

# GIS for SCIENCE

**E.O. Wilson**  
Two-time winner of  
the Pulitzer Prize

**VOLUME 3**

Maps for Saving  
the Planet

Edited by Dawn Wright  
and Christian Harder

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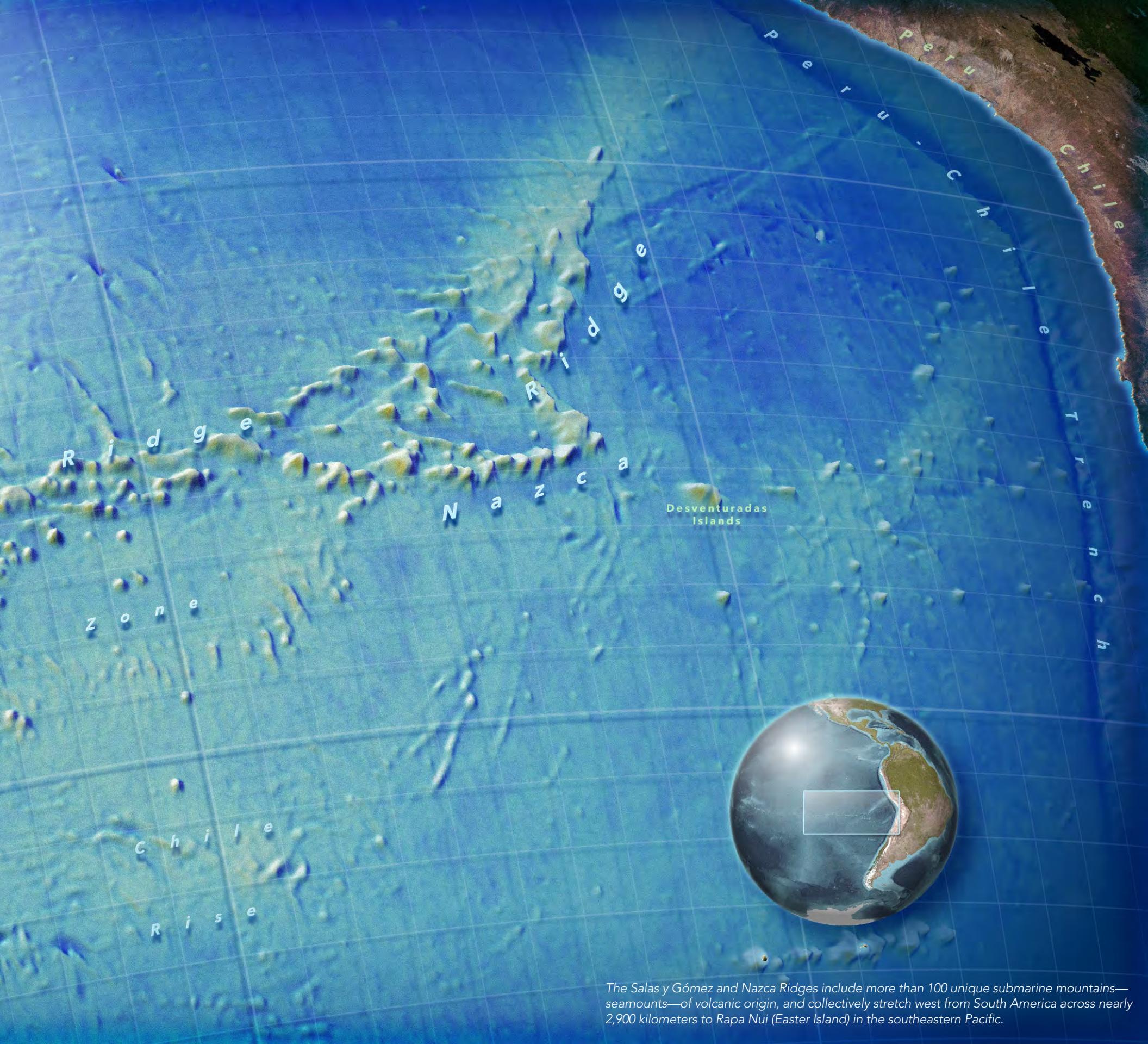
On the cover: This vibrant representation of our planet paints on its surface the World Ecological Land Units—a segmentation of distinct bioclimate, landform, lithology, and land cover that forms the basic components of terrestrial ecosystem structure. Hillshading was derived from GEBCO 2020 elevation and bathymetric data. It was created in ArcGIS Pro. The aesthetic was inherited from the Half-Earth globe, designed by John Nelson of Esri and Estefanía Casal of Vizzuality, with the goal of invoking the sense that our shared planet is something beautiful and charming and worthy of sound stewardship.

# CONSERVING THE LAST OCEAN FRONTIERS

The unique combination of natural and cultural resources has made the Salas y Gómez and Nazca Ridges a top priority for protection on the high seas. With support from global datasets and GIS analysis, researchers have identified this area off the west coast of South America as a key location to conserve and protect marine biodiversity without impacting industries.

By Daniel Wagner and T. 'Aulani Wilhelm, **Conservation International**; Alan M. Friedlander, **National Geographic Society, University of Hawai'i**; Richard L. Pyle, **Bernice P. Bishop Museum**; Kristina M. Gjerde, **International Union for Conservation of Nature**; Erin E. Easton, **University of Texas, Rio Grande Valley**; Carlos F. Gaymer and Javier Sellanes, **Universidad Católica del Norte**; Cassandra M. Brooks, **University of Colorado Boulder**; Liesbeth van der Meer, **Oceana Chile**; and Lance E. Morgan and Samuel E. Georgian, **Marine Conservation Institute**





The Salas y Gómez and Nazca Ridges include more than 100 unique submarine mountains—seamounts—of volcanic origin, and collectively stretch west from South America across nearly 2,900 kilometers to Rapa Nui (Easter Island) in the southeastern Pacific.

