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PRACTICE AND POLICY

Evaluating the conservation impact of Antarctica's protected areas

Joanna L. Burrows[1] | Jasmine R. Lee[1,2] | Kerrie A. Wilson[1]

[1]Securing Antarctica's Environmental Future, School of Biology and Environmental Science, Queensland University of Technology, Brisbane, Queensland, Australia

[2]British Antarctic Survey, Cambridge, UK

Correspondence
Joanna L. Burrows, Securing Antarctica's Environmental Future, School of Biology and Environmental Science, Queensland University of Technology, Gardens Point, Att. Joanna Burrows – Level 7, P Block, GPO Box 2434, Brisbane QLD 4001, Australia.
Email: jl.burrows@hdr.qut.edu.au

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Abstract

Antarctic specially protected areas (ASPAs) are a key regulatory mechanism for protecting Antarctic environmental values. Previous evaluations of the effectiveness of the ASPA system focused on its representativeness and design characteristics, presenting a compelling rationale for its systematic revision. Upgrading the system could increase the representation of values within ASPAs, but representation alone does not guarantee the avoided loss or improvement of those values. Identifying factors that influence the effectiveness of ASPAs would inform the design and management of an ASPA system with the greatest capacity to deliver its intended conservation outcomes. To facilitate evaluations of ASPA effectiveness, we devised a research and policy agenda that includes articulating a theory of change for what outcomes ASPAs generate and how; building evaluation principles into ASPA design and designation processes; employing complementary approaches to evaluate multiple dimensions of effectiveness; and extending evaluation findings to identify and exploit drivers of positive conservation impact. Implementing these approaches will enhance the efficacy of ASPAs as a management tool, potentially leading to improved outcomes for Antarctic natural values in an era of rapid global change.

Evaluación del impacto de conservación de las áreas protegidas de la Antártida

KEYWORDS

biodiversity, conservation planning, conservation policy, environmental assessment, environmental values, impact evaluation, protected area management

Resumen

Las áreas antárticas con protección especial (AAPE) son un mecanismo regulador clave para la protección de los valores ambientales en la Antártida. Las evaluaciones previas de la efectividad del sistema AAPE se centraron en su representatividad y características de diseño, lo que representó una justificación convincente para su revisión sistemática. La actualización del sistema podría aumentar la representación de los valores dentro de las AAPE, pero la representación por sí sola no garantiza que se evite la pérdida o la mejora de dichos valores. La identificación de los factores que influyen en la eficiencia de las AAPE contribuiría al diseño y la gestión de un sistema de AAPE con mayor capacidad de obtención de los resultados diseñados de conservación. Para facilitar las evaluaciones de la eficiencia de las AAPE, diseñamos una agenda política y de investigación que incluye la articulación de una teoría del cambio sobre cuáles resultados generan las AAPE y cómo lo hacen; la incorporación de principios de evaluación en los procesos de diseño y designación de AAPE; el empleo de enfoques complementarios para evaluar múltiples dimensiones de la eficiencia; y la ampliación de los resultados de la evaluación para identificar y explotar los impulsores del impacto positivo en la conservación. La aplicación de estos enfoques mejorará la eficiencia de las AAPE como herramienta de gestión, lo que potencialmente llevará a mejores resultados para los valores naturales antárticos en una era de rápido cambio global.

PALABRAS CLAVE
biodiversidad, evaluación ambiental, evaluación de impacto, gestión de áreas protegidas, planeación de la conservación, políticas de conservación, valores ambientales

【摘要】
建立南极洲特别保护区 (Antarctic specially protected areas, ASPAs) 是保护南极洲环境价值的关键监管机制。已有对 ASPA 系统有效性的评估集中在其代表性和设计特点上, 为其系统性修改提供了可靠依据。升级该系统可以提高 ASPA 价值的代表性, 但仅有代表性并不能保证避免价值丧失或增加价值。识别影响 ASPA 有效性的因素将为 ASPA 系统的设计和管理提供信息, 使其以最大的能力实现预期的保护结果。为了促进对 ASPA 有效性的评估, 我们设计了一个研究和政策议程, 包括阐明 ASPA 将产生什么结果以及如何产生结果的变革理论;将评估原则纳入 ASPA 设计和确定的过程;采用互补方法评估多个维度的有效性;以及拓展评估结论, 以确定和利用产生积极保护影响的驱动因素。这些方法的实施有利于提高 ASPA 作为管理工具的有效性, 并可能有助于在全球快速变化的背景下改进南极自然价值的保护成果。**【翻译: 胡怡思; 审校: 聂永刚】**

关键词: 影响评估, 保护政策, 保护规划, 保护区管理, 环境价值, 生物多样性, 环境评估

INTRODUCTION

Antarctic environments are at risk of harm from the impacts of local and global threatening processes. Climate change impacts on Antarctica have important implications both globally, given the potential for melting ice to contribute to sea level rise (IPCC, 2021), and locally, where direct and indirect changes will impact native species and ecosystems (Chown et al., 2015; Convey & Peck, 2019; Lee et al., 2017, 2022). Relative to the rest of the world, the direct human footprint on Antarctica is small (Brooks et al., 2019). However, scientific and tourism activities contribute to the introduction of non-native species, pollution, and habitat alteration (Brooks et al., 2019; Tejedo et al., 2016; Tin et al., 2009), which may in turn interact with climate change effects (Convey & Peck, 2019).

