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Reframing Antarctica's ice loss: impacts of cryospheric change on local human activity

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Abstract

Physical scientists, social scientists, humanities scholars, and journalists have all framed Antarctica as a place of global importance—as a laboratory for scientific research, as a strategic site for geopolitical agendas, and more recently as a source of melting ice that could catastrophically inundate populations worldwide. Yet, the changing cryosphere impacts society *within* Antarctica as well, and this article expands the focus of Antarctic ice research to include human activities on and around the continent. It reframes Antarctica as a place with human history and local activities that are being affected by melting ice, even if the consequences are much smaller in scale than the effects of global sea level rise. Specifically focused on tourism and conservation along the west Antarctica Peninsula (wAP), this article demonstrates the impacts of changing glaciers and sea ice on the timing, location, and type of tourism as well as the ability of changing ice to mediate human experiences through conservation agendas. As future ice conditions influence Antarctic tourism and conservation, an attention to issues emerging within the wAP region offers a new perspective on climate change impacts and the management of Antarctic activities in the 21st-century Anthropocene.

Introduction

Icebergs "twice the size of New York City" are breaking off Antarctica (Mettler, 2019), and the potential for runaway melting foreshadows a "complete loss of the West Antarctic ice sheet" that would cause "cities around the world to become submerged" (Morton, 2019). Scientists working in Antarctica draw on this globalised narrative, arguing that "change in the Antarctic has profound implications for the rest of the planet" (Kennicutt II et al., 2019, pp. 95–96). The recent IPCC *Special Report on Oceans and Cryosphere* (2019), thus, focuses on how Antarctic ice loss will affect global sea level rise. Antarctica also plays a role as a global laboratory, providing deep ice cores that yield global climate history records dating back hundreds of thousands of years. The race is now on to extract "million-year-old ice buried deep in Antarctica [that] could hold crucial information about the planet's past and help climate predictions" (*The Guardian*, 2019). The overarching message of these stories is clear: climate change and ice loss in Antarctica will generate extensive societal consequences far from the southern continent—from Miami and Mumbai to Guangzhou and Osaka.

Yet, Antarctica is not just a global laboratory or a source of sea level rise for people far away. These global dimensions matter profoundly, but so do the human dimensions of cryospheric change within Antarctica. Researchers in the social sciences and humanities have long worked to reorient understandings of Antarctica as a place with human history, calling for greater attention to Antarctic place-making (Antonello, 2017; Howkins, 2016; O'Reilly & Salazar, 2017), urging researchers to chronicle human impacts in the region (Kennicutt et al., 2015), and challenging the idea of Antarctica as an empty wilderness (Leane & McGee, 2020; Roberts, Howkins, & van der Watt, 2016). Indeed, these scholars have shown Antarctica to be a place of international geopolitical struggles, Cold War science, and imperialism, global exploration, and missions to prove manliness or rugged individualism (e.g. Antonello, 2019; Bloom, 1993; Dodds, Hemmings, & Roberts, 2017; Howkins, 2016; O'Reilly, 2017; Pyne, 1998; Roberts, 2011). Dodds (2016) praised the book *Antarctica and the Humanities* not only because it showcases humanities scholarship on the region, but also because it shifts the narrative towards people within Antarctica (Roberts et al., 2016). As Antonello (2019) explains, the history of Antarctica is typically less about Antarctica itself and more about how people far from the ice have assembled it in their minds, policies, sciences, and agendas. However, this quest to understand the global climate system and to lament ice loss and global sea level rise obscures the regional effects of cryospheric change within Antarctica. O'Reilly (2013) describes this discourse specifically around Antarctica as a "climate problem," since a global climate framing hides the local dynamics and promotes false perceptions of Antarctica as an empty wilderness. This framing of ice as a place where global agendas play out—where local human dynamics are often neglected—happens not just in Antarctica but worldwide (e.g. Antonello & Carey, 2017; Bjørst, 2010; Carey, 2007; Leane & Maddison, 2018). The problem is: when we view Antarctica only as a barometer for the world, as a driver of far-off human consequences, or even as a site for global geopolitics, we overlook the increasingly prominent effects of cryospheric change on people within Antarctica.

This article reorients research on Antarctic ice and society from the more frequent global approach to one that examines how cryospheric change affects human activities within Antarctica. The goal is not to deny how Antarctic ice loss could inundate tens of millions of people worldwide, but rather to augment that research with a better understanding of human impacts within Antarctica—even if the consequences are much smaller in scale than the effects of global sea level rise. We demonstrate that glacier and sea ice change influences the timing, location, and type of Antarctic tourism as well as the ability of conservation agendas to mediate human experiences in and around Antarctica. Our research focuses on the west Antarctic Peninsula (wAP), as it is the most visited part of Antarctica and particularly susceptible to cryospheric change. Tens of thousands of tourists visit the wAP every year, fishing has occurred off its coast for more than two centuries, thousands of researchers live in the region, and conservation practices have an extensive human history both beyond and within the wAP region (Leane & McGee, 2020). Although this article focuses primarily on tourism and conservation, the local human approach could be extended to analyse research practices, geopolitical relations, natural resource extraction, and perceptions of ice on the southern continent.

Research for this article consisted of a review of disparate published literature on the wAP spanning many fields and disciplines—from marine biology and glaciology to tourism studies, history, and anthropology. To extract scarce societal information about the wAP and ice from this literature, we combed through hundreds of articles in search of evidence that contributed to an understanding of human–ice interactions. We identified and reviewed relevant studies through academic databases such as Science Direct, Wiley Online Library, ResearchGate, and JSTOR, as well as common search engines, using keywords such as "Antarctica", "sea ice change", "ice sheet", "glacial retreat", "climate change", "ecology", "ecosystems", "human impact", "tourism", "conservation", and "research". We also collected limited anecdotal details from news stories, popular magazines, blogs, and tourism-related information and media in order to develop a broader perspective on these topics, although the analysis of peer-reviewed literature is at the heart of this study.

West Antarctic Peninsula: Regional ice, ocean, and atmospheric conditions

As a polar natural system, the structure and evolution of the wAP are intimately connected to ice in its many forms. Ice regulates and modifies the environment in critical ways: amongst others, it serves as a reservoir of freshwater, it modulates the energy budget of the surface of the earth, and it changes the very landscape it occupies (e.g. Morlighem, Rignot, Mouginot, Seroussi, & Larour, 2014; Perovich et al., 2007). On land, perennial ice forms glaciers that grow by snowfall and shrink by melting or calving (Cogley et al., 2011). A large enough accumulation of perennial ice forms ice sheets, which currently cover most of Antarctica. In the oceanic regions near the coast, marine-terminating glaciers drain the interior ice sheets to feed the formation of ice shelves reaching hundreds of metres below the sea surface (e.g. Silvano, Rintoul, & Herraiz-Borreguero, 2016). Icebergs break from these glaciers and ice shelves, transporting ice away from the coast and into the ocean. Additionally, cold air temperatures freeze surface waters to form sea ice. Sea ice can drift with ocean currents or winds, but it can also be connected to shallow coastlines as fast ice and compacted to cover the open ocean as pack ice (Cogley et al., 2011). All of these forms of ice modulate the physical environment, the ecology, and the human uses of the ocean around the wAP.

The wAP has been the fastest-warming region in the Southern Hemisphere, with air temperatures rising about 3°C from 1951 to 2004 (Turner et al., 2005) and the ocean warming by about 0.1°C per decade since 1980 (Meredith & King, 2005; Schmidtko, Heywood, Thompson, & Aoki, 2014). The ocean plays a critical role in determining the spatial patterns and rates at which ice is lost from land (Pritchard et al., 2012). Regions where the ocean is warmer show the fastest rates of melting (Rignot et al., 2019). Along the wAP, widespread glacier retreat has been documented throughout the 20th century (e.g. Cook & Vaughan, 2010), particularly in the southern region, where the ocean is significantly warmer (Cook et al., 2016). This melting has resulted in a contribution to the global sea level rise of 0.16 ± 0.06 mm yr^{-1} (Pritchard & Vaughan, 2007).

While there has been significant ice loss on the Antarctic continent in the last several decades (Rignot et al., 2019), observations do not show a similar decreasing trend in sea ice extent. When averaged across the continent, studies show little overall change (e.g. Maksym, 2019) or even an increase in ice extent (e.g. Jones et al., 2016). There is strong regional variability in changes to sea ice extent, however, as exemplified by the significant increase in the Weddell Sea and a significant decrease in the Amundsen and Bellingshausen Seas during the austral summer and fall between 1979 and 2017. In the wAP region, satellite observations show that the ice-covered season has shortened by 85 days between 1979 and 2004 as a result of earlier sea-ice retreat and later sea-ice advance (Stammerjohn, Martinson, Smith, & Iannuzi, 2008). While data for sea ice properties other than extent are scarce, some models suggest sea ice in this region has also become thinner in recent decades (Maksym, 2019). This change in the extent and distribution of sea ice on the wAP has had profound impacts on local ecosystems, including changes in marine phytoplankton (Montes-Hugo et al., 2009) and the displacement of key marine species (Cimino, Lynch, Saba, & Oliver, 2016). These changes in ice also impact human activities in the wAP region, as this paper describes in the following sections about tourism and conservation.

