Attachment

**Report of Member research and monitoring activities related to the Ross Sea Region Marine Protected Area (2022)**

Please include information from currently submitted projects in the CMIR, combining projects already submitted (e.g. see CM 91-05 paragraph 16) or newly submitted with the current report.

Member:

| |
|---|
| United States of America |

Year range of projects included:

| |
|---|
| 2016-2021 |

Number of projects reported (2016 – 2022):

| |
|---|
| 192 (26 active grants and 166 published studies) |

Are there activities related to research and monitoring that are relevant to the RSrMPA which have not already been submitted to the CMIR? Please submit data following procedures and formats below.

| |
|---|
| All activities as of 8 December 2021 have been submitted (see emails to Isaac Forster, David Agnew and Steve Parker, with cc to George Watters, from Cassandra Brooks). |

Are there "preliminary results" from the activities you reported in the CMIR that you can describe further?

| |
|---|
| Yes; please see attached summary of preliminary results from research projects submitted to the CMIR. |

**Data submission to the CMIR**

The CMIR user manual describes how projects may be uploaded directly to the CMIR and can be found on the CMIR website. Note, the template provided here includes a few additional fields to describe the type of project and collaboration among Members. Alternatively, information about multiple projects may be submitted to the Secretariat following the data template below. If projects have been submitted previously to the CMIR as ongoing or proposed, please update these data. Project data already loaded may be downloaded as a csv file from the repository (see user manual) for editing.

Name of data file(s) provided:

| |
|---|
| |

Please attach an excel file, csv, or delimited text file with project data in the following format to be added to the CMIR. Note * indicates required fields.

| | |
|---|---|
| Title | *Title of research project |
| Description | *Summary or abstract of research project |
| Research_start_date | *Research start date (known or estimated) |
| Research_end_date | *Research end date (known or estimated) |
| Proposing_party | *CCAMLR Member |
| Collaborators | *List CCAMLR Members collaborating on the project (e.g., USA, ITL, KOR) |
| Paper_type | *Peer reviewed, CCAMLR, Agency Report |
| Project_status | *Complete, On-going, or Proposed. Note that ongoing or proposed projects will require being updated. |
| Objectives | *Conservation objectives for which the research project links to (to see list of objectives visit the CMIR 'Objectives' tab or Table 3 from https://www.ccamlr.org/en/sc-camlr-xxxvi/20) |
| Themes | Relevant research and monitoring topics the project covers (see CMIR 'Themes' tab or Table 1 in https://www.ccamlr.org/en/sc-camlr-xxxvi/20) |
| Outcomes | Project objectives or targeted data outcomes |
| Management_zones | MPA management zones where research is occurring (e.g., SRZ) |
| Monitoring_areas | Research monitoring areas (e.g., Southwest Ross Sea, Terra Nova Bay, etc.) |
| Supporting_docs | Links or uploads of supporting documents, such as peer-reviewed papers, etc. These could include DOI numbers or CCAMLR meeting paper references |
| Primary_contact | *Primary contact name, e-mail |
| Priority_questions | Hypothesis or priority elements addressed (see Table 4 in https://www.ccamlr.org/en/sc-camlr-xxxvi/20) |
| Data_location | *Description of how to locate project data - indicate if privately held who/ what to contact, or internet links to data if publicly accessible |

Reports may be submitted via CMIR@ccamlr.org

**SOME PRELIMINARY RESULTS FROM RESEARCH CONDUCTED IN THE ROSS SEA REGION**

Delegation of the USA

## INTRODUCTION

The Ross Sea is among the most intensively investigated stretches of the Southern Ocean, including of biota in both the benthos and the water column, with results available from an extensive collection of peer-reviewed literature (summaries in Ainley et al. 2010, Smith et al. 2006, 2014, 2016). This Ross Sea research continues today largely due to the Antarctic programs of CCAMLR Member States, including China, Italy, New Zealand, the Republic of Korea, and the United States. Because of the scientific and conservation values of the Ross Sea region (RSR), the Ross Sea region Marine Protected Area (RSRMPA) was established in 2016.

We reviewed over 150 papers published since the establishment of the MPA. These papers, each of which include at least one U.S. author and incorporate data collected in the RSR by U.S. government-funded research, demonstrate a high level of international scientific collaboration in the RSR with participation of scientists from at least 20 Members of CCAMLR and at least 8 additional non-Member nations. Although most papers do not specifically mention the RSRMPA, many present results that are relevant to the protected area and improve our understanding of climate and ecosystem processes therein, namely the "structure and function" that the RSRMPA was designed to protect. In short, the literature we reviewed characterizes how the ecosystem in the RSR, both its benthic and water-column aspects, has changed and establishes expectations about future change that might continue as a function of climate forcing and human activity, independent of the protections provided by the RSRMPA or the several Antarctic Specially Protected Areas that line its shores. We reviewed literature that characterizes "baselines" that began before establishment of the protected area, identifies habitats that are contained within the various zones and geographical areas of the RSRMPA, and indicates analytical issues that may need to be considered when evaluating whether the specific objectives of the MPA are being achieved.

Our literature review was composed of several steps. First we cataloged all papers published in peer-reviewed journals since 2016 that have at least one U.S. author (note: this catalog has been submitted to the CCAMLR MPA Information Repository, CMIR, and represents the bulk of U.S. projects listed therein). These papers span a range of disciplines, including cryospheric science and physical oceanography, studies of the benthic communities, plankton and predator ecology, and research on indicator species, *i.e.*, emperor and Adélie penguins, Weddell seals, killer whales, and toothfish. We then reviewed the contents of these papers to assess the status of ongoing research within the RSR and RSRMPA. While most of the papers did not specifically mention the RSRMPA and were not presenting results from studies specifically designed to evaluate the protected area, we determined that the research presented in the papers do contain results of relevance to the RSRMPA. We categorized the results of these papers as, for example, "results that characterize baseline conditions," "results that are particularly relevant to the boundaries of the RSRMPA, its zones, and habitat or geographical areas in the RSR," and "results that indicate technical issues to take into consideration during future analyses" and also identified some possible predictions of how the RSR ecosystem might change, consistent with current patterns underway and projections of change.

This review is not exhaustive; for example, we did not include papers that were not authored by at least one U.S. scientist. Colleagues might also have different expectations about how the marine ecosystem in the RSR may change in the future and reach different conclusions regarding how to categorize results from the large volume of literature relevant to the RSRMPA. We do not cite every paper, but a complete bibliography of the papers considered is included in this summary (and has been submitted to the CMIR). We encourage colleagues to use our summary as a springboard for their own reading, careful thought, and, if desired, re-analysis. Where applicable, our entries in the CMIR indicate the location of publicly available data. We believe that extensive work will be needed to review the RSRMPA in 2027, as required by CM 91-05, expect the relevant literature to be even more complex and voluminous by that time, and hope this summary will be useful in the future.

## EXPECTATIONS ABOUT FUTURE CHANGE

Evaluating the efficacy of the RSRMPA requires an assessment of the degree to which the RSR ecosystem has changed and is changing, and whether such changes are consistent with our expectations in regard to the relative roles of climate versus fishing. Thus, based on the results of research relevant to the RSRMPA, we attempted to outline changes that may occur. We acknowledge that the cumulative effects of interannual variability among various factors will contribute to long-term change in the biota, with our expectations related to the latter.

We expect several trends in physical conditions driven by mid-latitude ocean warming and the Antarctic ozone hole to continue, though possibly more slowly than in the 1980s-90s. Physical changes should affect biota to varying degrees. These expectations are founded on improved understanding provided by the integration of *in situ* oceanographic and remotely sensed observations (e.g., Bronselear et al. 2018). Warming at mid latitudes, along with atmospheric energetics attributed to the ozone hole, have caused circumpolar winds to intensify over the past few decades (Thompson and Solomon 2002, Turner et al. 2009), and this trend is unlikely to reverse, though it has stabilized. We expect that strong, intensifying winds will have the following effects:

1. maintenance of more expansive sea ice in the RSR than elsewhere in the Southern Ocean (see Stammerjohn et al. 2012, Parkinson 2019). At its maximum, sea ice in the RSR already extends to the Southern Boundary of the Antarctic Circumpolar Current and is unlikely to extend further; thus any interannual variation should be in the negative direction from the maximum (Parkinson 2019);
2. continual increasing or at least high velocity of the Ross Sea Gyre (see Kwok et al. 2017), which contributes to the expanding sea ice;
3. continual increasing of the length of the sea-ice season at a regional scale while decreasing the sea-ice season in coastal, latent heat polynyas (Stammerjohn et al. 2012);

4. latent-heat polynyas opening earlier and developing faster (Ross Sea, McMurdo Sound, Terra Nova Bay) during the transition from winter to spring while also increasing their areal extent (Arrigo et al. 2015);
5. increase in the intrusion of Circumpolar Deep Water (CDW) into outer portions of cross-shelf canyons (Dinniman et al. 2015), in part affecting the development of sensible heat polynyas along the shelf break (Ross Passage, Pennell Bank; Jacobs and Comiso 1989);
6. continual decreasing of the surface salinity in the RSR owing to upstream ice shelf melt, though most recently it has returned to previous levels (Jacobs 2006; Castagno et al. 2019); and
7. increased input of iron into the marine environment, from wind-driven terrigenous input and upstream ice shelf melt, which would stimulate primary production (Arrigo et al. 2015).

Cumulatively, we expect the physical changes noted above will have effects on the overall ecology of the RSR, but the degree to which these changes are having or will have net effects on biota requires continued research. Broadly, we would expect large polynyas that open earlier and have increased iron input to increase primary production in the RSR (Arrigo et al. 2015). Though to-date increased production has had no effect on Adélie penguins (Dugger et al. 2014) and inconclusive effects on Weddell seals (Paterson et al. 2015), such production may most readily affect the filter-feeding benthic communities (Barry et al. 2003; Dayton et al. 2016). Open water in proximity to colonies has been important to these penguins and seals (Ainley et al. 2005; Dugger et al. 2014; LaRue et al. 2019) as their colonies are associated with polynyas (Santora et al. 2020; LaRue et al. 2021). Whether or not Adélie penguin and Weddell seal populations will continue to grow as they have been since around the year 2000 is unknown.

We also expect the toothfish fishery to continue operating in the RSR, and, independent of the RSRMPA, the fishery's access to fish will be determined by CCAMLR conservation measures and trends in sea-ice extent, duration, and thickness. The fishery has been changing the size and/or age structure of the population, and these changes may even be reflected within the General Protection Zone (GPZ), where commercial fishing has been prohibited since 2009 (although toothfish surveys do continue in the GPZ). For example, large fish have decreased in scientific catches taken from McMurdo Sound (Ainley et al. 2013, 2017), and those fish still present in the Sound have retreated from shallow depths (Parker et al. 2016). This spatial shift could also be the result of predation pressure from increasing numbers of Weddell seals in McMurdo Sound, beginning in the early 2000s (Ainley et al. 2015, 2020) and concomitant with increases in the abundance of emperor and Adélie penguins in the southern Ross Sea (Lyver et al. 2014; Kooyman and Ponganis, 2016; Schmidt and Ballard, 2019). One hypothesis is that a reduction in the abundance of large toothfish, which being neutrally buoyant can occur high in the water column, has significantly increased availability of energy-dense silverfish to these other predators (Lyver et al. 2014; Ainley et al. 2017, 2020). Having more silverfish in the diet leads to enhanced breeding success and post-fledging survival of indicator species like Adélie penguins (Ainley et al. 2018).