Human interactions with Antarctic environments are governed under the Antarctic Treaty, whose signatories meet annually at the Antarctic Treaty Consultative Meeting (ATCM) to exchange information, consult on matters of mutual interest, and adopt measures, decisions, and resolutions by consensus among consultative parties. Entered into force in 1998, the Protocol on Environmental Protection to the Antarctic Treaty (hereafter the Protocol) and its annexes establish a legal framework for conserving Antarctic environments. Annex V establishes a framework for area protection and management through the designation of Antarctic Specially Managed Areas (ASMAs) and Antarctic Specially Protected Areas (ASPAs). Although ASMAs assist the coordination and minimization of the environmental impacts of research and management activities, ASPAs have a more explicit conservation function and may be designated over any terrestrial or marine area to protect outstanding environmental, scientific, historic, aesthetic, or wilderness values. There are currently 75 ASPAs (Figure 1), with the majority designated primarily to protect important species, ecosystems, or landscape attributes. Visitation to ASPAs varies with reason for designation and proximity to research stations (Table 1; Figure 2). Each ASPA is proposed and managed by 1 or a group of proponents—most frequently, the Antarctic Treaty Party with research infrastructure in the locality (Hughes & Grant, 2017)—and has its own aims, objectives, and management activities summarized in management plans required to be reviewed every 5 years. Such reviews consider whether the ASPA continues to serve the purpose for which it was designated and the adequacy of management (ATCM, 2012).

The ASPA system is currently unrepresentative of the continent's biodiversity (Hughes et al., 2016; Wauchope et al., 2019) and ecosystems (Howard-Williams et al., 2021; Shaw et al., 2014) and covers <1.5% of its ice-free areas (Shaw et al., 2014). Consequently, several authors have called for the systematic revision and expansion of the ASPA system to improve its representativeness (Howard-Williams et al., 2021; Hughes & Grant, 2017; Hughes et al., 2016; Shaw et al., 2014; Wauchope et al., 2019). The Committee for Environmental Protection (CEP), the expert advisory body established by the Protocol, has endorsed the system's revision within the "systematic environmental-geographic framework" established under Article 3.2, Annex V of the Protocol (ATCM, 2019a), and the utility of systematic conservation planning methods for this revision is being explored (ASOC, 2019). But although the quantity and placement of protected areas have been scrutinized, little attention has been given to the quality of that protection in terms of measurable, on-ground conservation outcomes.