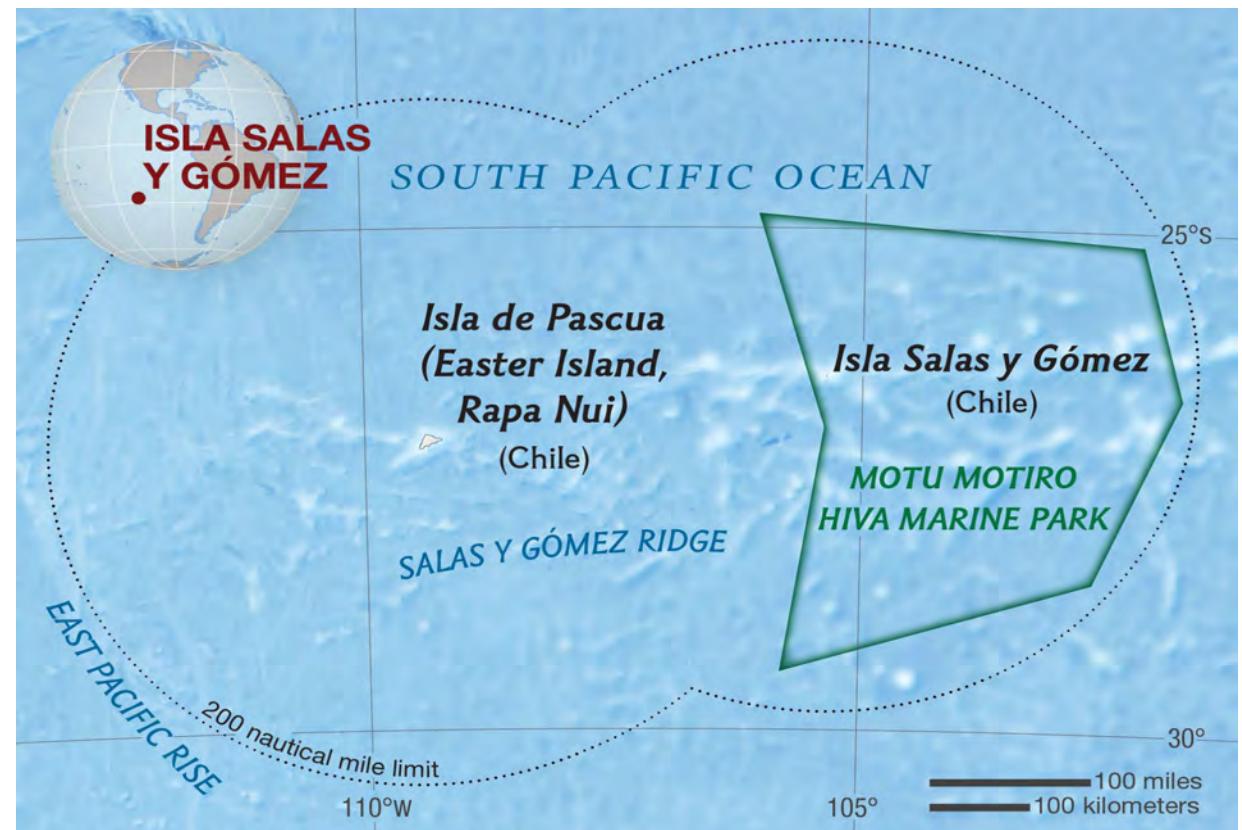
# INTRODUCTION

Covering more than 61% of the ocean's surface and 95% of its volume, marine areas known as the high seas represent one of the last science, conservation, and resource management frontiers on Earth. The laws of any one country are insufficient to protect the high seas because they lie beyond all national jurisdictions. These vast ocean expanses include the majority of the total inhabitable space for life on Earth. As such, they provide critical habitat to millions of species, the vast majority of which remain to be discovered. The high seas are crucial for sustaining life on Earth, because they produce nearly half of the oxygen we breathe, capture more than 1.5 billion tons of carbon dioxide each year, and contain nearly 90% of all life in the ocean by mass.

