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Research advances and conservation needs for the protection of the Salas y Gómez and Nazca ridges: A natural and cultural heritage hotspot in the southeastern Pacific ocean

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ABSTRACT

One of the main objectives of the BBNJ Treaty is to enable States to establish large-scale marine protected areas (MPAs) to encompass at least 30 % of areas beyond national jurisdiction (ABNJ) by 2030, contributing to the Kunming-Montreal Global Biodiversity Framework. We reviewed geological, oceanographical, biological, ecological, cultural and governance information on the Salas y Gómez and Nazca ridges in the southeast Pacific

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(SEP), described current and future threats, reviewed conservation measures and analyzed what remains to be done to achieve their effective protection. We point the relevance of creating a MPA under the BBNJ treaty and the establishment of specific actions from key intergovernmental organizations to conserve the fragile and unique ecosystems of this region facing multiple threats. Among other measures we propose the closure of the area to fishing, the enactment of effective conservation measures, the rejection of exploratory fishing and the increase of research and capacity-building activities within the region. Protecting this area will have major global benefits for ecosystem connectivity, climate regulation, food security, and other ecosystem services. It would also be seen as a global example for conserving biodiversity in ABNJ by collaboration between neighboring countries with common interests in a shared environment, contributing to global conservation goals. The information gathered here is key to build the scientific basis for decision-making on sustainable use, management, and conservation of biodiversity inhabiting the islands and seamounts of the Salas y Gómez and Nazca ridges, a natural and cultural heritage hotspot in the middle of the SEP.

1. Introduction

The Convention on Biological Diversity (CBD) Kunming-Montreal Global Biodiversity Framework (GBF) was adopted in December 2022, replacing the 20 Aichi Biodiversity Targets included in CBD 2011–2020 Strategic Plan for Biodiversity.[1] The GBF focuses on four overarching goals for 2050 and 23 specific targets with a deadline of 2030. Target 3 aims to protect 30 percent of Earth's land, oceans, coastal areas, and inland waters by 2030 (commonly known as the 30×30 target). For the ocean this primarily means the establishment of marine protected areas (MPAs). The High Seas Treaty also known as the "BBNJ Treaty" (biodiversity beyond national jurisdiction), is at the forefront of international initiatives to protect the ocean, promote equity and fairness, tackle environmental degradation, fight climate change, and prevent biodiversity loss in marine areas beyond national jurisdiction (ABNJ), including the high seas and deep seabed. One of the main objectives of the BBNJ Treaty is to enable States to establish large-scale marine protected areas to encompass at least 30 % of ABNJ by 2030.[2] To achieve these ambitious goals, it is of essence to acquire the most up-to-date and detailed information on the state of marine ecosystems. However, many areas in ABNJ (Areas Beyond National Jurisdiction) are currently unstudied, under-studied, or exhibit biased information towards certain taxa and disciplines. A particularly relevant example is the South Pacific Ocean, scattered with remote islands and seamount chains. The geological, oceanographic, and cultural information about this area is dispersed across bibliographic sources, and scientific studies on biodiversity in this region have primarily focused on establishing a species baseline and describing specific biogeographic and genetic patterns of marine species [1–3].

The Salas y Gómez and Nazca ridges are two contiguous volcanic seamounts chains that extend across more than 2900 km off the west coast of South America in the southeastern Pacific [2–4]. This region hosts one of the most unique and biodiverse seascapes on Earth, with an extremely high rate of endemism, critical habitats for benthic organisms, essential migration corridors for highly mobile species, and the presence of over 80 threatened or endangered species [3–6]. In addition, the Salas y Gómez and Nazca ridges possess a rich cultural and maritime heritage with profound connections to Indigenous islander and mainland communities from Chile as well as other nations [4,7]. The Nazca Ridge stretches across approximately 1100 km between the eastern edge of the Salas & Gómez Ridge and the subduction zone off the Peruvian coast and is located mostly in ABNJ, with a smaller northeastern section located in Peru's national waters [2,3]. The Salas y Gómez Ridge extends across approximately 2300 km between the Nazca Ridge and Rapa Nui (Easter Island) [8]. Its central portion is located in ABNJ, whereas both ends of this ridge fall within the Exclusive Economic Zone (EEZ) of Chile around Rapa Nui (~27°S-~109°W) and Desventuradas islands (~26.5°S-~70.9°W), respectively (Fig. 1) [3]. The seamounts of the Salas y Gómez and Nazca ridges represent approximately 41 % of all seamounts recorded throughout the southeastern Pacific [9,10,8] and its shallow waters span across two unique ecoregions: Easter Island and Desventuradas Ecoregions [3,11,12]. The deep waters of this region include two bathyal biogeographic provinces (Southeast Pacific Ridges and Nazca Plate), and one abyssal province (Chile, Peru, and Guatemala Basin) [3,13].

The waters, islands, and seamounts of the Salas y Gómez and Nazca ridges represent significant nursery areas for multiple species with ecological and economic importance, provide critical nesting and foraging habitats for seabirds [14–16], a nursery area for the Galapagos shark *Carcharhinus galapagensis* [17,18], and are considered stepping-stones for fishes, turtles, marine mammals and invertebrates [3,19,20]. The recognition of this region as a biodiversity hotspot in the middle of oligotrophic waters of the Pacific Ocean motivated the Convention on Biological Diversity (CBD) to recognize it as an Ecologically or Biologically Significant Marine Area (EBSA) in 2014.[3] In addition, the Salas y Gómez and Nazca ridges are also recognized as a Hope Spot by Mission Blue, and Rapa Nui, Salas y Gómez, and Desventuradas Islands are considered Important Bird Areas (IBAs), as well as Key Biodiversity Areas (KBAs) [3,4]. Most recently, the waters around Salas y Gómez Island were identified as an Important Shark and Ray Area (ISRA), and Rapa Nui and the entire Salas y Gómez and Nazca ridges were classified as a candidate Important Shark and Ray Area (ISRAc) by IUCN given the probable occurrence of endemic species and its function as a marine corridor for migratory species [21].

In recent years, efforts have been made by Chile and Peru to protect the portions of the ridges located in their EEZs [22,23]. Several large scale MPAs created by Chile cover all the waters of the Easter Island and Desventuradas ecoregions [24], and a recent MPA created by Peru aims to protect the easternmost portion of the Nazca Ridge (Decreto Supremo N° 008–2021-MINAM),[4] although fishing is still allowed above 1000 m. However, most of these ridges (over 73 %) are found in ABNJ, with no protection and facing multiple threats, such as climate change, overfishing, destructive fishing practices (e.g., bottom trawling), plastic pollution, and potential seabed mining, among others [3,4].

Of the entire Pacific Ocean, the Salas y Gómez and Nazca Ridges, as

[1] CBD, Nations Adopt Four Goals, 23 Targets for 2030 In Landmark UN Biodiversity Agreement (2022): https://n9.cl/bucp1

[2] UN, Further revised draft text of an agreement under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction: note / by the President, New York (2022).

[3] CBD, Decision XII/23: Marine and coastal biodiversity: Impacts on marine and coastal biodiversity of anthropogenic underwater noise and ocean acidification, priority actions to achieve Aichi Biodiversity Target 10 for coral reefs and closely associated ecosystems, and marine spatial planning and training initiatives. Conference of the Parties to the Convention on Biological Diversity Twelfth Meeting, Pyeongchang, Republic of Korea, 2014: pp. 168–177. https://www.cbd.int/meetings/COP-12

[4] https://www.gob.pe/institucion/produce/normas-legales/1952756–008-2021-minam

well as the Juan Fernández Ridge seamounts and oceanic islands (Rapa Nui, Motu Motiro Hiva = Salas y Gómez Island, Desventuradas, and Juan Fernández Archipelago) are among the least explored regions due to their isolation [1]. Most of the studies in this region were conducted by one US in 1958 and several USSR (now Russian Federation) expeditions between 1970 and 1990 outside of Chile's EEZ at 160–3000 m depth [5]. Recently, oceanographic cruises (CIMAR 21 and 22, EPIC 2019, Nat Geo-Oceana-ESMOI-Chilean Navy 2011, 2013, 2017) in the area have sampled benthic organisms from oceanic island coasts and several seamount summits within Chile's EEZ as part of the fieldwork of projects financed by the Chilean government (Millennium Nucleus for Ecology and Sustainable Management of Oceanic Islands (ESMOI), CONA C22 16–09 and FONDECYT Grant 1181153) and international initiatives (Japan Agency for Marine-Earth Science and Technology for EPIC Cruise, and Nat Geo Pristine Seas-Oceana).

This paper gathers geological, oceanographical, biological, ecological, and cultural information generated to date on the Salas y Gómez and Nazca ridges, describes current and future anthropic and natural threats and analyzes what remains to be done to achieve the protection of this remote region in the southeastern Pacific through cooperation with existing organizations as will be enabled by the new BBNJ treaty. This will build the scientific basis for decision-making on sustainable use, management, and conservation of biodiversity inhabiting the islands and seamounts of the Salas y Gómez and Nazca ridges, helping to achieve GBF Target 3 and the United Nations Sustainable Development Goals (SDGs) and their implementation.

2. Geology

Multiple geological hotspots and active hydrothermal vents are in the southeastern Pacific region [5,25–28]. The Salas y Gómez Ridge has been widely recognized for its diverse geology and submarine geography that includes over 110 seamounts [7]. This region is formed by submarine volcanoes that are distributed in groups and chains with a general linear East-West trend, where some of them are morphologically connected and form continuous structures of hundreds of kilometers that sometimes have flat tops like plateaus [9,29]. The most prominent volcanic structures correspond to Rapa Nui and Salas y Gómez Island with heights of more than ~3200 m with respect to the adjacent seafloor. The average height of the Ridge is around 2100 m above the surrounding seafloor, with the most common range being between 2000 and 2500 m [9,29]. Only in the area around Rapa Nui and Salas y Gómez islands, there are over 3000 submarine volcanic structures, where 383 of these are in the range of 200–3000 m height [30].

Seamounts located on the Salas y Gómez and Nazca ridges are all thought to have been produced by a common hotspot that is located close to the present location of Salas y Gómez Island [29,31–36]. This hypothesis is supported by higher Pb and Sr and lower Nd isotopic ratios detected in lavas from Salas y Gómez and adjacent seamounts [35]. Moving eastward along the Salas y Gómez and Nazca ridges, the seamounts become progressively older, from 2 million years on the western portion of the chain, to over 27 million years towards the northeastern end [29,34,35]. These seamounts provide a detailed record of the geological formation of this region that tracks the movement of the Nazca Plate as it moves northeastward before it becomes subducted under the South American Continent [36].

3. Oceanography

One of the main features dominating the mean circulation is the South Pacific Subtropical High (SPSH), a downward branch of the Hadley Circulation in the Southeastern Pacific Ocean (SEP) basin [37] that determines the presence of a quasi-permanent center of high atmospheric pressure at the surface around ~30°S. The SPSH plays a fundamental role in ocean-atmosphere interaction and climate variability at different temporal and spatial scales [38]. The SPSH is associated with the South Pacific Subtropical Gyre (SPSG), the large-scale anticyclonic low-level atmospheric circulation that feeds the trade winds that produce the upwelling along the coast of Peru and Chile, while depressing the thermocline in the mid-latitude open ocean through Ekman suction. The open-ocean region of the SEP is recognized as an ultra-oligotrophic zone [39] with the deepest nutricline and euphotic zone among all ocean gyres [40]. In addition, the SEP also hosts one of the largest oxygen minimum zones (OMZs) in the world, a subsurface layer of oxygen-depleted waters [41] due to the combined effects of the sluggish circulation [42] and the intense upwelling-induced organic matter export [41,43]. In the SPSG, the circulation system (Fig. 2a) is comprised of the westward South Equatorial

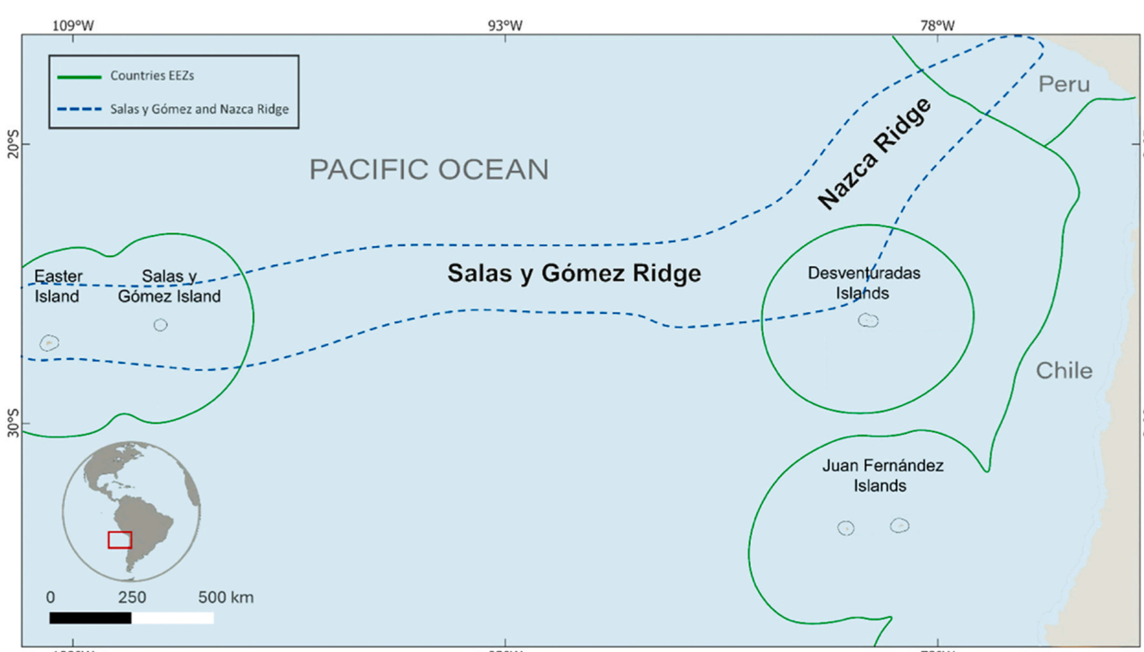

Fig. 1. Map of the Salas y Gómez and Nazca ridges located in the southeastern Pacific Ocean.

