In search of solutions for international conservation: Analyzing the governance complexities of managing marine resources in areas beyond national jurisdiction

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A dissertation submitted to the Faculty of the Graduate School of the

University of Colorado Boulder in partial fulfillment

of the requirement for the degree of

Doctor of Philosophy Department of

Environmental Studies

2024

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Abstract

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Dissertation directed by Dr. Cassandra Brooks

The governance of marine resources across the high seas (the ocean that lies beyond the 200 nautical mile jurisdictional limit of any one country) are governed by an amalgam of cooperative regulatory arrangements, ranging from international conventions that dictate the law of the seas to regional bodies with mandates to regulate shipping, mining, and fishing. Under this fragmented framework, the management of marine systems across international scales has largely failed at achieving their conservation goals. Regional fishery management organizations (RFMOs) have been predominantly ineffective at conserving fish stocks, and even lauded regional bodies such as the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) have been slow at achieving their conservation mandates.

Despite covering two-thirds of the ocean and encompassing many global biodiversity hotspots, ABNJ remain largely unprotected. International management organizations, tasked with ensuring the sustainable management of species and ecosystems in ABNJ, have been criticized for their inability to achieve conservation objectives. Challenges include a lack of coordination, failure to mitigate conflicts, and insufficient action to address cumulative impacts such as overfishing, bycatch, climate change adaptation, and the sustainable management of shared fish stocks. As it stands, the high seas are governed by 41 regional fishery bodies, each with their own conservation remits and governance limitations. Among these bodies, CCAMLR has been recognized as a pioneer in high seas governance, notable for its ecosystem-based approach to fisheries

management and stringent conservation principles. This dissertation examines the governance complexities involved in managing marine resources in ABNJ, highlighting progress, gaps, and opportunities for improvement. It presents three case studies that analyze different management frameworks, from national to international levels, addressing marine conservation and fisheries management in each context.

Chapter I provides a comprehensive analysis of the tools needed to manage Southern Ocean fisheries for climate resilience and assesses CCAMLR's progress toward managing for climate change. Unlike CCAMLR's comprehensive management of fisheries and ecosystems, the vast majority of the high seas lack a regional seas Convention or Agreement. Chapter II maps out potential policy pathways for the legal protection of one of such high seas areas lacking a regional seas convention, the Salas y Gomez and Nazca Ridges, a key biodiversity hotspot in the Southeast Pacific. Distant water fisheries remain as the primary threat to high seas ecosystems globally, with government subsidies playing a crucial role in their profitability, range, and duration at sea. Chapter III examines the role of government subsidies as funding mechanisms for Southern Ocean fisheries and provides an in-depth analysis of the complex operations that underlie these fisheries. Collectively, these three chapters highlight the current threats to high seas biodiversity, the available conservation opportunities, and the necessary governance tools needed to improve the management of marine resources in ABNJ. While conservation efforts are being addressed at national, regional, and international levels, continued cooperation to tackle the polycentric and fragmented management of marine resources in ABNJ will be crucial for the sustainable management of our ocean.

Dedication

This PhD would not have been possible without the unwavering support of my parents, Alonso and Lorena. I dedicate this work to both of them. Thank you for always supporting my passions and instilling in me a deep drive to continually learn and seek new perspectives. This PhD is as much yours as it is mine.

To my wife, Talia, you are my rock and constant source of strength. Thank you for always supporting me, no matter the time or day. Your advice and guidance were essential to shaping every chapter of this PhD.

To my late grandfather, Juan Chavez-Molina. You have been my guiding star and a beacon of inspiration. Thank you for instilling in me the importance of always fighting for the truth, believing in yourself, and advocating for what is right. Your influence has been invaluable throughout this PhD journey.

Acknowledgements

The idea of getting a PhD never crossed my mind. This was until I met Dr. Cassandra Brooks. You are an inspiration to everyone fortunate enough to know you, and I am profoundly grateful for your belief in me and for welcoming me into your research group. These past 3 years have flown by, but I guess time flies when you are having fun. They say PhDs are challenging, time consuming and exhausting, but your passion for your work is infectious, making working for you the easiest job ever. This journey has been immensely enjoyable, thanks largely to your guidance and unwavering support. When people ask me if they should pursue a PhD, I always stress the importance of finding a great advisor like you. Thank you, Cass, for being that person for me. I will deeply miss working with you.

To my committee members, Daniel, Max, Steve and Bryan, thank you so much for your support throughout this process. I have learned so much from each of you. From our in person meetings to impromptu zoom calls, I really appreciated how much time you dedicated to my research. The content of this PhD dissertation and our published papers was a team effort, and I could not have achieved that without each and every one of you.

To the amazing members of the Brooks Lab. Our weekly meetings were always something I looked forward to. Working alongside you was a treat. Learning from your research and collaborating with several of you was an integral part of my PhD trajectory. Always feel free to reach out and I hope we can cross paths again.

Thank you to the PEW Charitable Trusts for providing funding for my research for the past 3 years. Your financial support was essential for the success of my dissertation.

Thank you to the Environmental Studies Department for your support throughout these years. Your grants and financial assistance were invaluable, enabling me to attend conferences both within the United States and internationally.

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List of acronyms used throughout the dissertation

Acronym	Meaning
ABNJ	Areas Beyond National Jurisdiction
APEI	Areas of Particular Environmental Interest
ATS	Antarctic Treaty System
BBNJ	Biodiversity Beyond National Jurisdiction
CBD	Convention on Biological Diversity
CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
CPPS	Permanent Commission on the South Pacific
EBSA	Ecologically and Biologically Significant Areas
FAO	Food and Agriculture Organization
IMO	International Maritime Organization
ISA	International Seabed Authority
MPA	Marine Protected Areas
PSSA	Particularly Sensitive Sea Areas
SPRFMO	South Pacific Regional Fishery Management Organization
UNFSA	United Nations Fish Stock Agreement
UNCLOS	United Nation Convention on the Law of the Sea
VME	Vulnerable Marine Ecosystems

Introduction to the Dissertation

In search of solutions for international conservation: Analyzing the governance complexities of managing marine resources in areas beyond national jurisdiction

Vasco Chavez-Molina

Introduction to the Dissertation

The waters and seabed in areas beyond national jurisdiction (ABNJ), commonly known as the high seas, cover nearly 64% of the ocean surface (Figure 1.1) and represent one of the Earth's last frontiers for research management and conservation (Ban et al., 2014). ABNJ contain 90% of the available habitat for life in our ocean (Heffernan, 2018) and comprise most of the Earth's interconnected oceans, hosting complex ecosystems that play vital roles in sustaining life and providing goods and services (Gjerde et al., 2016). Biological diversity found within ABNJ is mostly unprotected, with mounting pressure from human activities (Gjerde et al., 2016; Yadav & Gjerde et al., 2020). The most pressing threats to species and ecosystems in ABNJ include pollution, shipping and trade, seabed mining, climate change, and industrial fishing (Carmine et al., 2020; Wagner et al., 2021).

Figure 1.1 Map of the high seas. Exclusive economic zones (EEZs) are shown in white and the areas beyond national jurisdiction (ABNJ) are shown in light green.

While industrial fishing remains the primary threat to high seas ecosystems, the direct and indirect effects of climate change on fish and wildlife populations is dramatically altering marine systems

as well as the livelihoods and food security they provide (Brander, 2010; Cheung et al., 2018; Miller et al., 2018). While very poorly studied throughout the high seas, climate change is impacting high seas ecosystems in a variety of ways, including increases in sea temperature, acidification, loss of oxygen, and changes in ocean currents; this in turn has caused shifts of species distributions, biodiversity declines, and loss of ecosystem integrity and function (Bijma et al., 2013; Frazao Santos et al., 2020; IPBES, 2019; Meredith et al., 2019; Reid et al., 2010). As warming continues, these shifts will become more common as species change their distribution patterns seeking an environment that suits their optimal thermal niche (McBride et al., 2021; Erauskin-Extramiana et al., 2019; Hobday et al., 2015).

Across the world's oceans, the Southern Ocean is among the fastest changing environments and among the most impacted by climate change (IPCC, 2021; Murphy et al., 2021). This region, which accounts for ~10% of the global ocean (Figure 1.2), is governed by an institution seen as a leader in marine resource management (Brooks et al., 2022). The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) mandates rational use and precautionary, science-based ecosystem management. This sets CCAMLR apart from regional fishery management organizations (RFMOs) and presents them with an urgent need and opportunity to manage for climate change impacts across Southern Ocean ecosystems.

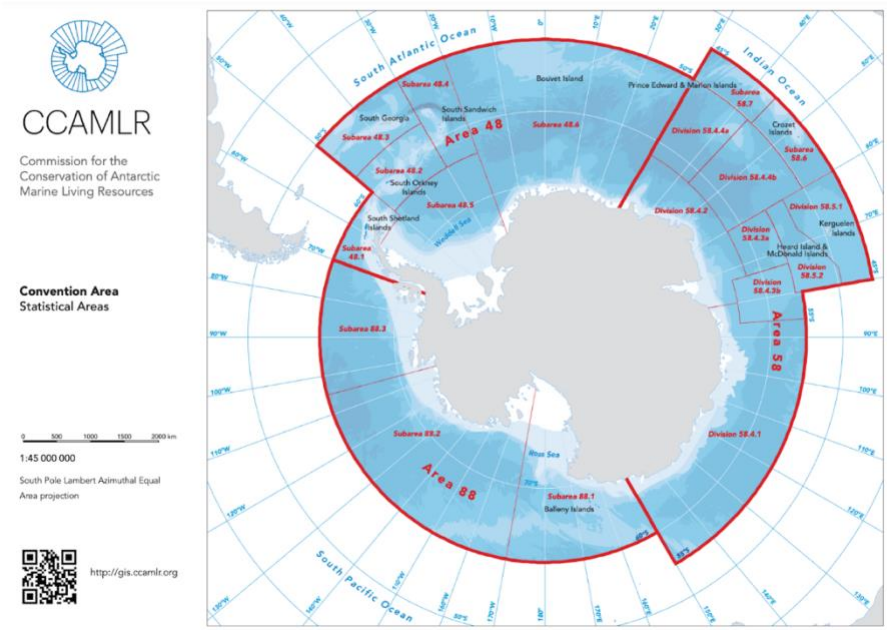

Figure 1.2. CCAMLR Convention area. The Southern Ocean is managed by 26 member States plus the European Union.

Established in 1982, CCAMLR's objective is to carry forward the provisions of the Convention on the Conservation of Marine Living Resources (CAMLR Convention). CCAMLR currently has 26 Member States plus the European Union, and all substantive decisions require consensus. While CCAMLR has legally binding mandates for conserving Antarctic species and ecosystems, the Convention also allows for rational use. Rational use allows for commercial fishing but demands it be in accordance with the strict conservation principles outlined in Article II (e.g., the mandate to minimize the risks of environmental changes in marine systems). CCAMLR's founding articles also contain language that allows for the designation of marine protected areas (MPAs), and CCAMLR has committed to implementing an ecologically representative network of Southern Ocean MPAs (Brooks et al., 2020). CCAMLR's conservation mandate, along with the pressing climate change threats faced by Southern Ocean ecosystems, make this an insightful case study for understanding how a management body might manage for climate resiliency (Chapter I).

Without the governance structure of a regional seas Convention with an ecosystem mandate, conservation across most ABNJ rests with various sectoral bodies that were primarily set up to manage large-scale industries like fishing, shipping, and mining (Chavez-Molina et al., 2023b, Wagner et al., 2021). These organizations are often characterized by narrow remits and governance gaps, making it difficult to effectively conserve high seas ecosystems. Historically, there has been little coordination between RFMOs and other sectoral bodies operating in ABNJ (Yadav & Gjerde, 2020), despite the overlapping issues affecting their mandates, particularly in terms of impacts to biodiversity. RFMOs have been criticized for failing to achieve their conservation objectives, with few attempts to coordinate activities, mitigate conflicts, and address cumulative impacts, such as overfishing, bycatch, and climate change adaptation (Ban et al., 2014; Haas et al., 2021; Kim, 2019; Pentz & Klenk, 2017; Peterson & Stoett, 2022). This fragmented governance which lacks harmonization among global and regional actors (De Santo et al., 2018), coupled with limited coordination, emphasizes the current challenges of managing marine ecosystems in ABNJ (O'Leary et al., 2020). Protecting them is even more difficult.

One ecosystem in ABNJ that has been increasingly recognized as a critical area in need of protection is the Salas y Gomez and Nazca Ridges in the Southeast Pacific (Wagner et al., 2021). These two adjacent seamount chains have the highest known level of marine endemism on Earth, and recent studies on this region show that protecting this ecosystem could have major benefits for ecosystem connectivity, climate regulation, food security, and ecosystem services for neighboring States like Peru and Chile, but also globally (Chavez-Molina et al., 2023b; Gaymer et al., 2022; Wagner et al., 2021). Across this ecosystem, fishery resources are managed by the South Pacific Regional Fisheries Management Organization (SPRFMO) and the Inter-American Tropical Tuna

Commission (IATTC). Additionally, the International Maritime Organization (IMO) manages shipping, and the International Seabed Authority (ISA) manages seabed mining (Figure 1.3).

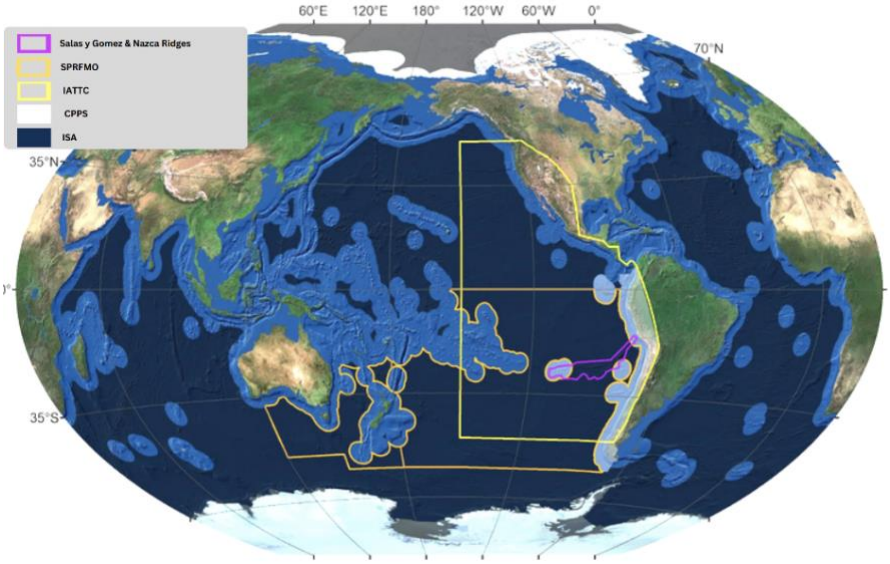

Figure 1.3 *International management organizations operating within the boundaries of the Salas y Gomez and Nazca Ridges (highlighted in purple). The South Pacific Regional Fisheries Management Organization (SPRFMO) is highlighted in orange. The Inter-American Tropical Tuna Commission (IATTC) is highlighted in yellow. The Permanent Commission for the South Pacific (CPPS) is highlighted in white. The International Seabed Authority (ISA) is the darker blue background that extends across all the ABNJ in the world's oceans. The International Maritime Organization (IMO) is not included in the figure because it applies to the whole ocean.*

Unlike CCAMLR, none of these international organizations have the ability to designate MPAs that apply to all sectors. To overcome these fragmentation challenges, in 2015 the UNGA agreed to develop a legally binding instrument under the United Nations Convention on the Law of the Sea (UNCLOS) on the conservation and sustainable use of marine biological diversity in ABNJ, also known as the Biodiversity Beyond National Jurisdiction (BBNJ) Agreement (UNGA, 2015; United Nations, 2022a). While the BBNJ Agreement may provide one avenue for the protection of ecosystems in ABNJ in the future, uncertainties about when the agreement will be adopted and ratified by 60 parties to the Convention, warrants the implementation of best available conservation measures more urgently (Friedlander et al., 2021). Even with the BBNJ Agreement

in place, protection of the Salas y Gomez and Nazca Ridges - as well as the vast majority of other high seas areas - rests on several bodies taking action. The bureaucratic process of developing international treaties is time consuming and slow, whereas identifying current best available conservation measures can have immediate benefits for ocean ecosystems (Chapter II).

The management of marine resources in ABNJ is dictated by the unique governance frameworks that operate in the high seas. Nonetheless, threats to high seas ecosystems, such as industrial fishing, are often exacerbated by national government subsidies which increase profit by reducing fishing costs, and can lead to overfishing (Martini & Innes, 2018; Sakai et al., 2019). Fishery subsidies have garnered significant global attention as key funding mechanisms for distant water fisheries (Sala et al., 2018; Schuhbauer et al., 2017, 2020; Skerritt & Sumaila, 2021a). Subsidies are typically categorized as capacity enhancing, beneficial, or ambiguous based on their impacts on fish stocks (Andreoli et al., 2023; Skerritt & Sumaila, 2021b; Sumaila et al., 2019). Within the scope of marine conservation and fisheries management, significant attention has been given to studying the broad ranging impacts of subsidies for distant water fisheries. While several global subsidy studies have been published (e.g., Sumaila et al., 2019; Villasante et al., 2022), none have been specific to the Southern Ocean.

Recent assessments of Southern Ocean ecosystems have underscored the global implications associated with Southern Ocean fisheries (Cavanagh et al., 2021; Grant et al., 2021; Murphy et al., 2021; Pertierra et al., 2021). Provisioning services, including primary production, climate change regulation, and support for regional and global biodiversity connectivity, are particularly vulnerable to the threats posed by overfishing and escalating human activities (Cavanagh et al., 2021; Wauchope et al., 2019). If subsidies are indeed playing a major role in the operational ability

of Southern Ocean fisheries, with implications for ecosystems and biodiversity, then a country-specific analysis of government subsidies is needed as a first step to identify potential solutions.

Chapter III aims to decipher the current state of Southern Ocean fishery subsidies and the role that these subsidies play in the fishing activities of CCAMLR member states. While there is extensive discourse on fishery subsidies and assumptions of their widespread presence, including in the waters around Antarctica, the lack of regionally focused studies on Southern Ocean fishery subsidies is notable. Through primary data collection in the form of interviews, I provide an in-depth analysis of the complex operations that underlie Southern Ocean fisheries.

Each of my chapters is designed to analyze the governance complexities of managing marine resources in ABNJ from different lenses. Chapter I takes a regional approach, solely investigating the application of climate resilient management measures under CCAMLR and its specific conservation protocols. Chapter II takes an international approach, identifying the policy pathways for the legal protection of the Salas y Gomez and Nazca Ridges under International Conventions and Agreements stemming from the United Nations. Lastly, Chapter III takes a national approach, addressing the interplay of national policies across scales and emphasizing the role of government subsidies in high seas fisheries. Here we provide a country specific subsidy analysis of Southern Ocean fisheries, evaluating the role that subsidies play in the fishing activities of CCAMLR Member States. Together, these three chapters will allow for an assessment of the current threats to high seas biodiversity, the conservation opportunities that exist, and how to implement them. My goal with this dissertation is to highlight the necessary tools to improve the management of social and ecological systems across the different management levels of ocean ecosystems in ABNJ.

Purpose of the Study

This dissertation addresses the governance complexities of managing marine resources in ABNJ, highlighting progress, gaps, and opportunities for improved management. It presents three individual case studies that aim to cover various management frameworks, ranging from national to international levels, addressing marine conservation and fisheries management within each governance structure. This was accomplished by breaking down the current management frameworks that make up the high seas, as well as the funding mechanisms that support high seas fisheries. By analyzing the individual policies of regional management organizations as well as those of the sectoral bodies that have jurisdiction over particular high seas industries, we were able to provide a comprehensive assessment of the pathways for improved conservation, natural resource governance, and fisheries management across ABNJ. Historically, the high seas have been often overlooked, leading to poor management structures and lack of conservation measures. The purpose of this dissertation was to emphasize the unique value of high seas ecosystems, identify current threats and opportunities for improved management, and evaluate existing measures for protecting high seas ecosystems and species. With the goal of providing new perspectives for these complex issues that might chart a new path forward.

Scope of the Study

To accomplish the goals set up for this PhD, a combination of policy analysis, quantitative data analysis, and investigative research were necessary to address the governance complexities of managing marine resources in ABNJ. Chapters I and II heavily relied on a comprehensive policy analysis for each Convention and sectoral body with jurisdiction over the area being studied. This

included analyzing each Convention document, such as those of CCAMLR, multiple RFMOs, and international bodies like the IMO, CBD, FAO, ISA, UNCLOS, UNFSA, and BBNJ. Additionally, it involved investigating the conservation measures for each body, including memorandums of understanding, meeting reports, conferences, publications, convention data, compliance reports, protocols, agreements, programs, and legal frameworks. This thorough policy analysis enabled us to identify the application processes for improved management measures, such as climate-resilient management tools for fisheries, and the pathways to enhance conservation measures, including the implementation of MPAs.

Chapter III, however, relied on a mixed method approach, relying on quantitative data analysis and investigative journaling. Unlike the fragmented international and regional policy frameworks that encompassed chapter I and II, the methodology for chapter III involved conducting country-specific interviews with industry representatives, government officials, and expert researchers. This allowed us to investigate the role of government subsidies for Southern Ocean fisheries through a national lens. Through primary data collection, we were able to conduct the first country specific subsidy analysis for Southern Ocean fisheries. A total of 29 interviews were conducted including CEOs, General Managers, Ministry of Fishery representatives, high level diplomats, and scientific researchers specializing in fishery subsidies across the 13 countries currently fishing in the Southern Ocean. This qualitative investigation was further supported by quantitative data on fisheries catch numbers for toothfish and krill, categorized by year, country, and region within the CCAMLR area. Altogether, this mixed-method approach enabled a comprehensive investigation into the current state of high seas fisheries management and identified essential pathways through national, regional, and international frameworks to enhance natural resource governance across our oceans.

Data Limitations

The governance of natural resources across the high seas is constantly evolving. When I started my PhD back in 2021, negotiations for the BBNJ text were still ongoing. Fast forward to today, eight countries have ratified the agreement, but a total of 60 is necessary for the agreement to come into force. Individual policies within fishery management organizations and sectoral bodies are also constantly being negotiated, from fishing closures to bans on seabed mining. The conservation tools and policy pathways identified in my published research may require adjustments in the future to align with evolving policy or management changes. While my research currently offers policy applications for enhanced management, these tools will require adaptation to align with the evolving landscape of high seas governance.

Chapter III, specifically, had several limitations that impacted our subsidy results. Primary data collection was largely based on interviews. While this provided us with insightful knowledge about individual companies and the relationship between national governments and the fishing industry, it also constrained us to rely on our interviewees' own accounts. It is very much possible that we received incomplete information from industry and government alike. To address these gaps in knowledge, there should be improved transparency between government spending data and its accessibility to the public.

Lastly, the vast majority of this dissertation research was conducted during a global pandemic. While I managed to attend international meetings like the 2023 UNFCCC CoP 28 in Dubai, my ability to attend in-person meetings was limited during the first years of my PhD. Many of my research meetings with collaborators had to be conducted via zoom, and while this is now considered to be the norm, it impacted the rate at which we progressed our research. The pandemic

also affected United Nation Conventions and Meetings, which in turn slowed down the negotiation processes for international agreements such as BBNJ. My research had to be constantly adjusted to reflect the current state of international conservation negotiations during a global pandemic.

Chapter I

Managing for climate resilient fisheries: applications to the Southern Ocean

Chavez-Molina, V., Becker, S. L., Carr, E., Cavanagh, R. D., Dorman, D., Nocito, E., Sylvester, Z., Wallace, B., White, C., & Brooks, C. M. (2023). Managing for Climate Resilient Fisheries: Applications to the Southern Ocean. Ocean and Coastal Management, 239 (March), 106580. https://doi.org/10.2139/ssrn.4149306

Abstract

Climate change is having profound effects on populations of fished species and the ecosystems on which they depend, lending to a growing body of work that advocates for climate resilience to be a priority in fishery management. Here, we provide a comprehensive analysis of the tools needed to manage for climate resiliency. The Antarctic region is among the most vulnerable to climate change, and thus, we then consider climate resilient management tools utilized by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the body responsible for the management of Antarctic marine living resources as part of the Antarctic Treaty System. We note progress, gaps, and opportunities for implementation. Across the literature, ecosystem-based management was cited as an appropriate tool for climate resilience of marine ecosystems, as was the use of climate model outputs (projections and simulations), marine protected areas (MPAs), and dynamic stock assessments. CCAMLR has a unique position where its Convention effectively mandates the principles of an ecosystem-based precautionary approach for managing fisheries, and many of its Member States have been advocating for climate initiatives within this approach. While CCAMLR has made limited overall progress towards ensuring climate resilience, it has advanced in some areas, such as MPA implementation, developing a risk assessment for krill, and including statements on climate change in fishery reports, although there is much work to be done. While climate change remains a worldwide issue that must be addressed on a global scale, CCAMLR holds the responsibility for adaptively managing Southern Ocean marine living resources for climate resilience.

Introduction

Across the world, climate change is dramatically altering marine systems and threatening fished populations as well as the livelihoods and food security they provide (Boersma et al., 2016; Brown et al., 2010; Cheung et al., 2018; Miller et al., 2018). Warming temperatures have been correlated with an overall reduction in fisheries yield over the past 80 years (Bryndum-Buchholz et al., 2019; Free et al., 2019). Global projections suggest this trend will continue with significant decreases in animal marine biomass by 2100 (Lotze et al., 2019). The Intergovernmental Panel on Climate Change (IPCC) has warned that by 2050, future shifts in fish distribution and decreases in their abundance will have profound effects on income, livelihoods, and food security (IPCC, 2019; Hannesson, 2007).

Climate change is currently impacting marine systems in a variety of ways, including increases in sea temperature, acidification, loss of oxygen, and changes in ocean currents; this in turn has caused shifts of species distributions, biodiversity declines, and loss of ecosystem integrity and function (Bijma et al., 2013; Brander, 2010; Frazao Santos et al., 2020; Funk & Brown, 2009; Hoegh-Guldberg & Bruno, 2010; IPBES, 2019; Meredith et al., 2019; Reid et al., 2010). Generally, marine species are responding to warming by shifting their geographic ranges both polewards and into deeper waters (Barhri et al., 2021; Mills et al., 2015; Pecl et al., 2017). Warming ocean temperatures are also linked to reductions in body size of marine species, and changes in reproduction and growth rates (Huang et al., 2021; Poloczanska et al., 2016). Earlier migrations have also been recorded in marine species as a response to changes in seasonality and sea temperature (Bell et al., 2020; Lennox et al., 2019, Mills et al., 2013). As warming continues, these shifts will become more common as species change their distribution patterns seeking an

environment that suits their optimal thermal tolerance (McBride et al., 2021; Erauskin-Extramiana et al., 2019; Hobday et al., 2015; Poloczanska et al., 2016; Porter et al., 2015).

Southern Ocean ecosystems are globally important due to their influence on the Earth system and are among the most impacted by climate change (Murphy et al., 2021; Newman et al., 2019). Current climate change projections predict the Southern Ocean will experience the most pronounced warming at depths of 0-2,000m compared to other ocean bodies (Bindoff et al., 2022; Hoegh-Guldberg et al., 2018). More specifically, the western Antarctic Peninsula has been identified as being one of the most climatically sensitive regions on Earth (Hendry et al., 2018; Meredith et al., 2019; Wang et al., 2021). The general prognosis for Southern Ocean systems is one of overall warming and freshening, increased acidification, strengthening of westerly winds, increase in ocean eddy activity, shifting currents, increased primary production in the water column and less in sea ice, and declines in sea ice extent; all these physical changes will have potentially dramatic impacts on Antarctic marine ecosystems (Bindoff et al., 2022; Chown & Brooks 2019; Collins et al., 2019; Constable et al., 2014; IPCC, 2021; Henley et al., 2020; Karp et al., 2019; Pinkerton et al., 2021; Rintoul et al., 2018; Rogers et al., 2019). Southern Ocean species can be especially vulnerable to climate change due to restricted ranges, thermal tolerances, and reliance on sea ice, (Braiser et al., 2021; Constable et al., 2014; Peck, 2018). Further, climate change is also predicted to decrease the overall capacity of the Southern Ocean to supply globally important ecosystem services (Cavanagh et al., 2021a; Meredith et al., 2019). However, quantifying the effects of climate change on Southern Ocean ecosystems has been difficult and wrought with uncertainty (Abrams et al., 2016; Bestly et al., 2020; Cavanagh et al., 2017; Constable et al., 2016; Constable et al., 2017; Freer et al., 2019; Goldsworthy & Brennan, 2021; Meyer et al., 2020; Press, 2021; Rayfuse et al., 2018; Watters et al., 2020).