Ice and tourism

Ice can influence not only *why* tourists visit Antarctica, but also *where* and *what* they visit. This relationship makes it crucial to understand how a rising number of tourists can be affected by changing ice conditions. The International Association of Antarctica Tour Operators (IAATO) documented over 74,000 visitors during the 2019–2020 season, with individual motivations for cruises ranging from sightseeing tours to expectations of icy spectacles to adrenaline rushes like skiing and scuba diving (IAATO, 2020; Lamers, Haase, & Amelung, 2008; Vereda, 2016). Further, media portrayals of diminishing ice fuel so-called "last chance" tourism, driving a surge in visitors wishing to experience places like Greenland, New Zealand, and Antarctica before it's too late (Bjørst & Ren, 2015; Carey, 2016; Stewart et al., 2016; Vila, Costa, Angulo-Preckler, Sarda, & Avila, 2016; Welling, Árnason, & Ólafsdottír, 2015). Some tourists are even inspired to participate in citizen science expeditions to help understand the ice (e.g. Lee Cusick, 2017), and operators offer citizen science projects to capitalise on tourist desires to contribute to "the greater scientific good" (SwoopTravel, 2020). Glacier change influences Antarctic tourists perceptually and physically, shaping both their imaginations and experiences in the region.

In addition to ice motivating tourism, an analysis of Antarctic tourism research and anecdotal experiences of tour operators suggest that changing sea ice has complicated access to areas along the wAP. Tour operators report variable effects of declining ice on ship access, since spatially- and temporally unpredictable sea ice conditions can result in either increased or decreased visitation at popular sites. Beyond issues of access, attractions that draw tourists to Antarctica are also affected by changing ice, such as iconic penguin colonies (Bender, Crosbie, & Lynch, 2016; Vereda, 2016). Of course, changing ice conditions affect tourism operations within a complex web of intersecting human and environmental forces. For example, the 2019 introduction of nine new ice-strengthened tour vessels conforming to the new Polar Code demonstrates the importance of not just ice, but also human factors such as improved technologies and growing investments in Antarctic tourism infrastructure (IAATO, 2019a). Nevertheless, the increasing impacts of changing ice on the tourism industry illustrates how changing ice conditions are influencing the future of Antarctica.

Sea ice and glacier effects on Antarctic tourism

The Antarctic tourism industry has experienced dramatic changes during the past 50 years, growing from small and infrequent trips, such as Lars-Eric Lindblad's 57 passenger *Antarctic Expedition* in 1966, to an industry with more than 50,000 visitors each year (Erceg, 2017; IAATO, 2019a). Wealthy passengers, predominantly from the USA, China, Australia, Germany, and the United Kingdom, spend $3,000–$20,000 USD per person to visit Antarctica for 10–21 days between November and March, when austral summer temperatures range from −4°C to 5°C and daylight can last up to 23 h per day (Bender et al., 2016; IAATO, 2017; Jabour, 2011; Picard, 2015; Shah, 2013). These visits are called expedition tours, with landings to camp on the ice, visit historic sites, view penguin and seal colonies, and go sea kayaking, trekking, or even scuba diving (Jabour, 2011; Liggett, McIntosh, Thompson, Gilbert, & Storey, 2011; Shah, 2013). Land-based adventure tourism is becoming increasingly popular, and now even air-supported tours take visitors sightseeing, hiking, mountain climbing, and skiing (Lamers et al., 2008). Tourists flock to Antarctica with preconceived ideas of "ice and coldness" (Vereda, 2016), and these tours offer firsthand encounters with ice in its many forms.

IAATO, established in 1991 to "promote the practice of safe and environmentally responsibly private-sector travel to the Antarctic," recently reported that changing sea ice extents produce direct effects on seasonal timelines of site visitation (IAATO, 2019b). During the 2018–2019 season, there was a 12% increase in the number of sites visited, and IAATO attributes this to "favourable ice conditions south of the Lemaire Channel and south of the Antarctic Circle" and "pack ice extent later in the season allowing visits to other areas" (IAATO, 2019c, pp. 4–5). This is corroborated by a Bark Europa guide logbook on 18 February 2018 stating that "the ice conditions are pretty good inside the Lemaire Channel" (Morales, 2018). These "good" and "favorable" conditions are explained by a June sea-ice extent of 10% below the 1981–2010 average—the lowest extent for June since recordkeeping began in 1979 (ECMWF, 2020). Changing ice could therefore be seen, at least in this specific case, as a short-term benefit for local tourism operations. Yet, this claim demands further examination due to a variety of interrelated factors such as increased operating risk, tourism extending into the shoulder seasons, and larger numbers of vessels and tourists.

In the wAP region, long-term changes in ice have directly affected ship access. Due to its accessibility, relatively mild climate, and location amongst warmer ocean currents, over 80% of all Antarctic tourist landings in the 2017–2018 season took place on the wAP (Bender et al., 2016; Clarke et al., 2007; Ducklow et al., 2013; IAATO, 2018; King & Harangozo, 1998). Between 1980 and 2010, the wAP's ice-free season increased by three months, resulting in an increase in tour vessels between Mikkelsen Harbor and Vernadsky Station (Bender et al., 2016; Stammerjohn, Massom, Rind, & Martinson, 2012). Data suggest the tour season length has expanded during the last 20 years, commencing in late October instead of early November and ending later in March or early April (Bender et al., 2016). These findings suggest declining sea ice along the wAP is contributing to changing patterns of tourism by increasing accessibility to areas that were formerly unnavigable or rarely navigable.

While some studies suggest a correlation between reduced sea ice and increased tourist access to some areas of the wAP, others reveal that changing conditions create uncertainty for tourism. For example, years with above-average sea ice extent tend to change tour itineraries most profoundly because these conditions can make certain areas inaccessible. During the 2004–2005 season, sea ice conditions in the Lemaire Channel and Penola Strait severely limited travel to popular sites farther south, decreasing passenger landings by 60% from the previous year at Hovgaard Island, Petermann Island, Yalour Islands, Pleneau Island, and Vernadsky Station (Lynch, Crosbie, Fagan, & Naveen, 2009). Several of these locations are popular sites to view Adelie penguin colonies, and the 127% increase in visitation to the northernmost Adelie penguin colony on the wAP during the 2004–2005 season was likely a result of the above-average sea ice extent of Lemaire Channel and Penola Straights (Lynch et al., 2009). As ice changes with regional variability, this uncertainty for Antarctic tourism is only likely to grow.

Informal conversations with more than a dozen tour operators also reveal varied effects of changing ice conditions on tourism activities around the wAP. Some tour operators noted access to the Weddell Sea has been markedly difficult and unpredictable due to variable sea ice extents in recent years. While operators claim they have not been shifting the dates of their season or altering ship schedules due to ice conditions, they do suggest that certain areas now tend to be more accessible due to less pack ice. However, as pack ice declines, it may not be possible to plan for earlier access due to riskier conditions. While some noted it is difficult to identify patterns over time due to seasonal and annual fluctuations, several operators with 20+ years of experience in the wAP region acknowledged a tendency towards starting the season earlier. In some cases, these earlier trips spend more time in the Falkland Islands/Islas Malvinas and South Georgia where sea ice is not a limiting factor, rather than heading directly to the wAP. Another operator explains this by stating that, although pack ice is receding earlier (Stammerjohn et al., 2012), fast ice adjacent to fjords can continue to block landing sites and make it difficult to push tours earlier in the season. Despite the contradictions and uncertainty, these examples reveal that both short- and long-term changes to sea ice can affect tour operators' route selection and timing.

In addition to the sea-ice effects on tourism, glacier change also influences tourist experiences, tour operator plans, and tourism regulations. Many of the wAP landing sites are located on small islands or peninsulas adjacent to retreating glaciers (Cook et al., 2016). One operator explained that tourists previously hiked onto glaciers for views, relying on snow bridges to cover crevasses. Visitor guidelines for these landscapes, such as Portal Point and Neko Harbor, identify "guided walking areas" that are "heavily crevassed and extremely dangerous" (Antarctic Treaty Secretariat, 2020). In recent years, newly exposed crevasses due to melting snow and ice have required operators to restrict glacier access in order to keep tourists safe. As IAATO-affiliated vessels record and often avoid areas with new crevasses, tour operators now have to alter itineraries while simultaneously juggling tourist expectations and safety.

Glacier shrinkage and ice shelf breakup also produce icebergs that influence tourism. Elsewhere in Antarctica, Iceberg B09B calved from the Eastern Ross Ice Shelf and was grounded for years along the eastern Antarctic coast. The massive berg affected marine habitats and ecosystems because it substantially increased the amount of fast ice in the area. The iceberg exemplified Antarctic ice scenery and attracted many tourists. In 2011, however, it began restricting access to Commonwealth Bay and the Mawson's Huts, eventually blocking access for the 100th-anniversary ceremonies for the Australasian Antarctic Expedition (1911–1914). Leane and Maddison (2018, p. 108) explain that Iceberg B09B directly influenced tourism within Antarctica and shaped tourist plans and perceptions back in Australia, since "the berg limited the extent to which the site could become even more imbued with a sense of national significance." The berg had become "entwined with both Australian national heritage and Antarctic tourism" (Leane & Maddison, 2018, p. 106). Focused again on the wAP, a veteran tour operator explained to the authors that the collapse of the Larsen B ice shelf has created variable sea ice conditions, delaying the previous mid-January access to the Weddell Sea until later in the season. While icebergs are a popular part of the Antarctic cryosphere, icebergs from melting glaciers contribute to uncertainty for tourism in Antarctica. Ice—whether glaciers, icebergs, pack ice, or fast ice—is a driver of the geography of Antarctic tourism, and management of emerging risks will necessitate spatial and temporal changes to the Antarctic tourism industry.