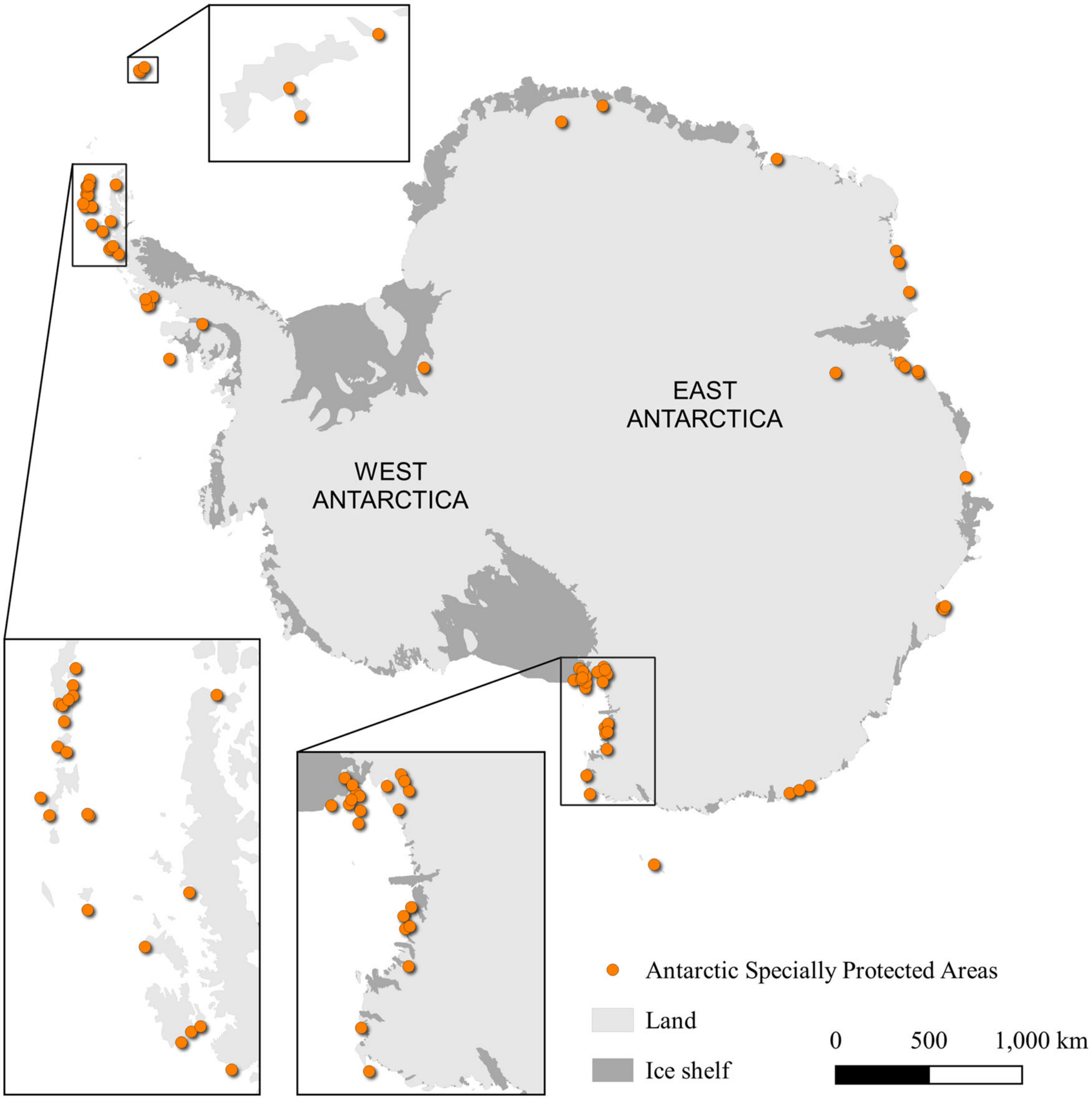

FIGURE 1 Locations of Antarctic Specially Protected Areas (Matsuoka et al., 2018; Terauds, 2016).

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To date, evaluations of ASPA effectiveness have focused on their sampling and design characteristics, and their findings present a compelling rationale to systematically revise the ASPA system. Although this can increase the representation of outstanding values within ASPAs, representation is not automatically synonymous with the avoided loss or improvement of those values (Pressey et al., 2015). Consequently, an important question remains unanswered: do ASPAs work? This is not a question of the effectiveness of ASPA design and associated outputs, but rather ASPA management and outcomes (Maxwell et al., 2020; McIntosh et al., 2017; Wauchope et al., 2022). To appreciate the potential conservation benefits of a revised ASPA system, understanding of the quality of protection ASPAs provide must be improved. Article 12 of the Protocol states that the CEP shall provide advice on "the effectiveness of measures taken pursuant to [the] Protocol" and "the need to update, strengthen, or otherwise improve such measures." Evaluating the effectiveness of ASPAs therefore falls comfortably within the purview of the CEP and aligns with the environmental protection directives of the Protocol.

There are numerous methodological approaches for assessing protected area effectiveness. Impact evaluation studies quantify the effect of a protected area relative to no (or an alternative) intervention (Ferraro, 2009), where impact means the difference between the outcome of interest in the protected area and what would have occurred in that same area without its designation. The latter scenario is called the *counterfactual*, against which impact is quantified (Ferraro & Pattanayak, 2006; Miteva et al., 2012; Pressey et al., 2015). Using a counterfactual approach, impact evaluation studies can identify the extent to which observed outcomes can be attributed to the intervention of interest and eliminate alternative explanations

TABLE 1 Average number of permitted annual visitors from 2012 to 2019 per square kilometer of Antarctic Specially Protected Area (ASPA) categorized by primary reason for designation (Secretariat of the Antarctic Treaty, 2022)

Primary reason for designation[a]	Total area (km^2)[b]	Average number of visitors[b c]	Average number of visitors[c] per square kilometer
Major terrestrial or marine ecosystems	93	513	5.5
Important or unusual assemblages of species	1587	1229	0.8
Inviolate areas	117	69	0.6
Ongoing or planned scientific research	1074	408	0.4
Geological, glaciological, or geomorphological features	676	149	0.2
Outstanding aesthetic and wilderness value	418	6	0.01

[a]Excluding the following ASPA designation categories: the type locality or only known habitat of any species (no ASPAs designated primarily for this purpose); sites or monuments of recognized historic value (outside scope of article and small total area of 0.3 km^2); and other areas as may be appropriate to protect the values set out in Article 3, paragraph 1 of Annex V (ambiguous categorization and small total area of 15.13 km^2).
[b]Rounded to nearest whole number.
[c]Any person (e.g., tourist, scientist, and other personnel) permitted to enter an ASPA, regardless of the nature of the visit.

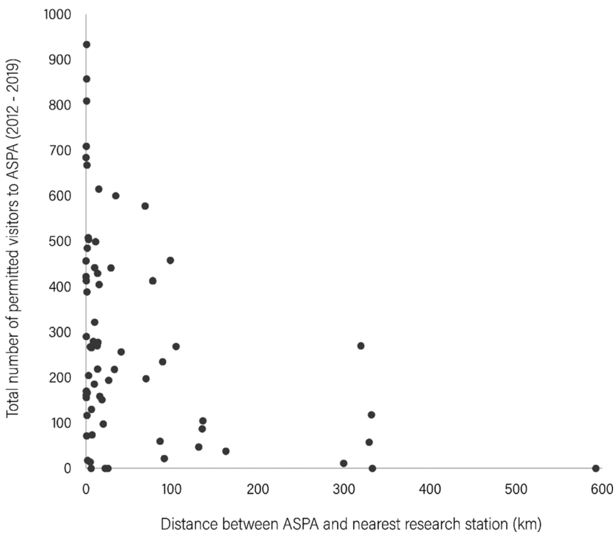

FIGURE 2 Distance to nearest research station versus total number of permitted visitors to each Antarctic Specially Protected Area (ASPA) from 2012 to 2019 (visitor means any person, e.g., tourist, scientist, and other personnel, permitted to enter an ASPA, regardless of the nature of the visit).