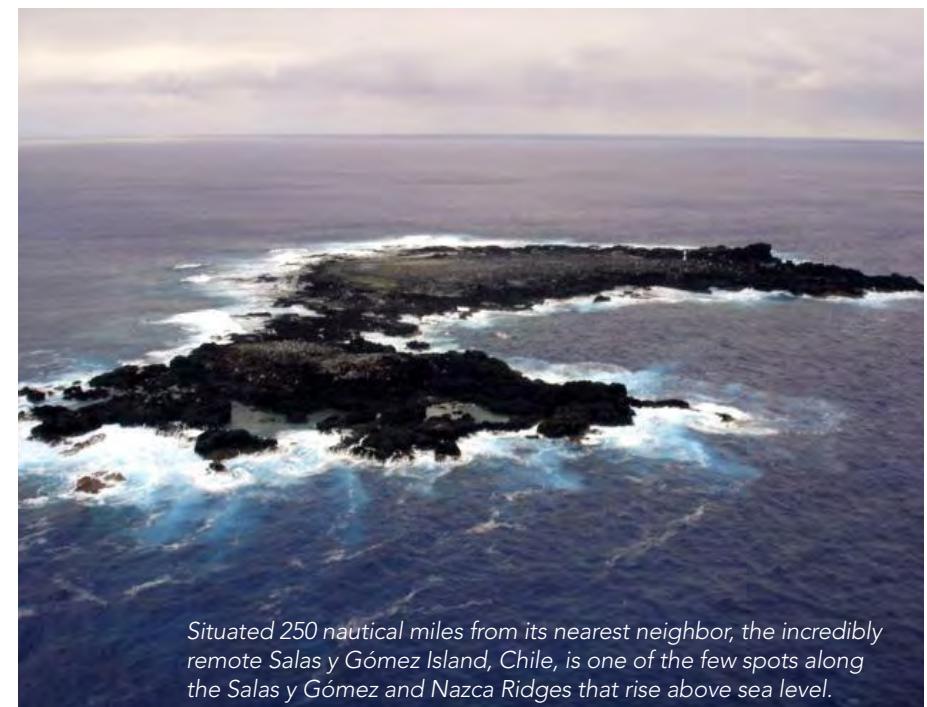
Although most people give little if any thought to these remote areas, the high seas have played a pivotal role in many seafaring cultures, which for millennia have navigated these areas to sustain themselves physically and spiritually. Even today, close to 90% of the world trade is carried out through international shipping on the high seas, and nearly 10 million tons of fish are caught there each year. Unfortunately, many of these activities are not well regulated. For example, some estimate that close to 90% of global fish stocks are either depleted or fully exploited, with much of this poorly regulated fishing taking place on the high seas. Various intergovernmental organizations, each with their own legal mandate, are responsible for regulating fishing, shipping, seabed mining, and other activities in these areas. The lack of a coordinated approach to conservation on the high seas makes resource management less effective.

Recognizing this critical gap, the United Nations in 2015 committed to develop a legally binding treaty to conserve and sustainably use marine biodiversity on the high seas. Plans for further negotiations offer hope that a legal mechanism will soon establish marine protected areas on the high seas. Currently, less than 8% of our ocean has any protection measures, far less than the 30% minimum that many scientific assessments conclude is necessary to limit the widespread impacts of climate change and arrest global declines in biodiversity. The high seas are by far the largest and least protected portion of our planet, and therefore our best opportunity for reaching the global target of protecting 30% of our oceans by 2030. However, scientific information is disproportionately scarce on the high seas, thereby complicating resource management and conservation planning.

This chapter presents a case study to show how various global datasets and GIS analyses supported the identification of one of the most promising places to establish a marine protected area on the high seas—the Salas y Gómez and Nazca Ridges. Numerous studies identified this region as one of the top protection priorities on the high seas because of its unique collection of natural and cultural resources. Fishing and other commercial activities are still minimal in this region, thus providing a narrow window of opportunity to proactively protect its natural and cultural resources without impacting industries. This chapter also is designed to serve as a foundation for guiding large-scale ocean conservation efforts elsewhere.



The Salas y Gómez and Nazca Ridges are anchored on the west side by the islands of Salas y Gómez and Rapa Nui, which have extraordinary significance in Rapa Nui culture and include one of the most renowned archaeological sites on Earth.



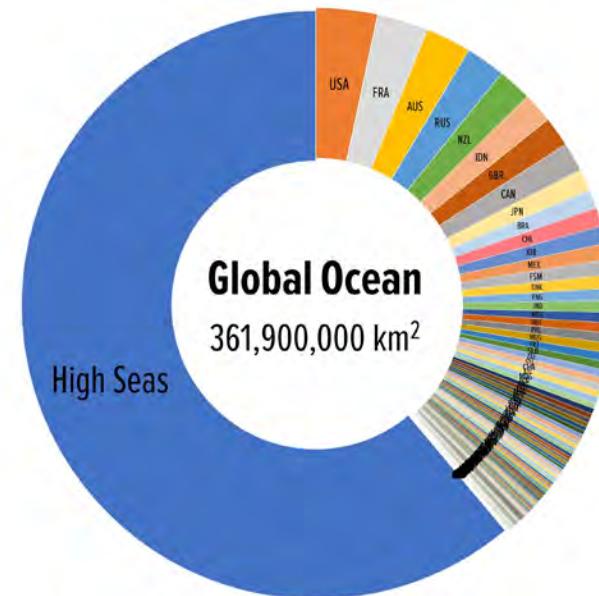
Situated 250 nautical miles from its nearest neighbor, the incredibly remote Salas y Gómez Island, Chile, is one of the few spots along the Salas y Gómez and Nazca Ridges that rise above sea level.

