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PROGRESSING ENVIRONMENTAL PROTECTION OF ANTARCTICA AND THE SOUTHERN OCEAN THROUGH SCIENCE

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Assessment of plant biodiversity in the Vestfold Hills, East Antarctica

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The Vestfold Hills is a 400 km2 ice-free oasis on the Ingrid Christenson coast, East Antarctica. The distribution of plant species across the Vestfold Hills was investigated through an extensive stratified random sampling design. Ten habitat types were identified through fuzzy c-mean classification of spatial data from high resolution Digital Elevation Models. Random points were assigned to these areas and 300 sites were visited during the 2019/20 austral summer. Each site was assessed for chasmoendoliths (algae or cyanobacteria growing in rock cracks), sublithic (under rock) flora and surface flora. Patterns identified in the 1980's of rich surface flora towards the ice plateau and away from salt and wind- blown sediment were confirmed. Most sites across the Vestfold Hills had sublithic and chasmoendolithic algae and cyanobacteria dominant plant assemblages under quartz rocks. Surface plant assemblages included moss and lichen beds in drainage valleys and lithic lichen assemblages on primarily protected south or west rock faces.

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A scientific work plan to develop effective ecosystem-based management for the Antarctic krill fishery

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Antarctic krill (Euphausia superba), thought to have the largest biomass of any animal species on Earth, are the center of Southern Ocean food webs. Krill are also at the center of management for the Southern Ocean: The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), originally known as the "krill convention," came into force in 1982 in response to the growth of the Antarctic krill fishery. With conservation as the core objective of the Convention, CCAMLR has the mandate and opportunity through the krill fishery to lead the world in developing precautionary ecosystem-based fisheries management.

CCAMLR has been working toward developing a new ecosystem-based fishery management system, grounded in robust science. A new scheme is urgently necessary since the current system allows concentrated fishing which is negatively impacting krill predators. Meanwhile, both krill and krill-dependent predators are experiencing the effects of one of the most rapidly warming climate systems on earth. In 2019, CCAMLR adopted a scientific work plan that will form the basis for the revision of the krill management measure that is scheduled for 2021.

Here we present an update on the status of Antarctic krill fishery management. We also outline the three key elements of the new krill science work plan - a biomass estimate and stock assessment to ensure a healthy krill population, and an ecosystem risk assessment that will allow CCAMLR to set catch limits that minimize the impact of the fishery on krill predators by reducing fishing in their key foraging areas.

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Who's going where? Making the best use of logistical information to get more science done

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The Southern Ocean is critically under-observed, which increases the uncertainty in global climate models and other scientific studies.

While individual nations have competitive systems to allocate space and time on their research vessels and aircraft, it is difficult for researchers to find advance information on where vessels outside their national programs are going. Between National Antarctic Programs, tourist vessels, and fishing programs, there are hundreds of vessels in the Southern Ocean each year. Many of these have the potential to deploy observing equipment or to carry scientists but it is difficult for scientists to take advantage of these opportunities because of the opaqueness of voyage planning information.

The Southern Ocean Observing System is tasked with knitting together a sustainable, comprehensive system of ocean observations. To do this, the community needs to make the best possible use of existing logistical resources.

DueSouth (https://data.aad.gov.au/duesouth/) - a Database of Upcoming Expeditions to the Southern Ocean - is designed to support this. DueSouth gets regular feeds of information about vehicle movements from National Antarctic Programs, CCAMLR fisheries vessels, and the Go-Ship program, courtesy of JCOMMOPS. We are working on getting tourist vessel information into the database as well. Additionally, we invite members of the Southern Ocean community to upload information about voyages in their programs.

We will share the lessons of our progress in developing DueSouth and invite contributors to help us create a richly populated tool that helps scientists make the best possible use of the resources we already have.

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Managing Marine Protected Areas in Remote Areas: The Case of the Subantarctic Heard and McDonald Islands

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Large marine protected areas (MPAs) are increasingly being established to contribute to global conservation targets but present an immense challenge for managers as they seek to govern human interactions with the environment over vast geographical expanses. These challenges are further compounded by the remote location of some MPAs, which magnify the costs of management activities. The Australian subantarctic Heard and McDonald Islands (HIMI) Marine Reserve is among the world's most remote MPAs and is relatively large (~71,000 km2). We performed an in-depth case study of the HIMI Marine Reserve using the social-ecological systems meta-analysis database (SESMAD) to characterize the structure of conservation governance and outcomes. The Marine Reserve has generally been successful in supporting a sustainable fishery for Patagonian toothfish while also addressing threats to biodiversity. The remote and isolated nature of the Marine Reserve was critical to its success, but also benefited greatly from collaborations between managers and the fishing industry. Commercial fishers keep watch over the Reserve while fishing, report any observations of illegal fishing, and have at times been asked to verify remote observation of potential illegal fishing vessels. The industry also undertakes annual ecological surveys in the MPA, allowing managers to track environmental trends. The fishing industry itself highlights the importance of industry participation in conservation planning, strengthened by secure access to resources via statutory fishing rights, which provide critical incentives to invest in conservation. We therefore reflect on the potential application of this case to other remote large MPAs, highlighting potential directions for future research.

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Conservation Planning for Antarctic Research Stations

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The small ice-free areas of Antarctica are essential locations for biodiversity and science, but are also subject to pronounced and expanding human impacts from research station activity. Awareness of the need to conserve these natural values by station operators does exist, but management of impacts typically occurs on a reactive basis. While there has been growing momentum to expand Antarctic Specially Protected Areas to ensure conservation of such values, there is also a need for wider management of impacts to be commensurate with the continent's designation as a natural reserve. By using a case study of Australia's Casey Station, this project found significant natural values still persist within close proximity of long-term station infrastructure, but encroachment by the footprint of activity has been an ongoing pressure. Here strategic planning to better conserve such values provides a direct opportunity to enhance protection of the Antarctic environment. This paper introduces a systematic conservation planning approach, tailored to Antarctic research stations, to aid operators to improve the conservation of values surrounding their activities. Use of this approach provides an opportunity to balance the need for scientific access to the continent with international obligations to protect the environment.