Expectations regarding the middle of the food web, particularly about Antarctic krill, crystal krill, and silverfish, are not well developed. Although the habitat characteristics of these species have been quantified (Davis et al. 2017), monitoring of these species is inadequate. What has been done suggests minimal change at the regional scale, at least in regard to Antarctic krill and climate during recent decades along the Ross Sea margin (Yang et al. 2021). While it is recognized that penguins and seals can be proxies for prey availability, it is challenging to deduce the direct links between indicator species trends and food web changes without additional experiments or krill and silverfish monitoring.

## PRELIMINARY RESULTS

Since the RSRMPA's adoption in 2016, an extensive scientific literature associated with the RSR has been published in peer-reviewed journals. This literature include studies on the physical oceanography and climatology of the Ross Sea, ecological papers on penguins, whales, seals and fishes, and research on Antarctic benthos and pelagic fauna. These papers and their extensive array of results and discoveries across the RSR extend the bountiful, existing RSR literature and provide a scientific baseline for all future studies relevant to how and why the RSR ecosystem is changing. Not only do these studies shape our understanding of "baseline conditions" in the RSR, but they will facilitate future evaluations of the effectiveness of the RSRMPA. As climate change and other anthropogenic effects continue to affect Southern Ocean ecosystems, these papers along with continuing research and monitoring across the RSR will allow for a comprehensive assessment of the MPA over time. Our literature review presents a condensed version of preliminary results relevant to the protected area, and identifies several baselines present in the Ross Sea since 2016.

### Physical Papers

Multiple studies on the oceanography and climatology of the Ross Sea contribute to our understanding of its physical characteristics. Many of these studies include time series that began decades ago (ex: Castagno et al. 2019), beginning with observations made from the USNS *Eltanin* in the 1960s. With the addition of satellites and various sensors, studies on water, air, ice and ocean-current dynamics have improved our understanding of how oceanography influences the biota (initially summarized by Jacobs 2006). Recent research has reported on the effects of local climatology and katabatic winds, enhanced knowledge of sea-ice dynamics, and investigated the physical properties of coastal polynyas and their impact on global ocean currents due to their production of dense, bottom water. Collectively, this research also improves understanding of controls on ecosystem-wide productivity, such as from the input of iron and dissolved trace metals and how these seawater constituents affect phytoplankton and algal blooms (Arrigo et al. 2015). Changing environmental conditions and sea-ice trends impact phytoplankton at the base of the food web, triggering bottom-up trophic responses affecting higher trophic levels (*e.g.*, Li et al. 2016; Kaufman et al. 2017).

One area of particular importance for continued research and monitoring is the Ross Sea Polynya, which has the highest primary production across all Antarctic waters (Gerringa et al. 2019, 2020). The RSR, especially waters overlying the Ross Sea continental shelf, experiences elevated spring and summer phytoplankton blooms as sea ice decreases and availability of light increases. These blooms play an important role in the marine carbon cycle. The seasonal phytoplankton bloom and the phytoplankton species assemblages in the RSR are dependent on nutrient availability. Dissolved nutrients, changes in temperature, and ice coverage could affect these assemblages (Smith et al. 2017; Ryan-Keogh et al. 2017; Smith and Kaufman, 2018; Smith et al. 2021). A better understanding about nutrient availability is required to accurately determine which nutrients limit sea-ice primary productivity and, therefore, affect the structure of the sympagic microbial community (Fripiat et al. 2017). Across the Southern Ocean, primary production is predominantly limited by iron and other dissolved metal availabilities (Alderkamp et al. 2019; Chen et al. 2021; Dinniman et al. 2020; Kaufman et al. 2018; Ryan-Keogh & Smith, 2021; Salomon et al. 2020; Schine et al. 2021; Smith, 2021; Tison et al. 2020). While the Ross Sea is a high productivity region compared to other Antarctic coastal regions, phytoplankton assemblages in the Ross Sea exhibit considerable spatiotemporal variability (Kaufman et al. 2018). The Ross Sea is projected to have reduced sea ice, a main source of dissolved iron, and longer periods of open water by 2100 (Salomon et al. 2020). Primary productivity in the Southern Ocean and the Ross Sea play a vital role in regulating global uptake of atmospheric carbon dioxide, and research on iron availability in the Ross Sea shows iron to be a limiting factor for primary productivity in this region (Arrigo et al. 2015; Tagliabue and Arrigo 2016; Oldham et al. 2021). Availability of dissolved iron therefore influences the impact of this carbon sink. Continued monitoring and research of iron uptake and availability in the Ross Sea is vital for our understanding of the Earth's changing climate and the impacts on the RSR ecosystem.

While extensive research on physical properties across the Ross Sea has been conducted for decades, continued monitoring of physical properties under the effects of climate change will be crucial for evaluating the efficacy of the RSRMPA. Moving forward, the use of climate models that incorporate the relationship between seasonal winds, sea-ice cover and sea-ice extent will improve predictions of sea-ice cover and extent across the Ross Sea region (Holland et al. 2017; Bronselear et al. 2018). Continued studies on sea-ice thickness and extent are recommended (Schlosser et al. 2018). As climate change and anthropogenic activities continue to affect Southern Ocean ecosystems, increased monitoring and scientific research on the physical properties of the RSR are warranted, some of which will continue to be greatly aided by deployed sensors and imagery from satellites. Our literature review on physical studies conducted in the RSR indicates that documenting the physical properties and continuing detailed characterization of baselines is necessary for the successful long-term monitoring of the ecosystem and the RSRMPA.

### Ecological Papers

Relatively new research, built on decades-long foundation of older research, has provided insight into both Antarctic marine ecosystems in general and the RSR ecosystem specifically, and have also improved our understanding of the population dynamics, physiologies, and life histories of many Antarctic species. For example, researchers successfully deployed long-term, continuously recording passive-acoustic sensors near the Balleny Islands and in the Terra Nova Bay polynya to assess physical and biological trends in the region (Sukyoung et al. 2021). These sensors successfully detected physical dynamics such as changes in sea ice and katabatic winds, and coupled this information with spatial and temporal trends in the presence and abundance of a variety of marine mammals, confirming a relationship between these trends and sea-ice dynamics. Other studies have relied on innovations in tools and methodologies to test the efficacy of the RSRMPA in respect to fishing and toothfish populations. For example, Ashford et al. (2021) suggested a potential spillover of toothfish from the RSRMPA into areas outside of the MPA. However this effect could be compromised if some of the hypothesized dispersal pathways and areas key to toothfish life cycle remain vulnerable to fishing (e.g., Iselin Bank, as well as the Pacific-Antarctic Ridge and Amundsen Sea, respectively) (Ashford et al. 2021). Remote sensing technology, simultaneous with on-the-ground research, has also played a large role in improving our understanding of population dynamics for Antarctic seal and penguin species. For example, Very High Resolution (VHR) satellites, coupled with crowdsourcing and citizen science, have been used successfully to analyze Weddell seal populations in the RSR. (LaRue et al. 2019a; LaRue et al. 2019b; LaRue et al. 2021). The application of new tools to study species within the boundaries of the RSRMPA facilitates management that may be adaptive and responsive to the combined effects of climate change and fisheries operating within and along the boundary of the RSRMPA.

Fish and Krill

There continues to be debate over the potential ecological and population level effects of the Antarctic toothfish fishery in the Ross Sea, including debate about the presence of large toothfish in McMurdo Sound. Ainley et al. (2013, 2016) detected a decrease in the abundance of large Antarctic toothfish in McMurdo Sound, with the remnant standing stock occupying deeper waters than in previous decades, as a result of both the fishery and recovering populations of Weddell Seals (Ainley et al. 2020). Ainley et al. (2017, also Lyver et al. 2014) further proposed that the dramatic growth in penguin populations in the southern Ross Sea since about the year 2000 could be the result of an increase in Antarctic silverfish and decreased competition among mesopredators, owing fewer competing toothfish in the water column. Indeed, Parker et al. (2016) show that large, old toothfish can now only be reliably caught in McMurdo Sound at depths greater than 500 m, whereas in the 1970-1990s large toothfish could be caught with high catch per unit effort (CPUE) at depths of 300 m or less (Ainley et al. 2020). Parker et al. (2019) contend that large toothfish from McMurdo Sound may mix with the wider Ross Sea toothfish population to only a limited extent. Ashford et al. (2017) built on these arguments, noting that transport pathways may also contribute to the variation observed in toothfish presence; Ainley et al. (2020) point out the depression in toothfish prevalence where predatory seals congregate. All authors agree on the need for continued monitoring using a spatially stratified, standardized approach (Ainley et al. 2016, Parker et al. 2016, Ashford et al. 2017). This is in agreement with others (e.g., Abrams et al. 2016) who also emphasized the need for a comprehensive ecosystem monitoring program to ensure precautionary management for toothfish, including using Weddell seals as an indicator species for ecosystem management (Ainley et al. 2020) and testing the efficacy of the RSRMPA (Parker et al. 2019). Further, while fisheries may drive changes in Ross Sea fish productivity, climate change presents an immense challenge in assessing future changes and compounds risks to Antarctic toothfish (Caccavo et al. 2021).

Several species at middle trophic levels are important to Southern Ocean food webs, with research in the Antarctic Peninsula region showing, at least in some respects, how sea-ice cover and persistence in response to climate change might affect one of these species, Antarctic krill. In the Ross Sea (which is considered to be one of the few sea-ice refugia should climate change continue its current trajectory), Antarctic krill, crystal krill, and Antarctic silverfish are the three key mid-trophic level species connecting primary production to the upper trophic levels. Davis et al. (2017) suggest that these species occupy different habitats determined by environmental conditions, with the habitat of Antarctic krill being distinct from that of crystal krill and silverfish. Antarctic krill concentrate along the shelf break, in a habitat characterized by relatively great bottom depth (>1000 m) and warm temperature (1-1.25°C), owing to upwelling of circumpolar deep water (CDW). The portion of this habitat along the western shelf break was also determined to be particularly important in the results of a particle tracking study (Pinones et al. 2016); the boundary of the RSRMPA's General Protection Zone (GPZ) bisects this important habitat. Crystal krill and Antarctic silverfish occur over the shelf, and are associated with sea ice, with specific spawning areas identified at least in Terra Nova Bay and the Bay of Whales, where efforts were made in search of eggs and larvae, and common characteristics of the habitat are coastal proximity and relatively cold temperature (-1.75 to -2°C). Those are temperatures, along with frazil ice, that emerge from beneath ice shelves. Predicted further warming (post-2050 in the Ross Sea) and other climate change related effects could affect these key species significantly (Davis et al. 2017). Additionally, the contribution of Antarctic krill to Southern Ocean carbon cycling should be considered in future studies and monitoring due to their extraordinarily high biomass in the Southern Ocean (D'Sa et al. 2021). Larval silverfish, which hatched much later in the season, were also found in the eastern Ross Sea (Bay of Whales), with Brooks et al. (2018) suggesting the presence of a geographically separate population or westward connectivity from the Amundsen Sea. Larval silverfish have also been detected in McMurdo Sound.