Marine living resources in the region are managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). Established in 1982, CCAMLR's objective is to carry forward the provisions of the Convention on the Conservation of Antarctic Marine Living Resources (CAMLR Convention). The CAMLR Convention is one of the agreements that make up the Antarctic Treaty System, which comprehensively dedicates Antarctica as a shared international space committed to peace, science, and environmental protection (Berkman et al., 2011). This important context, along with the CAMLR Convention's conservation principles (see Box 1, Article II), sets CCAMLR apart from regional fisheries management organizations (RFMOs). CCAMLR currently has 26 Member States plus the European Union, and all substantive decisions require consensus.

Article II

1. The objective of this Convention is the conservation of Antarctic marine living resources.

2. For the purposes of this Convention, the term 'conservation' includes rational use.

3. Any harvesting and associated activities in the area to which this Convention applies shall be conducted in accordance with the provisions of this Convention and with the following principles of conservation:

(a) prevention of decrease in the size of any harvested population to levels below those which ensure its stable recruitment. For this purpose, its size should not be allowed to fall below a level close to that which ensures the greatest net annual increment;

(b) maintenance of the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources and the restoration of depleted populations to the levels defined in sub-paragraph (a) above; and

(c) prevention of changes or minimization of the risk of changes in the marine ecosystem which are not potentially reversible over two or three decades, taking into account the state of available knowledge of the direct and indirect impact of harvesting, the effect of the introduction of alien species, the effects of associated activities on the marine ecosystem and of the effects of environmental changes, with the aim of making possible the sustained conservation of Antarctic marine living resources.

Box 1. CAMLR Convention Article II (CCAMLR, 1980)

CCAMLR's mandate is the conservation of Antarctic marine living resources. However, the Convention also allows for rational use, where commercial fishing is permitted, but must be in

accordance with the conservation principles outlined in Article II following a precautionary and ecosystem-based approach, which is grounded in the best available science (Constable et al., 2000) (see Box 1). Maintaining ecological relationships and managing for the effects of environmental change are among these principles. Climate change presents an unprecedented ongoing challenge to CCAMLR, demanding new approaches to management to meet the ecosystem provisions of Article II. The recent 2022 IPCC report cross-chapter on Polar Regions clearly demonstrates the need for improved Southern Ocean management, with recommendations including: improved spatial management, ecosystem-based fishery management (EBFM), marine protected areas (MPAs), climate informed management, protection of prey fields, climate resilient infrastructure, and diversification of harvest portfolios (Constable et al., 2022). Similarly, Sustainable Development Goal 14 of the United Nations calls for enhancement of scientific research to build resilient infrastructure to minimize and address the impacts of climate change across all oceans (Bebianno et al., 2021). Aligned with recent IPCC recommendations (IPCC, 2021) and much of the scientific research and discussion to date, a recent report by the Scientific Committee on Antarctic Research (SCAR) recommends identifying which species and ecosystems are the most vulnerable to climate change, determining how fishing will affect the Southern Ocean food web, and further supporting research to reduce scientific uncertainty and understand the impacts of mitigation and adaptation responses (Chown et al. 2022).

Given the stressors posed by climate change on marine ecosystem worldwide, a growing body of work has advocated for climate resilience of ecosystems to be a priority in fishery management (Burden and Fujita, 2019; Busch et al., 2016; Free et al., 2020; Karp et al., 2019; Link et al., 2020; Mellin et al., 2016; Ojea et al., 2020; Pentz et al., 2018; Sekadende et al., 2020). In this paper, we use Holsman et al.'s (2019, pg. 1379) definition of climate resilient fisheries management as

"precautionary, efficient, and responsive policies that address climate uncertainty, explicitly consider feedback within coupled marine social-ecological systems and integrate tools and politics at multiple spatiotemporal scales." The extent to which resilience can be operationalized in fisheries as a complex social ecological system is still a key question due to gaps across (i) ecological, (ii) socio-economic and (iii) governance dimensions (Mason et al., 2021). Globally, managing for climate resilient fisheries has focused on building resistance to stressors and recovery from both ecosystem disturbances and pressures from social systems (Mason et al., 2021). However, in the Southern Ocean, where there are no resident social systems in place, building climate resilience is skewed towards the former (Press and Constable, 2022). This is further emphasized by the objective of the CAMLR Convention: conserving Antarctic marine living resources (CCAMLR, 1980, Article II).

Managing fisheries for climate change has been slow and difficult (Pinsky and Mantua, 2014; Bryndum-Buchholz et al., 2021; Holsman et al., 2020, 2019; Rudd et al., 2018; Skern-Mauritzen et al., 2016), and often applied reactively in response to extreme events rather than proactively (Barhri et al., 2021). This is in part because managing for climate resilience demands an increased understanding of population and community dynamics to predict the effects of climate change within a system (Murphy et al., 2021). And yet, there is inherent uncertainty about marine system predictions, and the tools for managing for climate change are still being developed (Skern-Mauritzen et al., 2016; Bryndum-Buchholz et al., 2021).

In this paper, we identified best practices for managing fisheries for climate resilience of ecosystems, and then assessed the application of these best practices to the Southern Ocean. First, we provided background on Southern Ocean fisheries, including climate change impacts to the ecosystem. Then we performed a review of the peer-reviewed literature focused on climate

resilient fisheries management. The goal of our review was to be qualitative and descriptive (Xiao and Watson, 2019), rather than systematic or quantitative, and to derive common themes and tools that scholars and practitioners recommend for climate resilient fisheries management across scales, from local to global. Below we present and summarize these themes, offering examples where possible of the management tool in action. We then addressed these climate change management tools to CCAMLR's management practices, noting progress, challenges, gaps and opportunities for improvement. Further, we assessed CCAMLR's draft proposed Climate Change Response Work Plan (CCRWP) in the context of the literature, while noting that discussions on progressing this plan have not been undertaken since 2019 and would need to be updated to reflect current climate resilience literature. The CCRWP, however, provided a useful framework to assess CCAMLR's progress towards managing for climate change. While we aimed to be comprehensive in our review and assessment of CCAMLR, we acknowledge that some CCAMLR activities are not documented in the peer-reviewed literature or publicly available reports. We close with recommendations for CCAMLR to work towards improving climate resiliency of Southern Ocean fisheries and ecosystems.

Southern Ocean Fisheries

Antarctic krill (*Euphausia superba*, hereafter krill), are one of two main fisheries in the CCAMLR area. Krill are a key prey species supporting the Southern Ocean food web and are particularly vulnerable to a changing climate (Atkinson et al., 2019; Flores et al., 2012; Johnston et al., 2022). The Antarctic Peninsula region, where 70% of the current population of krill is concentrated (Atkinson et al., 2008), is experiencing some of the most rapid warming in the Southern Ocean (Meredith et al., 2019). The current population center for krill extends from the South Sandwich Islands to the Antarctic Peninsula. However, empirical evidence has shown that there has been a

southward contraction in the distribution of krill (Atkinson et al., 2019; Cooley et al., 2022; Trivelpiece et al., 2011; Watters et al., 2020). Modeling studies have also shown that as climate changes, the optimal conditions for krill are predicted to move poleward (Hill et al., 2013; Murphy et al., 2017; Veytia et al., 2020; Sylvester et al., 2021). Meanwhile, there is increasing pressure to expand krill fisheries in the Southern Ocean to meet the growing demand for nutraceutical products for krill oil (e.g., Omega-3 supplements) and for fishmeal and marine by-products (Meyer et al., 2020).

In addition to krill, and limited catch of Mackerel icefish (*Champsocephalus gunnari*), the other major fishery in the Southern Ocean is for Patagonian and Antarctic toothfish (*Dissostichus eleginoides* and *D. mawsoni*, respectively; hereafter toothfish), which are sold as the lucrative Chilean Sea Bass. Toothfish serve as the top fish predator, but also as an important prey species for seals and whales (Ainley and Ballard, 2012; Ainley and Siniff, 2009). Patagonian toothfish largely occupy the more northern subantarctic waters while Antarctic toothfish, which have antifreeze in their blood, occupy higher latitude waters further south (Caccavo et al., 2021). Like krill, much uncertainty remains around the projected impacts of climate change on Antarctic toothfish (Morley et al., 2020). For example, while one study emphasized the possible extinction of the Antarctic toothfish due to its restricted range and affinity to freezing temperatures (Cheung et al., 2008a), a later study instead argued that Antarctic toothfish may respond well to temperature and oceanographic changes due to their ability to thrive in various depths and locations (Constable et al., 2014). Although Antarctic toothfish are prevalent throughout Antarctic waters, many knowledge gaps remain. This includes uncertainty about their life history (e.g., spawning frequency), population status (e.g., virgin biomass), and connectivity (e.g., how many populations exist) (Abrams, 2014; Abrams et al., 2016; SC-CAMLR, 2018; Chown and Brooks, 2019), along

with potential cumulative impacts from environmental change and fishing (Brooks et al., 2018). In addition to fishing, the direct and indirect effects of climate change on fish and wildlife populations in the Southern Ocean are further complicated by the cumulative pressures of pollution, and overall increased human activity, including tourism (Roberts et al., 2017; Tulloch et al., 2019; Wauchope et al., 2019; Grant et al., 2021).

Climate Resilient Management Tools

The peer reviewed literature on climate resilient fisheries primarily highlighted the need for EBFM (including precautionary, adaptive, and dynamic approaches), along with applying outputs from climate models in developing management measures, utilizing environmentally informed dynamic stock assessments, and implementing MPAs. These tools ideally work in tandem as part of EBFM. Climate model outputs provide a means for predicting future ecosystem and environmental scenarios which can be used, for example, to help inform a dynamic stock assessment or to guide where a network of MPAs might best be placed. Below we examine each of these tools including some of the key elements that support them.

Ecosystem Based Fisheries Management

As a tool for climate resilience, EBFM provides an approach that integrates social, ecological, and economic factors to comprehensively manage the threats to an ecosystem. Unlike fixed management measures - which are only revisited periodically and are difficult to adjust - EBFM includes management measures that are able to adjust and respond to new conditions and new data, including ecosystem drivers, while also being forward-looking and proactive (Holsman et al., 2019; Hazen et al., 2018). EBFM inherently applies to managing not only the target species, but also the whole ecosystem. For the purposes of this paper, we use Pikitch et al.'s (2004) pillars for

achieving EBFM. These include: (i) avoiding degradation of ecosystems, (ii) minimizing the risk of irreversible change to species and ecosystem processes, (iii) maintaining long-term socioeconomic benefits, and (iv) continue to generate knowledge of ecosystem processes under anthropogenic actions, with the acknowledgement that EBFM will look different given the community in question's specific needs and values. EBFM encompasses the wide diversity of services provided by marine ecosystems, the cumulative effects of anthropogenic activities on ecological systems, and the importance of working towards a common goal for all parties and across all sectors (McLead et al., 2009).

There are a number of tools that can work as part of an EBFM approach and have the potential to be used towards managing for climate resilience. These include: scenario planning (a method to help managers identify the most potentially detrimental drivers of change and enable them to plan around them), protecting key habitats and species, designating MPAs (elaborated on further below), applying outputs from climate models (also elaborated on below), and being dynamic and adaptive (Chavez et al., 2017). Within EBFM and in response to the intrinsic dynamic nature of oceans, researchers have advocated for management to be dynamic over static (Dunn et al., 2016). Thus far, frameworks for dynamic management tend to operate on smaller scales and focus on managing grid-based fisheries closures for conservation (Dunn et al., 2016).

Similarly, EBFM relies on adaptive management measures that center on developing management practices tailored to a wide range of outcomes within an ecosystem. Adaptive management is a structured approach to decision-making in the face of uncertainty that focuses on monitoring and forecasting environmental outcomes to reduce uncertainty and improve fisheries management (Chavez et al., 2017; McCarthy and Possingham, 2007; Sekadende et al., 2020; Williams et al., 2009). Similarly, adaptive fisheries management requires the regular adjustment of management

measures based on ecosystem monitoring indices for stock assessments (Wang et al., 2021). Introducing adaptive management measures towards climate resilience can minimize the negative impacts of climate change on fisheries by aligning management practices with the spatial and temporal effects of climate change, ecosystem change, and socioeconomic responses (Free et al., 2019; Free et al., 2020; Kenny et al., 2018).

Climate Models

The use of climate models in fisheries management can help guide decision-making regarding the biological implications of climate change (Hewitt et al., 2020; Quentin Grafton, 2010; Saba et al., 2014). Global climate models are a mathematical representation of the four major components of the earth system (atmosphere, land surface, ocean, and sea ice). When applied across a three dimensional gridded representation of the earth, climate models formulate a system that allows interaction between all major components. In doing so, climate model outputs provide a vast set of tools for understanding the complexities of how climate functions within the earth system. For example, data from climate model outputs can provide scenarios of environmental change, which then enables identification of sensitive areas, or provides a means by which ecological models can be projected in space and time to see what impacts climate change might have on the biosphere.

Data from climate model outputs can provide fishery managers with tools to envision and prepare for climate change and climate variability (Free et al., 2020; Hare et al., 2016; Lindegren and Brander, 2018). Climate models can be applied to decipher forecasts on regional ocean productivity trends (Stock et al., 2017) and to inform future environmental conditions to manage risk and account for variability (Hobday et al., 2018). Monitoring the effects of seasonal variability, spatial variability, and the long term impacts of climate change on fish populations and

modeling them in climate models can help inform management decisions and determine species responses to climate induced changes (Bell et al., 2020; Goethel et al., 2021; Sekadende et al., 2020). For example, climate model outputs can be used in vulnerability analyses to help identify which species are at most risk from threats to an ecosystem, such as rising temperatures or increased ocean acidification. Climate model outputs can also be used in scenario planning (defined above), holistic ecosystem models (which connect the interactions of ecological systems to the socioeconomic systems) and climate vulnerability analyses (which combines the exposure and sensitivity of a species to a stressor to estimate overall vulnerability) (Free et al., 2020; Holsman et al., 2017; Metcalf et al., 2015; Moore et al., 2013). Using climate model data to aid decision-making can help managers respond to a wide range of potential outcomes to species and ecosystems at different spatial and temporal scales.

Recent technological advancements have increased capacity for incorporating climate model outputs into fisheries research and management (Bradley et al., 2019). One example is the development of dynamic bioclimatic envelope models (DBEM). These models process associations between climate and fish species to estimate the conditions that are suitable to maintain viable populations (Araujo and Peterson, 2012). One recent study used a DBEM approach to project species distributions in the Gulf of Maine and Pacific Northwest from 2015 to 2100 under specific IPCC climate change projections (IPCC Representative Concentration Pathways, RCP 2.6 & 8.5), along with potential fishery catches (Palacios-Abrantes et al., 2020). Another example is the Fisheries and Marine Ecosystem Model Intercomparison Project which uses climate models to investigate predicted impacts on fisheries and marine ecosystems under different climate change scenarios (Cooley et al., 2022). Building on previous studies (Cheung et al., 2008b, 2009),

models such as the DBEM seek to estimate future productivity, distribution, movement, and other life history and population parameters of targeted fisheries.

Environmentally informed dynamic stock assessments

Stock assessments are the foundational tool for fisheries management and consist of a range of statistical methods used to estimate current population size for a targeted species. Managers use stock assessments to analyze biological and fisheries data to determine changes in fishery stocks in response to fishing, predict future changes in stock abundance, and ultimately set informed catch limits (Hilborn, 2003). Most stock assessments assume single-species, single-stock dynamics and employ limited use of environmental data, often due to limited data availability. Therefore, data availability along with model structure can influence how sustainable catch limits are defined (Punt et al., 2020).

As targeted species continue to shift their distribution under climate change, stock assessments need to innovate towards accounting for environmental change and uncertainty as well as ecosystem dynamics (Funk and Brown, 2009; Karp et al., 2019). A stronger understanding of how environmental variables drive productivity and trophic dynamics can facilitate the development of multispecies and ecosystem-based stock assessments (Thøgersen et al., 2015; Wang et al., 2021). Not only can climate change affect distribution and movement, but it can also lead to changes in recruitment, mortality rate, and productivity (Pankhurst and Munday, 2011; Portner and Peck, 2010). Failing to account for the impacts of climate change on species life history could lead to stock collapse from inaccurate fishing quotas (Jensen et al., 2020). Fishery managers have advocated for environmentally informed dynamic stock assessments which aim to incorporate environmental variables that account for the effects of climate on spawning and recruitment (Crone

et al., 2019), as well as responding to data on ecosystem drivers (e.g., temperature, ice coverage, upwelling, primary production, predator-prey relationships) of stock productivity (Pankhurst and Munday, 2011; Portner and Peck, 2010; Skern-Mauritzen et al., 2016).

While moving towards ecologically informed stock assessments is a goal for many researchers and managers, currently, ecosystem drivers, ecological interactions, and the effects of climate change are rarely accounted for in fishery stock assessments (Skern-Mauritzen et al., 2016; Wang et al., 2021). Only 2% of global fisheries include ecosystem drivers of stock productivity in their management (Skern-Mauritzen et al., 2016), none of which are in the Southern Ocean. Applying this tool requires extensive data, computing power, and technical expertise to implement, and therefore remains out of reach for many fisheries (Burden and Fujita, 2019). This is particularly relevant in data-poor regions, where there is limited information on stock status and climate change (Cisneros-Mata et al., 2019; Punt et al., 2020; Van de Putte et al., 2021). Nonetheless, improving understanding of how spatial distributions correlate with environmental variables shows promise for improving accuracy of predictions of spatial shifts, and opportunities to link habitat selection models to climate projections for stock assessments (Tommasi et al., 2017; Wayte, 2013).

Another approach is to set aside some of the catch limit to account for potentially diminishing or stressed fish stocks due to climate change (Johnson and Welch, 2010). This climate change catch quota aims to build in more precaution because of the inherent uncertainties related to how climate change will affect key parameters in stock assessments (Johnson and Welch, 2010). This could in turn provide fisheries with greater resilience to climate and stock variability (Johnson and Welch, 2010). Long-term solutions to address fishery management under climate change will require extensive monitoring and updating of stock assessments in addition to refining data collection and sharing (Cvitanovic et al., 2015; Dunn et al., 2016; Frazão Santos et al., 2020). Setting climate

informed quotas that include recent as well as historical observations, is an important step towards strengthening climate resilient fisheries (Bryndum-Buchholz et al., 2021; Tanaka, 2019).

Marine Protected Areas

MPAs, defined as regions of the ocean where human activities are restricted to promote conservation (Lubchenco et al., 2003), are emerging as an important tool to conserve biodiversity, and mitigate threats, including those posed by climate change (Browman and Stergiou, 2004; Cabral et al., 2020; Grorud-Colvert et al., 2021; Lubchenco and Grorud-Colvert, 2015; Pentz and Klenk, 2017; Wendebourg, 2020). Well-designed MPAs with strong levels of protection that encompass all trophic levels of an ecosystem have been shown to increase species and genetic diversity, thus enhancing resilience to environmental impacts (McLeod et al., 2009; Barnett and Baskett, 2015; Olds et al., 2014; Roberts et al., 2017; Jacquemont et al., 2022).

In terms of climate change, MPAs can be implemented specifically towards managing in a changing seascape and towards climate resilience. Wilson et al. (2020) presented a framework with four main steps. First, define clear conservation goals and objectives for the MPA, and adapt these specifically to the effects of climate change to the marine ecosystem. Second, use vulnerability assessments to evaluate how climate change will impact the stated conservation goals. Third, based on the vulnerability assessment, identify and incorporate adaptation strategies to mitigate climate change impacts. Fourth, monitor the MPA to gauge effectiveness in response to climate change and use monitoring results to guide adaptive management (Wilson et al., 2020). Wilson et al. (2020) further identified the range of climate adaptation strategies that can be utilized in MPA design and management (based on vulnerability assessments). These include (Wilson et al., 2020): encompassing climate refugia, increasing resilience, protecting future habitat,

increasing heterogeneity (Jones et al., 2016), increasing connectivity, and reducing other stressors (Roberts et al., 2017). While there are many examples of MPA managers applying these adaptation strategies, the majority are in tropical coral reef systems (Wilson et al., 2020); yet the lessons could transfer globally. Finally, creating MPAs as a connected network can lead to enhanced ecosystem resilience (Engler, 2020; McLeod et al., 2009; Green et al., 2014) by protecting the critical life stages of species, from spawning aggregations and nursery or feeding grounds to migration corridors for highly mobile species (Grorud-Colvert et al., 2021).

Discussion

Applying climate resilient management tools to CCAMLR

Below we consider the main tools for managing for climate resilience of ecosystems as applied to CCAMLR's current management practices. We further note potential gaps in implementation and areas for improvement towards climate resilient fisheries management.

Ecosystem based fishery management

While Article II of the CAMLR Convention encompasses the principles of EBFM (Article II (3) (b) and (c)), CCAMLR has grappled with effectively applying an ecosystem approach to the management of its fisheries (Constable et al., 2016), including under a changing climate. CCAMLR has led in some EBFM innovations, including the development of the CCAMLR Ecosystem Monitoring Program (CEMP). CEMP, which has been fully implemented since 1987, has sites throughout the Antarctic in which monitoring data on key prey, predators, and environmental indicators are collected (Agnew, 2004). However, CCAMLR has yet to include the CEMP monitoring data as parameters for their fisheries management (Hill et al., 2020; Hinke et

al., 2017). Further, biodiversity information, including the status of key species, remains inadequate to fully understand Southern Ocean ecosystem dynamics (Chown and Brooks, 2019).

Notably, CCAMLR has been discussing climate change at its annual meetings since 2008 when it was added as an agenda item under its Scientific Committee (SC-CAMLR, the scientific advisory body with representatives from all Member States) (CCAMLR, 2009). In 2009, CCAMLR adopted a non-legally binding resolution which emphasized the need for increased consideration of Southern Ocean climate change impacts to better inform CCAMLR's management decisions, drawing attention to Article II (CCAMLR, 2009). In 2022, CCAMLR adopted an additional climate change resolution stressing urgent action, including managing for climate resilience, again highlighting the ecosystem management provisions under Article II (CCAMLR, 2022a).

Other important efforts have been made to incorporate climate change into CCAMLR's management approach (see Table 1.1). In 2015, an intersessional contact group was established to consider approaches for integrating climate change considerations into the work of CCAMLR (CCAMLR, 2015, paragraph 7.12). In 2016 CCAMLR held a joint workshop on climate change and monitoring with the Committee for Environmental Protection (CEP), the body which advises on the implementation of the Environmental Protocol to the Antarctic Treaty, (CEP/SC-CAMLR, 2016) with the goal of identifying the effects of climate change that are considered most likely to impact the conservation of the Antarctic. A recommendation from this workshop was to encourage support and cooperation between scientific programs (especially SCAR, the Southern Ocean Observing System (SOOS), and Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED)) and SC-CAMLR and CEP towards contributing work on climate change and monitoring (CEP/SC-CAMLR, 2016). Furthermore, in 2017 and 2018, Delegates from Australia and Norway, on behalf of the intersessional group, proposed a Climate Change Response Work

Program (CCRWP) for CCAMLR (Delegations of Norway and Australia, 2018). The proposed CCRWP identified five specific conservation issues in the Southern Ocean and recommended actions to incorporate responses into CCAMLR's management. Evidence underpinning the proposed management responses was grounded in science and aligned with best practices in the literature for climate resilient fisheries (see Table 1.2).

Table 1.1 EBFM for climate resilience can draw on a variety of management tools. Some fall under the general umbrella of EBFM as described in Row 1. Others fall under sub-areas identified in the literature: Climate models (Row 2), Integrated stock assessments (Row 3), and MPAs (Row 4). Column 1 describes the different tools, column 2 lists the elements within each tool, column 3 lists the supporting literature and column 4 describes CCAMLR's progress with respect to each of the management tools.

Climate Resilient Management Tools	**Elements within each tool**	**Supporting Literature**	**CCAMLR's progress**
Implementation of **ecosystem based fishery management tools** specific to enhance the resilience of marine ecosystems and help improve the future status of fisheries	- Adaptive management - Dynamic management - Holistic ecosystem management - Risk assessments - Integrated ocean management	Barnett & Basket, 2015; Burden & Fujita, 2019; Busch et al., 2016; Cavanagh et al., 2016; Free et al., 2020; Gaines et al., 2018; Harvey et al., 2018; Hillborn & Ovando, 2014; Holbrook & Johnson, 2014; Kirkfeldt et al., 2019; Link et al., 2020; Mellin et al., 2016; McLead & Leslie, 2009; Meyer et al., 2020; Ojea et al., 2020; Skedande et al., 2020	CCAMLR manages Southern Ocean fisheries under an EBFM approach, and has stated provisions for adaptive management, however its current management framework lacks integrated consideration of climate change impacts. It has made progress in areas (noted below) on MPAs, risk assessment (for krill), adding statements on climate change and environmental variability to Fishery Reports, and scientific discussions (e.g., SC-CAMLR's 2017-2022 five year work plan, and the draft CCRWP).
Incorporation of **climate model** output into fisheries management applications	- Weather forecasts - Regional productivity forecast - Mapping seasonal and spatial variability (of key ecosystem drivers and indicators) - Climate vulnerability analyses - Population forecasts - Scenario planning	Brander, 2010; Burden & Fujita, 2019; Cavanagh et al. 2017; Collins et al., 2019; Constable et al., 2014; Constable et al., 2017; Constable et al., 2022; Free et al., 2020; FAO, 2019; Goethel et al., 2021; Hill et al., 2020; Hobday et al., 2018; IPCC, 2012; IPCC, 2014;IPCC, 2019; IPCC, 2021; Karp et al., 2019; Lindegren & Brander, 2021; Meredith et al., 2019; Meyer et al., 2020; Murphy et al., 2021; Pinkerton et al., 2021; Quentin Grafton, 2010; Saba et al., 2014; Stock et al.,	Currently climate models have not been directly applied in CCAMLR's fisheries management, however, there has been discussion of the use of, and application of climate models and climate modeling tools in the context of targeted species in recent years in CCAMLR Working Groups and SC-CAMLR meetings. The CCRWP also identifies a variety of actions that are supported by the use of climate models (e.g., develop models on the impact of climate change on food web dynamics). A variety of scientific programmes (e.g., SCAR, ICED) are doing ongoing research in this vein and

	- Holistic ecosystem models - Mapping species distribution	2017; Tommasi et al., 2017; Watters et al., 2020	provide scientific outputs to SC-CAMLR and its Working Groups. For example, the development of ecosystem models is identified as a priority for established toothfish fisheries in SC-CAMLR's five year work plan.
Innovative **stock assessments** that account for environmental change and uncertainty	- Climate models - Population models and forecasts - Models that project changes in stock abundance - Climate change catch quotas - Monitor shifts in oceanographic conditions - Tracking species historical movements	Abrams et al., 2016; Cisneros-Mata et al., 2019; Constable et al., 2000; Constable et al., 2017; Karp et al., 2019; Miller & Slicer, 2014; Poloczanska et al., 2016; Quentin Grafton, 2010; Thogersen et al., 2015; Weatherdon et al., 2016	CCAMLR has yet to incorporate climate change or ecosystem monitoring indices as variables in their stock assessments. The development of integrated assessments at population scales to address the impacts of climate change is identified in SC-CAMLR's five year work plan. Currently, for krill, CCAMLR's stock assessment only considers the adult life stage of krill and assumes that the krill population is at equilibrium, with random recruitment, and that changes in krill population are always proportional to the year before. CCAMLR scientists are in the process of developing a risk assessment, and CCAMLR also considers information from the CCAMLR Ecosystem Monitoring Program. The CCRWP suggested the development of spatially explicit stock assessments that account for changes in spatial distribution of fish due to sea ice changes.
Implementation of **Marine Protected Areas** to conserve biodiversity and reduce the pressure of climate change on ocean ecosystems	-Create networks of MPAs that represent the full range of ecoregions and biodiversity -Promote conservation -Mitigate threats, including those posed by climate change	Brito-Morales et al., 2022; Cabral et al., 2020; Dunham et al., 2020; Free et al., 2020; Grorud-Colvert et al., 2021; Lubchenco et al., 2003; Lubchenco et al., 2015; Miller & Slicer, 2014; Pentz & Klenk, 2017; Pentz et al., 2018; Olds et al., 2014, Roberts et al., 2017; Wendebourg, 2020	CCAMLR has committed to designate a network of representative MPAs in the Southern Ocean. Thus far two MPAs have been adopted. However, current MPAs are not representative of the full range of benthic and pelagic ecoregions of the Southern Ocean. Three more MPAs in the East Antarctic, Weddell Sea, and western Antarctic Peninsula - remain under negotiation and would increase ecological representativeness of protection significantly.

