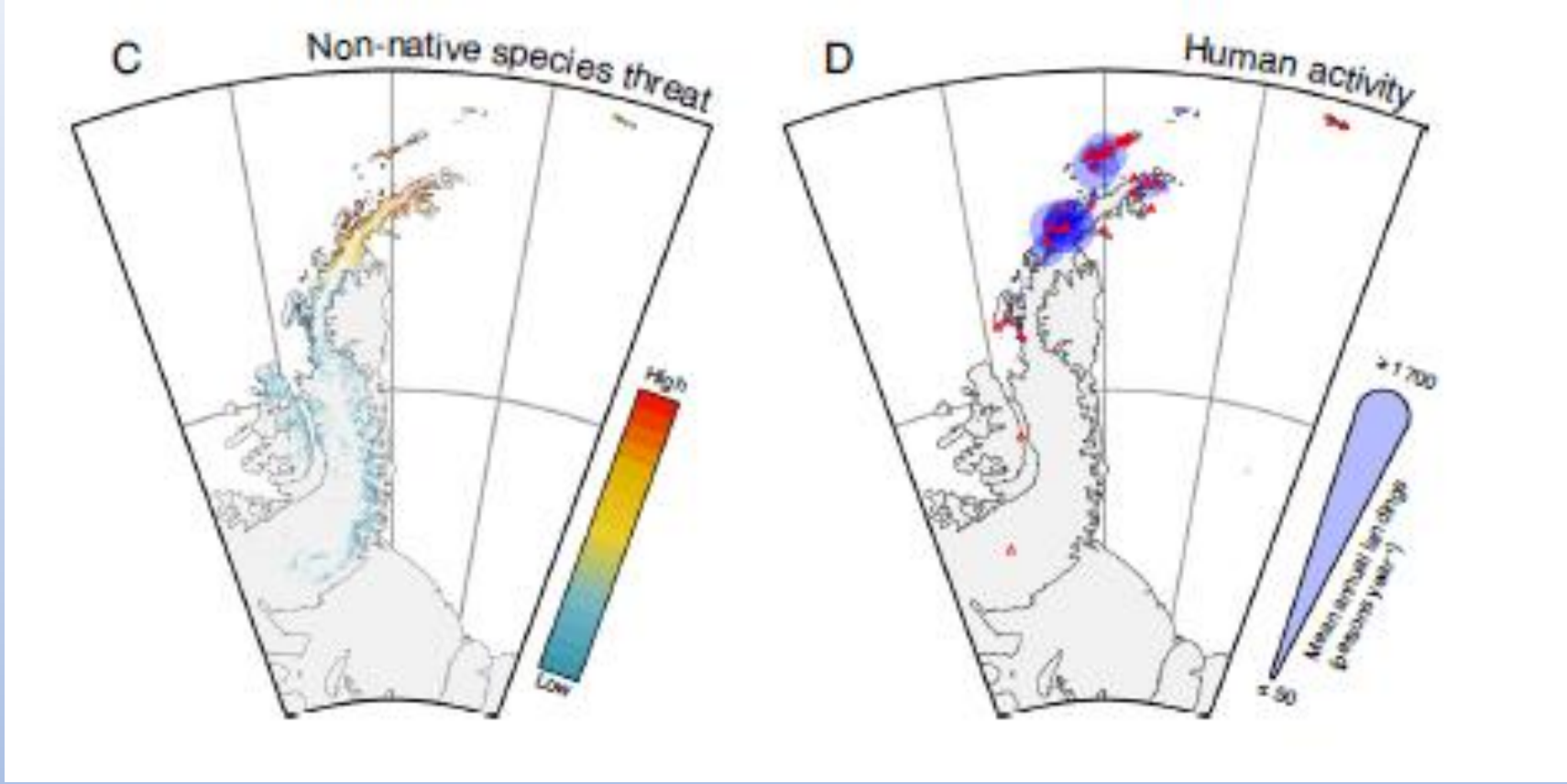
Ice-free areas across the Antarctic continent



Areas coloured blue are ice-free but **unsuitable** for any of the 24 modelled species.

Areas coloured red are ice-free and **climatically suitable** for at least one of the modelled non-native species

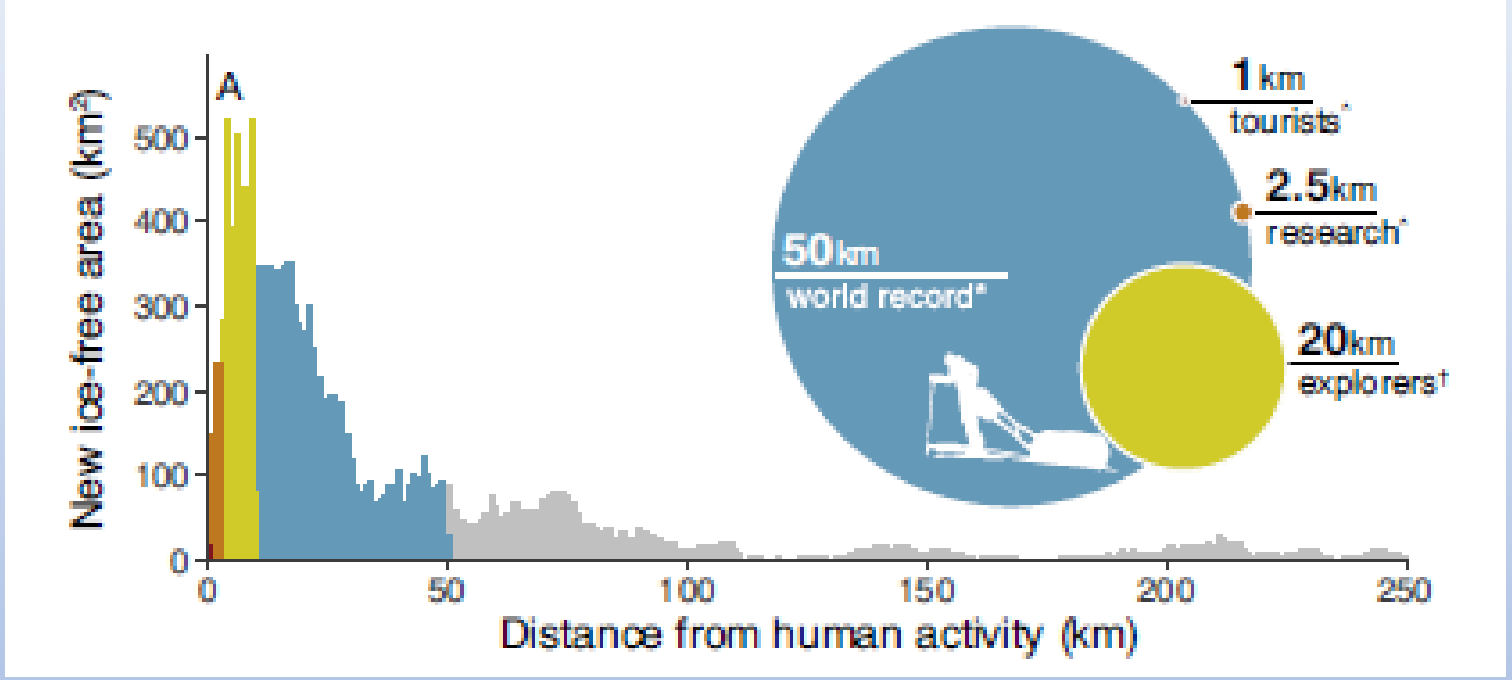
Overlap Non-Native Species threat and human activity



NNS threat predicted for icefree areas by the end of the 21st century (C) and current human activity (D) across the Antarctic Peninsula.

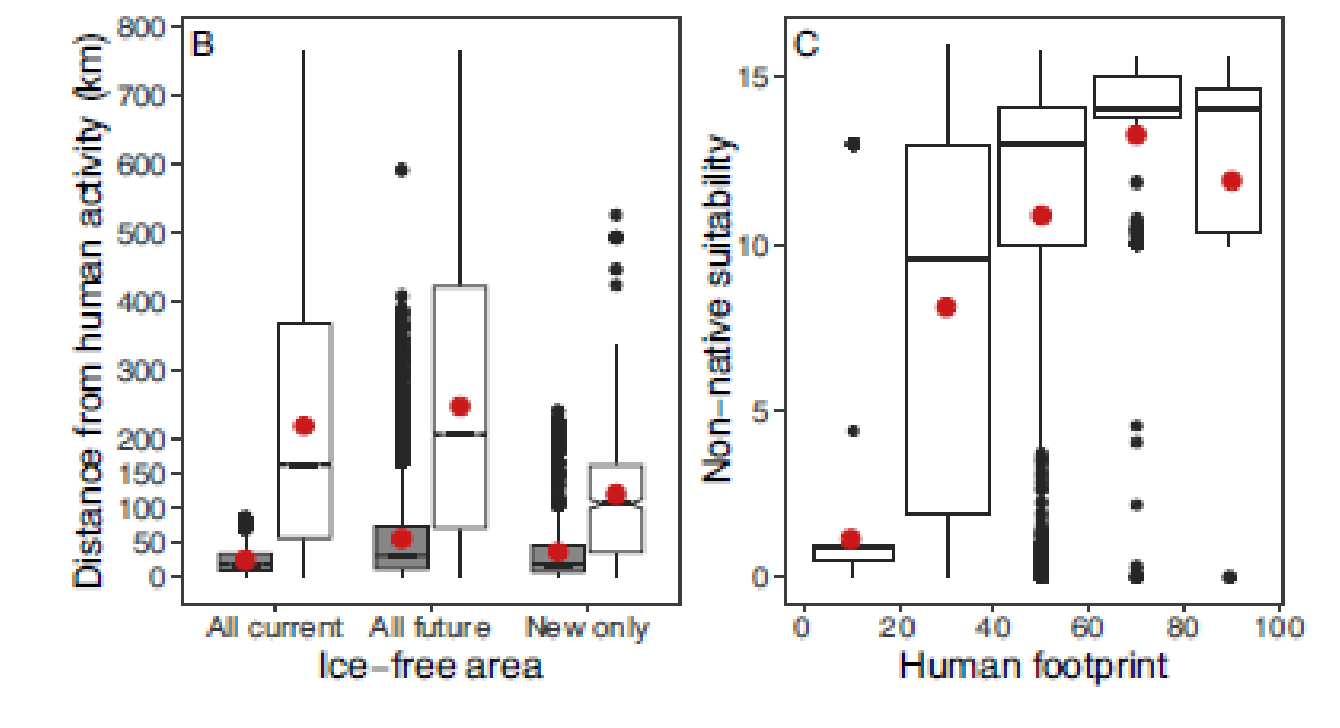
Blue circles represent sites of ship-based tourist landings, scaled by the frequency of landings. Red triangles represent the location of permanent (filled) and seasonal (open) research bases.

Predicted new ice-free area within n kilometres of human activity



Bars colour based on distance thresholds, which represent the area of influence of: tourists (red), researchers (orange), explorers (yellow), and the world record for daily unassisted/unpowered travel distance (blue).

Relation between suitability for climatic suitability for NNS and site of human activities



Ice-free areas that were climatically suitable for at least one non-native species (filled boxes; B) were consistently closer to human activity than ice-free areas that were unsuitable for all species modelled (empty boxes; B).

Future ice-free areas with the highest human footprint scores (C) overlapped with high non-native species suitability (number of species, of the 24 modelled, for which the climate is suitable). Red points represent mean values.

Concept of Human footprint

Human footprint = **spatial pressure** on Antarctic ice-free ground, due to existing (i.e. currently operating facilities) or potential presence (in terms of accessibility) of any **human activity** within the continent and off-shore islands located south of latitude 60°S.

Every **ice-free pixel** covered 30 arcseconds (1x1 km at the equator). Each pixel was assigned a **score** ranging from 1 to 10 per feature. 1 : remote ice-free area, 10 : built environment for stations, 6 : station influence area, 9 : tourist sites, 3 : visited ASPA….

by Pertierra et al., PlosOne, 2017

Ice-free areas and proximity of human activity

Distance (n km)	Current area (km^2)	Patches (#)	Future area (km^2)	Patches (#)
1	206 (< 0.01)	565 (0.02)	293 (< 0.01)	109 (< 0.01)
2.5	587 (0.01)	695 (0.03)	980 (0.01)	183 (0.01)
5	1354 (0.02)	1004 (0.04)	2729 (0.03)	315 (0.01)
10	2737 (0.04)	1600 (0.06)	6379 (0.07)	593 (0.03)
20	6322 (0.09)	3065 (0.12)	13,146 (0.15)	1411 (0.06)
50	10,531 (0.15)	4643 (0.18)	19,404 (0.23)	2488 (0.11)
∞	**71,809 (1.00)**	**25,237 (1.00)**	**85,977 (1.00)**	**21,839 (1.00)**

The bold row indicates the total ice-free area (n = ∞).

Total ice-free area (km^2) and total number of discrete ice-free patches that are within at least *n* kilometers of current human activity, either now or by the end of the century, as scientific facilities or tourist-landing sites.
Values in parentheses : % of total ice-free area within *n* km of human activity

Decline in the number of discrete ice-free patches as total ice-free area increases !

Predicted **increase in connectivity** amongst currently fragmented ice-free areas could also facilitate the **movement** of both native and non-native species across the region.

Habitat fragmentation, though traditionally identified as a conservation threat, has contributed to producing evolutionary and **genetically distinct** lineages of Antarctic terrestrial taxa.

Increased **connectivity** may, therefore, facilitate the **dispersal** of both native and nonnative species, which could eventually contribute to **homogenization** of regional ecosystems.

PERSPECTIVE

https://doi.org/10.1038/s41586-018-0173-4

Choosing the future of Antarctica

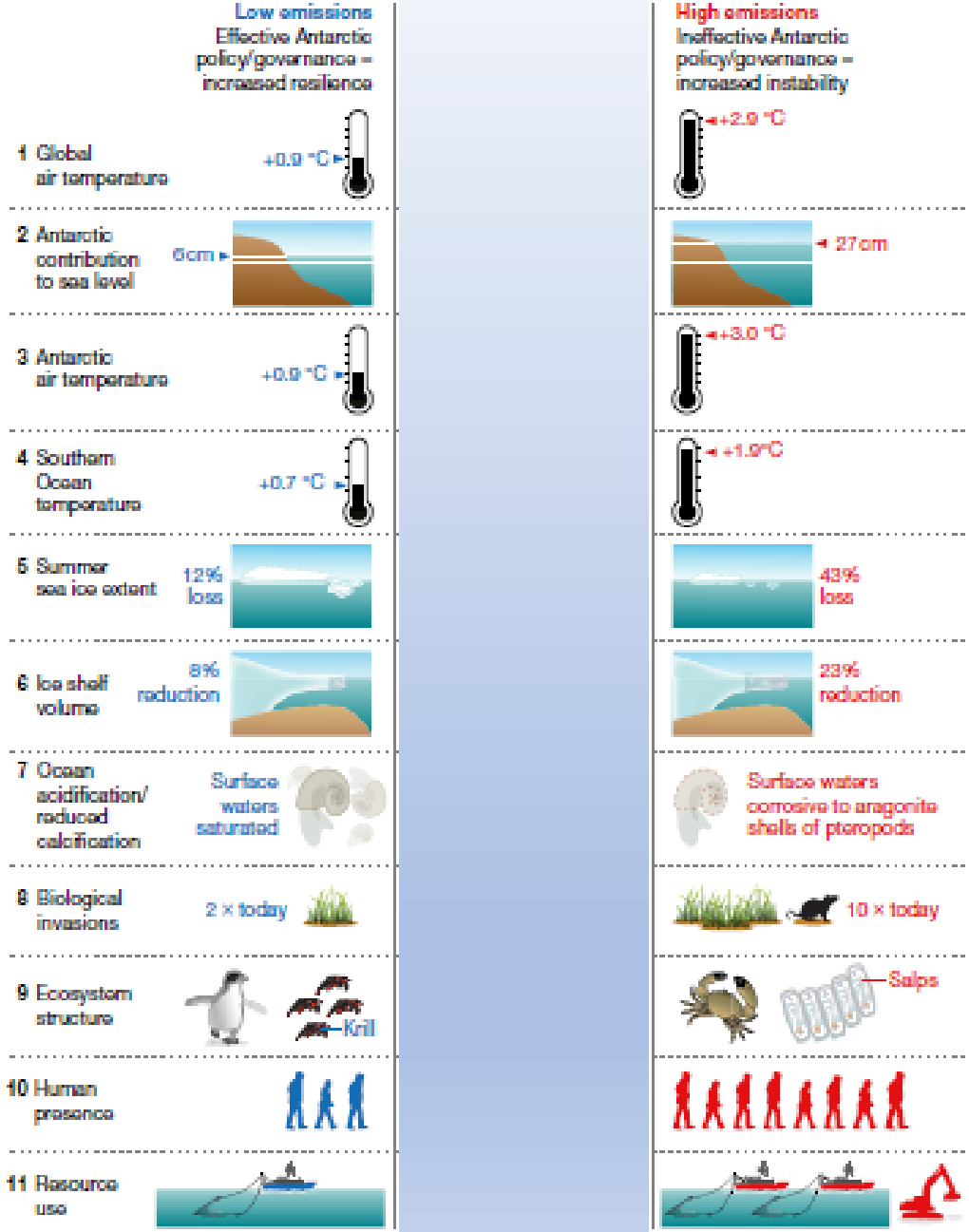
S. R. Rintoul[1,2,3*], S. L. Chown[4], R. M. DeConto[5], M. H. England[6], H. A. Fricker[7], V. Masson-Delmotte[8], T. R. Naish[9], M. J. Siegert[10] & J. C. Xavier[11,12]

Nature 2018

In the first scenario, greenhouse gas emissions remained unchecked, the climate continued to warm, and the policy response was ineffective; this had large ramifications in Antarctica and the Southern Ocean, with worldwide impacts.

In the second scenario, ambitious action was taken to limit greenhouse gas emissions and to establish policies that reduced anthropogenic pressure on the environment, slowing the rate of change in Antarctica.