(Ferraro, 2009; Schleicher et al., 2020). A recent global literature review by Rodríguez-Rodríguez and Martínez-Vega (2022) summarized the characteristics of 76 protected area effectiveness studies from the past decade. Factors most commonly reported to contribute to protected area effectiveness related to management, legal or regulatory factors, and policy or political influences. The most common indicators of effectiveness in terms of biodiversity outcomes were land use change, and species richness, abundance, or density. Studies in Europe, Asia, and America dominate the protected-area-effectiveness literature; no Antarctic studies have been published.

Impact evaluation requires attributing effects to causes via experiments or quasi-experiments (Ferraro & Pattanayak, 2006). Although randomized experimental designs produce more robust results, these are generally infeasible for protected area impact evaluation, so quasi-experimental methods are preferred. Quasi-experimental methods include natural experiments, instrumental variables, difference-in-differences, and matching (Ferraro, 2009; Ferraro & Pattanayak, 2006; Jones & Lewis, 2015; Miteva et al., 2012; Schleicher et al., 2020). Matching methods compare indicators in treated units (e.g., ASPAs) with those of control units (e.g., unprotected areas) that match in terms of observable characteristics that influence both the likelihood of a unit receiving the treatment and the outcome of interest (Figure 3). Such characteristics are confounding factors, which if not controlled for could mask the treatment effect (Ferraro & Pattanayak, 2006; Jones & Lewis, 2015; Schleicher et al., 2020). There are numerous examples in the literature of the description and application of matching and other quasi-experimental impact evaluation methods (see Ribas et al., 2021; Schleicher et al., 2020). Of the 76 protected-area-effectiveness evaluations described by Rodríguez-Rodríguez and Martínez-Vega (2022), 22 used quasi-experimental designs, which were considered to produce more reliable results.

Maxwell et al. (2020) outline 2 different approaches for evaluating the effectiveness of protected area management for conserving protected values: threat reduction evaluation and outcome evaluation. Threat reduction evaluation is used to assess the extent to which a protected area reduces human pressures on protected values. Outcome evaluation is used to assesses whether a protected area is achieving its end goals through examination of changes in indicators of the state of protected values. Each evaluation type relies upon counterfactual analyses (Maxwell et al., 2020; Pressey et al., 2015). Although outcome evaluation is the most direct approach for

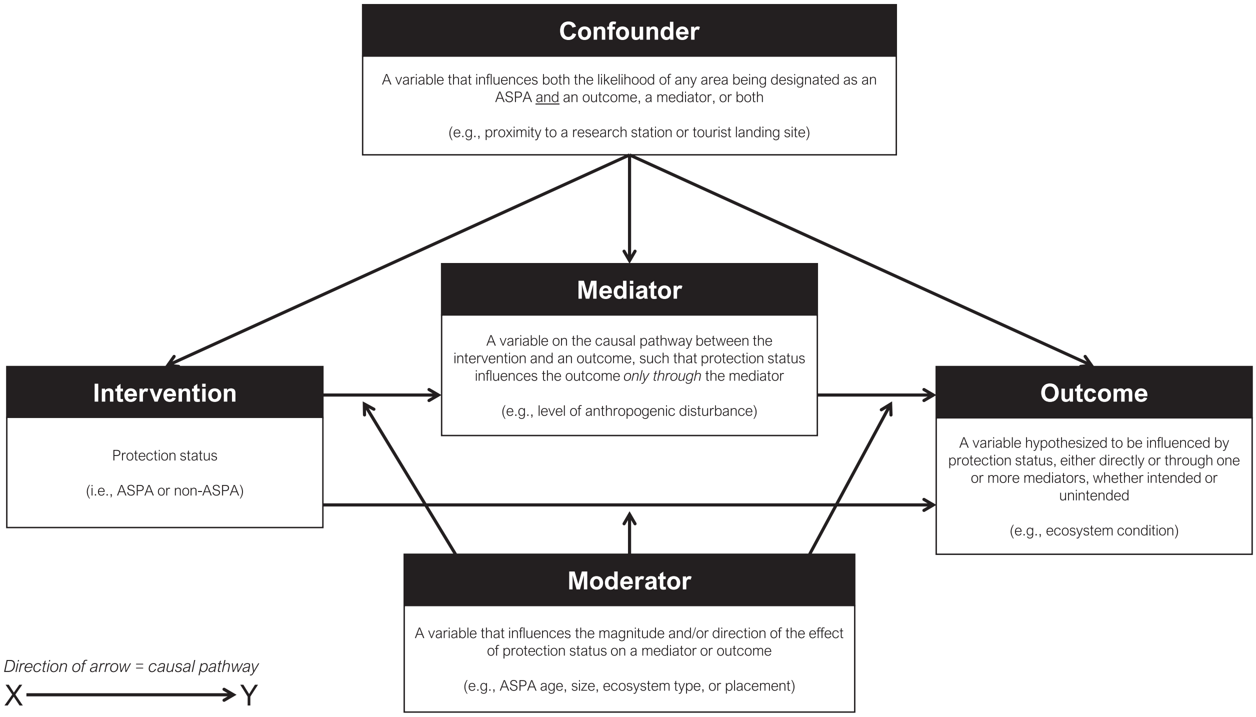

FIGURE 3 Relationships between variables influencing the causal effects of Antarctic Specially Protected Area (ASPA) designation on outcomes of interest for consideration in the design of impact evaluation studies (Ferraro & Hanauer, 2015; Pressey et al., 2015; Qiu et al., 2018).