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Benthic biodiversity associated with shallow rocky reefs in Antarctica.

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Marine benthic ecosystems are experiencing a pervasive change in biodiversity mostly due by global change, especially in polar ecosystems. In Antarctica, one the most conspicuous environments supporting a high biodiversity are rocky reefs, characterized by the presence of algae-dominated benthic communities from 5 to 25 m depth forming dense algal forest (Desmarestia antarctica), sheltering under the algal canopy there is a diverse biota composed of red algae, sponges, tunicates, hydrozoas, anemones, echinoderms, soft corals and other filter-feeding organisms. At the same time each of these organisms can act as a micro habitat for smaller species such as amphipods, pycnogonids, bivalves, brachiopods, worms, etc. The aim of the present study is to provide the baseline information describing the biodiversity, abundance, bathymetric distribution and physical parameters of shallow-water rocky reefs by classifying marine biogenic habitat in Fildes Peninsula, King George Island, Antarctica. Benthic assemblages between 5 and 15 m depth were sampled by SCUBA diving from 10 different rocky reefs. A total of 131 species of macro-organisms were found, belonging to 16 filo. These results show higher values of species richness than previously reported around Antarctic Peninsula. Fondap IDEAL 150003.

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The biggest moss transplant in Antarctica the case of Brazilian Station Comandante Ferraz

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During the reconstruction of the new Brazilian Station Comandante Ferraz, the new buildings were to be constructed partially over a moss carpet. It was decided by the Brazilian Navy, the Brazilian Environmental Agency (IBAMA) and the Chinese company CEIEC to move the carpet to a new location in order to protect it. Initially the area was measured and a new site as similar as possible to the original was chosen, for that was taken into consideration the size, slope, soil and humidity. Moss carpets where divided in manageable sizes (about 0,2 m²) and with the help of shovels, knife or manually, were removed. Mosses were disposed on trays or plastic boxes and immediately relocated. The patches contained also 5 cm depth of soil to keep the moisture, nutrients and associated fungi necessary. Transplants were performed during the summer of 2016/2017. The area was monitored the following summers to check if the transplanted patches were thriving. The total area is 650m2, making it the biggest moss transplant ever made in Antarctica and maybe in the planet. Transplanted carpets contained Sanionia uncinata, Schistidium antarctici, Polytrichastrum alpinum and the flowering plant Deschampsia Antarctica. Moss carpets have aesthetical value but also retain water and harbors little known communities of Springtails, Mites, Tardigrades, Nematoda, algae, Chromista, Protista, countless fungi and bacteria and certainly a handful of unknown organism as well. Some of them only survives due to shelter, water and temperature control provided. It is important to stress that a whole community is preserved hence.

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Phylogenetic diversity as an index for conservation planning in the Southern Ocean

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A huge barcoding effort has been ongoing since the last IPY (2007–2008) and resulted in a wealth of taxonomic findings. New species as well as yet unrecognised variants have been discovered and described. In parallel, conservation planning in Antarctica has strengthened with the enforcement of the Heard Island and McDonald Islands (HIMI) Marine Reserve, extension of the National Marine Reserve in the French exclusive economic zone (EEZ) at Kerguelen and Crozet, the implementation of the South Orkney Islands southern shelf and the Ross Sea region marine protected areas (MPAs), and East Antarctica, Weddell Sea phase 1 & 2, Domain I and sub-Antarctic MPA projects. Conservation planning has also acquired refined methods that can now include evolutionary indices such as phylogenetic diversity (PD) to take into account the history of taxa. This index is highly dependent on the number of species included in the analysis and also highly dependent on our knowledge of their inter-relationships.
Here we use multiple taxa for which a phylogeny is available (Echinodermata, Teleostei, Arthropoda, etc) to estimate PD at various geographical scales (habitat, ecoregion, statistical subarea) . We used the unifying approach of Chao et al. based on Hill numbers to derive rarefaction (interpolation) and extrapolation (prediction) curves to make fair comparisons of Faith's PD among several assemblages based on heterogeneous sampling effort in each assemblage.
Results show that contrasting PD indices may be derived from different areas around Antarctica. However, confidence limits may overlap as a result of knowledge gaps.

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Proposed Antarctic Specially Protected Area Argentine Islands – Kyiv Peninsula region

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The role of the Antarctic Specially Protected Areas (ASPA) in biodiversity protection is at risk due to its fragmentation and lack of representativeness. Expanding the protected area networks alone isn't enough. Ensuring effective ASPA functioning also requires continuous coverage, ongoing monitoring by the proponents and a systematic conservation planning (SCP). Here we propose establishing a new ASPA on the Argentine Islands, totaling approximately 35 km2.
The islands have diverse geological formations: the spectacular outcrops of the Antarctic Peninsula Volcanic Group succession, fossiliferous siliceous rocks, ancient gabbroids, and red jasper-like vein mineralization in the volcanites on the Yalour Islands. Numerous seasonal lakes and ephemeral springs occur here. The moss and lichen flora of Argentine Islands is very rich; some species show disjunct distribution patterns, which also emphasize the importance of creating large and continuous ASPA. The moss banks of the area are particularly valuable in the context of long-term climate monitoring. Both Antarctic vascular plants are abundantly growing here as well. A southern boundary of Pygoscelis antarctica and P. papua runs through the proposed ASPA, which provides unique observation possibilities.
Our approach is based on the SCP key steps; it enables the effective protection of local biodiversity, which is under pressure because of tourist and climate factors. To understand and monitor biological responses to climate change, numerous experimental plots were established as well, and equipment was constructed on the Argentine Islands area.