Penguins and people

Beyond physically blocking or opening tourist travel routes in Antarctica, ice also affects the ecosystems and wildlife that have become the expectations of tourists. For example, penguins are an iconic part of the Antarctic experience (Vereda, 2016), and tour operators design cruises to visit penguin colonies. Sea ice offers critical habitat for penguins and, as described in more detail in the "Ice and Conservation" Sections 4.1 and 4.2, shifting ice patterns are affecting penguin colonies. Climate warming and sea ice loss along the wAP parallel the decline of Adelie penguin populations (Hinke, S. Trivelpiece, & W. Trivelpiece, 2014), with some areas, such as the Palmer Station region, experiencing as much as an 80% decline (Ducklow et al., 2013). Reductions in sea ice along the wAP have also allowed for gentoo penguins to extend their range southward as Adelie populations decline.

These shifts in penguin populations along the wAP are affecting human experiences in the local tourism industry, since tourists are encountering less of some penguin species and more of others (Snyder, 2007). Between 1993 and 2014, gentoo penguin viewing increased while chinstrap and Adelie penguin sightings declined. During the 1993–1994 season, 59% of tour landings included a visit to a gentoo penguin colony, 29% included chinstrap penguins, and 27% include Adelie penguins (Bender et al., 2016). During the 2013–2014 season, however, more than 73% of tour landings included a gentoo penguin colony, while only 20% of landings included a chinstrap penguin colony and 16% included an Adelie penguin colony (Bender et al., 2016). As one tour manager explained to the authors, wAP tour operators generally attempt to construct itineraries that visit multiple penguin species. Colonies once popular amongst tourists, such as the Adelie penguin colony at Palmer Station, have so few Adelie penguins that operators are opting to avoid them altogether. The southward shift of Adelie penguins has meant passengers on shorter voyages cannot travel far enough south along the wAP or to the Weddell Sea to encounter the species. On longer voyages, operators have had to adjust itineraries to reach these more remote locations. These findings illustrate how changing sea ice affects the ability of tourists to view charismatic fauna, a focal point of many Antarctic tours.

As tourism accounts for the majority of human activity in Antarctica, particularly along the wAP, it is crucial to understand how ice influences the industry's numbers and behaviours. IAATO counted 55,614 onshore visitors during the 2019–2020 season, a 157% increase from a decade before and a staggering 25% increase from the previous 2018–2019 season (IAATO, 2020). This increase was aided by nine new ice-strengthened vessels discussed in this section's introduction. These vessels, developed as a response to ice conditions, demonstrate that future ice conditions will likely influence the geography of tourism, safety, access to and impacts on coastal areas, and the larger regulatory framework that guides Antarctic tourism. More explicit analysis and understanding of the relationship between ice and tourism will thus be crucial to maintaining safe and sustainable tourism practices in Antarctica.

"Last chance" tourism

Beyond the material effects of cryospheric change on tourism within Antarctica, there are also cultural and symbolic ways in which Antarctic sea ice and glaciers influence tourism in the region. Antarctic ice has inspired explorers for centuries, with a recent emphasis on adventure tourism and climate change concerns (Antonello, 2017; Pyne, 1998). Characterisations of a rapidly changing climate and diminishing ice have invoked a sense of urgency for people to witness disappearing Antarctic landscapes. The news on Antarctic ice loss is frequent in international outlets—not to mention the rise of popular movies about penguins and documentaries about climate change, such as Disney's *Happy Feet*, the documentary film *Encounters at the End of the World*, and BBC's *Frozen Planet*.

Media-generated climate change awareness and pro-environmental attitudes amongst modern tourists have cultivated a travel experience known as "last chance tourism." Last chance tourism is defined as "a niche tourism market where tourists explicitly seek vanishing landscapes or seascapes, and/or disappearing natural and/or social heritage" (Lemelin, Dawson, Stewart, Maher, & Lueck, 2010, p. 478). Tour agencies have capitalised upon the popularisation of climate change in the 21st century, highlighting the melting of glaciers in the Alps, Alaska, Iceland, and Antarctica (Bjørst & Ren, 2015; Carey, 2007, 2016; Hollander, 2019; Kristjánsdóttir, Ólafsdóttir, & Ragnarsdóttir, 2018; Rossi, 2019; Stewart et al., 2016; Welling et al., 2015). From a list of the top 10 reasons to visit Antarctica (Campbell, 2017) to various lists of places to visit before it's too late (TravelManager, 2018; Zhao, 2018), travel advertising readily employs climate change and ice loss as marketing tools. Using language like, "if you want to climb this snow-capped mountain, then you'd better consider starting that training soon" (Holmes, 2018) and "ensure you have the chance to experience Antarctica's wildlife, ice structures, and incredible mountains" (Kempker, 2016), these advertisements generate a narrative of impending doom and missed opportunities. They evoke a visceral response from potential tourists, who feel the pressure to visit "before it's precious polar ecosystem and wildlife are endangered and lost forever" (IExplore, n.d.). Thus, in addition to creating a sense of mourning about ice loss amongst the global community, this culture of "last chance tourism" directly affects human activities in Antarctica by increasing the number of tourist visits.

Ironically, some of these news outlets are realising the many different forms of "marketing," from time-sensitive offers to environmental stories of climate change, are actually working too well. For example, *The New York Times* does not include Antarctica in its "2020 Places to Go" list due to sustainability concerns (Virshup, 2020). This newfound desire to protect Antarctica from last chance tourism emphasises the connection between global perceptions of ice and local impacts of increased tourism. Indeed, the global attention demanded by diminishing ice—that is, ice as a discursive and imagined object rather than just a physical material—is contributing to the future of tourism in Antarctica.

Ice and conservation

As cryospheric change affects ecosystems and species in Antarctica, it creates challenges for environmental management and conservation agreements. For example, ice regulates food web dynamics and habitats for native species, and ice loss can expose new areas to invasive species or exacerbate unsustainable commercial krill fishing. These various biophysical transformations as a result of changing ice have significant implications for the continued implementation of environmental protection and management measures under the 1961 Antarctic Treaty System (ATS) and the 1982 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR).

Conservation protocols through the ATS and CCAMLR play a role in mediating human activities in and around Antarctica. Since Antarctica lacks a local population and instead supports a community of foreign visitors, the expertise of scientists and conservationists typically dominates decision-making for the continent (O'Reilly, 2017). This section, therefore, examines how the relationship between changing ice and conservation defines the human experience in Antarctica, expanding upon: (1) the ways ice and food webs drive the development of particular research activities; (2) the influence of ice and habitat on the designation of protected areas; and (3) the impacts of ice and conservation on the established commercial krill fishing industry. While there are various dynamic relationships between ice and conservation that can affect human experiences, the selected examples illustrate that changing ice—and simultaneously changing conservation—has implications for future human activities in Antarctica.

Krill, food webs, and scientific research

Krill do not inhabit many people's consciousness or imagination, yet krill play an integral role in constructing the human experience in Antarctica. As the Madrid Protocol and CCAMLR require the protection of Antarctic ecosystems, scientists, institutions, and states must collaborate to research and conserve krill. The importance of understanding and protecting krill was reinforced when the Scientific Committee on Antarctic Research (SCAR) created the Krill Action Group (SKAG). The key research questions identified in SKAG's 2019 meeting focused on "krill recruitment" and "krill's plasticity to climate change" (Nash, 2019), highlighting a concern about the future of krill populations. Krill, therefore, play a definitive role in the future of which scientific questions are asked, where research takes place, and how this research is carried out.

Krill (*Euphausia superba*) are a fundamental pillar of Antarctic ecosystems, and krill's survival is tied to the presence of sea ice (IPCC, 2019). Specifically, Antarctic krill feed on sea ice algae and have population densities closely linked to sea ice extent and duration (Flores et al., 2012; Kawaguchi, Nicol, & Press, 2009). Larval and juvenile krill overwinter beneath sea ice and rely on the algae for up to 88% of their carbon intake (Kohlbach et al., 2017). Krill are easy prey for large marine mammals, fish, squid, and seabirds (Hill, Murphy, Reid, Trathan, & Constable, 2006; Murphy et al., 2016; Rintoul et al., 2018; Schmidt & Atkinson, 2016), as they grow up to 6.2 cm in length (Atkinson, Siegel, Pakhomov, Jessopp, & Loeb, 2009), swim at slow speeds less than 0.25 m per second (Klevjer & Kaartvedt, 2011), and form dense clusters between 10 and 300 individuals per square metre (Atkinson et al., 2009). Krill, therefore, support one of the region's dominant energy pathways from primary production to top predators (Constable, Melbourne-Thomas, Trebilco, & Press, 2017; McCormack, 2017; Murphy et al., 2016). In fact, krill make up 80% of the food consumed by seabirds and marine mammals and 41% of the food are consumed by fish and cephalopods of the wAP (Murphy et al., 2016). Krill also account for between 86.5% and 99.5% of Adelie, gentoo, and chinstrap penguin summer diets (Lynnes, Reid, & Croxall, 2004; Rombolá, Marschoff, & Coria, 2006; W. Trivelpiece, S. Trivelpiece, & Volkman, 1987) and more than 90% of the crabeater seal diet (Forcada et al., 2012). Since Antarctic ecosystems rely so heavily on krill, conservation initiatives that work to protect iconic species and ecosystems must also be concerned about the health of krill populations.