Recent studies in the Ross Sea provide new insights into Southern Ocean fishes. For example, Eastman et al. (2020) emphasized that the pelagic biotope of Notothenioid fishes is habitat for just a few species, including the Antarctic toothfish and Antarctic silverfish due to their capacity for neutral buoyancy. Their high lipid content and occupation of the water-column biotope make these two fishes disproportionately important to upper trophic level predators. Further, Antarctic toothfish occupation of the water-column biotope may not be constant, but perhaps dependent on the availability of lipid-rich Antarctic silverfish as prey (Eastman et al. 2020). Comprehensive studies on global drivers for change in the Southern Ocean (*e.g.*, Morley et al. 2020) also indicate that changes in temperature, sea ice, and salinity will have direct effects on fish species across the Ross Sea region.

Penguins and Petrels

The RSR is a crucial breeding and foraging habitat for Antarctic seabirds. Known prior to establishment of the RSRMPA, about 30% of the world population of Antarctic petrels foraged along the eastern Ross Sea slope (van Franeker et al. 1999; Ballard et al. 2012). Recent research suggests that there may be a significant number of breeding colonies in Victoria Land, on the western side of the Ross Sea, as well as Marie Byrd Land on the eastern side (Schwaller et al. 2018). Their current population status is unknown. On the other hand, around the year 2000, several penguin populations began to increase, including Adélie penguins breeding at Cape Crozier, Cape Bird, and Beaufort Island (Ainley et al. 2018), and emperor penguins breeding at Cape Crozier and Beaufort Island (Kooyman & Ponganis, 2017; Schmidt & Ballard 2020).

A recent study indicates that emperor penguin colonies exhibit large annual variations in breeding population size, with chick abundance and survivorship being linked to fast ice persistence and local weather conditions (Kooyman and Ponganis, 2017; Schmidt and Ballard, 2019). The GPZ fully contains important foraging habitats for emperor penguins during the chick-rearing season (Kooyman et al. 2018, 2020), including multiple marginal ice zones and polynyas that support thriving biological hotspots and primary production (Saenz et al. 2020) plus two complete and part of a third "Areas of Ecological Significance" (AESs) for air-breathing predators (Hindell et al. 2020). Data indicate that non-breeding (post-moult) emperor penguins forage widely throughout the eastern RSR, with some foraging occurring within the GPZ and Special Research Zone (SRZ) and some foraging occurring outside the RSRMPA, with possible differences in diet among these areas (Goetz et al. 2018).

Results from research published since 2016 indicate that evaluating the efficacy of the RSRMPA will require careful thought. Adélie and emperor penguin abundances should continue to be monitored regularly and throughout the RSR to adequately characterize the frequent and variable colony-specific responses to change (Kooyman and Ponganis, 2017; Santora et al. 2020). Additionally, due to individual- and colony-specific variations in foraging ranges, the tracks from a few individual penguins may not be representative of habitat use by individuals from understudied colonies (Santora et al. 2020), and foraging range continues to be investigated at a number of RSR colonies.

<u>Seals</u>

Although one of many pinniped species in the region, Weddell seals are the most studied seal species of the RSR as they are year-long residents of the Ross Sea. Similar to the previously mentioned penguins that breed on Ross Island, the abundance of Weddell seals in Erebus Bay, McMurdo Sound, began to increase in about the year 2000 (Ainley et al. 2020), prior to the establishment of the RSRMPA, and continues increasing to this day. Long-term data on Weddell seals in Erebus Bay continue to inform our understanding of this population (Patterson et al. 2018; Macdonald et al. 2020), while new discoveries are still being made. For example, Cziko et al. (2020) reported the first recording of ultrasonic vocalizations in this species. Much of the focus on the Weddell seal is due to the fact that it is an excellent model organism for studying the food web in the RSR ecosystem. Weddell seals have been used to investigate the physiology of large mammals (Kooyman et al. 2020), and to collect oceanographic and atmospheric data that relate to RSR ecology by using satellite tags (Piñones et al. 2019). Weddell seals seem to be noticeably affected by climate change, as environmental changes can affect seal reproductive success (Beltran et al. 2020) and pup survival (Rotella et al. 2016). The potential climate-related effects on seal populations may be compounded by the effects of fisheries if toothfish removals reduce prey availability for seals (Salas et al. 2017) and subsequently reduce seal body mass (Beltran et al. 2017). The seals' diet includes a significant proportion of both Antarctic toothfish and silverfish, the interaction being a prime example of "intraguild predation" (Ainley et al. 2020).

<u>Whales</u>

Antarctic minke and type-C killer whales (also known as Ross Sea killer whales) occur within the RSR, and are most commonly observed in the southwestern Ross Sea (Ainley et al. 2017; Ainley et al. 2020; Lauriano et al. 2020). There are a few population clusters of type-C killer whales in the southwestern Ross Sea (Pitman et al. 2018; Lauriano et al. 2020), and, although their prevalence (apparent abundance) was decreasing along the outer Ross Island coast, it seems unlikely that their population size had been changing prior to establishment of the RSRMPA (Ainley et al. 2017, Pitman et al. 2018). The RSRMPA GPZ fully encompasses several regionally known coastal feeding areas of type-C killer whales (*e.g.*, Lauriano et al. 2020).

The movements of Antarctic minke whale and type-C killer whale populations are linked to sea-ice cover (Ainley et al. 2017), with coastal observations of whales generally increasing as sea ice retreats in the southern Ross Sea. Minke whales, feeding on krill and to a lesser extent silverfish, move between dense prey patches to forage, remaining in a patch to feed for several days at a time (Ainley et al. 2020), while type-C killer whales feed on various fish species including toothfish and silverfish (Lauriano et al. 2020). Even in small numbers, Antarctic minke whales measurably affect penguin foraging due to competition for prey (Ainley et al. 2017; Ainley et al. 2020), which should be considered when evaluating future population trends.

### Antarctic Benthos and Undersea Fauna

With increased research, and aid from technological advancements, Ross Sea scientists have continued to document the population dynamics of benthic fauna (Bowser et al. 2019; Chakrabarty et al. 2021; Dayton et al. 2019; Kim et al. 2021; Lenihan et al. 2018; Palmer et al. 2021; Wing et al. 2018), an avenue of research that began decades ago. This has revealed decadal patterns of community change, led to continued discovery of new species, and resulted in better understanding of the relationship between physical aspects of habitat and benthic communities on the Ross Sea shelf. New population surveys on undersea fauna in the Ross Sea have led to the identification of over 1,000 organisms (Chakrabarty et al. 2021), including corals, fishes, sea stars, spiders, and sponges (Kim et al. 2019; Moran et al. 2018; Szuta et al. 2018). High resolution undersea images from the Ross Ice Shelf show a diverse community of life that was largely unknown and may reveal new ecological insight (Chakrabarty et al. 2021).

Understanding how benthic communities will respond to changes in their physical habitats, i.e. sea ice cover, intrusion of water masses with different temperature signatures, linked with climate change will be useful to inform management decisions relating to the RSRMPA. Indeed, CCAMLR designates some benthic communities, as indicated by the presence of specific species, as vulnerable marine ecosystems (VMEs) and generally prohibits longline fishing at depths shallower than 550 m. Warming temperatures can have lethal effects on benthic species that have low thermal tolerances, and can also increase competition from non-native species (Brasier et al. 2021). Long-term monitoring should continue, as it will be necessary to detect and prepare for changes in benthic populations that are attributed to climate change and yet to be identified (Bowser et al. 2019; Brasier et al. 2021; Dayton et al. 2019; Palmer et al. 2021). The diverse set of studies included in this literature review can provide a useful inventory of benthic fauna that can be monitored to examine any potential changes through the years.

## ONGOING RESEARCH

There are currently 18 active, U.S.-funded grants supporting research taking place partially or fully in the RSR: 16 funded by the U.S. National Science Foundation (NSF) and two funded by the U.S. National Aeronautics and Space Administration (NASA). All of these directly or indirectly relate to the RSRMPA. Additionally, there are six recently expired NSF grants that, as of yet, may not have reported or published outcomes. The active grants span three general disciplines: physical science, primary productivity, and animal ecology or biology. The physical science research mainly focuses on changing physical conditions in response to a variable climate. Specifically, the research includes meteorology and atmosphere-ocean general circulation models, variability in sea ice and ice sheets, the Ross Gyre's exchange with the Antarctic Circumpolar Current (ACC), and processes controlling dissolved iron and carbon sequestration in the Ross Sea. Two active grants are being used to investigate the highly biologically productive Ross Sea polynyas and model the impacts of climate change. The animal ecology and biology studies constitute the majority of active grants. These grants are being used to investigate the following: Adélie and emperor penguin ecology, especially as it relates to changing sea ice and environmental conditions, Adélie and emperor penguin foraging relative to spatial variation in the preyscape, environmental and social factors affecting pup survivorship of Weddell seals, the microbial community in parts of the Ross Sea, and changes in benthic marine invertebrates related to past and present environmental variability. One NASA grant in particular is specifically related to the RSRMPA. This grant, to Principal Investigator Dr. Grant Ballard, is entitled "Opening the Black Box - Integrating Winter Ecology into the Management of the RSR Marine Protected Area", and the funded research aims to fill in considerable knowledge gaps related to the foraging patterns of RSR Adélie penguins over the winter months.

## REFERENCES

*References are listed by year of publication. All papers except those published prior to 2016 have been submitted to the CMIR.*

### Prior to 2016

Ainley, D. G., Nur, N., Eastman, J. T., Ballard, G., Parkinson, C. L., Evans, C. W., & DeVries, A. L. (2013). Decadal trends in abundance, size and condition of Antarctic toothfish in McMurdo Sound, Antarctica, 1972–2011. Fish and Fisheries, 14(3), 343-363.

Ainley, D.G, G. Ballard & J. Weller. 2010. Ross Sea Bioregionalization. Part I: Validation of the 2007 CCAMLR Bioregionalization Workshop Results Towards Including the Ross Sea in a Representative Network of Marine Protected Areas in the Southern Ocean CCAMLR WG-EMM-10/11, Hobart.

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

Ainley, D. G., M.A. LaRue, I. Stirling, S. Stammerjohn, and D.B. Siniff. 2015. An apparent population decrease, or change in distribution, of Weddell Seals along the Victoria Land coast. Marine Mammal Science, doi: 10.1111/mms.12220.

Arrigo, K.R., G.L. van Dijken, and A.L. Strong. 2015. Environmental controls of marine productivity hot spots around Antarctica. Journal of Geophysical Research Oceans 120, doi:10.1002/ 2015JC010888.