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The Development of the Visitor Site Guidelines for the Argentine Islands, Antarctic Peninsula

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The recent substantial increase in cruise tourism in Antarctica has placed a significant burden on its ecosystem. Anchoring, landing, walking and camping endanger Antarctic fragile vegetation, sea life, birds and hauling-out mammals. Although the Protocol on Environmental Protection to the Antarctic Treaty (1991) had incorporated code of conduct for Antarctic visitors, additional Recommendation XXVIII-1 Guidance for Visitors was adopted in 1994, aiming to enable visitors to comply with the Protocol restrictions. However, it became clear that some sites required additional instructions and hence Visitor Site Guidelines have been adopted since 2005. In this research, we present the Visitor Site Guidelines for central Argentine Islands (Galindez, Skua, Winter, and Grotto), that aim to ensure the safety and security of both local biota and visitors. This region is extremely rich in biodiversity: penguins, seals, petrels, terns, moss banks, dozens of lichens species, relatively abundant vascular plants. We believe that tourism activities, organized according to the proposed plan, will have minimum impact on these organisms. Firstly, we open Vernadsky station and historic Wordie House for tourists. Visitors can enjoy wildlife and landscapes on two open routes: to the Woozle Hill on Galindez Island and to the glacier on Winter Island. The rest area will be closed for tourist security. Secondly, we distinguish between closed waters – Skua Creek, Penguin Point sea areas, dangerous Cornice Channel, no-anchoring zone in Meek Channel and Stella Creek – and those for yachts anchorage and landing. Finally, maximum total number of visitors is limited for ensuring environmental protection.

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Biosecurity at Antarctica New Zealand: Past, Present, Future.

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Addressing non-native species (NNS) introductions in Antarctica is one of the Committee for Environmental Protection's (CEP) priority issues. Antarctica New Zealand has a NNS surveillance programme dating back to the 2005/2006 Antarctic season, which includes measures for the prevention, monitoring and response of NNS incursions to Scott Base, Ross Island. These measures align with the guidelines outlined in the 'CEP Non-Native Species Manual' (Resolution 6 (2011)) and the 'Checklists for supply chain managers' developed by the Scientific Committee on Antarctic Research (SCAR) and the Council of Managers of National Antarctic Programs (COMNAP). The two major risk pathways for the introduction of NNS as a result of New Zealand's Antarctic programme are between New Zealand and Antarctica (inter-continental introductions), and between regions within Antarctica (intra-continental introductions). Climate change and increases in human activities are predicted to exacerbate these risks.

The focus of the surveillance programme to date has been on the prevention and mitigation of inter-continental introductions of NNS and we now have over a decade's worth of data on the detection of NNS incursions at Scott Base. The movement of food, and cargo via aircraft, are the most common inter-continental pathways for introduction. Less is known about the risk of the intra-continental transfer of NNS across distinct Antarctic Biogeographic Regions but it is a risk we are exploring preventative measures for. With the upcoming Scott Base Redevelopment, Antarctica New Zealand has identified options to further reduce the risks of NNS introductions, thus expanding the scope of the biosecurity surveillance programme.

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Research and monitoring within marine protected areas: benefits for conservation effectiveness and response to change

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Marine protected areas (MPAs) are one of a suite of management tools that can be used to conserve biodiversity and habitats in response to the current and potential impacts of human activities such as fishing. Reducing such anthropogenic pressures may also go some way towards mitigating the broader impacts of climate change, but MPAs cannot themselves limit processes such as ocean warming or changing sea ice conditions, which are driven at regional or global scales. However, a strategically developed system of MPAs can be a valuable means by which to facilitate research that improves understanding of changing ecosystems, and provides the information necessary for protection and management measures to be effectively adapted in response to such changes. MPAs are therefore important as a scientific resource as well as a conservation mechanism.
We examine how the MPAs established in the Southern Ocean to date have approached the development of Research and Monitoring Plans (RMPs), and suggest practical steps to ensure that such plans are effective in generating outputs that can inform decision-making and support management into the future. Integrating considerations of climate change into both the design and review of MPAs, as well as their associated research and monitoring activities, should allow for a more responsive, adaptive and flexible system of spatial protection to be implemented. A collaborative approach to achieving RMP objectives will be critical to achieving this in practice.

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Metagenomic analysis of detectable population shifts in the bodily microflora of a single visitor over the course of a 22-day sailing voyage to Graham Land from Ushuaia

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With an emerging and ever-expanding human presence in Antarctica, we must likewise examine the movement of human-associated microbial flora that we carry to and from the continent.

Over the course of a 22-day voyage on the Bark Europa, voyage crew member and expedition scientist (microbiologist) Dr. J.J. Hastings collected swabs over eight sites on her body to follow the manner in which her microbiome changed over the course of her voyage. The initial swabs were taken as the ship sailed from Ushaia, then again midway through the voyage after reaching Graham Land, and finally after completing the return voyage across the Drake as the vessel entered the Beagle Channel. Through a metagenomic analysis of the 24 samples collected over the course of the voyage, Dr. Hastings was able to identify which species she carried to the Continent on her body, what then began to populate her body as she came into contact with the indigenous microflora of the South Shetland Islands and Graham Land, as well as what species of microflora remained with her on the journey back to South America.

Dr. Hastings has employed this methodology of longitudinal metagenomic analysis over the course of other expeditions she has led, including space simulation missions in confinement. She hopes to repeat this study with future expeditionary missions to Antarctica to provide better guidance for monitoring and providing effective countermeasures for environmental protection of Antarctica.