As Antarctic food webs depend on krill and krill depend on sea ice, changes in sea ice have the potential to disrupt the ecosystems protected under the ATS. The reduction of spatial and temporal winter sea ice extent along the wAP diminishes the available feeding habitat and survival rate for larval krill (Atkinson, Siegel, Pakhomov, & Rothery, 2004; Murphy et al., 2016; Rozema et al., 2017; Saba et al., 2014), resulting in noticeable changes in the spatial distribution and size of krill populations (Atkinson et al., 2019). With the projected 20%–30% decrease in Antarctica's sea ice by 2100, there will likely be significant habitat loss in regions currently supporting the largest krill populations (Piñones & Fedorov, 2016). The ecological consequences of a decline in krill will affect the entire ocean basin, as krill are transported over large ocean expanses and play important roles in a range of ecosystems, from areas with persistent winter sea ice to areas with year-round ice-free conditions (Atkinson et al., 2004; Murphy, Thorpe, Watkins, & Hewitt, 2004; Nicol, 2006). For example, it is predicted that the decline of krill will affect whale species (Tulloch, Plagányi, Brown, Richardson, & Matear, 2019). Additionally, the overall decline of Adelie and chinstrap penguin populations is due in part to declining krill populations (Lynch, Naveen, Trathan, & Fagan, 2012; Trivelpiece et al., 2011), suggesting the relationship between changing ice and krill is having negative long-term effects on local penguin populations.

Due to the significant role of ice in Antarctic ecosystems, future conservation efforts will need to be attentive to the dynamic relationship between changing ice, krill, and food webs. The Madrid

Protocol, which guides environmental protection in Antarctica, specifies that maintaining ecological relationships is fundamental to conservation (Antarctic Treaty Secretariat, 1991), yet the Protocol is largely silent on ice and its role as a driver of ecosystem change. SCAR identifies ice change and ecosystem resilience as priorities in all five of its 2012–2020 Scientific Research Programmes (SCAR, 2019), indicating that ice and krill—as pillars of ecosystem resilience—play a role in defining the future of research activities in Antarctica. Indeed, if conservation policy is to be effective, then scientists must sculpt their research programmes around changing ice. This relationship between ice and conservation may affect the geographical distribution of research projects, the technologies utilised and developed by researchers, and even the international interest in Antarctic science.

Habitats, biodiversity, and land protections

Ice is an essential component of Antarctic habitats, and conservation efforts have identified these "special" habitats as being in need of protection. There are currently 72 Antarctic Specially Protected Areas (ASPAs) in the ATS, and the 2016 designation of the Ross Sea Marine Protected Area (MPA) suggests a potential use of ASPAs as "climate refuges" for animal populations experiencing habitat decline (CCAMLR, 2016; Sidder, 2016). By providing habitat for species that conservationists and policies seek to protect, changing ice is thus central to conservation agendas and decision-making more broadly.

Sea ice provides habitat and lifecycle functions for a variety of marine species in Antarctica. For example, penguins require sea ice for hunting, breeding, and protection from predators (Forcada & Trathan, 2009; Fraser & Hofmann, 2003). Emperor penguins breed and rear young on fast ice, requiring approximately eight months of annual fast ice cover (Ainley et al., 2005; Trathan, Fretwell, & Stonehouse, 2011). The contracting fast-ice season along the wAP has considerable breeding implications for these colonies, and the Dion Island colony collapsed and disappeared entirely by 2009 (Trathan et al., 2011). Adelie penguins rely on pack ice, particularly as a place to congregate while molting (Ainley, 2002). They have become vulnerable in recent years, because the Adelie penguins typically molt in February, when sea ice is at its most minimal extent (Ainley, 2002). Several studies have identified a correlation between the 80% decline in Adelie penguin populations and the recent reduction in sea ice extent along the wAP (Ducklow et al., 2013; Hinke et al., 2014). Conversely, gentoo penguins, generally regarded as ice-intolerant, have established breeding populations on the wAP in the last 50 years (Ducklow et al., 2007; Forcada & Trathan, 2009). This divergent response by different species to shifting habitats suggests that changing ice has complex implications for penguin conservation efforts.

While penguins may have attracted the attention in recent decades, Antarctic seals also rely on sea ice for habitat and foraging. Crabeater, Ross, and leopard seals breed exclusively on pack ice, while Weddell seals breed on fast ice (Southwell, Kerry, Ensor, Woehler, & Rogers, 2003). Furthermore, crabeater seals prefer greater sea ice concentrations due to their high-krill diet and use of sea ice for rest (Burns et al., 2004; Forcada et al., 2012). As sea ice has declined along the wAP, so too has the available seal habitat (Forcada et al., 2012). As seal habitat disappears, especially during years with below-average sea ice, increased pup mortality and strandings have occurred (Johnston, Bowers, Friedlaender, & Lavigne, 2012; Stenson & Hammill, 2014). Thus, changing ice has depleted critical seal habitat, threatening protected populations in the wAP region.

Conservation in Antarctica is not only concerned about penguins and seals, and the spread of invasive species threatens the continent's unique biodiversity. Restrictions against invasive species have long been outlined within the ATS, targeted specifically in Annex II of the Madrid Protocol. CCAMLR identifies the protection of Antarctica from invasive species as a key objective, and at least two of SCAR's five 2012–2020 Scientific Research Programmes directly examine invasive and non-native species (CCAMLR, 2011; SCAR, 2019). Conservation agreements have tended to ignore the effects of cryospheric change on non-native species invasions, and, as of 2016, the ASPAs designated for biodiversity value and located in ice-free areas covered only 708 km^2, or between 1.5% and 3% of Antarctica's ice-free land (Burton-Johnson, Black, Fretwell, & Kaluza-Gilbert, 2016; Terauds & Lee, 2016). Through the creation of new ice-free areas, ice plays a role in determining the future of Antarctica's biodiversity—the very same biodiversity that motivates the actions of tourists, researchers, and conservation agendas.

Non-native species invasion poses a major threat in the places where glaciers have retreated and exposed new land to people (Chown et al., 2012). Retreating glaciers provide more exposed land for invasive species to colonise and promote larger infestations (Hughes et al., 2019). Exotic species can infiltrate any part of Antarctica, but new ice-free land is particularly sensitive. For example, *Poa annua* (annual bluegrass), a non-native vascular plant species that displaces native plants, has been successfully expanding its range from areas surrounding human settlements to more remote research sites and new ice-free habitat (Molina-Montenegro et al., 2012; Olech & Chwedorzewska, 2011). *Poa annua* has been identified at three distinct sites on the wAP (Molina-Montenegro et al., 2012), and on King George Island, it has colonised newly exposed terrain on moraines of the retreating Ecology Glacier (Olech & Chwedorzewska, 2011). Of the 13 highest risk invasive species identified by Hughes et al. (2019) for the wAP, 4 are terrestrial plants or invertebrates that can effectively advance into new ice-free areas. Furthermore, ice-free land will become increasingly suitable to a wider variety of invasive species as temperatures warm (Duffy & Lee, 2019).

Lee et al. (2017) projects Antarctica's glaciers to melt and expose between 2,000 and 17,000 km^2 of ice-free land by 2,100, with 85% of this new ice-free land occurring on the wAP. With tourism also growing in the region, the wAP is the highest risk region in Antarctica for non-native species invasion (Chown et al., 2012; Shaw, Terauds, Riddle, Possingham, & Chown, 2014). The Committee for Environmental Protection (CEP), established by article 11 of the Madrid Protocol to focus on Antarctica's priority environmental issues, lists non-native species invasion as the first primary concern and has created regulatory guidelines through the Non-Native Species Manual (Committee for Environmental Protection, 2016). The identification of 15 "Antarctic Conservation Biogeographic Regions" (ACBRs), which the CEP states will aid in minimising the spread of non-native species, mediates how tourists and researchers move between and operate within biogeographic regions (Committee for Environmental Protection, 2016). Similar to the 72 ASPAs, the ACBRs is an example of how the relationship between ice and critical ecosystems can shape the experiences and activities of people in Antarctica.

As conservationists and nation-state signatories of the ATS work to uphold their policy objectives and obligations, they must understand how cryospheric change is dynamically affecting Antarctic habitats and biodiversity. Anthropogenic climate change could even be considered a "harmful interference" on Antarctic ecosystems, alongside helicopters, explosives, and human disturbance of breeding or molting areas. Annex II of the Madrid Protocol specifically identifies harmful interference as "any activity that results in the significant adverse modification of habitats of any species or population of native mammal, bird, plant or invertebrate" (Antarctic Treaty Secretariat, 1991). As conservationists increasingly recognise cryospheric change as a harmful interference, protections for valuable habitats are likely to increase. Whether through travel restrictions or sustainability protocols, a new conservation policy will likely regulate the ways people visit, research, and imagine Antarctic landscapes.

Commercial krill fishing

While conservation mediates how people experience Antarctica through scientific objectives and land designations, conservation interests also directly clash with fishing activities in Antarctica. While CCAMLR was originally signed in 1980 to regulate krill for both commercial and environmental interests (CCAMLR, 2019), fishing and environmental conservation agendas often do not align. *The Guardian* recently claimed, for example, that "industrial fishing for krill in the pristine waters around Antarctica is threatening the future of one of the world's last great wildernesses" and "fishing for krill is an eco-disaster" (Packham, 2018; Taylor, 2018). As CCAMLR tries to balance the various concerns of industry and conservation, changing ice adds a new component to these debates and policies. Declining sea ice extents can diminish krill populations and simultaneously increase access to fishing grounds. This ice-induced stress on sustainable fishing practices creates tensions within international agreements, making it vital to understand the complex interactions between ice, krill, and commercial krill fishing.