Choices made in the next decade will determine what trajectory is realized.



Rintoul et al. 2018

DOI: 10.1111/ddi.12593

BIODIVERSITY RESEARCH

WILEY Diversity and Distributions

Barriers to globally invasive species are weakening across the Antarctic

Grant A. Duffy | Bernard W. T. Coetzee | Guillaume Latombe | Alexander H. Akerman | Melodie A. McGeoch | Steven L. Chown

Dversity and Distribution 2017

Climate, which is often cited as a key barrier to alien species establishment, may afford some protection to continental Antarctica, but that this protection is **not** currently extended to the **Southern Ocean islands**. Furthermore, existing climatic barriers to alien species establishment will **weaken** as warming continues across the region.

This conclusion is based on **distribution modelling** that can be used to inform targeted surveillance of introduction pathways and sites that have the highest risk of establishment of invasive alien species.

frontiers in Environmental Science

PERSPECTIVE
published: 28 June 2019
doi: 10.3389/fenvs.2019.00102

The Antarctic Peninsula Under a 1.5°C Global Warming Scenario

Martin Siegert[1], Angus Atkinson[2], Alison Banwell[3], Mark Brandon[4], Peter Convey[5], Bethan Davies[6], Rod Downie[7], Tamsin Edwards[8], Bryn Hubbard[9], Gareth Marshall[5], Joeri Rogelj[1], Jane Rumble[10], Julienne Stroeve[11,12] and David Vaughan[5]*

The Polar Regions have **warmed twice** as much as the global average since 1850. This has led to glacier retreat, ice shelf decay and the expansion of exposed land on which some plants have been able to grow.

By restricting global temperature **increase to 1.5◦C** above 1850 values, we can limit the damage to the Antarctic Peninsula's ecosystems.

However, we cannot avoid further **loss of ice**, **expansion** of **vegetation** and **invertebrate** communities on land (potentially with **alien** species), and **alteration to marine ecosystems** that are still recovering from marine resource extraction decades ago.

If we fail to restrict average global warming to 1.5◦C, **the Antarctic Peninsula** will likely experience **irreversible and dramatic change** to glacial, terrestrial, ocean, and biological systems.

Siegert et al.2019

Received: 19 December 2018 | Revised: 12 February 2019 | Accepted: 13 February 2019

DOI: 10.1111/gcb.14600

RESEARCH REVIEW

Global Change Biology WILEY

Antarctica: The final frontier for marine biological invasions

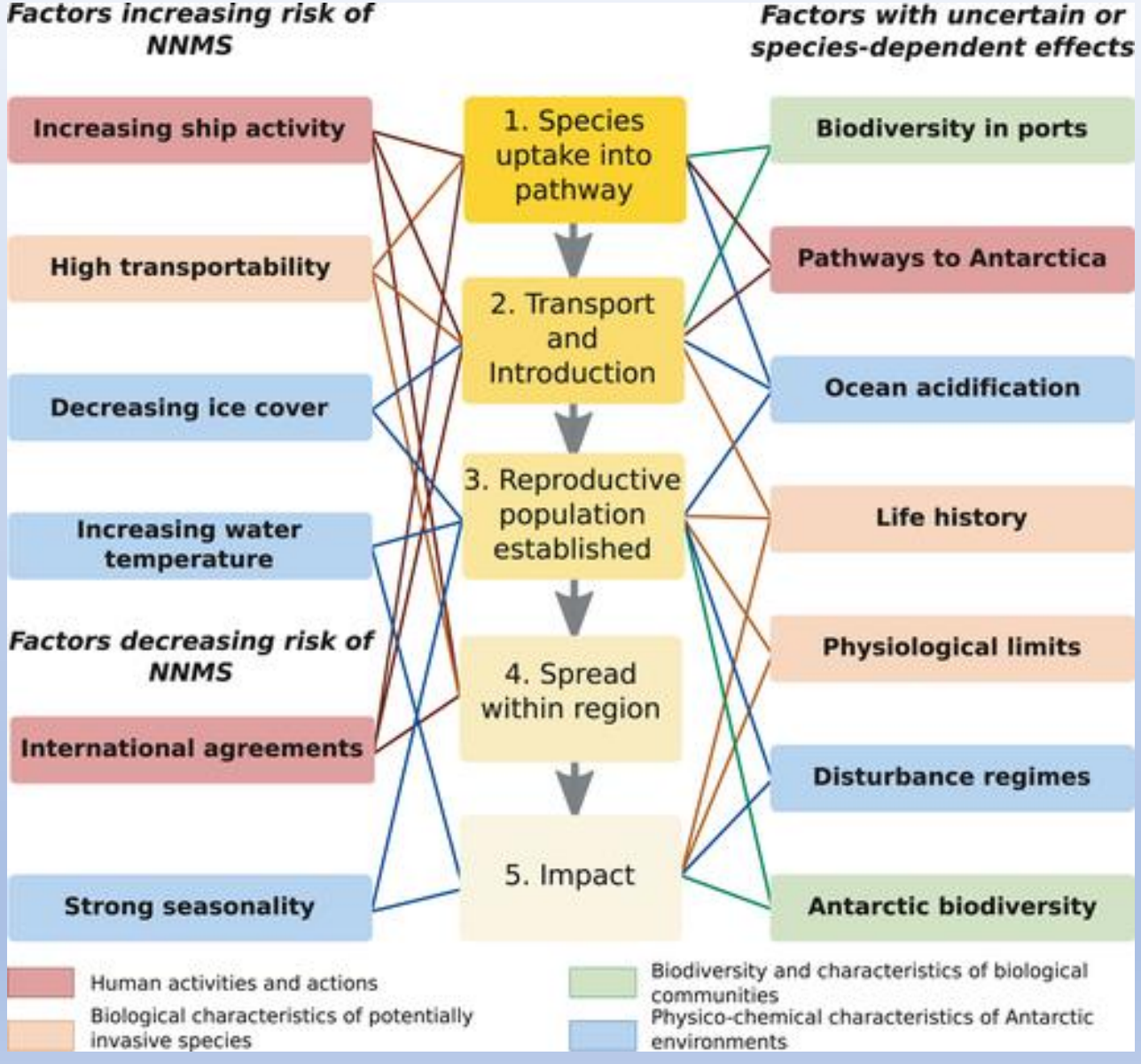
Arlie H. McCarthy[1,2] | Lloyd S. Peck[2] | Kevin A. Hughes[2] | David C. Aldridge[1,3]

The **Arctic** has **34 recorded non-native marine species** (NNMS) from 54 introduction events. In contrast, **Antarctic**a has **no confirmed populations of NNMS** and reports of only **five free-living marine species** that were potentially transported by **anthropogenic** means*: Ulva intestinalis* (cryptogenic, grass kelp), *Hyas araneus* (great spider crab), *Bugula neritina* (brown bryozoan*), Ciona intestinalis* (vase tunicate), *Ectopleura crocea* (pinkmouth hydroid).

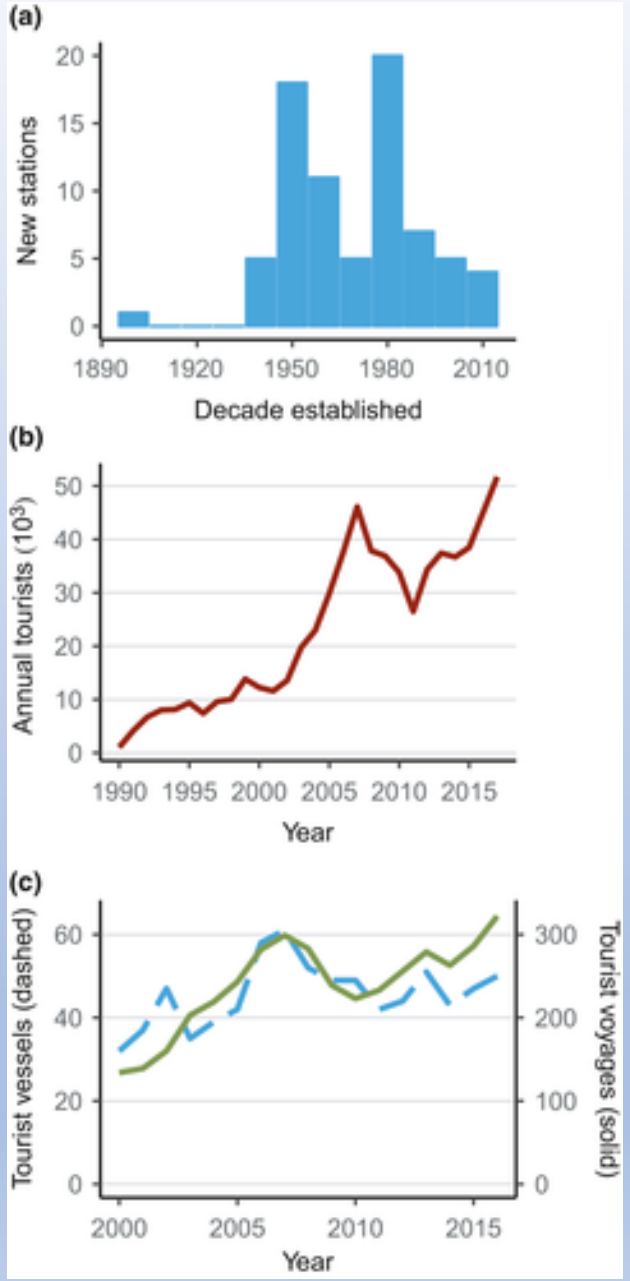
Nonetheless, given the high levels of **endemism** and **unique** taxonomic combinations within Antarctic ecosystems, changes in Antarctic biodiversity are recognized as globally important **conservation priorities**.

Although NNMS in the Antarctic region are rare and historically have been of little concern, climate change and increasing human activity are expected to **increase** the establishment and potential impact of NNMS.

Antarctica: The final frontier for marine biological invasions



Global Change Biology, Volume: 25, Issue: 7, Pages: 2221-2241, First published: 23 April 2019, DOI: (10.1111/gcb.14600)



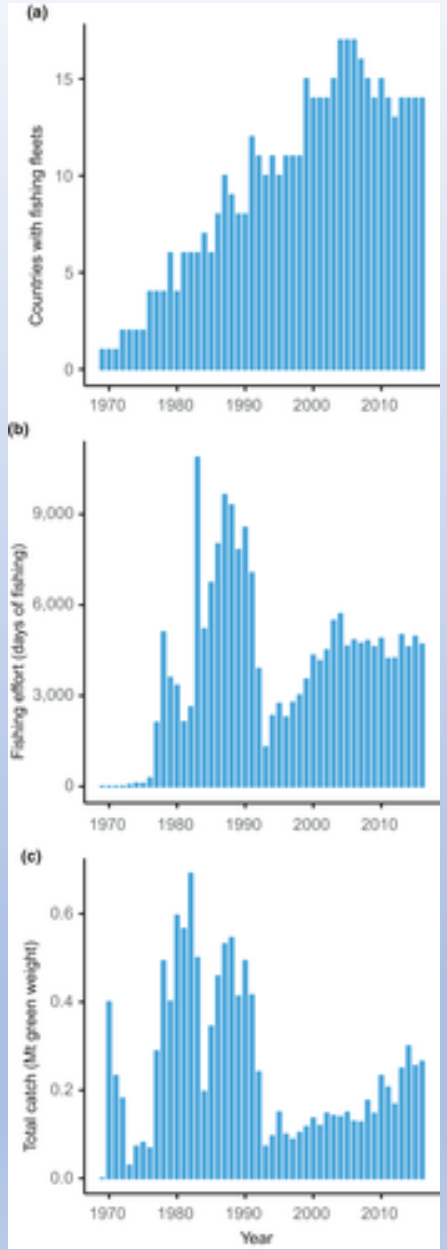
Changes in research and tourism activity in the Antarctic region over time.

(a) Number of **new Antarctic stations** built per decade, data from COMNAP (2018a);

(b) Number of **tourists per year** from the 1990–1991 to 2017–2018 austral summer seasons

(c) Number of **tourism vessels** per austral summer season between 2000–2001 and 2016–2017 active in Antarctica and the Southern Ocean (dashed) and number of **tourist voyages** per austral summer season to Antarctica and sub-Antarctic islands (solid), data from IAATO (2018a)

Global Change Biology, Volume: 25, Issue: 7, Pages: 2221-2241, First published: 23 April 2019, DOI: (10.1111/gcb.14600)



Fishing activity in the Southern Ocean since 1969

(a) Number of **countries** with fishing vessels in the Southern Ocean;

(b) total number of **fishing days** for all vessels per year;

(c) **total catch** (green weight – weight when caught) for all species per year. Data from CCAMLR (2018a)

Global Change Biology, Volume: 25, Issue: 7, Pages: 2221-2241, First published: 23 April 2019, DOI: (10.1111/gcb.14600)

Journal of Environmental Management 232 (2019) 73–89

Contents lists available at ScienceDirect

Journal of Environmental Management

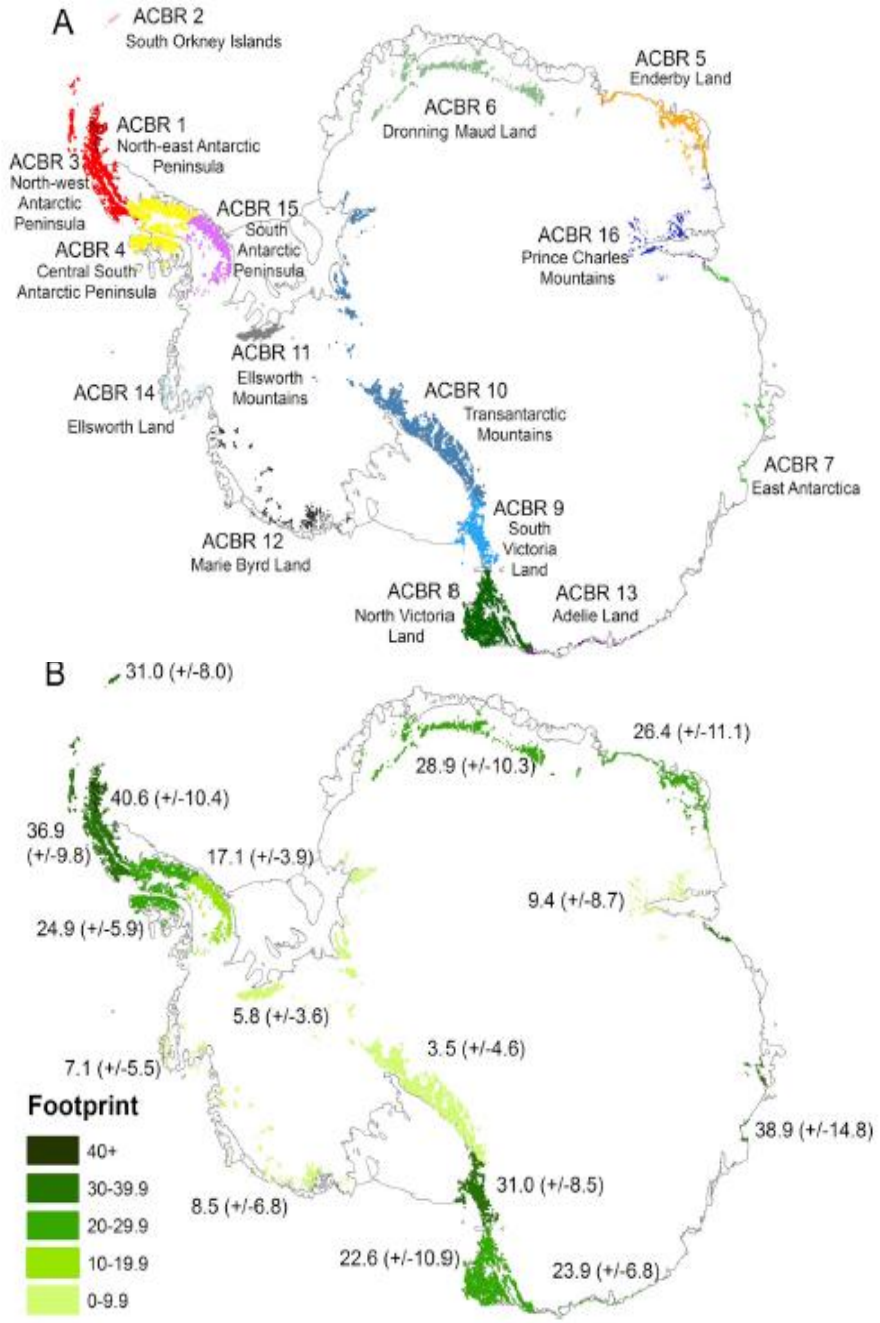
journal homepage: www.elsevier.com/locate/jenvman

Review

Human-mediated dispersal of terrestrial species between Antarctic biogeographic regions: A preliminary risk assessment

Kevin A. Hughes[a,*], Peter Convey[a], Luis R. Pertierra[b], Greta C. Vega[c], Pedro Aragón[b], Miguel Á. Olalla-Tárraga[c]