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Substantial increase of ship and air traffic on Fildes Peninsula, King George Island, the main logistic hub for the Antarctic Peninsula

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The Fildes Peninsula, King George Island, South Shetland Islands, hosts six permanent stations and a gravel runway. Due to the vicinity to South America and the good accessibility for aircrafts and ships the region represents the main logistic hub for the South Shetland Islands and the Antarctic Peninsula. Data on ship and air traffic on Fildes Peninsula and the adjacent Maxwell Bay have been collected during the austral summer since 2003/04 and revealed a substantial growth of ship and air traffic. The construction of an aircraft parking platform in 2004/05 allowed a considerably higher throughput of aircrafts. Furthermore, so-called air-cruise programs, where cruise passenger arrive and leave by air, were initiated in 2003/04 and have increased significantly since then. Consequently, a strong increase of ship and air traffic was observed on the Fildes Peninsula and in the Maxwell Bay during the study period. This observation is connected with a general increase of a multitude of human activities including scientific research, station operations, transport logistics and tourism in the area of the South Shetland Islands and the Antarctic Peninsulas. The increasing human pressure by increasing air and ship activities have the potential to negatively affect the local ecosystem, although some evidence of habituation effects in seabirds could be found.

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Bioremediation of fuel contaminants across Antarctica. Key findings from field based studies at Argentinian and Australian stations

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In response to the Madrid Protocol (1991), joint signatory nations, Australia and Argentina, have actively researched and implemented strategies for managing and remediating environmental impacts from human activities in Antarctica. Both nations have ongoing research programs into the effects of contaminants on the Antarctic environment, including the application of bioremediation techniques for hydrocarbon-contaminated soils.

Assessing human health and environmental risks and implementing effective bioremediation strategies for hydrocarbon fuels vary depending on a range of contaminant and site-specific factors. The chemical composition of the fuel and it's amenability to biodegradation as well as physicochemical and biological characteristics of Antarctic soils influence the assessment of risk and the selection of optimum bioremediation strategies.

Through examination of field-scale case studies, we present jointly on the similarities and differences in bioremediation of hydrocarbon contaminated soil in Antarctica, including fuel type and composition (fuels used by Australia and Argentina), environmental conditions (particularly differences between Carlini Station and Casey Station, at opposite sides of Antarctica), soil types, microbial responses, nutrient amendment, and measurement and assessment techniques.

Our research demonstrates the Antarctic-wide benefits of international collaboration through development of effective remediation strategies for Antarctica. These findings directly inform the guide for best practice environmental assessment and remediation in Antarctica, the Antarctic Clean-up Manual, developed by the Committee for Environmental Protection to provide scientifically proven guidance that can be applied to the clean-up of a range of impacted sites in Antarctica.

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Current state of Antarctic biodiversity monitoring

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Long term monitoring is considered to be an essential component of ecological research, allowing key scientific questions for species and communities to be answered. In a time of rapid global changes and ecosystem modification this monitoring becomes increasingly important. Antarctica is known for its unique flora and fauna, however, the current rate of change being experienced across the continent may place many of these species under threat. Therefore, knowing how these organisms are responding to environmental changes is vital in understanding community resilience and resistance and predicting regime shifts, in addition to providing essential information for management and policy development. This review investigates the limitations and gaps in existing long term biodiversity monitoring of Antarctic near-shore and terrestrial zones. Here, we focus on studies of three or more years of non-consecutive monitoring. As a whole, biodiversity monitoring in Antarctica was found to be limited, especially those spanning time scales of ten years or more. As previously highlighted by both Antarctic and global findings alike, there is a stark bias towards monitoring charismatic species, such as penguins and mammals; with more than 75 percent of published monitoring studies being focussed on charismatic species. The varied accessibility across the continent is evident in the scarce spread of monitoring programs. Additionally, inconsistencies in methods limits the capacity for comprehensive comparisons between studies. This review demonstrates the many organisms and communities which have remained under studied in Antarctica, as well as emphasises the need for harmonised protocols and data sharing.

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Using ecotoxicology to inform site specific environmental risk assessment of seepages from fuel spill sites on land into nearshore marine environments at subantarctic Macquarie Island.

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The Australian Antarctic Division has been remediating fuel contaminated sites at Macquarie Island since 2003 to mitigate environmental risk. Alongside this remediation program, a comprehensive environmental risk assessment (ERA) of potential impact of fuels to terrestrial microinvertebrate, plant and microbial communities was completed. As a final phase in this ERA, we determined the residual risk of offsite migration of contamination into nearshore marine environments. Direct toxicity assessments were conducted on seven composite test solutions prepared from field groundwaters and coastal seepages, adjusted to ambient seawater salinity. Eleven native marine invertebrates (including gastropods, bivalves, flatworms, amphipods, copepods, isopods) were exposed for up to 21d, with survival and behavioural observations through time. Lethal time estimates (LT10, LT50) were determined to rank the relative toxicity of test solutions. Sensitivity was time dependent (LT10s = 4-15d) and variable between species. Most species showed no response in the first 5 days, and three species showed no response to any test solution. Overall, no consistent patterns in relative toxicity of test solutions were identified, nor in responses based on hydrocarbon composition of test solutions. While toxicity was observed in some species, this was only under worst case conditions that would rarely occur naturally; undiluted continuous extended exposure without flushing. Results of these toxicity assessments, considered in the context of natural dynamics on-site; including low seep discharge rates, high dilution potential, and highly energetic receiving environment, provide robust evidence that residual contamination at remediated sites at Macquarie Island present a low overall risk to adjacent marine communities.

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Risk Assessment and Remediation of contaminants in Antarctica:

How clean is clean enough?