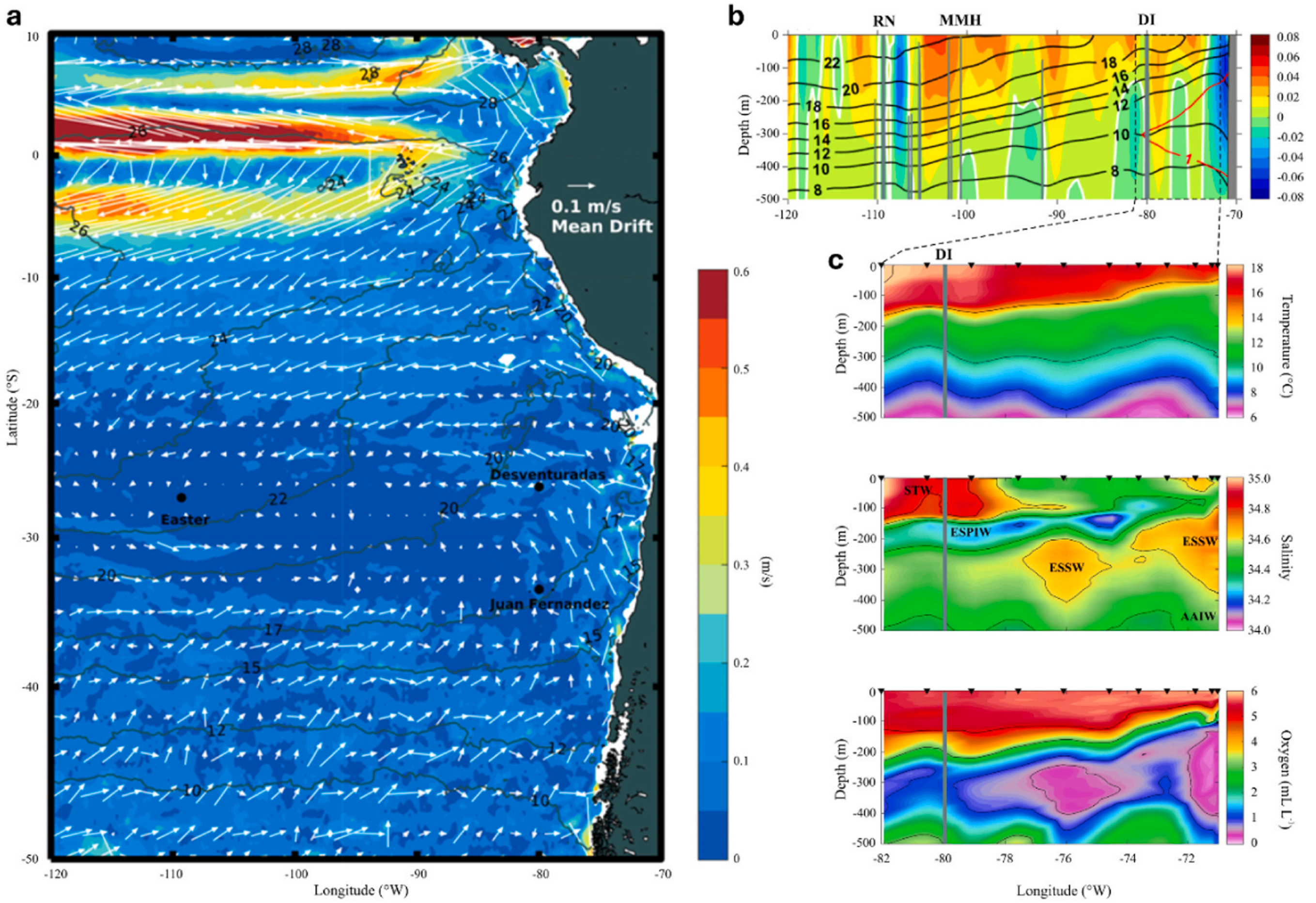

Fig. 2. a. Mean surface current from drifter data (Laurindo et al.) [50] for the period 1975–2015. Shading is for amplitude and vectors provide the direction (Taken from Dewitte et al.) [40]. Contours in gray correspond to the mean sea surface temperature. Black dots indicate the locations of Juan Fernandez Islands, Desventuradas Islands, and Easter Island. b. Mean zonal sections of temperature (black contours) and meridional geostrophic current referenced to a depth of 1000 m (red, northward; blue, southward) at 26°S (Taken from Dewitte et al.) [40]. The red line indicates the limit of the oxygen minimum zone (OMZ; isolepth 1 ml/L). **c.** Temperature, salinity, and oxygen zonal sections throughout CIMAR 22 transect at ~27°S (carried out between October 15 and 23, 2017). The water masses are indicated in the salinity panel as: Subtropical Water (STW), South Pacific Intermediate Water (ESPIW), Equatorial Subsurface Water (ESSW), and Antarctic Intermediate Water (AAIW).

Current, a narrow poleward western boundary current (East Australian Current), eastward South Pacific Current (streaming along the subtropical convergence zone), and the eastern flank by the Humboldt Current System (HCS), which is an archetype of eastern boundary upwelling system, that has a strong wind-driven upwelling and a very active eddy field. Below the surface, the HCS includes the poleward Peru-Chile Undercurrent (PCUC). The well-documented PCUC has been associated with the presence of oxygen-depleted waters at intermediate depths along the coast [44,45]. It is associated with westward propagation of surface eddies [46,47] and feeds the upwelling waters [48,49].

Longitudinally, the SEP presents oceanographic and hydrographic gradients, moving from the highly productive, temperate, and hypoxic (at mid-depth) waters near the coast of South America (i.e., HCS) to warmer, oxygenated, and oligotrophic waters to the west at Salas y Gómez Island and Rapa Nui (Fig. 2b, c) [44,51,52]. Schneider et al. [53] observed three water masses near Rapa Nui ~108°W: the water mass between the surface and 250 m is subtropical water (STW) (>35.5 psu, >19°C), immediately below this water and down to ~700 m is the Antarctic Intermediate Water (AAIW) with relative low salinity (34.3 psu, 5°C), and below the AAIW lies the Pacific Deep Water (PDW) (34.7 psu and 1.7°C). Fig. 2c shows the temperature, salinity, and oxygen sections at ~27°S from the CIMAR 22 cruise. From 82°W toward the continent, the STW (0–200 m) weakens and the salinity minimum strengthens in the surface layer (due to the South Pacific Intermediate Water, ESPIW) and the Equatorial Subsurface Water (ESSW) until the 380 m with a relative salinity maximum and an oxygen minimum (34.7, <0.1 ml/L), and subsequently the AAIW with a similar signal to offshore region.

Superimposed on this mean circulation, there is a relatively energetic mesoscale circulation (non-linear), whose amplitude is greater near the equator and alongshore off Peru and Central Chile, which results from the instability of the mean currents and mesoscale eddies, mainly by the Peru-Chile Undercurrent [45,46,54]. Mesoscale eddies generated along the coast have a complex vertical structure, with some cyclonic superficial eddies and other anticyclonic subsurface eddies, called intra-thermocline eddies, associated with the ESSW [45,47,55]. Such eddies can also transport low-oxygen waters and other properties in their core far beyond the longitude of these island systems [55,56]. In this sense, the Desventuradas and Juan Fernández seamount systems are in the route of westward-propagating eddies generated along the coast of Central Chile and forming a so-called striation in the eddy field [57]. In addition, these topographic elevations potentially affect ocean and local circulation [58]. In the case of oceanic islands, there is an island mass effect, as it produces a bloom in phytoplankton in the island wake [59,60]. Several physical processes can be involved in the island mass effect, such as coastal upwelling, Ekman pumping, eddies, or internal waves, and even the local human impacts [60]. Thereby, the bathymetric and longitudinal variation of oxygen, temperature, and salinity can influence marine species hosted by the seamounts near the continent, depending on the depth of the top of each seamount and the circulation patterns [61].

4. Biodiversity and ecology

The high degree of isolation of the Salas y Gómez and Nazca ridges due to the influence of the South Pacific Gyre, the Humboldt Current System, and the Atacama Trench, has produced a unique biodiversity in this region, marked by a high level of marine endemism and therefore are recognized as a global biodiversity hotspot [4,5,7,9,62]. The marine fauna of this region has higher biogeographical affinities to the Western Indo-Pacific than to the Eastern Pacific [3,5,9,12,14,20,61,63–72]. In addition, seamounts on the Salas y Gómez and Nazca ridges provide important habitat and migration corridors for large vertebrates (e.g., whales, sharks and turtles), numerous pelagic fishes, seabirds, corals and other ecologically and commercially important species [3,6,9,8,16,73–75]. The Salas y Gómez and Nazca ridges are also home to 93 species that are considered endangered, near threatened or vulnerable to extinction, including 25 species of sharks and rays, 21 species of seabirds, 16 species of corals, seven species of marine mammals, 7 species of bony fishes, 5 species of marine turtles, and 1 species of sea cucumber [3,76]. The unusual water clarity in this region allows sunlight to reach deeper depths than in other ocean areas, and consequently the peak of pelagic primary productivity in this region occurs around 200 m in depth, and crustose coralline algae can be found down to around 300 m depth, deeper than in any other place on Earth [3,6].

4.1. Benthic zone

The intrusion of the Equatorial Subsurface Water surrounding the Salas y Gómez and Nazca ridges intersects a region with low-oxygen waters, which may act as a barrier to dispersal and leading to high rates of deep-water speciation in this region [77–80]. Shallow benthic communities are only found around the islands Rapa Nui, Salas y Gómez and Desventuradas. The first two have distinct coral communities dominated by *Porites lobata* and *Pocillopora* spp. Living corals cover ~55 % of the bottom, providing refuge, feeding, and breeding habitats for numerous species of invertebrates and fishes [12]. Shallow community structure is strongly influenced by wave exposure and grazing both at Rapa Nui and Salas y Gómez islands [81,82].

Deep-sea explorations across the Salas y Gómez Ridge revealed a unique community composition of megafauna on every seamount; with a high rate of species discoveries and numerous taxa that are new to science, including fishes [6,83–94], mollusks [71,95], polychaetes [96,97] and crustaceans [72]. For instance, limited ROV surveys at 160–280 m depths recorded six new species of fishes [98], 15 morphospecies not previously reported, two potential new genera of echinoderms [99], dense assemblages of whip black corals (*Stichopathes* spp.) represented by at least four morphospecies [100,101], as well as mushroom-coral (*Cycloseris vaughani*) fields at mesophotic depths off Rapa Nui [102].

Recent investigations of bathyal and abyssal sediments in this region show that seamount meiofaunal communities are characterized by a high diversity of nematodes and low presence of other meiofaunal groups [103]. The sediment geochemistry shows a poor organic content explained by the low values of chlorophyll-a, carbon, and nitrogen observed, mainly around Salas y Gómez seamounts [103]. Studies on macrofaunal communities (300 micrones) indicate that polychaetes and harpacticoid copepods are dominant at the base of studied seamounts [104]. The overall number of individuals per species is low, the diversity of species is moderate, and the number of species is higher on those seamounts where polymetallic nodules were recorded [105]. Benthic communities dominated by polychaetes with special morphological adaptations suggests that summits of certain seamounts, located NW off Desventuradas Islands, could be sporadically influenced by intrusions of oxygen-depleted waters [97]. Sediment microbial communities are dominated by Proteobacteria (50 %) and by the presence of Firmicutes, Acidobacteria, Cloroflexi, Plactinomycetes, Actinobacteria and Gemmatimonadetes [105].

4.2. Pelagic zone

The Salas y Gómez Ridge and the southern portion of the Nazca Ridge are located near the center of the South Pacific Gyre, an area characterized by ultraoligotrophic waters, a deep chlorophyll maximum [106], and a particularly high biodiversity for picoplankton, siphonophores and other gelatinous pelagic invertebrates [62,107,108]. Studies made by Medellín-Mora et al. [109] about mesozooplankton communities at depths between 0 and 800 m between the islands of Rapa Nui and Salas y Gómez recorded high diversity of copepods. The copepod community was dominated by small-sized species, omnivores and with a higher presence of the cyclopoid order. Meroplankton distribution in Salas & Gómez and Rapa Nui islands would be influenced by geostrophic flow near the coast of Easter Island, determining the vertical migration behavior of the larvae, and promoting larval retention. The distribution pattern of ichthyoplankton endemic species between both islands could be an effect of larval duration in the plankton as well as connection through seamounts between islands [110].

Neustonic polychaete assemblages recorded a dominance of meroplanktonic species with higher abundance and diversity of the Spionidae family. The structure of the polychaete assemblage is determined by the interaction between mesoscale oceanographic processes (IME), as well as the distance from seamounts and oceanic islands [111].

4.3. Fishes

Shallow-water fishes along the Salas y Gómez and Nazca ridges have mostly been studied around the emerged islands of Rapa Nui, Motu Motira Hiva, and Desventuradas. These shallow-water fish assemblages are primarily of Indo-Pacific origin but are impoverished compared with locations further to the west in the central Pacific. Despite the low taxonomic diversity of these locations, they are known to have some of the highest marine endemism found anywhere on Earth because of their extreme geographic and oceanographic isolation [12,14,24]. The first scientific paper on the fishes of Rapa Nui was published in 1912 [112] and since then numerous papers have been published on the subject. There are currently 164 nearshore and epipelagic species known from Rapa Nui, of which 21.7 % are known only from that island [113]. At the eastern end of the Salas y Gómez and Nazca ridges, the Desventuradas Islands has only 43 species of nearshore fishes, of which 56 % are endemic to Desventuradas and nearby Juan Fernández islands [68]. These endemics are numerically dominant components of the fish assemblage at all these locations and these extremely high values of endemism highlight the global significance and uniqueness of these biodiversity hotspots [12,14,114].

High fish biomass and the abundance of top predators (primarily sharks and jacks) at uninhabited Salas y Gómez Island compared with Rapa Nui is likely evidence of extensive and long-term overfishing of target species at Rapa Nui [12,82,115,116]. Similarly, higher fish biomass and more top predators at uninhabited San Ambrosio Island in the Desventuradas Islands compared with the nearby populated Robinson Crusoe Island in the Juan Fernández Archipelago also shows how even small amounts of fishing effort can have significant impacts on the fish assemblages in these small, isolated ecosystems where recruitment is limited [14].