assessing protected area impact in terms of environmental protection objectives (Maxwell et al., 2020), threat levels can be a meaningful proxy for the state of protected values if threat reduction is a causal mechanism through which the desired state of protected values is achieved (Ferraro & Hanauer, 2015; Pressey et al., 2015).

Impact evaluation reveals whether conservation interventions work. What, then, are the implications for protected areas with nonsignificant or negative conservation impact? The degazettement of protected areas (i.e., removal of formal protection status) is controversial, though sometimes justifiable, such as where the replacement of underperforming protected areas with more effective ones can generate greater conservation outcomes overall (Fuller et al., 2010). Indeed, the degazettement of a protected area is unlikely to have a negative conservation impact if it was not delivering conservation benefits in the first place (Tesfaw et al., 2018). However, degazettement is neither the only nor necessarily the preferred option, particularly when considering system-wide performance. Impact evaluation of protected areas enables the identification of drivers of positive conservation impact, revealing opportunities for underperforming and new protected areas to be more effectively managed. For instance, an evaluation by Wauchope et al. (2022) showed that protected areas had mixed impacts on waterbird populations, but that effectiveness was positively associated with taxa-specific area management. Thus, adaptively learning from impact evaluation studies to enhance protected area effectiveness can uphold and strengthen the credibility of one of the key tools globally for conservation (Geldmann et al., 2019). Evaluating the conservation impact of ASPAs can support positive conservation outcomes in Antarctica by affirming a site's continued protection by demonstrating an ASPA's positive impact or revealing opportunities to improve ASPA effectiveness by adjusting specific management actions or broader policy settings.

APPROACHES AND CHALLENGES FOR EVALUATING ASPA IMPACT

Knowing *how* it works to find out *if* it works

The conservation impact of an ASPA is influenced by potentially numerous factors (Figure 3). A confounder is a variable that influences the likelihood of any area being designated as an ASPA and simultaneously influences an outcome of interest or a mediator that drives that outcome. As confounders present rival explanations for observed effects, they must be controlled for when evaluating impact. For instance, in forested ecosystems protected areas are often located at higher elevations where human impacts are less likely to occur (Joppa & Pfaff, 2009); thus, elevation is a confounder, presenting an alternative explanation to protection for a high-elevation site remaining intact. An ASPA impact evaluation must therefore compare treatment and control units that match as closely as possible in terms of any confounding factors. An example of a confounder may be proximity to sites of human activity because ASPAs are likely to be located closer to tourist landing sites and research stations

(Hughes & Grant, 2017; Shaw et al., 2014) and it is reasonable to expect that levels of anthropogenic disturbance may also be higher near sites of human activity (Figure 2). Moderators (or modifiers) are factors that influence the magnitude or direction of a treatment effect and generate heterogeneity in intervention outcomes (Ferraro & Hanauer, 2015). These factors may be geographical, ecological, or institutional, such as an ASPA's size, age, ecosystem type, or placement. Thus, to enable ASPA impact evaluation studies, the causal pathways through which ASPA designation generates conservation outcomes, and the confounders and moderators that influence these, must be articulated.

Applicability of data collection and monitoring efforts

Can existing data be used to evaluate the conservation impact of ASPAs? In terms of threat reduction evaluation, an ASPA's conservation impact is the avoided human pressure in the area as a result of its designation. The major pressures avoided by ASPA designation relate primarily to infrastructure development (e.g., stations, runways, wharfs, transport routes), though in practice it may be challenging to determine whether such developments would have progressed had an ASPA not been designated, making the counterfactual difficult to infer. Other local-scale, but less conspicuous, threats to ASPA effectiveness include environmental pollution, non-native species, and any negative effects of human activities inside ASPAs, which can be categorized as unintended negative impacts arising from permitted visitation (Table 1) that conforms with ASPA management plans; permitted visitation not fully conforming with ASPA management plans; or unauthorized visitation (ATCM, 2019b; Hughes et al., 2013). Given the potential for unauthorized activities to cause environmental harm, approaches to quantifying pressures on Antarctic environments are incomplete if those pressures include only permitted activities and exclude unregulated (and likely undocumented) impacts. The utility of existing data is further limited by some operators' failure to meet information exchange requirements about ASPA visitation (Pertierra & Hughes, 2013). There is evidence of impacts arising from breaches of ASPA protocols, such as vehicle tracks beyond regulated routes, interference with wildlife, abandoned equipment, trampled vegetation, unauthorized biological sampling, and littering (Braun et al., 2012; Hughes et al., 2013; Pertierra et al., 2018). However, because human impacts in ASPAs are not routinely monitored, the intensity, spatial extent, and effects of these impacts cannot be reliably quantified using existing data (Hughes et al., 2013). Given failures to report ASPA management plan breaches (Pertierra & Hughes, 2013) and the challenges of enforcing compliance with the Protocol (Convey et al., 2012), the legal consequences of breaching ASPA protocols may be inconsistent or even nonexistent, making impact evaluation all the more necessary.