Glacier melt and changes in sea ice can affect the spatial and temporal patterns of fishing as well as the management of fisheries (Constable, de la Mare, Agnew, Everson, & Miller, 2000; Kawaguchi & Nicol, 2007; Kawaguchi et al., 2009; Nicol & Foster, 2016; Santa Cruz, Ernst, Arata, & Parada, 2018). Due in part to longer ice-free seasons, fishing intensity shifted from the South Indian Ocean to the South Atlantic Ocean in the 1990s (Kawaguchi et al., 2009). In recent decades, fleets have tended to skip the traditional winter operations in South Georgia, choosing instead to begin near the South Shetland Islands until the summer ice retreats enough to move inland towards the South Orkney Islands (CCAMLR, 2019; Constable et al., 2000; Kawaguchi, Nicol, Taki, & Naganobu, 2005; Nicol & Foster, 2016). While this expansion of fisheries also depends on factors such as operational logistics and international politics (Kawaguchi et al., 2005; Nicol & Foster, 2016), sea ice plays a definitive role in driving fishing trends. Ice directly imposes seasonal barriers to fishing ground access, and the relationship between sea ice presence and krill density, as discussed in Section 4.1, influences the action of fleets that rely on large populations (Kawaguchi et al., 2009; Santa Cruz et al., 2018).

In addition to the spatial shifts in fishing activity, ice also influences the temporal behaviour of fleets in Antarctica. Fishing operations historically peaked during the summer and autumn, with the highest catches in March, but this has gradually shifted into autumn and winter, with peak catches in May from 1994 to 2009 (Nicol & Foster, 2016; Santa Cruz et al., 2018). Later, winter ice formation in the South Shetland Islands has allowed commercial fishing to operate in this region for a longer period of time (Nicol & Foster, 2016; Santa Cruz et al., 2018), resulting in higher seasonal catches. Due to an abnormal occurrence of ice-free areas during the 2009–2010 season, fishing operations continued throughout the winter and the Bransfield Strait received an overall season catch of 154,264 tons, totaling more than four times the prior season and double the following season (ASOC, 2011; Santa Cruz et al., 2018). Spikes in krill harvests can, therefore, be linked to reductions in sea ice, impacting both conservation agendas and the sustainability of the commercial krill fishing industry.

CCAMLR recognises the need to manage krill fisheries to preserve food for local predators such as penguins, seals, and whales (Hinke et al., 2017; Kock, Reid, Croxall, & Nicol, 2007), and the IPCC (2019) has identified changing ice as an increasing influence on Antarctica's krill fishing industry. In the CCAMLR's most recent Krill Fishery Report, however, precautionary catch limits are based on sustainable yield models that only account for krill dynamics, such as recruitment and mortality, and natural variability (CCAMLR, 2018). As Brooks et al. (2018) also recognised, these catch quotas are based on models that do not consider climate change scenarios. Beyond a concern for sustainable catch levels, changing ice can spur other changes to the fishing industry, such as an increased number of vessels, shoulder season fishing, and increased illegal fishing activities. Consequences associated with these changes could include a greater number of fishing-related accidents, higher pollution, or international conflict. If krill populations continue to decline, conservation initiatives may need to increasingly regulate the krill fishing industry. In order to maintain the CCAMLR's goals of a sustainable krill fishery and effective conservation of Antarctic ecosystems, both krill conservation efforts and fishery management must be considered within the context of changing ice.

Conclusion

This article shifts the framing of Antarctica's ice from its global implications—primarily its contribution to sea level rise and its place as a global laboratory for climate change—to local human activities in the wAP region. A focus on local cryospheric impacts on tourism and conservation prompts a deeper discussion of Antarctic governance, management, and scientific inquiry. In this research, we found that Antarctic tourism is affected by changing the ice in complex and divergent ways. Changing ice can physically block tourist access and force tour operators to alter their itineraries, but it can also inhibit the ability of tour operators to offer the anticipated interactions with iconic wildlife and ecosystems. Changing ice drives "last chance tourism" to the Antarctic, which now occurs alongside growing concerns about the impacts of increased visitation. Increased tourist traffic coupled with changing ice may cause new or greater risks and stress IAATO's ability to respond to emergency situations. The relationship between Antarctic tourism and ice is multifaceted and dynamic, but it is clear that changing ice will play an important role in the future of Antarctica's growing tourism industry.

Changing ice also creates challenges for ecosystem management and conservation. Through science-driven agendas, conservation mediates how people interact with Antarctica. The relationship between decreasing sea ice and declining krill, which threatens to destabilise Antarctic food webs and ecosystems protected under international treaties, influences the future of scientific activities. Additionally, many conservation agendas are designed to protect critical habitats and biodiversity hotspots, but changing ice is transforming habitable areas and contributing to the designation of new protected areas. Finally, as changing ice alters both access to fishing grounds and krill populations, unsustainable practices by the commercial krill fishing industry can create tensions within international agreements. Thus, conservation initiatives need to consider the role of changing the ice in shaping Antarctic food webs, habitats, biodiversity, and natural resources.

The effects of changing ice on tourism and conservation are altering human activities in Antarctica, and these changes often materialise as new policies and protocols. As such, there is a need to imagine how local cryospheric change emerging from global climate change will reverberate through the finely tuned modes of human governance in the region, embodied in the ATS. The ATS isn't *merely* law, but also an entire set of meanings, symbols, and relations that constitute Antarctic culture. How the ATS responds—or whether it responds—to cryospheric change will determine its legitimacy and effectiveness in the future. Current analysis of the ATS and its capacity to meld historic values and policies with constantly shifting environmental, political, and commercial forces delivers a mixed picture. Hemmings (2018), an Antarctic governance specialist, suggests the ATS has not kept up with various demands, pressures, policies, and activities, and he is concerned that environmental change could contribute to the destabilisation of an already inconsistent and hollowed-out ATS. Stephens (2018), an international lawyer, questions what the ATS should do in response to the Anthropocene. Writing that "the ATS itself cannot address the main threats Antarctica faces in the Anthropocene" (Stephens, 2018, p. 38), Stephens actually prescribes more globalism on the part of the ATS. His argument has force, yet in order to ensure ATS responsiveness not just to global processes but also local dynamics, our findings would simultaneously push for a greater focus on local human activities in Antarctica.

A local approach to understanding the effects of cryospheric change helps counter some simplistic yet widely circulated narratives of Antarctica. These storylines frame the continent's change as occurring without variation, in a unilateral direction of decline and catastrophe. As anthropologist Jessica O'Reilly puts it, the global discourse depicts Antarctica as "relentlessly falling apart under the pressures of anthropogenic climate change" (O'Reilly, 2013, p. 391). Antarctica is not monolithic or homogenous, and we show that changing ice can have diverse and contradictory implications—whether changing sea ice extent blocks tourism in some areas or facilitates it in others, whether habitat conservation promotes fishing in some places or restricts it in others. Shifting attention to a local analysis of people and ice offers a new perspective for envisioning the management of Antarctic activities in the 21st-century Anthropocene.

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References

Ainley, D. G. (2002). *The Adelie Penguin: bellwether of climate change*. New York, NY: Columbia University Press.

Ainley, D. G., Clarke, E. D., Arrigo, K., Fraser, W. R., Kato, A., Barton, K. J., & Wilson, P. R. (2005). Decadal-scale changes in the climate and biota of the Pacific sector of the Southern Ocean, 1950s to the 1990s. *Antarctic Science*, *17*(2), 171–182.

Antarctic Treaty Secretariat. (1991). *Protocol on environmental protection to the antarctic treaty*. Madrid, Spain: Secretariat of the Antarctic Treaty. Retrieved from: https://www.ats.aq/e/ep.htm

Antarctic Treaty Secretariat. (2020). Visitor site guidelines. Retrieved from https://www.ats.aq/devAS/Ats/VisitorSiteGuidelines

Antonello, A. (2017). Engaging and narrating the Antarctic Ice sheet: the history of an earthly body. *Environmental History*, *22*(1), 77–100.

Antonello, A. (2019). *The Greening of Antarctica: Assembling an International Environment*. New York: Oxford University Press.

Antonello, A., & Carey, M. (2017). Ice cores and the temporalities of the global environment. *Environmental Humanities*, *9*(2), 181–203.

ASOC. (2011). *30 years of krill fisheries management - challenges remain*. Retrieved from CCAMLR: https://www.asoc.org/news-and-publications/publications/489-30-years-of-krill-fisheries-management-challenges-remain

Atkinson, A., Hill, S., Pakhomov, E., Siegel, V., Reiss, C., Loeb, V., . . . Sailley, S. (2019). Krill (*Euphausia superba*) distribution contracts southward during rapid regional warming. *Nature Climate Change*, *9*, 142–147.

Atkinson, A., Siegel, V., Pakhomov, E., & Rothery, P. (2004). Long-term decline in krill stock and increase in salps within the Southern Ocean. *Nature*, *432*(7013), 100–103.

Atkinson, A., Siegel, V., Pakhomov, E. A., Jessopp, M. J., & Loeb, V. (2009). A re-appraisal of the total biomass and annual production of Antarctic krill. *Deep Sea Research Part I: Oceanographic Research Papers*, *56*(5), 727–740.

Bender, N. A., Crosbie, K., & Lynch, H. J. (2016). Patterns of tourism in the Antarctic Peninsula: a 20 year analysis. *Antarctic Science*, *28*(3), 194–203.

Bjørst, L. R. (2010). The tip of the iceberg: Ice as a non-human actor in the climate change debate. *Études/Inuit/Studies*, *34*(1), 133–150.

Bjørst, L. R., & Ren, C. (2015). Steaming up or staying cool? Tourism development and greenlandic futures in the light of climate change. *Arctic Anthropology*, *52*(1), 91–101.

Bloom, L. (1993). *Gender on Ice: American Ideologies of Polar Expeditions*. Minneapolis: University of Minnesota Press.

Brooks, C. M., Ainley, D. G., Abrams, P. A., Dayton, P. K., Hofman, R. J., Jacquet, J., & Siniff, D. B. (2018). Antarctic fisheries: factor climate change into their management. *Nature, 558*, 177–180.