# JURISDICTIONAL BOUNDARIES

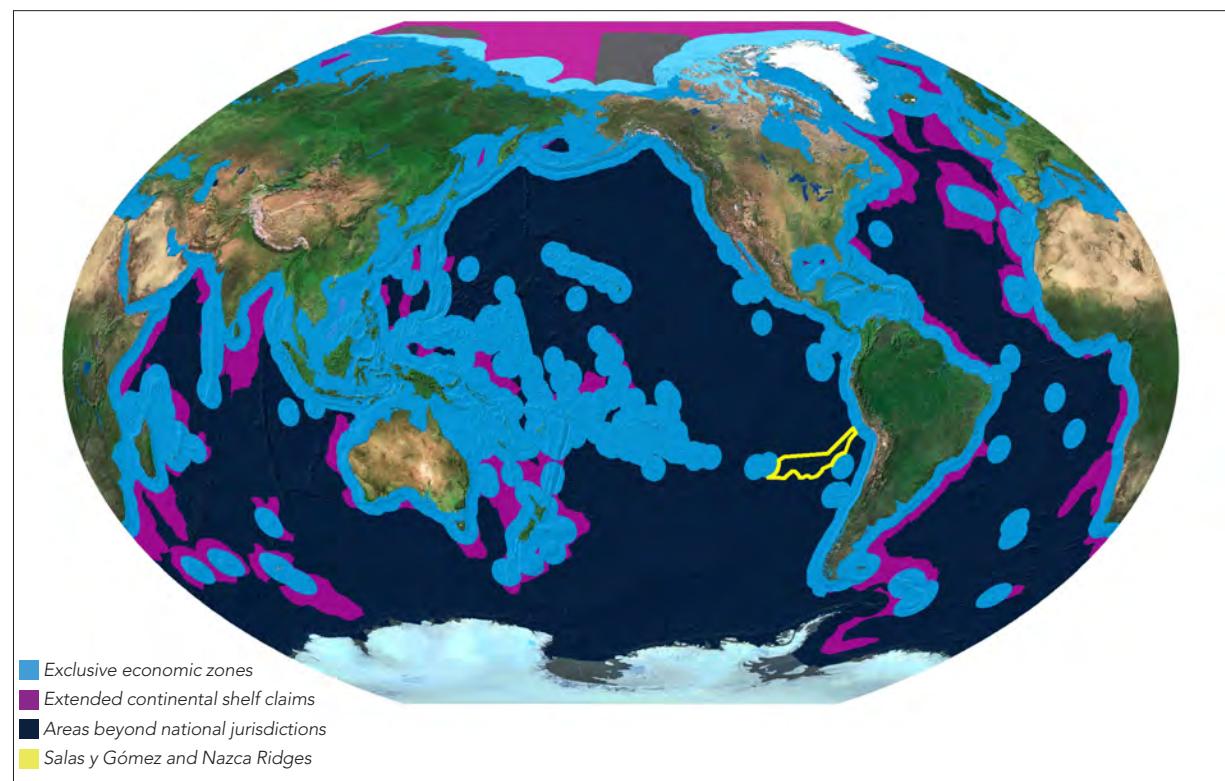
Unlike land, where the borders of many countries have been established and refined for many centuries, the delineation of countries' maritime borders is a relatively recent development. In 1982, the UN Convention on the Law of the Sea established the general rules that govern the uses of the ocean and its resources. Among many other things, the Convention provides the framework for how maritime borders are drawn, including those between adjacent coastal states, as well as those between coastal states and areas beyond national jurisdiction. Specifically, the Convention defines exclusive economic zones, an area in which countries have exclusive rights to explore, exploit, conserve, and manage all resources located on the seafloor and in the water column, including fishery resources, oil, gas, offshore energy, and seabed minerals. The Convention further gives nation states exclusive rights to establish artificial islands, installations, structures, conduct scientific research, and protect the marine environment within their exclusive economic zones. The boundaries of countries' exclusive economic zones generally extend to 200 nautical miles (370 kilometers) from their coastal baselines, with the exception of when that limit would overlap with another country.

The Convention also defines continental shelf boundaries of countries, which extend at least 200 nautical miles from coastal baselines, but potentially up to 350 nautical miles, if scientific evidence shows that the continental margin lies farther offshore. Countries that want to delimit their outer continental shelf beyond the 200 nautical miles limit can submit scientific justifications to the UN Commission on the Limits of the Continental Shelf. If the commission grants the claim, the country obtains sovereign rights over the seafloor and its resources in these additional areas. However, the country does not obtain rights over those resources found in the water column above it, which are still considered high seas. Consequently, areas claimed as extended continental shelf are governed in a mixed way, with activities on the seafloor regulated by the claimed country and activities in the water column regulated by the respective intergovernmental organization.

The Convention thus provides the framework for delimiting the maritime borders of countries and for those with areas beyond national jurisdiction. Seventy-three percent of the Salas y Gómez and Nazca Ridges are located in areas beyond national jurisdiction, with smaller portions located in the national waters of Chile and Peru. Specifically, the northeastern section of the Nazca Ridge is located in the national waters of Peru, whereas both ends of the Salas y Gómez Ridge are located within the Chilean exclusive economic zone. Additionally, in December 2020, the Chilean government submitted an extended continental shelf claim for 550,000 km<sup>2</sup> east of Salas y Gómez Island to gain sovereignty over the seafloor resources in this area, although the water column above it would still be considered high seas.



Marine areas beyond national jurisdiction, commonly known as the high seas, cover more than 61% of the surface of the global ocean. Jurisdiction over the other 39% of the global ocean surface is divided among 157 countries.<sup>1</sup>