The first deep-sea benthic ichthyological collection from the Salas y Gómez and Nazca area was made by the Downwind Expedition of the Scripps Institution of Oceanography in 1958 and consisted of a single specimen of sea robin, *Pterygotrigla picta* [117]. Much of the early comprehensive research on fishes of these ridges comes from Soviet research trawling in the 1970s and 1980s [20]. From these surveys, a total of 173 species of fishes in 66 families, exclusive of pelagic species, were described from these seamounts [5,20]. Of these, 136 species in 58 families were found at depths of 160–580 m. The other 37 species are deeper-dwelling species found on the seamount slopes at depths of more than 600 m. As with the shallow-water fishes, Parin [20] found an extremely high degree of endemism (42.8 %) in the deep-sea fishes. Recent surveys of the deep-dwelling fishes of the Easter Island Ecoregion by Easton et al. [98] revealed apparent depth breaks in fish assemblages between 150 m and 550 m and between 850 and 1100 m, which are comparable to breaks in the fish assemblages observed by Parin et al. [5] for seamounts along the Nazca and eastern Salas y Gómez Ridges. Several deeper water fish species endemics to Rapa Nui and Motu Motiro Hiva at the western edge of the ridge are also found near Desventuradas to the east, which suggest some level of species connectivity along this extensive ridge system [2].

Seamounts on the Salas y Gómez and Nazca ridges provide important habitat and migration corridors for numerous pelagic fishes. There has been historical fishing targeting Chilean jack mackerel (*Trachurus murphyi*), redbaits (*Emmelichthys* spp.), several species of tuna (*Thunnus alalunga*, *T. obesus*, *T. albacares*, and *Katsuwonus pelamis*), and bonito (*Sarda* spp.) [9]. Numerous species of billfishes (Istiophoridae) as well as sharks (*Prionace glauca*, *Carcharhinus* spp., *Sphyrna* spp., and *Alopias* spp.) have previously been recorded as retained catch managed by the Inter American Tropical Tuna Commission (IATTC) in high seas waters of the Salas y Gómez and Nazca ridges [75].

Overall, the shallow and deep-water fish assemblages of the Salas y Gómez and Nazca ridges harbor some of the most unique fish faunas found anywhere on Earth. However, the high degree of endemism also suggests that these assemblages have relatively limited dispersal potential and therefore pose higher extinction risks compared to more widely dispersed species. In addition, these endemics often have small thermal tolerances and unique habitat and environmental requirements, making them more susceptible to climate change [40]. Seamounts are also hotspots of pelagic biodiversity and the chain of seamounts along the ridges harbor a diverse assemblage of pelagic fishes and are an important corridor for many commercially important fisheries species. Moreover, this area is the main nursery area for jack mackerel in Chile, so an important area to the fishing grounds that are closer to the South American continent [73,118,119].

4.4. Turtles

The Salas y Gómez and Nazca ridges provide migratory corridors and foraging habitats for all five sea turtle species reported in the Eastern Pacific Region. Three of them have been cataloged as critically endangered by the IUCN (Loggerhead, *Caretta caretta*-South Pacific subpopulation, Leatherback, *Dermochelys coriacea*-East Pacific subpopulation and Hawksbill, *Eretmochelys imbricata*), one as Endangered (Green, *Chelonia mydas*), and one as Vulnerable (Olive ridley, *Lepidochelys olivacea*). Particularly in Easter Island, there is evidence of the presence of four of these species. Individuals of *D. coriacea* and *C. caretta* were caught by a longline fishery targeting swordfish around the island as part of a research/fishery cruise supervised by the Fisheries Development Institute-IFOP in 2004. In 2016 a juvenile loggerhead (*C. caretta*) was found with fishing line in both anterior flippers causing their amputation and death and corroborating the presence of the species in Rapa Nui [120]. A juvenile loggerhead was recently found (April 2023) by fishers in rapanui waters with a gillnet entangled around an anterior flipper and with part of this net at the end of its oral cavity. *Eretmochelys imbricata* was recently described for the island (and Chile) with reports based on underwater photographs and strandings [121], and *C. mydas* has been referred to as the most common species in this area as a result of increased research during recent years [122–126]. Although *L. olivacea* has also been mentioned as a turtle species that inhabits Rapa Nui [123], there are no photographs, fishery reports, or museum collection pieces that confirm its presence around the island.

Shillinger et al. [127] tagged forty-six female leatherbacks (*D. coriacea*) in Costa Rica between 2004 and 2007 and confirmed the existence of a persistent migration corridor spanning from the Pacific Coast of Central America, across the equator and into the South Pacific Gyre where leatherbacks likely migrate to forage [127]. This multi-year dataset corroborated leatherback movements around Easter Island, Salas y Gómez, and the Juan Fernández Archipelago. In the same way, Chandler [128] mentioned that leatherbacks were frequently caught near Juan Fernández. Another species commonly sighted in Juan Fernández Archipelago is *C. mydas*; however, to date there are no scientific or technical reports confirming its presence in this location. Recently a first photograph report of an olive ridley individual was obtained by a fisherman in Robinson Crusoe, Juan Fernández (Araya Ewert, F. pers. com., 2023). A study based on genetic data suggested that post-hatchling loggerhead turtles originating from the southwest Pacific rookeries undertake developmental transoceanic migrations to the southeastern Pacific Ocean associated with the South Pacific Subtropical Gyre [129]. It is probable that the absence of sea turtle reports in some specific areas associated with Salas y Gómez and Nazca ridges is due to a lack of research aimed at these species.

Recent investigations of *C. mydas* in Rapa Nui have demonstrated the existence of two morphotypes (black and yellow) with geographically distant natal origins in the Pacific Ocean [123,125,126]. These findings, together with the evidence of extensive migrations of the critically endangered leatherbacks from Central America [127] and loggerheads from the southwest Pacific rookeries, highlight the regional connectivity between populations and the relevance of this region for sea turtle conservation globally.

Ultimately, the need for further research on sea turtles and their protection in the Salas y Gómez and Nazca ridges is also supported by the existence of anthropogenic threats that have been detected in the region such as bycatch, interaction with fishing gear (entanglements with fishing lines, ghost nets, fishhook ingestion, etc.), boat collisions, organic pollution, plastic pollution, snorkeling/diving with turtles and artificial hand-feeding by tourists and fishermen [120,123,124,128,130].

4.5. Seabirds

As top marine predators, seabirds respond to changes in the oceanography, ocean productivity, and the ecology of their prey (e.g., krill, squid, fishes), shifting their at-sea distributions over multiple temporal scales (i.e., seasonally, inter-annually) [16,111]. Around the Nazca and Salas y Gómez ridges there are three archipelagos grouping a total of 10 islands and islets: Rapa Nui (Rapa Nui, Motu Nui, Motu Iti, and Salas y Gómez), Desventuradas (San Ambrosio, San Félix, and Islote González), and Juan Fernández (Robinson Crusoe, Santa Clara, and Alejandro Selkirk). These oceanic islands provide the nesting habitats for ~24 seabird species (Fig. 3) [111]. For instance, species such as the Christmas Island Shearwater (*Puffinus nativiatis*), the White-throated Storm-Petrel (*Nesofregetta fuliginosa*), and the Masked Booby (*Sula dactylatra*) nest in Salas & Gómez Island. Similarly, the Defilippi's Petrel (*Pterodroma defilippiana*) is an endemic species that only nests on Desventuradas and Juan Fernández archipelagos. These three insular systems are considered IBAs, namely, essential sites for the conservation of birds globally [131]. However, seabirds inhabiting these islands are threatened by plastic contamination via entanglement [132] and by ingesting floating microplastic [120]. In addition, invasive exotic and free-range domestic species are threatening seabirds nesting on Rapa Nui and Juan Fernández islands [133,134]; López and Luna-Jorquera 2024 (*submitted*)]. The study of Gusmao et al. [15] revealed that the structure of nesting assemblages across these islands is significantly different, reflecting changes in water temperature, primary productivity, and physiographic features of the islands (i.e., area, elevation and distance to the continent). Notably, species composition between the islands is significantly different and explained mainly by species replacement,

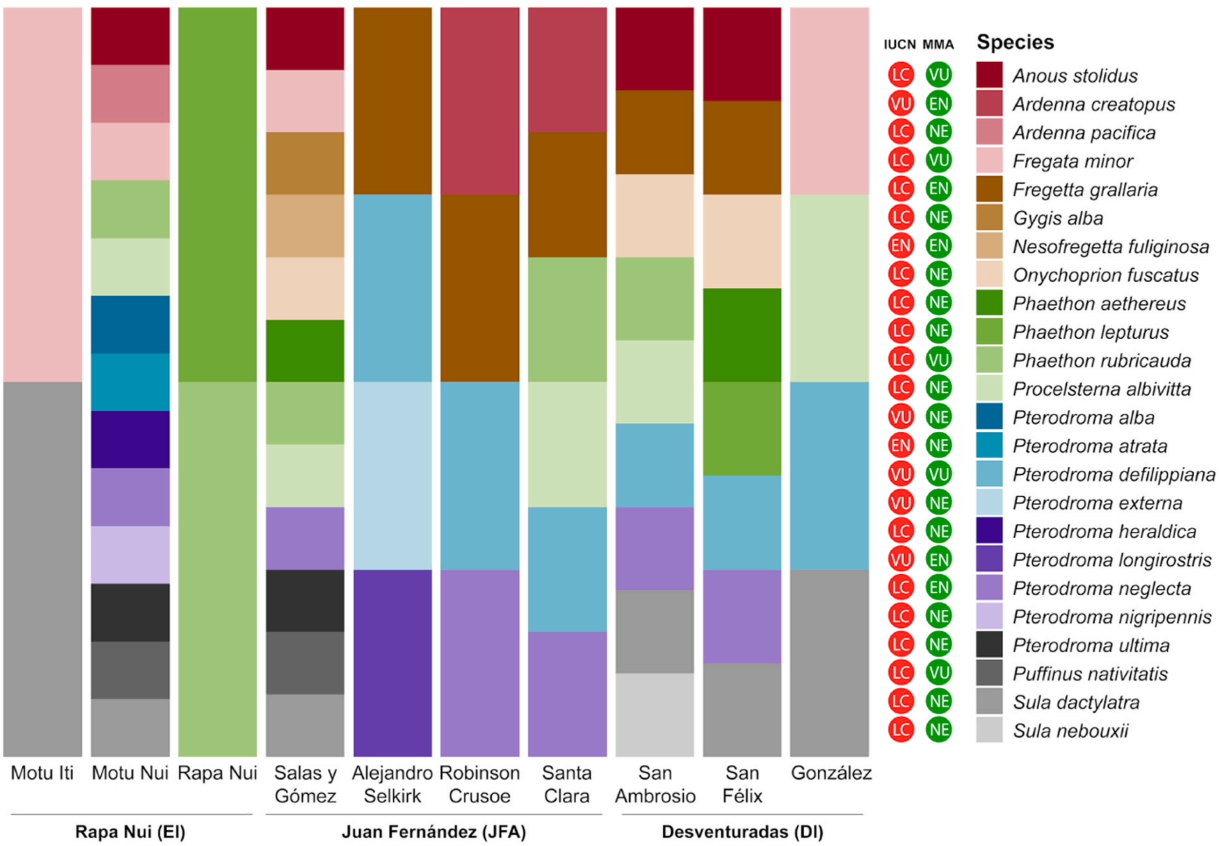

Fig. 3. Species richness of seabirds nesting on the islands around the Salas y Gómez and Nazca Ridges and their current conservation status according to IUCN (International Union for Conservation of Nature) and the MMA (Ministry of the Environment, Chile): CR: Critically endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern, DD: Data Deficient, NE: Not Evaluated. Data extracted from Gusmao et al. [15], Gusmao et al. [111], and Marín and González [137].

highlighting the relevance of developing conservation programs adapted to each island [135]. Likewise, a recent study analyzed the ecological interactions at fine scale of six Polynesian *Pterodroma* species at the Motu Nui (Rapa Nui), four of which have likely extended their breeding range to that island recently [135]. They found that multivariate ecological distance between individuals in a group of closely related species is a relevant predictor of gene flow, and locally, species boundaries may fade away rapidly under the stochastic mating of highly similar individuals. These results could question the accepted Polynesian *Pterodroma* species classification and they underline the importance of considering fine ecological structures for biodiversity mapping and conservation policies [136].

The Salas y Gómez and Nazca ridges provide foraging ground for at least 54 seabirds (Supplementary Material Table S1), considering the species breeding on the islands (Fig. 3) [15] and those species that visit the area for feeding [16]. The latter authors established that environmental conditions explain two community-level features highly related to the productivity in the area. First, the seabird abundance gradient observed between the continent and the oceanic islands responds to the distance to the Chilean coast, the ocean depth, and the influence of the coastal upwelling systems. Second, the seabird richness is explained by seasonality and the occurrence of water mass boundaries caused by sea surface temperature gradients. Thus, the environmental conditions of Salas y Gómez and Nazca ridges greatly influence the distribution and abundance of a significant number of species, shaping the biogeography of seabirds of the South Pacific Ocean. In this way, the marine ecosystem around the islands of Salas y Gómez and Nazca ridges is an important feeding area for different species of seabirds, which is evident from the high functional diversity of biological traits related to foraging behavior and diet of the seabirds inhabiting the study area [Muñoz and Luna-Jorquera, 2024 (*submitted*)]. Thus, efforts are required to protect the islands that provide nesting habitat for seabirds, but it is also necessary to develop conservation efforts for the sea of Salas y Gómez and Nazca ridges, which provide feeding habitats for a variety of seabird species.

4.6. *Marine mammals*

There is a scarcity of research regarding the status of marine mammals among Chile's EEZ and adjacent oceanic waters. The only systematic investigation on marine mammals performed to date was reported by Aguayo et al. [138], and included five cruises between 1993 and 1995, from Valparaiso to Easter Island (Rapa Nui) during the austral autumn and spring. Table 1 summarizes available information for the study area.