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The Antarctic and subantarctic are generally considered pristine, yet contamination from local and global sources regularly occurs. Contaminated sites from past and present human activities are currently being remediated by Australia, including fuel spills and former waste disposal sites. But when should these sites be considered clean? Ecotoxicological assessments and toxicity tests that determine effects of contaminants on biota are used worldwide as the basis for derivation of Environmental Quality Guidelines, and as lines of evidence in Environmental Risk Assessments. Standardised toxicity tests and Environmental Guidelines are available for temperate and tropical regions, but are not yet developed for Antarctica. Due to the unique properties of Antarctic environments and biota, these guidelines must be based on the response of a range of native Antarctic species. Over the past 15 years, the Australian Antarctic Program has developed a suite of traditional and novel ecotoxicological approaches to determine biological responses and the potential risk of contaminants to terrestrial soils and marine waters in Antarctica. Here we summarise progress to date and the process by which concentration-response curves from toxicity tests are used to derive scientifically robust Environmental Guidelines using Species Sensitivity Distribution models. These models predict concentrations that are protective to a certain proportion of the native community, which can be used as Remediation and Clean-up Targets. This work informs environmental decision making in the AAP, and will be incorporated into the Committee for Environmental Protection (CEP) Clean-up manual, and available for use by other Antarctic Treaty states more broadly.

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Antarctic krill fishery effects over penguin breeding populations under adverse climate conditions: implications for the management of fishing practices

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Fast climate changes in the western Antarctic Peninsula (WAP) are reducing krill density, which along with increased fishing activities in recent decades, may have had synergistic effects on penguin populations. We tested that assumption by crossing data on fishing activities and Southern Annular Mode (SAM) with all penguin population data available between 1980 and 2018 for the whole western Antarctic Peninsula, including areas of high and none fishing pressure. Increases in fishing catch within a 30km radius of penguin colonies during the non-breeding period were likely to result in impacts on both chinstrap (Pygoscelis antarcticus) and gentoo (P. papua) populations. Catches and climate change together elevated the probability of negative population growth rates: very high fishing catch under low values of the SAM implied a decreased growth rate. The current management of krill fishery in the Southern Ocean takes into account an arbitrary and fixed catch limit that does not reflect the natural variability of the krill population, therefore affecting penguin populations when the environmental conditions were not favourable. Since Krill flux and recruitment is still not understood, precaution should be applied on management of krill fisheries. Years of warm winter with low sea ice cover should be considered unfavourable and catches should be limited to the lower availability of Krill to top-predators.

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Systematic conservation planning for the Antarctic Peninsula

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The Antarctic Peninsula is one of the most rapidly changing places in the Southern Hemisphere. Home to much of the continent's biodiversity, it is essential that we determine how to best conserve the region's unique values as environmental change becomes more pronounced and as human activity grows. Improving the management of human activity in the region is a key priority for the International Association of Antarctica Tour Operators (IAATO), the Committee for Environmental Protection and the Antarctic Treaty Parties. An integrated approach is required to maintain multiple intrinsic values and stakeholder needs, particularly where human activity is highly concentrated. SCAR and IAATO have partnered in a collaborative project to develop an integrative, evidence-based approach to site management, incorporating science and tourism activities, and all known biodiversity features (such as breeding seabird colonies, vegetation, and invertebrates). Systematic Conservation Planning (SCP) is a conservation science approach employed to aid decision-makers in managing whole landscapes involving multiple stakeholders and multiple objectives. Here we present early results from this project. We highlight several scenarios that prioritise different aspects of site prioritisation, such as biodiversity connectivity, and identify sites important for biodiversity, science and tourism.

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Capturing Legacies of Terrestrial Biology Research for the Future

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Over fifty years of international research has shown that the Ross Sea Region (RSR) contains rich and iconic terrestrial flora and fauna that exhibit complex biogeographic patterns. The distribution and activity of these endemic biological communities are overwhelmingly determined by the availability of liquid water; however, localised warming may significantly change the hydrological patterns in terrestrial Antarctica, leading to non-linear and heterogeneous changes in these unique biotas.

A systematic and comprehensive understanding of taxa distribution and their associated biological and ecological processes is essential to understanding and projecting warming-induced changes in RSR terrestrial biology. As part of New Zealand's Antarctic Science Platform, we will synthesise fifty years of RSR terrestrial biology research outputs in various forms (estimated to be more than 20,000 journal articles and books as well as digital databases) using modern heuristic informatic technologies (e.g., natural language processing, geoparsing, and data mining) and high-performance computing. We will retrieve and organise knowledge embedded within these data sources, many of which were produced before the availability of GPS for field biologists and thus require sophisticated and novel applications of geographic information retrieval techniques.

The compiled data products require review and validation, and we will engage international researchers through a future workshop (tentatively scheduled for 2022) to ensure a balanced representation of the collective knowledge on RSR terrestrial biogeography, which will serve as the framework that enables evidence-based bioregionalisation of the RSR. Here we outline our plans for this ambitious undertaking and invite international researchers across disciplines to join this effort.

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Antarctic wilderness in decline after 200 years of human activity

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Recent assessments of Earth's dwindling wilderness have emphasised Antarctica as a crucial wilderness in need of protection. Yet human impacts on the continent are widespread, the extent of its wilderness unquantified, and the importance thereof for biodiversity conservation unknown. We have assembled a comprehensive record of human activity (2.7 million records, spanning 200 years) and used it to quantify the extent of Antarctica's wilderness, and its representation of biodiversity. In this presentation, we show that 99.6% of the continent's area can still be considered wilderness, but that this area captures few biodiversity features. Pristine areas, free from human interference, cover a much smaller area (< 32% of Antarctica), and are declining as human activity escalates. Urgent expansion of Antarctica's network of specially protected areas can both reverse this trend and secure the continent's biodiversity.

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Hotspots for marine invasive species around coastal Antarctica identified using a network-based risk index

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Previous estimates suggest approximately 180 vessels on 500+ voyages visit Antarctic waters annually [1], each potentially transporting new species to the region. On top of that, rapid environmental change in the Antarctic region is likely allowing new species to establish that were previously excluded by physiological barriers, but the risk they represent is poorly understood. Determining likely locations for anthropogenic introductions and the origins of newly arrived species has significant management implications, including eradication vs protection and where to monitor or implement biosecurity actions.