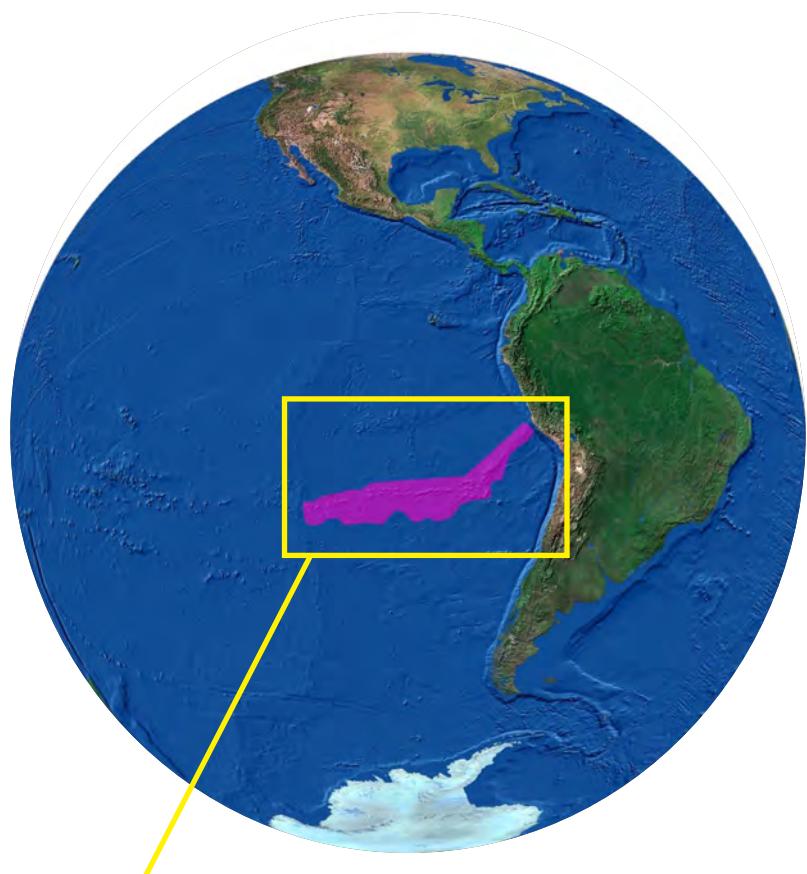


Unlike land, the delineation of countries' maritime borders occurred relatively recently through the 1982 UN Convention on the Law of Sea. Coastal states jurisdictions extend over all seafloor and water column resources within their exclusive economic zones,<sup>1</sup> which are generally located within 200 nautical miles of their coastlines. States can claim additional jurisdiction over seafloor resources if they can provide scientific evidence that their continental shelf extends beyond 200 nautical miles from shore.<sup>2</sup> The UN Convention of the Law of Sea therefore delimits both the maritime borders of countries, as well as those of areas beyond national jurisdiction, which cover the majority of the Salas y Gómez Ridges.

# THE SALAS Y GÓMEZ AND NAZCA RIDGES

Extending more than 2,900 kilometers of seafloor off the west coast of South America, the Salas y Gómez and Nazca Ridges are two adjacent underwater mountain chains of volcanic origin. The more adjacent ridge to the South American continent, the Nazca Ridge, stretches across roughly 1,100 kilometers between the coast of Peru and the Desventuradas Islands. The Salas y Gómez Ridge spans approximately 1,600 kilometers between the Desventuradas Islands and Rapa Nui, also known as Easter Island. The Desventuradas Islands, Rapa Nui, and its close neighbor, Salas y Gómez Island, are the only places where the Salas y Gómez and Nazca Ridges rise above sea level. All of the other 110 peaks of these seamounts lie underneath the sea surface, where they create important habitats and migration corridors for many unique species.

The islands and seamounts that make up the ridges are thought to have been produced by a common geological hot spot located close to the present location of Salas y Gómez Island. Magma that first erupted here more than 27 million years ago grew to form seamounts that were carried eastward with the tectonic movement of the Nazca Plate. New seamounts formed with new eruptions, which then followed the journey of their predecessors eastward on the Nazca Plate. These seamounts provide a detailed chronological record of the geological formation of this region that tracks the movement of the Nazca Plate eastward before it gets subducted under South America. In addition to becoming older from west to east, these seamounts generally become progressively deeper moving eastward and range between just a few meters below the surface on the western portion of the ridges to more than 3,000 meters toward the northeastern end. Drowned fringing and barrier reefs are still evident on many of these deep seamounts, reminding us that these features were all near the sea surface at some point in their past.



Located off the west coast of South America, the Salas y Gómez and Nazca Ridges<sup>3</sup> are two underwater mountain chains that collectively stretch across 2,900 kilometers in the South Pacific. The Salas y Gómez Ridge spans 1,600 kilometers between Rapa Nui and the Desventuradas Islands, where it connects to the Nazca Ridge, which covers another 1,100 kilometers of seafloor before meeting the coast of Peru.

