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RESEARCH/REVIEW ARTICLE

Demonstration of "substantial research activity" to acquire consultative status under the Antarctic Treaty

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Abstract

Antarctic Treaty Consultative Parties are entitled to participate in consensus-based governance of the continent through the annual Antarctic Treaty Consultative Meetings. To acquire consultative status, an interested Party must demonstrate "substantial research activity," but no agreed mechanism exists to determine whether a Party has fulfilled this criterion. Parties have generally demonstrated substantial research activity with the construction of a research station, as suggested within the Treaty itself. However, this largely demonstrates logistical capacity, rather than research activity, and often results in major and persistent impacts on Antarctic terrestrial environments. Our study found that national investment in Antarctic infrastructure, estimated by the number of bed spaces at stations, was not a reliable indicator of scientific output. Therefore, we investigated metrics to evaluate research activity directly, and identified both the overall number of Antarctic papers and the proportion of national scientific output these represented as meaningful metrics. Such metrics could (1) demonstrate a nation's level of research activity in Antarctica or (2) help Consultative Parties assess the level of research activity undertaken by a Party seeking to acquire consultative status. Our data showed that, even without land-based Antarctic infrastructure, Canada, Denmark and Switzerland may have reasonable grounds to demonstrate "substantial research activity" on a level comparable with existing Consultative Parties. The use of these metrics may help dispel any perceived requirement for the establishment of a research station to reach consultative status, by putting a greater emphasis on generation of scientific research outputs rather than construction of Antarctic infrastructure.

Antarctica is the only continent on the Earth where scientific research is the dominant activity. Substantial human activity in the region commenced with preparations for the International Geophysical Year of 1957/58, which set an important precedent of the use of Antarctica for scientific research that has been recognized in ATS legislation, and persists today (Jacobsson 2011; Walton 2011).

Antarctica is governed by consensus through the ATS (Rothwell 1996; Scully 2011). Under the Antarctic Treaty, which was agreed by the 12 original signatory Parties in 1959 and entered into force in 1961, Antarctic territorial claims by the seven claimant states were put into abeyance, the continent was demilitarized and testing of nuclear weapons was prohibited (SAT 2016a). Furthermore, the Treaty guaranteed freedom of scientific investigation in Antarctica, exchange of information and freedom of access and inspection by all Parties. Importantly, the Treaty also established a need for regular meeting of Parties to exchange information, consult on matters of common interest concerning Antarctica and recommend to their governments measures to further the objectives of the Treaty (Article IX, para. 1). Since the Treaty entered into force, 53 nations have become signatories, of which 29 are Consultative Parties, having the right to participate in consensus-based decision-making during the now-annual ATCM. The remaining 24 nations are non-Consultative Parties, which may

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Abbreviations in this article
ATCM: Antarctic Treaty Consultative Meeting(s)
ATS: Antarctic Treaty System
BAS: British Antarctic Survey
CCAMLR: Convention for the Conservation of Antarctic Marine Living Resources
COMNAP: Council of Managers of National Antarctica Programs
NCAOR: National Centre for Antarctic and Ocean Research, India
SCAR: Scientific Committee on Antarctic Research
SAT: Secretariat of the Antarctic Treaty

attend the ATCM but are not permitted to participate in governance decisions. To gain consultative status under the Treaty, a Party must demonstrate its interest in Antarctica by conducting "substantial research activity there" (Article IX, para. 2). The Treaty goes on to offer two examples of how this may be demonstrated: the establishment of a research station or the despatch of a scientific expedition. Legislation relevant to a Party acquiring consultative status is also contained within the Protocol on Environmental Protection to the Antarctic Treaty (adopted in 1991; entered into force in 1998; also known as the Madrid Protocol or Environmental Protocol; SAT 2016b). The Protocol designates Antarctica as a "natural reserve devoted to peace and science," prohibits commercial mineral resource activities and sets out a framework for environment protection through six Annexes. The Protocol states that before a Party's application to become a Consultative Party can be considered, it must first have "ratified, accepted, approved or acceded to the Protocol" (Article 22.4) and approved all Annexes to the Protocol that have become effective (Decision 4, 2005).