Hucke-Gaete [150] and Hucke-Gaete and Mate [151] reported the migratory pathways of five blue whales (*Balaenoptera musculus*) instrumented with satellite transmitters in the Gulf of Corcovado, Chile (43°45'S, 73°30'W) during February 2004. During the austral fall, two whales moved north and offshore to the Nazca Ridge region (25°S and ca. 800 km offshore of Chile) where transmissions ceased. More recently, Hucke-Gaete et al. [139] reported further information on blue whale migratory routes, mostly crossing the study area on its eastern portion towards wintering grounds in the Eastern Tropical Pacific. For humpback whales (*Megaptera novaeangliae*), Félix and Guzmán [152] reported a similar, but more coastal, migratory corridor in their way to summering grounds.

Recent information on other large whales (i.e., Brydés, minke and sperm) is lacking, other than that reported by Gales et al. [140] on a minke whale migrating from Antarctica to the Salas y Gómez ridge.

Table 1
Marine mammals recorded to date in the Salas y Gómez and Nazca Ridges and their current conservation status according to IUCN (International Union for the Conservation of Nature) and the MMA (Ministry of the Environment, Chile): CR: Critically endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern, DD: Data Deficient, NE: Not Evaluated.

Scientific name	Vernacular name	IUCN	MMA	Refs.
Order Cetartiodactyla				
Infraorder Cetacea				
Family Balaenopteridae				
Balaenoptera musculus	Blue whale	EN	EN	[74,138,139]
Balaenoptera edeni	Brydés whale	LC	DD	[138]
Balaenoptera bonaerensis/acutorostrata	Antarctic/Dwarf Minke whale	NT	LC	[138,140]
Megaptera novaeangliae	Humpback whale	LC	VU	[74,138,141,142]
Family Physeteridae				
Physeter macrocephalus	Sperm whale	VU	VU	[138,141,143]
Family Ziphiidae				
Ziphius cavirostris	Cuvier's beaked whale	LC	LC	[138]
Mesoplodon densirostris	Blainville's beaked whale	DD	DD	[138]
Family Delphinidae				
Pseudorca crassidens	False killer whale	DD	DD	[138,142,144]
Globicephala macrorhynchus	Short-finned pilot whale	LC	DD	[74]
Tursiops truncatus	Bottlenose dolphin	LC	LC	[145]
Delphinus delphis	Common dolphin	LC	LC	[138,146]
Order Carnivora				
Family Otariidae				
Arctocephalus philippii	Juan Fernandez fur seal	LC	VU	[147]
Family Phocidae				
Mirounga leonine	Southern elephant seal	LC	EN	[148]
Hydrurga leptonyx	Leopard seal	LC	LC	[74,149,146]

Small cetaceans need further investigation, since oceanic dolphins and Ziphiids are known to inhabit these types of habitats regularly [74]. Most records of pinnipeds come from vagrants (elephant and leopard seals) [74,153], but in the case of the endemic Juan Fernández fur seal (*Arctocephalus philippii*), the study area is probably an important region for fulfilling their life history requirements [154].

Securing connectivity between critical habitats such as breeding and feeding grounds for large whales and other migratory species is crucial. Evidence arising from recent telemetry studies have shed light on the timings and routes used by at least two baleen whale species (blue and humpback) on their migratory habits [152,149,155]. As studies progress, further delineation of preferred routes and destinations will become available, but at this point evidence indicates that a conservative corridor should span from Central America (10°N in Costa Rica) to southern Patagonia (56°S in Chile), extending latitudinally for over 7000 km and longitudinally for a breadth varying from 300 to 2000 km [149]. The Nazca Ridge is an integral part of this pathway, so strategies to diminish threats for marine mammals (mainly collisions with ships and by-catch) are urgently needed.

4.7. Biogeographic breaks

In the southeastern Pacific, marine biogeographical patterns have been well described along latitudinal gradients in continental areas [156] and major biogeographical breaks are widely known (e.g., Hernández et al., Ibáñez et al., Navarrete et al.) [157–159]. In contrast, studies of marine biogeography at a longitudinal scale are scarce in the region [5,61,66,116,160]. Parin et al. [5] and Poupin [66], suggested the existence of a biogeographical break at ~83°S that would separate the fauna of tropical and subtropical origin (from the West Pacific) and the temperate fauna (from continental origin). Most recently, Mecho et al. [61] observed a notable species turnover at ~86°W for echinoderms, where assemblages tend to be more variable across stations. Assemblages observed around Rapa Nui and the Desventuradas Islands presented a high occurrence of potentially endemic taxa and distinct species assemblages [99]. This study also suggested a faunistic break at ~101°W, with only two (out of 39 recorded morphospecies) co-occurrences between the Salas y Gómez ridge and Rapa Nui species. This break reflects the effects of physical-chemical barriers to dispersion (e.g., currents, temperature, oxygen, productivity) and habitat changes. However, this potential second break needs confirmation in echinoderms and other taxa, as the sampling effort in the western portion of the Salas y Gómez ridge (including the seamounts between Rapa Nui and Salas y Gómez Island) has been mainly limited to Russian expeditions conducted in the 1980s [5,66,69]. Gusmao et al. [111] also found that the assemblage structure of neustonic polychaetes significantly varies along the longitudinal gradient.

4.8. Connectivity between marine ecosystems

Both cosmopolitan and endemic species coexist in the Salas y Gómez and Nazca ridges, differing in time and space. Fishes, whales and turtles are among the species with large geographic population extensions that use this area to feed and travel to other areas in the Pacific Ocean [4]. An example of a cosmopolitan species is the green sea turtle *Chelonia mydas*, which uses the Salas y Gómez and Nazca ridges as a foraging ground. Individuals of this species corresponding to two distinct morphotypes are frequently observed in Rapa Nui waters, but they do not breed on the island. In fact, recent molecular studies suggest reproductive isolation between them, and reveal different natal origins, with one morphotype coming from Galapagos and Mexico in the eastern Pacific region, and the other one from French Polynesia in the central South Pacific [124–126]. These results demonstrate the importance of the area for the conservation of this endangered species, given that it hosts populations belonging to different regional conservation units in the Pacific basin [161]. A similar case is the Galapagos shark *Carcharhinus galapagensis*. Pazmiño et al. [162], using neutral genome-wide single-nucleotide polymorphisms (SNPs), reported at least two genetically discrete geographic groups for the Galapagos shark in the Pacific Ocean: an East Tropical Pacific group and a Central-West Pacific group. A preliminary study conducted in Rapa Nui and Salas y Gómez Island suggested the occurrence of a large and unique genetic stock (or conservation unit) in the entire ecoregion [163]. Thus, a high connectivity between Rapa Nui and the eastern Pacific populations is expected, although it also is possible that, similarly to the green sea turtle, this area hosts individuals coming from both the Central-Western Pacific and the East Tropical Pacific areas. Future studies should examine the relationship of this single population inhabiting the Easter Island Ecoregion with other locations in the Pacific Ocean where Galapagos sharks occur. A lack of population structure has also been described for the yellowtail amberjack *Seriola lalandi*, a globally distributed commercial fish species that inhabits the Salas y Gómez and Nazca ridges [115,164]. Premachandra et al. [165] using different molecular markers (mtDNA; microsatellites and SNPs) suggested only one genetic population of *S. lalandi* in the South Pacific, highlighting the high connectivity at a regional scale. Additional studies have suggested these seamounts facilitate the arrival of new species to the Easter Island province from the South American Continent, such as the greater amberjack *Seriola dumerili* [166], the whitetip reef shark *Triaenodon obesus* [167] and the whale shark *Rhincodon typus* [Morales unpublish data].

Invertebrates and reef fish species in the region are mostly endemic [14,168]. The life cycle of most of these organisms includes a low mobility or sedentary benthic adult and a planktonic larval phase [169]. Movement of individuals among populations is through the planktonic larvae, thus the distance of the population connectivity depends on the duration of the planktonic phase [169]. There are species that have a relatively short planktonic phase (up to three weeks) and low connectivity among populations. This is the case of the rudderfish *Kyphosus sandwicensis* and the cowry gastropod *Monetaria caputdraconis*, which show low connectivity between Rapa Nui and Salas y Gómez, probably mediated by rafting [170,171]. On the other hand, species that have an extended planktonic phase (more than three months) show the highest connectivity between their populations. For instance, using variability of microsatellite loci and a biophysical model, Meerhoff et al. [110] described asymmetric connectivity between Rapa Nui and Salas y Gómez for the spiny lobster *Panulirus pascuensis*. Similarly, a high population connectivity of the sea urchin *Centrostephanus sylviae* inhabiting both Desventuradas Islands and Juan Fernández Archipelago was recently detected using SNPs [172].

Overall, the information available on species connectivity in the Salas y Gómez and Nazca ridges shows that this region harbors migratory species that travel across the Pacific Ocean (Eastern and Western Pacific regions) as well as endemic species inhabiting a narrow area with connectivity between populations depending on the duration of the planktonic larva development [4]. In both cases, the Salas y Gómez and Nazca ridges are an important area for maintaining the viability of populations of many of these species, a large number of which are either threatened or vulnerable to anthropogenic stressors.

5. Cultural significance

Cultural significance is a key factor in place-based management of MPAs, and cultural assessments have been part of assessment, planning and management. As the quest for designation and protection of high seas MPAs continues, including cultural perspectives and concerns is critical. While physical remains of maritime activities may not be physically documented (e.g. as in surveys or assessments of shipwrecks), assessing cultural connections potentially yields a broader, cross-cultural context. The study by Delgado et al. [7] for the Salas y Gómez and Nazca ridges represented the first such assessment for a future high seas MPA.

5.1. Indigenous peoples

The ocean region between Eastern Polynesia and South America was well known to prehistoric indigenous communities. Polynesians developed sophisticated non-instrumental voyaging technologies and introduced some of this expertise to pre-Columbian Amerindians [173]. Voyages of discovery and trade between Polynesians and Amerindians are evidenced by a growing body of research in the fields of botany, archeology, anthropology, and genetics, among others [7]. Some studies suggest that contact between Polynesians and Amerindians (and subsequent Amerindian gene flow into Polynesia) preceded settlement of Rapa Nui [174] and other evidence proposes direct contact between Rapanui and Amerindians [175–179]. There is also prehistoric evidence of Polynesians in South America prior to European discovery of the continent [7].

Indigenous Pacific navigators were masters at observing natural phenomena including star tracks, anomalies in climate and weather, changes in ocean currents and the “shape” of waves, changes in atmospheric pressure, water temperature, and relative salinity (evidenced by freshwater lenses that collect on the ocean surface) as well as identifying areas of marine life abundance. They were also able to perceive disruptions in the flow of the ocean caused by islands, reefs, and seamounts [180–185]. All of these observations were used to identify “way stops” or “sea marks’’ and create mental sailing roads to a desired destination. The ability to sail by “feeling” for seamounts is still evident in 21st century indigenous Pacific communities where ancient navigation traditions have not been lost to cultural assimilation. Of special distinction was the skill of revered master navigator and canoe builder from Satawal, Topias Urupoa (also spelled “Uurupa”). Topias Urupoa navigated between islands blind (he lost his sight to retinitis pigmentosa). The “sea marks” he used to navigate between islands included disruptions caused by islands, reefs, and seamounts (B. Blankenfeld, pers. com, 2023; N. Thompson, pers. com, 2023) [182].

One of the most difficult sailing targets in all of Polynesia is Rapa Nui due to its isolation, size, and location upwind of prevalent tradewinds. The ancestors who made back and forth voyages from east Polynesia (presumably Mangareva or Marquesas) to Rapa Nui would have known how to take advantage of climate events (such as ENSO) that break down tradewinds, how to avoid hurricanes, and how to sail on the northern fringe of southern storms (N. Thompson, pers. com., 2023) [186,187]. Their accuracy and skill represent the apogee of Pacific sailing technology. These ancient Polynesian navigators possessed the skill sets to identify the ocean area above the Salas y Gómez and Nazca ridges and to use seamounts as “sea marks” when sailing to South America. The Salas y Gómez and Nazca ridges would have been a preferred navigational route given the availability of fishing opportunities (B. Blankenfeld, pers. com, 2023; N. Thompson, pers. com, 2023) [184].

Living marine organisms and the sea itself are economic and cultural resources from an indigenous islander perspective. The indigenous Rapanui gathered seabird eggs and fished in the waters near Motu Motiro Hiva prior to European discovery of the island in 1793. Motu Motiro Hiva itself was considered sacred as were the seabirds that traveled between Motu Motiro Hiva and the offshore islets of Rapa Nui (Motu Iti, Motu Nui, Motu Kao-Kao). One of these bird species, the manutara (*Onychoprion fuscatus*), played a protagonist role in the Rapanui *tangata manu* (birdman) cult during which clans would compete for political control of Rapa Nui. In addition, the *tangata manu* period marked the end of several tapu associated with pelagic species and seabirds (“tapu” refers to restrictions on resource gathering) (S. Rapu Haoa, pers. com, 2020) [188]. Traditional fishing methods are still used today by the indigenous community to fish the seamounts of the Salas y Gómez ridge [7]. Presence of rocks used as anchors and lines on the seafloor provides evidence of traditional Rapanui fishing practices in Rapa Nui, Salas y Gómez and surrounding seamounts [7].

It is important to note that in the Polynesian worldview, the concept of “homeland” is not limited to land boundaries nor to the western-construct of EEZs. Kāinga (“homeland” in the Rapanui language) is “that which feeds” an individual and a community; kāinga is a source of physical, intellectual, and spiritual nourishment; kāinga is both living and nonliving resources of an area. There is a cultural impetus to protect and care for kāinga that still exists among the present-day Rapanui. This impetus is evidenced by the overwhelming participation of this community in the creation of the multiple-use marine protected area known as Rapa Nui MUMPA [189] and the admonition of elders to “care for that which feeds you” (R. Haoa, pers. com, 2023).

5.2. Seafaring

Although uninhabited, the Salas y Gómez and Nazca ridges show an exceptionally rich history of seafaring and cultural significance [7]. This region has served as an active voyaging highway from indigenous cultures who first ventured to this remote region (approximately a thousand years ago) to the European colonial exploration, as well as the rise of the modern global economy that have led to substantial increases in maritime traffic in the area [7].

During and after the colonial era, many of these voyages were in response to international trade networks, the extension of sovereignty, and the deployment of naval forces in conflict [7]. Despite no conclusive evidence of shipwrecks, the archival record suggests the potential for numerous shipwreck events within this region associated with maritime activities such as whaling, guano trade, copper trade, coal trade and nitrate trade, as well as pelagic fishing and wartime losses of World War I [7].