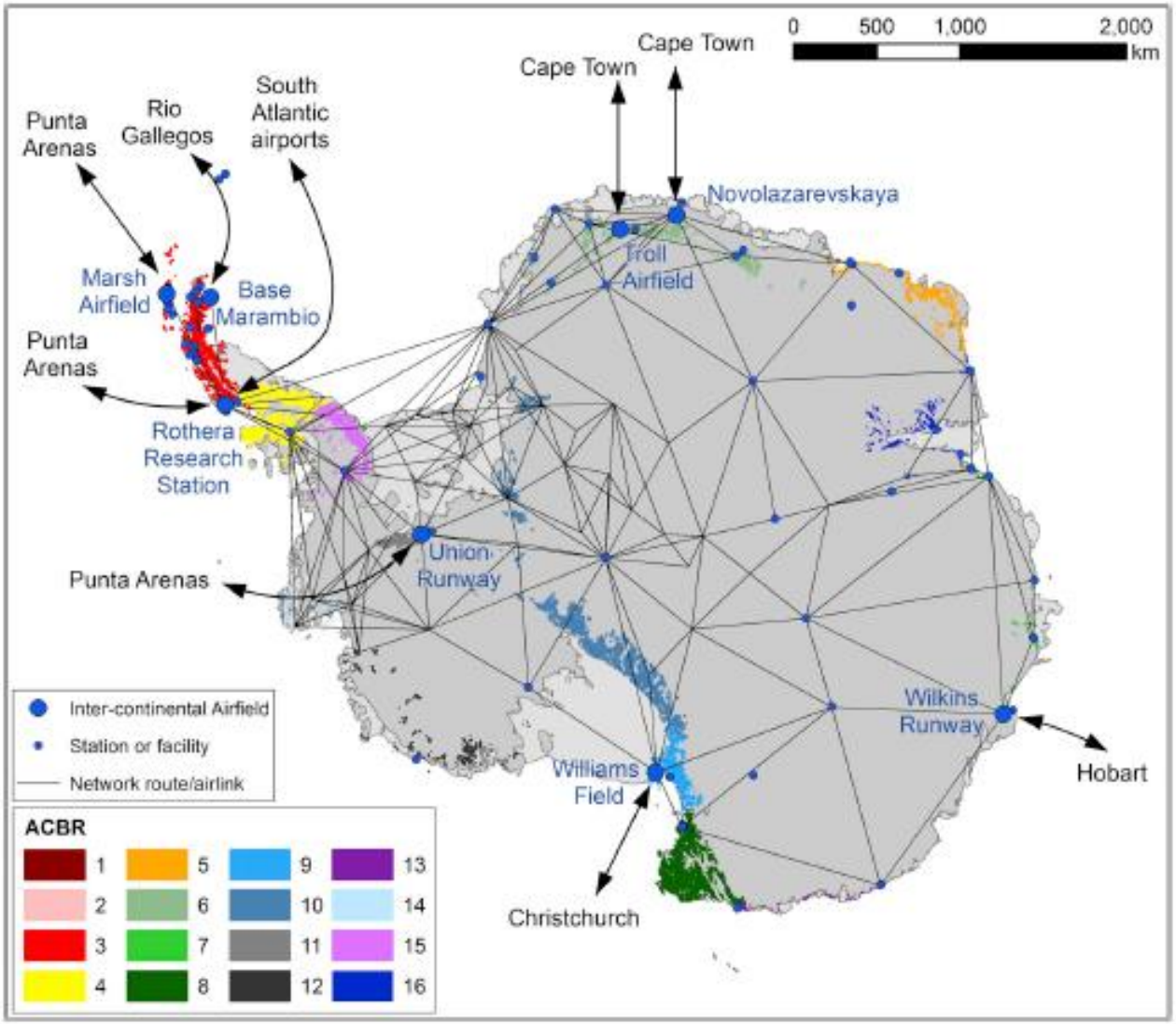
Journal of Environmental Management 232 (2019) 73–89



16 Antarctic Bioconservation Regions (Terauds et al.)

Mean footprint values (—SD) for each ACBR

Location of runways for intercontinental aircraft and other landing sites constructed predominantly on permanent snow and ice.



Risk assessment for transport of propagules between ACBRs by different anthropogenic transportation mechanisms.

Scores in the range 1–5. Overall risk is calculated as the product of the scores shown in columns 2 to 5.

	Relative propagule load of a typical vector including associated personnel and cargo[1]	Relative number active within Antarctica	Proportion moving between ACBRs	Relative likelihood of propagule entrainment and release in different ACBRs	Overall risk score
National Operator vessels[2]	5	5	3	5	375
Ship-borne tourism[3]	2	5	3	2	60
Helicopters on ice-free ground	2	3	2	2	24
Yachts	2	3	2	2	24
Fishing vessels	3	5	1	1	15
Fixed wing aircraft landing on rock airstrips[4]	3	2	1	2	12
Travelling field parties predominantly on ice-free ground	3	1	1	3	9
Fixed wing aircraft landing on ice	2	4	1	1	8
Tractor trains	4	2	1	1	8
Aircraft-borne tourism	2	2	1	2	8
Autonomous and remotely piloted aircraft systems	1	3	1	1	3
Travelling field parties predominantly on ice	1	1	1	1	1

Science of the Total Environment 609 (2017) 225–231

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Wastewater contamination in Antarctic melt-water streams evidenced by virological and organic molecular markers

L.F.L. Tort [a], K. Iglesias [b], C. Bueno [c], A. Lizasoain [a], M. Salvo [a], J. Cristina [d], N. Kandratavicius [c], L. Pérez [e], R. Figueira [f], M.C. Bícego [f], S. Taniguchi [f], N. Venturini [b], E. Brugnoli [c], R. Colina [a], M. Victoria [a,*]

Science of the Total Environment 598 (2017) 220–227

Contents lists available at ScienceDirect

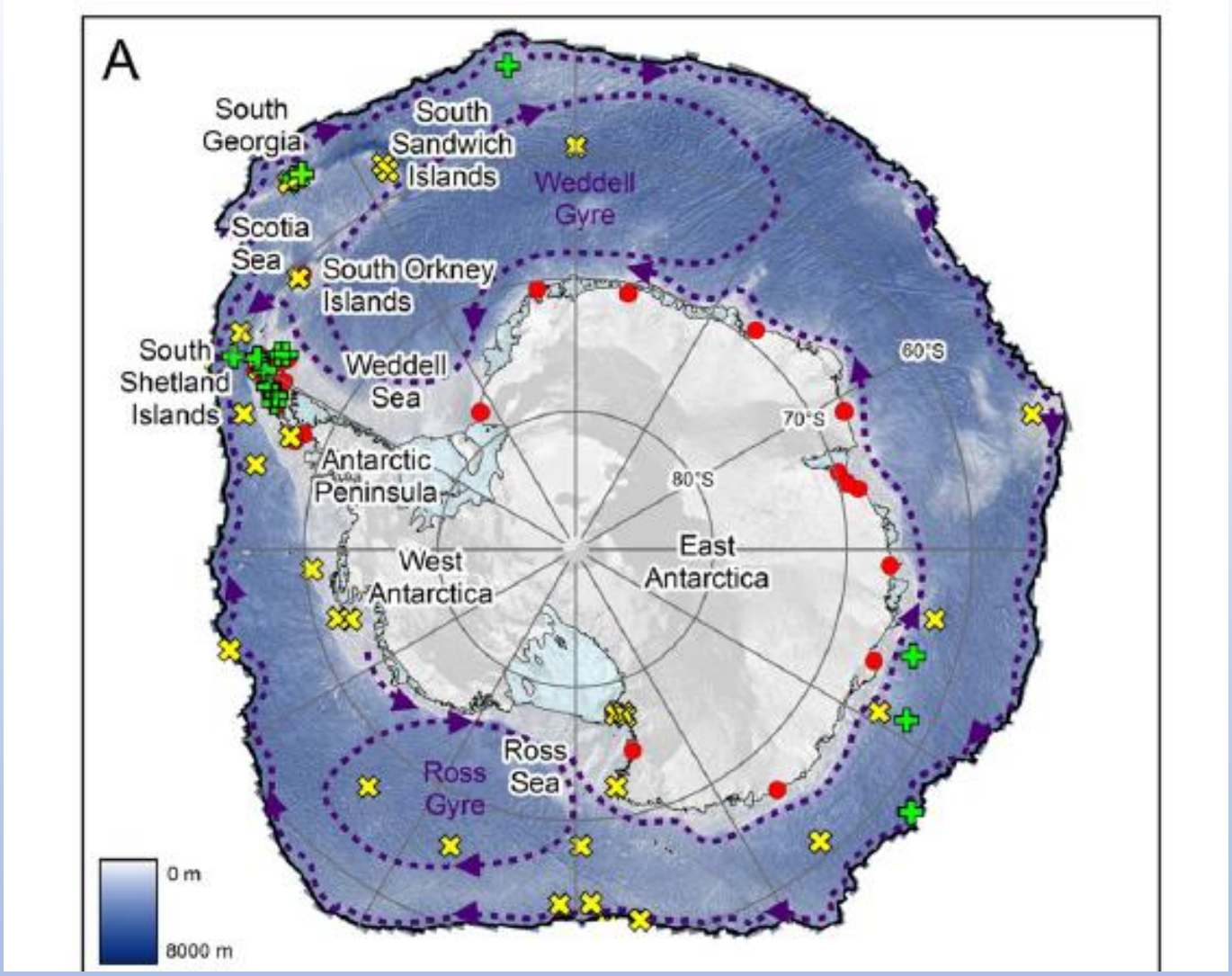
Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Review

Microplastics in the Antarctic marine system: An emerging area of research

Catherine L. Waller [a,*], Huw J. Griffiths [b], Claire M. Waluda [b], Sally E. Thorpe [b], Iván Loaiza [c], Bernabé Moreno [c], Cesar O. Pacherres [c], Kevin A. Hughes [b]



(A) Main coastal Antarctic facilities operated by National Antarctic Programmes and recorded findings of microplastics and macroplastics in surface waters, on beaches and in sediments south of the Polar Front. Plot boundary: mean position of the Polar Front. Red dots: research stations and facilities. Yellow crosses: records of macroplastics. Green crosses: records of microplastics. Purple arrows: direction of major ocean currents.

Waller et al. 2017

SCIENTIFIC REPORTS

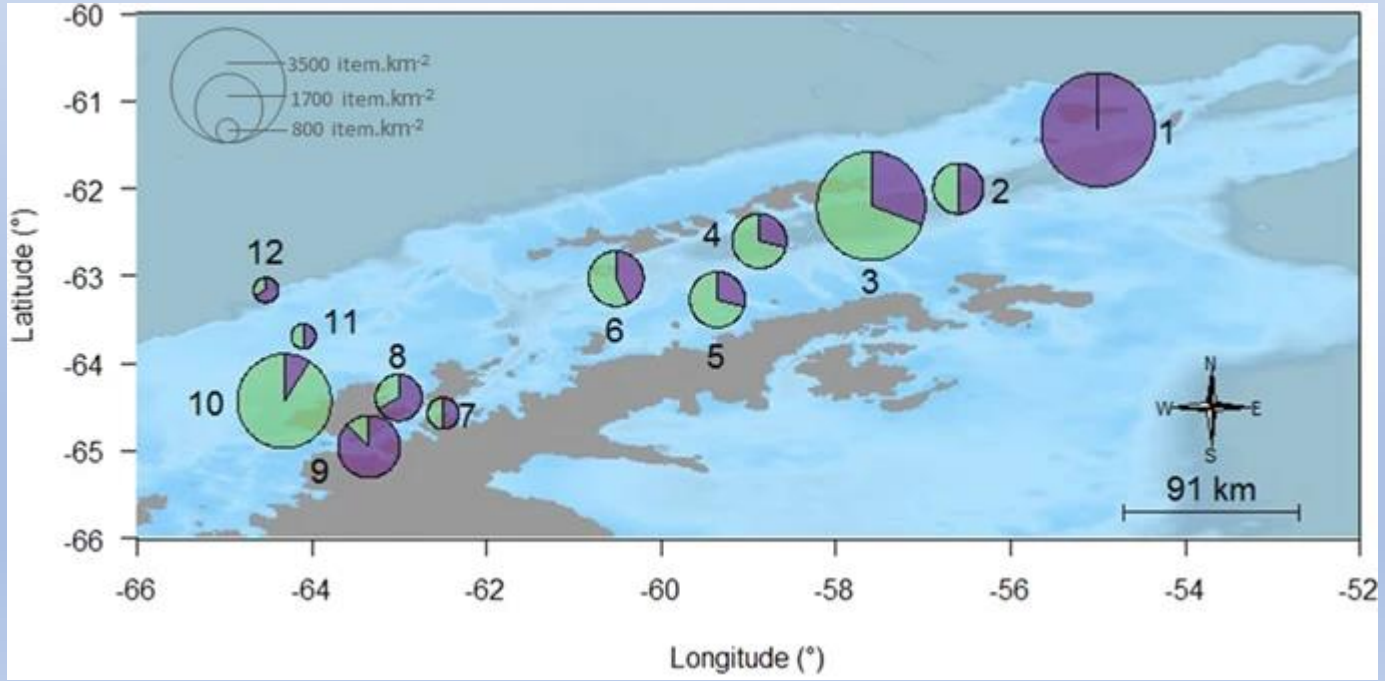
2019

OPEN

Plastics in sea surface waters around the Antarctic Peninsula

Ana L. d.F. Lacerda[1,2], Lucas dos S. Rodrigues[2], Erik van Sebille[3], Fábio L. Rodrigues[4], Lourenço Ribeiro[1,5], Eduardo R. Secchi[2], Felipe Kessler[6] & Maira C. Proietti[1]

Abundance of **plastics** in Antarctica lower than in the center of subtropical gyres or highly urbanized coastlines. However, due to the unique characteristics of this environment, it could be highly **sensitive** even to low levels of this type of pollution



micro ((<5 mm),purple) and mesoplastics ((5–200 mm),green) per sampling point

Antarctic microorganisms' diversity

- Is of significant importance in the terrestrial realm

- Shows patterns and ecological ranges

Antarctic microorganisms' diversity

- Is of significant importance in the terrestrial realm

- Shows patterns and ecological ranges

- Could be impacted by climate change

- Could be impacted by anthropogenic activities and the introduction of non-native microorganisms

(Microbial) habitats are under anthropogenic pressure

New ‘entry points‘ for **microbial contamination** (Chown et al. 2012)

- Due to **human presence**, non-indigenous microorganisms are released from bodies, clothing, cargo and food into the environment (Cowan et al. 2011).

Microbial habitats are under anthropogenic pressure

New ‘entry points‘ for **microbial contamination** (Chown et al. 2012)

- Due to **human presence**, non-indigenous microorganisms are released from bodies, clothing, cargo and food into the environment (Cowan et al. 2011).

- Increase of **tourism** and its diversification from coastal cruises to adventurous expeditions into the continent

- Increase of **research stations** and associated impacts

Impacts of such introductions are still unknown !

- ? loss of the native microbial biodiversity
- ? modification by lateral gene transfer.

Non-indigenous microorganisms in the Antarctic: assessing the risks

Don A. Cowan[1], Steven L. Chown[2], Peter Convey[3], Marla Tuffin[1], Kevin Hughes[3], Stephen Pointing[4] and Warwick F. Vincent[5]

Trends in Microbiology 289, 2011

« Humans disseminate non-indigenous microorganisms into their immediate environment »

Surface of the human body : over 10^{12} microorganisms

If daily body surface turnover = 0.1%

→ Daily personal dissemination to the immediate environment = about 10^{9} microbial cells!

Impact of a ‘normal’ field camp

(Cowan et al. 2011)

6 persons
Camp surface = 50 m^2
10 days

Cumulative impact of humans: ~ 6 $x10^{10}$ cells

If cells distributed into top 1 cm of soil (ca. 5 x 10^5 cm^3 volume)

→ each 1 cm^3 volume would receive around 10^5 cells, equivalent to between **0.1%** and **10%** of the natural microbial load in such soils!

This is likely to leave a **substantial genetic fingerprint**. Given the prevalent conditions of Antarctic soil environments (cold and dry), these fingerprints may be very long-lived.

Virtually **nothing is known** of the consequences of this nonindigenous biological input, the mobility and transport of the contaminants, their long-term stability, the quantitative and qualitative consequences of horizontal gene transfer, or the consequence in terms of ecosystem functioning.