Table 1.2. Description of the five conservation issues outlined in the proposed climate change response work plan (CCRWP) with suggested actions and responses for implementation by

CCAMLR. We also highlight CCAMLR's progress towards the identified action, based on CCRWP (Delegations of Norway and Australia, 2018) and CCAMLR, SC-CAMLR and Working Group reports. Issues and actions in direct quotes are directly from the CCRWP (Delegations of Norway and Australia, 2018).

Issue	CCRWP Action	CCAMLR's progress
"Structural reform and dialogues to improve consideration of climate change impacts"	"Include climate change as agenda item for all working groups & incorporate climate change advice into considerations for SC-CAMLR; Working Groups to identify specific research and monitoring requirements"	Climate change was added to the permanent agenda of SC-CAMLR in 2008; also added to the Working Group on Ecosystem Monitoring and Management (WG-EMM) but has not yet been added for all Working Groups (WGs). However, this is now set to change as SC-CAMLR requested that climate change be added to the Terms of Reference for all WGs in 2023.
	SC-CAMLR & CCAMLR papers & Fishery reports to include climate change implication statements	All fishery reports include a climate change implication statement; A work plan is only included for *D. mawsoni* in 88.1; Climate Change Implication Statements have been considered for inclusion (since 2015) in SC-CAMLR and CCAMLR papers, but they have not yet been adopted into CCAMLR's practice.
	Coordination across CCAMLR and with the Committee for Environmental Protection (CEP)	The intersessional contact group (ICG) continues to operate. Updated Terms of Reference have been proposed but not yet endorsed. SC-CAMLR coordinates and facilitates relevant actions (e.g., in their 5-year work plan). CEP and CCAMLR conducted a joint workshop for "climate change and monitoring" in 2016 with the potential for a second one in the near future.
	"Identify and engage relevant climate experts, and ensure experts have opportunity to provide information to SC and its WGs;" SC-CAMLR engage with relevant international research programs	CCAMLR has made efforts in recent years to build capacity (e.g., through the CCAMLR Scientific Scholarship Scheme), but has still been criticized for its need to improve transparency and provide independent experts access to WGs. CCAMLR is currently engaging with relevant research programmes in the context of climate change including SCAR, ICED, SOOS.
"Effects of climate change on Antarctic marine living resources and associated sustainable exploitation"	Encourage research and assessment on climate change impacts on key species, ecosystems, & food webs. Includes national, international (e.g., SCAR, ICED) programs, including field-based.	Continuous advice from SC-CAMLR and WG, but not yet being applied in management.
	Develop quantitative scenarios and projections of change in Antarctic marine living resource populations, food web/community structure and regions; Assess status and trends of fisheries (including fishing impacts and spatial changes); Spatially explicit stock	Research (including through fishing vessels) is ongoing. Scientific efforts e.g., through SCAR, MEASO (Marine Ecosystem Assessment for the Southern Ocean), and ICED (including the 2018 ICED-CCAMLR Projections Workshop (Murphy et al., 2018) and the 2021 ICED krill modeling workshop (Veytia et al., 2021) have sought to fill some

	assessments; Improve habitat and species baseline data.	of these gaps. Outputs from these groups are submitted to SC-CAMLR and its WG, but improved mechanisms for incorporation into management are needed. A SC-CAMLR workshop on integrating climate change and ecosystem interactions into CCAMLR science is scheduled for 2023.
	Develop and evaluate models of krill populations, including dependent predators and climate change effects; develop and adopt feedback management for krill fisheries, including stock assessments.	In 2019, SC-CAMLR endorsed a new work plan towards updating management for kill, which included a risk assessment. In 2021, the krill management strategy was further updated to encompass more nuanced spatial scale, connectivity, and ecosystem impacts. Environmental drivers have yet to be incorporated into krill stock assessments.
	Enhance ecosystem resilience, including through establishing a representative system of MPAs	Two MPAs are adopted, with three MPAs in the East Antarctic, Weddell Sea and western Antarctic Peninsula - under negotiation.
"Marine habitats at risk due to climate change"	Research and assessment on ocean acidification impacts; review and revise management tools to address the risk from ocean acidification	National programs, including the Australian Antarctic Program, have increasingly advocated for more research on the impacts of ocean acidification on Antarctic Krill specifically. SCAR has ongoing work on this, via the Ocean Acidification Group.
	Encourage research by national programs, SCAR, ICED and others regarding habitat status, trends, vulnerability and distribution; include collaborative long-term monitoring of change. Revise existing management tools towards climate change adaptation for at risk habitats.	Conservation Measure 24-04 provides a framework for this. However, it has only been fully implemented in one location thus far. Ongoing work, including through scientific research programs such as by SOOS, ICED, and SCAR, and information sharing with CCAMLR.
	"Identify reference areas for future research, including research specified in MPA Research and Monitoring Plans."	Underway in current Southern Ocean MPAs (South Orkney Islands Southern Shelf and Ross Sea region MPAs); current MPA proposals include reference areas; ongoing research activities, including through SCAR and ICED.
"Marine species at risk due to climate change"	"Examine spatial management across CCAMLR to account for changes in species distribution"	Management for CCAMLR fisheries does not account for changes in species distributions. However, fishery reports on toothfish in the Ross Sea indicate that climate change and environmental variability can affect "recruitment, maturity and stock distribution" (Fishery Report Sub Area 88.2, 2021).
	Synthesize existing information for important species, complete quantitative analyses of population processes, develop models of impacts of change on food webs & community structure, and identify knowledge gaps; encourage targeted field studies and research by	Programs such as those operating through SCAR, SOOS, ICED & MEASO all have extensive efforts underway including: 2018 MEASO conference and related publication outputs (see Frontiers in Ecology & Evolution, 2022); the 2018 & 2021 ICED workshops (see above); ongoing joint ICED-CCAMLR activities; ongoing SCAR and

	national programs including SCAR and ICED.	ICED studies of key species' and systems responses to change; activities by the SCAR Krill Action Group (SKAG); ICED development of key species models; ICED-Sentinel benchmarking field program will address aspects of this; 2017 third International Symposium on Krill (WG-EMM-16/34, 2017). Outputs from these groups are submitted to SC-CAMLR and its Working Groups, but better mechanisms for incorporation into management are needed.
	Review and revise management tools towards affording the best adaptation promise and conservation status for species at risk of climate change; consider if and how IUCN Red List criteria can be applied; continue to identify reference areas for future research (including in MPA research and monitoring plans).	Information sharing with SCAR and other programs; MPA research and monitoring plans (current and proposed) have some climate change elements.
"Enhanced potential for non-native species introduction and establishment"	"Assessment of whether existing regimes for preventing marine non-native species introductions and transfer are sufficient. Analyze management tools applied in other marine ecosystems."	CEP leads on non-native species in the Antarctic, and its work plan has prioritized work on risks associated with marine non-native species in coming years
	"Assessment of risks of introducing non-native marine species"; ongoing monitoring.	The CEP Protection is scheduled to undertake a risk assessment in 2023/24.

The CCRWP built on related work of SC-CAMLR and its Working Groups, along with ongoing work of the CEP and scientific programs such as the SCAR, SOOS, and ICED. Modeled on the CCRWP of the CEP, CCAMLR's version was designed "to provide a mechanism to facilitate the production, delivery, and use of climate related information and advice for the Commission to take account of climate change impacts in achieving the objective of the CAMLR Convention." (Delegations of Norway and Australia, 2018, p. 1).

SC-CAMLR recommended that CCAMLR adopt the CCRWP (SC-CAMLR, 2017a; para 8.13), however two members opposed its adoption, ultimately rejecting the scientific advice provided by SC-CAMLR (Goldsworthy, 2022). While the draft CCRWP has not been discussed at CCAMLR

since 2019, and would need to be updated, its basic premise would support management for the resilience of Southern Ocean ecosystems in the face of climate change. Moving forward, CCAMLR could better integrate ecosystems and fisheries work streams by utilizing an adaptive management approach to understand the mechanism by which climate change will affect multiple trophic levels across the food web (Saba et al., 2014). CCAMLR could increase the effectiveness of its conservation strategies by applying systematic conservation planning principles such as the ongoing development of Southern Ocean MPAs (elaborated on further below), adaptive management, including risk assessments (also elaborated below), and incorporating information from climate model outputs (elaborated on below).

To date, CCAMLR has not collaborated sufficiently with climate experts, yet there is recognition that this would strengthen its capacity to incorporate relevant scientific information and inform decision-making, including developing methods for assessing current and future impacts of climate change on ecosystem structure and function (Constable et al., 2014; Cavanagh et al., 2017, 2021b; Murphy et al., 2017). Successful integration of climate information into CCAMLR's decision frameworks will depend on open dialogue and collaboration between CCAMLR decision-makers and climate scientists (Tommasi et al., 2017; Francis et al., 2018; Cavanagh et al., 2021b). Decision-makers will then need to incorporate ecosystem-based strategies to achieve their conservation objectives in relation to climate change (McCormack et al., 2021). While, as noted in Table 2, an array of scientific bodies and programs submit work outputs to CCAMLR, among them only SCAR serves as an observer to CCAMLR and SC-CAMLR, and none have access to the Working Groups (unless individuals which are part of these groups sit on a national delegation). This can be a barrier to enabling independent work being integrated in the decision-making process. However, SC-CAMLR does allow in its Rules of Procedure the invitation of independent

experts (SC-CAMLR, 2021a), and would greatly benefit from further seeking climate specific expertise, including from SCAR, ICED and other Antarctic science programs.

Climate models

The application of climate model outputs within CCAMLR's management of Southern Ocean ecosystems could enhance population models and stock assessments, such as for krill and toothfish, (Constable et al., 2017). Using climate models to inform fishery management could allow CCAMLR to account for current and future climate trends (Constable et al., 2017), and ultimately respond to these changes by applying environmentally informed dynamic stock assessments (described further below) and adaptive spatial and temporal management. While extensively discussed by SC-CAMLR and its Working Groups, currently climate models have not been directly applied in CCAMLR's fisheries management (see Table 1.1).

Fisheries across the globe have grappled with applying climate models for fishery management; and thus, CCAMLR is not alone. This is in part due to the high costs associated with adopting new technologies, lack of resources for data collection, bureaucratic barriers preventing the adoption of high tech fishery data systems, lack of trust from fishery management organizations, and ultimately lack of expertise (Bradley et al., 2019). Similarly, discrepancies between scales (spatial and temporal) of climate models versus biological processes is a substantial challenge, partially due to the mismatch between global climate forecasts and localized environmental effects (Brown et al., 2016; Cavanagh et al., 2017).

Yet, these barriers are not insurmountable. Recent improvements in global dynamic climate models are already proving to be helpful across a wide variety of industries and could be applied to the Southern Ocean. Applications of climate model outputs have allowed industry managers to

reduce the vulnerability of the agricultural sector to climate variability (Meza et al., 2008) as well as enhancing the capability of seasonal forecasts of living marine resources targeted by the fishing industry (Siedlecki et al., 2016; Stock et al., 2017). When applied to the Southern Ocean, identifying models that consider seasonal variability and the potential effects of climate change and fisheries on recruitment, such as for krill, will be crucial for setting sustainable catch limits (Meyer et al., 2020). Currently, CCAMLR's krill biomass estimate in the Antarctic Peninsula region (~62 million tonnes) was conducted by a single acoustic survey, and therefore only represents a snapshot in time that does not consider seasonal variability and the potential effects of climate and fisheries on krill recruitment (Hill et al., 2020; Meyer et al., 2020).

Environmentally informed dynamic stock assessments

While CCAMLR has a precautionary catch limit for krill and toothfish (and icefish) (Miller and Slicer, 2014), the parameters used for the stock assessments do not consider environmental change nor the effects of climate on recruitment, mortality, and growth (Hill et al., 2020). This is especially problematic because krill recruitment is extremely variable (recruitment cycles can take 5–8 years) and distinctly specific to each region (Loeb, 2007; Ross et al., 2014; Watters et al., 2020). A long term goal of CCAMLR has been to manage krill fisheries based on ecosystem monitoring indices (Wang et al., 2021), as stated in the CEMP. Implementing this would require an integrated and environmentally informed stock assessment, one that considers the environmental factors affecting the life stages of krill populations. (Fabra and Gascón, 2008; Wang et al., 2021). Similarly, toothfish fishery stock assessments are single-species and do not incorporate ecosystem monitoring indices or environmental variability (Abrams et al., 2016). In CCAMLR's second performance review conducted in 2017, the panel observed that harvest strategies for both krill and toothfish use parameters that imply no change to the ecosystem other than due to natural

variability. The panel argued that strategies need to be developed that will achieve the Convention objectives and be robust to ecosystem changes, including climate change, fishing, and tourism (Performance Review Panel, 2017).

While climate informed quotas (based on climate data) and climate quotas (implemented to reduce catch to factor stress/declines from climate change) have not been widely implemented in fisheries, other industries have implemented similar strategies. For example, many water managers now account for climate change and predicted reductions in rainfall by setting "reduced irrigation allowances from river flow" to protect the future ecological integrity of the system (Johnson and Welch p. 119, 2010). Considering climate informed quotas and incorporating ecosystem monitoring indices in CCAMLR's stock assessments might allow for accounting for climate variability and its long term effects on the ecological system, thereby helping to meet the objectives under Article II.

Notably, in 2018, SC-CAMLR's Working Group on Fish Stock Assessment updated all of CCAMLR's Fishery Reports to include a section on climate change and environmental variability (SC-CAMLR, 2018; CCAMLR, 2022b). This section includes information on potential changes in model parameters and productivity assumptions as well as considering the impact of observed changes in biological parameters on management advice. Thus far, while all of CCAMLR's fishery reports for krill, toothfish and icefish have this section, almost all of them have the same statement which points to the risk and CCAMLR's approach to climate resilience being focused on a EBFM approach, MPAs, and monitoring programs (see Table 1.3). Only Antarctic toothfish fisheries in the Ross Sea (Subarea 88.1 and 88.2) had a stock specific statement and there is only a Work Plan for Antarctic toothfish in Subarea 88.1. While having these statements is a useful first step, formal evaluation and work plans are needed to move towards actually assessing the stocks and managing

for climate change and environmental variability. A Climate Change workshop is planned for 2023 to focus on integrating climate change and ecosystem interactions into CCAMLR science (SC-CAMLR, 2022; Hughes et al., 2022).

Table 1.3. Climate change and environmental variability statements and work plans for CCAMLR managed fisheries (extracted from CCAMLR's Fishery Reports (CCAMLR, 2022b, Section 7).

Fishery & Area	**Statement**	**Workplan**
Euphausia superba, Area 48 *Dissostichus eleginoides*, Subareas 48.2, 48.3, 48.4, 51, 58.6, 58.7; Divisions 58.4.3a, 58.4.3b, 58.4.4a, 58.4.4b, 58.5.1, 58.5.2 *Dissostichus mawsoni*, Subareas 48.2, 48.4, 48.6, 88.1; Divisions 58.4.1, 58.4.2, 58.4.3b *Champsocephalus gunnari*, Subarea 48.3 (statement and work plan listed to the right applies to all fisheries and areas listed above)	"A recent summary of the potential impacts of climate change on Southern Ocean fisheries (FAO, 2018) highlights the following key points: *The Antarctic region is characterized by a complex interaction of natural climate variability and anthropogenic climate change that produce high levels of variability in both physical and biological systems, including impacts on key fishery taxa such as Antarctic krill.* *The impact of anthropogenic climate change in the short-term could be expected to be related to changes in sea ice and physical access to fishing grounds, whereas longer-term implications are likely to include changes in ecosystem productivity affecting target stocks.* *There are no resident human populations or fishery-dependent livelihoods in the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Area, therefore climate change will have limited direct implications for regional food security. However, as an "under-exploited" fishery, there is potential for krill to play a role in global food security in the longer term.* *The institutional and management approach taken by CCAMLR, including the ecosystem-based approach, the establishment of large marine protected areas, and scientific monitoring programmes, provides measures of resilience to climate change*."	There is no formal evaluation of the impacts of climate change and environmental variability available for any of these fisheries.

Dissostichus mawsoni, Subarea 88.1, 88.2	"The impact of Anthropogenic climate change in the short-term could be expected to be related to changes in sea ice and physical access to fishing grounds, whereas longer-term implications are likely to include changes in ecosystem productivity affecting target stocks (FAO, 2018). In anticipation of potential impacts of climate change on targeted fish stocks, the Scientific Committee indicated that changes in productivity parameters may impact assessments and management advice, and these changes may be related to long-term environmental change, shorter-term variability, or potential effects of fishing (SC-CAMLR XXXVII paragraph 3.51, Annex 9 paragraph 2.28). The parameters that could be evaluated for the effects of environmental variability and change would include mean recruitment, recruitment variability, mean length at age, mean weight at length, natural mortality, and maturation ogives. Other factors that may impact assumptions underlying the assessments that could also be considered, including stock distribution (for example, for its impact on tagged fish distribution or research survey interpretation), sex ratio (indicating maturation or other sex specific changes), and the ages or lengths observed in the fishery (indicating changes in vulnerability patterns or mortality)."	The work plan associated with the impacts of climate change on Subarea 88.1 *D. mawsoni* is to: i. Use historical data to investigate trends in key parameters affecting estimates of toothfish yield (and hence management advice). ii. If trends are identified, adjust parameters in stock assessment and yield estimate to allow for trends continuing in future. iii. Investigate evidence for trends being related to physical, oceanographic or ecological drivers, but note that establishing causality of trends may not be possible and is not essential. --- There is no formal evaluation of the impacts of climate change and environmental variability available for Subarea 88.2 *D. mawsoni*.

CCAMLR has made other modest strides towards managing for climate change. For example, they have an ongoing Memorandum of Understanding with some adjacent RFMOs (e.g., the South Pacific Regional Fisheries Management Organization) (SPRFMO, 2022) which would allow for cross institutional collaborative management if harvested species shift distributions. Further, in 2019 CCAMLR agreed on a new framework for managing Antarctic krill (SC-CAMLR, 2019), which includes the use of a risk management approach that ideally provides actionable information to inform decision-making (Bryndum-Buchholz et al., 2021). The risk assessment entails looking at areas where predators and fisheries access krill, and ultimately minimizing the risk of overlap (SC-CAMLR, 2021b; Warwick-Evans et al., 2022). Evidence shows that even low scale fishing for krill in the wrong place at the wrong time can have significant effects on predators (Trathan et

al., 2022; Watters et al., 2020). While the risk assessment is not included as a parameter in the stock assessment, it can be considered when setting catch limits.

Marine Protected Areas

CCAMLR has committed to create a network of Southern Ocean MPAs for the conservation of marine biodiversity, including being a tool for climate resilience (CCAMLR, 2011). While CCAMLR's efforts to establish a network of MPAs has been commendable, CCAMLR has come under criticism for the rate at which it is able to complete work on MPA designations (Performance Review Panel, 2017). Only two MPAs have been adopted, with three more MPAs under negotiation (see Fig. 1.4). These additional proposed MPAs would increase ecological representativeness of protection significantly (Brooks et al., 2020). Most of these MPA proposals also include climate change reference areas and explicit intention to enhance resilience to climate change. CCAMLR Members have been discussing these proposals for years (e.g., the East Antarctic Proposal has been discussed since 2011), and while the majority of members agree on the establishment of MPAs as an essential part of their obligations to conserve Antarctic marine life, two members of CCAMLR have continued to object (Goldsworthy, 2022; Teschke et al., 2021; Sylvester and Brooks, 2020; Tang et al., 2020). MPA implementation will improve adaptation capacities and ultimately contribute to enhancing the Southern Ocean ecosystem's resilience to the effects of climate change (Constable et al., 2022; Pentz et al., 2018; Roberts et al., 2017; Chown and Brooks, 2019).

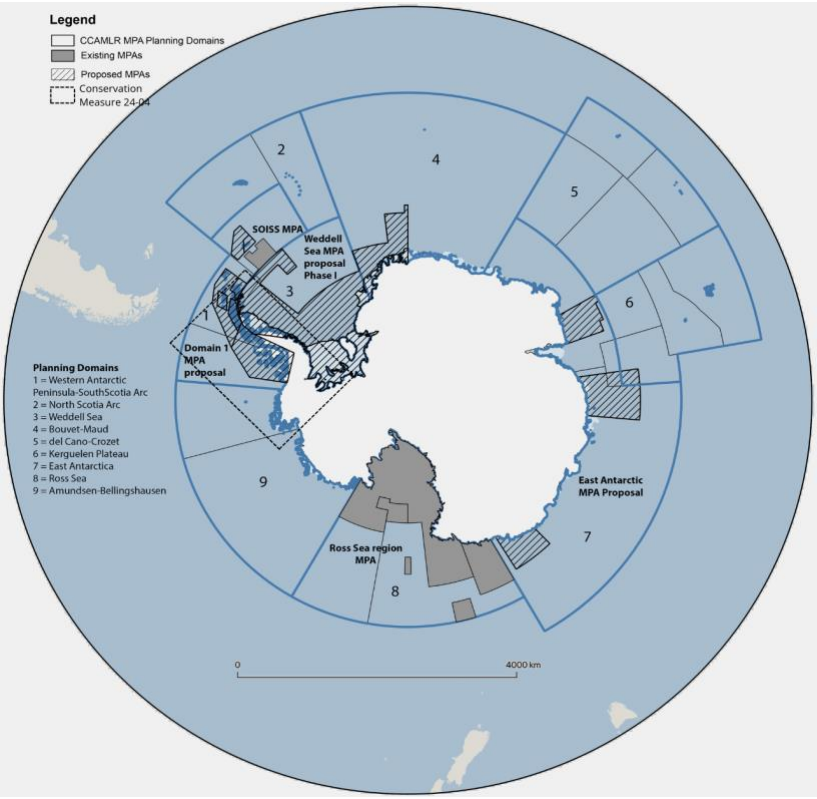

Fig 1.4 CCAMLR area boundaries, showing the nine MPA planning domains, along with adopted and proposed MPAs. The region applicable to Conservation Measure 24–04 (time-limited Special Areas for Scientific Study in newly exposed marine areas following ice-shelf retreat or collapse) shown by dashed line box (CCAMLR boundaries, MPA planning domains, adopted MPAs, Conservation Measure 24–04 all based on CCAMLR data (CCAMLR, 2022a, CCAMLR, 2022b); MPA boundaries based off of previous published coordinates in Apelgren and Brooks (2021) (CCAMLR, 2017).

Adjacent to CCAMLR's MPA discussions, in 2016 CCAMLR adopted an innovative climate responsive spatial management measure. Conservation 24–04 Establishing time-limited Special Areas for Scientific Study in newly exposed marine areas following ice-shelf retreat or collapse in Statistical Subareas 48.1, 48.5 and 88.3 (CCAMLR, 2017), focused on the rapidly warming Antarctic Peninsula, provides a means to protect areas recently exposed due to ice-shelf retreat or collapse so that they can be studied. This measure provides a powerful tool to facilitate studying the most rapidly changing regions of the Antarctic and was first implemented in 2017 with a section of the Larson C Ice Shelf designated as a Special Area for Scientific Study (protected for

a ten year period, through 2028). A major calving of the Pine Island Glacier received initial designation in 2019. However, consensus could not be reached to extend its designation (CCAMLR, 2021), due to political barriers and challenges with consensus-based decision-making (see below).

Challenges in managing fisheries under climate change

While much attention has been given to the effects of climate change on ocean ecosystems across the globe, fisheries management bodies have grappled with implementing strategies to manage for climate change (McBride et al., 2021; Bryndum-Buchholz et al., 2021), and CCAMLR is no exception. Beyond barriers noted above (e.g., related to data availability, scale, capacity), this is in part due to the lack of political incentives to acknowledge and prepare for the effects of climate change (Termeer et al., 2017). Hughes et al. (2021) suggests some of the major challenges facing Southern Ocean management are: (i) helping CCAMLR policymakers understand the current and future impacts of climate change on Southern Ocean ecosystems, and (ii) successfully implementing conservation management tools to address climate change impacts at a regional level. CCAMLR is aware of the urgent need to develop climate responsive options within its ecosystem approach to management, however, factors such as limited capacity and political differences have slowed progress (Cavanagh et al., 2021b). The situation is further complicated by CCAMLR's consensus requirement. For example, while there is emphasis on the use of "best available science" to determine appropriate harvest levels (Performance Review Panel, 2017; Constable et al., 2000), there is often disagreement between CCAMLR Members about what "best available" constitutes, and a tendency to delay policy adoption in the face of scientific uncertainty (Constable, 2011). In the context of climate change, while better climate models and forecast evaluations for Antarctic ecosystems are needed (Murphy et al., 2017; Constable et al., 2014;

Brooks et al., 2018; Busch et al., 2016; Cavanagh et al., 2017; Heenan et al., 2015; Karp et al., 2019; Quentin Grafton, 2010), policymakers should not wait for the perfect scientific information – to do so would foreclose options for future decision-making and restrict the ability to manage for environmental change effectively (Press, 2021).

Furthermore, managing for climate resilience in the Southern Ocean could be improved by increasing scientists' awareness of the opportunities to inform environmental policy making within the Antarctic Treaty System (Hughes et al., 2018, 2022). This would allow for better communication across the Antarctic Treaty System and the possibility to address knowledge gaps in research and management (Hughes et al., 2018). Achieving climate resilient fisheries in the Southern Ocean will heavily rely on the co-production of knowledge to build governance and management strategies that consider the effects of climate change (Mills et al., 2022). There is an argument that CCAMLR's consensus-based decision-making approach will ultimately progress only to the level deemed acceptable by the parties least interested in reform (Pentz and Klenk, 2017). Consensus-based rules, especially when employed in multilateral conventions having members with diverse interests, such as CCAMLR, heavily favor the status quo rather than embracing adaptive approaches (Pentz and Klenk, 2017; Goldsworthy, 2022).

Some fisheries across the globe are making significant strides to manage for climate resiliency and can provide lessons learned to CCAMLR. The Australian government for example, passed a climate adaptive management strategy to enhance the resilience of fishing industries to climate change, and between 2010 and 2016, 9 million AUD were invested in preparatory research for a climate adaptation program (Bryndum-Buchholz et al., 2021). In Belize, in 2020, after decades of fisheries being managed through an open-access system, Belize adopted the New Fisheries Resource Act which incorporates an MPA program and a Managed Access Program to transition

Belize fisheries management towards long term sustainability and climate resiliency (Rader et al., 2021). However, as Bryndum-Buchholz et al. (2021) points out, none of the active fishery policies and legislations reviewed in the extensive study, including Australia and Belize, explicitly address climate change impacts or incorporate mandates to account for climate change in stock assessments.

A similar study by Sumby et al. (2021) examined RFMOs (including CCAMLR in the RFMO category) operating in "climate change hotspots" and showed that while 94% of the fisheries managers surveyed demonstrated awareness of climate change, only 41% showed some sort of action; most of which were mainly procedural and administrative, such as requesting more research, forming committees, proposing education programs etc. (Sumby et al., 2021). Of the 17 RFMOs or fisheries bodies surveyed, only two made explicit statements about incorporating climate change in their future management (Sumby et al., 2021) and CCAMLR was one of them. Other more substantive actions by RFMOs included making climate change considerations part of stock assessments, pushing for management reforms that are resilient to climate change, and reaching out to the international community for greater transparency and action against climate change (Sumby et al., 2021). However, there is very little indication that climate change management is accounted for in RFMOs fishery policy, annual decision-making, or operational regulation (Sumby et al., 2021).