From Polynesian to modern voyages of the 18–20th centuries, fish, turtles, sharks and other marine species complemented the diet of people sailing through the area [7]. Fishing, transportation of commodities and the extraction of natural resources such as offshore whaling and sealing also impacted this region [7,147]. US seal-hunting vessels journeyed and hunted with impunity off the Chilean coast at the Juan Fernández Archipelago and Desventuradas Islands [7]. This early harvesting had substantial impacts, such as the case of the endemic Juan Fernández fur seal which was hunted until almost extinct in the Desventuradas Islands [147]. Likewise, whaling by British and American ships showed activity in the area between mid-18th and 19th century, declining in intensity after the mid-19th century [190]. Archeological evidence suggests that five species of marine mammals were exploited directly off Rapa Nui as well as Salas y Gómez [74]. All this confirms that the whaling and sealing had a profound impact on marine fauna throughout the Salas y Gómez and Nazca ridges surrounding waters. Industrial fishing is more recent, starting in the early 20th century and expanding after World War II continuing to this day [3].

6. Major threats

6.1. Fishing activities

Historically, fishing has impacted the waters around the Salas y Gómez and Nazca ridges and today this threat is the dominant human activity occurring in the region [3,4]. Since the 1970s Russian and Chilean vessels have caught species such as the Chilean jack mackerel (*Trachurus murphyi*), redbaits (*Emmelichthys* spp.), orange roughy (*Hoplostethus atlanticus*), alfonsino (*Beryx splendens*), jagged lobster (*Projasus bahamondei*) and golden crab (*Chaceon chilensis*) on seamounts of the Salas y Gómez and Nazca ridges, as well as seamounts around the Juan Fernández Archipelago (reviewed in Wagner et al.) [3]. In addition, in the region there has been historic pelagic long-line fishing impacting pelagic species (i.e., sharks and swordfish, among others), and a historical fishing targeting Chilean jack mackerel (*T. murphyi*), squid (*Dosidicus gigas*), tuna (*Thunnus alalunga, T. obesus, T. albacares,* and *Katsuwonus pelamis*), striped bonito (*Sarda orientalis*) and marlin (*Makaira indica* and *M. nigricans*) [3]. Today, most of the fishing in the region is primarily focused on ABNJ and fishing effort is mainly undertaken by distant water fishing nations [3]. Most fishing activity in high seas waters of the Salas y Gómez and Nazca ridges occurs just outside Peruvian national waters, and it targets tuna, specifically skipjack (*Katsuwonus pelamis*), bigeye (*Thunnus obesus*), and yellowfin tuna (*Thunnus albacares*) (reviewed in Wagner et al.) [3]. Fishing by bordering countries to the Salas y Goméz and Nazca ridges mainly takes place within their national jurisdiction [4]. Catch data on Jack mackerel, squid and orange roughy in this region are available from the South Pacific Regional Fishery Management Organization [191], whereas catch data on tuna and swordfish are available from the Inter-American Tropical Tuna Commission [75]. Additional fishing effort data in this region are available from Global Fishing Watch [192]. The most recent data indicates that from 2019 to 2023, 725 fishing vessels appeared to fish within the ABNJ of both ridges, mostly squid jiggers with 535 vessels, followed by drifting longline with 132 vessels.

The fishing effort on both ridges is low compared to adjacent areas [3] and led by the Chinese fleet and followed by Spain (Fig. 4; Supplementary Material Table S2). The orange roughy fishery has been closed in this region since 2006 and squid fishing is low in the Nazca and Salas y Gómez Ridges [3,191]. SPRFMO reported catch data for Jack mackerel and other unidentified bony fishes is also low in this region [191]. A recent bottom contact exploratory fishing by Cook Islands has reported a catch of 48 tonnes of jagged lobster *Projasus bahamondei* in the Nazca Ridge and a total catch of 218 tonnes between 2019 and 2022 (Annual Report of the Cook Islands to SC11).[5]

[5] SPRFMO, Annual Report of the Cook Islands to SC11, in: 11th Meeting of the Scientific Committee, Panama City, Panama, 2023.

Longline and purse seine catch data from IATTC indicate that six fleets (China, Colombia, Ecuador, Peru, Japan and Spain) are responsible for most of the catch targeting tuna-like species in the vicinity of the Nazca and Salas y Gómez ridges [75]. Analyzing the fishing activity from AIS data, Morales et al. [55] found that even though there is virtually no industrial fishing activity within the Easter Island ecoregion, China, Vanuatu, and Spain are the three nations with fishing activity outside of the EEZ area. Unfortunately, the absence of records within the EEZ, does not guarantee the lack of Illegal, Unreported, and Unregulated (IUU) fishing within the territory (reviewed in Morales et al.) [55]. In 2013–2017, the Chinese longline fleet caught 438 tons of fish in the area, 88 % of which were albacore. Of this volume, approximately 81 % was caught in an area north of the Salas y Gómez Ridge. The Chinese fleet obtained a higher catch of albacore and striped marlin within this area when compared to all other global fishing grounds. For all other fishery species, the Chinese fleet obtains higher catches outside the Salas y Gómez and Nazca ridges (Fig. 4; Supplementary Material Table S2) [192].

Colombia's purse seine fleet mainly targets skipjack and yellowfin tuna and operates in a substantial portion of the Eastern Tropical Pacific. Within the Salas y Gómez and Nazca ridges, the Colombian fleet concentrates its efforts on the northern portion of the Nazca Ridge. In 2013–2017, catch per unit effort inside the region were between 143 % and 354 % higher when compared to the rest of the nearly 28 million square kilometers where the Colombian fleet operates [75].

The Ecuadorian fleet also concentrates its fishing effort in the northern section of the Nazca Ridge and targets bigeye, striped bonito, skipjack, and yellowfin, with skipjack tuna being most important. Catch per unit effort for yellowfin, skipjack, and bonito are higher within the region in comparison to all other fishing grounds where the Ecuadorian fleet operates. The Peruvian purse seine tuna fleet is relatively small and is essentially a coastal fleet operating north of the Nazca Ridge. In 2013–2017, this fleet did not operate in areas directly above seamounts of the Nazca Ridge or the Salas y Gómez Ridge [75].

The Japanese longline fleet operates in a vast area of the Pacific Ocean, but mostly north of the Salas y Gómez Ridge, and also on the Nazca Ridge. In 2013–2017, catch per unit effort for tuna on the Nazca Ridge was almost 26 % higher than for all other Pacific fishing grounds. The Spanish longline fleet operates in close proximity of the Salas y Gómez and the Nazca ridges and targets Swordfish exclusively [75,193]. In 2013–2017, the Spanish fleet caught more than 30 % of its total catch within this region, and nearly 5 % in areas north of the Nazca or Salas y Gómez Ridges. However, catch per unit effort was higher outside this region. Thus, although the Spanish fleet has caught large percentages of its total catch in this region, it has been much more productive outside of it [75].

6.2. Bycatch

Based on bycatch data (2001–2021), the Highly Migratory Resources Fisheries Monitoring Project developed by the Fisheries Development Institute of Chile (IFOP), identified bycatch high-risk areas for highly migratory species in offshore Chilean waters. Very high-risk areas were identified within the Desventuradas and Juan Fernández ecoregions and their adjacent waters, before the establishment of marine protected areas (MPAs). Among the most affected species were sea turtles (leatherback, loggerhead, and olive ridley), seabirds (e.g., wandering albatross) and marine mammals (e.g., Juan Fernández fur seal) [194]. Even though these analyses considered years previous to MPAs designation (when fishing was permitted), some illegal fishing activities have been reported within them [194]. The historical analyses indicated that during winter and spring, 90 % of captures occurred between 18°-20°C in oceanic waters, and they were mainly associated with industrial longline fishing [194].

Given that 73 % of the Salas y Gómez and Nazca ridges area are in ABNJ and unprotected, bycatch is a substantial threat to marine

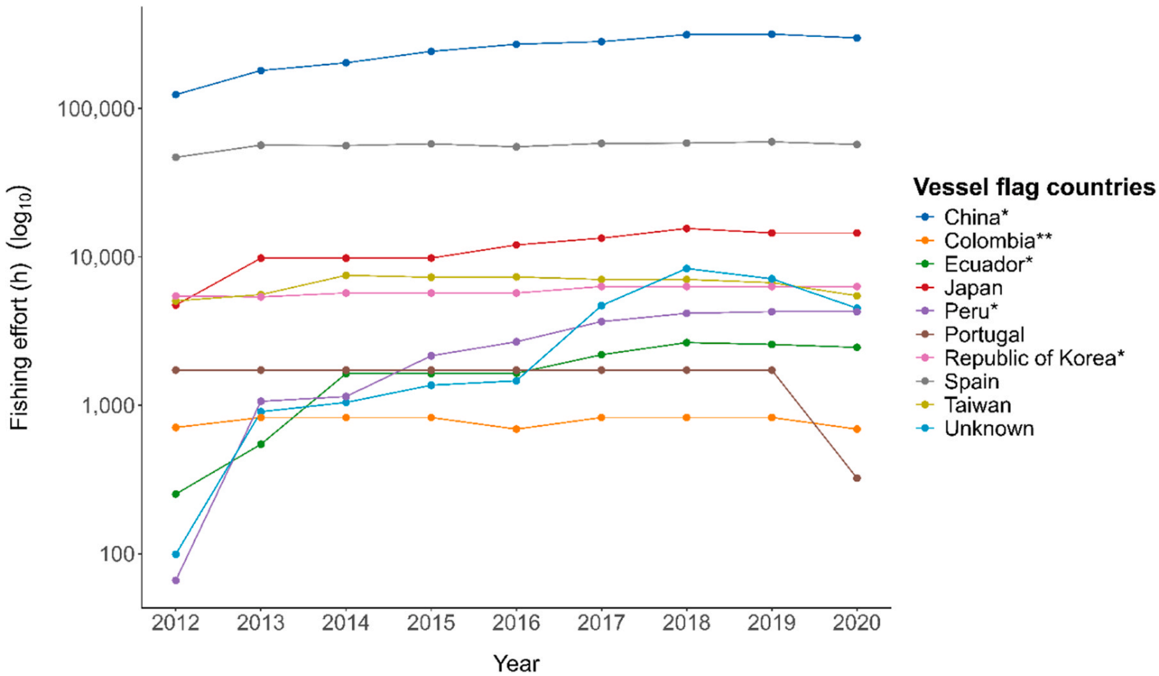

Fig. 4. Total annual fishing effort (h) of the top 10 vessel flags for the Salas y Gómez and Nazca ridges. *Flags of vessels from SPRFMO member countries; **Flags of vessels from cooperating countries. Global Fishing Watch [192]. Data are shown on a logarithmic scale.

biodiversity.

6.3. Seabed mining

Despite several efforts to explore offshore areas in this region, to date there are no known oil or gas reserves on or near the Salas y Gómez or Nazca ridges [27,195]. However, seamounts on the Salas y Gómez and Nazca ridges are known to possess cobalt-rich ferromanganese crusts with Cu+Ni contents up to 0.3 %. Furthermore, commercially valuable manganese nodules are known to exist on both sides of the Nazca Ridge, which could have important concentrations of Cu and Ni (up to 1.38 % Cu+Ni) and Co (mean values up to 0.53 %) (Fig. 5) [27,196–198]. Also, polymetallic massive sulfides are known from hydrothermal vents located to the west of the Salas y Gómez Ridge on the East Pacific Rise (EPR) [27], that could have similar compositions to those samples obtained further north over the EPR: 35.8 % Fe, 9.1 % Zn, 6.8 % Cu, 45.5 % S, 1.2 % SiO2 [199]. The International Seabed Authority (ISA) regulates mineral-related activities in the international seabed in ABNJ [3]. While there are currently no contracts to explore or prospect deep-sea minerals in this region, these resources may attract mining interests in the future (see e.g., Toro et al.) [198], especially considering that at the moment there are no closed areas to mining activities in the region [3,200,201].

6.4. Marine pollution

The Salas y Gómez ridge is in the center of the South Pacific Subtropical Gyre (SPSG) where high concentrations of floating litter and marine debris accumulate (Fig. 5) [3,132,202–206]. Floating marine debris in this region mostly consists of microplastics [207,208], and medium-sized plastic fragments, lines, buoys, plastic trays, plastic bags and nets [120–132]. Most recognizable plastic litter originates from the high sea's fisheries around Rapa Nui and Salas y Gómez Islands [132,206].

These floating pollutants primarily originate from sources on the continental coasts, including cities, beach-goers, aquaculture, and fisheries (Fig. 5) [209]. Also, small fishing villages and the large artisanal fishing fleet from the Chilean and Peruvian coast contribute high loads of marine litter [210]. As the transport of the floating litter from continental sources to the center of the gyre may take several years, most of it is breaking down to microplastic fragments, which by far dominate the litter items found around Rapa Nui and Salas y Gómez Island [203,207,208,211,212].

This litter affects more than 100 species of marine vertebrates, particularly sharks, fishes, turtles, birds and mammals, through entanglement and ingestion (Fig. 5) [120,213]. In addition, incorporation of litter collected at sea into seabird nests is commonly observed and reported, causing death of seabird chicks [214–216]. Microplastics are ingested by a wide range of fishes [211,217] and also higher-level consumers [218,219]. Microplastics are often concentrated in small and mesoscale oceanographic features, such as local fronts (with visual slicks), which has been observed around Rapa Nui, where also zooplankton and fish larvae are often aggregated [212].

Floating litter could also potentially transport non-indigenous species from other regions around the South Pacific. Some of the identifiable litter items collected on the shores and in the waters surrounding Rapa Nui show indication of having origins in New Zealand and Chile [209,220,221]. Oceanographic models simulating surface transport of floating particles confirm that litter from the South American continent can reach the Easter Island Ecoregion within 2–3 years [205]. While a range of different species have been identified on floating litter, there were no species from continental coasts reaching Rapa Nui, which possibly is because coastal species cannot survive for extended times in the ultraoligotrophic waters of the SPSG [220]. However, as vast quantities of floating litter are continuously stranding on the shores of Rapa Nui [206], there is an ever-increasing risk of non-indigenous species arriving with this litter. This risk is very high for the Nazca ridge and for the proximal portion of the Salas y Gómez ridge, as well as for the Juan Fernandez Archipelago, which are only about 700–800 km off the Chilean continental coast, but floating litter has not been studied for attached organisms.