Procedures for the acquisition of consultative status are set out in Decision 4 (2005; SAT 2016c). The applicant must notify the depository government (the United States) that it considers that it has fulfilled the criteria for consultative status and provide evidence of its past scientific activities and future planned activities. The United States then circulates this information to the existing Consultative Parties for their consideration. The application is then discussed at the next ATCM, where a decision is made by consensus. Guidance on acquisition of consultative status was outlined in the *Guidelines on notification with respect to consultative status* adopted at the ATCM XIV in 1987 (para. 46–49 in SAT 2016d, e). The guidelines state that information provided by the Party to support a notification relating to consultative status would usefully include (a) a complete description of its past scientific programmes and activities in Antarctica, including published results or studies; (b) a complete description of its ongoing and planned scientific programmes and activities in Antarctica, including how they relate to long-term scientific objectives; and (c) a complete description of the planning, management and execution of its scientific programmes and activities in Antarctica, including identification of the governmental and non-governmental institutions involved. The guidelines suggest that the Party provides information on past scientific outputs and future science plans and how they will be achieved, but they provide no indication of how this information should be assessed, or criteria against which an assessment should be made by existing Consultative Parties. To complicate matters further, there is the potential for a Party's consultative status to depend on continuing scientific research activity. Under the Treaty, the 12 original signatories were automatically regarded as Consultative Parties for all time. In contrast, it has been suggested that a new member remains a Consultative Party only during such time as it continues its scientific interest in Antarctica (Auburn 1979; Qasim & Rajan 1985). However, the Treaty contains no formal mechanism for reviewing whether an existing Consultative Party continues to demonstrate "substantial scientific research," and none has been formally agreed since the Treaty became effective (Pannatier 1994; Dudeney & Walton 2012). Furthermore, given the ATCM makes decisions by consensus, an existing Consultative Party is unlikely to judge its own research activity inadequate to merit consultative status, thereby excluding itself from participation in Antarctic governance.

Research stations

The ATCM recognized Poland as the first non-Consultative Party to attain consultative status in 1977. This was after Poland had established a research station, which set a precedent for almost all subsequent "would be" Consultative Parties. The majority of research stations are constructed in scarce coastal ice-free areas, which harbour Antarctica's richest terrestrial habitats, penguin rookeries and seal haul-out sites (Convey et al. 2012). Station construction and operation generally results in substantial environmental impacts that are greater than "minor and transitory" in nature (see Annex I to the Protocol; Poland et al. 2003; Tin et al. 2009; Kennicutt et al. 2010; Tin et al. 2014). Consequently, in areas such as the northern Antarctic Peninsula and its offshore islands, where approximately 50% of research stations are already located, there may be intense competition between humans and indigenous fauna and flora for remaining ice-free ground (Chwedorzewska & Korczak 2010; Hughes et al. 2011; Braun et al. 2012). Recorded impacts include disturbance or displacement of wildlife, destruction of habitat, environmental pollution and introduction of non-native species (Tin et al. 2009;

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Hughes, Pertierra et al. 2015; Coetzee & Chown 2016). Impacts can be amplified where stations operated by several Parties are co-located (Braun et al. 2012). Construction of multiple stations in relatively accessible locations, such as the South Shetland Islands, in order to demonstrate substantial research activity and justify consultative status, is likely to have substantial impacts on the environmental, scientific, wilderness and aesthetic values of Antarctica—all of which Parties aspire to protect under the Protocol.

Recent developments

At the ATCM XXXIX in 2016, following the unsuccessful application for consultative status by a non-Consultative Party, several Parties suggested that a set of criteria should be developed to help determine whether it was appropriate to grant a Party consultative status (ATCM XXXIX Final Report, para. 94–98 in SAT 2016f). The ATCM agreed that it would be useful to review the existing guidelines and consider whether there was a need for additional or updated guidance on the conditions to be satisfied by a Party seeking consultative status. Consequently, an intersessional contact group charged with working on the criteria for consultative status was established.

Acknowledging the current policy interest in this issue, the aim of this paper was to examine the relationship between Antarctic infrastructure extent and scientific research output. We also aimed to investigate alternative potential metrics by which "substantial research activity" could be evaluated. Such metrics could be used (1) by a non-Treaty nation to assess whether it has a substantial interest in Antarctic science, (2) to inform a non-Consultative Party's decision to apply for consultative status, (3) by a Consultative Party to indicate whether or not it is delivering sufficient research activity to merit its ongoing consultative status or (4) to help Consultative Parties evaluate the application of a nation seeking consultative status. The use of these metrics may also help dispel any perceived requirement for the establishment of a research station prior to consultative status being acquired by putting the emphasis on generation of scientific research outputs, rather than Antarctic infrastructure (see ATCM XXIX Final Report, para. 73 in SAT 2016g).

Methods

Nations included in this study and their Antarctic Treaty status

The nations included in the study comprised all Consultative Parties, all non-Consultative Parties, all signatories to CCAMLR, all members of SCAR and a number of scientifically active nations that are not signatories to any ATS agreements. In total, there were 29 Consultative Parties, 24 non-Consultative Parties, four non-Treaty CCAMLR/SCAR members and six additional nations with active scientific output, defined as having more than 15 papers during the search period.

Bibliometric database selection

In this study, the bibliometric searches were performed using the Scopus database (www.scopus.com). For the purpose of this research, Scopus offered a suitably sophisticated system of indexing by country and had a broad scope in terms of minor journals and non-journal material. The only Antarctic journal we checked for that was not present was *Czech Polar Reports*, which was only included in Scopus from 2014 onwards. Manually including the papers published in earlier volumes increased the Czech count by 32 publications and some other countries between one and eight papers over the five-year period. This was considered negligible for all countries except the Czech Republic, and we found that adding these publications did not substantially change the relative position of the Czech Republic in terms of the metrics examined.