The future of global fisheries has the potential to be sustainable for the long-term, but depends in part on the implications of climate change being accounted for in their management (Free et al., 2020; Gaines et al., 2018). There is a global need to develop and utilize new technologies focused on ecosystem-based principles that ultimately improve knowledge of linkages between the physical environment and biological productivity at all scales (Tin et al., 2014). CCAMLR has

taken some strong strides towards managing for climate change by adopting a climate change Resolution, committing to a network of representative MPAs, adopting Conservation Measure 24–04 to protect areas recently exposed by ice shelf collapse, progressing on a krill risk assessment, improving coordination across CCAMLR, developing a draft CCRWP, and holding an upcoming 2023 Climate Change Workshop. Continuing this work and further integrating climate resilient tools that are specific to the climate change impacts faced in the Southern Ocean will allow CCAMLR to better address the vulnerability of this system. CCAMLR has the opportunity to pave the way for other fisheries management bodies by incorporating climate change into its management (Cavanagh et al., 2021b). However, CCAMLR must move faster and with a sense of urgency to incorporate climate change considerations into its management actions, and ultimately find efficient ways to achieve consensus on climate-related measures.

Conclusion

While scientists have proposed numerous methods for climate resilient fisheries management - such as EBFM and tools such as MPAs, climate model outputs, and environmentally informed dynamic stock assessments - fishery management bodies across the globe are grappling with implementing these, and the extent of fisheries explicitly addressing climate change remains low (Bryndum-Buchholz et al., 2021; Sumby et al., 2021; Skern-Mauritzen et al., 2016). While CCAMLR has precautionary catch limits based on stock assessments and has implemented MPAs within its ecosystem approach to management, it does not yet use climate model outputs to inform its decision-making, and incorporation of climate change considerations into its management is lacking. Further, despite substantial efforts by many CCAMLR Members to propose and support progress with this, together with extensive ongoing scientific research in this area, lack of consensus and ultimately lack of political will continue to delay progress. Resilience of Southern

Ocean ecosystems to global warming will require the establishment of science-based, climate-informed, ecosystem-based management (Constable, 2022). Given the threats to the Southern Ocean posed by climate change, and that the CAMLR Convention encompasses the principles of an ecosystem-based precautionary approach, CCAMLR has an urgent responsibility to develop and implement climate resilience management tools. Ultimately, climate resilient management of the Southern Ocean will require diverse perspectives in planning and implementation (Constable et al., 2022), and will only be possible with the cooperation of all CCAMLR Member States.

With a mandate for managing marine living resources in the Southern Ocean, which comprises 10% of the global oceans, CCAMLR has the chance to lead the way on climate resilient fisheries and to be a catalyst for other ocean management bodies to follow. The tools and recommendations highlighted above provide an avenue of strategies that can facilitate a transition to climate resilient fisheries. As climate change and increased human activity across the world's oceans continues to pose a threat to fish, fisheries, and biodiversity, implementing dynamic, flexible, and forward looking tools for fishery management would facilitate fisheries resilience to climate change impacts (Free et al., 2019; 2020).

Chapter II

Protecting the Salas y Gomez and Nazca Ridges: A review of policy pathways for creating conservation measures in the international waters of the Southeast Pacific

Chavez-Molina, V., Wagner, D., Nocito, E. S., Benedum, M., Gaymer, C. F., Currie, D., Beam, E. G., & Brooks, C. M. (2023b). Protecting the Salas y Gomez and Nazca Ridges: A review of policy pathways for creating conservation measures in the international waters of the Southeast Pacific. Marine Policy, 152(March), 105594. https://doi.org/10.1016/j.marpol.2023.105594

Abstract

Seamount ecosystems host ecologically important species, including many that are found nowhere else on Earth. The Salas y Gomez and Nazca Ridges, two adjacent seamount chains in the Southeast Pacific, are biodiversity hotspots marked by the highest levels of marine endemism on Earth. Historically isolated from many human activities, this region has produced a unique biodiversity and provides an excellent opportunity for protecting a global biodiversity hotspot before it is degraded. However, no legal protection mechanism currently exists for comprehensively protecting areas beyond national jurisdiction (ABNJ) of the Salas y Gomez and Nazca Ridges. After years of negotiations at the United Nations for a legally binding instrument to address conservation in ABNJ, the Biodiversity Beyond National Jurisdiction (BBNJ) Agreement was finally agreed in March 2023. While this Agreement may provide one avenue for protecting the high seas, the Agreement has yet to be adopted and ratification may take several years. As it stands, conservation efforts in ABNJ will rest on sectoral bodies primarily set to manage large-scale industries like fishing, shipping, and mining, but that do have the ability to enact conservation measures other than restricting these industrial activities. Our study provides an overview of the major international organizations managing activities in the ABNJ of the Salas y Gomez and Nazca Ridges, identifies current conservation measures, and maps out potential policy pathways for creating conservation measures in this unique region. Our synthesis focused on identifying conservation procedures within the documents of international organizations and applying their rules and procedures to implement conservation measures. We identify three potential pathways. A regional and national pathway that relies on cooperation among international organizations spearheaded by the South Pacific Regional Fisheries Management Organization (SPRFMO), and an international pathway through the BBNJ Agreement.

Introduction

Over 60% of the ocean lies in areas beyond national jurisdiction (ABNJ) (Yadav & Gjerde, 2020), yet only 1.2% lie within marine protected areas (MPAs), ocean spaces where human activities are limited or prohibited (MPAtlas, 2022; Lubchenco et al., 2003; Lubchenco & Grorud-Colvert, 2015). Thus, the waters and seabed in ABNJ represent one of the Earth's last resource management and conservation frontiers (Ban et al., 2014). ABNJ contain 90% of the available habitat for life in our ocean (Smith & Jabour, 2018; Heffernan, 2018) and comprise most of the Earth's interconnected oceans, hosting complex ecosystems that play vital roles in sustaining life and providing goods and services (Gjerde et al., 2016). Biological diversity found within ABNJ is mostly unprotected, with mounting pressure from human activities (Gjerde et al., 2016; Yadav & Gjerde et al., 2020). Oceanic seamounts and coral ecosystems, found throughout ABNJ, are considered among the most fragile environments to anthropogenic activities and climate change (Bell et al., 2013; Friedlander & Gaymer, 2021; Mecho et al., 2019; Ramirez-Llodra et al., 2011; Wagner et al., 2020a). These habitats harbor unique ecosystems, species, and ecological processes that exist nowhere else on Earth (Wagner et al., 2020a). An integrated approach for the conservation of ABNJ is urgently needed to protect these important marine ecosystems from anthropogenic impacts (Easton et al., 2019; Gjerde et al., 2016; Mecho et al., 2019; Ramirez-Llodra et al., 2011; Wagner et al., 2021).

The Salas y Gomez and Nazca Ridges are recognized as an Ecologically and Biologically Significant Area (EBSA) by the United Nations Convention on Biological Diversity (CBD) (CBD, 2017; Wagner et al., 2020; Wagner et al., 2021; and references therein). This region is also recognized as an important area by the Global Ocean Biodiversity Initiative and the Census of Marine Life on Seamounts, highlighting its ecological value and need for protection (CBD, 2017;

Wagner et al., 2021; SPRFMO, 2021). These two adjacent seamount chains in the Southeast Pacific have the highest known level of marine endemism on Earth (CBD, 2017; Friedlander et al., 2013; Friedlander et al., 2016; Friedlander & Gaymer, 2021; Georgian et al., 2021; Mecho et al., 2019; Visalli et al., 2020; Wagner et al., 2021). Similarly, recent studies provide evidence that this region has numerous vulnerable marine ecosystems (VMEs) and endemic taxa of high natural significance and conservation value (Friedlander & Gaymer, 2021; Galvez-Larach, 2009; Georgian et al., 2021; Watling et al., 2013). The United Nations General Assembly (UNGA) has passed resolutions 61/105 & 59/25 for the identification and protection of VMEs from the effects of bottom fisheries (UNGA, 2007), and calls on States and Regional Fishery Management Organizations (RFMOs) to protect VMEs, including through the closure of fisheries (Ashford et al., 2019; FAO, 2009; Georgian et al., 2021; Ardron et al. 2014). The Food and Agriculture Organization (FAO) of the United Nations is the body responsible for setting the guidelines for the identification and conservation of VMEs, but does not hold the power to designate VMEs. The protection of VMEs centers on the presence of "distinct, diverse benthic assemblages that are limited and fragmented in their spatial extent, and dominated by rare, endangered or endemic component species that are physically fragile and vulnerable to damage by human activities" (Ashford et al., 2019, p. 2). Furthermore, UNGA resolution 64/72 specifically calls on RFMOs to implement appropriate protocols to protect VMEs from significant adverse impacts and implement FAO guidelines for the management of deep sea fisheries in the high seas (SPRFMO, 2022b). Despite international recognition towards the need for protecting the ABNJ of the Salas y Gomez and Nazca Ridges, and its diverse benthic assemblages and endemic species, this global biodiversity hotspot remains unprotected.

Ecosystems in international waters such as the Salas y Gomez and Nazca Ridges have been difficult to protect. Historically, most marine conservation measures have been developed near coastal areas within national jurisdiction (Klein et al., 2010; Olds et al., 2014; Morgan et al., 2018), which does not have the governance complexities of working within ABNJ (Gjerde et al., 2016). There continues to be a lack of awareness that globally important ecosystems exist in the remote high seas (Dight & Scherl, 1997; Durussel et al., 2017; Gjerde et al., 2016; Wagner et al., 2020a). ABNJ are characterized by a fragmented and polycentric management structure, which lacks cooperation and harmonization among global and regional actors (Ban et al., 2014; Brito-Morales et al., 2022; De Santo et al., 2018; Haas et al., 2021; Petersson & Stoett, 2022; Yadav & Gjerde, 2020). To date, only two regional sea Conventions have implemented MPAs in ABNJ (Smith & Jabour, 2018). Two MPAs have been established in the Southern Ocean by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), and several others in the Northeast Atlantic through a collective arrangement between the Oslo Paris (OSPAR) Commission and the North-East Atlantic Fisheries Commission (NEAFC) (Davies et al., 2021; De Santo, 2018; Smith & Jabour, 2018).

Unlike CCAMLR or the collective Arrangement between the OSPAR Commission and NEAFC, the Southeast Pacific lacks a regional seas Convention or Agreement. This is the case in most ABNJ, where the mandate to conserve biodiversity is divided and rests with various sectoral bodies that were primarily set up to manage large-scale industries like fishing, shipping, and mining. Historically, there has been little coordination between RFMOs and other sectoral bodies operating in ABNJ (Yadav & Gjerde, 2020), despite the overlapping issues affecting their mandates, particularly in terms of impacts to biodiversity. RFMOs have been criticized for failing to achieve their conservation objectives, with few attempts to coordinate activities, mitigate conflicts, and

address cumulative impacts, such as overfishing, bycatch, climate change adaptation, and managing shared fish stocks sustainably (Ban et al., 2014; Haas et al., 2021; Kim, 2019; Pentz & Klenk, 2020; Peterson & Stoett, 2022). Their narrow remits coupled with governance gaps and limited coordination emphasize the current challenges of managing marine ecosystems in ABNJ (O'leary et al., 2020).

Under this framework the management of the Salas y Gomez and Nazca Ridges is fragmented. Fishery resources are managed by the South Pacific Regional Fisheries Management Organization (SPRFMO) and the Inter-American Tropical Tuna Commission (IATTC). SPRFMO whose conservation remit encompasses "fish within the Convention Area, including: molluscs; crustaceans; and other living marine resources" (SPRFMO, 2015, p. 2) makes legally binding decisions on deep sea fisheries in the region (Oanta, 2018). Whereas IATTC has a conservation remit for the "conservation and management of tuna and tuna -like species, associated species and their ecosystems" (IATTC, 2022b). Unlike SPRFMO, IATTC has no competence in the field of conservation and management of deep sea fisheries (Oanta, 2018). Additionally, the International Maritime Organization (IMO) manages shipping, and the International Seabed Authority (ISA) manages seabed mining for the ABNJ of the Southeast Pacific. For the RFMOs, the United Nations Fish Stock Agreement (UNFSA), provides a set of obligations and conservation frameworks that obliges States and RFMOs to "assess the impacts of fishing, other human activities and environmental factors on target stocks and species belonging to the same ecosystem" (UNFSA, 1995, Part II Article 5d, p. 4) and assess impacts on "non-target and associated or dependent species and their environment" (UNFSA, 1995, Part II Article 6-3d, p. 4) (O'leary et al., 2020). While the UNFSA calls for the conservation of species and ecosystems in ABNJ, a lack of

comprehensive coordination between RFMOs complicates the implementation of conservation measures across the high seas (Ban et al., 2014; Gjerde et al., 2016; Maxwell et al., 2020).

To overcome these challenges, in 2015 the UNGA agreed to develop a legally-binding instrument under the United Nations Convention on the Law of the Sea (UNCLOS) on the conservation and sustainable use of marine biological diversity in ABNJ, also known as the Biodiversity Beyond National Jurisdiction (BBNJ) Agreement (UNGA, 2015; United Nations, 2022a). The BBNJ Agreement has the potential to set the basic framework via a Conference of Parties for regulating human resource use throughout the high seas, as well as a specific obligation to protect rare and fragile ecosystems (see UNCLOS articles 192 and 194(5), 1982) (United Nations, 2022b). In accordance with UNGA resolution 72/249, the conference will address "the conservation and sustainable use of marine biological diversity in ABNJ in particular, together and as a whole, marine genetic resources, including questions on the sharing of benefits, measures such as area-based management tools (ABMTs), including marine protected areas, environmental impact assessments and capacity-building and the transfer of marine technology" (BBNJ IGC4, 2022, p. 1). The BBNJ Agreement provides a potential opportunity to enhance cooperation and coordination of management bodies under one legal framework, without undermining existing legal instruments and frameworks such as RFMOs (Crespo et al., 2019; Pentz et al., 2018; Visalli et al., 2020, United Nations, 2022c). The BBNJ meetings resumed in August 2022 after the COVID-19 pandemic disrupted the timeline, but did not yet result in an Agreement, with an additional Conference of the Parties taking place in February 2023.

The BBNJ Agreement may provide one avenue for the protection of ecosystems in ABNJ in the future. However, given uncertainties about whether and when an Agreement will be reached, signed, and ratified, identifying currently available conservation measures in ABNJ is warranted

(Friedlander et al., 2021). In this paper, we define best available conservation measures as rulings that (1) are legally binding on the contracting parties of the decision making center and (2) meet the mandates outlined by their Convention. Best available conservation measures can operate within the remit of the decision making body such as mining closures (e.g., through the ISA), fishing gear restrictions (e.g., through an RFMO), or marine spatial planning through multisectoral engagement (e.g., two RFMOs or an RFMO and the ISA). While MPAs have been identified as one of the most important tools to conserve biodiversity, manage fisheries, and mitigate threats to marine systems (Brito-Morales et al., 2022; Cabral et al., 2020; Lubchenco et al., 2003; Lubchenco & Grorud-Colvert, 2015; Roberts et al., 2017 Wendebourg et al., 2020), they are not the only tool for ocean conservation, and their effectiveness rests on being well-designed and managed (Chaigneau & Brown, 2016; Edgar et al. 2014). Other tools, such as fishing closures and spatial management measures, have been successful with respect to their specific design objectives (Ban et al., 2014; Dichmont et al., 2013; Frazao Santos et al., 2020). Without the BBNJ Agreement, protection of the Salas y Gomez and Nazca Ridges - as well as the vast majority of international waters - rests on several bodies taking action.

The purpose of this study is to review information on the significance of protecting a critically important area in ABNJ –the Salas y Gomez and Nazca Ridges– and to discuss policy pathways to achieve this. This study builds on a previous review of the importance, opportunities, and challenges for protecting this unique region (Wagner et al. 2021a), by presenting a more detailed account on the legal pathways to achieve best available conservation measures of this region. Our synthesis focused on identifying conservation procedures within the documents of international organizations and applying their rules and procedures to implement conservation measures. Specifically, we identify the existing management bodies in this region and outline potential

conservation measures that could be enacted through them. Finally, we outline pathways for increasing protection, focusing on fishing, shipping, and mining, that might be enacted through national, regional or international mechanisms.

Study Area

The Salas y Gomez and Nazca Ridges consist of about 110 seamounts of volcanic origin that stretch across 2,900 km in the Southeast Pacific (reviewed in Wagner et al., 2021). The average depth of these ridges is 2,100 m, with most of the ridge ranging in depth between 2,000 - 2,500 m, but with some portions reaching into the photic zone (Galvez-Larach, 2009; Gaymer et al., 2022). Located 105 km off the coast of Peru, the Nazca Ridge stretches 1,100 km westward towards the eastern edge of the Salas y Gomez Ridge, which then stretches another 1,600 km westward towards Rapa Nui (also known as Easter Island) (Figure 1). The majority of these two ridges lie in international waters (~73%) and account for 41% of seamounts found in the Southeast Pacific (Galvez Larach, 2009). Despite its geographic proximity to Peru and Chile, the Salas y Gomez and Nazca Ridges are isolated from the South American continent by the Humboldt Current and the Atacama Trench (Roberts et al., 2017; Rogers, 2000; Von Dassow & Collado-Fabbri, 2014). As a result of its isolation and historically low levels of anthropogenic impacts, this region contains a unique biodiversity that is marked by the highest level of marine endemism on Earth (Friedlader et al. 2016; Newman & Foster, 1983; Parin, 1991; Parin et al., 1997; Poupin, 2003; Rehder, 1980; Wagner et al., 2021). Regional endemism estimates for fish and invertebrates range from 40-46.3% (CBD, 2017; UNEP, 2020; Newman & Foster, 1983; Rehder, 1980). The dominance of endemic species is unlike any place on Earth (Friedlander et al., 2016).

To date, this region has remained free from mining and largely unimpacted by international shipping commerce (Wagner et al., 2021), with industrial fishing levels remaining moderate since Soviet Union trawling for Mackerel and Pilchard in the 1970-80s (Pitcher et al., 2008). Soviet Union fisheries utilized several fishing methods including longlines, baited fish traps, and otter trawls (Parin, 1997). On average, historical fishing effort on these ridges has declined over time, with the last bottom trawl fishery having closed in the 1980s, and with no bottom fisheries developed since 1992 (SPRFMO, 2021). However, historical damage caused by bottom trawlers continues to be seen through ROV surveys (Gaymer et al., 2022). Commercial fishing continues to occur in the pelagic realms of this ecosystem, especially outside Peruvian national waters of the Nazca Ridge (Global Fishing Watch, 2022). Fishing in this area targets Skipjack Tuna (*Katsuwonus pelamis*), Bigeye Tuna (*Thunnus obesus*), Yellowfin Tuna (*Thunnus albacares*), and other pelagic species (Wagner et al., 2021). International commercial fisheries also target anchovies, squid, Jack mackerel (*Trachurus murphyi*) and Bonito (*Sarda chiliensis*) (Global Fishing Watch, 2022). Furthermore, squid jiggers have become considerably more active in this region from 2012-2020 (Gaymer et al., 2022). The vast majority of the fishing effort in this area is accounted for by vessels flagged to China (72.7% of all vessels), and to a lesser degree Spain (16.5%), and Japan (3.4%) (Wagner et al., 2021). Future fishing activities are actively being proposed (SPRFMO, 2022a).

Apart from fishing, the other major threats to this ecosystem include: marine pollution, shipping, climate change, and the potential for seabed mining (Gaymer et al., 2022; Wagner et al., 2021). Due to its proximity to the center of the South Pacific Gyre, where floating litter and debris concentrate, hundreds of species of marine vertebrates including sharks, turtles, birds, and mammals are at risk of entanglement and plastic ingestion (Gallardo et al., 2021; Gaymer et al.,

2022). Commercial shipping is relatively low (except for the northern section of the Nazca Ridge which intersects with a major international shipping route), but this region has been identified as a potential trans-shipment route for distant water fleets (Gaymer et al., 2022; Wagner et al., 2021). This could potentially threaten thousands of species via collision, light pollution, noise pollution, and biological invasions (Gaymer et al., 2022; O'leary et al., 2020). The nutrient poor waters of the Nazca Ridge make this region extremely susceptible to climate change and anthropogenic disturbances. Under predicted climate change scenarios, the seafloor will experience an increase in temperature, pH, and dissolved oxygen, making it inhabitable to many endemic species and ultimately threatening the biodiversity and biogeochemistry of the region (Cheung & Levin, 2018; Dewitte et al. 2021; Gaymer et al., 2022). Lastly, there are known cobalt-rich crusts throughout the ridges, which could attract mining interest (Gaymer et al., 2022). While there are currently no mining contracts in this region, and no mining contracts have yet been leased, the potential for future mining remains uncertain. Protecting the Salas y Gomez and Nazca Ridges from current and potential threats will lead to major global benefits including ecosystem connectivity, climate change regulation and food security (Gaymer et al., 2022). Likewise, threat mitigation is only one of many reasons to conserve a region or set up a protected area - many areas are protected based on their immense ecological value (regardless of threat).

Management Bodies

Fishing and shipping are the primary current activities, with mining as an emerging activity, within the ABNJ of the Southeast Pacific. All are governed by a suite of organizations. Each of these organizations has a distinct decision-making body which is represented by Member States. Without the BBNJ Agreement in place, the application of best available conservation measures in the ABNJ of the Salas y Gomez and Nazca Ridges rests on these organizations (see Table 2.1).

Table 2.1 List of primary international organizations involved in the management of the primary activities (i.e., fishing, shipping, and mining) within the ABNJ jurisdiction of the Salas y Gomez and Nazca Ridges.

Organization	Abbreviation	Area of Interest	Description
South Pacific Regional Fisheries Management Organization	SPRFMO	South Pacific high seas	RFMO of 15 Member States responsible for conservation and sustainable use of fisheries resources (manages all benthic, demersal, and pelagic species, except for tuna and tuna-like species) in the South Pacific Ocean
Inter American Tropical Tuna Commission	IATTC	Eastern Pacific Ocean (high seas and areas under national jurisdiction)	RFMO of 16 Member States responsible for the long-term conservation and sustainable management of tuna and tuna-like species in the Eastern Pacific Ocean.
International Seabed Authority	ISA	Global seabed in the high seas	Autonomous international organization established under the 1982 United Nations Convention on the Law of the Sea responsible for overseeing all mineral-resources-related activities with a mandate to ensure the effective protection of the marine environment from harmful effects that may arise from deep-seabed related activities.
International Maritime Organization	IMO	Global oceans	United Nations specialized agency with responsibility for the safety and security of international shipping and the prevention of marine and atmospheric pollution by ships.
Permanent Commission on the South Pacific	CPPS	Primarily national waters of Chile, Colombia, Ecuador, and Peru, but also adjacent regions of the high seas	Maritime organization that coordinates regional maritime policies in order to adopt concerted positions of its Member States (Chile, Peru, Ecuador and Colombia) in international negotiations, development of the Law of the Sea, International Environmental Law and other multilateral initiatives, including MPAs.

Cooperation among these organizations is vital for the effective conservation of the Salas y Gomez and Nazca Ridges (Ban et al., 2014; De Santo et al., 2018), but has proven difficult due to lack of effective coordination and policy integration across agreements (Petersson & Stoett, 2022,

Velazquez Gomar 2016). SPRFMO is the major management body for benthic, demersal, and pelagic fisheries (e.g., Jack Mackerel (Trachurus murphyi), squids and deep-sea fishes) in the high seas of the South Pacific. On the other hand, IATTC covers tuna and other highly mobile species. Overlapping membership of these two RFMOs, (sharing eight members: China, Colombia, Ecuador, Panama, Peru, South Korea, U.S.A., and Vanuatu) has the potential to enhance political will, promote ownership over coordination, and increase policy coherence (Petersson & Stoett, 2022). For example, for IATTC, UNCLOS includes tuna species in the category of "highly migratory species" which are governed under Article 64 of UNCLOS which establishes the duty to cooperate with appropriate international organizations to ensure conservation beyond the Exclusive Economic Zones (EEZs) of Nation States (UNCLOS, 1982). Therefore, if the IATTC is tasked with ensuring the conservation and sustainable management of tuna species, cooperation with other international organizations will be essential for achieving its Convention's goals.

Enhancing cooperation among existing structures through cross-sectoral work among international organizations with mandates to regulate all human activities is crucial for the conservation of ABNJ (Petersson & Stoett, 2022; Velazquez Gomar, 2016). As such, an ecosystem approach is required, in which all users of the ocean operating within the Salas y Gomez and Nazca Ridges (Figure 2.1) collaborate to strengthen the effectiveness of area-based management tools in ABNJ to prevent adverse impacts on biodiversity as a whole (Barnett & Basket, 2015; Crespo et al., 2019; Fanning & Mahon, 2020; Gjerde et al., 2016).

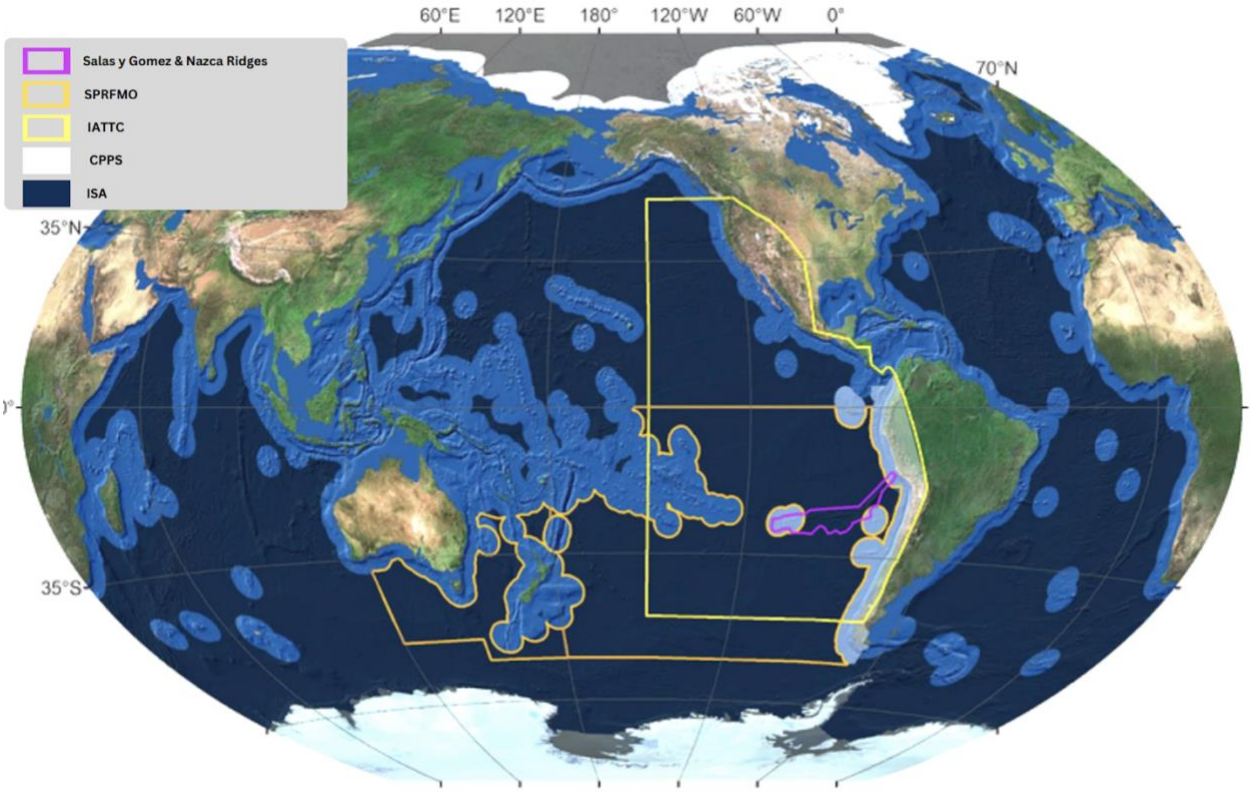

Figure 2.1 International management organizations operating within the boundaries of the Salas y Gomez and Nazca Ridges (highlighted in purple), which extend from Peruvian national waters to Chilean waters around Rapa Nui Island. The South Pacific Regional Fisheries Management Organization (SPRFMO) is highlighted in orange and its management extends from Southern Australia to South America's Pacific coast. The Inter-American Tropical Tuna Commission (IATTC) is highlighted in yellow and extends throughout the eastern Pacific Ocean, from Canada, in the north, to Chile, in the South. The Permanent Commission for the South Pacific (CPPS) is highlighted in white, and its management extends throughout the EEZs of Colombia, Ecuador, Peru and Chile. The International Seabed Authority (ISA) is the darker blue background that extends across all the ABNJ in the world's oceans. The International Maritime Organization (IMO) is not included in the figure because it applies to the whole ocean. See Wagner et al. (2021b) for source details on map layers.