In contrast to abundant floating marine litter, benthic litter seems to be less abundant. Exploration of mesophotic bottoms through ROV surveys has also shown that, while benthic litter is not observed at mesophotic depths (~60–340 m) off Desventuradas Islands and nearby seamounts within the Chile EEZ, at similar depths off Rapa Nui, fishing

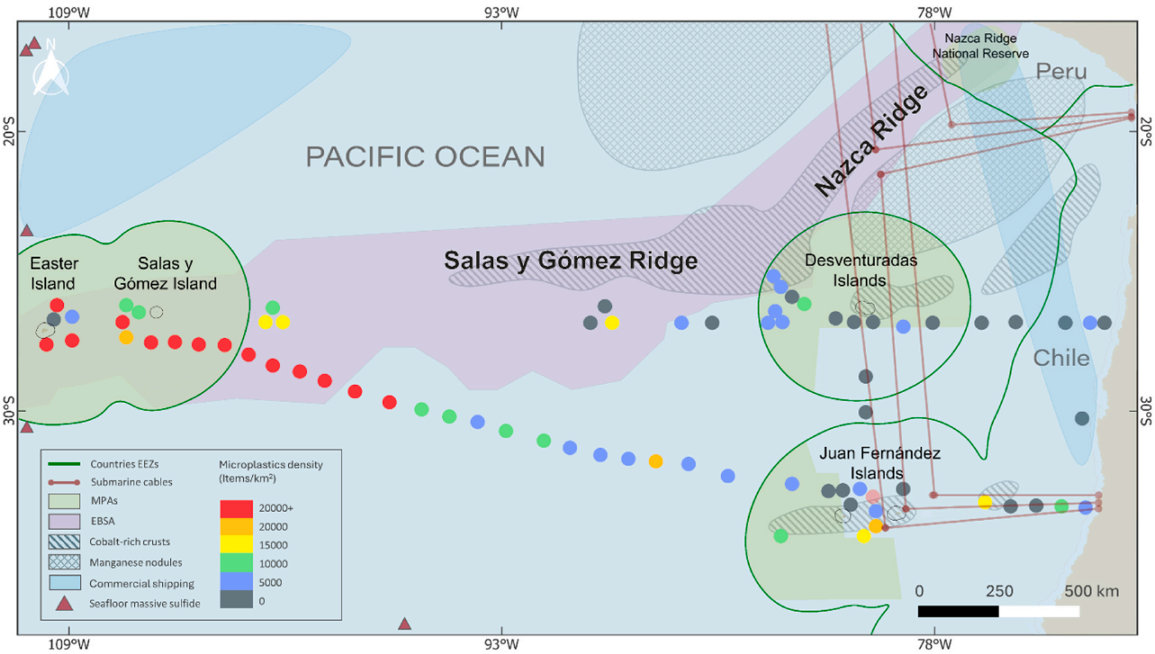

Fig. 5. Distribution of exclusive economic zone (EEZ) of Chile and Peru, marine protected areas (MPAs), ecologically or biologically significant marine area (EBSA), and anthropogenic threats (commercially valuable seabed minerals, microplastics density, distribution of submarine cables, and major shipping routes) in the study area. Figure modified from Thiel et al. [120] and Wagner et al. [3].

lines, plastic ropes tied to anchor stones as well as glass and metal objects are frequently observed [222]. Unlike litter observed on Rapa Nui beaches, which is mainly of foreign origin, items observed at depth are evidently local. Further surveys on the seamounts in ABNJ are necessary to assess the presence and impact of benthic marine litter, usually associated with maritime and fishing routes [223].

Another emerging threat observed in the Salas y Gómez ridge is the proliferation of filamentous mats covering mesophotic sandy bottoms and coral reefs (Fig. 6) [224]. Mats have been sighted mainly off Hanga Roa, the main village of the island located on the southwestern side of it and at ~80–90 m in depth. Preliminary morphologic identification indicates that mats (Fig. 6a) are composed by at least four filamentous taxa, including two cyanobacteria (cf. *Lyngbya* sp. and *Pseudoanabaena* sp.), a brown alga (*Ectocarpus* sp.), and a green alga (*Cladophora* sp.) (Sellanes et al., 2021). While mesophotic *Leptoseris* spp. reefs at the Hanga Roa side are dead and covered with filaments (Fig. 6b), at the northern unpopulated side of the island, mesophotic reefs appear to be healthy (Fig. 6c). An ongoing eutrophication process, associated with sewage pollution is preliminarily identified as the most plausible cause explaining the recent proliferation of these mats in front of the village [224]. Stable isotope analysis has also corroborated the incorporation of nutrients of anthropogenic origin by intertidal benthic communities nearby the most urbanized areas of the island [225]. Álvarez-Varas et al. [124] reported the presence of green turtles (*Chelonia mydas*) in Hanga Roa bay showing lesions congruent with bacterial, fungal and/or viral infections probably associated with marine pollution. Recently, a new monitoring of turtles included blood samples for mercury (Hg) assessment and results showed that green turtles from Rapa Nui exhibit one of the highest blood Hg concentrations reported for the species globally, leading to an altered immune function and impaired kidney function in these individuals (Álvarez-Varas et al., 2024, *submitted*). The latter shed light on the impact that both, anthropogenic nutrients and heavy metals, may have in ABNJ due to the natural pollution along with heavy human use of this area.

6.5. Shipping

Commercial shipping is relatively low throughout the waters of this region, except for the northern section of the Nazca Ridge which intersects a major international shipping route connecting ports along the west coast of South America, but also waters surrounding the Salas y Gómez or Nazca ridges have been identified as a major global transshipment location for distant-water fishing fleets [3,197,200]. The latter may have several implications for threatened fauna such as sea turtles, sea birds and whales that could be affected by collisions and light pollution [226–228]. Indeed, a recent study carried out in Rapa Nui showed that 50 % of monitored green turtles in 2018 exhibited carapace wounds caused by propellers [124]. This situation has also been previously reported in other places with strong tourist activity such as Galapagos in Ecuador and Florida in USA [229,230].

Shipping could also be a risk of non-indigenous species introductions in the ridges, especially in the shallow seamounts, both through hull fouling or the transport of propagules in the ballast water [231,232].

6.6. Submarine cables

There are also several submarine cables that run across the Nazca Ridge, including in ABNJ of this region (Fig. 5) [3,233]. However, in comparison to other human activities in the deep sea, submarine cables are considered to have a relatively low impact on the environment. That said, since the Salas y Gómez and Nazca ridges provide habitat for many fragile benthic species like corals [6,9,10,8,234], any future cable laying through this area should be carefully evaluated and planned. While UNCLOS already affords all States the freedom to lay submarine cables in ABNJ [235], activities requiring maintaining or repairing cables need to be considered in this region.

6.7. Climate change

Like other oceanic regions of the planet, the marine life in the SEP is under the threat of warming, deoxygenation and acidification, with impacts on marine habitat and food-web that are still difficult to assess

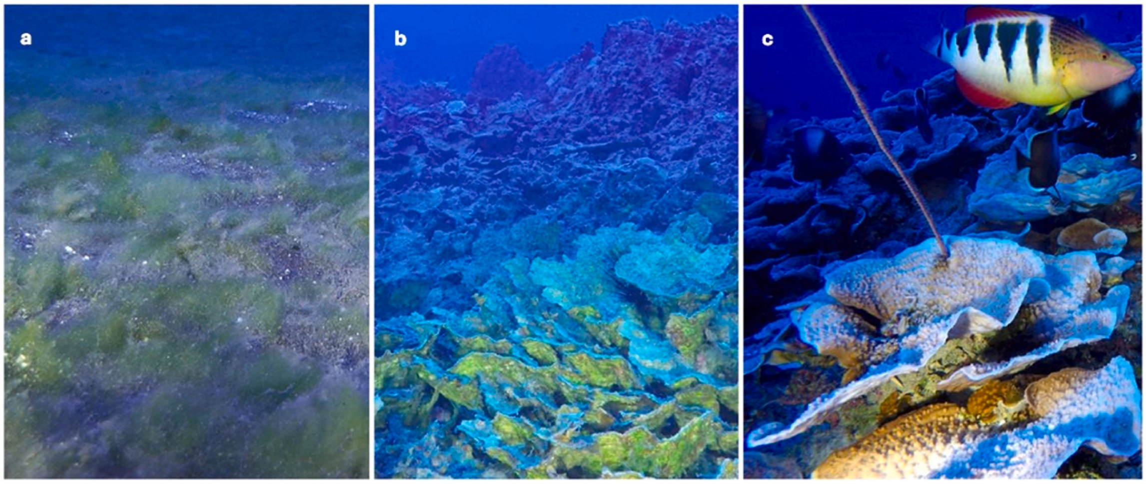

Fig. 6. Images from ROV surveys at ~80–90 m depth around Rapa Nui. a. Filamentous mats covering sandy bottoms off Hanga Roa, main village of the island, b. dead *Lepstoseris* spp. reef off Hanga Roa, and **c.** healthy *Leptoseris* spp. reef and a colony of the whip coral *Stichopathes* sp. off Anakena at the northern side of the island.

due to uncertainties in the magnitude of the changes as predicted by climate models, the lack of information on the physiological traits of the species of the region [236], as well as incomplete knowledge of physical processes controlling the fine scale circulation in the intricate seamounts and island systems. Regarding surface warming, there is a consensus amongst climate models that, like the equatorial region, the coasts of Peru and northern and central Chile will significantly warm by ~ 2–3°C by the end of the 21st century, forming a so-called El Niño-like pattern [40]. While the warming trend peaks within the upper thermocline, it extends to the sub-thermocline, reaching depths of ~ 400 m to the east of the Desventuradas and Juan Fernández archipelagos. On the other hand, the South Pacific Gyre is projected to experience one of the weakest warming rates of the planet due to increased evaporative cooling associated with the intensification of the South Pacific anticyclone. This will result in a decrease in the mean thermal gradient between the coastal and open-ocean regions, which may produce circulation changes that are yet to be documented. The tropical warming may also alter the precipitation regime over the SEP with a tendency for drier conditions in the mid-latitudes although consensus is low in terms of the magnitude of the changes [237]. Robust evidence indicates however a southward expansion of the South Pacific Subtropical High (SPSH) during the last decades associated with global warming [238]. This migration is currently strongly impacting climate variability off Chile in two ways i) promoting a megadrought in the central zone [239] and ii) altering oceanic and coastal atmospheric dynamics by impacting surface winds [57,240,241] and coastal upwelling [242–244]. For instance, the enhanced equatorward surface circulation in the mid-latitudes associated with the intensification of south pacific anticyclone yields the expectation that the effectiveness of the physical connectivity will increase both between the Salas y Gómez Island and Rapa Nui and between the Juan Fernandez and Desventuradas Archipelago [40]. However other factors come into play. In particular, the faster surface oceanic warming will yield increased vertical stratification, which will affect circulation and biogeochemistry. While increased stratification may be favorable to increase in ocean mesoscale activity near the coast [245], it also tends to impede nutrient uplifts towards the surface, reducing primary productivity in the already nutrient-poor waters of the South Pacific Gyre [62,108]. Such increase in stratification is more pronounced between the Desventuradas (Juan Fernandez) archipelago and the coast (Fig. 7a), which is favorable to reduced nutrient uplift into the euphotic layer despite the projected increase in Ekman-transport along the coast of central Chile [246,247]. Currently there is however a low consensus in model projections regarding NPP (Net Primary Production) in the SEP [248]. Such uncertainties extend to the projections of the dissolved oxygen [249]. In fact, while temperature-driven solubility effects imply a reduction of dissolved oxygen at global scale, the already oxygen-depleted waters of the SEP may in fact become more ventilated due to the changes in upwelling dynamics (i.e., flattening of the isotherms on-shorward due to the coastal warming). Models, however, indicate that most of the Salas y Gómez and Nazca ridges region, outside the oxygen minimum zone, will experience a marked deoxygenation trend (Fig. 7b). The low availability of nutrients makes this region particularly susceptible to anthropogenic and climatic disturbances particularly for the benthic communities not capable of migrating over long distances [59]. The changes in temperature and oxygen have also the potential to yield changes in viability of metabolic habitat in the SEP for the epipelagic and mesopelagic zones [250] although this is still difficult to assess quantitatively due to the scarcity in physiological data. The SEP will also experience a significant acidification of its waters. Model projections indicate that the open-ocean waters of the SEP will experience one of the largest increases extending from the surface up to ~400 m (see Fig. 7c) [249]. Superimposed to these long-term trends, high-frequency fluctuations of temperature, dissolved oxygen or pH can produce oceanic extremes (e.g., marine heat waves, hypoxic or acidic events) that can have detrimental effects on the marine ecosystems of the SEP. These extreme events can even occur simultaneously or in close sequence forming so-called compound events. Global pattern and trends of marine heatwaves and biogeochemical extremes over the contemporary period indicate that the SEP is a hot spot of increased occurrence of compound events (Gruber et al.) [251]. Some consequences of these events include biogeographic range shifts, habitat loss, decreased biodiversity, and decreased resilience, among others. Importantly, many of these consequences will be compounded by the El Niño Southern Oscillation and the Pacific Decadal Oscillation, which already have widespread impacts throughout the region [54,252,253]. Since the individual effects of these extremes may interact synergistically (e.g., in the case for oxygen and temperature [254] or pH and oxygen [255]), this thus represents a major concern with regards to the fate of the marine ecosystems and biodiversity of the SEP. To date, most literature on ocean extremes has focused on the surface ocean only, and little is known on their vertical extent. This limitation needs to be addressed to better understand the impacts of these hazards on both pelagic and benthic organisms that populate the SEP. So far, most efforts relevant for the SEP region have focused on analyzing low-resolution global ESMs that, although incorporating ecological complexity, suffers the limitation of not including