Although a majority of ASPA management plans allow entry for sporadic or ongoing site monitoring, few specify monitoring as a management requirement. "Ambient monitoring" (Mascia et al., 2014) may generate some information about the presence and condition of ASPA values over time, but it cannot enable an outcome evaluation unless meaningful comparisons can be drawn to a carefully established counterfactual. Even when the goal of an ASPA is simply to maintain the current condition of its protected values, the maintenance (or otherwise) of those values in practice cannot be causally attributed to the ASPA without reference to the counterfactual. Although monitoring the presence and condition of ASPA values over time may suffice to confirm outstanding values remain intact, it does not allow conclusions about an ASPA's impact to be made. It can therefore be difficult to infer the effectiveness of conservation interventions from studies that were not designed in such a way to enable evaluation of impact based on causal inference (Ferraro & Pattanayak, 2006; Miteva et al., 2012). However, ambient monitoring data could be repurposed and supplemented to enable impact evaluation (Mascia et al., 2014); therefore, the applicability of existing data sets should first be assessed to achieve efficiencies where possible.

Many factors challenge the collection of suitable data for ASPA impact evaluations. To date, most researchers evaluating protected area impact have used satellite imagery to detect changes in forest cover as an indicator of ecosystem condition (e.g., Jones & Lewis, 2015; Miteva et al., 2012). There is a significant gap in the research about how to apply similar methods to different ecosystem types, including polar environments. Adams et al. (2015) explored this gap in the context of impact evaluation in freshwater systems that, despite contrasting biophysically from Antarctic environments, share similar challenges in impact evaluation, the most prevalent being the unsuitability of satellite imagery for environmental monitoring at a resolution relevant to impact assessment (Patricio-Valerio et al., 2022). In situ sampling, however, is complicated by the fragility of Antarctic ecosystems and the logistical difficulties of accessing remote or hostile environments. Unmanned aerial vehicles may increase the likelihood of successful data collection by allowing remote and fragile ecosystems to be surveyed with high fidelity and low impact, overcoming some accessibility issues (Bollard et al., 2022).

Relevance of scale of analysis to management

Individual ASPAs, despite together comprising the ASPA system described by Article 12 of the Protocol, are not united by a common conservation objective beyond the general protection of outstanding values. Although all ASPAs are established under the same regulatory framework (Annex V of the protocol), via the same institutional process (a Measure adopted at an ATCM), and have management plans with similar structures and language, ASPAs differ in terms of the values they are designated to protect, their age, their managing parties, their permitting criteria, and their management objectives and actions. Moreover, once adopted by the ATCM, ASPAs are predominantly managed discretely by their proponent parties (Hughes & Grant, 2017). Though evaluations of protected area impact at national, continental, or global scales can contribute valu-

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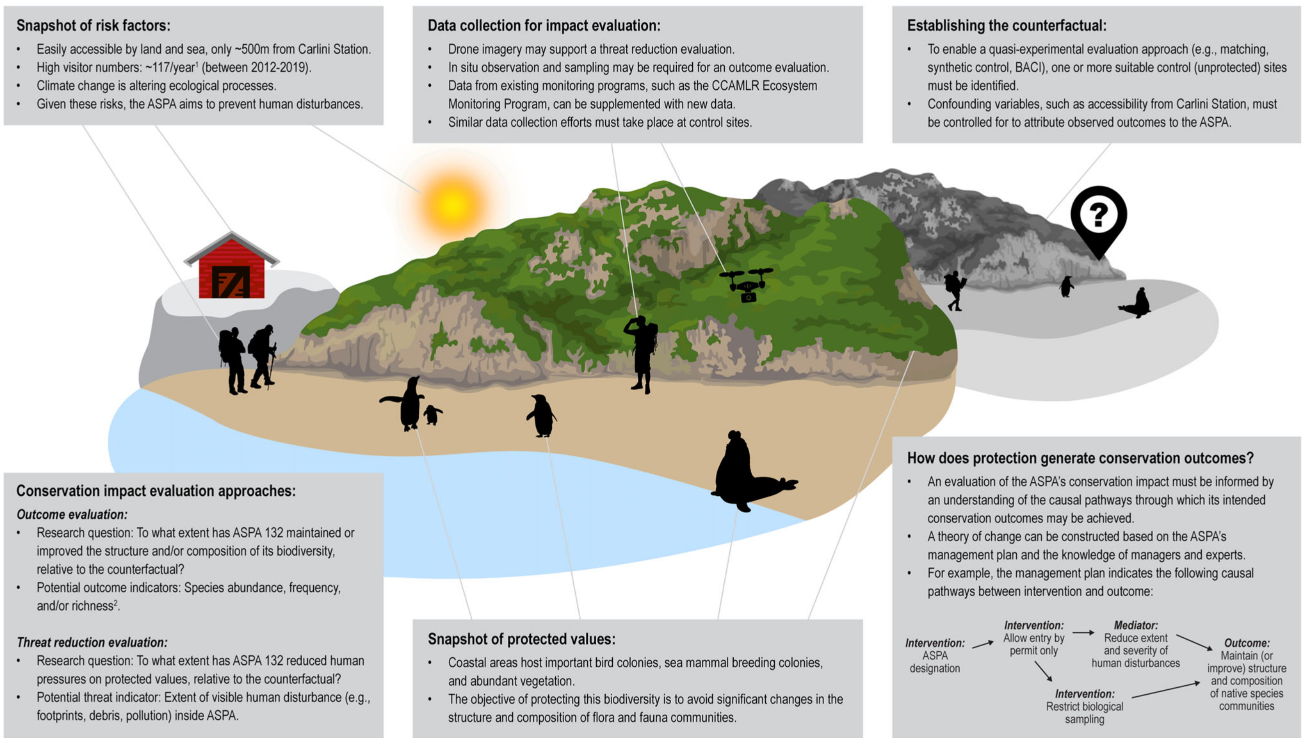