→ Need to integrate the microbial communities into conservation strategies

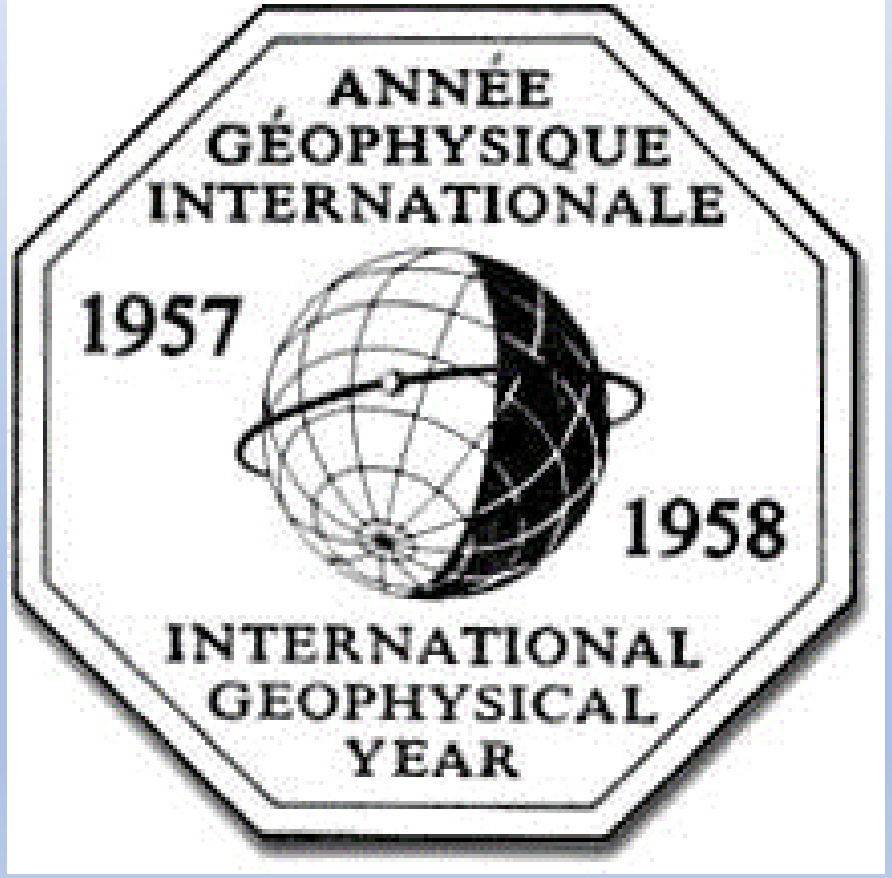
e.g. soil crusts in hot deserts

Antarctica unique biodiversity

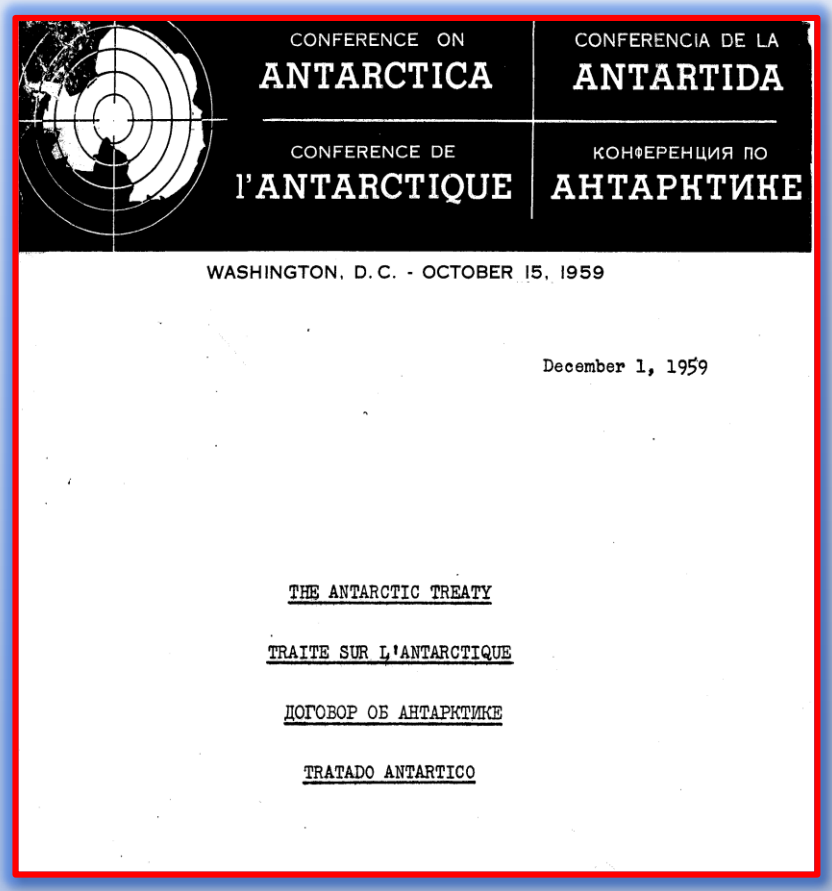
Threats to the Antarctic environments and biodiversity

Science and policy tools

The Antarctic Treaty 1959



The Antarctic treaty 1959


CONFERENCE ON
ANTARCTICA
CONFERENCIA DE LA
ANTARTIDA
CONFERENCE DE
l'ANTARCTIQUE
КОНФЕРЕНЦИЯ ПО
АНТАРКТИКЕ

WASHINGTON, D.C. - OCTOBER 15, 1959

December 1, 1959

THE ANTARCTIC TREATY

TRAITE SUR L'ANTARCTIQUE

ДОГОВОР ОБ АНТАРКТИКЕ

TRATADO ANTARTICO

40TH MEETING OF THE ANTARCTIC TREATY CONSULTATIVE MEETING 2017

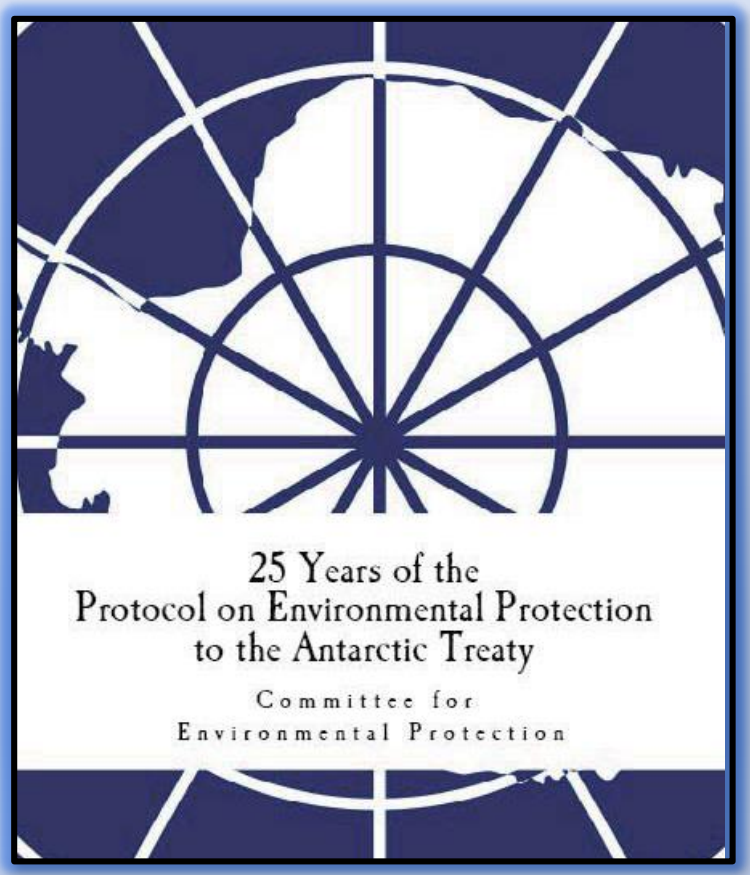
ATCM =
29 members
24 observers

1988: Separate treaty – Convention on the regulation of the activities on antarctic mineral ressources

Replaced by the Madrid Protocole on the Environmental Protection in 1991

A fabulous story, where Australia, France and Spain have worked to obtain a real environmental protection and the interdiction of the exploitation and the interdiction of the exploitation of mineral ressources (except for research)

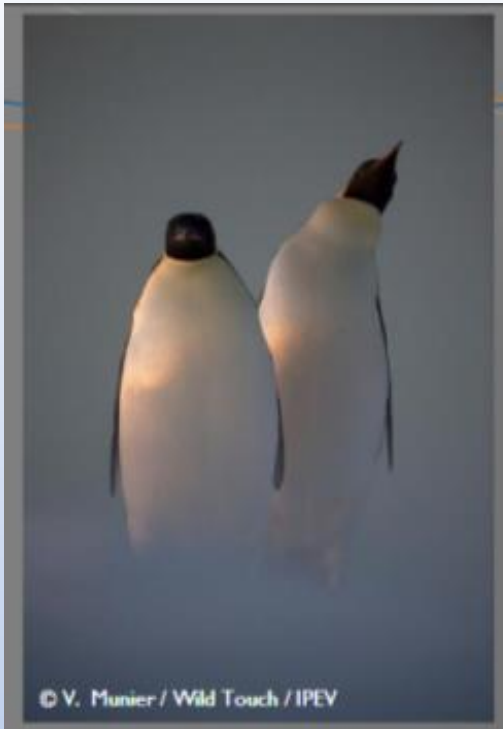
THE PROTOCOL ON ENVIRONMENTAL PROTECTION TO THE ANTARCTIC TREATY, 1991



20TH MEETING OF THE CEP, 2017

CEP (2019) =
40 members
13 observers

This year in Prague!



Protocol on Environmental Protection to the Antarctic Treaty

Madrid, 4th october 1991

designates Antarctica as a natural reserve, devoted to peace and science

(Article 2)

There is no expiration date for the Protocol

Entry into force on January 14th, 1998

EPB-APECS Webinar
23 October 2017

Dr Yves Frenot, IPEV

Preserving antarctica's science value

"Activities shall be planned and conducted.....so as to accord priority to scientific research and to preserve the value of Antarctica as an area for the conduct of such research, including research essential to understanding the global environment" - Article 3(3) of the Protocol

Dr Yves Frenot, IPEV

Protocol - Article 7

Prohibition of Mineral Resource Activities

Any activity relating to mineral resources, other than scientific research, shall be prohibited.

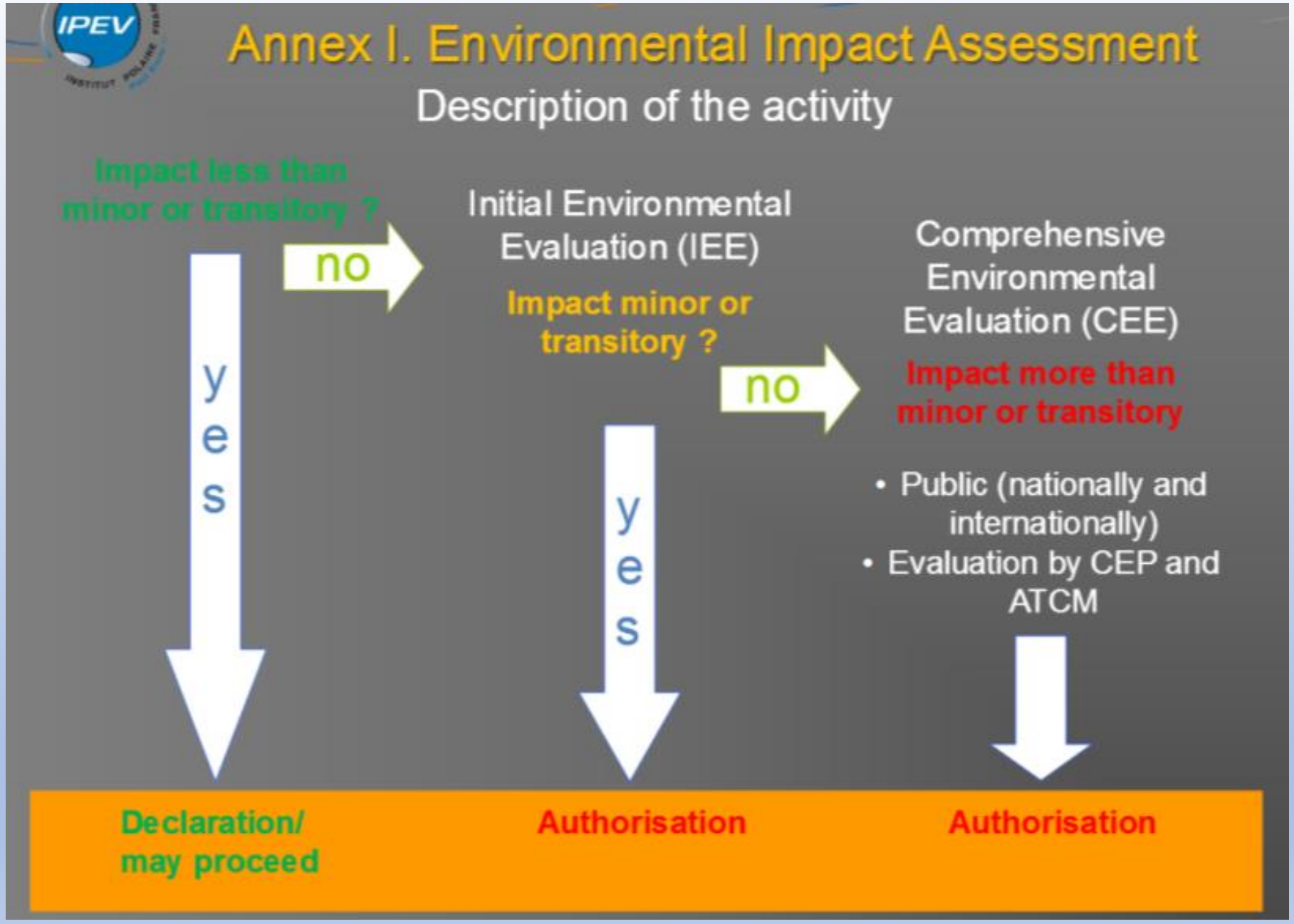
EPB-APECS Webinar
23 October 2017

Dr Yves Frenot, IPEV

6 ANNEXES

- Annex I – Initial environmental evaluation
- Annex II - Conservation of Antarctic fauna and flora
- Annex III – Waste disposal and waste management
- Annex IV - Prevention of marine pollution
- Annex V – Area protection and management
- Annex VI – Liability arising from Environmental Emergencies

Dr Yves Frenot, IPEV



Dr Yves Frenot, IPEV

Annexe II : conservation flora and fauna

Taking or harmful interference shall be prohibited, except in accordance with a permit

No species of animal or plant not native to the Antarctic Treaty area [...] except in accordance with a permit

Dr Yves Frenot, IPEV

Annex III - Waste disposal and management

Wastes must be removed from Antarctica

23 October 2017

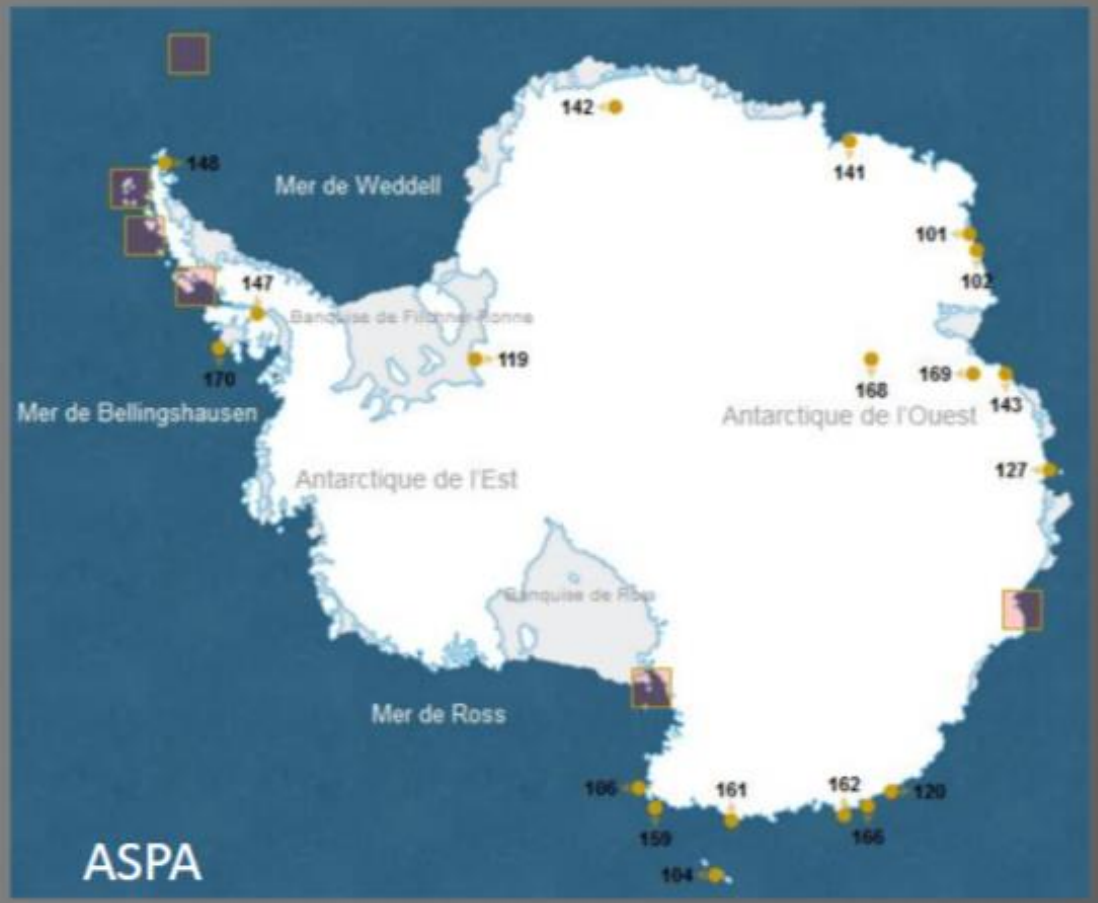
Dr Yves Frenot, IPEV

Annex IV : Prevention of marine pollution

EPB-APECS Webinar
23 October 2017

Dr Yves Frenot, IPEV

Annex V
Protected Areas, Managed Areas, Historic Sites and Monuments



ASMA ▲ ▼ HSM

EPB-APECS Webinar
23 October 2017

Dr Yves Frenot, IPEV

Challenges:

knowledge of Antarctic environment is incomplete and situation is not static

The CEP's top priorities currently include:

- understanding and responding to the environmental consequences of climate change in the Antarctic region;
- addressing the risks to biodiversity associated with the introduction to Antarctica of non-native species, including the transfer of native species between bioregions within Antarctica;
- appropriately managing the environmental impacts of tourism and non-governmental activities; and
- improving the effectiveness of protected area management, and further developing the Antarctic protected area system.