Results and Discussion

Below, we first outline existing conservation policies; we then introduce ongoing conservation proposals; and finally, we outline potential policy pathways for the Salas y Gomez and Nazca Ridges. Our policy analysis, based on the policies and Conventions in place, resulted in three

distinct pathways to implement conservation measures in the ABNJ of the Salas y Gomez and Nazca Ridges. The first two pathways involve (1) regional and (2) national approaches that rely on cooperation among international organizations spearheaded by SPRFMO. The third pathway involves an international approach, which based on our analysis, seems to be the most comprehensive. We finish with additional conservation pathways (outside the scope of the major international organizations operating in this region).

Existing conservation measures

The Salas y Gomez and Nazca Ridges were recognized as an EBSA in 2014 (CBD, 2017; UNEP, 2020). While EBSAs are recognized as marine areas that are in need of protection or enhanced management, the EBSA status does not in itself provide protection or management. The responsibility of protecting the region encompassed by the EBSA falls to the States and management bodies which govern the area.

Peru and Chile, in accordance with the EBSA designation, have created protected areas within their EEZs of this region. In June 2021, Peru designated the Nazca Ridge National Reserve, which encompasses 62,392 km2, which amounts to the entirety of the seafloor portion of the EBSA that lies in Peru's EEZ (Wagner et al., 2021). However, the Peruvian government allows for industrial fishing over two seamounts within the reserve, and the concept of "reserve" under Peruvian legislation does not imply a non-take area. Similarly, in the past decade, Chile has designated three large-scale protected areas that encompass the entirety of the EBSA within their EEZ: the Motu Motiro Hiva Marine Park (a fully no-take MPA that protects 150,000 km2 around Salas y Gomez Island), the Rapa Nui Coastal and Marine Multiple-Use MPA (a multi-use area that bans industrial fishing and deep-sea mining for 579,368 km2 around Rapa Nui Island), and the Nazca

Desventuradas Marine Park (a fully no-take MPA that protects 300,035 km2 around San Ambrosio and San Felix Islands) (Easton et al., 2019; Friedlander & Gaymer, 2021; Wagner et al., 2021). While Peru's Nazca Ridge National Reserve and Chile's offshore island ecosystems are under protection (Friedlander & Gaymer, 2021), the remaining areas (~73%) that exist within ABNJ lack legal protections (Figure 2.2).

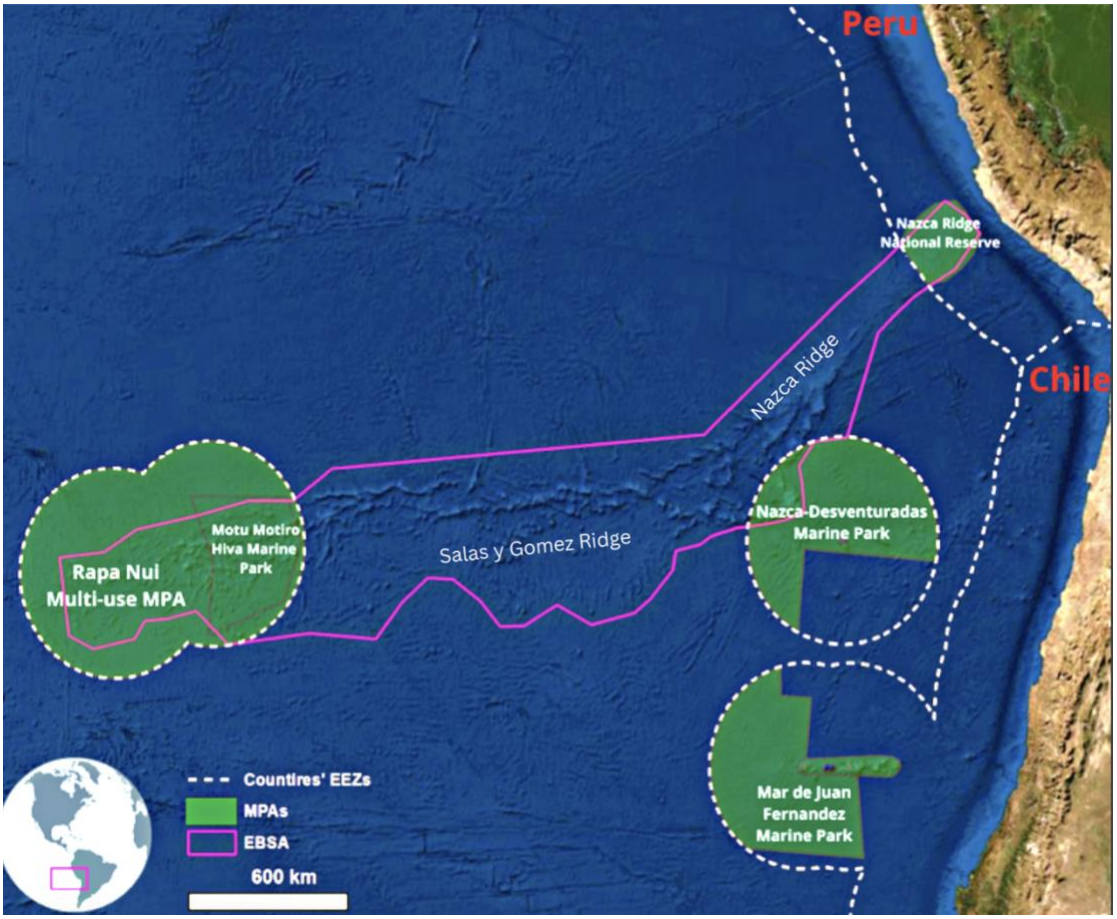

Figure 2.2 The Salas y Gomez and Nazca Ridges were designated as an Ecologically and Biologically Significant Area (EBSA) (outlined in purple) by the Convention on Biological Diversity (CBD). Established marine protected areas (MPAs) within the jurisdiction of Peru and Chile are highlighted in green. The dotted lines represent the Exclusive Economic Zones (EEZs) of Peru and Chile.

Current Conservation Proposals

In an attempt to protect the ABNJ of Salas y Gomez and Nazca Ridges, a group of experts from academic and non-governmental organizations grouped in the Coral Reefs of the High Seas Coalition (www.coralreefshighseas.org) presented a proposal for a fishing closure in the SPRFMO area in 2020 that encompassed the EBSA area of the high seas (Wagner et al., 2020b). Building on this proposal, in 2021, Chile subsequently put forward a paper at the 9th meeting of SPRFMO's Scientific Committee on the importance of protecting the high seas of this region (SPRFMO, 2021). More recently, at the 10th meeting of SPRFMO's Scientific Committee in 2022, the Chilean delegation, together with the Coral Reefs of the High Seas Coalition submitted a revised paper again calling for a fishing closure across the EBSA (Gaymer et al., 2022). The authors recommended: (1) the ABNJ classified as an EBSA should be closed to fishing activities and regulated by SPRFMO; (2) SPRFMO should collaborate with other international organizations to ensure best available conservation measures, including with IATTC and CPPS; (3) SPRFMO should not accept any proposals for exploratory fishing in the EBSA area; and (4) research and capacity development activities should be expanded to support further scientific understanding (Gaymer et al., 2022). Chile recommended the SPRFMO Commission to "carefully consider the scientific value of the information provided in this report, and to explore management and conservation options, including area-based measures" (SPRFMO, 2021, 3).

In response to the proposal, the Scientific Committee noted that a fishing closure across the EBSA would affect an exploratory lobster trap fishery run by the Cook Islands, which is managed under SPRFMO arrangements (SPRFMO, 2022a). The Scientific Committee further suggested that Chile's proposal did not demonstrate that a lobster trap fishery would cause irreparable harm to the Salas y Gomez and Nazca Ridges. However, other research in this region has documented that lobster trapping has destroyed long-lived (hundreds of years old) corals (e.g., black corals,

classified as VME indicator species by SPRFMO CMM 03-2022 and the FAO (Gaymer et al., 2022). Ultimately, the Scientific Committee suggested the need for additional research to explore the location and threats to VMEs before revisiting Chile's fishing closure proposal (Gaymer et al., 2022; SPRFMO, 2022a).

Potential Conservation Pathways

Developing policy pathways for best available conservation measures requires an understanding of the governance framework in ABNJ of the Southeast Pacific. There are multiple stakeholders across varying geographic scales that have purview over the management of activities in the Salas y Gomez and Nazca Ridges (Figure 2.3). The United Nations sits at the top as the leading international body for global governance (Kumar, 2020) and forms the foundation for all international bodies below it (Figure 2.3). There are other international bodies such as the IMO, CBD, FAO, ISA, as well as existing Conventions and Agreements like UNCLOS (which established the current legal framework for all marine and maritime activities) and UNFSA (a multilateral treaty under the UN that focuses on enhancing cooperative management of highly migratory and straddling stock fishery resources). International bodies in this region are responsible for managing large-scale industries like mining and shipping, but they are also responsible for designating conservation classifications such as EBSAs (designated under CBD), VMEs (for which the FAO lists the guidelines for identification and conservation of VMEs, but legal protection rests on States and RFMOs under UNGA resolution 61/105 and 59/25), particularly sensitive sea areas (PSSAs) (designated under the IMO), and areas of particular environmental interest (APEIs) (designated under the ISA) (Figure 2.3). Furthermore, the existing Conventions and Agreements have led to the establishment of RFMOs such as SPRFMO (in 2012). IATTC, however, was established in 1949, well before the 1995 UNFSA conference that directed

UNCLOS signatories to establish RFMOs as a means to achieve the fishery and conservation objectives outlined in the UNCLOS text (Zacharias & Ardron, 2020). These RFMOs are then represented by Member States, such as Peru and Chile.

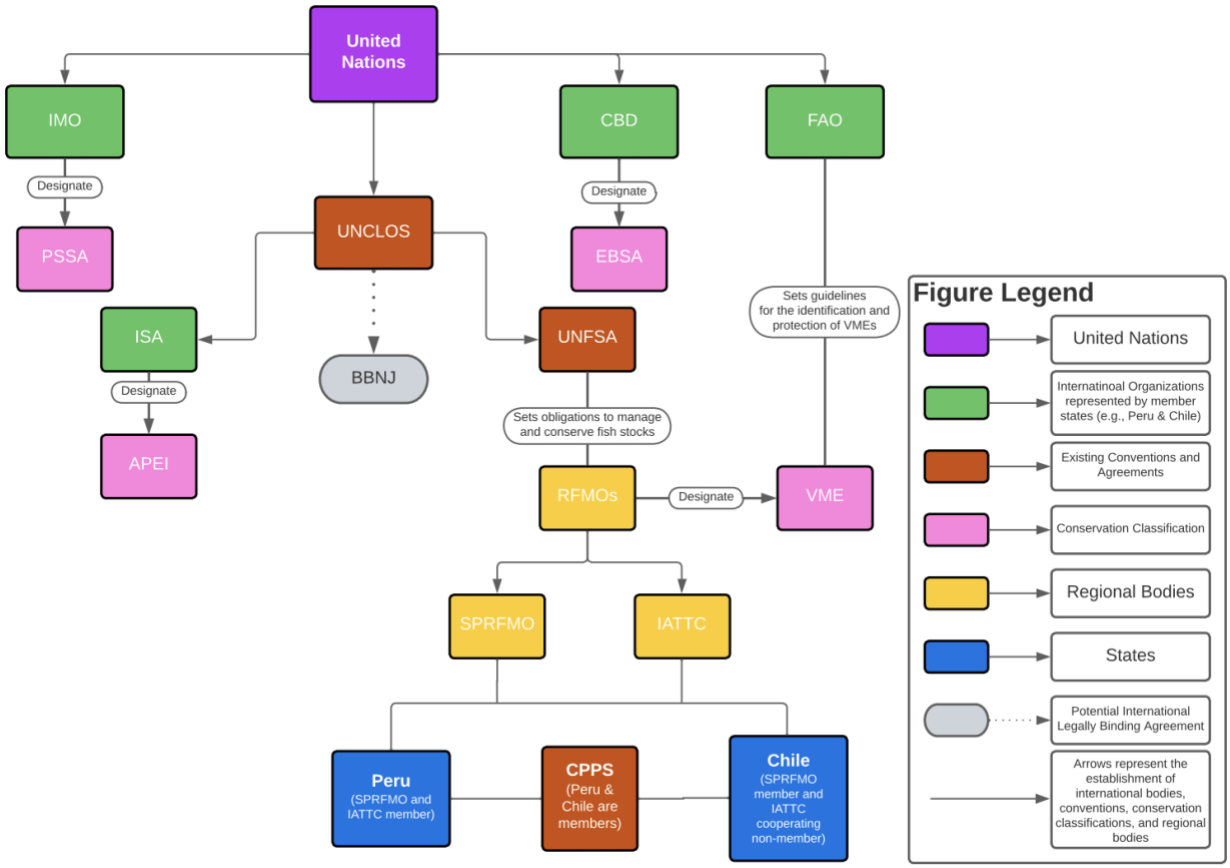

Figure 2.3 Diagram showcasing the international organizations (purple, green, orange, and yellow) that manage activities in the ABNJ of the Salas y Gomez and Nazca Ridges, and the process that led to their establishment (represented by arrows). The purple box represents the United Nations, with green boxes representing international bodies, orange boxes representing existing Conventions and Agreements at both the international and regional scale, and gray boxes representing potential Agreements currently under negotiations (Biodiversity Beyond National Jurisdiction (BBNJ) Agreement). Yellow boxes represent Regional Fisheries Management Organizations (RFMOs), with blue boxes representing individual Member States to the RFMO (connected by lines). Pink boxes represent different conservation classifications designated by either international or regional bodies. Note: this diagram does not show all connections or partnerships between international bodies and Member States (e.g., Peru and Chile are members of the ISA, IMO, CBD, and FAO). Instead, this figure shows the processes that led to the

establishment of international and regional bodies that have the capacity to designate or implement conservation classifications in the Salas y Gomez and Nazca Ridges.

Regional Pathways

Regional coordination among SPRFMO and IATTC could lead to a concrete pathway for increasing conservation measures for protecting the ecosystems and marine living resources in ABNJ of the Salas y Gomez and Nazca Ridges, and is mandated under UNFSA Part III Article 8. Under Article 20 of the SPRFMO Convention, the Commission is able to implement fishing closures or "the general or specific locations in which fishing may or may not occur" (SPRFMO Article 20, 2015). Similarly, IATTC can apply spatio-temporal fishing closures and restrict purse-seine fishing vessels (IATTC, 2022a; Gaymer et al., 2022). While neither of these approaches equate to an MPA sensu stricto, closing the Salas y Gomez and Nazca Ridges to fishing would add a strong layer of protection for the ecosystem (Gaymer et al., 2022). While SPRFMO and IATTC have never established a joint fishing closure, SPRFMO and IATTC signed a Memorandum of Understanding in 2022 to ensure the objectives of the Antigua Convention and promote cooperation and collaboration in order to advance their respective objectives, particularly with respect to matters of common interest (MOU, 2022). This is a promising step towards the implementation of collaborative conservation measures in ABNJ of the Salas y Gomez and Nazca Ridges.

Fishing closures alone would not be able to protect the whole ecosystem. To achieve full protection, no impact from extractive or destructive activities of both the water column and underlying bottom (Grorud-Colvert et al., 2021), cross-sectoral work on area-based management as well as cooperation with organizations with global mandates such as the IMO and ISA will be necessary (De Santo, 2018; Fanning & Mahon, 2020; Galvez-Larach, 2009). For example,

exploration and exploitation of seabed minerals in the Southeast Pacific requires approval of the ISA. The ISA can also designate both preservation reference zones (PRZs) and areas of particular environmental interest (APEIs), in which mining is prohibited (De Santo, 2018). Similarly, the IMO can designate PSSAs, which may include environmental protection measures, including areas to be avoided by all ships, or by certain classes of ships (De Santo, 2018). The designation of PRZs, APEIs and PSSAs is particularly important for the Salas y Gomez and Nazca Ridges given the unique and fragile species that are known to exist on its seabed and overlying water column (Parin et al., 1997; Friedlander et al., 2021; Georgian et al., 2021), and the widespread environmental impacts that would result if large-scale activities were to take place over these sensitive habitats (Miller et al., 2018b). To ensure that human activities are not harming the Salas y Gomez and Nazca Ridges, coordination between all sectoral bodies with jurisdiction over this entire region will be necessary.

SPRFMO and IATTC

Both SPRFMO and IATTC have the ability to enact conservation measures within their Convention policies. The SPRFMO Convention affirms that its conservation measures are compatible with those of the United Nations and the Member States party to their Convention (see SPRFMO Article 31, and Article 4, 2015). This provides two important pathways for the protection of the Salas y Gomez and Nazca Ridges: 1) a regional pathway that relies on political compatibility with international organizations with jurisdiction over this region (described below), and 2) a national pathway (discussed on the next section) that relies on extending Peru's and Chile's conservation measures to the high seas under the SPRFMO Convention.

Article 31 of the SPRFMO Convention stipulates that the Commission shall cooperate with the FAO and specialized agencies of the United Nations on matters of mutual interest, and that the Commission shall take account of conservation and management measures adopted by international organizations "that have competency in relation to the Convention Area" (SPRFMO, 2015, p. 31). The Salas y Gomez and Nazca Ridges fit this category as a recognized EBSA by the CBD, making it a matter of "mutual interest" under the SPRFMO Convention (CBD, 2017; UNEP, 2020). Article 31 of the SPRFMO Convention stipulates a regional pathway to establish CMMs in this region based on compatibility between SPRFMO and conservation classifications designated by the CBD (Figure 3).

While the VME indicator species are widespread across the region (CBD, 2017; Friedlander & Gaymer, 2021; Friedlander et al., 2021; Galvez-Larach, 2009; Georgian et al., 2021; Wagner et al., 2020a; CBD, 2017) neither SPRFMO or IATTC have classified areas within this region as VMEs. Multiple studies have identified species across the Salas y Gomez and Nazca Ridges that are listed as VME indicators under SPRFMO CMM 03-2022 (CBD, 2017; Friedlander & Gaymer, 2021; Friedlander et al., 2021; Galvez-Larach, 2009; Georgian et al., 2021; Wagner et al., 2020a; CBD, 2017). Annex 5 of SPRFMO CMM 03-2022 lists stony corals, black corals, anemones and hexacorals as VME indicator species, all of which have been identified in the region (Friedlander et al., 2021; Georgian et al., 2021). FAO guidelines for high seas deep-sea fisheries (FAO, 2009), specifically outline the process for identification and protection of VMEs (Watling et al., 2013), but designation of VMEs in the ABNJ of the Salas y Gomez and Nazca Ridges has yet to be implemented.

The objective of SPRFMO CMM 03-2022 includes the prevention of significant adverse impacts on VMEs (CMM 03, 2022; SPRFMO, 2021). Significant adverse impacts are defined by the FAO

as “those that compromise the ecosystem integrity (structure and function), i.e. impairs the ability of populations to replace themselves, degrades the long-term natural productivity of the habitat, or causes significant loss of species richness, habitat or community type on more than a temporary basis” (FAO, 2017, p. 1). UNGA resolution 59/25 mandates RFMOs, such as SPRFMO, to protect VMEs (Georgian et al., 2021). In response to the 2004 UNGA resolution 59/25 and more recently the 2011 UNGA resolution 66/68 (focused on the management of bottom fisheries in ABNJ), several management bodies across the world have established area closures to protect VMEs (O’Leary et al., 2020). For example, CCAMLR has designated 61 VMEs in the Southern Ocean. While SPRFMO Members have been informed of the presence of VMEs across the Salas y Gomez and Nazca Ridges, have a legal mandate to follow UNGA resolution 61/105 and 59/25 to protect VMEs and the conservation guidelines outlined by the FAO, however, SPRFMO has yet to designate any VMEs in this region. Furthermore, SPRFMO has not designated any VMEs within its jurisdiction. As written, SPRFMOs CMM 03 would still allow for deep sea trawling in areas potentially designated as VMEs (DSCC, 2021). The 2023 amendment to CMM 03 included a new procedure to identify and register VMEs and ensure the Management Area boundaries are updated to exclude the VME from areas open to fishing (personal communication, Ducan Currie, February 2023). The conservation classification of the Salas y Gomez and Nazca Ridges as an EBSA by the CBD coupled with the mounting scientific evidence to protect VMEs in this region (CBD, 2017; Friedlander & Gaymer, 2021; Georgian et al., 2021; Friedlander et al., 2021) justifies the use of SPRFMO Article 31 combined with Article 20 as a pathway for the protection of this region.

SPRFMO and IATTC have the responsibility to conserve and manage natural resources (UNFSA Part II Articles 5 and 6) as well as the mandate to not only conserve species targeted by fisheries under their jurisdiction (CMM 03, 2022 SPRFMO Articles 3(1)(a)(i) and (vii), Resolution C-22-

02 IATTC, 2022a), but the entirety of the Salas y Gomez and Nazca Ridges. Under its collaborative arrangements, and their recent MOU agreement, if SPRFMO implements a fishing closure, it should, in principle, be possible to create an analogous fishing closure for IATTC (Fanning and Mahon, 2020; Gaymer et al., 2022). To strengthen regional conservation, fishing closures that apply to both RFMOs and not just SPRFMO, would protect the entirety of fish species in the ecosystem potentially targeted by fisheries. At the 73rd meeting of IATTC, Member States created a capacity building plan which clearly states that IATTC should support cooperation with relevant fishery management organizations to promote international conservation measures (IATTC 73, 2005) such as the protection of EBSAs and VMEs. A conservation partnership between SPRFMO and IATTC would allow for a stronger protection of the ecosystem as no significant human activities aside from fishing currently take place in this region.

National Pathways

As noted above, Peru and Chile have effectively responded to the United Nations designation of the Salas y Gomez and Nazca Ridges as an EBSA by implementing several protected areas within their EEZs (Castellanos-Galindo et al. 2022; Friedlander & Gaymer, 2021; SPRFMO, 2021). Peru, Chile or any one other country, however, do not have the authority to designate protected areas outside their national jurisdiction.

Article 4 of the SPRFMO Convention states that "conservation and management measures established for the high seas and those adopted for areas under national jurisdiction shall be compatible in order to ensure conservation and management of straddling fishery resources in their entirety" (SPRFMO, 2015, p. 5). As noted above, the Chilean Government has taken a leadership role in this by submitting a document to the SPRFMO Scientific Committee advocating for the

usage of Article 4 to ensure conservation compatibility with Chile's protected areas (SPRFMO, 2021). However, the ABNJ of the Salas y Gomez and Nazca Ridges remain unprotected. Article 4 clearly indicates that if coastal States take the initiatives to protect ecosystems within their jurisdiction, as Peru and Chile both have with the creation of protected areas (Figure 2), then the Convention has the responsibility to "ensure conservation compatibility beyond their national jurisdiction to match the conservation measures implemented at a national scale" (SPRFMO, 2021). Under this Convention provision, Peru and Chile can request an extension to their protected areas under SPRFMO fishery management measures, such as spatial and temporal closures for bottom fisheries (CMM 03, 2022) in the ABNJ that border the protected areas in their EEZs. Under resolution C-22-05 IATTC can also apply a similar strategy by implementing a purse-seine fishing closure for tuna species (IATTC, 2022a). Both regionally and nationally, the SPRFMO Convention alludes to the protection of ecosystems in international waters through Article 31 and Article 4, and coordination with IATTC would allow for a stronger conservation measure.

International Pathways

There are several international pathways for the implementation of conservation measures in the ABNJ of the Salas y Gomez and Nazca Ridges. However, the most robust pathway relies on the finalization and ratification of the BBNJ Agreement, which at the time of writing, is still being negotiated. Once negotiations for this Agreement conclude and the Agreement enters into force, bringing into existence the BBNJ bodies, this pathway could serve as the most effective and likely path for the protection of the Salas y Gomez and Nazca Ridges. However, this process could take many years, during which harm to the unique ecosystems of the region could occur.

The BBNJ Agreement will be an implementing Agreement for UNCLOS (Gjerde et al., 2022), and the current RFMOs operating within the boundaries of the Salas y Gomez and Nazca Ridges which are mandated by the UNFSA Agreement (Figure 3). A policy pathway for conservation proposals under the BBNJ Agreement could provide the most comprehensive and encompassing conservation measure. The current BBNJ Agreement text under negotiation aims to invite participation from all relevant stakeholders, such as regional and sectoral bodies and frameworks, which would include the International Whaling Commission (IWC) and RFMOs such as SPRFMO and IATTC, among others (United Nations, 2022c). While the text of the BBNJ Agreement is not yet finalized, the 2015 Working Group report that led to the recommendation of the BBNJ Agreement emphasized that the new legally binding instrument enhances cooperation and coordination among regional and sectoral bodies operating within ABNJ (United Nations, 2015).

To date, discussions on how to structure institutional arrangements for BBNJ continue to be at the forefront of the negotiations. Global, regional and hybrid approaches have emerged as the major models for institutional arrangements, with the global model enabling the international community to adopt a more prompt and comprehensive approach to establish conservation measures in the high seas that apply to all sectoral bodies (Clark, 2020). This would allow for an overarching protection of the high seas, and apply to the ISA, IMO and all RFMOs in the Southeast Pacific.

Additional Conservation Pathways

While the regional, national, and international pathways identified in our study provide comprehensive approaches to the conservation of ABNJ of the Salas y Gomez and Nazca Ridges, additional international conservation measures could be enacted by other bodies that regulate human activities across international borders, including those of the high seas (Ardron & Warner,

2005). Among others these include the International Whaling Commission (IWC), which regulates whaling, the Inter-American Sea Turtle Convention, which oversees the protection and conservation of sea turtles, the London Convention and Protocol, which regulate the dumping of wastes in the ocean (London Convention, 1972; London Protocol, 1978), and the Convention on Migratory Species, which seeks to conserve migratory species, their habitats and migratory routes (CMS, 1979). Conservation of the natural and cultural resources located in ABNJ of this region (Wagner et al., 2021; Delgado et al., 2022; and references therein) could also be promoted through the World Heritage Convention. While this convention can be applied to all of Earth's outstanding natural and cultural places, to date it has not been applied within international waters (Laffoley et al., 2017). Research has shown that the high seas and deep seabed of the Salas y Gómez & Nazca Ridges meets several of the criteria of Outstanding Universal Value for inscription under the World Heritage Convention (Wagner et al., 2021; Delgado et al., 2022; and references therein). Thus, this area could in theory be inscribed under the Convention, which would not only provide potential financial support, but also encourage States Parties to enhance their protection through educational and information programs.

Similarly, the CPPS could also play an important role in advancing conservation measures in the ABNJ of this region. Article 4 of the CPPS Convention gives it the competence to promote conservation of marine living resources beyond national jurisdiction (Durussel et al., 2017). Given the large number of floating pollutants surrounding the Salas y Gómez and Nazca Ridges transported through the South Pacific Gyre (Gennip et al. 2019), CPPS could play an important role in helping to address this issue. Specifically, it could encourage its Member States to implement coordinated measures to increase garbage collection systems in coastal municipalities,

eliminate discharges from vessels including through improved port waste reception facilities, and reduce the widespread use of disposable materials that could eventually become marine debris.

Conclusion and Broader Implications

Our process for identifying regional and national policy pathways for protecting the Salas y Gomez and Nazca Ridge can be applied to all international waters across the globe. While our study focused on the Southeast Pacific, this same approach can be applied to all oceans that are not governed by a commission such as CCAMLR and OSPAR with competence for MPAs. Identifying stakeholders, their partnerships and collaborations, and more importantly the rules, policies and regulations within their conventions and possible MOUs, is crucial for setting policy pathways for conservation measures in ABNJ.