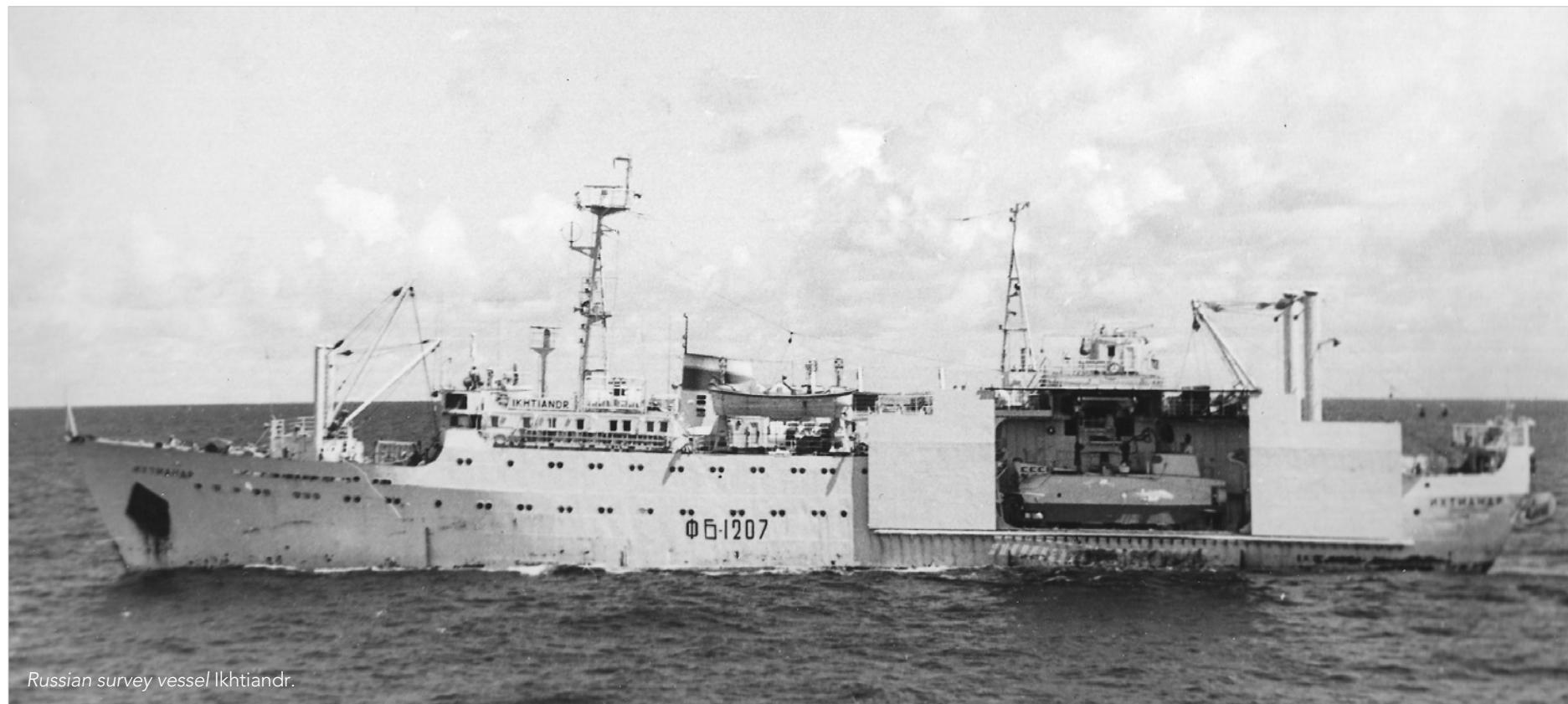
# HISTORIC SCIENTIFIC SURVEYS

The general lack of exploration of the most remote high seas—compared with waters closer to shore—is evident in that one-third of all recorded species on the high seas is represented by a *single* record in the most comprehensive repository of global ocean biodiversity, the Ocean Biogeographic Information System. For the Salas y Gómez and Nazca Ridges, however, the Ocean Biogeographic Information System contains a relatively dense collection of records, including more than 14,000 occurrences of 930 species.<sup>4</sup> This number includes numerous records of ecologically important species such as whales, sea turtles, sharks, and reef-building corals, which is quite unique for an area on the high seas.

These species records result from various scientific expeditions, most notably a series of Russian expeditions that surveyed the ridges from 1973 to 1987. The

Chilean National Oceanographic Committee surveyed the high seas portions of the ridges in 1999 and 2016. And in 2019, the Japan Agency for Marine-Earth Science and Technology led an expedition that included Chilean and other partners.

These scientific explorations noted that the marine biodiversity of this region is composed of a high proportion of endemic species, or species that are not known to occur anywhere else on Earth. For many groups of organisms, nearly half of the species are endemic to the region, the highest level of marine endemism known anywhere on Earth. Furthermore, previous surveys noted that every seamount of these ridges appears to have a unique community composition, with few species shared between opposite ends of the ridges. This finding highlights the need to protect all the ridge features to safeguard representative biodiversity.



Russian survey vessel Ikhtiandr.



Professor Mesyatzev



Professor Shtokman



Mirai

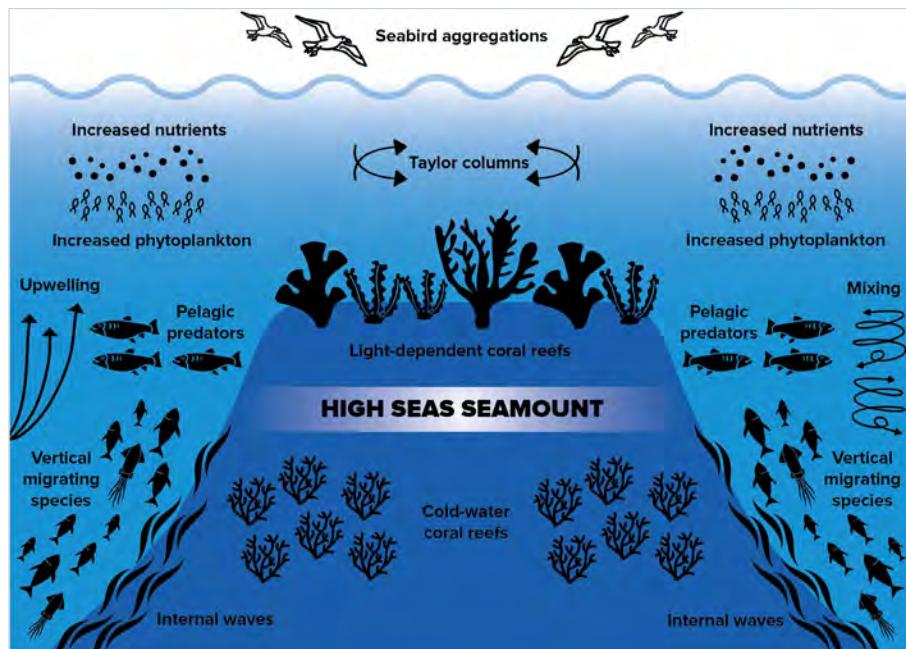


Cabo de Hornos

Compared to many still virtually unexplored regions of the world's high seas, the international waters of the Salas y Gómez and Nazca Ridges have been surveyed by a series of Russian, Chilean, and Japanese expeditions beginning in the early 1970s. These vessels carried the latest technologies of the day. Data from these expeditions have since made it into GIS databases and applications such as Esri's Ocean Basemap, which can be accessed at [GISforScience.com](http://GISforScience.com).