Dr Yves Frenot, IPEV

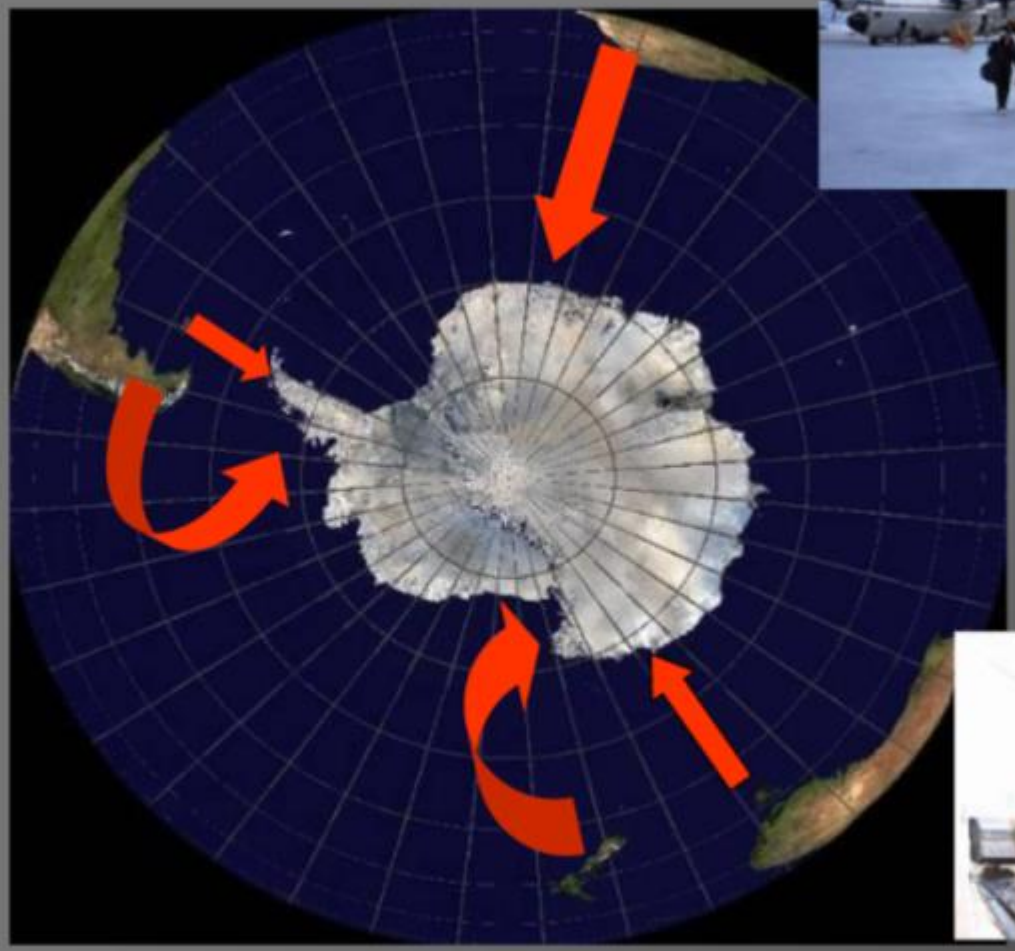
Non-native species

Nassauvia magellanica, isla Decepción - Removed in 2010

Hyas araneus, Antarctic Peninsula
Tavares & de Melo 2004

Dr Yves Frenot, IPEV

Propagule fluxes



IPY Project « *Aliens in Antarctica* »

EPB-APECS Webinar
23 October 2017

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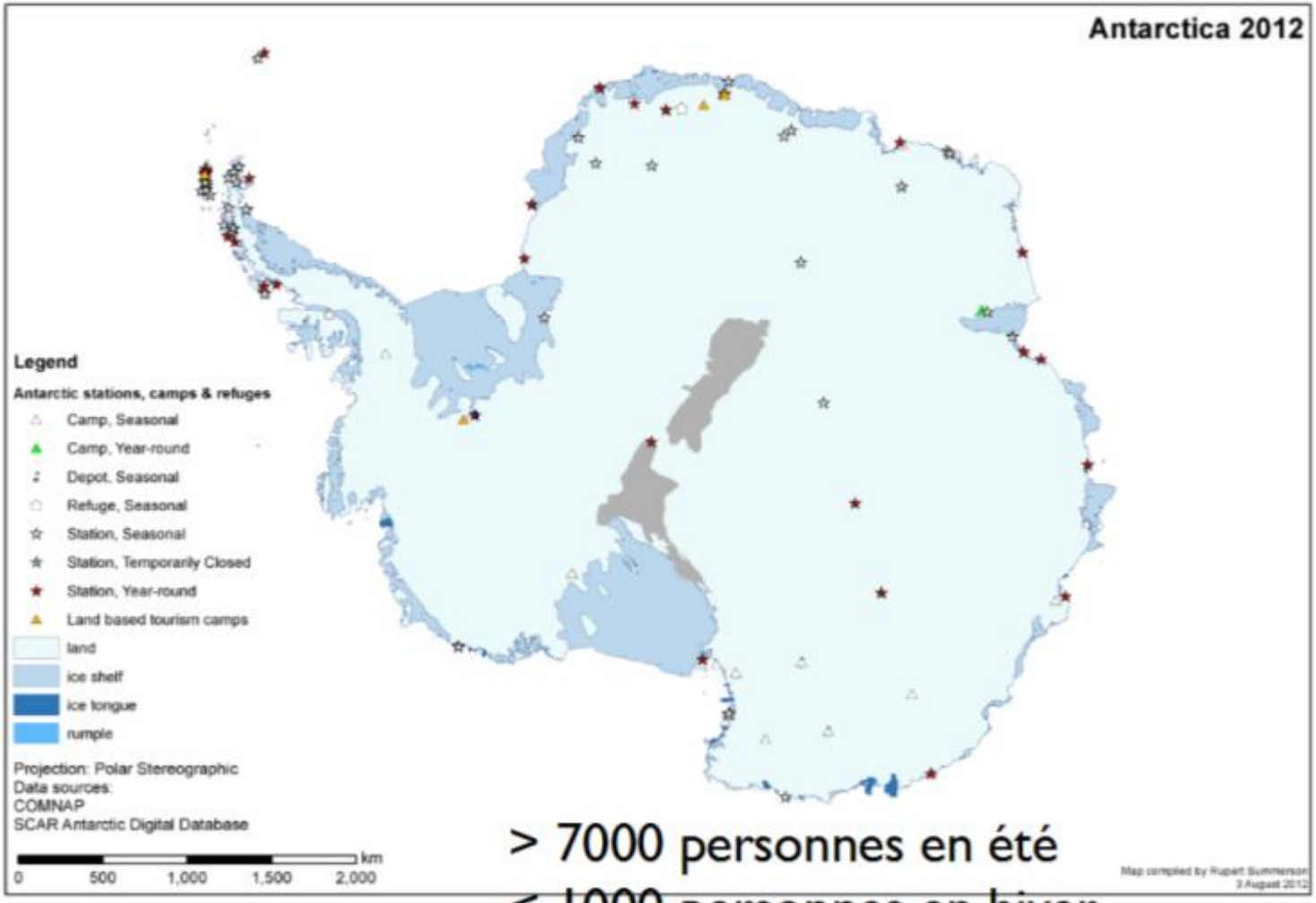
Programmes antarctiques nationaux



> 7000 personnes en été

< 1000 personnes en hiver

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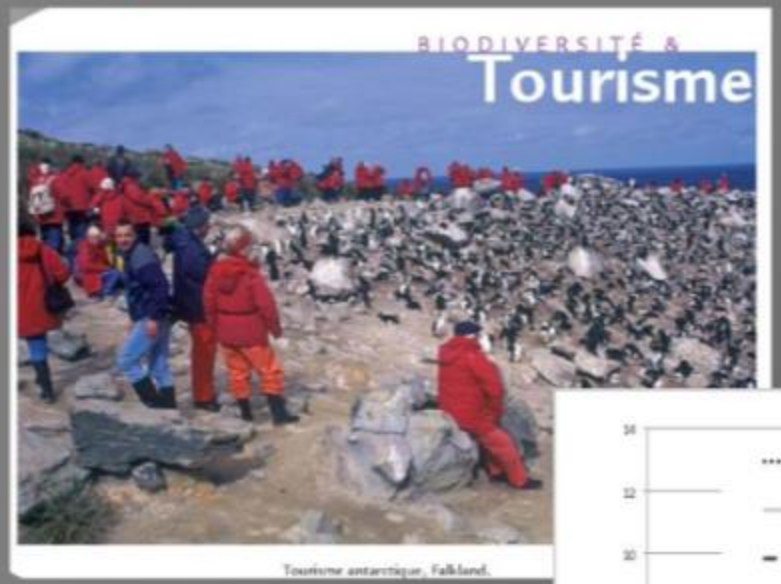
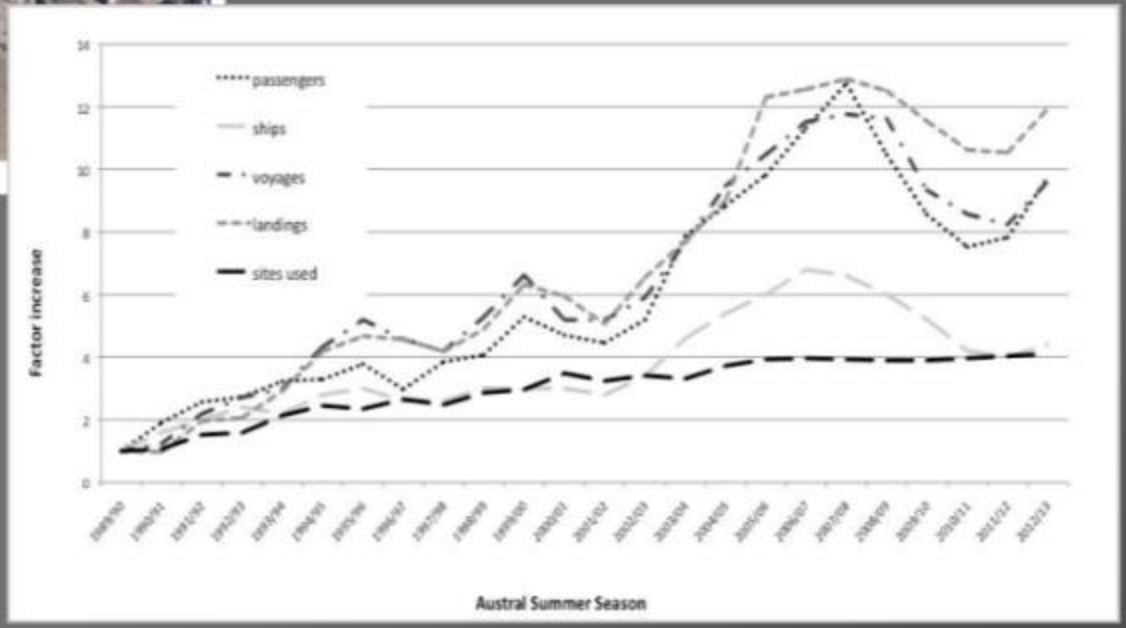
Increasing number of visitors



Tourisme antarctique, Falkland.

Up to 40 000 tourists a year
(between november and March)

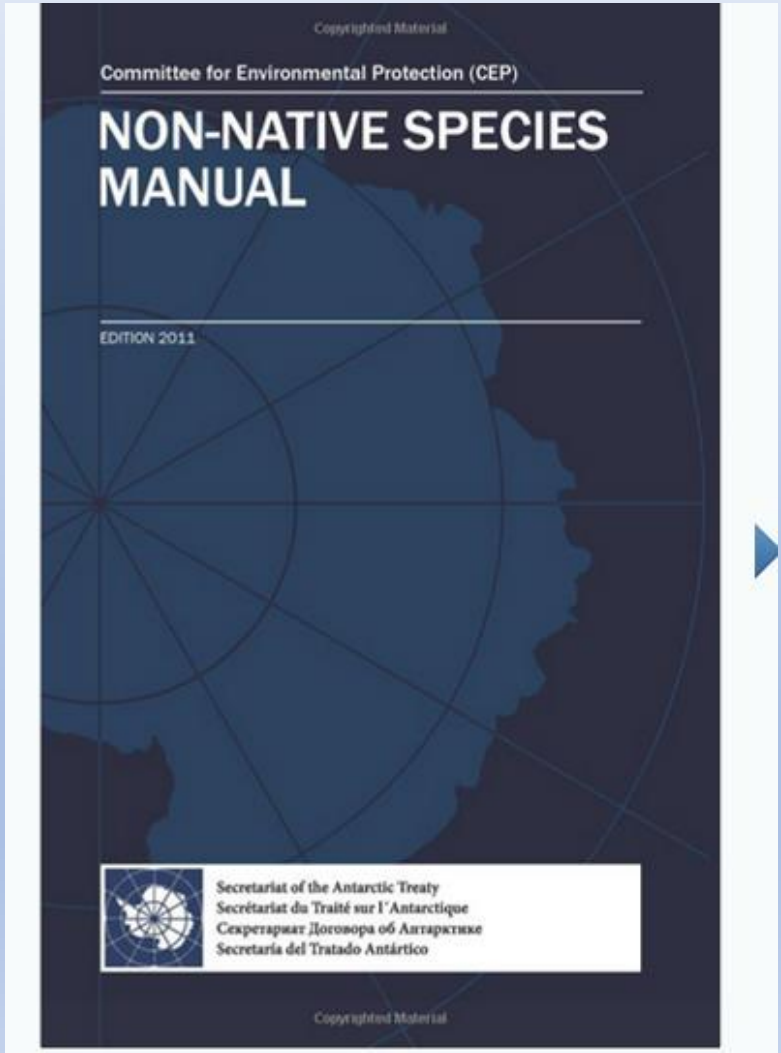
principally in the Antarctic Peninsula



EPB-APECS Webinar
23 October 2017

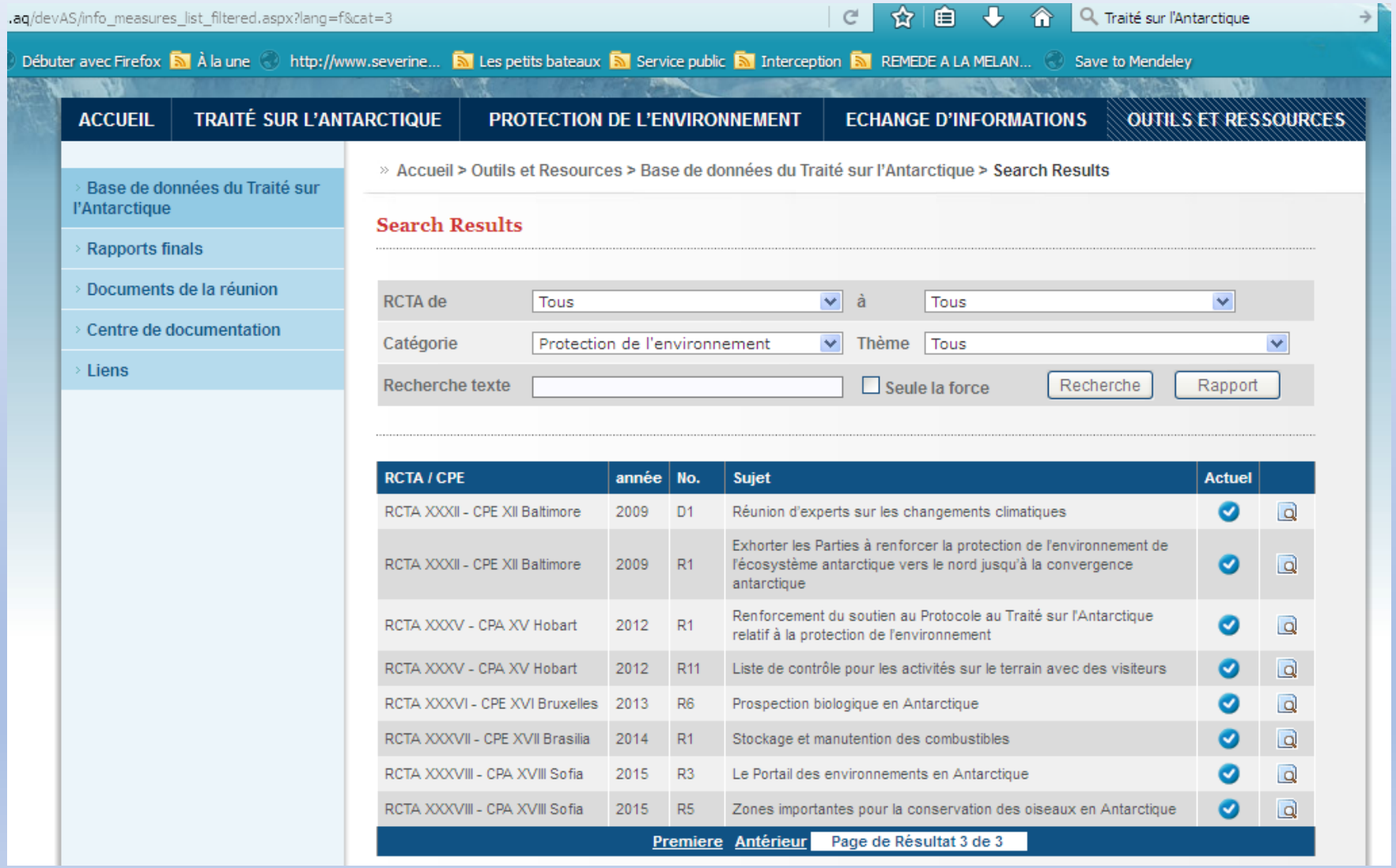
Dr Yves Frenot, IPEV

Measures to avoid introduction of **non-native species**, a growing danger due to the increase of the human presence (introductions) and the climate warming



www.ats.aq

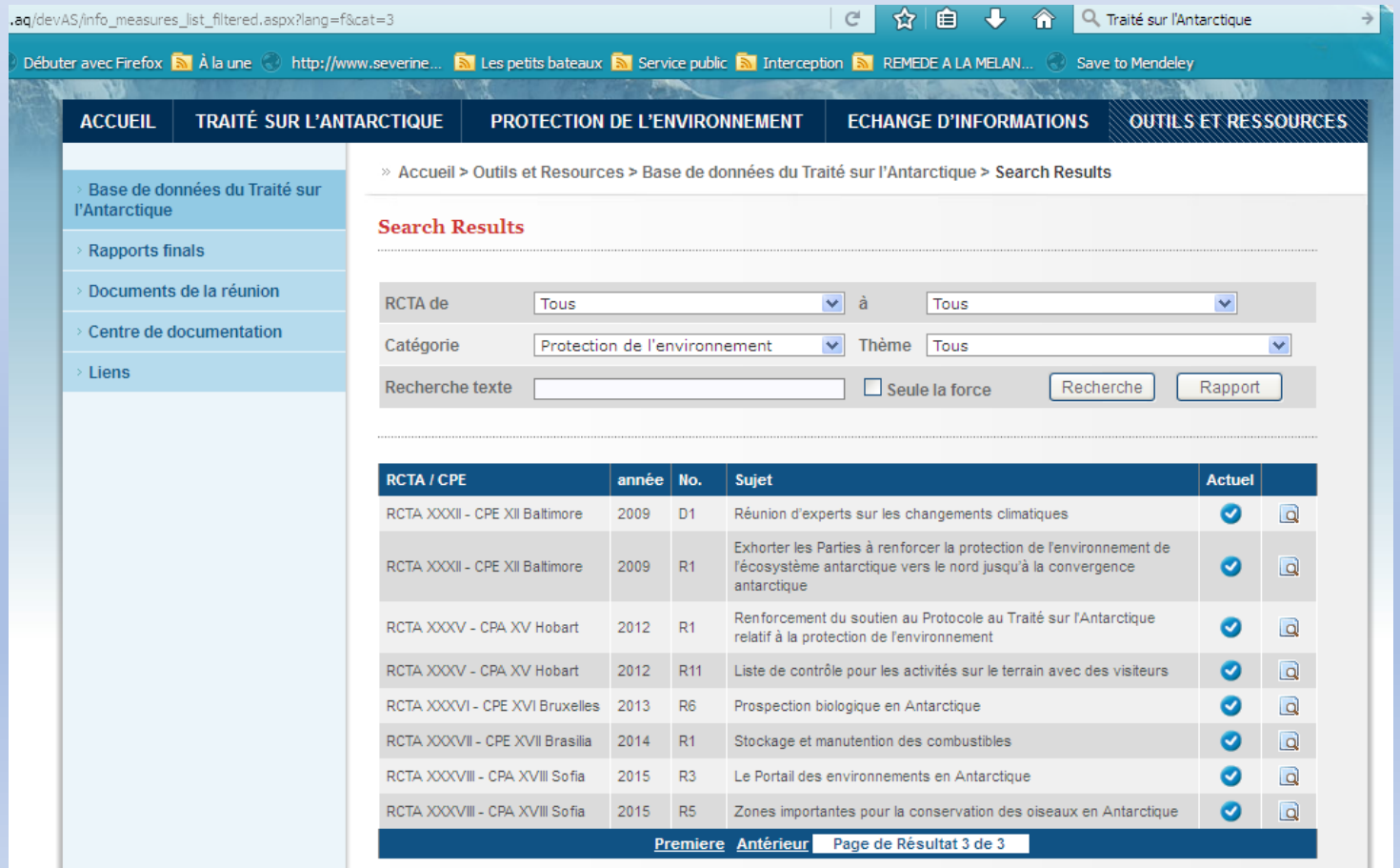
Open database on Internet



6 ASMA's and 72 ASPA's

- **Antarctic Protected Areas Database**

www.ats.aq/devPH/apa/ep_protected.aspx?