We present a spatial risk assessment for shallow coastal areas around Antarctica using network-based metrics derived from worldwide activity of Antarctic-going vessels. Data on activity in the Southern Ocean and worldwide port calls were used to create a transport network for ships that visited the Antarctic Treaty Area from 2014-2018 inclusive. The network quantifies previous estimates of much higher ship activity in the Antarctic Peninsula region, especially from South America, but also captures substantial ship connectivity to the Arctic and temperate Northern hemisphere ports, which may have been overlooked as donor regions for anthropogenic introductions in the Antarctic region. The tourism, fishing and research sectors represent different risk and may benefit from tailored management responses.

We recommend targeted monitoring of highest risk areas and further quantification of species within pathways to Antarctica (e.g. fouling Antarctic vessels). Moreover, cooperation between operators of different activity types could ensure maximum impact of biosecurity measures in targeted locations.

[1] McCarthy et al. (2019). Global Change Biology, 25(7).

840

Treading lightly – Monitoring physical human impacts on glacial sediments, East Antarctica

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The Vestfold Hills in East Antarctica is the third largest ice-free area on the continent. The coastal oasis comprises 400 km² of exposed rock, glacial, marine, and aeolian sediments, and numerous fresh and saline lakes. There is a sustained human presence from Australia's Davis station but systematic information on the vulnerability of this environment to physical impacts, such as walking tracks, is lacking.

We mapped the composition, distribution, and morphology of different landforms across the Vestfold Hills to better understand their variability. We also set up test sites on different substrates to monitor natural recovery from walking tracks over time and to inform an assessment of the vulnerability of these different substrates to human impacts. At these test sites, we analysed a range of near-surface sediment characteristics to determine visual and non-visual changes resulting from foot traffic. Visual changes are the strongest indicator of impact and recovery on heterogeneous sediments such as glacial till. Structure from Motion photogrammetry is a useful tool for capturing baseline information and tracking change over time.

The data highlight the usefulness of substrate mapping, sediment analysis, and Structure from Motion photogrammetry for understanding human impacts, increasing the range of techniques available to track disturbance in ice-free areas. This information is also important as a baseline for current conditions to monitor natural landscape change in a warming climate.

756

The use of granular activated carbons for contaminant site clean-up in the Antarctic, and its in situ regeneration for increased longevity and continuous use

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The large surface area, microporous structure, and increased surface reactivity associated with granular activated carbon (GAC) makes it one of the most powerful adsorbent materials used in purification and separation processes. Coinciding with this, its inexpensive nature makes GAC a viable option for the treatment of contaminated sites in remote regions such as the Antarctic. Whether it be utilized within in situ (i.e. permeable reactive barriers) or ex situ (i.e. pump-and-treat) treatment methods, the GAC will remove contaminants from groundwaters, ultimately preventing further spread into the environment.

Despite this, the leading shortcoming of GAC is the limited lifetime for which it can perform. Upon reaching its adsorptive capacity it is no longer effective and is often returned to Australia for disposal and replaced with fresh material. Such continuous changeout of GAC makes the process infeasible due to the high costs associated with transport, and the disposal of exhausted material into landfill leads to the possibility of toxic contaminants leaching into the environment. A more economical and environmentally friendly option is to regenerate the material so that it can be used for several cycles of adsorption and regeneration.

This work discusses how GAC can be regenerated in situ using electrochemical methods. The data presented suggests that it is a beneficial pathway for use in the Antarctic due to its low cost and minimal energy usage. Additionally, when the appropriate reactions are promoted, it is able to fully degrade contaminants, suggesting that the GAC can be used over and over again.

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Future Directions for Research on Contaminant Containment in Antarctica

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The experience of 20 years of work in environmental remediation and contaminant containment in the Australian Antarctic Territories has highlighted the need for further research to reduce the cost and increase the efficacy of deployment of containment and remediation technologies in the Antarctic.

This presentation will focus on the experience gained at Thala Valley, a dig and haul remediation process and the containment of oil spills at the main power house at Casey, a permeable reactive barrier deployment, to examine and justify the need for better understanding of how adsorbents work, both physically and from a microbiological point of view, in the Antarctic and how their performance can be enhanced through in situ remediation to extend their life.

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Permeable Reactive Barriers for contaminant remediation in Antarctica

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Transportation and storage of petroleum hydrocarbons in Antarctica has resulted in numerous accidental fuel spills. Migrating fuel leads to significant impacts to marine and terrestrial ecosystems, whilst typically low soil nutrient concentrations and temperatures result in low rates of natural attenuation.

Permeable Reactive Barriers (PRB's) are a method to contain and remediate migrating contaminant plumes in an efficient and cost-effective manner. Once placed in situ they require minimal energy, monitoring and maintenance.

This presentation discusses parameters requiring optimisation for the design of efficient and effective PRB's. These parameters include; physical dimensions; reactive material selection; and site placement, considering variables such as; site water fluxes; contaminant characteristics and concentrations; and site access. It will also present the results and key learnings from various case studies located at Casey Station, East Antarctica and discuss how these findings may be translated to other sites across the Antarctic continent.

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EPB's initiative on reducing Environmental Impacts of Polar Research and Logistics

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The impacts of human activities to Polar environments are diverse in their scale and in the level to which they are understood. The environmental impacts of Arctic and Antarctic research and logistics varies with type of activity, technology used and the environment in which it takes place, still the Polar community collectively has a responsibility to minimise the negative impacts of its activities.

The European Polar Board (EPB) launched its initiative in 2018 with a workshop for Members and logistics managers at the POLAR2018 conference in Davos, Switzerland. This workshop, focused on plastic use in Polar research, was followed by a breakout session at the 2018 Arctic Circle Assembly, co-convened with INTERACT, titled 'Minimising the footprint of Arctic research'. Discussions at these events led to the establishment of an Action Group on Environmental Impacts of Polar Research and Logistics, which aims to collate best practices and develop practical guidelines for EPB Members and others. These guidelines will be useful to researchers and managers at all scales, from individuals conducting small-scale campaigns, to managers of national Polar research programmes. Guidelines will address all aspects of research and logistics activity in the Antarctic and Arctic. The EPB initiative recognises the important challenge to reduce current environmental impacts in Polar research and logistics, without compromising on research quality or safety.