Even when BBNJ negotiations are concluded and the Agreement enters into force, competent management organizations and their stakeholders in the Southeast Pacific will remain active within their competent areas, and potentially, within the BBNJ Conference of the Parties as well. The Agreement aims for universal participation of stakeholders and shall not undermine existing international frameworks and bodies. Specifically, RFMOs as well as mining, and shipping organizations will continue to manage large-scale industries with direct effects to ocean ecosystems in ABNJ. Regional and national policy pathways demonstrate that intergovernmental organizations are already able to implement conservation measures within their own competence. Measures like fishing or mining closures, or bans on shipping routes, will have immediate benefits for ocean ecosystems. International organizations with competence in ABNJ have the opportunity to safeguard and protect the resources and ecosystems they operate within. Waiting for the bureaucratic process of international treaties can often be time consuming and slow. Applying the

precautionary approach, international organizations have the ability to apply their best available conservation measures without the help of BBNJ. Likewise, several RFMOs such as SPRFMO, already mandate a precautionary and ecosystem based approach to fishery management (CMM 13, 2021). Protecting the Salas y Gomez and Nazca Ridges could have major benefits for ecosystem connectivity, climate regulation, food security, and ecosystem services for neighboring States like Peru and Chile, but also globally (Bell et al., 2013; Boteler et al. 2022; Brander et al., 2020; Burden & Fujita, 2019; Miller et al., 2018a; Roberts et al., 2017; Sumaila et al., 2015; Wagner et al., 2021; Yadav & Gjerde, 2020).

These three pathways (regional, national, and international) represent current opportunities for protection of the ABNJ of the Salas y Gomez and Nazca Ridges. The current fragmentation of management in the Southeast Pacific will require international organizations to collaborate with one another to achieve the best available conservation measures. Identifying policy pathways within individual organizations as well as the opportunities for them to collaborate will become even more important as climate change and increased human activity in the high seas threatens these isolated and unique ecosystems.

Chapter III

Subsidizing the Deep Blue: A Comprehensive Analysis of Southern Ocean Fishery Subsidies, and the Economics of Distant Water Fleets

Chavez-Molina, V., Miller, S., The, L., Sumaila, R., Francis, E., Brooks, C. (2024). Subsidizing the Deep Blue: A Comprehensive Analysis of Southern Ocean Fishery Subsidies, and the Economics of Distant Water Fleets [Manuscript Submitted for Publication to Frontiers in Ocean Sustainability, Marine Governance Sep. 20, 2024].

Abstract

Across the high seas, distant water fisheries have benefited from government subsidies, i.e., public funds directed towards supporting the fishery sector have enabled these fisheries to extend their range and duration at sea, directly threatening fish populations and the health of ocean ecosystems. Fuel subsidies have been identified as the primary form of subsidy, often allowing fishing vessels to continue operations despite declining revenues. While significant attention has been directed towards understanding fishery subsidies and their impacts on ocean health on a global scale, no studies have comprehensively analyzed the magnitude of fishery subsidies in the Southern Ocean. The Southern Ocean accounts for approximately 6% of the global oceans by area, and its two main fisheries, krill and toothfish, are managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). Through primary data collection in the form of interviews, our study provides a comprehensive analysis of the complex operations that underpin Southern Ocean fisheries. Our research drew upon 29 expert interviews with industry representatives, government officials, and researchers from 13 CCAMLR Member States engaged in fishing activities in the Southern Ocean. The most commonly identified subsidies in our interviews included fuel subsidies, tax breaks, discounted loans, research, development, and innovation grants, infrastructure support, and import subsidies. However, our results show that only a minority of Southern Ocean fisheries heavily depend on government subsidies, with subsidy allocation varying greatly by country. For the majority of CCAMLR Member States, our findings indicate that Southern Ocean fishery subsidies are largely insufficient to induce significant changes in fishery operations. Instead, private fishery organizations continually adjust their economic strategies and operational dynamics to increase profitability and lower expenses, often foregoing

government subsidies by relocating their operations (e.g., home ports) to foreign countries closer to the Southern Ocean.

Introduction

Fishery subsidies have garnered significant global attention as key funding mechanisms for distant water fisheries (DWF) (Sala et al., 2018; Schuhbauer et al., 2017, 2020; Skerritt & Sumaila, 2021a). Reports indicate that DWF receive subsidies amounting to up to 40% of their catch value, suggesting that without such financial support, these fleets might not be profitable (Skerritt & Sumaila, 2021a). In areas beyond national jurisdiction (ABNJ) (i.e., the high seas), ocean areas that lie beyond the 200 nautical mile jurisdictional limit of countries it is estimated that 54% of fishing grounds would be unprofitable without subsidies (Sala et al., 2018). This is underscored by the World Trade Organization's (WTO) 12th Ministerial Conference (MC12) Agreement, which aims to prohibit harmful fishery subsidies, which are typically categorized as capacity enhancing, beneficial, or ambiguous based on their impacts on fish stocks (Andreoli et al., 2023; Skerritt & Sumaila, 2021b; Sumaila et al. 2010). Capacity enhancing subsidies are often regarded as those that encourage excessive fishing by reducing fishing costs or fish price, thus artificially increasing profits. Ambiguous subsidies can either contribute to sustainable management or to the overexploitation of resources, depending on how they are implemented (Sumaila et al., 2019). Beneficial subsidies, in the eyes of sustainability, are considered investments that promote the sustainable management of fishery resources, such as those supporting the establishment and maintenance of protected areas (Andreoli et al., 2023). Capacity-enhancing subsidies represent the largest subsidy category, with an estimated total of over US$22 billion in 2018 (Sumaila et al., 2019). Within this category, fuel subsidies constitute the largest subsidy type, accounting for 22% of global subsidies (Sumaila et al., 2019).

DWF, which operate outside their Exclusive Economic Zones (EEZ) or in ABNJ are largely dominated by a small number of fishing nations (Sala et al., 2018). This is particularly evident in the Southern Ocean, the waters surrounding Antarctica, which represents approximately 6% of the global ocean by area and hosts some of the most remote and inaccessible fisheries worldwide (Brooks et al., 2022). Unlike most fisheries operating in ABNJ, which are managed by regional fishery management organizations (RFMOs), the Southern Ocean fisheries are managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). Through carrying out the provisions of the Convention on the Conservation of Marine Living Resources (CAMLR Convention), CCAMLR imposes stringent conservation measures on its 26 Member States, along with the European Union. Its Convention effectively mandates the principles of an ecosystem-based precautionary approach for the conservation of Antarctic marine living resources (Chavez-Molina et al., 2023; Constable et al., 2000). The Convention Area encompasses all waters south of the Polar Front. While most of these waters are considered ABNJ, some of the northern parts of the Convention Area include subantarctic islands, some of which have uncontested sovereign rights (CAMLR Convention 1980, Chairman's Statement). These include Prince Edward and Marion Islands, Crozet Islands, Kerguelen Islands, and Heard and McDonald Islands, which have EEZs surrounding them.

Within the scope of marine conservation and fisheries management, significant attention has been given to studying the broad ranging impacts of subsidies for DWF. While several global subsidy studies have been published (e.g., Sumaila et al., 2019; Villasante et al., 2022; Skerritt et al. 2023), few have specifically focused on the Southern Ocean (Cappell et al., 2022). Under CCAMLR's rules, Member States must notify their intention to fish in the Convention Area, and receive approval from CCAMLR. In the most recent season (2023), 13 Member States notified to fish,

with a total of 39 vessels authorized by CCAMLR. In addition, eight French vessels fished in the Crozet and Kerguelen French sub-Antarctic EEZ. Antarctic Krill (*Euphausia superba*, hereafter krill) and Patagonian and Antarctic toothfish (*Dissostichus eleginoides* and *D. mawsoni*, respectively; hereafter toothfish) are the two main fisheries in the Southern Ocean. While global studies suggest that many DWF are highly subsidized (Sala et al., 2018; Sumaila et al., 2010a, 2016, 2019) there is very little information about Southern Ocean specific fisheries subsidies. A recent study on the economics of the krill industry shed light on the varying levels of government subsidies among CCAMLR Member States (Capell et al., 2022).

Studies have shown that direct transfers of funds to private fisheries can enable them to operate beyond economically sustainable limits (Schuhbauer et al., 2020; Skerrit et al., 2023; Skerritt & Sumaila, 2021a). Subsidies can enable fisheries to extend their range and duration at sea. For instance, fuel subsidies frequently allow fishing vessels to continue operations despite declining revenues, or in some cases even at a net loss that is offset by the subsidy (Skerrit & Sumaila, 2021a). This raises a fundamental question: can DWF remain viable without government subsidies? This is particularly important for the Southern Ocean, which is characterized by its remoteness and inaccessibility (Murphy et al., 2021), making it an ideal case study. Given the evidence suggesting that the profitability of most distant water fleets hinges significantly on substantial government subsidies (Sakai et al., 2019; Sala et al., 2018; Skerrit & Sumaila et al., 2021a), it is reasonable to infer that Southern Ocean fisheries greatly depend on such support. This is further emphasized by Capell et al. study (2022), which indicates that private fishing companies in several CCAMLR Member States benefit from direct subsidies, including fuel subsidies, for their krill fishery operations.

Recent assessments of Southern Ocean ecosystems have underscored the global implications associated with Southern Ocean fisheries (Cavanagh et al., 2021; Grant et al., 2021; Murphy et al., 2021; Pertierra et al., 2021). Krill and toothfish fisheries may impact the overall capacity of the Southern Ocean to provide globally significant ecosystem services (Cavanagh et al., 2021; Meredith et al., 2019). Regulating services, including primary production, climate change regulation, and support for regional and global biodiversity connectivity, are particularly vulnerable to the threats posed by overfishing and escalating human activities (Cavanagh et al., 2021; Wauchope et al., 2019). If subsidies are contributing to playing a major role in promoting fishing effort in the Southern Ocean, with implications for ecosystems and biodiversity, a country-specific analysis of government subsidies is warranted.

In this paper, we aim to decipher the current state of Southern Ocean fishery subsidies and the role these subsidies play in the fishing activities of CCAMLR Member States. This research specifically seeks to identify the extent to which each of the 13 Member States included in this study is subsidizing their Southern Ocean fleet, including the sources and types of subsidies distributed. Through primary data collection in the form of interviews, we provide an in-depth analysis of the complex operations that underlie Southern Ocean fisheries. Our investigation focused on interviewing industry representatives and government officials to shed light on the intricate operations and economic factors that characterize Southern Ocean fisheries. This was further combined with secondary sources including company financial documents, government reports, Global Fishing Watch data, and CCAMLR catch data to enhance our understanding of fishery operations and subsidy allocation. Our findings and implications demonstrate that Southern Ocean fishery subsidies are complex and diverse, varying significantly between member states and individual companies. Our results suggest that countries have unique and distinct relationships

with subsidies, influenced by both the type of subsidy and the fishery location. This implies that distant water subsidies may be far more nuanced than previously thought.

Methods

Definition

Documenting fishery subsidies requires defining what subsidies are, and there is no single accepted definition. For the purposes of this study, we define fishery subsidies to include all direct and indirect transfer of funds from government and public bodies to private fishery organizations operating in the Southern Ocean. Our holistic definition, which is a broadening of the WTO definition, is appropriate given our interest in understanding how government support may alter participation in Southern Ocean fisheries. While narrower definitions might be suitable in other contexts—such as assessing fair treatment across industries, regulatory capture, or the impacts of fishery-specific policy changes—our approach aims to provide a comprehensive understanding of the various mechanisms through which public resources affect operations in this critical region.

Historically, the term subsidy has been subject to ongoing debate regarding its definition (Rickard, 2018). The WTO, the leading international body governing trade rules between nations, defines subsidies as "financial contributions made by a government or any public body that confer a benefit and are generally considered to be trade-distorting" (WTO, 2023 p1; WTO, 2022a; WTO 2022b). However, the WTO definition includes specific clauses on "specificity" (ASCM, 1996), which exclude subsidies related to pre- and post-harvesting activities, such as transportation, processing, packaging, and distribution of catch (Irschlinger & Tipping, 2023). Additionally, subsidies that are not "industry specific" but benefit multiple industries (e.g., fisheries and agriculture alike) are not accounted for under the WTO's legal definition of fishery subsidies. While the WTO definition

serves as a foundation, it is essential to recognize that it originated as a political compromise shaped by extensive diplomatic negotiations among the 164 current WTO Member States (WTO, 2023). In our research, we aim to broaden the scope beyond the confines of this legal definition by including subsidies related to pre- and post-harvesting activities, as well as non-industry-specific subsidies.

Semi-structured interviews

To gather primary data on fishery subsidies, we conducted semi-structured interviews with industry representatives, government officials, and expert researchers from the 13 Member States that fished in the Southern Ocean during the 2023 season, which starts on December 1st 2022 and ends November 30, 2023. During this season, under CCAMLR's list of authorized vessels, a total of 13 countries notified to fish, representing 23 fishing companies, with a combined total of 39 authorized vessels (Table 3.1). Additionally, eight French vessels from five companies based in Réunion Island registered to fish in the Crozet and Kerguelen islands (French subantarctic EEZ) within the CCAMLR Area. Altogether, this included 47 vessels representing 28 companies registered to fish in the Southern Ocean (Table 3.1). By interviewing stakeholders from both the industry and government sectors, we sought to get a more comprehensive picture and enhance the diversity of our interviewees. In countries with available research on fishery subsidies, we interviewed expert researchers knowledgeable about both their own countries' fishery subsidies and those specific to the Southern Ocean.

Table 3.1. List of countries, registered fishing companies, and registered number of fishing vessels for the 2023 CCAMLR fishing season. Data extracted from CCAMLRs list of authorized vessels. https://www.ccamlr.org/en/compliance/licensed-vessels

Member States	Authorized Fishing Companies	Number of Registered Fishing Vessels

Australia	Australian Longline Fishing Pty Ltd, Austral Fisheries Pty Ltd	4
Chile	Pesca Chile S.A.	2
China	Liaoning Pelagic Fisheries Co., Ltd, Rongcheng East China Fisheries Co., LTD, Zhongyu GLobal Seafood Corp (ZGSC), Jiangsu Sunline Deep Sea Fishery Co., Ltd	4
France	Pêche Avenir S.A., COMATA, Cap Bourbon, Samper S.A., Armements Réunionnais, Reunion Pêche Australe	9
Japan	Taiyo A & F Co. Ltd	1
Korea	TNS Industries Inc., Hongjin Corporation, Jeongil Corporation, Dongwon Industries Co. Ltd.,	10
New Zealand	Talleys Limited, Sanford Limited	3
Norway	Aker Biomarine	3
South Africa	Pesquera Azul S.A	1
Spain	Pesquerias Georgia SL	1
Ukraine	LLC Fishing Company Neptuno, Taurus Logistics Group LP, Marissco Fishing Limited	5
United Kingdom	Argos Froyanes Ltd	3
Uruguay	Pesquera Azul S.A.	1

Information on licenses, permits and authorizations were collected via CCAMLR's "List of Authorized Vessels" for the 2023 season (CCAMLR, 2023). These countries include: Australia, Chile, China, France, Japan, Republic of Korea, New Zealand, Norway, South Africa, Spain, Ukraine, the United Kingdom, and Uruguay. Among these countries, some have exclusively targeted toothfish, such as Australia, France, New Zealand, South Africa, and the United Kingdom. Others, such as China and Norway, have focused on fishing for krill in recent years. Additionally,

countries like Chile, Korea, Japan, and Ukraine have fishing companies that historically targeted both toothfish and krill.

We sought to interview industry representatives from each company and government officials from each Member State fishing in CCAMLR's waters. For each vessel registered in the CCAMLR Authorized Vessels database, we first determined the flag state and the company to which the vessel belonged. Subsequently, we conducted a web search for the 23 fishing companies operating in the Southern Ocean, identifying industry representatives from each company. For French Southern Ocean fishing companies specifically, we conducted a separate investigation. This included researching French fisheries operating from Reunion Island and identifying the companies active in the Southern Ocean. For government representatives, we adopted two approaches. First, we visited the Ministry of Fisheries website for each country and identified government representatives with expertise in DWF operations and subsidies. Second, we consulted the CCAMLR 2023 annual meeting report list of participants, identifying government officials in fishery relevant positions. Lastly, we also targeted key informants who had completed research on fisheries subsidies either in the Southern Ocean or in a specific Member State. This also included reaching out to representatives of the Coalition of Legal Toothfish Operators (COLTO) and the Association of Responsible Krill Harvesting Companies (ARK). Approval for interviews was obtained through the University of Colorado Boulder's Institutional Review Board.

We developed three sets of interview questions, each tailored to the specific stakeholder group identified above. Most interviews were conducted in English, some in Spanish. Although we inquired about specific aspects such as subsidies, fishery operations, and catch data, our interviews adhered to a semi-structured format. This approach provided both the interviewee and interviewer with the flexibility to explore certain topics in greater depth or introduce additional questions as

necessary. Research shows that semi-structured interviews work best when dealing with high-level government officials and elite members of an industry (Bernard, 2006). Each interview questionnaire consisted of two sections (Appendix 1). The first section focused on fishery operations, encompassing topics such as catch numbers, vessel movement, costs, crews, gear, and export markets. This section aimed to obtain quantitative data on fishery operations. The second section delved into subsidy data, covering various types of subsidies, including fuel subsidies, tax breaks, royalties, catch share programs, discounted loans, research development and innovation grants, infrastructure support, import subsidies, and export subsidies (Table 3.2). Each interviewee was asked to elaborate on the presence or absence of these subsidies in their context. Through this process, a total of six subsidy types were identified as the most frequently mentioned by the interviewees. This section predominantly focused on qualitative data, as subsidies are frequently indirect, and there is a lack of a universally agreed upon method for calculating vessel specific subsidies.

Table 3.2. Definitions of subsidy types discussed with interviewees

Subsidy Type	**Definition**
Fuel Subsidy	Financial assistance to fisheries for the cost of fuel. Fuel subsidies can take various forms, including fuel tax concessions, fixed prices, tax exemptions on consumption, sales tax reductions, and restitution payments (Rickard, 2018).
Tax Breaks	Tax breaks reduce companies' tax burdens allowing businesses to keep a larger portion of their revenue (Rickard, 2018). They are made possible by legislative enactments typically in the form of credits or deductions tailored to specific industries or individual behaviors.
Royalties	Direct payments received by industry for the use of government property or rights, based on an agreed rate per unit extracted, produced, manufactured, or on a fixed share of the income or profit resulting from the use of the property (USDT, 2024)

Catch Share Programs	Fishery management strategy often enacted by governments that allocate a portion of the total allowable fishery catch to individuals, cooperatives, communities, or industry (NOAA, 2024)
Discounted Loans	A loan sold at a lower price in which the borrower gets an amount that is already reduced by the interest and other charges (Cambdrige, 2024). Discounted loans are a form of subsidy often prevalent in countries with banks that are state owned and state funded. This allows private companies to apply for low interest loans, long term loans, and financial guarantees.
Research, Development and Innovation (RDI) grants	Grants intended to stimulate scientific and technological innovation to particular sectors. RDIs are often regarded as beneficial subsidies, promoting fisheries resource conservation, management and sustainability (Andreoli et al., 2023)
Infrastructure Support	Direct transfer of funds for the development of infrastructure in the fishery sector, such as for fishing vessels, equipment, technology, ports, and processing facilities (Sumaila et al., 2019)
Import Subsidies	Payments made by governments or public institutions to industry for imported goods. In the fishery sector, import subsidies are often used as financial incentives for the import of catch at municipal or federally managed ports (Mallory et al., 2021)
Export Subsidies	Policies that provide financial encouragement from governments to beneficiaries for the export of goods, often to achieve desired export objectives (UNCTAD, 2024).

Our correspondence began with industry representatives, followed by government officials, and concluded with expert researchers. This sequential approach allowed us to prioritize collecting primary data from the Southern Ocean fishery industry before engaging in discussions about subsidy data and economic operations with government officials. Each interviewee was contacted three times before being considered unreachable, resulting in no responses from 20 industry representatives, 22 government officials, and six researchers. Within industry representatives, we interviewed those representing a diverse range of fisheries which varied in vessel numbers, size, catch, and operational scale. For France, Korea, and Ukraine, we interviewed the companies with the largest vessel fleets involved in their countries' Southern Ocean operations. In other Member

States, such as Chile, Norway, and Spain, we interviewed their sole Southern Ocean fishing company.

The majority of interviews were conducted using the Zoom platform and were recorded with permission from the interviewees. A limited number were conducted in person or on the phone. Each interview session lasted approximately one hour. The Zoom AI assistant was utilized for qualitative transcription and note-taking purposes. Following each interview, subsidy information across various categories was recorded in a spreadsheet, detailing both country-specific and company-specific subsidies. Information on the nature of subsidies and fishery operations was documented in an interview-specific file, capturing the perspectives of each interviewee. Quantitative data on fishery operations and subsidies, along with qualitative insights from the interviews, were ultimately consolidated into a country-specific document detailing the subsidy categories, sources, and their influence on fishery operations for each Member State.

Other sources of information

While interview data was the focal point of our investigation, our results also drew on government reports and secondary sources. For countries where we were unable to conduct interviews with fishery representatives or government officials, we relied on data provided by expert researchers to enhance the robustness of our scientific research. This included scientific reports from institutes and organizations conducting subsidy research, government reports, scientific literature, and company financial documents.

Our investigation also relied on CCAMLRs statistical bulletin catch data to better understand fishery dynamics. This data was used to quantify the total catch in tonnes per country, species, and subarea locations (Appendix II). We did this for the 2022 season as the 2023 data has not been

published yet. Coupled with our subsidy analysis, this allowed us to highlight the countries with the highest catch, the regions most heavily targeted by the fishing industry, and the distribution of krill and toothfish catch by Member States.

This was then supplemented by mapping the home ports and fishing grounds of each fishing company interviewed. For each industry representative interviewed, we gathered information on their fishing operations, including their home ports, catch landing locations, refueling sites, maintenance service locations, and whether their boats operate in any regions outside the Southern Ocean. This data enabled us to map the trajectory of 26 individual Southern Ocean fishing vessels, from their port of origin to where they land their catch. We overlaid the CCAMLR ArcGIS Convention Area map onto a map of the Southern Ocean and used Canva to draw the movement patterns of each vessel, tracing their routes from their home ports to their targeted fishing grounds. This approach enabled us to present an overview of the current state of Southern Ocean fishing operations, highlighting the distribution patterns of various fishing companies, their selection of home ports, and the role subsidies play in their fishing operations. For the Member States and companies, we were unable to interview, we used Global Fishing Watch to track the movements of their fishing vessels. This was particularly important for monitoring Chinese krill vessels.

Results and Discussion

Below, we begin by outlining our interview results for Southern Ocean fishery subsidies, which are contextualized in Figure 3.1. This figure presents an initial overview of the presence and absence of Southern Ocean fishery subsidies by type, as well as the number of interviews conducted with each stakeholder group. We then examine two integral components of Southern Ocean fishery operations: fishery catch and vessel movement. Following this, we discuss our country-specific subsidy findings, derived from interviews with fishery representatives,

government officials, and expert researchers. Finally, we highlight knowledge gaps and apply the lessons learned from Southern Ocean fishery subsidies to the broader context of subsidies for DWF.

Interviews

In our study, we conducted interviews with a total of 29 participants from 13 Member States. This group included 11 industry representatives, nine government officials, and nine expert researchers (Figure 3.1). Industry and government representatives together accounted for 53% of the total sample. Specifically, we interviewed 11 industry representatives from 23 registered companies and eight government officials from 13 Member States. Industry representatives included CEOs, general managers, and policy managers. Government officials included high level diplomats, national directors of fishery operations, and several ministries of fishery representatives. Researchers interviewed specialized in fishery subsidies, some focusing on their own countries' jurisdiction and others on subsidies specific to the Southern Ocean. At least one stakeholder group was interviewed for each country, and both industry and government officials were interviewed for Australia, Chile, France, New Zealand, South Africa, Spain, and Ukraine (Figure 3.1).

Figure 3.1. This figure displays the presence or absence of subsidies by category (fuel subsidies, tax breaks, discounted loans, research development and innovation grants, infrastructure support, and import subsidies) for each of the 13 CCAMLR Member States which had representatives interviewed in our study. Green boxes indicate the presence of subsidies, while gray boxes indicate their absence. Additionally, green check marks show the number of interviews conducted with industry, government, and research representatives, whereas gray dashes indicate the absence of interviewees for those stakeholders.

The extent of subsidies received by Southern Ocean fisheries varied greatly among CCAMLR Member States. While a couple of Member States were identified as providing substantial subsidies to their Southern Ocean fleets, the vast majority of fisheries receiving government support found the amount insufficient to significantly alter operations or greatly affect profitability. Notably, there were no fundamental discrepancies between the data collected from industry and government sources within each country. While we emphasize the qualitative aspects of our

results, quantitative data provided by some interviewees suggest subsidies range from zero to millions of dollars per year across different fleets. Figure 1 shows the presence and absence of subsidies for each category among the 13 Member States that fished in the 2023 CCAMLR fishing season, as well as the number of interviews conducted with stakeholder groups in each country. Notably, government subsidies directed to private fishery organizations was highest for Chinese and Norwegian Southern Ocean fisheries. Additionally, we highlight the impact of companies' home port locations as major factors in their availability to access government subsidies.

Southern Ocean Fishery Operations

The most recent catch data published in the CCAMLR Statistical Bulletin is for the 2022 season (CCAMLR, 2022), during which 13 Member States registered to fish. Of these, ten countries engaged in toothfish fishing, while only five targeted krill. France, Australia, and the UK reported the highest toothfish catches by tonnage, with Norway significantly surpassing other nations in krill catch (figure 3.2). A total of 37 vessels registered to fish for toothfish with only 13 targeting krill (CCAMLR, 2023). This includes eight French vessels operating within their subantarctic EEZs (Lefebvre & Maghin, 2019). While the eight French vessels were not registered under the CCAMLR authorized vessels (CCAMLR 2023), their catch was reported in the statistical bulletin (CCAMLR, 2022). Collectively, a total of 50 vessels registered to fish in the CCAMLR Convention Area, resulting in a combined catch of 15,031 tonnes of toothfish and 415,509 tonnes of krill (Figure 3.2).

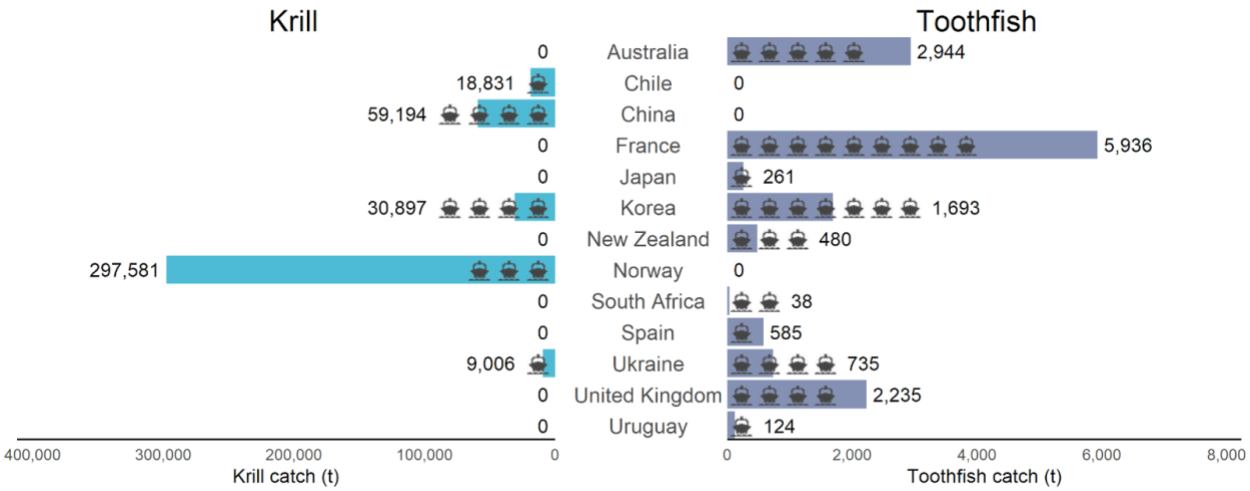

Figure 3.2. This bar chart displays the tonnes (t) of krill and toothfish caught during the 2022 CCAMLR fishing season by the 13 Member States that registered to fish. The total catch per country is shown in tonnes, with blue bars representing krill catches and purple bars representing toothfish catches. Black boat icons indicate the number of registered fishing vessels per country and per fishery and the numbers next to the boat represent catch in tonnes. Norway recorded the highest krill catch at 297,581 tonnes, while France had the highest toothfish catch at 5,936 tonnes. Catch data was collected from the latest CCAMLR statistical bulletin for the 2022 season, with totals calculated by summing the catches from each CCAMLR area and subarea.