Management plans of protected zones

Liste des documents

Réunion	No.	Points de l'ordre du jour	Titre	Soumis par	A	F	R	E	Pièces jointes
RCTA XXXVIII CPA XVIII	WP001	CPE 9a	Plan de gestion révisé pour la zone spécialement protégée de l'Antarctique n° 106 CAP HALLETT, TERRE VICTORIA DU NORD, MER DE ROSS	Etats-Unis d´Amérique	X	X	X	X	ASPA 106 Map 1 ASPA 106 Map 2 ASPA 106 Map 3 ASPA 106 Map 4 ZSPA 106 Plan de gestion révisé
RCTA XXXVIII CPA XVIII	WP002	CPE 9a	Plan de gestion révisé pour la zone spécialement protégée de l'Antarctique no 119 vallée Davis et étang Forlidas massif Dufek, montagnes Pensacola	Etats-Unis d´Amérique	X	X	X	X	ASPA 119 Map 1 ASPA 119 Map 2 ZSPA no 119 Plan de gestion révisé
RCTA XXXVIII CPA XVIII	WP003	CPE 9a	Plan de gestion révisé pour la zone spécialement protégée de l'Antarctique n° 152 Détroit de Western Bransfield	Etats-Unis d´Amérique	X	X	X	X	ASPA 152 Map 1 ZSPA No 152 Plan de gestion révisé
RCTA XXXVIII CPA XVIII	WP004	CPE 9a	Plan de gestion révisé pour la zone spécialement protégée de l'Antarctique n° 153 Baie Eastern Dallmann	Etats-Unis d´Amérique	X	X	X	X	ASPA 153 Map 1 Plan de gestion révisé de la ZSPA n° 153
RCTA XXXVIII	WP005	CPE 3	Plan de travail quinquennal adopté lors de la 17e réunion du Comité pour la protection de	Australie	X	X	X	X	Plan de travail quinquennal du

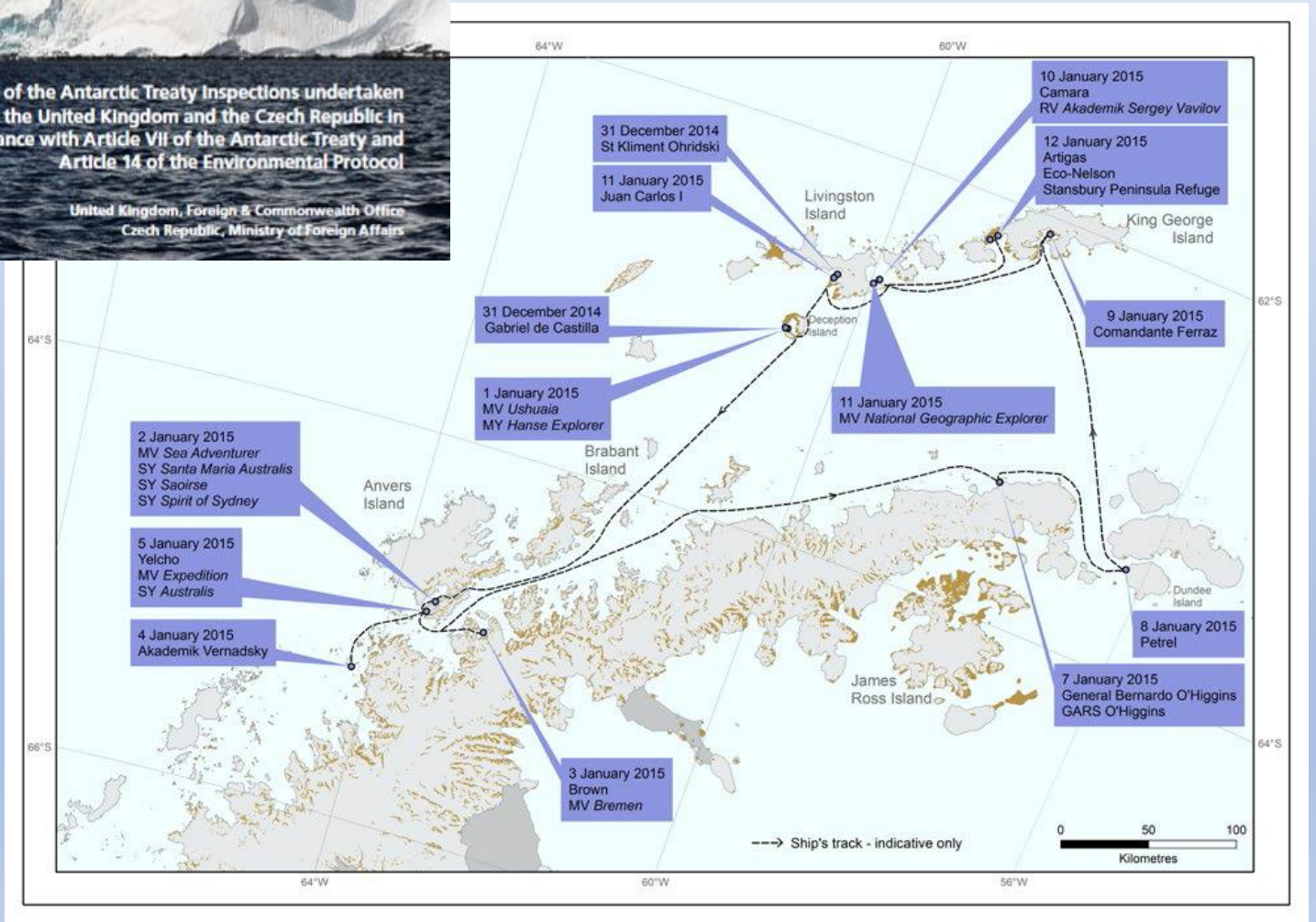
Conservation Letters
A journal of the Society for Conservation Biology
Open Access

REVIEW

Expanding the Protected Area Network in Antarctica is Urgent and Readily Achievable

Bernard W.T. Coetzee[1,2,3], Peter Convey[4,5], & Steven L. Chown[1]

Inspections of stations, ships, installations

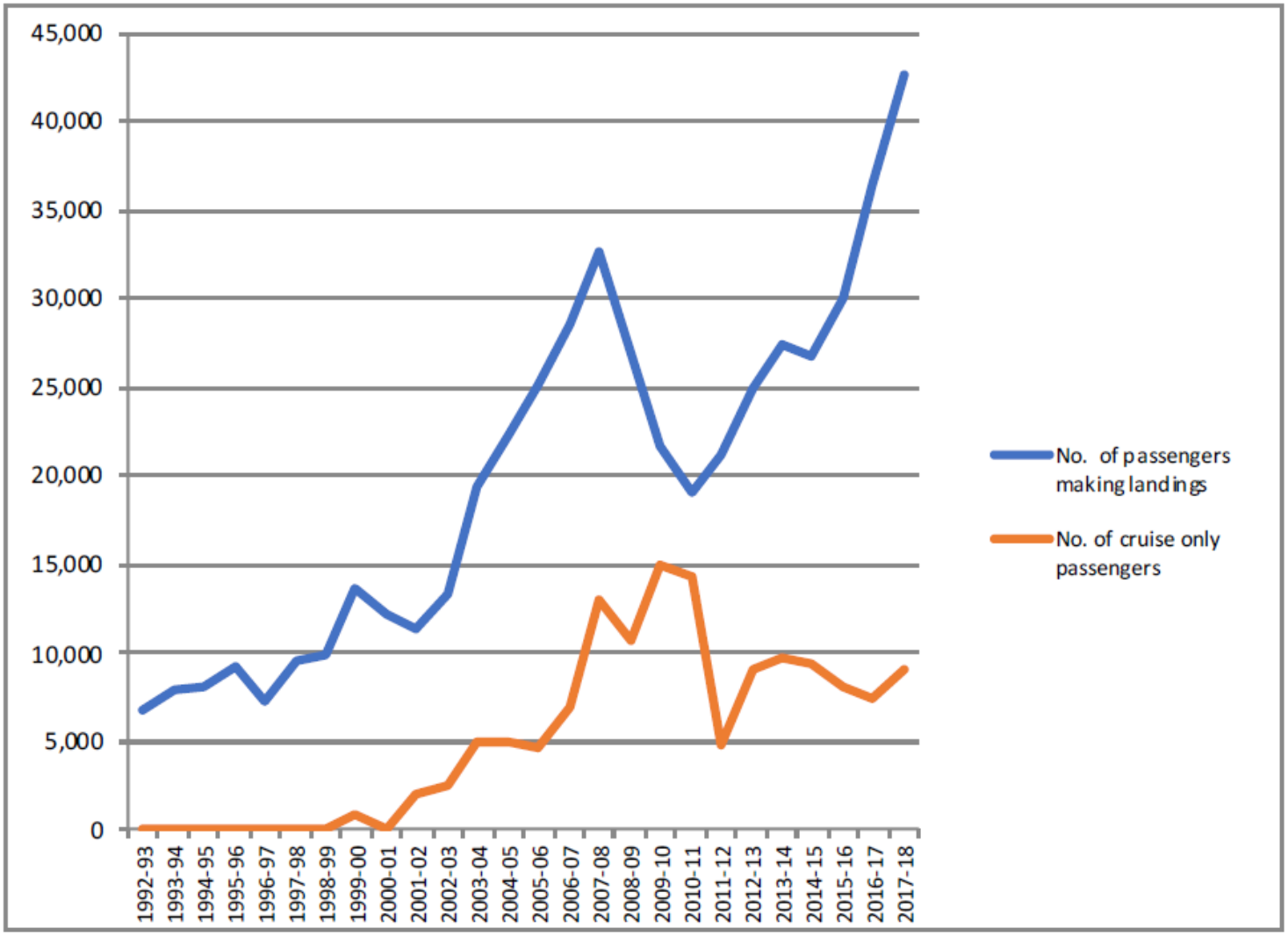


Challenges for ATS

1) Regulation of **commercial tourism**.

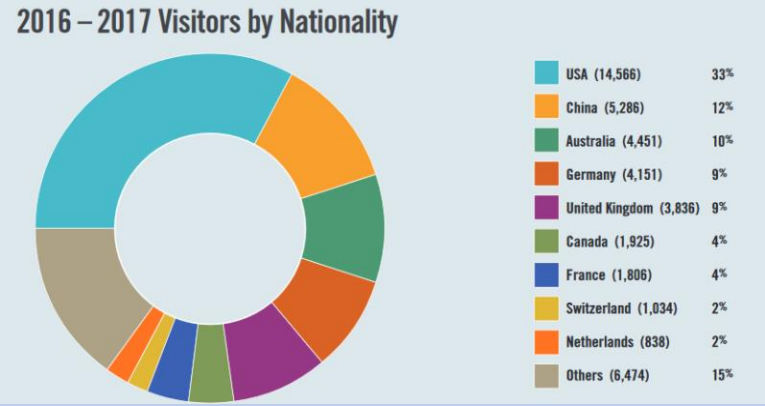
There is no global system, with a legal value to avoid mass tourim, the use of non-compliant ships and ground infrastructures.

51,707 tourists in 2018-19



igure 1. Trend in passenger landings and cruise-only passengers since the 1992/93 season.

- Cruises, more and more popular, are managed at 95 % by the International Association of Antarctic Tour operators. This international association, created in 1991, has 115 members.



- In 2016, 40 000 tourists were accompanied by 20 086 navigating staff and 2 455 marine officers, nécessaires à l'encadrement et au bon déroulement de ces voyages.

2009: ATCM Baltimore (Maryland), ships with more than 500 passengers cannot moor and number of tourists present simultaneously in one site cannot exceed 100 persons.

Novembre 2007, rhe M/V Explorer, with 154 passagers wi(h a Liberian flag, has hit an inceberg. All passengers were saved, but the sunken ship lies at 1 300 m depth. She contained about 200 m^3 fuel

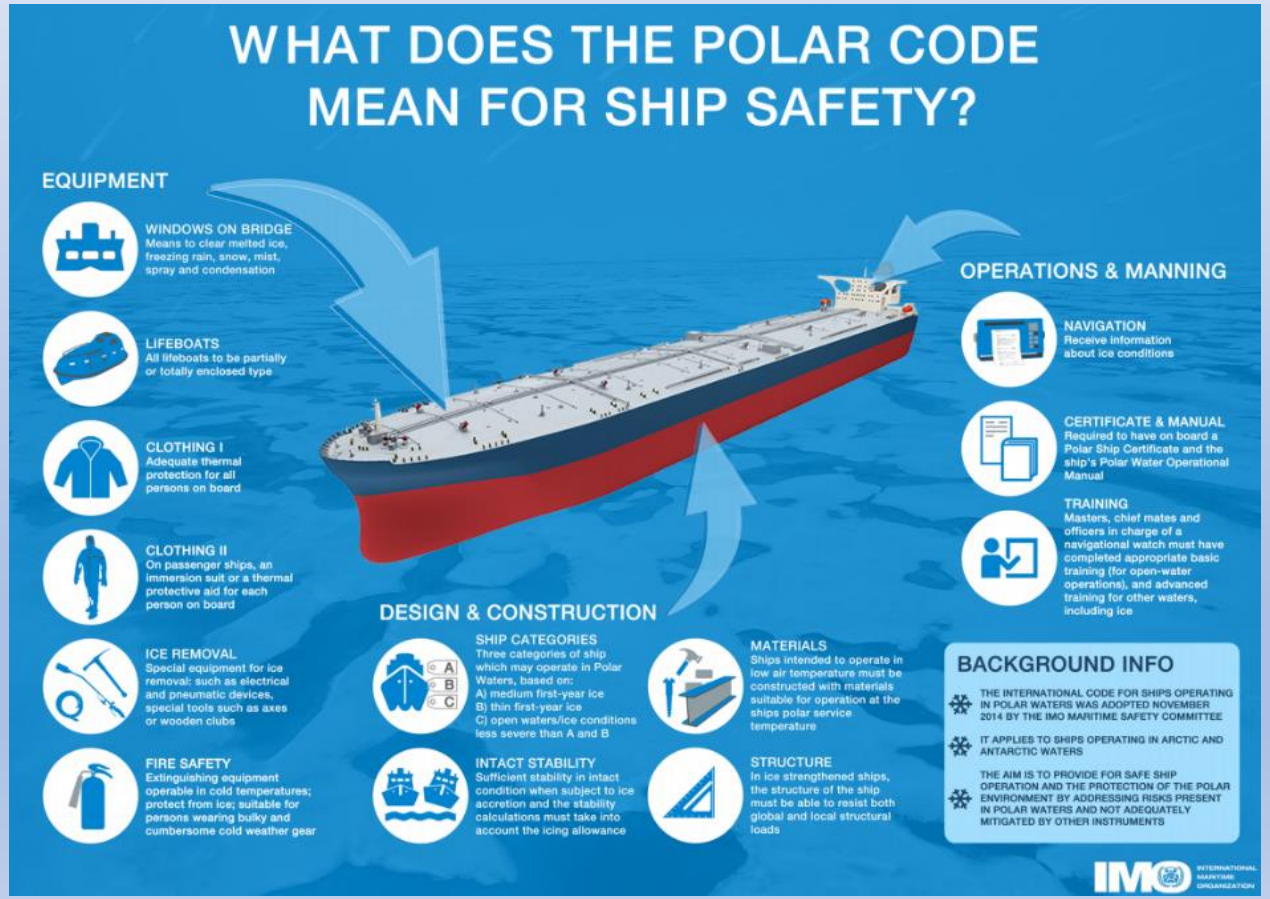
Cinq rescue centers, situated in South Africa, Argentina, Australia, Chile and New Zealand but nothing is prepared for a ecological catastrophy of large amplitude.