FIGURE 4 An example of a conservation impact evaluation approach at Antarctic Specially Protected Area (ASPA) 132: Potter Peninsula, King George Island. Situated in the South Shetland Islands above the Antarctic Peninsula, the 2.17-km^2 ASPA was designated primarily to protect the site's diverse wildlife, which is representative of the broader ecosystem. The information about ASPA 132 presented in this figure was sourced from the Management Plan for ASPA Number 132 Potter Peninsula (ATCM, 2018). Additional sources: (1) Secretariat of the Antarctic Treaty (2022) and (2) Noss (1990).

able insights to system-wide governance approaches, in addition to the data collection challenges discussed above, these differences between individual ASPAs complicate the selection of confounders and indicators to inform a threat reduction or outcome evaluation of the ASPA system as a whole. Thus, at least in the first instance, impact evaluation of multiple ASPAs individually is likely a more feasible method for assessing the effectiveness of the ASPA "system," which may be taken as the sum of that of its parts. Further, this approach is potentially more informative for management given the scale at which it occurs in practice, enabling the identification of management factors that influence effectiveness. Both spatial and temporal heterogeneity in ASPA impact may be relevant for identifying these factors (Miteva et al., 2012). An example of an approach to evaluating the conservation impact of an individual ASPA based on the principles outlined in this section is presented in Figure 4.

WAYS FORWARD FOR ASPA IMPACT EVALUATION

The systematic revision of the ASPA system is a vital aspect of ensuring its effectiveness; however, it should not be considered as an end in itself as neither extent nor representativeness of protection equates to, or guarantees, conservation impact. Although impact evaluation studies in Antarctica will incur new research and monitoring requirements, they will ultimately improve the efficiency of Antarctic area-based conservation interventions by identifying what does and does not work to preserve Antarctic biodiversity and environments (Miteva et al., 2012). To enhance existing ASPA monitoring and review procedures, our overarching recommendation is to begin conducting impact evaluation studies for ASPAs to determine their causal effects on Antarctic environments. The following actions will enable progress toward that goal.

Articulating a theory of change

To determine the conservation impact of ASPAs, the specific conservation outcomes ASPAs are intended to generate—and how—must first be articulated (McIntosh et al., 2017). This requires a theory of change—a hypothesis based on explicit assumptions about the causal pathways by which an intervention generates particular outcomes (Ferraro, 2009; McIntosh et al., 2017). A theory of change is required to determine the suitability of study designs and data sources (Ferraro & Hanauer, 2015). Without one, ASPA impact evaluations may exclude covariates that influence the treatment effect (Figure 3) (Miteva et al., 2012) or control for irrelevant variables. A theory of change can also serve as a guide for policy review and improvement by highlighting variables that can be manipulated and assumptions that must be satisfied to ensure ASPAs achieve desired conservation outcomes (McIntosh et al., 2017).

To improve policy settings, theories of change should also include unintended outcomes, whether positive or negative (Qiu et al., 2018), so that these can be managed appropriately. Importantly, acknowledging that ASPAs are discretely managed units with unique spatial and institutional characteristics, evaluators must draw upon context-specific data sets and the knowledge of experts to ensure theories of change are tailored to the ASPAs whose effects they describe.

Theories of change can also articulate what effect, if any, ASPAs may produce in relation to mitigating the effects of threatening processes acting at different scales. For instance, when conducting a threat reduction evaluation, the evaluator must consider what threats the intervention can feasibly mitigate. With regard to climate change, although protected areas provide refugia to allow species to adapt to a changing climate in the absence or reduction of other threatening processes, they may do little to shield an ecosystem from the effects of climate change if these effects cannot be directly managed (Smith et al., 2020). Thus, although monitoring the effects of climate change inside protected areas may be of interest, such an assessment may not be relevant within an impact evaluation if the theory of change does not describe a causal pathway by which an area's protection would mitigate the effects of climate change relative to the counterfactual. Further, climate change can interact synergistically with other threats and may therefore act as a moderator by influencing the magnitude of a treatment effect. For example, the effects of anthropogenic disturbance inside an ASPA (a mediator) on ecosystem condition (an outcome) may be moderated by the changing climate, such as where climate warming interacts synergistically with human activity to heighten the risk of human-assisted non-native species dispersal (Tin et al., 2009).