# SEAMOUNT AND SEAFLOOR MAPPING DATA

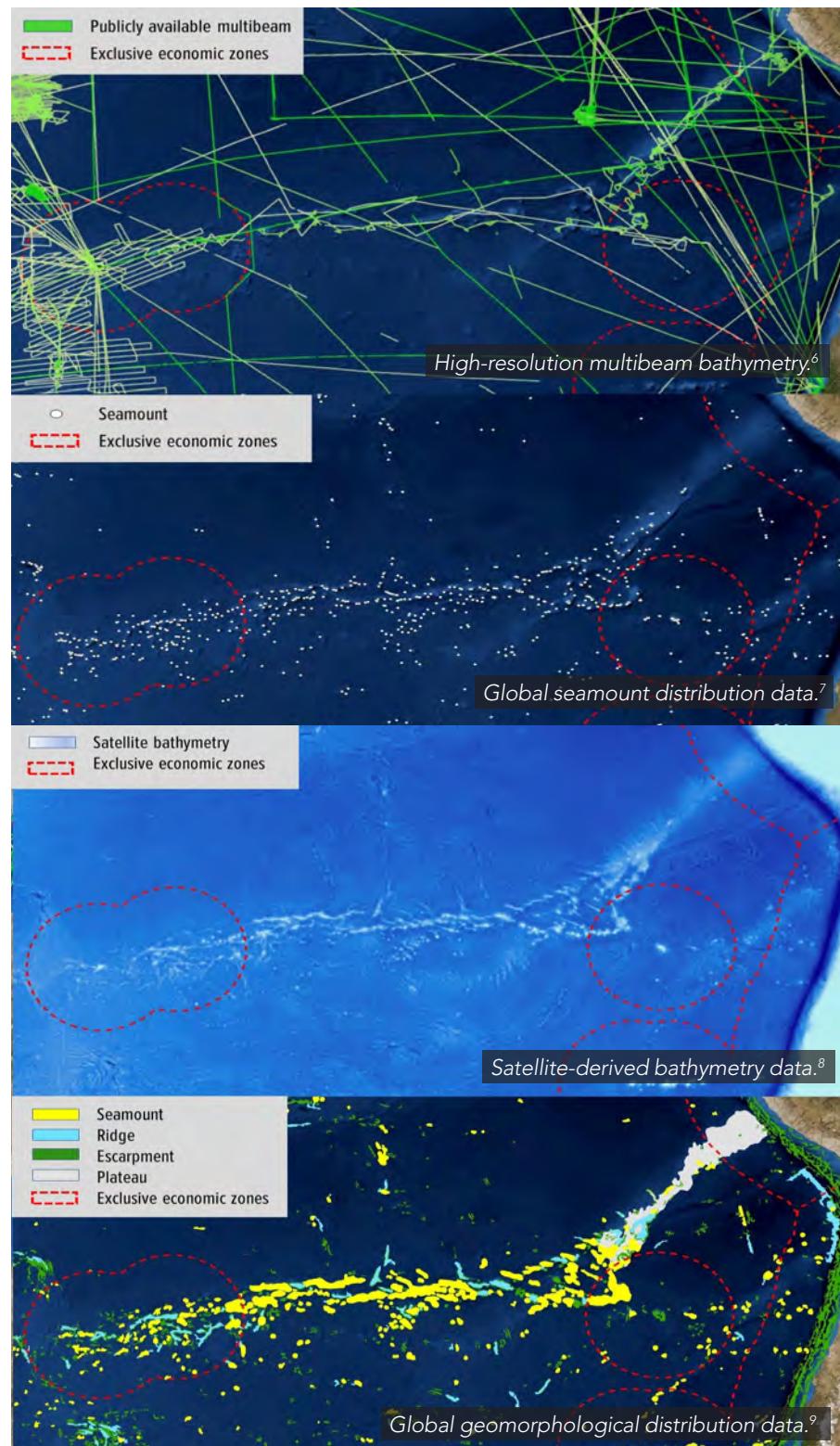
Seamounts are defined as underwater mountains that rise at least 1,000 meters above the seafloor. Seamounts and other steep topographical features significantly impact the deep-sea environment, because they accelerate currents, increase upwelling, and increase food supply, and thereby provide favorable habitat for a wide variety of organisms. Many conservation initiatives have prioritized seamounts for protection because they are regarded as some of the most diverse and productive habitats in the ocean.



Seamounts are widely regarded as one of the top ocean conservation priorities globally, because these features create favorable conditions and habitats for a wide variety of marine life.<sup>5</sup>

The most accurate way to identify seamounts is to map the seafloor using echosounders mounted on ships or on submersible vehicles. Using such modern mapping technologies, researchers have mapped about 20% of the seafloor to date at a resolution high enough to identify fine topographic details (~100 meters).<sup>6</sup> Most of the areas lacking detailed mapping are located on the high seas, where there have been almost no dedicated mapping surveys, and only few surveys during opportunistic ship transits. This pattern is also true for high seas waters surrounding the Salas y Gómez and Nazca Ridges, the majority of which has not been mapped in detail using modern mapping systems.

In areas that lack high-resolution mapping, satellite altimetry data can help generate coarser maps of the seafloor that can resolve large topographical features to a resolution of about 1 kilometer. Satellite-derived bathymetry data have been used to generate various databases on seamounts and other steep topographical features. These datasets indicate that the Salas y Gómez and Nazca Ridges contain a large aggregation of seamounts and other steep topographical features, such as ridges and escarpments, which are known to provide suitable habitat for diverse marine life. The Salas y Gómez and Nazca Ridges contain an estimated 110 or more seamounts, or approximately 41% of all seamounts found in the southeastern Pacific Ocean.