Ballard, G., D. Jongsomjit, S.D, Veloz, and D.G. Ainley. 2012. Coexistence of mesopredators in an intact polar ocean ecosystem: The basis for defining a Ross Sea marine protected area. Biological Conservation 156:72–82.

Barry, J.P., J. Grebmeier, J. Smith, R.B. Dunbar. 2003. Bathymetric versus oceanographic control of benthic megafaunal patterns in the Ross Sea, Antarctica. Antarc. Res. Ser. 78: 327-354.

Dinniman, M.S., Klinck, J.M., Baie, L-S., Bromwich, D.H., Hines, K.M.and Holland. 2015. The Effect of Atmospheric Forcing Resolution on Delivery of Ocean Heat to the Antarctic Floating Ice Shelves. Journal of Climate 28: 6067-6085.

Dugger, K.M., G. Ballard, D.G. Ainley, P.O'B. Lyver, and C. Schine. 2014. Adélie Penguins coping with environmental change: results from a natural experiment at the edge of their breeding range. Frontiers in Ecology and Evolution 2: 68.

Jacobs, S. 2006. Observations of change in the Southern Ocean. Philosophical Transactions of the Royal Society A, doi:10.1098/rsta.2006.1794.

Jacobs, S. & J. Comiso. 1989. Sea ice and oceanic processes on the Ross Sea continental shelf. J. Geophys. Res. 94 (C12): 18195-18211.

Jacobs, S.S., C.F. Giulivi, and P.A. Mele. 2002. Freshening of the Ross Sea during the late 20th century. Science 297: 386–389.

Lyver, P.O'B., M. Barron, K.J. Barton, D.G. Ainley, A. Pollard, S. Gordon, S. McNeill, G. Ballard, and P.R. Wilson. 2014. Trends in the breeding population of Adélie Penguins in the Ross Sea, 1981–2012: a coincidence of climate and resource extraction effects. PLoS ONE 9:e91188.

Paterson, J.T., J.J. Rotella, K.R. Arrigo, and R.A. Garrott. 2015. Tight coupling of primary production and marine mammal reproduction in the Southern Ocean. Proceedings of the Royal Society B 282, doi.org/10.1098/rspb.2014.3137.

Smith, W.O. Jr., D.G. Ainley, K.R. Arrigo and M.S. Dinniman. 2014. The oceanography and ecology of the Ross Sea. Annual Review of Marine Science 6:469–487.

Smith, W.O., Jr., D.G. Ainley and R. Cattaneo-Vietti. 2006. Marine Ecosystems: the Ross Sea. In Antarctic Ecology: From Genes to Ecosystems, Phil. Trans. R. Soc. B (2007) 362, 95–111.

Smith, W.O. Jr., D.G. Ainley, R. Cattaneo-Vietti and E.E. Hofmann. 2012. The Ross Sea continental shelf: Regional biogeochemical cycles, trophic interactions, and potential future changes. In: Antarctic Ecosystems: An Extreme Environment in a Changing World (A.D. Rogers, N.M. Johnston, E.J. Murphy and A. Clarke, Eds.). Chapter 7, Blackwell Publishing, London, pp. 213-242.

Stammerjohn, S., R. Massom, D. Rind, and D. Martinson. 2012. Regions of rapid sea ice change: An inter-hemispheric seasonal comparison. Geophysical Research Letters 39: L06501. doi:10.1029/2012GL050874.

Thompson, D. W. J. & Solomon, S. 2002 Interpretation of recent Southern Hemisphere climate change. Science 296, 895–899. (doi:10.1126/science.1069270)

Turner, J., J.C. Comiso, G.J. Marshall, T.A. Lachlan-Cope, T. Bracegirdle, T. Maksym, M.P. Meredith, Z. Wang, and A. Orr. 2009. Non-annular atmospheric circulation change induced by stratospheric ozone depletion and its role in the recent increase of Antarctic sea ice extent. Geophysical Research Letters 36, L08502, doi: 10.1029/2009GL037524.

Van Franeker, J.A., M. Gravilo, F. Mehlum, R.R. Veit & E.J. Woehler. 1999. Distribution and abundance of the Antarctic petrel. Waterbirds 22: 14-28.

**2016**

Abrams, P. A., D. G. Ainley, L. K. Blight, P. K. Dayton, J. T. Eastman and J. L. Jacquet (2016). Necessary elements of precautionary management: implications for the Antarctic toothfish. Fish and Fisheries. 17: 1152-1174.

Ainley, D.G., G. Ballard, J.T. Eastman, C.W. Evans, N. Nur, and C.L. Parkinson. 2016. Changed prevalence, not absence, explains toothfish status in McMurdo Sound. Antarctic Science doi:10.1017/S0954102016000584.

Ainley, D. G., J. T. Eastman and C. M. Brooks (2016). Comments on "The Antarctic toothfish (Dissostichus mawsoni): biology, ecology, and life history in the Ross Sea region," by S. Hanchet et al.: (Hydrobiologia, 2015, 761:397–414). Hydrobiologia, Springer International Publishing. 771: 1-7.

Barker, L. D. L., S. L. Kim, B. T. Saenz, D. Osborne and K. L. Daly (2016). Towable instrumentation for use with a hand-deployed Remotely Operated Vehicle. OCEANS 2016 MTS/IEEE Monterey, OCE 2016.

Buck, C. B., K. Van Doorslaer, A. Peretti, E. M. Geoghegan, M. J. Tisza, P. An, J. P. Katz, J. M. Pipas, A. A. McBride, A. C. Camus, A. J. McDermott, J. A. Dill, E. Delwart, T. F. F. Ng, K. Farkas, C. Austin, S. Kraberger, W. Davison, D. V. Pastrana and A. Varsani (2016). The Ancient Evolutionary History of Polyomaviruses. PLoS Pathogens. 12: 1-26.

Dayton, P., S. Jarrell, S. Kim, S. Thrush, K. Hammerstrom, M. Slattery and E. Parnell (2016). Surprising episodic recruitment and growth of Antarctic sponges: Implications for ecological resilience. Journal of Experimental Marine Biology and Ecology, Elsevier B.V. 482: 38-55.

Dayton, P. K., K. Hammerstrom, S. C. Jarrell, S. Kim, W. Nordhausen, D. J. Osborne and S. F. Thrush (2016). Unusual coastal flood impacts in Salmon Valley, McMurdo Sound, Antarctica. Antarctic Science. 28: 269-275.

Hobbs, W. R., R. Massom, S. Stammerjohn, P. Reid, G. Williams and W. Meier (2016). A review of recent changes in Southern Ocean sea ice, their drivers and forcings. Global and Planetary Change, Elsevier B.V. 143: 228-250.

Jennings, S., A. Varsani, K. M. Dugger, G. Ballard and D. G. Ainley (2016). Sex-based differences in adélie penguin (Pygoscelis adeliae) chick growth rates and diet. PLoS ONE. 11: 1-13.

Kwok, R., J. C. Comiso, T. Lee and P. R. Holland (2016). Linked trends in the South Pacific sea ice edge and Southern Oscillation Index. Geophysical Research Letters. 43: 10,295-210,302.

Lawrence, C. J., B. Schmidt, L. Winslow, P. T. Doran, S. Kim, C. C. Walker, J. Buffo, M. L. Skidmore, K. M. Soderlund, D. D. Blankenship, N. E. Bramall, A. Johnson, F. R. Rack, W.

Stone, P. Kimball and E. {Clark} (2016). Insights into ice-ocean interactions on Earth and Europa. AGU Fall Meeting Abstracts: P31A-2077.

Li, Y., R. Ji, S. Jenouvrier, M. Jin and J. Stroeve (2016). Synchronicity between ice retreat and phytoplankton bloom in circum-Antarctic polynyas. Geophysical Research Letters. 43: 2086-2093.

Meehl, G. A., J. M. Arblaster, C. M. Bitz, C. T. Y. Chung and H. Teng (2016). Antarctic sea-ice expansion between 2000 and 2014 driven by tropical Pacific decadal climate variability. Nature Geoscience. 9: 590-595.

Paterson, J. T., J. J. Rotella, J. M. Mannas and R. A. Garrott (2016). Patterns of age-related change in reproductive effort differ in the pre-natal and post-natal periods in a long-lived mammal. Journal of Animal Ecology. 85: 1540-1551.

Piñones, A., E. E. Hofmann, M. S. Dinniman and L. B. Davis (2016). Modeling the transport and fate of euphausiids in the Ross Sea. Polar Biology. 39: 177-187.

Rotella, J. J., J. T. Paterson and R. A. Garrott (2016). Birth dates vary with fixed and dynamic maternal features, offspring sex, and extreme climatic events in a high-latitude marine mammal. Ecology and Evolution. 6: 1930-1941.

Tagliabue, A. and K. R. Arrigo (2016). Decadal trends in air-sea CO2 exchange in the Ross Sea (Antarctica). Geophysical Research Letters. 43: 5271-5278.

Thomas, P. O., R. R. Reeves and R. L. Brownell (2016). Status of the world's baleen whales. Marine Mammal Science. 32: 682-734.

**2017**

Ainley, D. G., G. Ballard, J. T. Eastman, C. W. Evans, N. Nur and C. L. Parkinson (2017). Changed prevalence, not absence, explains toothfish status in McMurdo Sound. Antarctic Science. 29: 165-171.

Ainley, D. G., E. L. Crockett, J. T. Eastman, W. R. Fraser, N. Nur, K. O'Brien, L. A. Salas and D. B. Siniff (2017). How overfishing a large piscine mesopredator explains growth in Ross Sea penguin populations: A framework to better understand impacts of a controversial fishery. Ecological Modelling. 349: 69-75.

Ainley, D. G., K. Lindke, G. Ballard, P. O. B. Lyver, S. Jennings, V. Toniolo, J. Pennycook, M. Massaro and J. A. Santora (2017). Spatio-temporal occurrence patterns of cetaceans near Ross Island, Antarctica, 2002–2015: implications for food web dynamics. Polar Biology, Springer Berlin Heidelberg. 40: 1761-1775.

Ashford, J., M. Dinniman and C. Brooks (2017). Physical-biological interactions influencing large toothfish over the Ross Sea shelf. Antarctic Science. 29: 487-494.

Beltran, R. S., J. W. Testa and J. M. Burns (2017). An agent-based bioenergetics model for predicting impacts of environmental change on a top marine predator, the Weddell seal. Ecological Modelling, Elsevier B.V. 351: 36-50.

Bercovici, S. K., B. A. Huber, H. B. DeJong, R. B. Dunbar and D. A. Hansell (2017). Dissolved organic carbon in the Ross Sea: Deep enrichment and export. Limnology and Oceanography. 62: 2593-2603.

Castagno, P., P. Falco, M. S. Dinniman, G. Spezie and G. Budillon (2017). Temporal variability of the Circumpolar Deep Water inflow onto the Ross Sea continental shelf. Journal of Marine Systems, Elsevier B.V. 166: 37-49.

Davis, L. B., E. E. Hofmann, J. M. Klinck, A. Piñones and M. S. Dinniman (2017). Distributions of krill and Antarctic silverfish and correlations with environmental variables in the western Ross Sea, Antarctica. Marine Ecology Progress Series. 584: 45-65.