Burns, J. M., Costa, D. P., Fedak, M. A., Hindell, M. A., Bradshaw, C. J. A., Gales, N. J., . . . Crocker, D. E. (2004). Winter habitat use and foraging behavior of crabeater seals along the Western Antarctic Peninsula. *Deep Sea Research Part II: Topical Studies in Oceanography*, *51*(17–19), 2279–2303.

Burton-Johnson, A., Black, M., Fretwell, P. T., & Kaluza-Gilbert, J. (2016). An automated methodology for differentiating rock from snow, clouds and sea in Antarctica from Landsat 8 imagery: a new rock outcrop map and area estimation for the entire Antarctic continent. *The Cryosphere*, *10*(4), 1665–1677.

Campbell, C. (2017). My top 10 reasons why everyone needs to visit Antarctica. Retrieved from https://eclipsetravel.com.au/my-top-10-reasons-why-everyone-needs-to-visit-antarctica/

Carey, M. (2007). The history of ice: how glaciers became an endangered species. *Environmental History*, *12*(3), 497–527.

Carey, M. (2016). The trouble with climate change and national parks. In A. Howkins, J. Orsi, & M. Fiege (Eds.), *National parks beyond the nation: global perspectives on "America's Best Idea"* (pp. 258–277). Norman: University of Oklahoma Press.

Conservation Measure 91-04 (2011): General framework for the establishment of CCAMLR Marine Protected Areas, 91-04 C.F.R. (2011).

Conservation Measure 91-05 (2016): Ross Sea region marine protected area, 91-05 C.F.R. (2016).

CCAMLR. (2018). *Krill fishery report*. Retrieved from https://www.ccamlr.org/en/document/publications/krill-fishery-report-2018

CCAMLR. (2019). Krill fisheries. Retrieved from https://www.ccamlr.org/en/fisheries/krill

Chown, S. L., Huiskes, A. H. L., Gremmen, N. J. M., Lee, J. E., Terauds, A., Crosbie, K., . . . Bergstrom, D. M. (2012). Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. *Proceedings of the National Academy of Sciences of the USA*, *109*(13), 4938–4943.

Cimino, M. A., Lynch, H. J., Saba, V. S., & Oliver, M. J. (2016). Projected asymmetric response of Adélie penguins to Antarctic climate change. *Scientific Reports*, *6*(1), 1–9.

Clarke, A., Murphy, E. J., Meredith, M. P., King, J. C., Peck, L. S., Barnes, D. K. A., & Smith, R. C. (2007). Climate change and the Marine ecosystems of the Western Antarctic Peninsula. *Philosophical Transactions: Biological Sciences*, *362*, 149–166.

Cogley, J. G., Hock, R., Rasmussen, L. A., Arendt, A. A., Bauder, A., Braithwaite, R. J., . . . Zemp, M. (2011). Glossary of glacier mass balance and related terms. *IHP-VII Technical Documents in Hydrology*, *86*, 0–114.

Committee for Environmental Protection. (2016). *Non-native species manual*. Retrieved from https://ats.aq/documents/atcm34/ww/atcm34_ww004_e.pdf

Constable, A., Melbourne-Thomas, J., Trebilco, R., & Press, A. J. (2017). ACE CRC position analysis: managing change in Southern Ocean ecosystems. *Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Australia*.

Constable, A. J., de la Mare, W. K., Agnew, D. J., Everson, I., & Miller, D. (2000). Managing fisheries to conserve the Antarctic marine ecosystem: practical implementation of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). *ICES Journal of Marine Science*, *57*(3), 778–791.

Cook, A. J., Holland, P. R., Meredith, M. P., Murray, T., Luckman, A., & Vaughan, D. G. (2016). Ocean forcing of glacier retreat in the western Antarctic Peninsula. *Science*, *353*(6296), 283–286.

Cook, A. J., & Vaughan, D. G. (2010). Overview of areal changes of the ice shelves on the Antarctic Peninsula over the past 50 years. *The Cryosphere*, *4*(1), 77–98.

Dodds, K. (2016). Foreword. In P. Roberts, A. Howkins, & L.-M. van der Watt (Eds.), *Antarctica and the humanities* (pp. v–vii). London: Palgrave Macmillan.

Dodds, K., Hemmings, A. D., & Roberts, P. (2017). *Handbook on the politics of Antarctica*. Cheltenham, UK, Northampton, MA, USA: Edward Elgar Publishing.

Ducklow, H. W., Baker, K., Martinson, D. G., Quetin, L. B., Ross, R. M., Smith, R. C., … Fraser, W. (2007). Marine pelagic ecosystems: the West Antarctic Peninsula. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *362*(1477), 67–94.

Ducklow, H. W., Frasier, W. R., Meredith, M. P., Stammerjohn, S. E., Doney, S. C., Martinson, D. G., … Amsler, C. D. (2013). West Antarctic Peninsula: an ice-dependent coastal marine ecosystem in transition. *Oceanography*, *26*(3), 190–203.

Duffy, G. A., & Lee, J. R. (2019). Ice-free area expansion compounds the non-native species threat to Antarctic terrestrial biodiversity. *Biological Conservation*, *232*, 253–257.

ECMWF. (2020). Sea ice cover for June 2019. Retrieved from https://climate.copernicus.eu/sea-ice-cover-june-2019#

Erceg, D. (2017). *Explorers of a different kind: a history of Antarctic tourism 1966–2016*. Canberra, Australia: Australian National University.

Flores, H., Atkinson, A., Kawaguchi, S., Krafft, B., Milinevsky, G., Nicol, S., … Werner, T. (2012). Impact of climate change on Antarctic krill. *Marine Ecology Progress Series*, *458*, 1–19.

Forcada, J., & Trathan, P. N. (2009). Penguin responses to climate change in the Southern Ocean. *Global Change Biology*, *15*, 1618–1630.

Forcada, J., Trathan, P. N., Boveng, P. L., Boyd, I. L., Burns, J. M., Costa, D. P., … Southwell, C. J. (2012). Responses of Antarctic pack-ice seals to environmental change and increasing krill fishing. *Biological Conservation*, *149*(1), 40–50.

Fraser, W. R., & Hofmann, E. E. (2003). A predator's perspective on causal links between climate change, physical forcing and ecosystem response. *Marine Ecology Progress Series*, *265*, 1–15.

Hemmings, A. D. (2018). The hollowing of Antarctic governance. In P. S. Goel, R. Ravindra, & S. Chattapadhyay (Eds.), *Science and geopolitics of the white world: Arctic-Antarctic-Himalaya* (pp. 17–31). Cham, Switzerland: Springer.

Hill, S. L., Murphy, E. J., Reid, K., Trathan, P. N., & Constable, A. J. (2006). Modelling Southern Ocean ecosystems: krill, the food-web, and the impacts of harvesting. *Biological Reviews of the Cambridge Philosophical Society*, *81*(4), 581–608.

Hinke, J. T., Cossio, A. M., Goebel, M. E., Reiss, C. S., Trivelpiece, W. Z., & Watters, G. M. (2017). Identifying risk: concurrent overlap of the antarctic krill fishery with krill-dependent predators in the Scotia Sea. *PLoS ONE*, *12*(1), 1–24.

Hinke, J. T., Trivelpiece, S. G., & Trivelpiece, W. Z. (2014). Adélie penguin (*Pygoscelis adeliae*) survival rates and their relationship to environmental indices in the South Shetland Islands, Antarctica. *Polar Biology*, *37*(12), 1797–1809.

Hollander, Z. (2019). Vanishing ice: Alaska's shrinking glaciers drive a new brand of tourism. *Anchorage Daily News*. Retrieved from https://www.adn.com/alaska-news/2019/06/02/vanishing-ice-alaskas-shrinking-glaciers-drive-a-new-brand-of-tourism/

Holmes, E. (2018). 15 Destinations to see before they disappear. Retrieved from https://www.travelocity.com/inspire/15-destinations-to-see-before-they-disappear/

Howkins, A. (2016). *Frozen Empires: An Environmental History of the Antarctic Peninsula*. New York: Oxford University Press.

Hughes, K. A., Pescott, O. L., Peyton, J., Adriaens, T., Cottier-Cook, E. J., Key, G., … Roy, H. E. (2019). Invasive non-native species likely to threaten biodiversity and ecosystems in the Antarctic Peninsula region. *Global Change Biology*, *26*, 2702–2716.

IAATO. (2017). Antarctica: key facts on tourism 2017–2018. Retrieved from https://iaato.org/wp-content/uploads/2020/01/IAATO-Fact-Sheet-2017-18.pdf

IAATO. (2018). Tourism statistics. Retrieved from https://iaato.org/tourism-statistics

IAATO. (2019a). *IAATO overview of Antarctic tourism: 2018–19 season and preliminary estimates for 2019–20 season*. Retrieved from https://iaato.org/wp-content/uploads/2020/03/IP140-IAATO-Overview-of-Antarctic-Tourism-2018-19-Season-and-Preliminary-Estimates-for-2019-20-Season.pdf

IAATO. (2019b). *Report on IAATO operator use of Antarctic Peninsula landing sites and ATCM visitor site guidelines, 2018–19 season*. Retrieved from Prague, Czech Republic:

IAATO. (2020). Data & statistics. Retrieved from https://iaato.org/information-resources/data-statistics/

IExplore. (n.d.). Top 10 reasons to visit Antarctica. Retrieved from https://www.iexplore.com/destinations/antarctica/experiences/antarctica/top-10-reasons-to-visit-to-antarctica/big-ice

IPCC. (2019). IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. In H.-O. Poörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N. M. Weyer (Eds.). Retrieved from https://www.ipcc.ch/srocc/

Jabour, J. (2011). *Introduction to international Antarctica*. Akureyri, Iceland: University of Akureyri.