Search terms

Papers were identified with the following Scopus search query, returning a total of 13 701 papers: (TITLE-ABS-KEY [antarct* OR "southern ocean" OR "ross sea" OR "amundsen sea" OR "weddell sea"] AND NOT TITLE-ABS-KEY [candida OR "except antarctica" OR "not antarctica"]) AND PUBYEAR > 2010 AND PUBYEAR < 2016

Use of this detailed search term was unusual, as much previous work on the topic used a search term such as "antarct*" without qualifiers (e.g., Dastidar 2007; Dudeney & Walton 2012). Our early tests using the "antarct*" search term revealed that it was not uncommon for marine biology or oceanographic research publications to mention the general oceanic regions represented within the Treaty area, but not to mention Antarctica in the keywords or abstract. To correct for this, we added "ross sea", "southern ocean", "amundsen sea" and "weddell sea" as keywords. Depending on the geographical definition used for the Southern Ocean, this term could potentially encompass works done outside the Treaty area (i.e., north of latitude 60°S), but we considered this was reasonable as the majority of Southern Ocean research was of direct relevance to environments and ecosystems within the Treaty area. The use of "south pole" as an additional

keyword was considered for incorporation (as by Aksnes & Hessen [2009]), but this produced a large number of false positives dealing with, for example, the Martian south pole. Adding searches for "south orkney" or "south shetland", two of the major island groups, found few additional papers with some false positives, and so they were not used.

We also identified at an early stage that there were potential issues with false positives. The primary problem was papers published on the yeast *Candida antarctica*; this represented around 1000 papers in our original "antarct*" search, and was a significant fraction of the output for some smaller countries. The qualifying terms (e.g., "except antarctica") helped to filter out a number of papers that used phrases such as "found on every continent except antarctica". It was not practical to review all the search results manually to remove such false positives, and an automatic filter like this was seen as a pragmatic solution.

The chosen search term identified around 350 papers that matched the term "sub-antarct*" rather than "antarct*". Unlike the Southern Ocean papers, we did not feel that sub-Antarctic material was as directly relevant to the current study; much of this work was restricted to the sub-Antarctic islands and was quite distinct from Antarctic research. However, around half of these papers dealt with both sub-Antarctic and Antarctic regions, and so we decided not to filter this set out. This meant that around 150–200 papers (or 1.1–1.5% of the total) dealing solely with research on the sub-Antarctic islands were likely to be false positives. This would have led to a slight increase in the number of publications for some countries, particularly those with sub-Antarctic territories, although it should be noted that all of these nations were original signatories to the Treaty and have already attained consultative status. We acknowledge that this is a limitation of the particular search tool used and could perhaps be improved in future work.

Overall, the more complex search terms described here gave a more meaningful result than a simple "antarct*" or "antarctic*"; however, not all of the possible additional geographic keywords were found to be appropriate, and there were still a small number of known false positives to contend with.

An additional complication arose from publications that dealt with phenomena such as ionospheric, magnetospheric or cosmological research. These disciplines often have their origins in research undertaken within Antarctica, but it may be unusual to name Antarctica in the title or abstract of these papers. Inevitably, these publications may be missed by a keyword-based search. However, as noted by Dudeney & Walton (2012), work in these areas of science is largely undertaken by a small number of countries that already deliver substantial levels of scientific output, and so this issue may not significantly skew the overall results.

Throughout the data collection process, no attempt was made to weigh scientific publication output by number of contributors from a given country, lead authorship, dual affiliations or other factors. This means that a given paper may be counted several times over in the analysis if its authors are from different countries. On average, papers in this study were associated with 5.2 authors from 1.65 countries.

Scientific publication output compared with logistical capacity

Research station bed space numbers were used as a proxy for logistical capacity. Data were obtained from COMNAP (COMNAP 2016) and, unless noted otherwise, we used the 2015/16 data set. The bed numbers for the Netherlands reflect their use of United Kingdom facilities at Rothera Research Station, the numbers for Romania and Australia assume an even split of Law-Racoviţă station (taken from the 2014/15 COMNAP data set) and the numbers for France and Italy assume an even split of Concordia Station. Data for Indian stations, partly missing in the COMNAP list, were taken directly from the NCAOR website (NCAOR 2015). Bed space numbers attributed to Parties did not take account of any additional capacity aboard ships or at seasonal field camps, as it was not practical to identify figures that could be reliably compared across all Parties. As such, total values only reflected any facility listed as a "station," not "camp" or "refuge." It should also be noted that individual Parties may have used different definitions of what constituted a "station" as compared to a "camp," or may have chosen to count station bed spaces in different ways.

Metric 1: quantity of scientific publications

The total number of publications for each nation was obtained, which included all papers matching the search term (described above) that had at least one author from the relevant nation and were recorded by Scopus as published between 2011 and 2015 inclusive. One non-Consultative Party (Democratic People's Republic of Korea) and one CCAMLR member state (Vanuatu) returned no papers, and both were omitted from later analyses.