Wedding in Antarctica…

Challenges

Collaborate with International Maritime Organisation (IMO) for the **Code Polar Code** for all vessels operating in Antarctica, to implement standards adapted for ice :

2015:



HOW THE **POLAR** CODE PROTECTS THE ENVIRONMENT

OIL

DISCHARGES
Discharge into the sea of oil or oily mixtures from any ship is prohibited

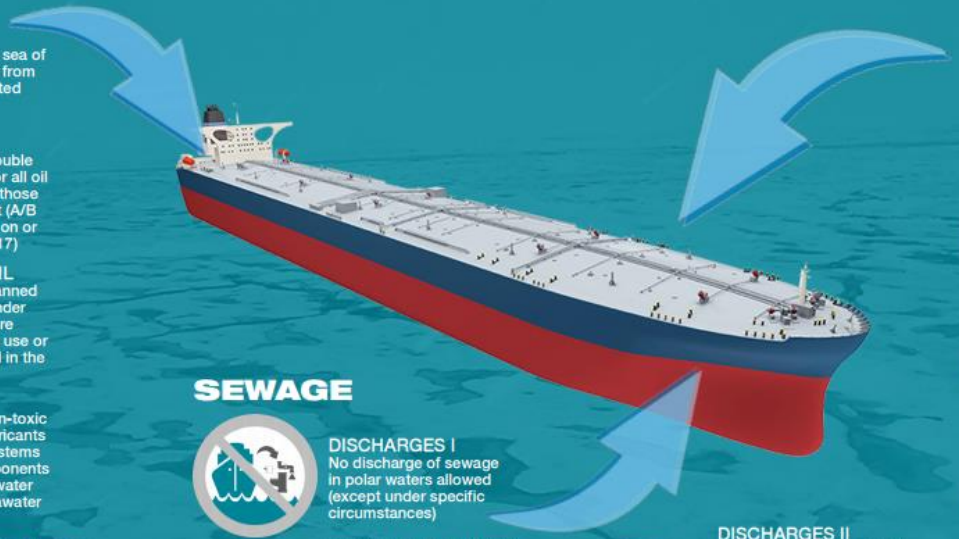
STRUCTURE
Double hull and double bottom required for all oil tankers, including those less than 5,000dwt (A/B ships constructed on or after 1 January 2017)

HEAVY FUEL OIL
Heavy fuel oil is banned in the Antarctic (under MARPOL). Ships are encouraged not to use or carry heavy fuel oil in the Arctic

LUBRICANTS
Consider using non-toxic biodegradable lubricants or water-based systems in lubricated components outside the underwater hull with direct seawater interfaces

INVASIVE SPECIES

INVASIVE AQUATIC SPECIES
Measures to be taken to minimize the risk of invasive aquatic species through ships' ballast water and biofouling



SEWAGE

DISCHARGES I
No discharge of sewage in polar waters allowed (except under specific circumstances)

TREATMENT PLANTS
Discharge is permitted if ship has an approved sewage treatment plant, and discharges treated sewage as far as practicable from the nearest land, any fast ice, ice shelf, or areas of specified ice concentration

DISCHARGES II
- Sewage not comminuted or disinfected can be discharged at a distance of more than 12nm from any ice shelf or fast ice
- Comminuted and disinfected sewage can be discharged more than 3nm from any ice shelf or fast ice

GARBAGE

PLASTICS
All disposal of plastics prohibited (under MARPOL)

FOOD WASTES I
Discharge of food wastes onto the ice is prohibited

FOOD WASTES II
Food wastes which have been comminuted or ground (no greater than 25mm) can be discharged only when ship is not less than 12nm from the nearest land, nearest ice shelf, or nearest fast ice

ANIMAL CARCASSES
Discharge of animal carcasses is prohibited

CARGO RESIDUES
Cargo residues, cleaning agents or additives in hold washing water may only be discharged if: they are not harmful to the marine environment; both departure and destination ports are within Arctic waters; and there are no adequate reception facilities at those ports. The same requirements apply to Antarctic area under MARPOL

CHEMICALS

DISCHARGES
Discharge of noxious liquid substances (NLS) or mixtures containing NLS is prohibited in polar waters

BACKGROUND INFO

- THE INTERNATIONAL CODE FOR SHIPS OPERATING IN POLAR WATERS WILL ENTER INTO FORCE ON 1 JANUARY 2017
- IT APPLIES TO SHIPS OPERATING IN ARCTIC AND ANTARCTIC WATERS: ADDITIONAL TO EXISTING MARPOL REQUIREMENTS
- IT PROVIDES FOR SAFE SHIP OPERATION AND PROTECTS THE ENVIRONMENT BY ADDRESSING THE UNIQUE RISKS PRESENT IN POLAR WATERS BUT NOT COVERED BY OTHER INSTRUMENTS

DEFINITIONS

SHIP CATEGORIES
Three categories of ship designed to operate in polar waters in:
A) at least medium first-year ice
B) at least thin first-year ice
C) open waters/ice conditions less severe than A and B

FAST ICE: Sea ice which forms and remains fast along the coast, where it is attached to the shore, to an ice wall, to an ice front, between shoals or grounded icebergs

ICE SHELF: A floating ice sheet of considerable thickness showing 2 to 50m or more above sea-level, attached to the coast

IMO INTERNATIONAL MARITIME ORGANIZATION

Challenges

Create a representative system of large marine protected areas. 11 zones were selected by CCAMLR and the CEP and a first deadline fixed at 2012.

There is opposition from a few countries that want to continue to fish everywhere.

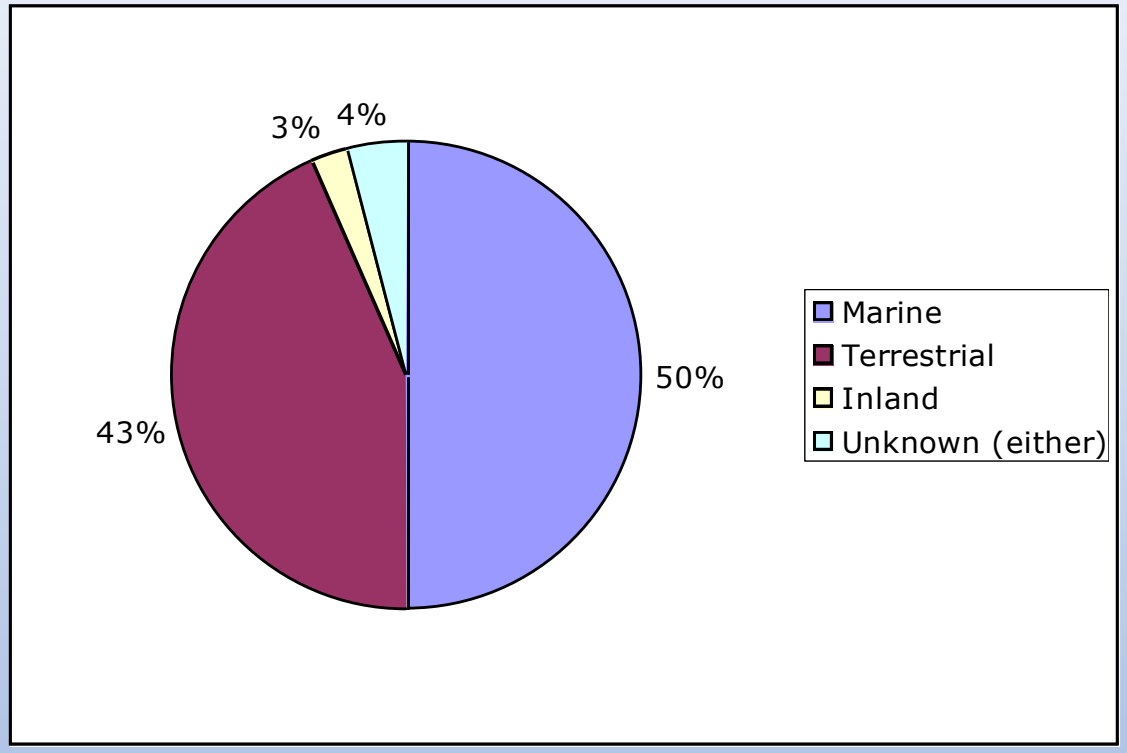
Stop Illegal fishing – a profitable business for a nomber of companies and ships, that collect about 25% of the legal fishing.

Crew of the Kunlun illegally fishing toothfish in Southern Ocean Greenpeace

Challenges

Develop a framework for **bioprospection** of biological and genetic ressources, that represent a growing commercial activity.

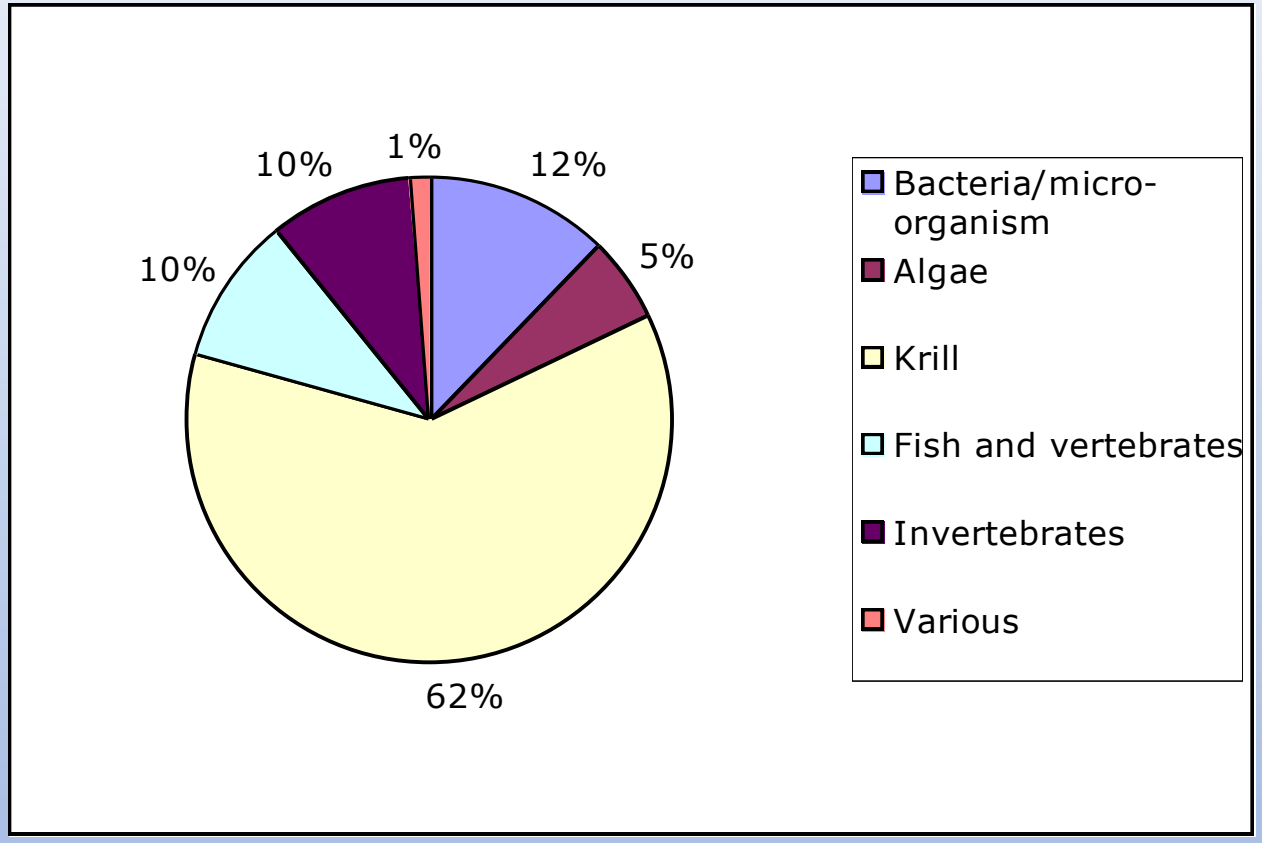
UNU/IAS database on bioprospection in Antarctica



Breakdown of patents or commercial products from Antarctica for each biome.

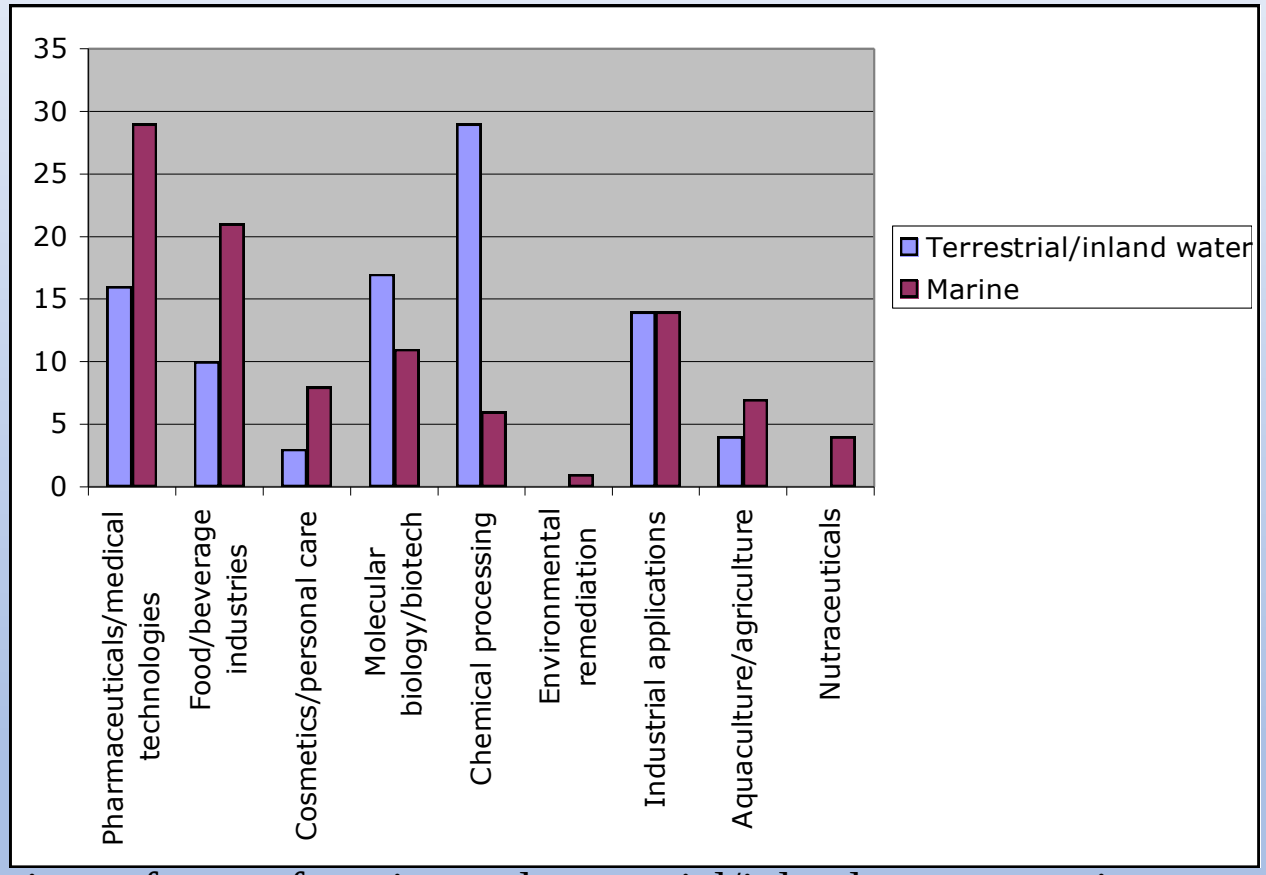
Source: UNU & Federal public service Health, Food chain safety and Environment, as contribution to the discussion of the Committee of Environmental Protection of the Antarctic Treaty on bioprospecting (2009)

Krill represents 62% of source organisms for marine bioprospecting in Antarctica



Source: UNU & Federal public service Health, Food chain safety and Environment, as contribution to the discussion of the Committee of Environmental Protection of the Antarctic Treaty on bioprospecting (2009)

Marine genetic ressources: mainly for pharmaceutical/medical uses, and food/beverage industry

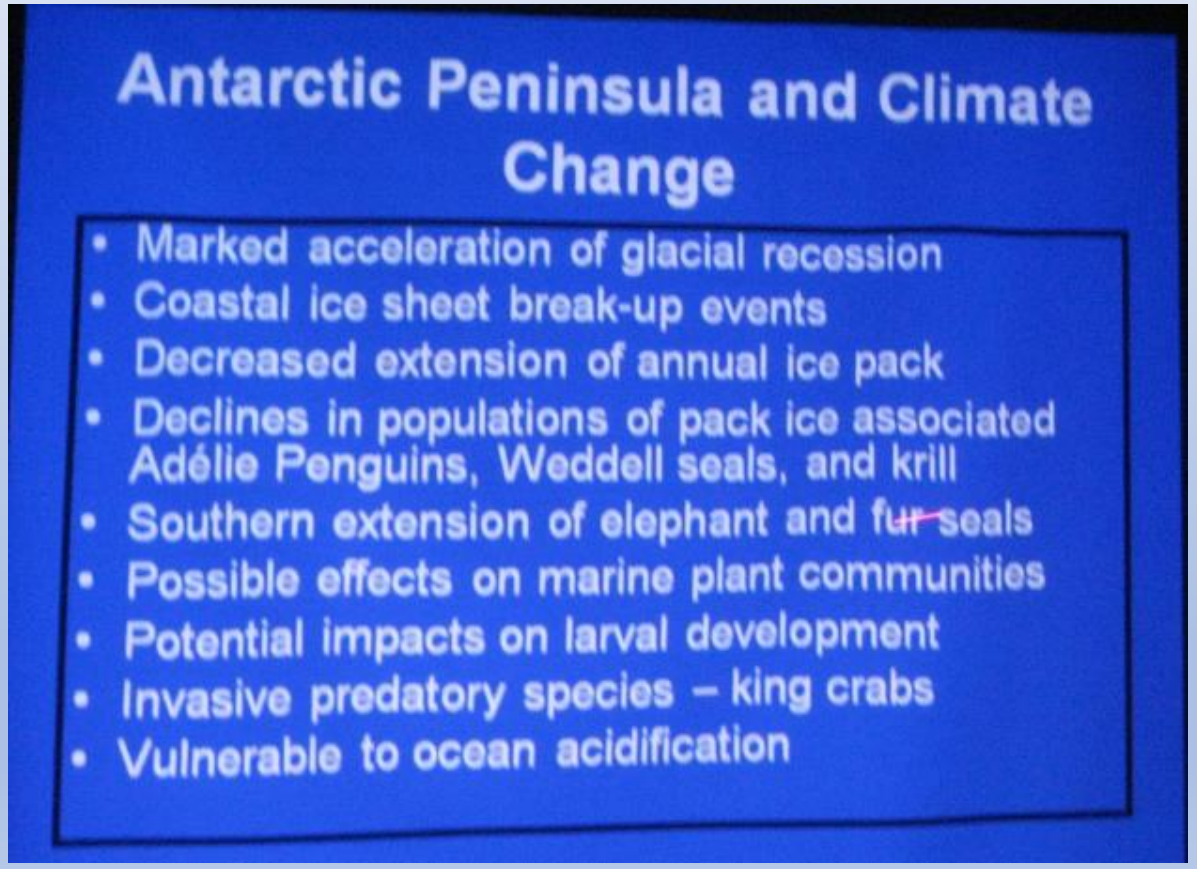


Comparison of uses of marine and terrestrial/inland water genetic resources

Source: UNU & Federal public service Health, Food chain safety and Environment, as contribution to the discussion of the Committee of Environmental Protection of the Antarctic Treaty on bioprospecting (2009)