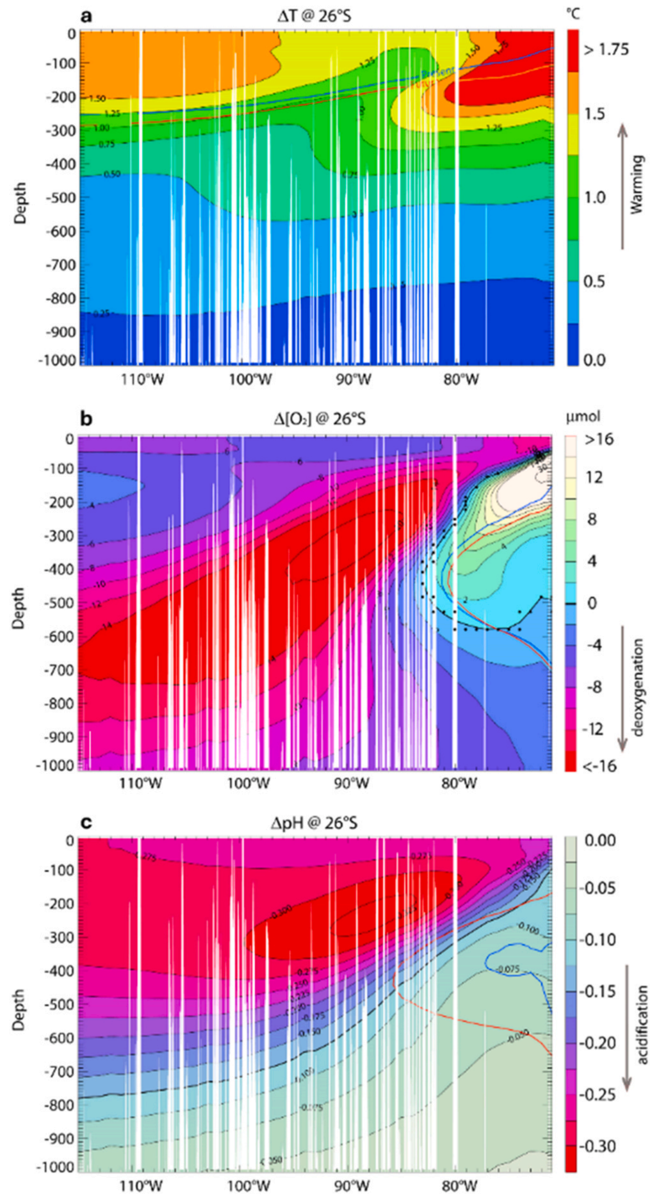

Fig. 7. Effect of climate change on the oceanic conditions along a section at 26° S (Salas y Gómez Ridge), as simulated by the NCAR CESM model: difference in mean conditions between the present (1950–2005, 'historical' scenario) and the future (2050–2100, RCP8.5 scenario) for a. temperature, b. dissolved oxygen, and c. pH. The blue and red lines stand for the 15 °C isotherms in (a), for the oxygen minimum zone limit, $[O_2] < 1$ ml/L, in (b), and for the pH isopleth of 7.35 in (c) for the present (blue) and future (red) climates. Note the deepening of the 15 °C isotherm (a proxy for thermocline depth) by approximately 40 m in the warmer climate and the increase in oxygen content in the vicinity of the oxycline (orange colour, approx. 30 µmol/kg). The model also indicates an overall decrease in pH more pronounced in the surface layer (red-pink colour, approx. 0.3 unit). The black dots in (b) correspond to the locations where the change in oxygen concentration is not significant at the 99 % level according to a Wilcoxon rank sum test. Topography from the General Bathymetric Chart of the Oceans (GEBCO version 2019) corresponds to the seamounts and islands within ±1° around 26°S. Modified from Dewitte et al. [40].

fine scale oceanic processes relevant for simulating realistically dispersal and connectivity patterns within the intricate systems of islands and seamounts. Regional observational programs also need to be implemented to accompany the modeling efforts. Recommendations in that direction have been formulated in several recent reports [256–258].

7. Regional governance

The UN Convention on the Law of the Sea (UNCLOS) lays down rules for governing uses of the ocean and its resources; however, it does not specify how States should conserve and sustainably use biodiversity in ABNJ. The treaty text is based on a 1970s world view, where pollution and commercial fishing were the key threats to biodiversity, and climate change as well as high seas biodiversity, including deep sea ecosystems, were not a conservation priority or had not yet been discovered [259,260]. As a result, States identified that regional conservation of fisheries and ecosystems was a weakness of the UNCLOS text [261]. In 1995 the duty to cooperate via Regional Fisheries Management Organisations (RFMOs) was confirmed and elaborated in the UN Fish Stock Agreement, requiring Parties to establish RFMOs as a means to achieve the fishery objectives outlined in UNCLOS [261]. Since then, a host of agreements covering activities such as fishing, shipping, and mining were developed both before and after UNCLOS came into force in 1994 (22 RFMOs introduced after 1994). As in other ABNJ, human activities in international waters around the Salas y Gómez and Nazca ridges are regulated by different intergovernmental bodies, including the International Seabed Authority (ISA) for mining, the International Maritime Organization (IMO) for shipping, and RFMOS for fishing, within the region specifically the Inter-American Tropical Tuna Commission (IATTC) for tuna and other highly-migratory fishery species, and the South Pacific Regional Fishery Management Organization (SPRFMO) for non-highly migratory fishery species [3,204,262].

Although numerous regional and global agreements regulate human activities in international waters around the Salas y Gómez and Nazca ridges, to date there has been a lack of coordination between many of these international bodies. To overcome these challenges, in 2015 the United Nations General Assembly agreed to develop an international legally binding instrument under UNCLOS on the conservation and sustainable use of marine biological diversity in ABNJ, also known as the BBNJ treaty [3]. The BBNJ treaty was agreed on March 4, 2023, formally adopted by consensus on June 19, 2023, and signed by 82 countries in September 2023 (105 have signed by October 2024). The treaty requires 60 ratifications before it comes into force after a 120-day period, and by October 2024 14 parties have ratified it. This treaty addresses the conservation and sustainable use of marine biodiversity, including benefit sharing of marine genetic resources, area-based management tools including marine protected areas, environmental impact assessments and capacity-building and the transfer of marine technology [23].[6]

7.1. SPRFMO

The South Pacific Regional Fisheries Management Organisation (SPRFMO) is an intergovernmental organization that regulates fishery resources occurring in high seas waters of the South Pacific Ocean, including the Salas y Gómez and Nazca ridges [3]. Currently, it comprises 17 country members from Asia, Europe, America and Oceania, as well as two cooperating non-contracting parties.

In the South Pacific Ocean, SPRFMO has implemented fishing effort measures, maintains a vessel monitoring system, measures on control, inspections in port and at sea, regulates trans-shipment, and implements an on-board observer system. In addition, SPRFMO prohibits the use of large-scale pelagic driftnets and deep-water gillnets and has by-catch management measures for seabirds. Regarding bottom fishing, SPRFMO has Conservation and Management Measures for the Management of Bottom Fishing with the opening of new bottom-fishing areas requiring a research assessment of potential impacts [3].

The regulation of bottom fisheries by SPRFMO, and in fact the

[6] Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction adopted on 19 June 2023.

political impetus to establish SPRFMO in the first place, was a response to a series of United Nations General Assembly resolutions, beginning with Resolution 59/25 adopted in 2004, which commits States individually and through RFMOs to bottom fisheries to prevent significant adverse impacts on vulnerable marine ecosystems such as cold water corals and seamounts to protect deep-sea biodiversity in areas beyond national jurisdiction.[7] United Nations General Assembly Resolution 61/105 adopted in 2006 called for the closure of areas where vulnerable marine ecosystems are known or likely to occur, unless bottom fisheries can be managed to prevent significant adverse impacts.[7] These commitments have been reaffirmed and elaborated upon in subsequent resolutions adopted by the United Nations General Assembly, including most recently United Nations General Assembly Resolution 77/118, adopted in 2022, which further strengthens the global call to protect deep-sea biodiversity in areas beyond national jurisdiction from the harmful impacts of fishing. In addition, States have expanded upon these commitments to marine conservation more broadly, such as through the adoption of the 2030 Sustainable Development Goals (SDGs), in particular SDG 14, Target 2, which calls for avoiding significant adverse impacts on marine ecosystems, strengthening their resilience and taking action to recover degraded ecosystems. The SPRFMO Convention empowers the Commission to determine the general or specific locations in which fishing may or may not occur.[8]

7.2. IATTC

The Inter-American Tropical Tuna Commission (IATTC) is the international commission responsible for the long-term conservation and sustainable management of tuna and tuna-like in the Eastern Pacific Ocean.[9]

Currently, the IATTC has 21 members and five cooperating non-members. Its geographical scope addresses both the national jurisdiction of its member States and the high seas in the Eastern Pacific, including those of the Salas y Gómez and Nazca ridges [3]. Among the conservation measures implemented by the IATTC are the establishment of spatio-temporal closures for the purse-seine fishing activity, the restriction of the number of fish-aggregating devices each purse seine fishing vessel can have at a given time and limiting the total annual catch for bigeye tuna caught by long-line fishing vessels [263].

7.3. ISA

The International Seabed Authority (ISA) regulates mineral-related activities in the international seabed beyond the limits of national jurisdiction [197,235]. Currently its membership comprises 168 States and the European Union. The regulation of mining activities is through the development of rules, regulations and procedures setting terms for the approval of plans of work for exploration and exploitation (under development) and establishing the necessary measures for the effective protection of the marine environment [197]. To date, environmental measures have been focused on the environmental management plan for the Clarion-Clipperton Zone which designates areas of particular environmental interest (APEI), which are provisionally protected from future mining activities [201].

There are currently no exploration contracts for deep-sea minerals in the Southeastern Pacific, nor are any areas closed to mining in this region [197,201]. A precursor of any future exploitation contracts in the current discussions around draft regulations for exploitation[10] is a regional environmental management plan (REMP). There are no current discussions for REMPs for the South Pacific in the Area surrounding the Salas y Gómez and Nazca ridges [3].

7.4. IMO

The International Maritime Organization (IMO) is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. The regulation of international shipping activities includes the designation of particular sensitive sea areas (PSSAs), areas that need special protection because of their ecological, socio-economic or scientific significance and which may be vulnerable to damage by international maritime activities. These PSSAs may be protected by ship routing measures, such as areas to be avoided by all ships, or by certain classes of ships [264,265]. There are currently no PSSAs anywhere in international waters, nor are there any PSSAs or shipping route limitations around the Salas y Gómez and Nazca ridges. However, except for the northern section of the Nazca Ridge, this region does not contain any major commercial shipping routes [266].

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention addressing the prevention of pollution of the marine environment by ships from operational or accidental causes. IMO through MARPOL defines certain sea areas as "special areas" in which the adoption of special mandatory methods for the prevention of sea pollution is required. To date, there are no MARPOL special areas in the South Pacific [3]. Particularly for the Chilean waters, standards for ballast water release within all oceanic MPAs of the region is currently developed by the Chilean Navy [3].

7.5. CPPS

The Permanent Commission for the South Pacific (CPPS) is a strategic regional alliance aiming to promote political, technical and scientific cooperation and coordination amongst its member States (Chile, Colombia, Ecuador and Peru) for the conservation and sustainable use of the ocean and its resources and to reduce the effects of pollution on marine ecosystems. While the jurisdiction of CPPS generally lies in the national jurisdictions of its member States, the CPPS jurisdiction can extend to adjacent high seas areas that could be affected by marine pollution [267,268]. Article 4 of the CPPS Convention gives it the competence to promote conservation of marine living resources beyond national jurisdiction. In 2012, CPPS member States signed the Galapagos Commitment, in which they committed to foster coordinated action regarding their interests in living and non-living resources in ABNJ [204,267,268]. Currently, CPPS has an active working group on marine biological diversity in ABNJ, whose main goal is studying, monitoring and advising about conservation and sustainable use in these areas [3].

8. International distinctions and conservation efforts

The Salas y Gómez and Nazca ridges have been internationally recognized by several organizations for their unique biodiversity including being recognized as an ecologically or biologically significant area (EBSA), and this has fueled large-scale conservation efforts by Chile

[7] United Nations General Assembly resolution 59/25. Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments. 17 January 2005.

[8] Convention on the Conservation and Management of High Seas Fishery Resources in the South Pacific Ocean. Adopted 14 November 2009. Entered into force 24 August 2012. Article 20(2)(d).

[9] Convention for the Strengthening of the Inter-American Tropical Tuna Commission Established by the 1949 Convention Between the United States of America and the Republic of Costa Rica, done at Washington June 27, 2003; Entered into force August 27, 2010. Article 1(1).

[10] ISA, Draft regulations on exploitation of mineral resources in the Area ISBA/24/LTC/WP.1 https://www.isa.org.jm/documents/isba24ltcwp1/

and Peru within their jurisdictional waters and ongoing research projects [3].

8.1. EBSA

An EBSA is an area of the ocean that has special ecological and biological significance and that need protection or enhanced management [3]. In 2008, the United Nations Convention on Biological Diversity (CBD) put in place a process to recognize these areas based on a set of seven scientific criteria. These criteria include: i) uniqueness or rarity, ii) special importance for life history stages of species, iii) importance for threatened, endangered or declining species and/or habitats, iv) vulnerability, fragility, sensitivity, or slow recovery, v) biological productivity, vi) biological diversity and vii) naturalness.[11] In 2014, the Salas y Gómez and Nazca ridges were recognized as an EBSA at the 12th Meeting of the Conference of the Parties given their importance on almost all the criteria (except productivity and rarity), highlighting the exceptional importance of protecting this region (Fig. 5).[3] Since designated as an EBSA, Peru and Chile have both protected areas of the Salas y Gómez and Nazca Ridges within their EEZ.