Metric 2: quality of scientific publications

Citations were counted as reported by Scopus on 5 October 2016; a single day was used to avoid any inflation

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in citation numbers over time. Citation counts included citations in papers published in 2016 (and, in a few rare cases where a paper had been in press or circulated as a preprint, before 2011). Scientific output quality was reported as mean citations per paper. Citations per paper for the Czech Republic were calculated solely on the basis of the papers and citations reported in Scopus, as tracing citations for the additional *Czech Polar Reports* papers would be impractical. Assuming these particular papers were not unusually highly cited, this omission was unlikely to affect the overall results.

Metric 3: national focus on Antarctic science

The total number of publications was identified using a Scopus search for the country of affiliation during the reporting period, and no other filters. This was then divided by the known number of Antarctic-related papers in order to give a percentage representing the proportion of national research capacity focused on Antarctic science.

For each metric, the significance of the difference between mean values for Consultative, non-Consultative and non-Treaty nations was determined by analysis of variance, and between groups using the *t*-test.

Results

Scientific output compared with research station capacity

In our comparison of scientific research output with individual Parties' station capacity (i.e., papers over the five years per station bed space), all the nations examined were Consultative Parties, with the exception of Romania. Within these Parties, there was a wide variation in papers per bed space (mean: 6.82 ± 7.63 [SD]; range 0.29–41.30). The five Parties with the highest values produced between eight and 142 times more scientific publications per bed than the five Parties with the lowest values.

Examination of Fig. 1 revealed three main groups. The first group was the largest and consisted of Parties with more than approximately 100 publications per year that showed a consistent relationship between bed spaces and scientific paper production. The second group, comprising Argentina, Russia and Chile, showed a similar relationship but with substantially lower levels of productivity on a papers per bed basis. The third group consisted of smaller national Antarctic programmes—broadly defined as those Parties operating stations with fewer than one hundred beds and publishing fewer than 100 papers—that showed no obvious relationship between scientific output and station capacity.

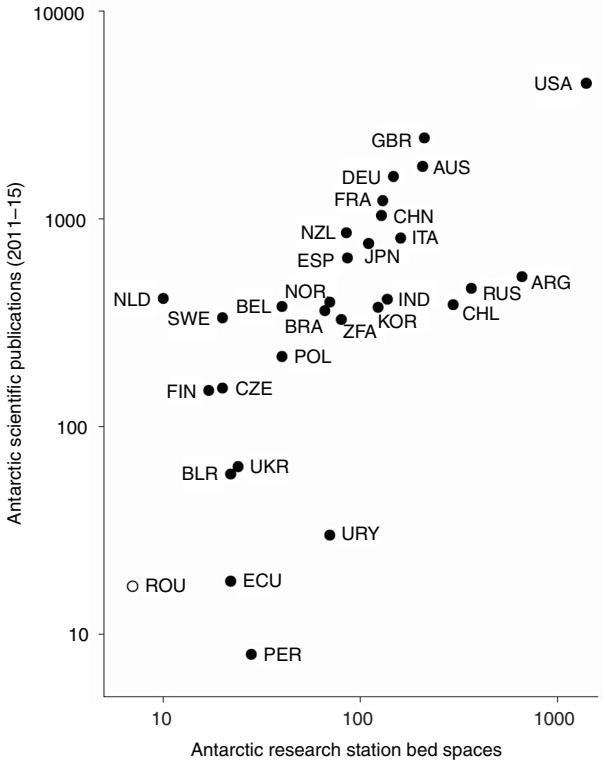

Fig. 1 The number of scientific research publications produced during the study period 2011–15 by each Party compared with the number of bed spaces within that Party's land-based Antarctic research facilities. Consultative Parties are denoted by black dots. Romania, the only non-Consultative Party with a research station, is denoted by an empty circle.

Two outliers were also noted: the United States fells somewhere between the first and second groups, while the Netherlands showed a disproportionately high publication output for the number of station beds.

In part, the lower productivity of the second group could be explained by the different infrastructure requirements of those national programmes. Argentina and Chile have established functioning civil communities in Antarctica, comprising a high proportion of non-scientific personnel, which require substantial support infrastructure not needed by other countries. In addition, the large number of stations operated by these Parties (13 and 11, respectively) may require higher than normal overheads, on account of duplication of essential support personnel, or lead to potential underutilization of some more remote stations. Russia, while not supporting civil communities, also operates a large number of Antarctic research stations (11), and may be subject to similar factors. The United States, while only operating three permanent research stations, has a substantial logistical burden associated with the support of operations at Amundsen–Scott South Pole Station, which has required the deployment of a large number of logistical personnel at McMurdo

Station. In contrast, our data showed that most Parties with larger Antarctic programmes that operated out of a smaller number of stations (e.g., the United Kingdom and Germany) tended to score higher values using this metric. The same was true for some nations that, to some degree, shared available logistic infrastructure with other Parties (e.g., New Zealand, Finland and Sweden). Indeed, the Netherlands produced the highest number of publications per station bed, mainly because all of its logistical requirements at the Dirck Gerritsz Laboratory at Rothera Research Station have been provided by the United Kingdom.