There are large differences in catch among CCAMLR Member States particularly for the toothfish industry. Countries with subantarctic territories, such as Australia and France have exclusive access and fishing rights to large areas of the Southern Ocean. This is also true for South Africa, which has exclusive access to the Prince Edward and Marion Islands (subarea 58.7), however these fisheries have been less profitable in recent years. As interviewee 019 states, South Africa's Southern Ocean fisheries catch has declined because “one boat broke down, and the other was decommissioned due to illegal fishing.” Fisheries operating in these EEZs often land substantially more catch than those in the rest of the CCAMLR Convention Area and have less competition for marine resources. Australia has exclusive access to the Heard Island and McDonald Islands (CCAMLR subarea 58.5.2) and its four boats caught 2,944 tonnes of toothfish in the 2022 season. France has eight fishing vessels in the Crozet and Kerguelen Islands (CCAMLR subareas 58.6 and 58.5.1, respectively) and in the 2022 season registered a total catch of 5,936 tonnes of toothfish.

That same season, the UK was the only country that fished for toothfish in the waters around South Georgia and South Sandwich Island (CCAMLR sub areas 48.3 and 48.4 respectively) and caught a total of 2,235 tonnes. These three countries (UK, France, Australia) dominate the Southern Ocean toothfish industry (Figure 3.2). Subantarctic EEZs play a critical role in the profitability of toothfish fisheries. They enable private industries operating within them to capitalize on reduced competition with foreign nations.

Vessel Movement

Data on home ports and vessel movement was collected through interviews with industry representatives from Australia, Chile, France, Korea, New Zealand, Norway, South Africa, Spain, Ukraine, and the United Kingdom (Figure 3.3). These interviews involved representatives from 11 companies, accounting for 26 fishing vessels, of which 22 targeted toothfish and 4 targeted krill. Data on each vessel's movement was collected by asking interviewees to detail the home ports and target fighting grounds for each of their Southern Ocean vessels. While not every state is included in this figure (e.g., China and Japan), or every fishing company (11/23), it provides a picture of where some countries' fisheries are operating from and what fishing grounds they are targeting. This in turn, reveals the operational distribution of some Southern Ocean fisheries, and underscores how decisions by private fishery organizations to operate from abroad could influence the extent of government subsidies they receive.

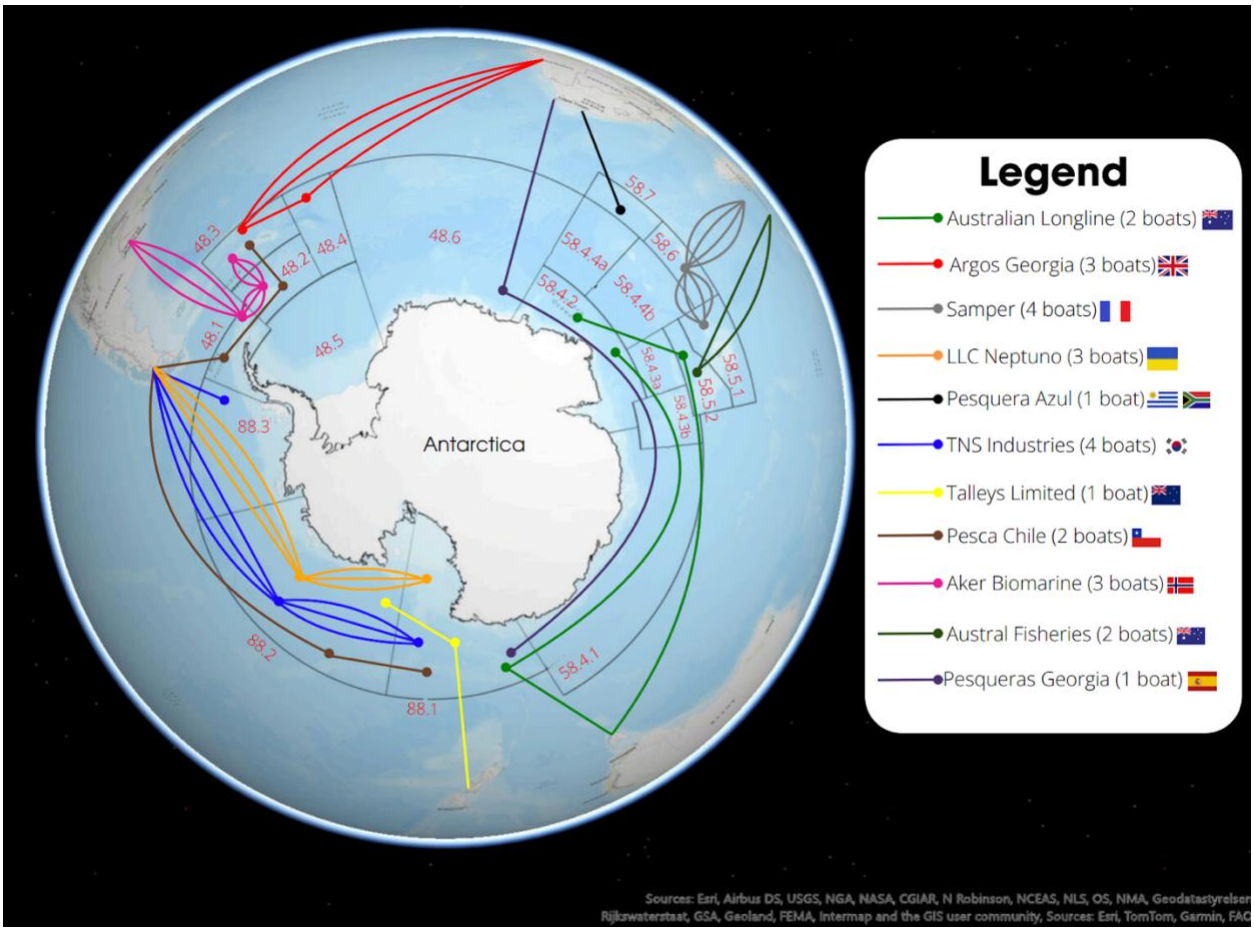

Figure 3.3. This figure illustrates the movements of 26 fishing vessels from their home ports to their targeted fishing grounds during the 2023 CCAMLR fishing season. These vessels are operated by 11 different companies from 10 CCAMLR Member States. Each line represents one fishing vessel, commencing at the port of origin with the circles at the end of each line indicating general areas of fishing activity within CCAMLR areas and subareas (labeled in red), rather than precise locations. Movement data was obtained through interviews with fishery representatives from each company included in this figure to confirm the operational routes from their home ports to their target fishing grounds.
*Pesquera Azul (black line) is a Uruguayan fishing vessel that was granted permission by the South African government to fish in sub area 58.7, a subantarctic EEZ.

Our vessel movement data shows that fishing companies are mostly operating outside of ports of their flag state, ultimately moving their home ports to nation states closer to the Southern Ocean. Only the fisheries whose flag states are relatively close in proximity to the Southern Ocean (e.g., Australia, Chile, New Zealand, South Africa and Uruguay) operate from their national territory. For Australia, however, one of its two Southern Ocean fishing companies, Austral Fisheries,

operates from its home port in Mauritius (Figure 3.3). This is due to cost efficiencies compared to Australian ports and the advantage of quicker access to fishing grounds. Interviewee 003 noted that the “cost of repairs, maintenance, and port space” were also determining factors for Austral Fisheries not to operate from Australia. Unlike Austral Fisheries, Australian Longline Fisheries, a competing company, operates from Hobart, Tasmania (Figure 2) and can access government support programs, such as the Tasmanian Freight Equalisation Scheme, that don't apply for the former.

The remaining fishery companies included in Figure 3 have all shifted their operations to foreign nations. Interviewee 008 from Samper, a toothfish fishery from France, stated that their company operates from Reunion Island, a French island territory east of Madagascar which is much closer to the Southern Ocean than France. Interviewee 013 from TNS industries, a Korean toothfish fishery, mentioned that they had moved its four toothfish vessels to Punta Arenas, Chile. Interviewee 026 clarified that Aker Biomarine, a krill fishing company from Norway, recently signed an agreement with Uruguay to have their home port in Montevideo. Pesqueras Georgia from Spain is a joint venture between Spain and the Falkland Islands, and interviewee 020 indicated that its toothfish vessel normally operates from Cape Town, South Africa. Interviewee 023 from LLC Fishing Company Neptuno, a Ukrainian toothfish company, mentioned that they also operate from Punta Arenas Chile, and its Southern Ocean fishery represents Ukraine’s sole distant water fishing operation. Lastly, interviewee 024 from Argos Froyanes LTD, the UK’s only Southern Ocean fishery, explained that they had recently changed their home port from New Zealand to Namibia. Unlike many of its European counterparts, it chose not to operate from the South American continent due to political tensions between UK and Argentina over the Falkland Islands.

Our tracking and home port data elucidate the differences between Southern Ocean fisheries and DWF. While research shows that a great portion of DWF operate from their flag states territorial boundaries, fish in ABNJ for several months, and then return to their home ports to land their catch (Chen et al., 2008; Stäbler et al., 2022; Yu & Wang, 2021), Southern Ocean fisheries mostly operate from foreign ports and frequently change ports to improve profitability. DWF that operate from their countries' home ports are bound to their countries' regulations which include taxes, licenses and insurance but also state and federal subsidies. Government subsidies often encourage fisheries to operate from their domestic ports, regardless of the geographic distance between their nation and the international fishing grounds they target (Mallory et al., 2021). Countries have been shown to offer economic incentives in the form of subsidies to encourage the transportation of catch back to their home port (Mallory et al., 2021). Within the Southern Ocean, and during the period of our study, only one country, China, has been shown to do this. Government reports show that certain municipalities in China are willing to provide DWF, including those in the Southern Ocean, with subsidies of up to 200 CYN (~30 USD) per tonne of catch, along with additional exemptions from import taxes, contingent on vessels offloading their catch at local ports (Mallory et al., 2021).

Unlike most DWF, if the majority of Southern Ocean fishing vessels were to depart from the ports within their national borders, the mere act of reaching the Southern Ocean would entail a significant voyage. Even fisheries arguably close to the Southern Ocean (e.g., New Zealand toothfish fisheries) take over 10 days just to reach the fishing grounds. Interviewee 015 mentioned that New Zealand Southern Ocean fisheries use approximately 380,000 liters of gasoline, amounting to an estimated cost of around $340,000 USD per trip. Countries like China, France, Japan, Korea, Norway, Spain, United Kingdom, and Ukraine are each over 10,000 kilometers from

Antarctica. The combination of fuel costs, and the duration of round trips to and from the Southern Ocean, would result in a significant financial burden. Dozens of private fishery organizations operate from foreign ports closer to the Antarctic Continent. Operating within foreign jurisdictions subjects these companies to varying tax regimes, licensing requirements, and ultimately, subsidies. In many cases, as interviewee 020 argued, fisheries whose home countries provide fuel subsidies (e.g., Spain), are unable to benefit from such subsidies due to refueling operations occurring in foreign territories like Cape Town or the Falkland Islands.

Subsidy Results by Category

Across the three categories of fishery subsidies - capacity enhancing, ambiguous, and beneficial - governments and public institutions have provided over a dozen types of subsidies to private fishery organizations (Sumaila et al., 2019). Among these, the most commonly identified within our 29 interviews include fuel subsidies, tax breaks, discounted loans (below market rate), research, development and innovation grants (RDI), infrastructure support, and import subsidies (Figure 1). In the following subsections, we present our results by subsidy type and discuss their role in the operations of individual Member State fisheries, drawing on our data on fishery operations and vessel movement. For each subsidy type identified in our research, we refer to Figure 1 and determine the proportion of the amount that is provided to Southern Ocean fisheries operating in this high seas region, highlighting differences in subsidy allocations among Member States and individual companies.

Fuel Subsidies

Previous research suggests that fuel subsidies destined to large-scale fisheries constitute 20% of total global fishery subsidies (Schuhbauer et al., 2020). This substantial level of support,

amounting to approximately $7.2 billion annually, establishes fuel subsidies as the largest category of capacity-enhancing subsidies and currently represents the principal form of government assistance for the fishing industry (Sala et al., 2018; Sumaila et al., 2020; Sumaila et al., 2021). Within the Southern Ocean, our interview data highlights that fishing companies from China, France and Spain have received or currently receive fuel subsidies for their Southern Ocean fleets. Among these countries, the Chinese government stands out as the largest contributor to fuel subsidies. It is worth noting that fuel subsidies can take various forms, including fuel tax concessions, fixed prices, tax exemptions on fuel consumption, sales tax reductions, and restitution payments (Rickard, 2018).

While Chinese government reports show that fuel subsidies have decreased by up to 40% from 2014-2019, new data shows that these subsidies are now flowing disproportionately to the distant water fishing industry (Mallory et al., 2021). As it stands, interviewee 007 argues that Chinese fuel subsidies for distant water vessels are categorized by fishing ground (location of the fishery), tonnage (boat size), and number of days of the vessel at sea (Wang et al., 2023). Government allocation of fuel subsidies is further supported by local government subsidy incentives that encourage the transportation of catch back to mainland China. For krill specifically, the municipal governments of Weihai, Shandong Province, provides 30 CYN ($4USD) per tonne of Antarctic krill plus tax exemptions for landing their catch at their municipal port (Mallory et al., 2021). Fuel subsidies coupled with economic incentives for landing Southern Ocean catch in mainland China likely alleviate some of the financial constraints on Chinese companies engaged in round-trip voyages to the Southern Ocean. This is the case for “Fu Yuan Yu 9818” a Chinese krill vessel owned by Fujian Zhengguan Fishery Development Co., and “Long Fa”, a Chinese krill vessel operated by Zhongyu Global Seafood Corp (ZGSC), both of which have registered multiple docks

in the Shandong Province of China. Unlike Chilean, Korean, Norwegian, and Ukrainian krill vessels, the Chinese ones engage in transboundary commutes between the Southern Ocean and ports of their flag state (Figure 3.4), with fuel subsidies likely playing a crucial role in facilitating this operational dynamic. Data from Global Fishing Watch reveal notable differences in travel patterns: Chinese vessels undertake long transboundary commutes between China and the Southern Ocean, whereas vessels from other countries operate from foreign home ports to minimize travel distance, cost and enhance profitability (Figure 3.4).

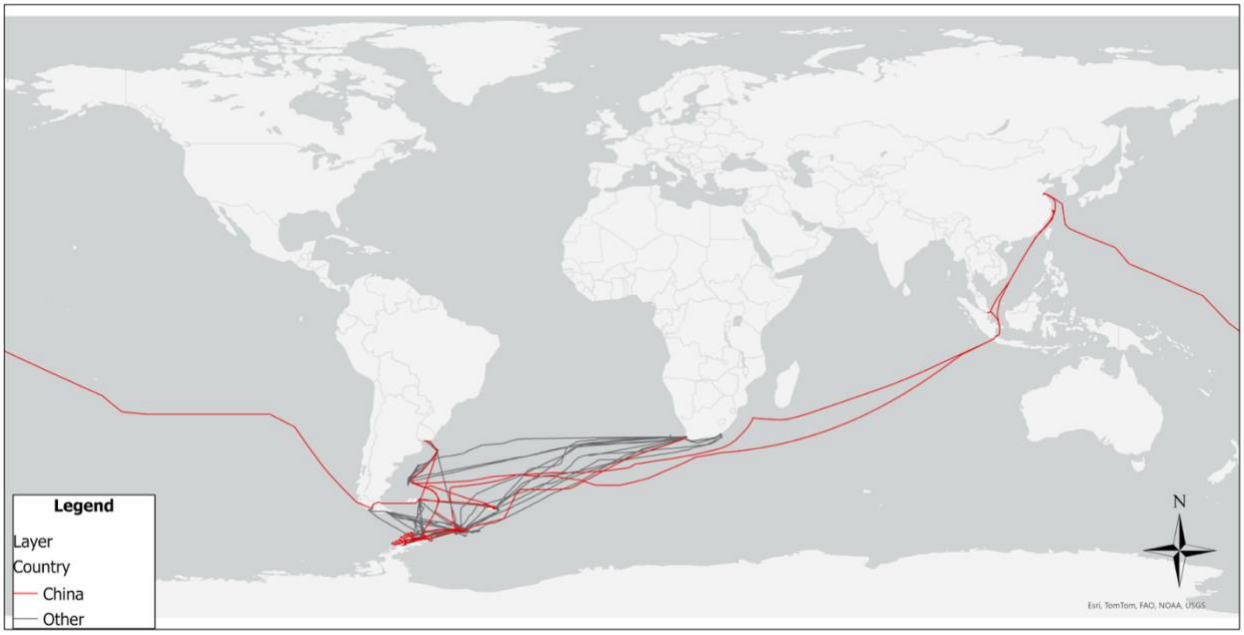

Figure 3.4. Map depicting the movements of vessels engaged in the Southern Ocean krill fisheries during the 2023 CCAMLR fishing season. Although 12 vessels were registered to fish for krill in the 2023 CCAMLR season, Global Fishing Watch data indicates that only 9 vessels actively fished. These included two Chinese (Long Fa and Shen Lan), one Chilean (Antarctic Endeavour), two Korean (Sae In Leader and Sejong), three Norwegian (Antarctic Endurance, Antarctic Sea, and Saga Sea), and one Ukrainian (More Sodruzhestva). Red lines denote the paths of the Chinese vessels, while dark gray lines represent the routes of vessels from Chile, Korea, Norway, and Ukraine.

Our results suggest that fuel subsidy allocation in France and Spain are different from those in most Member States because they are subject to both national and European Union (EU) public

subsidies. In France, a study by Bloom Association and the Institute Rousseau indicated that in 2021 tax exemptions on French fuel subsidies accounted for almost 63% (€206 million out of €237 million) of all fishery subsidies (Bloom, 2024). French fisheries receive a wide range of tax benefits of which the most significant is the exemption from the 'Taxe Intérieure de Consommation sur les Produits Énergétiques' (Domestic Tax on the Consumption of Energy Products, or TICPE). This is a tax on fuel prices that amounts to €0.6091 for each liter of fuel purchased (Bloom, 2024). Similarly, in response to the Ukraine War, the EU relaxed State aid rules giving governments more flexibility to support industries impacted by the war. French fisheries benefited from "discounts at the pump" of between 20 and 35 euro cents per liter of diesel (Bloom, 2024). French Southern Ocean fisheries operating from Reunion Island (Figure 2) can benefit from French national subsidies because under French law Reunion Island is classified as an "outermost territory". Therefore, fuel subsidies to Southern Ocean fisheries operating from Reunion Island registered under a French flag benefit from federal government support to the same extent as fisheries operating from mainland France.

This, however, is not the case for Spanish Southern Ocean fisheries. Interviewee 020 discussed that because the Spanish company Georgia Seafoods LTE is not based in a Spanish territory, it does not receive the same level of subsidy support that Spanish fisheries operating from Spain do. Georgia Seafoods is a joint venture between Spain and the Falkland Islands (50/50) and mostly operates from Cape Town, South Africa (Figure 2). Its Southern Ocean vessel, the Tronio, operates 8 of 12 months a year, both in the Southern Ocean and in other ABNJ, refueling in both Cape Town and the Falkland Islands. This exposes the company to varying fuel prices, taxes, and subsidies particular to each state. While Georgia Seafoods does not currently receive any fuel subsidies for its Southern Ocean fishery, interviewee 020 mentioned that it previously received

€250 thousand in 2022 from the EU. Amidst the Ukraine war, fuel prices spiked and our interviewee detailed that “prices reached as high as $1500 per tonne, up from the usual $900 per tonne”. To alleviate this financial burden, the EU enacted a legislation, included in Spain's Royal Decree (Order APA/986/2022), to alleviate the fuel costs associated with the fishing industry. Article 8 of the legislation stipulates that vessels refueling in foreign ports are also eligible for fuel subsidies (BOE-A-2022-17151). This greatly benefited Georgia Seafoods LTE, however, this legislation only offered a one time payment and Spanish Southern Ocean fisheries currently do not receive ongoing fuel subsidies according to our industry and government interviewees.

Other sources of evidence suggest that countries with DWF operations, such as Japan and Korea, also benefit from fuel subsidies (OECD, 2021a, 2021b). While the OECD data suggests that both Japan and Korea provide fuel subsidies to their fisheries, these results are not specific to the Southern Ocean. Our interview data collected from Interviewees 011, 012 and 013, shows that Taiyo A & F Co. Ltd (the only Japanese company fishing in the Southern Ocean) and TNS Industries Inc (the largest Korean fishing company in the Southern Ocean) do not receive fuel subsidies. The Japanese toothfish vessel Shinsei Maru No. 8 operates from both Cape Town, South Africa and Punta Arenas, Chile. TNS Industries has four toothfish vessels all of which operate from Punta Arenas, Chile. Interviewee 013 explained that “because their vessels do not operate from Korea, they are not subject to the same fuel subsidies that vessels operating from Korea otherwise do”. Korea has been identified as one of the top 10 nations providing harmful fishery subsidies (Skerrit & Sumaila, 2021a); however, our interview data suggests that these subsidies are likely not distributed to Southern Ocean fisheries. Home port location plays a critical role in the operation of Southern Ocean fisheries and greatly influences the distribution of fuel subsidies to fishing companies.

Several governments have taken a stance against subsidizing fuel for Southern Ocean DWF. Our interviews with government officials from Australia, Chile, New Zealand, South Africa, Ukraine, and Uruguay indicate that these countries do not provide direct fuel subsidies to fishing companies in the Southern Ocean. While some countries like New Zealand indirectly support fuel subsidies through tax exemptions for road use charges, these subsidies are primarily aimed at cars, trucks, and heavy machinery. While the fishing industry indirectly benefits from these fuel subsidies for the transportation of catch, and the loading and unloading of equipment, they are part of broader sectoral support that also benefits recreational vessels, public transportation, machinery and freight vessels (Interviewee 014). The differences in fuel subsidies from some governments to their fisheries (e.g., China) could be a significant determinant in the profitability of their operations across the Southern Ocean.

Tax Breaks

Our interview data and supplementary sources suggest that Southern Ocean fisheries from China, France, and Norway benefit from tax breaks. To start, tax breaks are made possible by legislative enactments typically in the form of credits or deductions tailored to specific industries or individual behaviors. Tax breaks are implemented to stimulate certain sectors of the economy and can be industry specific such as those to the fishing sector. These subsidies ultimately reduce companies' tax burdens allowing businesses to keep a larger portion of their revenue (Rickard, 2018).

While fuel subsidies are often awarded through tax concessions, as is the case with Chinese and French Southern Ocean fisheries, our examination of tax breaks encompasses all aspects except those related to fuel. Chinese DWF, including those in the Southern Ocean, benefit from income tax exemptions with potentially as much as $522 million USD in income tax exemptions and $414

million in catch import tax breaks (Mallory, 2021). China began exempting DWF from paying corporate tax in the 1990s and more recently Article 86 of the Chinese Enterprise Income Tax Law states that catch from DWF is 100% exempted from corporate income tax (Mallory et al., 2021). Similarly, the Chinese General Administration of Customs has a long standing policy that states that fish species caught by Chinese DWF operating in the high seas or foreign EEZs are not subject to import taxes when transported back to China (Mallory et al., 2021). While this is not necessarily specific to the Southern Ocean, Chinese krill fisheries fishing in Antarctica land their catch in China (Figure 4) and therefore would qualify for these tax breaks. Like fuel subsidies, these tax breaks provide an incentive for Chinese fisheries to engage in recurrent voyages to and from the Southern Ocean despite the substantial costs of travel.

A recent report from Bloom shows that French fisheries, including those in the Southern Ocean, benefit from government tax breaks to social security payments/contributions (Bloom, 2024). These subsidies represented a combined saving for fishing companies of almost 37 million euros in 2021 (Bloom, 2024). Tax exemptions from social security contributions represented the second highest subsidy for all French fisheries (Bloom, 2024), therefore potentially playing a role in Southern Ocean fisheries as well (Interviewee 009). Interviews with French researchers highlight the importance of tax exemptions related to employment, and how compared to other industrial sectors, the fishing industry often receives a higher tax advantage. In addition to employment subsidies, French DWF have also received several tax breaks for the acquisition of equipment, including the development of computerized fisheries monitoring and control tools (Bloom, 2024).

Norway also stands out as a recipient of subsidies, including tax breaks, from municipal and federal governments. Due to its proportional electoral system, subsidy allocations are prepared by each ministry's budget proposal (Rickard, 2018). The Ministry of Trade, Industries and Fisheries puts

together the budget for the fishery sector but is heavily influenced by national organizations responsible for subsidy allocation, such as “Innovation Norway”, a state owned national development bank (Rickard, 2018). Our interviews with Norwegian industry representatives show that their Southern Ocean krill fisheries largely benefit from direct subsidies from Norwegian innovation funds, state and federal agencies, and tax deductions for research and development. These categories will be further analyzed in the next subsections.

Apart from our primary data collection on China, France and Norway, we found no concrete evidence that other Southern Ocean fisheries are receiving government tax breaks for their fishing operations. In the six countries (Australia, Chile, New Zealand, South Africa, Spain, and Ukraine) where we conducted interviews with representatives from both private industry and government sectors, interviewees consistently emphasized that Southern Ocean fisheries in their respective nations do not receive government tax incentives. Interviewee 006, a government official from Chile, stated that “the Chilean government has not once awarded tax breaks to Southern Ocean industrial fishery companies”. Data from both the private and public sector suggests that tax breaks are likely not a significant subsidy avenue for most of these fisheries.

Discounted Loans

Our interview data along with the examination of government reports (Mallory et al., 2022), show that Southern Ocean fisheries from China, Norway and Ukraine benefit from publicly sourced discounted loans. Discounted loans are a form of subsidy often prevalent in countries with banks that are state owned, state funded, or under the leadership of a State Council, as is the case with China and Norway. This allows private companies to apply for low interest loans, long term loans, and financial guarantees. In China, for example, there is no systematic reporting for policy bank

loans. However, government reports show that several industrial projects for DWF received loans from the Export-Import Bank of China (EXIM) (Mallory et al., 2021). In 2013, EXIM signed a strategic agreement with the Chinese Overseas Fishery Organization (COFA) to provide policy oriented financial support including in the construction of distant water fishing vessels, construction of overseas bases, and the construction of ports and processing plants in mainland China (Mallory et al., 2021). National policy banks such as EXIM have been shown to provide low-interest, long-term loans that cover up to 30% of the cost of construction and renovation of distant water fishing vessels, including krill vessels (Mallory et al., 2021). EXIM has further extended its support through provision of low-interest loans to the Rongcheng Oceans and Fisheries Bureau in Shandong Province, specifically designated for the establishment of fishing bases within China and overseas (Mallory et al., 2021). This initiative has been particularly advantageous for multiple Southern Ocean krill fisheries, as they frequently offload their catch in Shandong Province (Figure 4), thus capitalizing on the benefits of these preferential loans. Within China, national banks like EXIM offer notably reduced interest rates, potentially as low as 2% in contrast to the standard 5% rate charged by commercial banks (Mallory et al., 2021). Consequently, DWF, including those operating in the Southern Ocean, stand to significantly profit from these favorable loan terms.

Across industries, and through their national banking system, the Norwegian government has been known to provide loans at below market interest rates, loan guarantees, and capital injections (Rickard, 2018). As conveyed by interviewee 017, Aker Biomarine, has received guarantees on investment from the Norwegian Export Credit Guarantee Agency (Garanti Instituttet for eksportkreditt, or GIEK), finance loans for the construction of krill fishing boats from Export Finance Norway (Eksfin), research grants from the Norwegian research council, and investment

grants for the construction of a processing facility in Norway by Innovation Norway. For the processing facility, our interviewee indicated that they received an $18 million USD government grant. While Norway's Southern Ocean fishery home port is based outside of Norway (Figure 3) this processing facility will directly benefit their operations and profitability. Norway stands out for its high levels of government support and the close cooperation between commercial banks and government agencies.