DeJong, H. B. and R. B. Dunbar (2017). Air-Sea CO2 Exchange in the Ross Sea, Antarctica. Journal of Geophysical Research: Oceans. 122: 8167-8181.

DeJong, H. B., R. B. Dunbar, D. A. Koweek, D. A. Mucciarone, S. K. Bercovici and D. A. Hansell (2017). Net community production and carbon export during the late summer in the Ross Sea, Antarctica. Global Biogeochemical Cycles. 31: 473-491.

Fahsbender, E., J. M. Burns, S. Kim, S. Kraberger, G. Frankfurter, A. A. Eilers, M. R. Shero, R. Beltran, A. Kirkham, R. McCorkell, R. K. Berngartt, M. F. Male, G. Ballard, D. G. Ainley, M. Breitbart and A. Varsani (2017). Diverse and highly recombinant anelloviruses associated with Weddell seals in Antarctica. Virus Evolution. 3: 1-11.

Fripiat, F., K. M. Meiners, M. Vancoppenolle, S. Papadimitriou, D. N. Thomas, S. F. Ackley, K. R. Arrigo, G. Carnat, S. Cozzi, B. Delille, G. S. Dieckmann, R. B. Dunbar, A. Fransson, G. Kattner, H. Kennedy, D. Lannuzel, D. R. Munro, D. Nomura, J. M. Rintala, V. Schoemann, J. Stefels, N. Steiner and J. L. Tison (2017). Macro-nutrient concentrations in Antarctic pack ice: Overall patterns and overlooked processes. Elementa. 5.

Goetz, K. T., J. M. Burns, L. A. Hückstädt, M. R. Shero and D. P. Costa (2017). Temporal variation in isotopic composition and diet of Weddell seals in the western Ross Sea. Deep-Sea Research Part II: Topical Studies in Oceanography. 140: 36-44.

Holland, M. M., L. Landrum, M. Raphael and S. Stammerjohn (2017). Springtime winds drive Ross Sea ice variability and change in the following autumn. Nature Communications, Springer US. 8.

Jones, R. M. and W. O. Smith (2017). The influence of short-term events on the hydrographic and biological structure of the southwestern Ross Sea. Journal of Marine Systems, Elsevier B.V. 166: 184-195.

Kooyman, G. L. and P. J. Ponganis (2017). Rise and fall of Ross Sea emperor penguin colony populations: 2000 to 2012. Antarctic Science. 29: 207-208.

Kwok, R., S. S. Pang and S. Kacimi (2017). Sea ice drift in the Southern Ocean: Regional patterns, variability, and trends. Elementa. 5.

Li, Y., D. J. McGillicuddy, M. S. Dinniman and J. M. Klinck (2017). Processes influencing formation of low-salinity high-biomass lenses near the edge of the Ross Ice Shelf. Journal of Marine Systems, Elsevier B.V. 166: 108-119.

Mack, S. L., M. S. Dinniman, D. J. McGillicuddy, P. N. Sedwick and J. M. Klinck (2017). Dissolved iron transport pathways in the Ross Sea: Influence of tides and horizontal resolution in a regional ocean model. Journal of Marine Systems, Elsevier B.V. 166: 73-86.

Mosby, A. F. and W. O. Smith (2017). Structural equation modeling of the influence of environmental factors on summer phytoplankton growth in the Ross Sea. Polar Biology. 40: 291-299.

Ryan-Keogh, T. J., L. M. DeLizo, W. O. Smith, P. N. Sedwick, D. J. McGillicuddy, C. M. Moore and T. S. Bibby (2017). Temporal progression of photosynthetic-strategy in phytoplankton in the Ross Sea, Antarctica. Journal of Marine Systems, Elsevier B.V. 166: 87-96.

Salas, L., N. Nur, D. Ainley, J. Burns, J. Rotella and G. Ballard (2017). Coping with the loss of large, energy-dense prey: A potential bottleneck for Weddell Seals in the Ross Sea: A. Ecological Applications. 27: 10-25.

Smith, W. O., L. M. Delizo, C. Herbolsheimer and E. Spencer (2017). Distribution and abundance of mesozooplankton in the Ross Sea, Antarctica. Polar Biology, Springer Berlin Heidelberg. 40: 2351-2361.

Smith, W. O., D. J. McGillicuddy, E. B. Olson, V. Kosnyrev, E. E. Peacock and H. M. Sosik (2017). Mesoscale variability in intact and ghost colonies of Phaeocystis antarctica in the Ross Sea: Distribution and abundance. Journal of Marine Systems, Elsevier B.V. 166: 97-107.

Stuecker, M. F., C. M. Bitz and K. C. Armour (2017). Conditions leading to the unprecedented low Antarctic sea ice extent during the 2016 austral spring season. Geophysical Research Letters. 44: 9008-9019.

Swartz, J. M., B. M. Jones and J. M. Swartz (2017). Mesoscale variability of the summer bloom over the northern Ross Sea shelf: A tale of two banks. Journal of Marine Systems, Elsevier B.V. 166: 50-60.

Szuta, D. (2017). Community Structure and Zonation of Antarctic Benthic Invertebrates : Using a Remotely Operated Vehicle under Ice to Define Biological Patterns.

Tozzi, S. and W. O. Smith (2017). Contrasting Photo-physiological Responses of the Haptophyte <em>Phaeocystis Antarctica</em> and the Diatom <em>Pseudonitzschia</em> sp. in the Ross Sea (Antarctica). AIMS Geosciences. 3: 142-162.

Van Doorslaer, K., V. Ruoppolo, A. Schmidt, A. Lescroël, D. Jongsomjit, M. Elrod, S. Kraberger, D. Stainton, K. M. Dugger, G. Ballard, D. G. Ainley and A. Varsani (2017). Unique genome organization of non-mammalian papillomaviruses provides insights into the evolution of viral early proteins. Virus Evolution. 3: 1-12.

Varsani, A., G. Frankfurter, D. Stainton, M. F. Male, S. Kraberger and J. M. Burns (2017). Identification of a polyomavirus in Weddell seal (Leptonychotes weddellii) from the Ross Sea (Antarctica). Archives of Virology, Springer Vienna. 162: 1403-1407.

Youngflesh, C., S. Jenouvrier, Y. Li, R. Ji, D. G. Ainley, G. Ballard, C. Barbraud, K. Delord, K. M. Dugger, L. M. Emmerson, W. R. Fraser, J. T. Hinke, P. O. B. Lyver, S. Olmastroni, C. J. Southwell, S. G. Trivelpiece, W. Z. Trivelpiece and H. J. Lynch (2017). Circumpolar analysis of the Adélie Penguin reveals the importance of environmental variability in phenological mismatch. Ecology. 98: 940-951.

**2018**

Ainley, D. G., K. M. Dugger, M. L. Mesa, G. Ballard, K. J. Barton, S. Jennings, B. J. Karl, A. Lescroël, P. O. B. Lyver, A. Schmidt and P. Wilson (2018). Post-fledging survival of Adélie penguins at multiple colonies: Chicks raised on fish do well. Marine Ecology Progress Series. 601: 239-251.

Beltran, R. S., J. M. Burns and G. A. Breed (2018). Convergence of biannual moulting strategies across birds and mammals. Proceedings of the Royal Society B: Biological Sciences. 285.

Beltran, R. S., B. Ruscher-Hill, A. L. Kirkham and J. M. Burns (2018). An evaluation of three-dimensional photogrammetric and morphometric techniques for estimating volume and mass in Weddell seals Leptonychotes weddellii. PLoS ONE. 13: 1-15.

Bronselaer, B., M. Winton, S. M. Griffies, W. J. Hurlin, K. B. Rodgers, O. V. Sergienko, R. J. Stouffer and J. L. Russell (2018). Change in future climate due to Antarctic meltwater. Nature. 564: 53-58.

Brooks, C. M., J. A. Caccavo, J. Ashford, R. Dunbar, K. Goetz, M. La Mesa and L. Zane (2018). Early life history connectivity of Antarctic silverfish (Pleuragramma antarctica) in the Ross Sea. Fisheries Oceanography. 27: 274-287.

Cziko, P. 2018. Population dynamics in the Antarctic benthos: Inter-annual fluctuation of foraminiferal, tunicate, and scallop abundances in Explorers Cove, western McMurdo Sound. NOPC Abstracts. 77.

Dayton, P. K. and K. Hammerstrom (2018). A hagfish at Salmon Bay, McMurdo Sound, Antarctica? Antarctic Science. 30: 243-244.

Dayton, P. K., G. A. Robilliard, J. S. Oliver, S. Kim, K. Hammerstrom, K. O'Connor, J. Fisher, J. Barber and S. Jarrell (2018). Long-term persistence of wood on the sea floor at McMurdo Sound, Antarctica. Antarctic Science. 30: 355-356.

DeJong, H. B., R. B. Dunbar and E. A. Lyons (2018). Late Summer Frazil Ice-Associated Algal Blooms around Antarctica. Geophysical Research Letters. 45: 826-833.

Dinniman, M. S., J. M. Klinck, E. E. Hofmann and W. O. Smith (2018). Effects of projected changes in wind, atmospheric temperature, and freshwater inflow on the Ross Sea. Journal of Climate. 31: 1619-1635.

Frazer, E. K., P. J. Langhorne, M. J. M. Williams, K. T. Goetz and D. P. Costa (2018). A method for correcting seal-borne oceanographic data and application to the estimation of regional sea ice thickness. Journal of Marine Systems, Elsevier. 187: 250-259.

Grémillet, D., A. Lescroël, G. Ballard, K. M. Dugger, M. Massaro, E. L. Porzig and D. G. Ainley (2018). Energetic fitness: Field metabolic rates assessed via 3D accelerometry complement conventional fitness metrics. Functional Ecology. 32: 1203-1213.

Grimaldi, W., D. G. Ainley and M. Massaro (2018). Multi-year serological evaluation of three viral agents in the Adélie Penguin (Pygoscelis adeliae) on Ross Island, Antarctica. Polar Biology, Springer Berlin Heidelberg. 41: 2023-2031.

Kaufman, D. E., M. A. M. Friedrichs, J. C. P. Hemmings and W. O. Smith (2018). Assimilating bio-optical glider data during a phytoplankton bloom in the southern Ross Sea. Biogeosciences. 15: 73-90.

Kim, S., B. Saenz, J. Scanniello, K. Daly and D. Ainley (2018). Local climatology of fast ice in McMurdo Sound, Antarctica. Antarctic Science. 30: 125-142.

Kimball, P. W., E. B. Clark, M. Scully, K. Richmond, C. Flesher, L. E. Lindzey, J. Harman, K. Huffstutler, J. Lawrence, S. Lelievre, J. Moor, B. Pease, V. Siegel, L. Winslow, D. D. Blankenship, P. Doran, S. Kim, B. E. Schmidt and W. C. Stone (2018). The ARTEMIS under-ice AUV docking system. Journal of Field Robotics. 35: 299-308.