Overall, infrastructure capacity was not found to be a reliable predictor of science output. The calculation did not account for any ship-based accommodation, meaning that nations with significant ship-based programmes could appear to be producing science from a smaller number of bed spaces, which could artificially boost their papers per bed space score. Furthermore, level of infrastructure capacity could not be used to estimate research activity in scientifically active nations that did not operate land-based Antarctic infrastructure. Consequently, attempts were made to examine other metrics that might be more effective in demonstrating substantial research activity.

Metric 1: quantity of scientific publications

To assess each nation's scientific output, the simplest approach was to consider the total number of papers published during the study period (2011–15). Figure 2a shows the scientific output for all Consultative and non-Consultative Parties, along with a group of other non-Treaty nations that had published research on Antarctica or were members of a related group such as CCAMLR. Mean publication output from Consultative Parties was significantly greater than the output for non-Consultative Parties and non-Treaty nations ($p < 0.001$ in both cases), but there was no significant difference between non-Consultative Parties and non-Treaty nations. Broadly speaking, most Consultative Parties (83%) produced more than approximately 100 papers during the five-year study period. However, more generally, a great variation was observed with several non-Consultative Parties producing more scientific publications than Consultative Parties. Indeed, some non-Treaty nations produced more publications than many non-Consultative and even some Consultative Parties.

Metric 2: quality of scientific publications

The conventional proxy for the quality of published scientific output is the number of citations. Figure 2b shows the mean numbers of citations received by all Antarctic papers published during the five-year study period, as of October 2016, without any weighting by overall publication numbers. The mean citations for Consultative Parties, non-Consultative Parties and non-Treaty nations were not significantly different ($p > 0.05$) and provided no clear evidence that any one group published higher quality science outputs. With this metric, the outliers were generally smaller nations, often with very low numbers of publications produced over the five-year study period. The small numbers involved made the data for these nations more susceptible to being skewed by high or low citation values for single papers; for example, the high average for Saudi Arabian papers (46 citations per paper) was driven by a single highly cited paper on climate modelling, representing approximately 80% of the nation's total citations for the study period. Without that one paper, the national average would have been around nine citations per paper.

Metric 3: national focus on Antarctic science

We examined the proportion of each nation's overall scientific publication output connected to Antarctica (i.e., national focus). Importantly, this metric was independent of the overall scientific output level, thereby enabling us to compare Parties independently of nation size and wealth and state of development of their domestic scientific programme (Fig. 2c). Consultative Parties had significantly higher mean values for national focus on Antarctic research than non-Consultative Parties and non-Treaty nations ($p = 0.016$ and 0.001, respectively). The difference in mean values between non-Consultative Parties and non-Treaty nations was not significant if all non-Treaty nations selected for this study were included. However, this result was skewed by a relatively high value for Namibia, which was also the least productive nation in the group, with four papers over the five-year study period. When the data for the four Namibian papers were omitted, the difference in mean values was significant ($p = 0.019$). Some other outliers were also observed, as was the case with the scientific publication quality metric described above. For example, for the national focus metric, many of the very high or low values for non-Consultative Parties were a result of small numbers of publications produced nationally during the study period. In these examples, even a small change in the number of Antarctic papers would have produced a large shift in the national focus value.

Discussion

The system for attaining consultative status is set out in Article IX of the Antarctic Treaty, but the criteria