Building evaluation principles into intervention design

Conservation interventions should be designed and implemented in a way that allows for future evaluation of their impact—especially in Antarctica, where logistical factors restrict ambient monitoring at a scale and resolution relevant for impact evaluation studies (though autonomous monitoring stations, such as those proposed by the Antarctic Nearshore and Terrestrial Observing System, could support such efforts). To support future impact evaluations, ASPA management plans could specify suitable control (i.e., unprotected) sites for comparison based on methods such as statistical matching. Further, the collection of baseline data from control and treatment sites at the time of ASPA designation would support robust before–after, control–intervention studies (Jones & Lewis, 2015). In addition to environmental variables, baseline data collection should align with a social–ecological systems approach by incorporating relevant social (e.g., political and institutional) factors given their potential to influence treatment effects (Mascia et al., 2017). Additionally, ASPA management plans should specify the indicators on which a threat reduction evaluation (e.g., extent of anthropogenic disturbance) or outcome evaluation (e.g., ecosystem condition) should be based (Hughes & Grant, 2018). Appropriate indicators will not be identifiable, however, until a coherent theory of change specifies the mediators and outcomes for which indicators are required. Existing research into ASPA values, though not in the context of impact evaluation, highlights potentially suitable indicators of ASPA effectiveness. For instance, indicators of mediators may include severity of human trampling damage to moss assemblages (Pertierra et al., 2018) or extent of human footprints and artifacts (Bollard et al., 2022), and indicators of outcomes may include coverage and density of native or non-native vegetation (Bollard et al., 2022). Finally, ASPA management plans should specify approaches for reporting the methods and results of impact evaluations (McIntosh et al., 2017). Ideally, these approaches would be standardized within and mandated by Antarctic institutional documents and practices.

Employing complementary approaches

Impact evaluation is one of many ways to address questions of protected area effectiveness, and other methods can contribute important information for improving management and ultimately conservation outcomes. Two such tools, both drawing upon expert knowledge, are the rapid assessment and prioritization of protected area management (RAPPAM) methodology, for assessing the overall management effectiveness of protected areas across a region (Ervin, 2003), and the management effectiveness tracking Tool (METT), for reporting progress on the management effectiveness of individual protected areas (Stolton et al., 2007). Similarly, the protected areas benefits assessment tool + (PA-BAT+) utilizes stakeholder opinion to describe how benefits are perceived to flow from conservation areas (Ivanić et al., 2020). These tools could inform decision-making about ASPA management, and facilitate comparisons with, and lesson learning from, other protected areas around the world. Evaluation frameworks will also benefit from incorporating social dimensions because social–ecological interactions both shape and are shaped by the effects of conservation interventions (Mascia et al., 2017). The social dimensions of protected areas include the functions and services they provide to people (Li et al., 2022), and frameworks for describing these typically examine indicators relating to economic well-being, health, political empowerment, education, and culture (Mascia et al., 2017). However, it is currently unclear to what extent such indicators are relevant in the Antarctic context, and how to identify alternative indicators. Thus, there is an opportunity to adapt existing or develop new evaluation frameworks incorporating the social dimensions of environmental management in the Antarctic context.

Evaluating ASPA impact and extending findings

Post evaluation, findings about ASPA effectiveness have several policy implications. As knowledge about ASPA performance comes to light, in addition to informing the adaptive management of individual ASPAs, evaluations can examine spatial, temporal, and institutional heterogeneity in ASPA outcomes and explore the extent to which contributors to success are transferable or scalable across the continent. It is also important to look beyond the boundaries of ASPAs to identify any spillover effects of protection, whether positive or negative (i.e., leakage), which are consequential not only for impact evaluation study design (Schleicher et al., 2020), but also for the legitimacy and functioning of the Protocol because they represent unintended effects of conservation interventions that may require management. Finally, by extending impact evaluation approaches to Antarctica's other conservation mechanisms, decision makers can compare the benefits, limitations, and impact of each approach to optimize conservation outcomes over land and sea and work toward policy harmonization.

CONCLUSIONS

The external legitimacy of the Antarctic Treaty System depends on the "credible and effective" protection of the Antarctic environment (Flamm, 2022, p. 16). Evaluating the effectiveness of ASPAs, and identifying factors that influence their effectiveness, will enhance the standard of best available science that is required by Article 10 of the Protocol to inform Antarctic environmental management. Importantly though, the application of impact evaluation approaches must be combined with a precautionary approach to conservation. Given spatial and temporal heterogeneity in the availability of data to enable impact evaluation studies, the evaluability of ASPAs is unlikely to be uniform at present. Acknowledgement of the current lack of knowledge about the conservation impact of ASPAs should not be considered a barrier to the expansion of the ASPA system, but rather a timely opportunity to improve its efficiency in its design phase by illuminating, understanding, and exploiting drivers of ASPA effectiveness.

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ORCID

Joanna L. Burrows https://orcid.org/0000-0002-7799-1362

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