This poster outlines the priorities and outcomes that have emerged from the EPB Action Group on Environmental Impacts of Polar Research and Logistics, and detail plans for its future work.

1046

A call for protection of a growing Antarctic ecosystem service: Blue Carbon gains on Antarctic Continental Shelves are an increasing negative feedback on climate change

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The reduction of seasonal sea-ice extent, retreat of marine terminating glaciers and loss of ice-shelves are allowing new and longer lasting phytoplankton blooms over shallower waters, and opening up habitat for benthos. Zoobenthos have increased feeding and growth duration. The net results are increases in carbon drawdown from the atmosphere into phytoplankton and carbon storage in benthic invertebrates. Although carbon sequestration – defined as removal of carbon from the carbon cycle for hundreds or thousands of years – is likely to be only a small percent of the carbon captured, the area of sea floor where this is taking place is very large and increasing. The number of ice-free days, and thus the number of days the bloom is available for feeding duration potential, is crucially increasing across shallower shelf waters where benthos is in direct contact with the bloom. This is further compounded by the predicted increase of growth rates that may double with a moderate (1°C) increase in sea temperature. However, new and increased coastal productivity faces considerable threats (harvesting, climate spikes, pollution etc) some of which can be reduced through pre-emptive action. We suggest incentivising Antarctic Blue Carbon protection by building a 'non-market framework' via provisions in the UNFCCC Paris Agreement. This could be connected and coordinated through the Antarctic Treaty System to promote and motivate member states to value the ecosystem service Antarctic Blue Carbon provides.

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Revisiting the moss flora of Admiralty Bay (King George Island) Antarctica

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The Antarctic Continent has 13.661.000 km2. It's the most inhospitable place on Earth because it's the coldest, highest, driest and it has the largest and most extensive layer of ice on the planet. Within the archipelago of the South Shetlands Islands is King George Island, where Admiralty Bay is located. The bay has 122.08 km² of surface and the vegetation is mainly cryptogamic, but also tree species of angiosperms. In the process of revisiting the Management Plan for Admiralty Bay, of the 116 species of mosses found in the Antarctic, a total of 63 species of moss were found, divided between 33 genera and 17 families. Other than that, 8 new occurrences were found for the region, Brachythecium austroglareosum (Müll. Hal.) Kindb., Gemmabryum dichotomum (Hedw.) J.R. Spence & H.P. Ramsay, Dicranella campylophylla (Taylor) A. Jaeger, Campylopus vesticaulis Mitt., Schistidium lewis-smithii Ochyra, Pohlia wilsonii (Mitt.) Ochyra, Schizymenium pusillum (Hook. f. & Wilson) A.J. Shaw and Notoligotrichum trichodon (Hook. f. & Wilson) G.L. Sm. Considering the total number of species of mosses in Antarctica, the Bay area houses about 54% of all Antarctic moss species, a highly significant number, considering the size of the Bay. The human influence has grown lately with more cruise ships and tourists visiting the area, this can impact negatively the local ecosystems. From the results presented, it is possible to conclude that the diversity of mosses occurring in the Admiralty Bay is high, generating a need for environmental monitoring to preserve the species richness to the site.

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The Scott Base Redevelopment Environmental Monitoring Programme: A Multidisciplinary Approach

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Scott Base opened in 1957. 60 years on, it is reaching the end of its functional life.
The Scott Base Redevelopment (SBR) is the largest project ever undertaken by New Zealand in Antarctica. The Antarctic Treaty System requires a Comprehensive Environmental Evaluation (CEE) before redevelopment begins. The CEE is underway, supported by a monitoring programme to verify the accuracy of the CEE's impact assessment and detect unforeseen impacts.
In the austral summers of 2018/19 and 2019/20, a multidisciplinary team established an environmental baseline against which future natural and SBR-related changes will be measured.
In 2018/19, 25 monitoring plots were established around Scott Base. They were selected by stratified sampling. Biodiversity surveys, chemical, spectroradiometry, and microbial DNA analysis of soils were completed. Three seals cameras and 12 dust collectors were installed. A multispectral imagery drone survey captured vegetation and surface disturbance.
In 2019/20, the plots were re-visited for vegetation assessments and sampling of invertebrates, soil, dust, microplastics, and meltwater. Five monitoring plots were established as control sites at nearby Cape Evans. Three marine monitoring sites were established to quantify seafloor biodiversity, assess contaminant concentrations in four sentinel species, and measure water currents to understand the potential for sediment and contaminant transport. The sites were selected based on previous research in consultation with Antarctica New Zealand to identify the most likely locations to be impacted by SBR.
The draft CEE and fieldwork findings will be presented at the 2021 Committee for Environmental Protection.

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Overview of Environmental Remediation Research for improved environmental protection within the Australian Antarctic Program

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A legacy of land and coastal marine pollution exists in Antarctica following decades of human occupation and activities. Hydrocarbon contamination of soil and water is most common, while abandoned stations, legacy waste disposal sites and ongoing wastewater discharges cause impacts through multiple contaminants (e.g. metals, polychlorinated biphenyls, fuels, inert and putrescible waste, ammunition and laboratory chemicals). Antarctica's extreme environmental conditions and remote location makes the clean-up of contaminants difficult and resource intensive. Past clean-up solutions have often relied on all contaminated material being excavated and returned to Australia for treatment and disposal. However, where possible, on-site remediation is preferable to provide a sustainable solution for site restoration – ensuring soil, once remediated, remains in the rare ice-free areas where it is most ecologically valued. For over 20 years, scientists and engineers as part of the Australian Antarctic Program have been conducting applied human impacts and remediation research to develop procedures and technologies that reduce environmental impacts from chemical contaminants in the Antarctic. This talk will provide an overview of our progress in developing, designing and applying cost-effective remediation technologies for Antarctic and subantarctic regions, and highlight the full scale application of these techniques using a number of case studies. Research outcomes inform the guide for best practice environmental assessment and remediation in Antarctica, the Antarctic Clean-Up Manual, and can be applied to the clean-up of a range of impacted sites across Antarctica.