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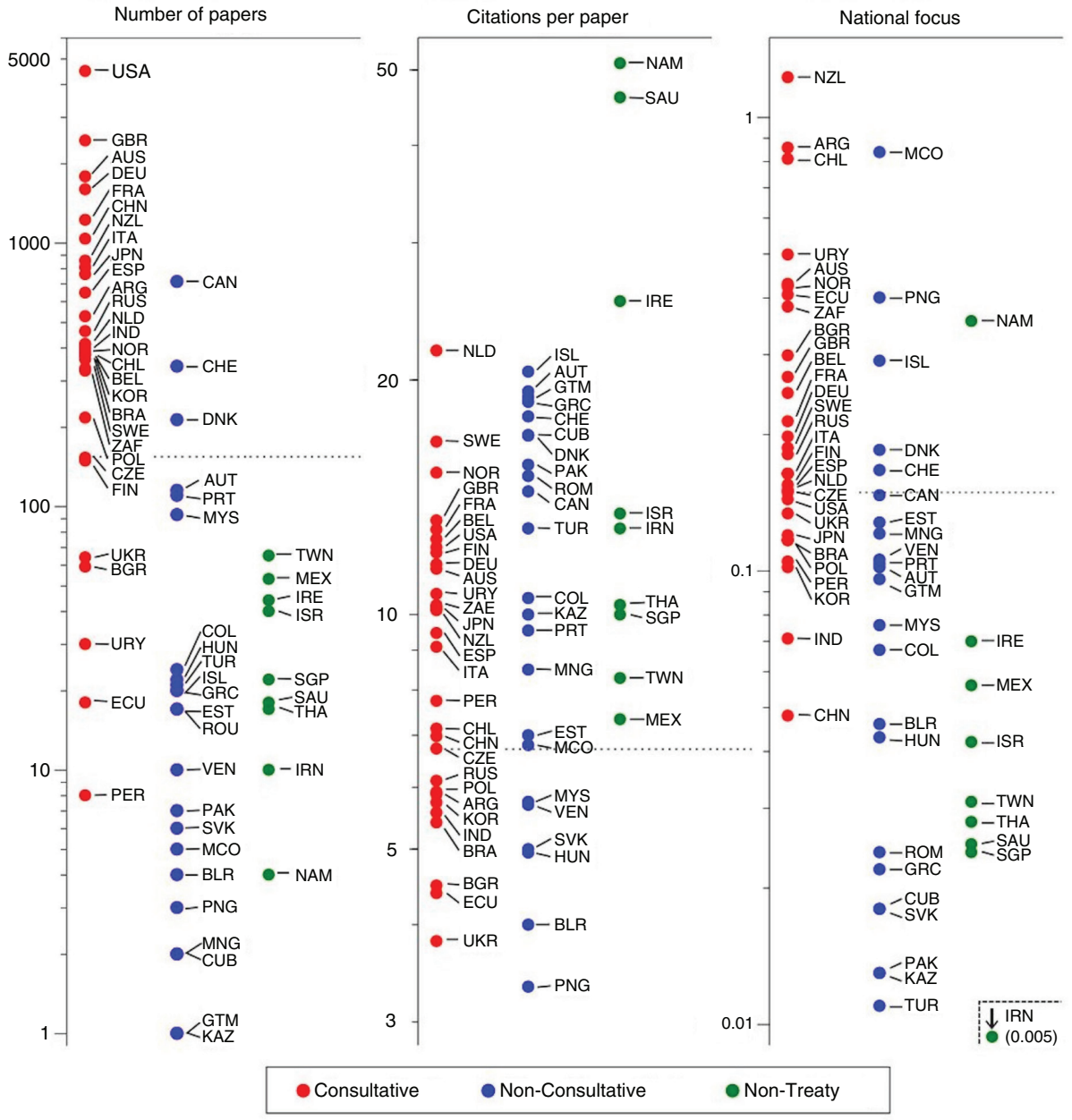

Fig. 2 Potential metrics to demonstrate ''substantial research activity'' by each nation based on scientific research publications generated during the study period 2011–15: (a) number of papers, (b) mean citations per paper and (c) national focus (i.e., Antarctic research outputs as a percentage of total national science output). The dotted lines indicate the values for the Czech Republic, the most recent Consultative Party. Abbreviations of nations are as given in Table 1.

for demonstrating substantial research activity may still lack clarity. Provision of a transparent pathway to consultative status, and an international appreciation that this is available to any scientifically active country, is of importance in affirming the legitimacy of the Treaty system and for incentivizing countries to develop Antarctic scientific programmes.

Antarctic infrastructure

To attain consultative status, aspiring nations may perceive research station construction as an almost essential part of demonstrating a credible commitment to Antarctic research. Historically, infrastructure was generally a necessary precondition to scientific activity as it was almost

Table 1 Data and representative metrics for each country studied.