While Norway's Southern Ocean krill fishery has been lauded for their decarbonization efforts and sustainability operations (Misund, 2014), their yearly catch (Figure 2) eclipses that of their competition (Chile, China, Korea, Ukraine). With three vessels operating 11 out of 12 months per season in the Antarctic Peninsula (Area 48; Figure 2), and a cargo vessel shuttling between Montevideo and the Southern Ocean for the purpose of transporting supplies, offloading catch, crew rotation, and refueling (Interviewee 017), Aker Biomarine's operations exhibit a significantly higher level of sophistication compared to its competitors. All of this comes at a great cost. Publicly available company reports from AkerBiomarine, show that the company has consistently failed to make a profit, with a net loss of 1 million in 2018, 23.7 million in 2019, 5.4 million in 2020, 8 million in 2021 and eventually making a profit of 9 million in 2022 (Akerbiomarine 2024; Orbis, 2024). The magnitude of this financial deficit underscores Akerbiomarine's substantial investment in the krill industry. Governmental support, in the form of loans, guarantees, and grants, plays a pivotal role in Aker Biomarines strategic long-term initiatives, suggesting potential success in leveraging these subsidies for continued growth.

Ukrainian Southern Ocean fisheries also have the opportunity to apply for government loans to support their fishery operations. Unlike China and Norway, with a banking system that is state owned and state financed, interviewee 022 stated that government loans in Ukraine are the

responsibility of the Ministry of Economics. These discounted loans are therefore very general and not industry specific. Our interviews with Fishing Company Neptuno and the International Cooperation of the State Agency of Fishery of Ukraine indicate that Ukrainian Southern Ocean fisheries have not received any government loans, although the potential for future loans remains. Interviewee 022, a Ukrainian government official, stated that "due to the war with Russia, all available funds are directed to cover security issues," indicating that there is presently no "possibility to financially support the Southern Ocean fishing industry", with future prospects uncertain.

Apart from China, Norway and Ukraine, interviews from the 10 other Member States suggested that government loans are not prevalent throughout the Southern Ocean fishing industry. Instead a significant number of these fishing companies stated that they depend on loans obtained from both domestic private banks or international financial institutions. Interviewee 004 argued that "even the interest rates at the Chilean National Banks are too high" and that their company often looks elsewhere for bank loans. Similarly, interviewee 002, a fishery representative from Australian Longline, mentioned that their newest toothfish vessel was largely funded by a Japanese bank through a long term loan. Interviewee 013, a fishery representative from TNS industries, stated that their company works with two private banks in Korea and a third one that specializes in fisheries industries and distributors. In the absence of discounted government loans, Southern Ocean fishery organizations seek to secure favorable terms through private banking institutions from across the world.

Research, Development and Innovation Grants

Within its Convention Articles (particularly Article IX), CCAMLR requires its Member States to facilitate research and comprehensive studies of Antarctic marine living resources and ecosystems.

Interviewees from Australia, Japan, New Zealand, and Norway reported robust collaborations in research between the public sector and private fishing industries. Unlike fuel subsidies, tax exemptions, and discounted loans which increase profit by reducing fishing costs, and can lead to overfishing (Martini & Innes, 2018; Sakai et al., 2019), RDI grants are often regarded as beneficial subsidies because they can promote fisheries resource conservation, management and sustainability (Andreoli et al., 2023).

Interviewee 001, a government representative from Australia, clarified that RDI grants constitute one of the three legal subsidy categories reported to the World Trade Organization (WTO) by the Australian Government. While RDI subsidies are available to fishing companies, most of these subsidies are destined to researchers and universities over industry. Our Australian government representative, who has participated in WTO subsidy negotiations for 25 years, indicated that approximately 90% of RDI subsidies are allocated to the research industry. Nonetheless, our conversation with fishery representatives from Australian Longline show that research partnerships between fisheries and the government exist. Interviewee 002 mentioned that Australian Longline conducts stock assessment research, particularly in the Australian subantarctic islands, and have previously received government funding for their scientific endeavors. Regardless of RDI subsidies, Australian Longline engages in annual research activities, and if the findings are relevant or of interest to the Australian government, they have received financial compensation for their studies.

Interviewees 011 and 012 indicated that RDI grants are widely distributed to the fishing industry by the Japanese government. Interviewee 012 indicated that there are several government programs supporting innovation, such as one funding the implementation of fishery infrastructure for distant water vessels, and another specifically targeting energy-saving measures for fishing

vessels. Japan's Fishery Research and Education Agency (FRA) supervises research and development activities throughout Japan's fisheries sector, with a goal of integrating scientific and technological advancements into the country's fishing industry (FRA, 2023). Although government data on RDI grants is not publicly accessible, insights from our interviewees suggest that Taiyo A & F Co. Ltd, as the sole Japanese company in the Southern Ocean, likely receives government funding for research. This inference is supported by the government's widespread distribution of RDI grants (Sakaguchi et al., 2021).

Similar to Australia, RDI grants in New Zealand are mostly given to researchers and universities, as indicated by interviewee 014 and 016. One of the major funders for fishery research are the "Crown Research Funds". These RDI grants are subject to high competitiveness, with only certain segments of the fishing industry qualifying for eligibility. The availability of RDI grants persists throughout the year, however, our interviews with government officials and industry representatives from New Zealand indicate that no Southern Ocean fishing company has ever been awarded such a grant. Nonetheless, New Zealand stands out as a major funder for Antarctic research, often regarded as a leader for scientific diplomacy in the CCAMLR community (Morten, 2017; Scott, 2022). Interviewee 016 mentioned that New Zealand is one of the leading nations conducting the Ross Sea toothfish stock assessment, a costly research endeavor that yields benefits for nations and private fishing organizations alike.

Norway stands out as a major recipient of RDI grants for their Southern Ocean fisheries. Our interview with Aker Biomarine representatives suggested that the company benefits from tax deductions related to research and development initiatives. Interviewee 017 mentioned that each year, Aker Biomarine can claim tax deductions for Southern Ocean research expenses, subject to an undisclosed monetary limit. Additionally, Aker Biomarine has the option to participate in

general innovation programs administered by the Norwegian Research Council, where their proposals are evaluated alongside research projects from various industries. Presently, Interviewee 017 stated that Aker Biomarine is the recipient of a 5-year research grant (currently in its third year), covering 40% of a $14 million USD research endeavor in the Southern Ocean. Norway offers extensive funding opportunities for research and development, providing a vital foundation for the continuity of Southern Ocean research.

Infrastructure Support

Our interviews indicate that direct financial support for the development of infrastructure, such as fishing vessels, equipment, technology, ports, and processing facilities for Southern Ocean fisheries, is limited. While our investigation focused on the 2023 fishing season, it is important to acknowledge that although most fishing organizations are not currently receiving financial support for infrastructure development, it does not imply that they have not received such support in the past. For example, in 2004, the EU instituted a ban on subsidies for the construction of fishing vessels. However, interviewee 009, 010 and 028 argued that many EU registered vessels that operate across the high seas, including in the Southern Ocean, were built before 2004. This is the case for three of Sampers' fishing boats: Austral, built in 1993, and Albius and Cap Horn 1, both built in 2002. Interviewee 009 stated that today," most of the EU fishery subsidies are limited to fuel tax concessions and tax concessions related to employment, with little to no direct subsidies for modernization". However, this analysis overlooks the substantial investment of millions of tax dollars in the construction of distant water fishing vessels in the late 1990s and early 2000s, which continue to be operational today.

Our interviews alongside government reports suggest that Chinese and Norwegian fishing companies stand out as major recipients of infrastructure subsidies. Chinese government reports indicate that one of the largest subsidy categories in China is for vessel renovation and construction (Mallory et al., 2021). This subsidy program is known as the "Central Governmental Subsidy Fund for Fisheries Development, Vessel Decommissioning and Renovation, and Fisheries Vessel Reduction and Industry Transition". Within this program, one of the major goals is to increase the application of "high performance materials" that maximize fishery operations for distant water vessels (Mallory et al., 2021). In 2016, the Ministry of Agriculture (MOA) issued a policy that mandates that subsidies for vessel renovation and construction should not exceed 30% of the total cost of renovation or construction (Mallory et al., 2021).

For the Southern Ocean specifically, the MOA document translated by Mallory et al., 2021, details that newly built professional Antarctic krill fishing and processing vessels have the highest maximum allowable subsidy for any distant water vessel at 150 million CNY (~21 million USD) (Mallory et al., 2021). This is followed by renovated Antarctic krill vessels at 30 million CNY (~4 million USD) per vessel. The MOA document delineates 19 vessel categories, with Antarctic krill fishing vessels comprising the top two most heavily subsidized vessel types. China's substantial subsidies not only support infrastructure development for Southern Ocean fisheries but also allocate the highest subsidies for vessel construction and renovation among all Chinese DWF. This underscores China's firm commitment to expanding and modernizing their Southern Ocean krill fishery, as evidenced by its significant subsidy support.

Our interview with Norwegian industry representatives shows that Norwegian public institutions have subsidized infrastructure development for boat construction and the development of a processing plant for krill. The Norwegian GIEK and Eksfin are two public institutions that offer

government loans and guarantees in close cooperation with commercial banks for infrastructure development. Interviewee 017 mentioned that Aker Biomarine's largest krill vessel received a "financial guarantee" from Eksfin, indicating that if the debtor defaults on payment, the bank would assume responsibility for it. Interviewee 017 further argued that "investment guarantees" mitigate foreign political risks for investors and lenders seeking to invest abroad, providing significant benefits to Aker Biomarine's Southern Ocean fishery projects. Similarly, Interviewee 017 stated that Aker Biomarine has secured approximately $5.6 million USD (40% of the total cost) from the Norwegian Research Council to finance a new company factory. As Norway's sole Southern Ocean fishing company, Akerbiomarine has received substantial infrastructure support from the Norwegian government for its current operations and future investments.

Import Subsidies

Among all Southern Ocean fishing countries, our interview data and analysis of government reports suggest that only two countries offer import subsidies, with China offering substantial financial incentives for the importation of Antarctic catch. China not only offers national import subsidies through the MOA and the General Administration of Customs (GAC), but Chinese provinces also implement financial incentives for the import of catch through their regional ports (Mallory et al., 2021). Nationally, the MOA and GAC jointly issued a policy in 2000 stating that fish caught by distant water fishing vessels operating in the high seas would not be subject to import taxes when transported back to China (GAC, 2000). In 2019, research suggested that Chinese import tax incentives for DWF amounted to 2.805 billion CNY (388 million USD) (Mallory et al., 2021). At the regional level, provincial governments enhance this support by offering financial incentives to encourage DWF to import their catch at local ports. Oceana researchers calculated that Chinese provinces spent about 40 million CNY (5.5 million USD) on

these programs (Mallory et al., 2021). Import subsidies are likely pivotal for China's Southern Ocean fishery, serving as a primary driver for Chinese krill companies to undertake round trips to and from the region (Figure 4). Notably, no other Southern Ocean fishery interviewed directly offloads their catch in countries in the Northern Hemisphere, highlighting the unique subsidy dynamics that propel China's operations in the area.

In Australia, the Tasmanian Freight Equalisation Scheme (TFES) provides financial assistance for costs incurred by shipments of eligible non-bulk goods moved by sea across the Bass Strait (TFES, 2024). Because Australian Longline unloads its toothfish catch in Hobart, Tasmania, and then ships it to Mainland Australia, they receive “net sea freight assistance” for the importation of their catch. For example, interviewee 002 shared a company report that shows that from May 2022 to September 2022, Australian Longline received $21,000 in freighting subsidies. More recently, from October 2022 to January 2023, Australian Longline fishery received $23,100 in freight subsidies. The objective of TFES is to “provide Tasmanian industries with equal opportunities to compete in other markets” and in 2022 TFES spent $181.7 million in financial assistance (TFES, 2024). Although these subsidies are not exclusive to the fishery sector and benefit various industries, Australian Longline gains a competitive edge from government subsidies that reduce their export costs to key Australian markets.

In Uruguay, the Montevideo Port has become a popular choice for Southern Ocean fisheries to offload their catch. Interviewee 026 mentioned that Montevideo is classified as a "free port," which according to transit law, shipments unloaded in Uruguay but not intended for distribution within the country are exempt from import taxes. Operating under the free port regime, which offers various tax benefits, incentivizes the utilization of the Montevideo Port by foreign companies. Interviewee 026 clarified that currently, the only payments needed to unload catch in Uruguay are

service fees, which amount for $3 USD per ton of fish caught unloaded at the port. Akerbiomarines krill fishery has taken advantage of these tax incentives and its entire krill fishery operation is now based from Montevideo. When Aker Biomarine offloads its catch in Montevideo, it promptly exports it, circumventing the national fees applicable to vessels distributing their catch within Uruguay. While Uruguay does not provide any direct import subsidies it provides tax incentives that aim to incentivize foreign investment within the country.

Import subsidies, however, might have only a limited impact on the extensive margin of Southern Ocean fisheries if vessels would continue to operate without them. Interviewee 002 clearly stated that "while import subsidies alleviate the costs of transporting the catch to mainland Australia, they are not detrimental to their operations." This view is further supported by Interviewee 003, who stated that moving Austral Fisheries' home port from Australia to Mauritius saved them money even in the absence of subsidies. Therefore, the removal of import subsidies for most Southern Ocean fisheries would likely have little to no effect on fishing activity. The exception is China, which stands out as the sole supplier of import subsidies aimed at incentivizing Southern Ocean fisheries to land their catch on the nation's mainland. While countries such as Australia offer financial assistance for goods transportation and Uruguay provides tax incentives for foreign companies to unload catch at its port, none of these measures rival the financial benefits enjoyed by Chinese Southern Ocean fisheries. Additionally, interviews conducted with government officials from Chile, New Zealand, and South Africa, the only other nations hosting Southern Ocean fisheries operating from their domestic ports, reveal that these countries do not offer import subsidies. With the exception of China, import subsidies do not significantly impact the operations of private fishery organizations targeting krill and toothfish.

Lessons learned, Knowledge Gaps and Limitations

Government subsidies for Southern Ocean fishing companies are complex and diverse, varying significantly between countries and among individual companies. Similarly, within the broader context of DWF, the Southern Ocean stands out as a unique region for fishery subsidy allocation, characterized by the complex operations of private companies targeting toothfish and krill. Because the vast majority of fisheries operate from home ports outside their countries' national jurisdiction, the extent of subsidies they would otherwise receive becomes compromised. Several of our interviewees, including those from Australia, Korea, Spain, Ukraine and the UK, argued that moving fishery operations to home ports closer to the Southern Ocean, where costs are lower, proved far more profitable than staying in their original home ports and potentially benefiting from government subsidies. Similarly, many of these companies continuously adjust their operations to improve profitability, often relocating their home ports, changing their vessel maintenance locations, and docking their boats in the off-season wherever it is most cost-effective. This constant movement, and often yearly changes to their fishing routes and operations, subjects Southern Ocean fisheries to varying tax regimes, operational costs, and state and national policies.

Among DWF, Southern Ocean fishery subsidies must be understood on a country-by-country basis and, in many cases, on a company-specific basis. This is because there is substantial heterogeneity across countries and companies. Interviews reveal that many fishing companies operating in the Southern Ocean do not receive substantial subsidies, in contrast to their national counterparts fishing within their EEZs (interviewees 005, 008, 013, 019, 020, 021, 026) or in other distant water regions, as suggested by global literature on fishery subsidies (Sala et al., 2018; Skerritt & Sumaila, 2021a; Sumaila et al., 2019; Villasante et al., 2022). Second, for countries with multiple Southern Ocean fishing companies, our results indicate that subsidies are inconsistently distributed, with some companies receiving them while others do not (interviewees 002, 003).

When applied to the Southern Ocean, global subsidy datasets often overlook the complex operational dynamics of this region and their impact on the allocation of government subsidies. For one, careful consideration must be given to the influence of home port locations, aspects frequently overlooked in global datasets. Developing a global dataset that addresses the regional aspects and nuances specific to Southern Ocean fisheries is extremely complicated. Applying country- and company-specific subsidies within the complex framework of Southern Ocean fisheries on a global scale presents significant challenges. However, our research highlights the importance of understanding these challenges both nationally and regionally. While our results reveal a unique distribution of fishery subsidies in the Southern Ocean, similar nuances could potentially be observed in other high seas regions. Regional studies that delve into the intricate interplay between private fisheries and governmental resources can provide valuable insights into the complexities surrounding subsidy distribution within DWF.

Primary data collection and evidence for this study was largely based on interviews. While this provided us with insightful knowledge about individual companies and the relationship between national governments and the fishing industry, it also constrained us to rely on our interviewees' own accounts. Even though our data collection was supplemented with other sources of information, which were often presented to our interviewees during our interview, it is possible that we received incomplete or biased information. Similarly, our interviews represent only a subset of all Southern Ocean fishing companies. Despite reaching out to all registered fishing companies, we were unable to interview representatives from every company. This limitation also applies to other Member States that have fished in previous seasons outside the scope of our study, such as Russia. Although Russia has been an active participant in Southern Ocean fisheries, it was not represented in our study because it had not registered to fish since 2021. However, Russia

registered again in 2024, along with a new Member State, Namibia. Knowledge gaps could be addressed through more interviews and research as well as by CCAMLR Member States increasing transparency and providing detailed information on the direct transfer of funds from government and public entities to their Southern Ocean fishing companies.

While we acknowledge the gaps in knowledge and the potential for incomplete information, our results suggest the need for a closer investigation of all distant water regions. Although global studies are valuable for representing the overall state of subsidy distribution to DWF, detailed regional analyses that assess subsidy allocations by country and, further, by individual companies, will provide a more comprehensive understanding of the current state of DWF subsidies.

Conclusion:

While prior research emphasizes the significant reliance of DWF on government subsidies (Sala et al., 2018; Schuhbauer et al., 2017, 2020; Skerritt & Sumaila, 2021a; Sumaila et al., 2019a; Sumaila et al., 2016; Sumaila et al., 2010a), our country-specific study reveals a surprising trend: only a minority of Southern Ocean fisheries heavily depend on government support, with the majority operating independently of such subsidies. This prompts the question: if all fishery subsidies were eliminated, would Southern Ocean fisheries cease to exist? Are their operations contingent on government support? Our primary data collection suggests otherwise. While many Southern Ocean fisheries receive some level of subsidies, these subsidies are likely insufficient to significantly alter their operations. Instead, private fishery organizations continually adjust their economic strategies and operational dynamics to enhance their annual earnings. This is frequently demonstrated by private fishery organizations choosing to operate from foreign ports, which effectively reduces their costs and travel time to reach the Southern Ocean. The economic value

of these fisheries is therefore a key driver of fishing activity in the Southern Ocean. For toothfish specifically, the exponential growth in its consumer market (Greely et al., 2015), and the associated economic benefits, have led many fishing companies to forego potential subsidies from their governments. As argued by interviewee 023, "the extent of such support would still be lower than the costs saved by operating from foreign ports." It can be inferred that in the absence of fishery subsidies, the vast majority of Southern Ocean fishing vessels would persist in operating at their current scale. This finding stands in contrast to the results reported in Sumaila et al. 2010b, which reported that while the profitability of deep and high seas was 10% of gross revenues, the amount of subsidies received by the group as a whole was 15% of gross revenues.

Chinese and Norwegian fisheries, however, stand out as major recipients of subsidies, with a portion of their operations heavily reliant on government support. China's unique ability to conduct transpacific voyages and land their catch back at national ports, unlike any other fishery in the northern hemisphere, is primarily enabled by a combination of national and provincial subsidies. These subsidies are specifically aimed at encouraging fisheries to land their catch in mainland China. They are distributed through various means, including fuel subsidies, tax breaks, discounted loans, infrastructure support (e.g., vessel construction, of which krill fishing vessels receive the highest subsidies among all distant water fishing vessels in China), and import subsidies (Mallory et al., 2021). Chinese Southern Ocean fisheries are heavily reliant on government subsidies and greatly benefit from national laws and regulations enacted by the government and its ministries. These legislations aim to reduce the costs associated with Chinese DWF, ultimately incentivizing fisheries to engage in longer voyages, fish for longer periods, and expand their reach by investing in new equipment and fishing vessels financed by the government.

Unlike most Southern Ocean fishing companies that operate from foreign ports, including those from Japan, Korea, Spain, Ukraine, and the United Kingdom, Norway continues to benefit from government subsidies regardless of its location of operation. Norway's proportional electoral system and state-funded banking system provide a platform for industries, including fisheries, to receive high levels of economic support. This support comes from Norwegian government innovation funds, state and federal agencies, and national banks (Rickard, 2018). Akerbiomarine, Norway's only Southern Ocean fishing company, has received millions of dollars in subsidies from several government agencies and banking institutions in the form of tax breaks, discounted loans, research and development grants, and infrastructure support. Moreover, the magnitude of Akerbiomarines Southern Ocean operations, responsible for catching over 70% of Antarctic Krill in the 2022 season (Figure 3.2), has been highly influenced by investment support and fishery subsidies allocated by the Norwegian government.

While the potential profitability of China's and Norway's Southern Ocean fisheries hinges upon their government subsidies, the analysis of the 11 other countries examined in this study presents a contrasting scenario. For one, countries with sub antarctic EEZs, such as Australia, France, and the UK, tend to have much larger catches and less competition for resources (Figure 3.1 & 3.2), than those exclusively fishing within the areas managed by the CCAMLR Convention (e.g., Chile, China, Japan, Korea, New Zealand, Norway, Spain, Ukraine, Uruguay). When addressing the profitability of Southern Ocean fisheries one must first consider the substantial heterogeneity across years and vessels. Several of our interviewees, including interviewees 019 and 021, contended that the profitability of toothfish fluctuates greatly by season. They noted that in many years, their companies pivot to other areas of the ocean, targeting different fish species to diversify their portfolio and operate in a more commercially viable manner.

Conversely, insights drawn from our interviews with industry representatives from Australia, France, and the UK underscored the remarkable profitability of their toothfish fisheries. For certain companies, such as Samper from France, their toothfish fishery has evolved into a highly lucrative venture, in stark contrast to some of their other DWF operations, such as for tropical tuna, which have incurred significant costs and financial losses over the years (Interviewee 009). Similarly, Interviewee 024 mentioned that "if their fisheries operated on the high seas outside their Southern Ocean EEZs, like some foreign companies have done in the past, they would make significantly less compared to their current earnings". This ultimately highlights the disparity in financial success among vessels. It is noteworthy that the companies with the highest toothfish catches, and potentially the most profitable, operate without reliance on government subsidies.

The profitability of Southern Ocean fisheries and the extent of fishery subsidies is inherently nuanced and country-specific, cautioning against broad generalizations that overlook the unique circumstances and dynamics at play within each national context. Southern Ocean fishery subsidies should thus be assessed based on their impact on individual companies' operations, within the broader context of national policies and practices. While the fishing operations of a minority of companies are greatly influenced by their government subsidies, Southern Ocean fisheries uniquely position themselves via economic and geographic partnerships that enable them to reduce costs and maximize fishing time in the absence of government subsidies.

Conclusion to the Dissertation

ABNJ remain one of the last frontiers for resource management and conservation (Ban et al., 2014). While our research identifies specific measures to address conservation challenges and advocates for the application of tools to tackle climate change, sustainability, and legal protection enforcement, the governance of natural resources in ABNJ continues to heavily favor the status quo rather than embracing adaptive approaches. This trend is particularly evident in multilateral conventions such as CCAMLR and RFMOs, as well as in certain subsidiary bodies of the United Nations. Nevertheless, there is substantial scientific evidence supporting the application of climate-adaptive measures that enhance the resilience of fisheries to climate change, while also safeguarding species and ecosystems against the cumulative effects of anthropogenic activities.

When addressing the governance complexities of managing marine resources in ABNJ, it is essential to consider these three primary governance layers that influence decision-making activities: national, regional, and international. This PhD dissertation aimed to do just that. At the national level, government funding for private companies involved in distant water fishery operations heavily influences their activities, often leading to resource overexploitation (Martini & Innes, 2018; Sakai et al., 2019; Sumaila et al., 2019). Addressing economic partnerships, incentives, and subsidiary support from governments to private fishery organizations is crucial for understanding the current state of distant water fishery operations. While these fisheries are often governed by multilateral conventions and agreements, their operational dynamics, geographic movement, and catch are heavily influenced by the economic support they receive from their national governments. Our research specifically addressed this issue for the 13 countries fishing in the Southern Ocean and identified China and Norway as two Member States heavily dependent on fishery subsidies. This approach can be applied to other regions of the world, offering a clearer

picture of the funding mechanisms driving high seas fisheries and their potential impact on the health of ecosystems and fish stocks.

At the regional level, addressing fishery management and natural resource conservation is contingent on the policies and decision-making processes enacted by Conventions and RFMOs tasked with governing marine resources in ABNJ. Consequently, identifying policy pathways for the legal protection of marine ecosystems or applying climate-resilient fishery management tools cannot be easily transferred from one region to another. Our application of climate-resilient management measures under the CCAMLR policy was unique to the CCAMLR Convention and required unilateral agreement among all member states due to its consensus-based decision-making process. In contrast, our work in the Southeast Pacific revealed a fragmented conservation structure, influenced by various stakeholders with distinct legal remits and multiple RFMOs managing different species in the same area. Unlike CCAMLR, identifying pathways for ecosystem conservation, such as through MPAs, required addressing the conservation mandates of each management body and finding cross-sectoral policies or partnerships to regulate human activities in the region.

Lastly, the governance of marine resources in ABNJ is heavily influenced by United Nations frameworks such as the United Nations Convention on the Law of the Sea, the United Nations Fish Stock Agreement, and UN bodies including the Convention on Biological Diversity, the UN Food and Agriculture Organization, the International Maritime Organization, and the International Seabed Authority. While the international conservation field remains fragmented, the potential of the Biodiversity Beyond National Jurisdiction (BBNJ) Agreement as a legally binding instrument offers a promising opportunity for comprehensive management and protection of high seas ecosystems. This new attempt to facilitate international coherence and coordination differentiates

from previous treaties by ensuring the conservation and sustainable use of marine biological diversity in ABNJ through four main issues: marine genetic resources, area based management tools (including MPAs), environmental impact assessments, and capacity building. The BBNJ treaty provides the legal tools to manage, regulate and protect high seas ecosystems.

This dissertation aimed to provide a comprehensive overview of available management tools and conservation strategies for national, regional, and international frameworks governing marine resources in ABNJ. Each chapter analyzed the governance complexities of managing these resources from different perspectives, collectively shedding light on the intricate operations needed to enhance the current management system for the high seas. While I am confident that international efforts are underway to address the polycentric and fragmented structure of high seas governance, I believe that limiting public-private partnerships that incentivize fishing while also promoting the sustainable development of human activities is crucial. Collectively, high seas conservation and the sustainable management of resources will progress only to the level deemed acceptable by the parties least interested in reform. Therefore, the most significant change must occur at the national level. If individual countries prioritize conservation efforts—such as ratifying the BBNJ treaty and committing to prohibit harmful fishery subsidies—then there is the potential for significant advancements in the sustainable management of ABNJ.

As I conclude this dissertation, my main recommendation for high seas governance is to build upon international treaties that provide the legal framework for conservation, while recognizing the importance for regional management organizations and national governments in marine governance. International treaties such as the BBNJ Agreement are extremely important, but it is equally important to engage countries that are not members to these agreements (e.g., China) or even the United Nations Convention on the Law of the Sea. Especially when these countries

frequently dominate high seas fishery operations. Involving these countries within the regional conventions they are members to (e.g. China's membership to SPRFMO) will be essential, especially in the absence of their participation at the international level. Ultimately, high seas governance can't overlook the significant influence that governments and private companies exert on the high seas. The future of this field must advance on all fronts - strengthening international policies to foster better governance, while also promoting greater dialogue, data sharing, and scientific collaboration at regional and national levels. This in turn will encourage cross collaboration with the ultimate goal of achieving sustainable management of marine resources across the high seas.

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