Johnston, D. W., Bowers, M. T., Friedlaender, A. S., & Lavigne, D. M. (2012). The effects of climate change on Harp Seals (*Pagophilus groenlandicus*). *PLoS One*, *7*(1), e29158.

Jones, J. M., Gille, S. T., Goosse, H., Abram, N. J., Canziani, P. O., Charman, D. J., … Vance, T. R. (2016). Assessing recent trends in high-latitude Southern Hemisphere surface climate. *Nature Climate Change*, *6*, 917–926.

Kawaguchi, S., & Nicol, S. (2007). Learning about Antarctic Krill from the fishery. *Antarctic Science*, *19*(2), 219–237.

Kawaguchi, S., Nicol, S., & Press, A. J. (2009). Direct effects of climate change on the Antarctic krill fishery. *Fisheries Management and Ecology*, *16*(5), 424–427.

Kawaguchi, S., Nicol, S., Taki, K., & Naganobu, M. (2005). Fishing ground selection in the Antarctic krill fishery: trends in patterns across years, seasons and nations. *CCAMLR Science Journal of the Scientific Committee and the Commission for the Conservation of Antarctic Marine Living Resources*, *13*, 117–141.

Kempker, S. (2016). 10 Places to see before they disappear. Retrieved from https://www.wildjunket.com/10-places-to-see-before-they-disappear/

Kennicutt II, M. C., Bromwich, D., Liggett, D., Njåstad, B., Peck, L., Rintoul, S. R., … Chown, S. L. (2019). Sustained Antarctic research: a 21st century imperative. *One Earth*, *1*(1), 95–113.

Kennicutt, M. C., Chown, S. L., Cassano, J. J., Liggett, D., Peck, L. S., Massom, R., … Sutherland, W.J. (2015). A roadmap for Antarctic and Southern Ocean science for the next two decades and beyond. *Antarctic Science*, *27*(1), 3–18.

King, J. C., & Harangozo, S. A. (1998). Climate change in the Western Antarctic Peninsula since 1945: observations and possible causes. *Annals of Glaciology*, *27*, 571–575.

Klevjer, T. A., & Kaartvedt, S. (2011). Krill (*Meganyctiphanes norvegica*) swim faster at night. *Limnology and Oceanography*, *56*(3), 765–774.

Kock, K.-H., Reid, K., Croxall, J., & Nicol, S. (2007). Fisheries in the Southern Ocean: an ecosystem approach. *Philosophical Transactions: Biological Sciences*, *362*(1488), 2333–2349.

Kohlbach, D., Lange, B. A., Schaafsma, F. L., David, C., Vortkamp, M., Graeve, M., … Flores, H. (2017). Ice algae-produced carbon is critical for overwintering of Antarctic krill *Euphausia superba*. *Frontiers in Marine Science*, *4*, 310.

Kristjánsdóttir, K. R., Ólafsdóttir, R., & Ragnarsdóttir, K. V. (2018). Stakeholder participation in developing sustainability indicators for a European northern periphery tourism system. *Journal of Rural and Community Development*, *12*, 210–235.

Lamers, M., Haase, D., & Amelung, B. (2008). Facing the elements: analysing trends in Antarctic tourism. *Tourism Review*, *63*(1), 15–27.

Leane, E., & Maddison, B. (2018). A biography of Iceberg B09B. *Australian Humanities Review*, *63*, 99–115.

Leane, E., & McGee, J. (Eds.). (2020). *Anthropocene Antarctica: perspectives from the humanities, law and social sciences*. New York: Routledge.

Lee Cusick, A. (2017). FjordPhyto: Antarctic citizen science project. *UC San Diego: Center for Marine Biodiversity and Conservation*. Retrieved from https://escholarship.org/uc/item/9m05m5g3

Lee, J. R., Raymond, B., Bracegirdle, T. J., Chadés, I., Fuller, R. A., Shaw, J. D., & Terauds, A. (2017). Climate change drives expansion of Antarctic Ice-free habitat. *Nature*, *547*, 49–67.

Lemelin, H., Dawson, J., Stewart, E. J., Maher, P., & Lueck, M. (2010). Last-chance tourism: the boom, doom, and gloom of visiting vanishing destinations. *Current Issues in Tourism*, *13*(5), 477–493.

Liggett, D., McIntosh, A., Thompson, A., Gilbert, N., & Storey, B. (2011). From frozen continent to tourism hotspot? Five decades of Antarctic tourism development and management, and a glimpse into the future. *Tourism Management*, *32*(2), 357–366.

Lynch, H. J., Crosbie, K., Fagan, W. F., & Naveen, R. (2009). Spatial patterns of tour ship traffic in the Antarctic Peninsula region. *Antarctic Science*, *22*(02), 123.

Lynch, H. J., Naveen, R., Trathan, P. N., & Fagan, W. F. (2012). Spatially integrated assessment reveals widespread changes in penguin populations on the Antarctic Peninsula. *Ecology*, *93*(6), 1367.

Lynnes, A. S., Reid, K., & Croxall, J. P. (2004). Diet and reproductive success of Adelie and chinstrap penguins: linking response of predators to prey population dynamics. *Polar Biology*, *27*(9), 544–554.

Maksym, T. (2019). Arctic and Antarctic Sea Ice change: contrasts, commonalities, and causes. *Annual Review of Marine Science*, *11*(1), 187–213.

McCormack, S. A. (2017). *Simplification of complex ecological networks – species aggregation in Antarctic food web models. Proceedings of the 22nd International Congress on Modelling and Simulation.* Hobart, Tasmania, Australia.

Meredith, M. P., & King, J. C. (2005). Rapid climate change in the ocean west of the Antarctic Peninsula during the second half of the 20th century. *Geophysical Research Letters*, *32*(19), L19604.

Mettler, K. (2019, 25 Feb.). An iceberg twice the size of New York City is about to break off of Antarctica. *Washington Post.* Retrieved from https://www.washingtonpost.com/climate-environment/2019/2002/2025/an-iceberg-twice-size-new-york-city-is-about-break-off-antarctica/

Molina-Montenegro, M. A., Carrasco-Urra, F., Rodrigo, C., Convey, P., Valladares, F., & Gianoli, E. (2012). Occurrence of the non-native annual bluegrass on the Antarctic mainland and its negative effects on native plants. *Conservation Biology*, *26*(4), 717–723.

Montes-Hugo, M., Doney, S. C., Ducklow, H. W., Fraser, W., Martinson, D., Stammerjohn, S. E., & Schofield, O. (2009). Recent changes in phytoplankton communities associated with rapid regional climate change along the western Antarctic Peninsula. *Science*, *323*(5920), 1470–1473.

Morales, J. P. (2018). Lemaire channel. Retrieved from https://www.barkeuropa.com/logbook/detail/lemaire-channel

Morlighem, M., Rignot, E., Mouginot, J., Seroussi, H., & Larour, E. (2014). Deeply incised submarine glacial valleys beneath the Greenland ice sheet. *Nature Geoscience*, *7*(6), 418–422.

Morton, A. (2019, 9 July). Glacial melting in Antarctica may become irreversible. *The Guardian.* Retrieved from https://www.theguardian.com/world/2019/jul/2009/glacial-melting-in-antarctica-may-become-irreversible.

Murphy, E. J., Cavanagh, R. D., Drinkwater, K. F., Grant, S. M., Heymans, J. J., Hofmann, E. E., ... Johnston, N. M. (2016). Understanding the structure and functioning of polar pelagic ecosystems to predict the impacts of change. *Proceedings of the Royal Society B: Biological Sciences*, *283*(1844), 20161646.

Murphy, E. J., Thorpe, S. E., Watkins, J. L., & Hewitt, R. (2004). Modeling the krill transport pathways in the Scotia Sea: spatial and environmental connections generating the seasonal distribution of krill. *Deep Sea Research Part II: Topical Studies in Oceanography*, *51*(12–13), 1435–1456.

Nash, R. (2019). *SCAR Krill action group – 2019 meeting report*. Retrieved from https://scar.org/library/science-4/life-sciences/skag/5395-skag-2019-meeting-report/

Nicol, S. (2006). Krill, currents, and Sea Ice: *Euphausia superba* and its changing environment. *BioScience*, *56*(2), 111–120.

Nicol, S., & Foster, J. (2016). The fishery for Antarctic Krill: its current status and management regime. In *Biology and Ecology of Antarctic Krill* (pp. 387–421). Cham: Springer.

O'Reilly, J. (2013). Antarctic climate futures: how *Terra Incognita* becomes *Terra Clima*. *The Polar Journal*, *3*(2), 384–398.

O'Reilly, J. (2017). *The technocratic Antarctic: an ethnography of scientific expertise and environmental governance.* Ithaca: Cornell University Press.

O'Reilly, J., & Salazar, J. F. (2017). Inhabiting the Antarctic. *The Polar Journal*, *7*(1), 9–25.

Olech, M., & Chwedorzewska, K. J. (2011). Short note: the first appearance and establishment of an alien vascular plant in natural habitats on the forefield of a retreating glacier in Antarctica. *Antarctic Science*, *23*(02), 153–154.

Packham, C. (2018). Fishing for krill is an eco-disaster: we must protect the Antarctic. *The Guardian*. Retrieved from https://www.theguardian.com/commentisfree/2018/mar/13/fishing-krill-eco-disaster-ocean-sanctuary-protect-antarctic

Perovich, D. K., Light, B., Eicken, H., Jones, K. F., Runciman, K., & Nghiem, S. V. (2007). Increasing solar heating of the Arctic Ocean and adjacent seas, 1979–2005: attribution and role in the ice-albedo feedback. *Geophysical Research Letters*, *34*(19), L19505.