Country	Code	Status	Stations	Beds	Antarctic papers	Cites per paper	National focus (%)
Argentina	ARG	Consultative	13	660	526	5.88	0.86
Australia	AUS	Consultative	3	207	1786	11.45	0.43
Austria	AUT	Non-Consultative			115	19.34	0.10
Belarus	BLR	Non-Consultative			4	4	0.05
Belgium	BEL	Consultative	1	40	378	12.5	0.25
Brazil	BRA	Consultative	1	66	361	5.41	0.12
Bulgaria	BGR	Consultative	1	22	59	4.49	0.30
Canada	CAN	Non-Consultative			713	14.39	0.15
Chile	CHL	Consultative	11	296	385	7.14	0.81
China	CHN	Consultative	3	128	1036	6.98	0.05
Colombia	COL	Non-Consultative			24	10.5	0.07
Cuba	CUB	Non-Consultative			2	17	0.02
Czech Republic	CZE	Consultative	1	20	153	6.73	0.15
Democratic People's Republic of Korea	PRK	Non-Consultative			0		
Denmark	DNK	Non-Consultative			213	16.97	0.19
Ecuador	ECU	Consultative	1	22	18	4.39	0.41
Estonia	EST	Non-Consultative			17	7	0.13
Finland	FIN	Consultative	1	17	149	12.01	0.16
France	FRA	Consultative	2	130	1222	12.86	0.21
Germany	DEU	Consultative	5	147	1596	11.6	0.20
Greece	GRC	Non-Consultative			20	18.75	0.02
Guatemala	GTM	Non-Consultative			1	19	0.10
Hungary	HUN	Non-Consultative			22	4.95	0.04
Iceland	ISL	Non-Consultative			20	20.5	0.29
India	IND	Consultative	2	137	409	5.57	0.07
Iran	IRN	Non-Treaty (SCAR)			10	12.9	0.01
Ireland	IRE	Non-Treaty			44	25.25	0.07
Israel	ISR	Non-Treaty			40	13.48	0.04
Italy	ITA	Consultative	2	160	807	9.09	0.16
Japan	JPN	Consultative	1	110	760	10.2	0.12
Kazakhstan	KAZ	Non-Consultative			1	10	0.01
Malaysia	MYS	Non-Consultative			93	5.75	0.08
Mexico	MEX	Non-Treaty			53	7.34	0.06
Monaco	MCO	Non-Consultative			5	6.8	0.84
Mongolia	MNG	Non-Consultative			2	8.5	0.12
Namibia	NAM	Non-Treaty (CCAMLR)			4	51	0.36
Netherlands	NLD	Consultative	1	10	413	21.82	0.15
New Zealand	NZL	Consultative	1	85	855	10.13	1.23
Norway	NOR	Consultative	1	70	397	15.21	0.42
Pakistan	PAK	Non-Consultative			7	15.57	0.01
Papua New Guinea	PNG	Non-Consultative			3	3.33	0.40
Peru	PER	Consultative	1	28	8	7.75	0.11
Poland	POL	Consultative	1	40	217	5.92	0.12
Portugal	PRT	Non-Consultative			110	9.54	0.10
Republic of Korea	KOR	Consultative	2	123	375	5.74	0.10
Romania	ROU	Non-Consultative	1	7	17	15.06	0.02
Russian Federation	RUS	Consultative	11	365	462	6.12	0.18
Saudi Arabia	SAU	Non-Treaty			18	46.11	0.03
Singapore	SGP	Non-Treaty			22	10	0.02
Slovakia	SVK	Non-Consultative			6	5	0.02
South Africa	ZAF	Consultative	1	80	327	10.28	0.38
Spain	ESP	Consultative	2	86	647	9.47	0.16
Sweden	SWE	Consultative	1	20	333	16.67	0.19
Switzerland	CHE	Non-Consultative			340	17.96	0.17
Taiwan	TWN	Non-Treaty			65	8.29	0.03
Thailand	THA	Non-Treaty (SCAR)			17	10.29	0.03
Turkey	TUR	Non-Consultative			21	12.9	0.01
Ukraine	UKR	Consultative	1	24	64	3.81	0.13
United Kingdom	GBR	Consultative	3	211	2445	13.21	0.27
United States	USA	Consultative	3	1399	4485	12.2	0.14
Uruguay	URY	Consultative	1	70	30	10.63	0.50
Vanuatu	VUT	Non-Treaty (CCAMLR)			0		
Venezuela	VEN	Non-Consultative			10	5.7	0.11

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impossible to undertake credible science without physical presence, often involving overwintering parties and/or multi-year expeditions. However, in the 55 years since the Treaty entered into force, several developments, considerations and events may have made station construction less relevant to attaining consultative status. These are delineated below.

Technological changes in recent years have made development of new station infrastructure less critical for Antarctic science, which is undertaken increasingly (i) during short visits to existing research stations or offshore cruises, (ii) through data reanalysis, or (iii) using remote sensing techniques aboard satellite, aircraft or unmanned autonomous vehicle platforms (Casanovas et al. 2015; Hughes, Ireland et al. 2015; Christie et al. 2016), all of which require little or no new permanent Antarctic infrastructure (Hughes 2015).

Contrary to precedent at the time, in November 1990, the Netherlands successfully argued for consultative status, without having constructed any permanent infrastructure of its own and with no declared intention of doing so at the time, using existing infrastructure of other Parties with whom it collaborated (Abbink 2009).

Spare capacity still exists at the Antarctic research stations of many nations, making collaboration with nations without research stations a relevant option, as well maintaining the spirit of "international cooperation of scientific investigation" set out in the Treaty (Article III b; see ATCM XXIX Final Report, para. 73) and the Environmental Protocol (Article VI.1) (Zumberge & Kimball 1985; Hughes 2010; Hemmings 2011). Indeed, Ukraine, which attained consultative status in 2004, did not construct a new station, but took over Faraday/Vernadsky Station from the United Kingdom in 1996.

Commentators have suggested that the earlier accepted practice of establishing a research station was an expensive hurdle for those seeking consultative status, and "a disincentive to any such nation even acceding to the Treaty when it cannot have a say in decision-making" (Auburn 1982). It is perhaps significant that, of the five new Consultative Parties since 1990, only three have attained this status through the route of building their own stations, with the others sharing or taking over existing facilities.

Physical presence in Antarctica inevitably comes with an environmental cost and, given the priority now placed on environmental protection with the agreement of the Protocol, infrastructure may no longer be considered the most appropriate way to demonstrate "substantial research activity" (Article VI.1). Indeed, infrastructure development may greatly reduce or eliminate the scientific value of the impacted area (Watts 1992; Chown et al. 2012), which is at odds with the aim of the Treaty to promote scientific investigation.

Adding to these observations, our research showed that just because a Consultative Party operated one or more research stations, it did not necessarily follow that substantial scientific research outputs would result. Therefore, other methods of assessment could be more appropriate for determining whether a nation still merited or should be considered for consultative status based on its research activity.