Kooyman, G. L., R. P. Van Dam and L. A. Hückstädt (2018). Night diving by some emperor penguins during the winter breeding period at Cape Washington. Journal of Experimental Biology. 221: 1-3.

Lawrence, J. D., B. E. S. Pi, M. R. Meister, D. J. G. Dichek, C. D. Ramey, B. Hurwitz, A. M. Spears, A. D. Mullen, F. E. Bryson and J. J. Lutz (2018). Life Under Ice : Antarctic Ocean World Analogs with HROV Ice n & RISE UP: 2-3.

Lenihan, H. S., C. H. Peterson, R. J. Miller, M. Kayal and M. Potoski (2018). Biotic disturbance mitigates effects of multiple stressors in a marine benthic community. Ecosphere. 9.

Moran, A. L., H. A. Woods, C. M. Shishido, S. J. Lane and B. W. Tobalske (2018). Predatory behavior of giant Antarctic sea spiders (Colossendeis) in nearshore environments. Invertebrate Biology. 137: 116-123.

Paterson, J. T., J. J. Rotella, W. A. Link and R. Garrott (2018). Variation in the vital rates of an Antarctic marine predator: the role of individual heterogeneity. Ecology. 99: 2385-2396.

Phan-Tan, L., L. Nguyen-Ngoc, W. O. Smith and H. Doan-Nhu (2018). A new dinoflagellate species, Protoperidinium smithii H. Doan-Nhu, L. Phan-Tan et L. Nguyen-Ngoc sp. nov., and an emended description of Protoperidinium defectum (Balech 1965) Balech 1974 from the Ross Sea, Antarctica. Polar Biology, Springer Berlin Heidelberg. 41: 983-992.

Pitman, R. L., H. Fearnbach and J. W. Durban (2018). Abundance and population status of Ross Sea killer whales (Orcinus orca, type C) in McMurdo Sound, Antarctica: evidence for impact by commercial fishing? Polar Biology, Springer Berlin Heidelberg. 41: 781-792.

Schlosser, E., F. Alexander Haumann and M. N. Raphael (2018). Atmospheric influences on the anomalous 2016 Antarctic sea ice decay. Cryosphere. 12: 1103-1119.

Schwaller, M. R., H. J. Lynch, A. Tarroux and B. Prehn (2018). A continent-wide search for Antarctic petrel breeding sites with satellite remote sensing. Remote Sensing of Environment, Elsevier. 210: 444-451.

Sequeira, A. M. M., J. P. Rodríguez, V. M. Eguíluz, R. Harcourt, M. Hindell, D. W. Sims, C. M. Duarte, D. P. Costa, J. Fernández-Gracia, L. C. Ferreira, G. C. Hays, M. R. Heupel, M. G. Meekan, A. Aven, F. Bailleul, A. M. M. Baylis, M. L. Berumen, C. D. Braun, J. Burns, M. J. Caley, R. Campbell, R. H. Carmichael, E. Clua, L. D. Einoder, A. Friedlaender, M. E. Goebel, S. D. Goldsworthy, C. Guinet, J. Gunn, D. Hamer, N. Hammerschlag, M. Hammill, L. A. Hückstädt, N. E. Humphries, M. A. Lea, A. Lowther, A. Mackay, E. McHuron, J. McKenzie, L. McLeay, C. R. McMahon, K. Mengersen, M. M. C. Muelbert, A. M. Pagano, B. Page, N. Queiroz, P. W. Robinson, S. A. Shaffer, M. Shivji, G. B. Skomal, S. R. Thorrold, S. Villegas-Amtmann, M. Weise, R. Wells, B. Wetherbee, A. Wiebkin, B. Wienecke and M. Thums (2018). Convergence of marine megafauna movement patterns in coastal and open oceans. Proceedings of the National Academy of Sciences of the United States of America. 115: 3072-3077.

Shero, M. R., K. T. Goetz, D. P. Costa and J. M. Burns (2018). Temporal changes in Weddell seal dive behavior over winter: Are females increasing foraging effort to support gestation? Ecology and Evolution. 8: 11857-11874.

Smeele, Z. E., D. G. Ainley and A. Varsani (2018). Viruses associated with Antarctic wildlife: From serology based detection to identification of genomes using high throughput sequencing. Virus Research, Elsevier. 243: 91-105.

Smeele, Z. E., J. M. Burns, K. Van Doorsaler, R. S. Fontenele, K. Waits, D. Stainton, M. R. Shero, R. S. Beltran, A. L. Kirkham, R. Berngartt, S. Kraberger and A. Varsani (2018). Diverse papillomaviruses identified in weddell seals. Journal of General Virology. 99: 549-557.

Walsh, J. E., D. H. Bromwich, J. E. Overland, M. C. Serreze and K. R. Wood (2018). 100 Years of Progress in Polar Meteorology. Meteorological Monographs. 59: 21.21-21.36.

Wing, S. R., J. J. Leichter, L. C. Wing, D. Stokes, S. J. Genovese, R. M. McMullin and O. A. Shatova (2018). Contribution of sea ice microbial production to Antarctic benthic communities is driven by sea ice dynamics and composition of functional guilds. Global Change Biology. 24: 3642-3653.

**2019**

Alderkamp, A. C., G. L. Van Dijken, K. E. Lowry, K. M. Lewis, H. L. Joy-Warren, W. Van De Poll, P. Laan, L. Gerringa, T. O. Delmont, B. D. Jenkins and K. R. Arrigo (2019). Effects of iron and light availability on phytoplankton photosynthetic properties in the Ross Sea. Marine Ecology Progress Series. 621: 33-50.

Asper, V. L. and W. O. Smith (2019). Variations in the abundance and distribution of aggregates in the Ross Sea, Antarctica. Elementa. 7.

Ballard, G., A. E. Schmidt, V. Toniolo, S. Veloz, D. Jongsomjit, K. R. Arrigo and D. G. Ainley (2019). Fine-scale oceanographic features characterizing successful Adélie penguin foraging in the SW Ross Sea. Marine Ecology Progress Series. 608: 263-277.

Bebieva, Y. and K. Speer (2019). The Regulation of Sea Ice Thickness by Double-Diffusive Processes in the Ross Gyre. Journal of Geophysical Research: Oceans. 124: 7068-7081.

Beltran, R. S., A. L. Kirkham, G. A. Breed, J. W. Testa and J. M. Burns (2019). Reproductive success delays moult phenology in a polar mammal. Scientific Reports. 9: 1-12.

Bochdansky, A. B., R. B. Dunbar, D. A. Hansell and G. J. Herndl (2019). Estimating Carbon Flux From Optically Recording Total Particle Volume at Depths Below the Primary Pycnocline. Frontiers in Marine Science. 6: 1-12.

Brault, E. K., P. L. Koch, D. P. Costa, M. D. McCarthy, L. A. Hückstädt, K. T. Goetz, K. W. McMahon, M. E. Goebel, O. Karlsson, J. Teilmann, T. Harkonen and K. C. Harding (2019). Trophic position and foraging ecology of Ross, Weddell, and crabeater seals revealed by compound-specific isotope analysis. Marine Ecology Progress Series. 611: 1-18.

Castagno, P., Capozzi, V., DiTullio, G. R., Falco, P., Fusco, G., Rintoul, S. R., ... & Budillon, G. (2019). Rebound of shelf water salinity in the Ross Sea. Nature communications, 10(1), 1-6.

Cerovečki, I., A. J. S. Meijers, M. R. Mazloff, S. T. Gille, V. M. Tamsitt and P. R. Holland (2019). The effects of enhanced sea ice export from the ross sea on recent cooling and freshening of the southeast pacific. Journal of Climate. 32: 2013-2035.

Dayton, P. K., S. C. Jarrell, S. Kim, P. Ed Parnell, S. F. Thrush, K. Hammerstrom and J. J. Leichter (2019). Benthic responses to an Antarctic regime shift: food particle size and recruitment biology. Ecological Applications. 29: 1-20.

Dayton, P. K., J. S. Oliver, S. F. Thrush and K. Hammerstrom (2019). Bacteria defend carrion from scavengers. Antarctic Science. 31: 13-15.

De Pace, L., M. Smith, J. Thomson, S. Stammerjohn, S. Ackley and B. Loose (2019). Frazil ice growth and production during katabatic wind events in the Ross Sea, Antarctica. The Cryosphere Discussions: 1-43.

Frankfurter, G., R. S. Beltran, M. Hoard and J. M. Burns (2019). Rapid prototyping and 3D printing of antarctic seal flipper tags. Wildlife Society Bulletin. 43: 313-316.

Gerringa, L. J. A., P. Laan, K. R. Arrigo, G. L. van Dijken and A. C. Alderkamp (2019). The organic complexation of iron in the Ross sea. Marine Chemistry, Elsevier. 215: 103672.

Harcourt, R., A. M. M. Sequeira, X. Zhang, F. Roquet, K. Komatsu, M. Heupel, C. McMahon, F. Whoriskey, M. Meekan, G. Carroll, S. Brodie, C. Simpfendorfer, M. Hindell, I. Jonsen, D. P. Costa, B. Block, M. Muelbert, B. Woodward, M. Weise, K. Aarestrup, M. Biuw, L. Boehme, S. J. Bograd, D. Cazau, J. B. Charrassin, S. J. Cooke, P. Cowley, P. J. N. de Bruyn, T. Jeanniard du Dot, C. Duarte, V. M. Eguíluz, L. C. Ferreira, J. Fernández-Gracia, K. Goetz, Y. Goto, C. Guinet, M. Hammill, G. C. Hays, E. L. Hazen, L. A. Hückstädt, C. Huveneers, S. Iverson, S. A. Jaaman, K. Kittiwattanawong, K. M. Kovacs, C. Lydersen, T. Moltmann, M. Naruoka, L. Phillips, B. Picard, N. Queiroz, G. Reverdin, K. Sato, D. W. Sims, E. B. Thorstad, M. Thums, A. M. Treasure, A. W. Trites, G. D. Williams, Y. Yonehara and M. A. Fedak (2019). Animal-borne telemetry: An integral component of the ocean observing toolkit. Frontiers in Marine Science. 6.

Hays, G. C., H. Bailey, S. J. Bograd, W. D. Bowen, C. Campagna, R. H. Carmichael, P. Casale, A. Chiaradia, D. P. Costa, E. Cuevas, P. J. Nico de Bruyn, M. P. Dias, C. M. Duarte, D. C. Dunn, P. H. Dutton, N. Esteban, A. Friedlaender, K. T. Goetz, B. J. Godley, P. N. Halpin, M. Hamann, N. Hammerschlag, R. Harcourt, A. L. Harrison, E. L. Hazen, M. R. Heupel, E. Hoyt, N. E. Humphries, C. Y. Kot, J. S. E. Lea, H. Marsh, S. M. Maxwell, C. R. McMahon, G. Notarbartolo di Sciara, D. M. Palacios, R. A. Phillips, D. Righton, G. Schofield, J. A. Seminoff, C. A. Simpfendorfer, D. W. Sims, A. Takahashi, M. J. Tetley, M. Thums, P. N. Trathan, S. Villegas-Amtmann, R. S. Wells, S. D. Whiting, N. E. Wildermann and A. M. M. Sequeira (2019). Translating Marine Animal Tracking Data into Conservation Policy and Management. Trends in Ecology and Evolution. 34: 459-473.