Picard, D. (2015). White magic: an anthropological perspective on value in Antarctic tourism. *Tourist Studies*, *15*(3), 300–315.

Piñones, A., & Fedorov, A. V. (2016). Projected changes of Antarctic krill habitat by the end of the 21st century. *Geophysical Research Letters*, *43*(16), 8580–8589.

Pritchard, H. D., Ligtenberg, S. R. M., Fricker, H. A., Vaughan, D. G., van den Broeke, M. R., & Padman, L. (2012). Antarctic ice-sheet loss driven by basal melting of ice shelves. *Nature*, *484*(7395), 502–505.

Pritchard, H. D., & Vaughan, D. G. (2007). Widespread acceleration of tide-water glaciers on the Antarctic Peninsula. *Journal of Geophysical Research*, *112*(F3), F03S29.

Pyne, S. J. (1998). *The Ice: a journey to Antarctica*. Seattle: University of Washington Press.

Rignot, E., Mouginot, J., Scheuchl, B., Van Den Broeke, M., van Wessem, M. J., & Morlighem, M. (2019). Four decades of Antarctic Ice Sheet mass balance from 1979–2017. *Proceedings of the National Academy of Sciences of the USA*, *116*(4), 1095–1103.

Rintoul, S. R., Chown, S. L., DeConto, R. M., England, M. H., Fricker, H. A., Masson-Delmotte, V., ... Xavier, J. C. (2018). Choosing the future of Antarctica. *Nature*, *558*(7709), 233–241.

Roberts, P. (2011). *The European Antarctic: science and strategy in Scandinavia and the British Empire.* New York: Palgrave Macmillan.

Roberts, P., Howkins, A., & van der Watt, L.-M. (2016). Antarctica: a continent for the humanities. In P. Roberts, A. Howkins, & L.-M. van der Watt (Eds.), *Antarctica and the humanities* (pp. 1–23). London: Palgrave Macmillan.

Rombolá, E., Marschoff, E., & Coria, N. (2006). Interannual study of Chinstrap penguin's diet and reproductive success at Laurie Island, South Orkney Islands, Antarctica. *Polar Biology*, *29*(6), 502–509.

Rossi, M. (2019). People are flocking to see melting glaciers before they're gone —bringing both benefit and harm. *Environmental Health News*. Retrieved from https://ensia.com/features/melting-glaciers-tourism-impacts/

Rozema, P. D., Venables, H. J., van de Poll, W. H., Clarke, A., Meredith, M. P., & Buma, A. G. J. (2017). Interannual variability in phytoplankton biomass and species composition in northern Marguerite Bay (West Antarctic Peninsula) is governed by both winter sea ice cover and summer stratification. *Limnology and Oceanography*, *62*(1), 235–252.

Saba, G. K., Fraser, W. R., Saba, V. S., Iannuzzi, R. A., Coleman, K. E., Doney, S. C., ... Schofield, O. M. (2014). Winter and spring controls on the summer food web of the coastal West Antarctic Peninsula. *National Communication*, *5*, 4318.

Santa Cruz, F., Ernst, B., Arata, J. A., & Parada, C. (2018). Spatial and temporal dynamics of the Antarctic krill fishery in fishing hotspots in the Bransfield Strait and South Shetland Islands. *Fisheries Research*, *208*, 157–166.

SCAR. (2019). Scientific research programmes. Retrieved from https://www.scar.org/science/srp/

Schmidt, K., & Atkinson, A. (2016). Feeding and food processing in Antarctic Krill (*Euphausia superba* Dana). In V. Siegel (Ed.), *Biology and Ecology of Antarctic Krill* (pp. 175–224). New York: Springer.

Schmidtko, S., Heywood, K. J., Thompson, A. F., & Aoki, S. (2014). Multidecadal warming of Antarctic waters. *Science*, *346*(6214), 1227–1231.

Shah, R. M. (2013). Mitigating the impact of human activities in Antarctica for better quality of life. *Procedia - Social and Behavioral Sciences*, *101*, 284–291.

Shaw, J. D., Terauds, A., Riddle, M. J., Possingham, H. P., & Chown, S. L. (2014). Antarctica's protected areas are inadequate, unrepresentative, and at risk. *PLoS ONE*, *12*(6), 1–5.

Sidder, A. (2016). Antarctica could lose most of its penguins to climate change. *National Geographic*. Retrieved from https://www.nationalgeographic.com/news/2016/06/adelie-penguins-antarctica-climate-change-population-decline-refugia/#close

Silvano, A., Rintoul, S., & Herraiz-Borreguero, L. (2016). Ocean-Ice shelf interaction in East Antarctica. *Oceanography*, *29*(4), 130–143.

Snyder, J. (2007). *Tourism in the polar regions: the sustainability challenge*. Paris: United Nations Environmental Programme.

Southwell, C., Kerry, K., Ensor, P., Woehler, E. J., & Rogers, T. (2003). The timing of pupping by pack-ice seals in East Antarctica. *Polar Biology*, *26*(10), 648–652.

Stammerjohn, S., Massom, R., Rind, D., & Martinson, D. (2012). Regions of rapid sea ice change: an inter-hemispheric seasonal comparison. *Geophysical Research Letters*, *39*(6), L06501.

Stammerjohn, S. E., Martinson, D. G., Smith, R. C., & Iannuzi, R. A. (2008). Sea Ice in the Western Antarctic Peninsula region: spatio-temporal variability from ecological and climate change perspectives. *Deep-Sea Research II*, *55*, 2041–2058.

Stenson, G. B., & Hammill, M. O. (2014). Can ice breeding seals adapt to habitat loss in a time of climate change? *ICES Journal of Marine Science*, *71*(7), 1977–1986.

Stephens, T. (2018). The Antarctic treaty system and the Anthropocene. *The Polar Journal*, *8*(1), 29–43.

Stewart, E. J., Wilson, J., Espiner, S., Purdie, H., Lemieux, C., & Dawson, J. (2016). Implications of climate change for glacier tourism. *Tourism Geographies*, *18*(4), 377–398.

SwoopTravel. (2020). Citizen science. Retrieved from https://www.swoop-antarctica.com/travel/things-to-do/citizen-science

Taylor, M. (2018). Krill fishing poses serious threat to Antarctic ecosystem, report warns. *The Guardian*. Retrieved from https://www.theguardian.com/environment/2018/mar/13/krill-fishing-poses-serious-threat-to-antarctic-ecosystem-report-warns

Terauds, A., & Lee, J. R. (2016). Antarctic biogeography revisited: updating the Antarctic Conservation Biogeographic Regions. *Diversity and Distributions*, *22*(8), 836–840.

The Guardian. (2019). Scientists prepare to drill for million-year-old ice in Antarctica. *The Guardian*. Retrieved from https://www.theguardian.com/science/2019/sep/2023/scientists-prepare-to-drill-for-million-year-old-ice-in-antarctica

Trathan, P. N., Fretwell, P. T., & Stonehouse, B. (2011). First recorded loss of an emperor penguin colony in the recent period of Antarctic regional warming: implications for other colonies. *PLoS One*, *6*(2), e14738.

TravelManager. (2018). 3 places you must see before it's too late. Retrieved from https://www.travelmanagers.com.au/special-interest/three-places-must-see-late/

Trivelpiece, W. Z., Hinke, J. T., Miller, A. K., Reiss, C. S., Trivelpiece, S. G., & Watters, G. M. (2011). Variability in krill biomass links harvesting and climate warming to penguin population changes in Antarctica. *Proceedings of the National Academy of Sciences of the USA*, *108*(18), 7625–7628.

Trivelpiece, W. Z., Trivelpiece, S. G., & Volkman, N. J. (1987). Ecological segregation of Adelie, Gentoo, and Chinstrap Penguins at King George Island, Antarctica. *Ecological Society of America*, *68*(2), 351–361.

Tulloch, V., Plagányi, É., Brown, C., Richardson, A., & Matear, R. (2019). Future recovery of baleen whales is imperiled by climate change. *Global Change Biology*, *24*(4), 1263–1281.

Turner, J., Colwell, S. R., Marshall, G. J., Lachlan-Cope, T. A., Carleton, A. M., Jones, P. D., . . . **Lagovkina, S.** (2005). Antarctic climate change during the last 50 years. *International Journal of Climatology*, *25*(3), 279–294.

Vereda, M. (2016). Antarctica in the mind of visitors: representations of a remote destination. In M. Schillat, M. Jensen, M. Vereda, R. A. Sanchez, & R. Roura (Eds.), *Tourism in Antarctica: a multidisciplinary view of new activities carried out on the white continent* (Vol. SpringerBriefs in Geography, pp. 1–19). Switzerland: Springer.

Vila, M., Costa, G., Angulo-Preckler, C., Sarda, R., & Avila, C. (2016). Contrasting views on Antarctic tourism: 'Last Chance Tourism' or 'Ambassadorship' in the last of the wild. *Journal of Cleaner Production*, *111*, 451–460.

Virshup, A. (2020). How we picked the 2020 'Places to Go' List. *The New York Times*. Retrieved from https://www.nytimes.com/2020/01/09/travel/top-destinations-52-places.html?auth=login-facebook

Welling, J. T., Árnason, P., & Ólafsdottír, R. (2015). Glacier tourism: a scoping review. *Tourism Geographies*, *17*(5), 635–662.

Zhao, H. (2018). 3 'last chance' destinations drawing travelers worried about climate change. Retrieved from https://www.cnbc.com/2018/02/23/climate-change-worries-push-travelers-to-these-last-chance-locales.html