Metrics

We propose that if a clear method of demonstrating that a nation's scientific publication characteristics fitted more closely with the characteristics of existing Consultative Parties than the non-Consultative Parties, this may be considered as good evidence to support a bid for consultative status. However, other information described in the *Guidelines on notification with respect to consultative status* would be important in any considerations. Nevertheless, the two metrics discussed in this research—"quantity of scientific output" and "national focus on Antarctic science"—could be used to help put a nation's scientific activity into context. For example, among existing Consultative Parties, the median quantity of publications produced over the five-year period was 397 papers and the median national focus was 0.181%. Among the existing non-Consultative Parties, Canada exceeded the median publication output with 713 papers and Denmark exceeded the median national focus value with 0.185%. These data can be put into context further when compared to the equivalent results for the Czech Republic, which was the most recent country to gain consultative status in 2014. Over the study period, the Czech Republic produced 153 scientific publications and had a national focus value of 0.149%, while Canada, Denmark and Switzerland all had both higher publication outputs (213–713 papers) and similar or higher national focus values (0.147–0.185%). Use of these metrics may provide a more quantitative demonstration of "substantial research activity" than has existed up until now. When combined with other criteria defined by the ATCM, the metrics may help guide the thinking of Canada, Switzerland and Denmark regarding their pursuit of consultative status, should that be of interest to them. In addition, our data highlighted some reasonably substantial Antarctic research output from communities within non-Treaty Parties. Four non-signatories—Taiwan, Mexico, Ireland and Israel—produced 40 or more papers during the five-year period, which exceeded the output of two-thirds of the existing non-Consultative Parties and indeed was

more than that produced by some Consultative Parties. Consequently, accession to the Treaty may potentially be appropriate. Examination of the papers attributed to these four Parties showed that the majority were collaborative papers written with researchers from existing Treaty Parties; however, in each case, a small proportion of papers were authored solely by researchers from the non-Treaty Party in question, indicating some degree of independent national scientific interest in Antarctic research.

Our results on scientific publication characteristics for these non-Consultative Parties and non-Treaty nations aligned well with a study produced 11 years earlier (Dastidar & Persson 2005) in which Canada, Denmark and Switzerland were identified as among a group of particularly productive non-Consultative Parties. Indeed, another member of this group, the Czech Republic, has since become a Consultative Party. The same study also noted that Ireland, Israel and Taiwan, although not signatories to the Treaty, had "continuously exercised their interest in Antarctic science" (Dastidar & Persson 2005: 1554). In comparison, our study focused on data produced during the period 2011–15, but the similarity in results suggested that these non-signatories and non-Consultative Parties have sustained their interest over a prolonged period.

Data from our study showed that few Consultative Parties had scientific publication output or national focus values substantially below those of the non-Consultative Parties, as a group. Some Consultative Parties that had relatively low values using one metric had some of the highest values in the other (e.g., Ecuador had relatively low publication output values but high national focus, while the opposite was true for China). However, some Consultative Parties had low values for both metrics.

The "national focus" metric, which builds on a more limited recent study (Gray 2016), is a novel way of considering Antarctic scientific activity. It bears some similarities to a past study of Consultative Parties' science publications and ATCM working papers normalized by national Gross Domestic Product (Dudeney & Walton 2012). Both studies identified a particularly high level of Antarctic science and/or policy focus in the Antarctic neighbour states—New Zealand, Argentina, Chile and, to a slightly lesser degree, Australia and South Africa. Among the remaining claimant states, Norway had a high value, with lower values recorded for the United Kingdom and France. Looking at national focus also highlighted high levels of relative activity in some non-claimant states with smaller scientific programmes, including Ecuador, Uruguay and Bulgaria.

Conclusions

Science, technology and levels of environmental awareness have changed in the 57 years since the Antarctic Treaty was agreed. In practical terms, conducting Antarctic research no longer requires the establishment of an Antarctic research station; indeed, to do so may be contrary to the principle of reducing environmental impact within the Treaty area as enshrined in the Protocol (Article III). We have demonstrated that on a national level, building a station, with its associated environmental impacts, may not always result in significant science outputs.

To determine a future Party's eligibility for consultative status, a broader perspective may be more appropriate: Is the Party seeking consultative status a member of SCAR and COMNAP? When undertaking its Antarctic activities, has it demonstrated environmental responsibility, in accordance with the Protocol? Has it participated in collaborative expeditions with other Parties, or shared the use of other nation's facilities to reduce logistical impact? Have the Party's Antarctic activities involved a high proportion of scientists compared to support staff? Consideration of these factors, combined with the scientific publication metrics described in this paper, may contribute to the development of more transparent criteria for an aspiring nation to attain consultative status.

With the Consultative Parties recently marking the 25th anniversary of the Protocol in 2016, and bearing in mind developments in international environmental thinking, perhaps now is an opportunity for the ATCM to consider a wider range of aspects as part of a bid for consultative status. Assessing the scientific element primarily on the basis of measured outputs, as discussed in this paper, would serve to prioritize actual research activity. It would move away from using logistical activity as an indirect proxy for research, which encourages the inadvertent environmental impacts that may result from station construction. This development would only serve to protect further the scientific values of the continent, which is entirely in keeping with the original principles of the Treaty.

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