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Where science meets policy: The Antarctic Clean-up Manual as a case study in protecting the Antarctic environment

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One of the key obligations of the 1991 Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol) is the clean-up of "past and present waste disposal sites on land and abandoned work sites of Antarctic activities" unless clean-up would result in greater environmental impact.

To assist Parties in addressing their clean-up obligations, in 2013 the Committee for Environmental Protection developed the Antarctic Clean-Up Manual. The Clean-Up manual provides scientifically proven guidance and practical resources that National Antarctic Programs can draw on to clean-up a range of contaminated sites in Antarctica. Recognizing the on-going nature of Antarctic contaminant risk assessment and remediation research, the manual is an evolving central resource, available online, and updated and added to as "new work, research and best practice emerges". Input from the scientific community is therefore essential to the continuing development and improvement of the Clean-Up manual.

Here, we present jointly on the Clean-Up manual as a case study for the effective and ongoing integration of science into environmental policy for Antarctica, providing both a science and policy perspective. The current components of the manual are presented, along with a discussion on priority research needed to strengthen the manual into the future. Finally, we promote the Clean-Up manual as a best practice tool for environmental managers and policy makers in order to support the effective and timely clean-up and remediation of sites across Antarctica, and the ongoing protection of the Antarctic environment.

1119

The polychaete reefs of Ellis Fjord – a vulnerable and unique benthic community in the Vestfold Hills, East Antarctica

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In 1985 a survey of benthic communities in Ellis Fjord (Vestfold Hill, East Antarctica) discovered a large reef of polychaete worms unlike any other encountered anywhere on Earth. The reefs are comprised of thin (3 - 5 mm diameter) but long (estimated 0.5 – 1 m) calcareous tubes of Serpula narconensis, a polychaete species distributed in Antarctic and sub-Antarctic seas, but normally in small isolated clumps. These reefs were estimated to extend for over 8 km in the lower reaches of the Fjord and cover the bottom from 5 to 30 m deep. These reefs are also home to an incredible density and diversity of epifaunal invertebrates including urchins, crinoids, holothurians and prawns, as well as fish. A survey conducted in 2019 confirmed the continued presence of these reefs and will provide data to determine whether any changes have occurred in this community.

The unique environmental conditions of Ellis Fjord may have afforded these communities protection from physical disturbance which has allowed them to flourish, possibly for millennia. A narrow and shallow entrance to the fjord, which combined with strong tidal currents moving through the narrows and offshore winds prohibits the entrance by any floating ice. In addition it is hypothesised that the narrow entrance also discourages the entry of Weddell seals which are known to disturb the seabed while foraging for fish and prawns in coastal waters, particularly during breeding season. This rare and vulnerable community is worthy of consideration for special protection status such as an ASPA.

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Protecting Antarctica through Co-production of actionable science: Lessons from the CCAMLR marine protected area process

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Global threats to ocean biodiversity have driven international targets calling for a worldwide network of marine protected areas (MPAs). In line with these targets, the Commission on the Conservation of Marine Living Resources (CCAMLR) has been working towards adopting MPAs in the Southern Ocean. CCAMLR is considered a leader in science-based management and has been guiding the way on international MPAs. The west Antarctic Peninsula, threatened by climate change and industrial fishing, has been a priority area for MPA planning in CCAMLR. Since 2011, Chile and Argentina have worked to develop an Antarctic Peninsula MPA proposal which they submitted to CCAMLR in 2018. We use the Antarctic Peninsula MPA proposal process as a case study for understanding the science-policy interface in this international conservation regime. Specifically, we use existing frameworks for co-production of actionable science to examine the Antarctic Peninsula MPA process. We show that the Antarctic Peninsula MPA Proponents engaged in a highly collaborative, transparent, and science-based process which exemplified best practices for actionable science and co-production. Despite following best practices for actionable science, the MPA proposal has not yet been adopted, largely due to political barriers. We elaborate on the importance of co-production of actionable science and its effectiveness as well as to limitations in the Southern Ocean and beyond. Finally, we highlight that science-policy best practices may not be sufficient to drive consensus and the ultimate need for political will in the decision-making underpinning MPA designation in the Southern Ocean.

1010

Further developing the terrestrial Antarctic Specially Protected Area system using Systematic Conservation Planning

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Systematic Conservation Planning is regarded as an effective and well-developed mechanism for facilitating the development of protected areas globally. To date, however, its application in Antarctica has been limited. In July 2019, SCAR and the Committee for Environmental Protection (CEP) convened a workshop on further developing the Antarctic protected area system, where discussions included the inputs, benefits and challenges of applying a systematic conservation planning process to Antarctica. The findings of this workshop were presented to the XXII CEP meeting which subsequently encouraged research to build on the existing body of scientific evidence and to support the further development of the protected area system.

In response to discussions in the multi-stakeholder workshop, and subsequent encouragement by the CEP, work has now begun on applying the principles of systematic conservation planning to terrestrial Antarctica. Here we report on the initial stages of this continent-wide research, including data acquisition, software and challenges. We show that the data that are currently available as potential inputs to a systematic conservation planning process are now extensive, and range from existing spatial layers to more recent data, including continent-wide, spatially explicit data on biodiversity distribution (actual and predicted), wilderness areas, type localities and habitats. We highlight that despite the challenges inherent in combining complex and disparate data from multiple sources, systematic conservation planning processes can be aligned with guidance in Annex 5 of the Environmental Protocol, and have significant potential for improving environmental protection through the further development of protected areas in Antarctica.

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