Holsman, K. K., E. L. Hazen, A. Haynie, S. Gourguet, A. Hollowed, S. J. Bograd, J. F. Samhouri, K. Aydin and E. Anderson (2019). Towards climate resiliency in fisheries management. ICES Journal of Marine Science. 76: 1368-1378.

Kim, S. (2019). Complex life under the McMurdo Ice Shelf, and some speculations on food webs. Antarctic Science. 31: 80-88.

Kim, S., K. Hammerstrom and P. Dayton (2019). Epifaunal community response to iceberg-mediated environmental change in mcmurdo sound, antarctica. Marine Ecology Progress Series. 613: 1-14.

Larue, M., D. Iles, S. Labrousse, L. Salas, G. Ballard, D. Ainley and B. Saenz (2019). A possible Adélie penguin sub-colony on fast ice by Cape Crozier, Antarctica. Antarctic Science. 31: 189-194.

LaRue, M. A., L. Salas, N. Nur, D. G. Ainley, S. Stammerjohn, L. Barrington, K. Stamatiou, J. Pennycook, M. Dozier, J. Saints and H. Nakamura (2019). Physical and ecological factors explain the distribution of Ross Sea Weddell seals during the breeding season. Marine Ecology Progress Series. 612: 193-208.

Lescroël, A., G. Ballard, M. Massaro, K. Dugger, S. Jennings, A. Pollard, E. Porzig, A. Schmidt, A. Varsani, D. Grémillet and D. Ainley (2019). Evidence of age-related improvement in the foraging efficiency of Adélie penguins. Scientific Reports. 9: 1-13.

Mack, S. L., M. S. Dinniman, J. M. Klinck, D. J. McGillicuddy and L. Padman (2019). Modeling Ocean Eddies on Antarctica's Cold Water Continental Shelves and Their Effects on Ice Shelf Basal Melting. Journal of Geophysical Research: Oceans. 124: 5067-5084.

Morandini, V., K. M. Dugger, G. Ballard, M. Elrod, A. Schmidt, V. Ruoppolo, A. Lescroël, D. Jongsomjit, M. Massaro, J. Pennycook, G. L. Kooyman, K. Schmidlin, S. Kraberger, D. G. Ainley and A. Varsani (2019). Identification of a novel adélie penguin circovirus at cape crozier (Ross Island, Antarctica). Viruses. 11: 1-10.

Parker, S. J., S. Mormede, S. M. Hanchet, A. Devries, S. Canese and L. Ghigliotti (2019). Monitoring antarctic toothfish in mcmurdo sound to evaluate the Ross Sea region marine protected area. Antarctic Science. 31: 195-207.

Parkinson, C. L. (2019). A 40-y record reveals gradual Antarctic sea ice increases followed by decreases at rates far exceeding the rates seen in the Arctic. Proceedings of the National Academy of Sciences of the United States of America. 116: 14414-14423.

Piñones, A., E. E. Hofmann, D. P. Costa, K. Goetz, J. M. Burns, F. Roquet, M. S. Dinniman and J. M. Klinck (2019). Hydrographic variability along the inner and mid-shelf region of the western Ross Sea obtained using instrumented seals. Progress in Oceanography, Elsevier. 174: 131-142.

Porter, D. F., S. R. Springer, L. Padman, H. A. Fricker, K. J. Tinto, S. C. Riser and R. E. Bell (2019). Evolution of the Seasonal Surface Mixed Layer of the Ross Sea, Antarctica, Observed With Autonomous Profiling Floats. Journal of Geophysical Research: Oceans. 124: 4934-4953.

Raphael, M. N., M. M. Holland, L. Landrum and W. R. Hobbs (2019). Links between the Amundsen Sea Low and sea ice in the Ross Sea: seasonal and interannual relationships. Climate Dynamics, Springer Berlin Heidelberg. 52: 2333-2349.

Roach, C. J. and K. Speer (2019). Exchange of Water Between the Ross Gyre and ACC Assessed by Lagrangian Particle Tracking. Journal of Geophysical Research: Oceans. 124: 4631-4643.

**2020**

Ackley, S. F., S. Stammerjohn, T. Maksym, M. Smith, J. Cassano, P. Guest, J. L. Tison, B. Delille, B. Loose, P. Sedwick, L. Depace, L. Roach and J. Parno (2020). Sea-ice production and air/ice/ocean/biogeochemistry interactions in the Ross Sea during the PIPERS 2017 autumn field campaign. Annals of Glaciology. 61: 181-195.

Ainley, D. G., T. W. Joyce, B. Saenz, R. L. Pitman, J. W. Durban, G. Ballard, K. Daly and S. Kim (2020). Foraging patterns of Antarctic minke whales in McMurdo Sound, Ross Sea. Antarctic Science. 32: 454-465.

Björdal, C. G. and P. K. Dayton (2020). First evidence of microbial wood degradation in the coastal waters of the Antarctic. Scientific Reports, Nature Publishing Group UK. 10: 1-8.

Brusa, J. L., J. J. Rotella, R. A. Garrott, J. T. Paterson and W. A. Link (2020). Variation of annual apparent survival and detection rates with age, year and individual identity in male Weddell seals (Leptonychotes weddellii) from long-term mark-recapture data. Population Ecology. 62: 134-150.

Cziko, P. A., L. M. Munger, N. R. Santos and J. M. Terhune (2020). Weddell seals produce ultrasonic vocalizations. The Journal of the Acoustical Society of America, Acoustical Society of America. 148: 3784-3796.

Dinniman, M. S., P. St-Laurent, K. R. Arrigo, E. E. Hofmann and G. L. van Dijken (2020). Analysis of Iron Sources in Antarctic Continental Shelf Waters. Journal of Geophysical Research: Oceans. 125: 1-19.

Eastman, J. T. (2020). The buoyancy-based biotope axis of the evolutionary radiation of Antarctic cryonotothenioid fishes. Polar Biology, Springer Berlin Heidelberg. 43: 1217-1231.

Emslie, S. D. (2020). Ancient AdéLie Penguin Colony Revealed by Snowmelt at Cape Irizar, Ross Sea, Antarctica. Geology. 49: 145-149.

Gerringa, L. J. A., A. C. Alderkamp, G. van Dijken, P. Laan, R. Middag and K. R. Arrigo (2020). Dissolved Trace Metals in the Ross Sea. Frontiers in Marine Science. 7.

Hindell, M. A., R. R. Reisinger, Y. Ropert-Coudert, L. A. Hückstädt, P. N. Trathan, H. Bornemann, J. B. Charrassin, S. L. Chown, D. P. Costa, B. Danis, M. A. Lea, D. Thompson, L. G. Torres, A. P. Van de Putte, R. Alderman, V. Andrews-Goff, B. Arthur, G. Ballard, J. Bengtson, M. N. Bester, A. S. Blix, L. Boehme, C. A. Bost, P. Boveng, J. Cleeland, R. Constantine, S. Corney, R. J. M. Crawford, L. Dalla Rosa, P. J. N. de Bruyn, K. Delord, S. Descamps, M. Double, L. Emmerson, M. Fedak, A. Friedlaender, N. Gales, M. E. Goebel, K. T. Goetz, C. Guinet, S. D. Goldsworthy, R. Harcourt, J. T. Hinke, K. Jerosch, A. Kato, K. R. Kerry, R. Kirkwood, G. L. Kooyman, K. M. Kovacs, K. Lawton, A. D. Lowther, C. Lydersen, P. O. B. Lyver, A. B. Makhado, M. E. I. Márquez, B. I. McDonald, C. R. McMahon, M. Muelbert, D. Nachtsheim, K. W. Nicholls, E. S. Nordøy, S. Olmastroni, R. A. Phillips, P. Pistorius, J. Plötz, K. Pütz, N. Ratcliffe, P. G. Ryan, M. Santos, C. Southwell, I. Staniland, A. Takahashi, A. Tarroux, W. Trivelpiece, E. Wakefield, H. Weimerskirch, B. Wienecke, J. C. Xavier, S. Wotherspoon, I. D. Jonsen and B. Raymond (2020). Tracking of marine predators to protect Southern Ocean ecosystems. Nature, Springer US. 580: 87-92.

Kooyman, G. L., K. Goetz, C. L. Williams, P. J. Ponganis, K. Sato, S. Eckert, M. Horning, P. T. Thorson and R. P. Van Dam (2020). Crary bank: a deep foraging habitat for emperor penguins in the western Ross Sea. Polar Biology, Springer Berlin Heidelberg. 43: 801-811.

LaRue, M. A., D. G. Ainley, J. Pennycook, K. Stamatiou, L. Salas, N. Nur, S. Stammerjohn and L. Barrington (2020). Engaging 'the crowd' in remote sensing to learn about habitat affinity of the Weddell seal in Antarctica. Remote Sensing in Ecology and Conservation. 6: 70-78.

Lauriano, G., E. Pirotta, T. Joyce, R. L. Pitman, A. Borrell and S. Panigada (2020). Movements, diving behaviour and diet of type-C killer whales (Orcinus orca) in the Ross Sea, Antarctica. Aquatic Conservation: Marine and Freshwater Ecosystems. 30: 2428-2440.

Lescroël, A., P. O. B. Lyver, D. Jongsomjit, S. Veloz, K. M. Dugger, P. Kappes, B. J. Karl, A. L. Whitehead, R. Pech, T. L. Cole and G. Ballard (2020). Inter-individual differences in the foraging behavior of breeding Adélie penguins are driven by individual quality and sex. Marine Ecology Progress Series. 636: 189-205.

Macdonald, K. R., J. J. Rotella, R. A. Garrott and W. A. Link (2020). Sources of variation in maternal allocation in a long-lived mammal. Journal of Animal Ecology. 89: 1927-1940.

Massaro, M., D. G. Ainley, J. A. Santora, P. Quillfeldt, A. Lescroël, A. Whitehead, A. Varsani, G. Ballard and P. O. B. Lyver (2020). Diet segregation in Adélie penguins: Some individuals attempt to overcome colony-induced and annual foraging challenges. Marine Ecology Progress Series. 645: 205-218.

Morley, S. A., D. Abele, D. K. A. Barnes, C. A. Cárdenas, C. Cotté, J. Gutt, S. F. Henley, J. Höfer, K. A. Hughes, S. M. Martin, C. Moffat, M. Raphael, S. E. Stammerjohn, C. C. Suckling, V. J. D. Tulloch, C. L. Waller and A. J. Constable (2020). Global Drivers on Southern Ocean Ecosystems: Changing Physical Environments and Anthropogenic Pressures in an Earth System. Frontiers in Marine Science. 7: 1-24.

Pitman, R. L., J. W. Durban, T. Joyce, H. Fearnbach, S. Panigada and G. Lauriano (2020). Skin in the game: Epidermal molt as a driver of long-distance migration in whales. Marine Mammal Science. 36: 565-594.