Challenges

Manage and mitigate the impacts of climatic change (modify the protection measures, locations of ASPA, etc)



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ARTICLE

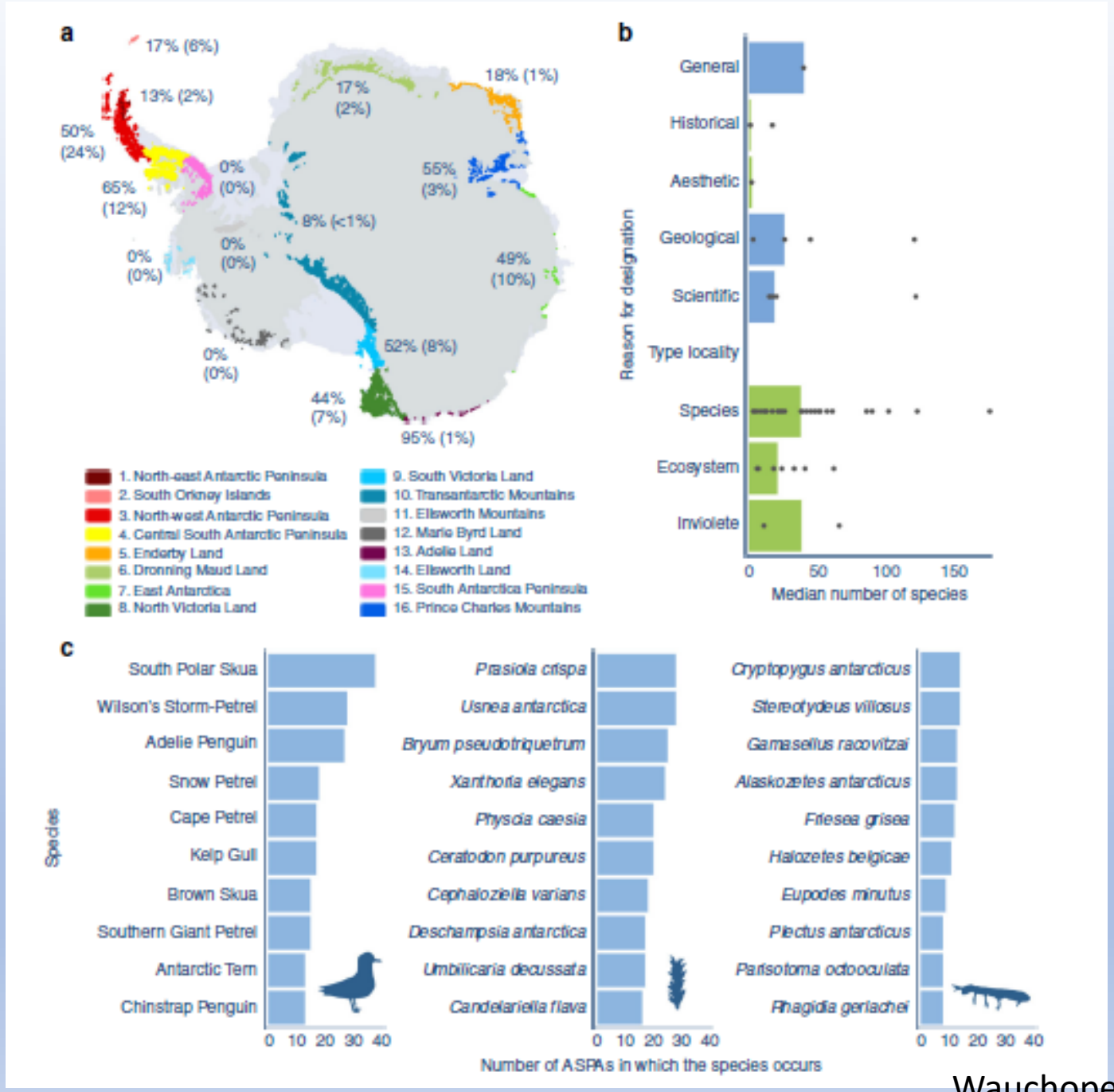
https://doi.org/10.1038/s41467-019-08915-6 OPEN

A snapshot of biodiversity protection in Antarctica

Hannah S. Wauchope[1], Justine D. Shaw[2] & Aleks Terauds[3]

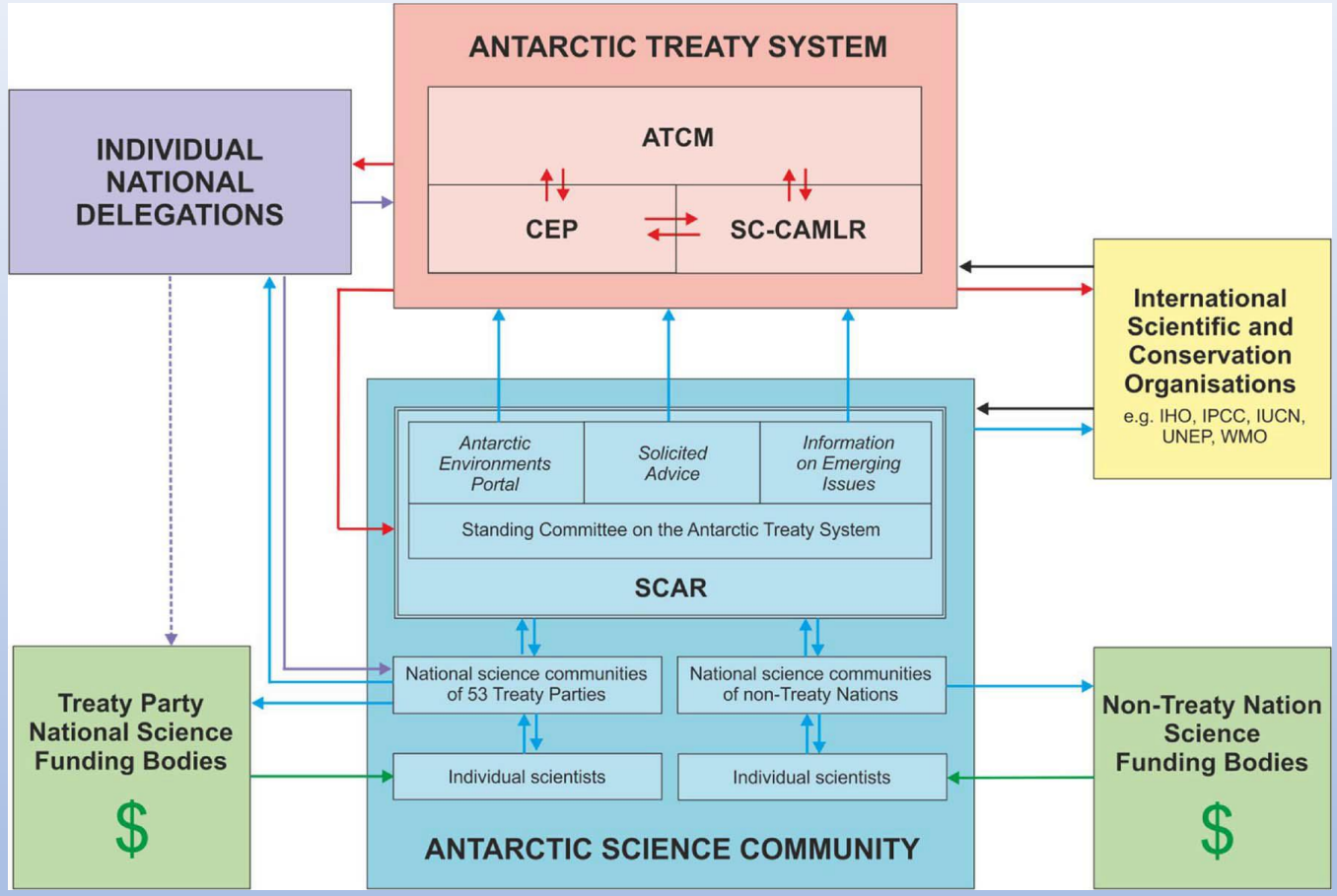
Despite Antarctic Specially Protected Areas covering less than 2% of Antarctica, **44% of species** (including seabirds, plants, lichens and invertebrates) are found in one or more protected areas.

However, protection is regionally **uneven** and **biased** towards easily detectable and charismatic species like seabirds. **Systematic processes** to prioritize area protection using the best available data will maximize the likelihood of ensuring long-term protection and conservation of Antarctic biodiversity.



Wauchope et al. 2019

Scientists, you, play an important role and provide crucial data!



Antarctic science-policy communication pathways

Hughes et al. 2017

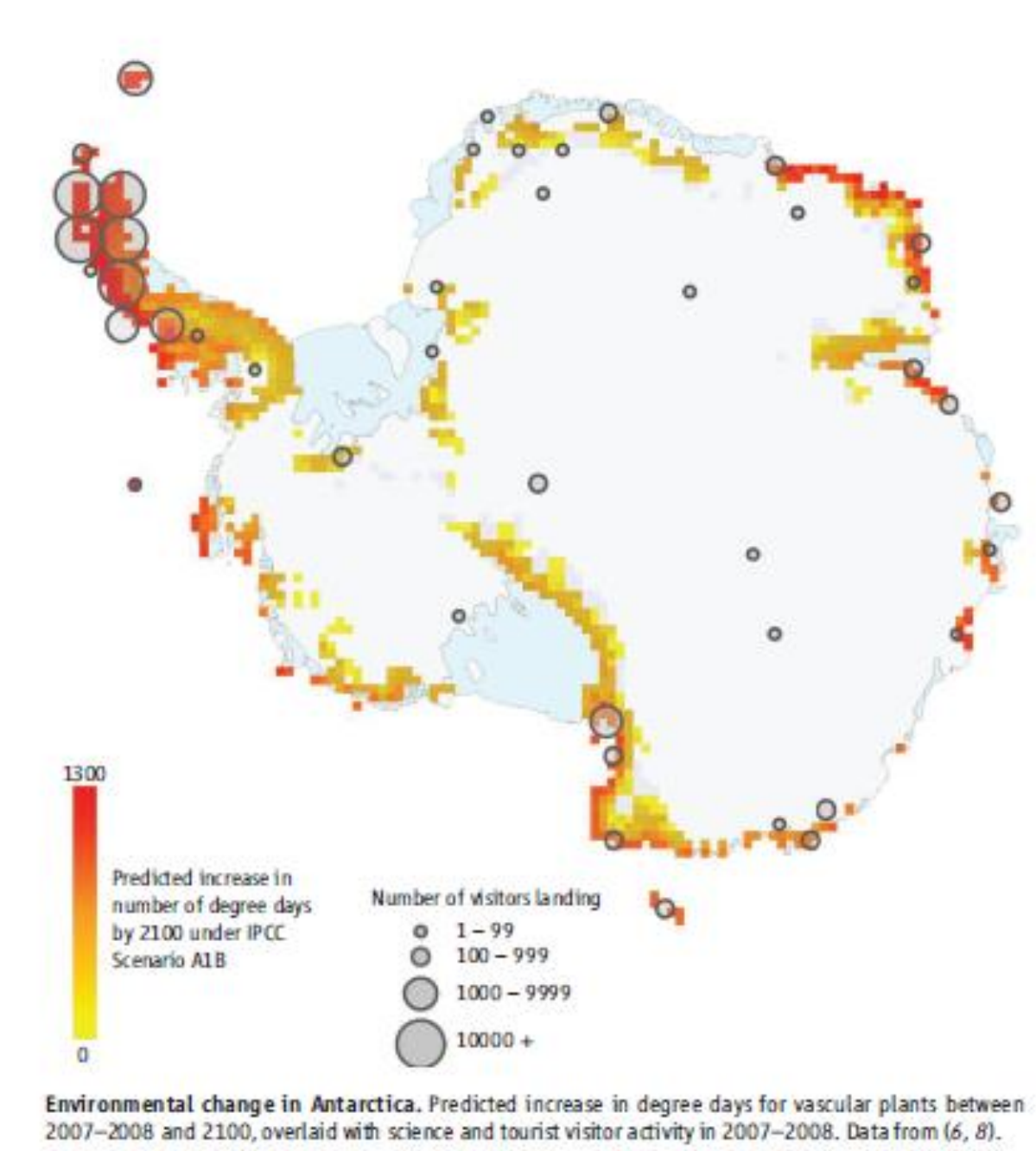
POLICYFORUM

CONSERVATION

Challenges to the Future Conservation of the Antarctic

S. L. Chown,[1,2*†] J. E. Lee,[1] K. A. Hughes,[3] J. Barnes,[4] P. J. Barrett,[5] D. M. Bergstrom,[6] P. Convey,[3] D. A. Cowan,[7] K. Crosbie,[8] G. Dyer,[9] Y. Frenot,[10,11] S. M. Grant,[3] D. Herr,[12] M. C. Kennicutt II,[13] M. Lamers,[14] A. Murray,[15] H. P. Possingham,[16] K. Reid,[17] M. J. Riddle,[6] P. G. Ryan,[18] L. Sanson,[19] J. D. Shaw,[6,16] M. D. Sparrow,[20] C. Summerhayes,[21] A. Terauds,[6] D. H. Wall[22]

Science, 2012



Environmental change in Antarctica. Predicted increase in degree days for vascular plants between 2007–2008 and 2100, overlaid with science and tourist visitor activity in 2007–2008. Data from (*6*, *8*).

Chown et al. 2012

Which are the tools available for the Committee on Environmental Protection (CEP) to protect **microbial diversity?**

The Protocol on Environmental Protection was signed in **1991.**

At that time:

- **little knowledge** on the biodiversity of tiny and microscopic organisms

- molecular methods for biodiversity assessments in their infancy

Annex II : Conservation of Antarctic Fauna and Flora

The conservation only concerns native mammals, birds, plants (incl. mosses, lichens, fungi and algae), invertebrates

Microorganisms mentioned only **'negatively'**
- for the need to issue permits to import **laboratory** ones,
- for the precautions to prevent the introduction of microorganisms with **poultry** and **non-sterile soil.**

(http://www.ats.aq)

Annex V : Area protection and Management

ARTICLE 3

Antarctic Specially Protected Areas (ASPA)

1. …to protect "outstanding **environmental, scientific,** historic, aesthetic or **wilderness values,** any combination of those values, or ongoing or planned **scientific research**"

(http://www.ats.aq)

- 2. … include in the series of ASPA:

(a) « areas kept **inviolate** from human interference so that future comparisons may be possible with localities that have been affected by human activities »

(b) representative of major **ecosystems**

(c) Important or unusual assemblages of **species**

(d) Type locality or only know habitat of any **species**

(e) …

→ nothing hinders to use **microbial species** for ASPA designation

The notion of **'inviolate'** areas exist in the Protocol…. but is hardly mentioned at CEP, and hardly used.

We need **'reference' areas** without microbial anthropogenic introductions for latter comparisons, especially as molecular methods become more sensitive and high-throughput

→ Need to communicate this message to the CEP delegates !

Microorganisms are largely ignored by The Protocol on Environmental Protection of the Antarctic Treaty

Antarctic Specially Protected Areas (**ASPA**) to protect “outstanding environmental, scientific, historic, aesthetic, or wilderness values, any combination of those values, or on-going or planned scientific research” (http://www.ats.aq/e/ep_protected.htm).

However, **no systematic planning** and general focus on the conservation of **large** animals or **higher** plant communities.

Terrestrial habitats are protected in 55/72 ASPAs (in total less than **700 km²**), mostly based on the need to protect vascular plants and bryophyte communities (Shaw et al., 2014).

- 28 ASPAs: **lichens**; 16 ASPAs: **microalgae;** 7 ASPAs: **cyanobacteria**; 3 ASPAs: snow **microalgae**
- 8 ASPAs mention ‘**microbial** habitats’, ‘**microbial** communities’ or ‘soil and lake **micro**flora’.

One tool of the Protocol that could be specifically used to protect microbial habitats is the creation of **inviolate areas** where no visitation is permitted (inside ASPAs, for example).

These zones could be set aside for future research (Hughes et al. 2013) and become extremely valuable.

After a few decades, they would be unique examples of **truly pristine habitats**, representative of the native microbial diversity and processes.

The notion of '**inviolate**' areas exist in the Protocol…. but is hardly mentioned at CEP, and rarely used : only ASPA 172, Lower Taylor Glacier and Blood Falls and a restricted zone in ASPA 126, Byers Peninsula.

Need of cooperation to gather more scientific evidences and fill these ‘gaps’ in our knowledge.

! Undertaking research at a site may compromise, to some degree, the value of that location for future molecular biological research.

Could different scientific disciplines consider choosing their research sites to minimize this risk?

For microbiological research, we need **'reference areas'** without microbial anthropogenic introductions for latter comparisons, especially as molecular methods become more sensitive and high-throughput

→ Need to communicate this message to the CEP delegates and policy-makers and …. our colleagues!


Thanks for your attention!