8.2. Other distinctions

The Salas y Gómez and Nazca ridges have been recognized as a Hope Spot by Mission Blue given its significance for the global health of the ocean. Particularly, the islands of Salas y Gómez, San Félix and San Ambrosio are all considered IBA by BirdLife International [234] and these places as well as Rapa Nui are considered KBA by the KBA Partnership Program [269]. More recently, within the Salas y Gómez and Nazca ridges one important and two candidate Important Shark and Ray Areas (ISRA and cISRA, respectively) were identified by the International Union for Conservation of Nature (IUCN) Shark Specialist Group (SSG).[12] Salas y Gómez Island was described as a reproductive (nursery) area for the Galapagos shark, given the higher abundance, year-round occurrence and philopatry of neonates, young-of-the-year, and juveniles around the island (Morales-Serrano and Gonzales-Pestana, 2024). Rapa Nui, on the other hand, was also proposed as a nursery area for the galapagos shark; however, the island does not have enough evidence to fulfill the needed criteria. Lastly, the Salas & Gómez and Nazca ridge was also identified as cISRA given the occurrence of endemic species (e.g., Juan Fernandez Dogfish *Squalus cf. fernandinus*), threatened species (e.g., shortfin mako *Isurus oxyrinchus*), their potential as aggregation area for pelagic species, and due to their importance as biological corridors to connect distant areas of the Pacific. The waters around Salas y Gómez and Desventuradas islands are both considered critical habitats by the International Finance Corporation's Performance Standard [270]. Likewise, this region has been identified as an important area by experts consulted by the Global Ocean Biodiversity Initiative (GOBI) and the Census of Marine Life on Seamounts (CENSEAM) [271,272].

8.3. MPAs

Undoubtedly, the Salas y Gómez and Nazca ridges represent a natural and cultural global heritage [3,4]. Consequently, several marine protected areas (MPAs) have been established in the jurisdictional waters of Chile (Motu Motiro Hiva Marine Park, Rapa Nui Multi-Use Coastal Marine Protected Area, Nazca-Desventuradas Marine Park, Mar de Juan Fernández Marine Park; Mar de Juan Fernández Multiple-Use Coastal Marine Protected Area), and one in Peruvian waters (Dorsal de Nasca National Reserve) (Fig. 5) [24,273]. Likewise, since 2014, all seamounts (considered vulnerable marine ecosystems) located within the Chilean waters of this region are protected from bottom trawling by the Law 20,657.[13]

Although these protection efforts represent significant progress to safeguarding this place, all of the seamounts that fall within ABNJ (73 % of the Salas y Gómez and Nazca ridges) are unprotected and threatened [3], which highlights the relevance of extending the area under protection.

8.4. International conservation efforts

A global alliance of partners whose objective is to protect coral reefs in areas beyond national jurisdiction, known as the "Coral Reefs of the High Seas Coalition (CRHSC)" has been working for four years to collect and synthesize scientific information and propose conservation measures to protect the Salas y Gómez and Nazca ridges [3]. As a result, many scientific papers and educational materials summarizing this information have been published in the last four years,[14] including two papers presented to the SPRFMO during its scientific committee meetings in October 2020[15] and September 2022.[16]

The recently concluded Strong High Seas (Strengthening Regional Ocean Governance for the High Seas) project (2017–2022), aimed to strengthen regional ocean governance for the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction in the Southeast Pacific in a joint effort with several international and regional partners, including the support of CPPS.[17]

In October 2020, Chile presented a partial submission to extend the limits of the Eastern Continental Shelf of the Easter Island Chilean Province, to the Commission on the Limits of the Continental Shelf of the UNCLOS. This area reaches 700 nautical miles (Mn) and covers 550,000 km^2 on the western portion of the Salas y Gómez Ridge [274], which includes around 60 % of the Salas y Gómez ridge. This was presented as a way of protecting natural resources and marine biodiversity of this region [273].

In April 2021, Chile announced the launch of efforts to create a high seas marine protected area (MPA) in the Salas y Gómez and Nazca ridges, as a priority measure to address the climate crisis.[18] This was the first political action carried out by a government to protect this area. After the announcement, the proposal was presented to the scientific committee of SPRFMO in September 2021[19] and in June 2022 it was announced during the UN Ocean Conference in Lisbon. In November 2022 Chile and CRHSC co-hosted the workshop "Pathway to Protect Salas y Gómez and Nazca Ridges" in Chile, and more recently, in February 2023, the event "Pathway to Protect Critical High Seas Areas" during the International Marine Protected Areas Congress (IMPAC 5) in Vancouver. Although these are important steps, any protection measure must be agreed upon with the other countries of the Southeast Pacific, such as Peru, Ecuador and Colombia, as well as other countries interested in using the waters of the Salas y Gómez and Nazca ridges.

9. Discussion

A great deal of research has documented the extraordinary

[11] CBD, Decision IX/20: Marine and Coastal Biodiversity. Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its Ninth Meeting. Bonn, Germany, 19–30 May 2008.https://www.cbd.int/decisions/cop/?m=cop-09

[12] https://sharkrayareas.org/

[13] https://bcn.cl/2lhbq

[14] https://www.coralreefshighseas.org/where-we-work

[15] https://www.sprfmo.int/assets/Meetings/SC/8th-SC-2020/SC8-Obs01-Oceana-SPRFMO-Proposal-for-Salas-y-Gómez -and-Nazca-ridges.pdf

[16] https://www.sprfmo.int/assets/Meetings/SC/10th-SC-2022/SC10-Report-Final-19Jan2023-v2.pdf

[17] https://www.prog-ocean.org/our-work/strong-high-seas/

[18] https://minrel.gob.cl/news/president-pinera-announces-chile-will-advance-a-proposal-to-fully

[19] SPRFMO, 9th Scientific Committee Meeting Report, 2021

biological, ecological, oceanographic, geological, and cultural significance of the Salas y Gómez and Nazca ridges in the southeastern Pacific. These studies have noted not only the remarkable uniqueness of species and habitats of this region, but also their vulnerability to impending impacts, highlighting the relevance of protecting it at the earliest opportunity [3,4].

The waters, islands and seamounts of the Salas y Gómez and Nazca ridges represent foraging grounds, nesting and nursery habitats and transit area for innumerable species of global ecological and commercial importance [3–5]. Likewise, the extreme geographic and oceanographic isolation result in a high endemism in this region, with species showing specific environmental requirements, making them more susceptible to anthropic threats such as overfishing, marine pollution and climate change [24].

Beyond the overexploitation of marine resources, fishing could be impacting highly migratory species through bycatch and collision [123,124,130,275], and the marine litter is affecting many vertebrate species through entanglement, ingestion, and its incorporation into nests of seabird species. The northern section of the Nazca Ridge intersects a major international shipping route and waters surrounding the Salas y Gómez and Nazca ridges are important transshipment location for fishing fleets [197,200], representing a threat for marine biodiversity. Likewise, any future cable laying and seabed mining activities through this area could affect the viability of benthic populations irreversibly [3,6,9].

Although impacts of climate change on marine diversity of this area are still not clear, the nutrient-poor waters, the predicted increase in water temperature and decrease in dissolved oxygen, make the region particularly susceptible to climate change [40]. As such, substantial changes in biochemical cycles and biodiversity, particularly shifts in species geographic distribution and population connectivity are expected [276–278]. Such changes could be significantly exacerbated by ENSO and other oceanographic features of the region [54,252,253], demanding further research.

Deep-water surveys of the Salas y Gómez and Nazca ridges have shown that every seamount has a unique faunal composition [1,99], emphasizing that it is not enough to protect only some of them to protect representative biodiversity. In the same way, numerous studies demonstrate this region results in a significant area for maintaining the viability of highly mobile and endemic species [3–6]. Thus, it is not only necessary to create new protected areas properly managed, but it is also crucial to facilitate and maintain the connectivity between these protected areas at a regional scale [4]. In this context, Chile has already protected most of the ecosystems of the region that fall within its jurisdiction (Friedlander and Gaymer 2021), and Peru has protected a large portion of the deep-water habitats that lie within its national waters (Decreto Supremo N° 008–2021-MINAM).[4] However, over 73 % of the biologically and ecologically significant area falls within ABNJ, which nowadays is threatened and unprotected [3,4].

As previously described, several intergovernmental organizations regulate human activities in the Salas y Gómez and Nazca ridges, including SPRFMO for management of non-highly migratory fishery species, IATTC for management of tuna and other highly migratory fishery species, ISO for shipping, ISA for seabed mining, and CPPS for regional collaboration amongst Chile, Peru, Ecuador, and Colombia in marine policy, resource exploitation, conservation, environmental protection, and research. Aside from the creation of marine protected areas and connectivity among them, specific actions will be required within each one of these intergovernmental organizations to conserve the fragile and unique resources of the region. Actions should include i. the closure of the area located in ABNJ of the Salas y Gómez and Nazca EBSA for fishing activities, ii. the collective work of intergovernmental organizations with competence over activities in the area to ensure the enactment of effective conservation measures, iii. the rejection of any proposal for exploratory fishing in the region since this could cause irrevocable harm to these extremely unique and fragile ecosystems, and iv. an increase of research and capacity development activities in all areas of knowledge to improve our understanding of the Salas y Gómez and Nazca ridges. These proposed actions would cause little to no impact on ongoing fishing operations, however, they would provide enormous advances in safeguarding the unique biodiversity of this region from future threats. A first step was recently (February 2024) made by the SPRFMO Commission, which agreed a Decision to task the Scientific Committee at its next meeting and annually as an agenda item, to compile and review all relevant scientific information and data about the Nazca and Salas y Gómez Ridge area and recommend possible measures to the Commission at its following regular meeting, based on an ecosysving its biodiversity and SPRFMO fishing resources, as well a sustainable use of marine resources.[20]This will be carried out by a Task Team that was agreed to be created by the SPRMFO scientific committee in October 2024.[21]

According to United Nations General Resolution 71/123, regional fishery management organizations should consider the potential impacts of climate change in taking measures to manage deep-sea fisheries and protect vulnerable marine ecosystems.[22] The high seas play a critical role as a global carbon sink [279,280] and protecting international waters of the Salas y Gómez and Nazca ridge would represent an important global contribution towards mitigating impacts of anthropogenic carbon emissions [3].

Protecting this area would have major global benefits for ecosystem connectivity, climate regulation, food security, and other ecosystem services. Seamounts and other deep-water habitats found on the Salas y Gómez and Nazca ridges represent important reservoirs of global marine biodiversity [281], and via connectivity with surrounding waters, they also play a critical role of sustaining productivity more broadly [282]. Furthermore, protecting this region would be seen as a great accomplishment to the world as a whole, and provide a global example for conserving biodiversity in ABNJ. Specifically, it would establish an example of a high seas protected area being established by neighboring countries that have similar interests in a shared ecosystem, thereby showcasing global leadership. This has already been successfully done in other high seas areas by member states of the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) and the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), which established marine protected areas in ABNJ of the Northeast Atlantic and Southern Ocean, respectively [283].

At the same time, regional fishery management organizations with the legal competence to manage bottom fisheries in ABNJ have established closed areas to protect vulnerable marine ecosystems and biodiversity [284]. Increased protections in this region would therefore also be consistent with the commitments adopted through the United Nations General Assembly resolutions on bottom fisheries, the Sustainable Development Goals and other marine conservation objectives and obligations, including the obligation to protect habitats of special concern and biodiversity in Articles 5–6 of the 1995 United Nations Fish Stocks Agreement (UNFSA).

Importantly, fishing effort has been relatively low in this region, and thereby it is possible to protect it, without significantly impacting the

[20] Decision 17-2024 to protect the Salas y Gomez and Nazca ridges area (2024)

[21] The Scientific Committee agreed to establish a Task Team for the Salas y Gomez and Nazca Ridges Area to compile and review all relevant scientific information and data about the Area and recommend possible measures to be presented to the SC-13 in 2025, based on an ecosystem-based approach that aims at preserving its biodiversity and fishing resources in the Convention Area.

[22] Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments. 7 December 2016.

fishing industry [3]. Likewise, industrial activities are still absent or relatively low [3], so there is a time-sensitive opportunity to conserve its natural and cultural heritage before they are lost forever. Ultimately, the protection of this high sea area is perfectly feasible; nevertheless, it will require significant international coordination and political willingness both at a regional and global scale.

The recent adoption of BBNJ Treaty and its eventual entry into force, represents a unique opportunity to advance in the protection of the Salas y Gómez and Nazca ridges and move closer to the achievement of CBD GBF Target 3 (30×30), this in parallel with efforts that should be made by the different intergovernmental organizations [23]. The BBNJ treaty invites participation from all relevant stakeholders, such as regional and sectoral bodies and frameworks, which could include the International Whaling Commission (IWC) and RFMOs such as SPRFMO and IATTC, among others. The BBNJ Treaty further aims to enhance cooperation and coordination of management bodies under one legal framework, without undermining existing legal instruments and frameworks such as RFMOs [285–287]. Proposals for conservation measures under the BBNJ Agreement such as an MPA or a network of MPAs could provide the most comprehensive and encompassing measures that would be applicable globally by all Parties to the treaty.

To date, there is an important amount of scientific information available for the Salas y Gómez and Nazca ridges to date which provide a sound basis for protection [3]. Likewise, recent joint research efforts have been carried out in this region during 2024 and are also planned for the coming years. The recently finished CIMAR 26 cruise organized by the Chilean National Oceanographic Committee (CONA) monitored the Salas & Gómez ridge including Rapa Nui and Salas y Gómez Island, focusing on oceanographic conditions, litter abundance, seabirds at sea and cetaceans.[5] Similarly, the CIMAR 28 cruise in October 2023 focused on the same topics at the Desventuradas Islands and the Juan Fernandez Archipelago. Two Falkor (too) cruises from the Schmidt Ocean Institute explored the Nazca ridge in January and August 2024, and another one studied the Salas y Gómez ridge between February-March 2024. This unprecedented scientific effort will allow filling gaps of knowledge in an area that has increasingly been studied in recent years. The next challenge is to transfer this scientific basis for decision-making on the sustainable use, management and conservation of the biodiversity that inhabits both the islands and seamounts of the Salas y Gómez and Nazca ridges, contributing to the CBD GBF Target 3 (30×30) and the Sustainable Development Goals of United Nations.

Ultimately, we recommend that the entire proposed high seas protected area incorporate an ethos of cooperation with the indigenous Amerindian and Polynesian communities, especially the indigenous Rapanui. We further recommend collaboration with the community of the Juan Fernandez Archipelago that although not an indigenous community, have inhabited these islands for over two and a half centuries and developed a unique islander culture that prides itself on the stewardship of its marine resources. This would serve to effectively implement a key provision of Target 3 of the Kunming-Montreal Global Biodiversity Framework adopted by the 15th Conference of Parties to the Convention on Biological Diversity which commits States to recognize indigenous and traditional territories and to recognize and respect the rights of indigenous peoples and local communities, including over their traditional territories, in the designation of protected areas and other effective area-based conservation measures.[1]

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2024.106453.

Data availability

Data will be made available on request.

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