Saenz, B. T., D. G. Ainley, K. L. Daly, G. Ballard, E. Conlisk, M. L. Elrod and S. L. Kim (2020). Drivers of concentrated predation in an Antarctic marginal-ice-zone food web. Scientific Reports. 10: 1-17.

Salmon, E., E. E. Hofmann, M. S. Dinniman and W. O. Smith (2020). Evaluation of iron sources in the Ross Sea. Journal of Marine Systems, Elsevier. 212: 103429.

Santora, J. A., M. A. LaRue and D. G. Ainley (2020). Geographic structuring of Antarctic penguin populations. Global Ecology and Biogeography. 29: 1716-1728.

Schmidt, A. E. and G. Ballard (2020). Significant chick loss after early fast ice breakup at a high-latitude emperor penguin colony. Antarctic Science. 32: 180-185.

Shah, K., G. Ballard, A. Schmidt and M. Schwager (2020). Multidrone aerial surveys of penguin colonies in Antarctica. Science Robotics. 5: 1-12.

Silvano, A., A. Foppert, S. R. Rintoul, P. R. Holland, T. Tamura, N. Kimura, P. Castagno, P. Falco, G. Budillon, F. A. Haumann, A. C. Naveira Garabato and A. M. Macdonald (2020). Recent recovery of Antarctic Bottom Water formation in the Ross Sea driven by climate anomalies. Nature Geoscience, Springer US. 13: 780-786.

Thurber, A. R., S. Seabrook and R. M. Welsh (2020). Riddles in the cold: Antarctic endemism and microbial succession impact methane cycling in the Southern Ocean: Microbial Succession and Methane. Proceedings of the Royal Society B: Biological Sciences. 287: 1-9.

Tison, J. L., T. Maksym, A. D. Fraser, M. Corkill, N. Kimura, Y. Nosaka, D. Nomura, M. Vancoppenolle, S. Ackley, S. Stammerjohn, S. Wauthy, F. Van Der Linden, G. Carnat, C. a. l. Sapart, J. De Jong, F. c. o. Fripiat and B. Delille (2020). Physical and biological properties of early winter Antarctic sea ice in the Ross Sea. Annals of Glaciology. 61: 241-259.

Trathan, P. N., B. Wienecke, C. Barbraud, S. Jenouvrier, G. Kooyman, C. Le Bohec, D. G. Ainley, A. Ancel, D. P. Zitterbart, S. L. Chown, M. LaRue, R. Cristofari, J. Younger, G. Clucas, C. A. Bost, J. A. Brown, H. J. Gillett and P. T. Fretwell (2020). The emperor penguin - Vulnerable to projected rates of warming and sea ice loss. Biological Conservation, Elsevier. 241: 108216.

Walcott, S. M., A. L. Kirkham and J. M. Burns (2020). Thermoregulatory costs in molting Antarctic Weddell seals: Impacts of physiological and environmental conditions. Conservation Physiology. 8: 1-14.

Wellard, R., R. L. Pitman, J. Durban and C. Erbe (2020). Cold call: The acoustic repertoire of Ross Sea killer whales (Orcinus orca, Type C) in McMurdo Sound, Antarctica. Royal Society Open Science. 7.

Wenta, M. and J. J. Cassano (2020). The atmospheric boundary layer and surface conditions during katabatic wind events over the Terra Nova bay Polynya. Remote Sensing. 12: 1-32.

**2021**

Ainley, D. G., P. A. Cziko, N. Nur, J. J. Rotella, J. T. Eastman, M. Larue, I. Stirling and P. A. Abrams (2021). Further evidence that Antarctic toothfish are important to Weddell seals. Antarctic Science. 33: 17-29.

Beltran, R. S., A. M. Kilpatrick, G. A. Breed, T. Adachi, A. Takahashi, Y. Naito, P. W. Robinson, W. O. Smith, A. L. Kirkham and J. M. Burns (2021). Seasonal resource pulses and the foraging depth of a Southern Ocean top predator. Proceedings of the Royal Society B: Biological Sciences. 288.

Bowen, M. M., D. Fernandez, A. Forcen-Vazquez, A. L. Gordon, B. Huber, P. Castagno and P. Falco (2021). "The role of tides in bottom water export from the western Ross Sea." Sci Rep 11(1): 2246.

Brasier, M. J., D. Barnes, N. Bax, A. Brandt, A. B. Christianson, A. J. Constable, R. Downey, B. Figuerola, H. Griffiths, J. Gutt, S. Lockhart, S. A. Morley, A. L. Post, A. Van de Putte, H. Saeedi, J. S. Stark, M. Sumner and C. L. Waller (2021). "Responses of Southern Ocean Seafloor Habitats and Communities to Global and Local Drivers of Change." Frontiers in Marine Science 8.

Caccavo, J. A., H. Christiansen, A. J. Constable, L. Ghigliotti, R. Trebilco, C. M. Brooks, C. Cotte, T. Desvignes, T. Dornan, C. D. Jones, P. Koubbi, R. A. Saunders, A. Strobel, M. Vacchi, A. P. van de Putte, A. Walters, C. M. Waluda, B. L. Woods and J. C. Xavier (2021). "Productivity and Change in Fish and Squid in the Southern Ocean." Frontiers in Ecology and Evolution 9.

Castellan, G., L. Angeletti, S. Canese, C. Mazzoli, P. Montagna, S. Schiaparelli and M. Taviani (2021). "Visual Imaging of Benthic Carbonate-Mixed Factories in the Ross Sea Region Marine Protected Area, Antarctica." Minerals 11(8).

Chakrabarty, P., U. R. Desai, C. Peck, C. Mah, R. Singer, R. Downey, E. Rodriguez and P. Bart (2021). "Preliminary checklist of the undersea fauna of the Ross Sea Antarctic continental shelf based on yo-yo camera surveys." Museum of Zoology, University of Michigan 209(2): 1-11.

Chen, S., W. O. Smith and X. Yu (2021). "Revisiting the Ocean Color Algorithms for Particulate Organic Carbon and Chlorophyll-a Concentrations in the Ross Sea." Journal of Geophysical Research: Oceans 126(8).

Cronin, K. E., S. E. Walker and S. S. Bowser (2021). Striae in the Antarctic scallop Adamussium colbecki provide environmental insights but not reliable age increments. Polar Biology, Springer Berlin Heidelberg. 44: 729-738.

D'Sa, E. J., H.-C. Kim, S.-Y. Ha and I. Joshi (2021). "Ross Sea Dissolved Organic Matter Optical Properties During an Austral Summer: Biophysical Influences." Frontiers in Marine Science 8.

Fraser, A. D., R. A. Massom, M. S. Handcock, P. Reid, K. I. Ohshima, M. N. Raphael, J. Cartwright, A. R. Klekociuk, Z. Wang and R. Porter-Smith (2021). "Eighteen-year record of circum-Antarctic landfast-sea-ice distribution allows detailed baseline characterisation and reveals trends and variability." The Cryosphere 15: 5061-5077.

Harcourt, R., M. A. Hindell, C. R. McMahon, K. T. Goetz, J.-B. Charrassin, K. Heerah, R. Holser, I. D. Jonsen, M. R. Shero, X. Hoenner, R. Foster, B. Lenting, E. Tarszisz and M. H. Pinkerton (2021). "Regional Variation in Winter Foraging Strategies by Weddell Seals in Eastern Antarctica and the Ross Sea." Frontiers in Marine Science 8.

Kappes, P. J., K. M. Dugger, A. Lescroël, D. G. Ainley, G. Ballard, K. J. Barton, P. O. B. Lyver and P. R. Wilson (2021). Age-related reproductive performance of the Adélie penguin, a long-lived seabird exhibiting similar outcomes regardless of individual life-history strategy. Journal of Animal Ecology. 90: 931-942.

Kim, S. and C. A. Collins (2021). Iceberg disturbance to benthic communities in McMurdo Sound, Antarctica. Polar Record. 57: 1-14.

Koo, Y., H. Xie, N. T. Kurtz, S. F. Ackley and A. M. Mestas-Nuñez (2021). "Weekly Mapping of Sea Ice Freeboard in the Ross Sea from ICESat-2." Remote Sensing 13(16).

Kooyman, G. L., B. I. McDonald, C. L. Williams, J. U. Meir and P. J. Ponganis (2021). The aerobic dive limit: After 40 years, still rarely measured but commonly used. Comparative Biochemistry and Physiology -Part A : Molecular and Integrative Physiology, Elsevier Inc. 252: 110841.

Moser, D. E., S. Jackson, H. A. Kjær, B. Markle, E. Ngoumtsa, J. B. Pedro, D. Segato, A. Spolaor, D. Tetzner, P. Vallelonga and E. R. Thomas (2021). "An Age Scale for the First Shallow (Sub-)Antarctic Ice Core from Young Island, Northwest Ross Sea." Geosciences 11(9).

Oldham, V. E., R. Chmiel, C. M. Hansel, G. R. DiTullio, D. Rao and M. Saito (2021). "Inhibited Manganese Oxide Formation Hinders Cobalt Scavenging in the Ross Sea." Global Biogeochemical Cycles 35(5).

Palmer, T. A., A. G. Klein, S. T. Sweet, P. A. Montagna, L. J. Hyde, J. Sericano, T. L. Wade, M. C. Kennicutt and J. Beseres Pollack (2021). Long-term changes in contamination and macrobenthic communities adjacent to McMurdo Station, Antarctica. Science of the Total Environment, Elsevier B.V. 764: 142798.

Ryan-Keogh, T. J. and W. O. Smith (2021). Temporal patterns of iron limitation in the Ross Sea as determined from chlorophyll fluorescence. Journal of Marine Systems, Elsevier B.V. 215: 103500.

Schine, C. M. S., A. C. Alderkamp, G. van Dijken, L. J. A. Gerringa, S. Sergi, P. Laan, H. van Haren, W. H. van de Poll and K. R. Arrigo (2021). Massive Southern Ocean phytoplankton bloom fed by iron of possible hydrothermal origin. Nature Communications, Springer US. 12: 1-11.

Smith Jr, W. O. (2021). "Primary productivity measurements in the Ross Sea, Antarctica: A regional synthesis." ESSD.

Xi, Y., A. Mercier, C. Kuang, J. Yun, A. Christy, L. Melo, M. T. Maldonado, J. A. Raymond and A. K. Bertram (2021). "Concentrations and properties of ice nucleating substances in exudates from Antarctic sea-ice diatoms." Environ Sci Process Impacts 23(2): 323-334.

Yun, S., W. S. Lee, R. P. Dziak, L. Roche, H. Matsumoto, T.-K. Lau, A. Sremba, D. K. Mellinger, J. H. Haxel, S.-G. Kang, J. K. Hong and Y. Park (2021). "Quantifying Soundscapes in the Ross Sea, Antarctica Using Long-Term Autonomous Hydroacoustic Monitoring Systems." Frontiers in Marine Science 8.

Zou, X., D. H. Bromwich, A. Montenegro, S. H. Wang and L. Bai (2021). "Major surface melting over the Ross Ice Shelf part II: Surface energy balance." Quarterly Journal of the Royal Meteorological Society 147(738): 2895-2916.