Maps showing seafloor mapping data surrounding the Salas y Gómez and Nazca Ridges from four source technologies.

# INTERNATIONAL DISTINCTIONS

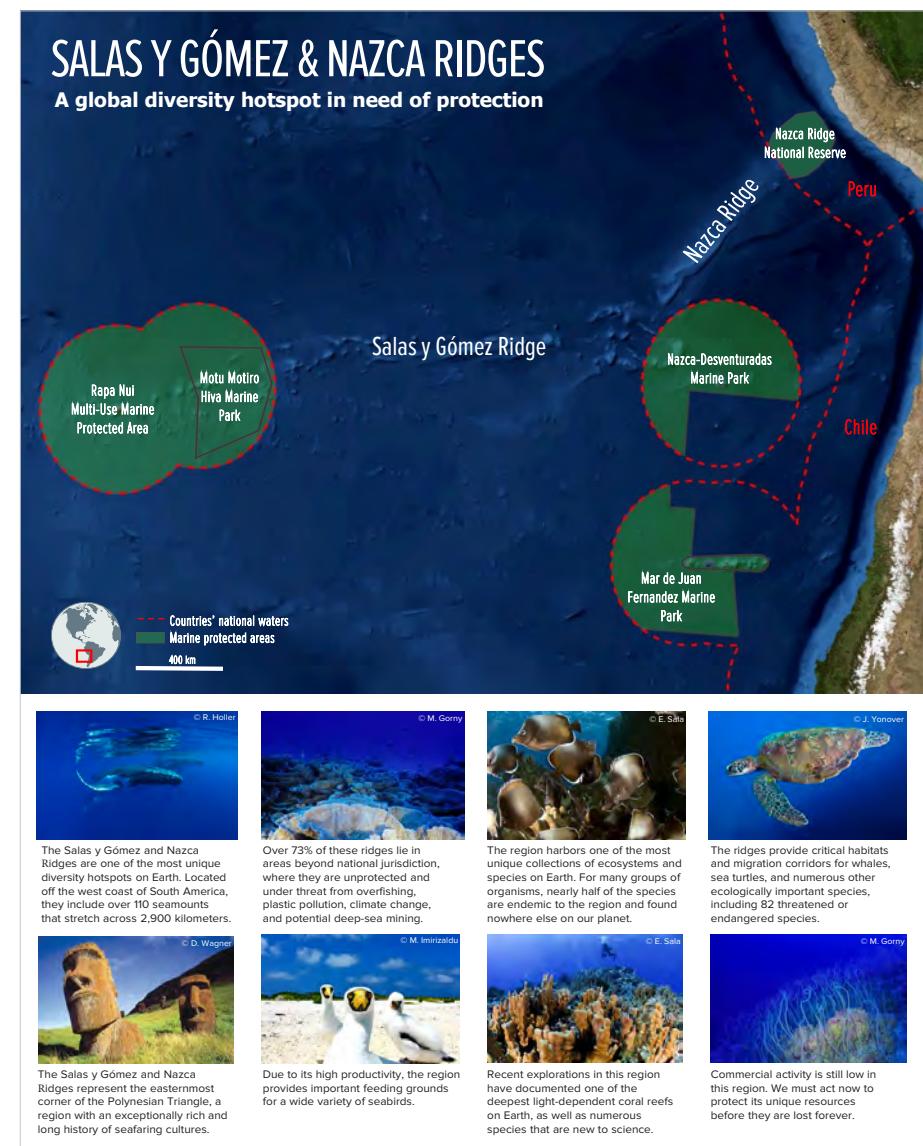
In 2014, the Conference of the Parties to the Convention of Biological Diversity<sup>3</sup> recognized the Salas y Gómez and Nazca Ridges as an ecologically or biologically significant marine area. This distinction recognizes globally significant marine areas that need protection. These areas are evaluated based on seven criteria, including uniqueness, special importance for life stages of species, importance for threatened or endangered species, vulnerability, biological productivity, biological diversity, and naturalness.



Seamounts provide critical habitats and ecological stepping-stones for whales, sea turtles, corals, and many other ecologically important species, including 82 threatened or endangered species that are known to inhabit the Salas y Gómez and Nazca Ridges.<sup>11</sup>

The Global Ocean Biodiversity Initiative and the Global Census of Marine Life on Seamounts also recognized the ridges as an important area, and Mission Blue identified the ridges as a Hope Spot, which are classified as special places critical to the health of the ocean.<sup>12</sup> Based on spatial distribution data of the International Union for Conservation of Nature Red List of Threatened Species,<sup>13</sup> the ridges provide important habitats to 82 threatened or endangered species, including 25 species of sharks and rays, 21 species of birds, 16 species of corals, 7 species of marine mammals, 7 species of bony fishes, 5 species of marine turtles, and 1 species of sea cucumber. Salas y Gómez Island and the Desventuradas Islands are considered Important Bird Areas by BirdLife International,<sup>14</sup> because they host important colonies of Christmas Island shearwater, masked booby, white-throated storm petrel, de Filippi's petrel, and Chatham petrel.

The region has also been recognized internationally based on its rich cultural heritage. The island of Rapa Nui includes one of the most renowned archaeological sites on Earth, which has been distinguished globally as a World Heritage Site by the United Nations Educational, Scientific and Cultural Organization (UNESCO).<sup>15</sup> The broader region that contains the Salas y Gómez and Nazca Ridges represents the easternmost corner of the Polynesian Triangle, a region with an exceptionally rich and long history of seafaring cultures. Polynesian and other seafarers have sailed across these ridges for centuries, and archival research indicates several shipwrecks likely occurred in this region.



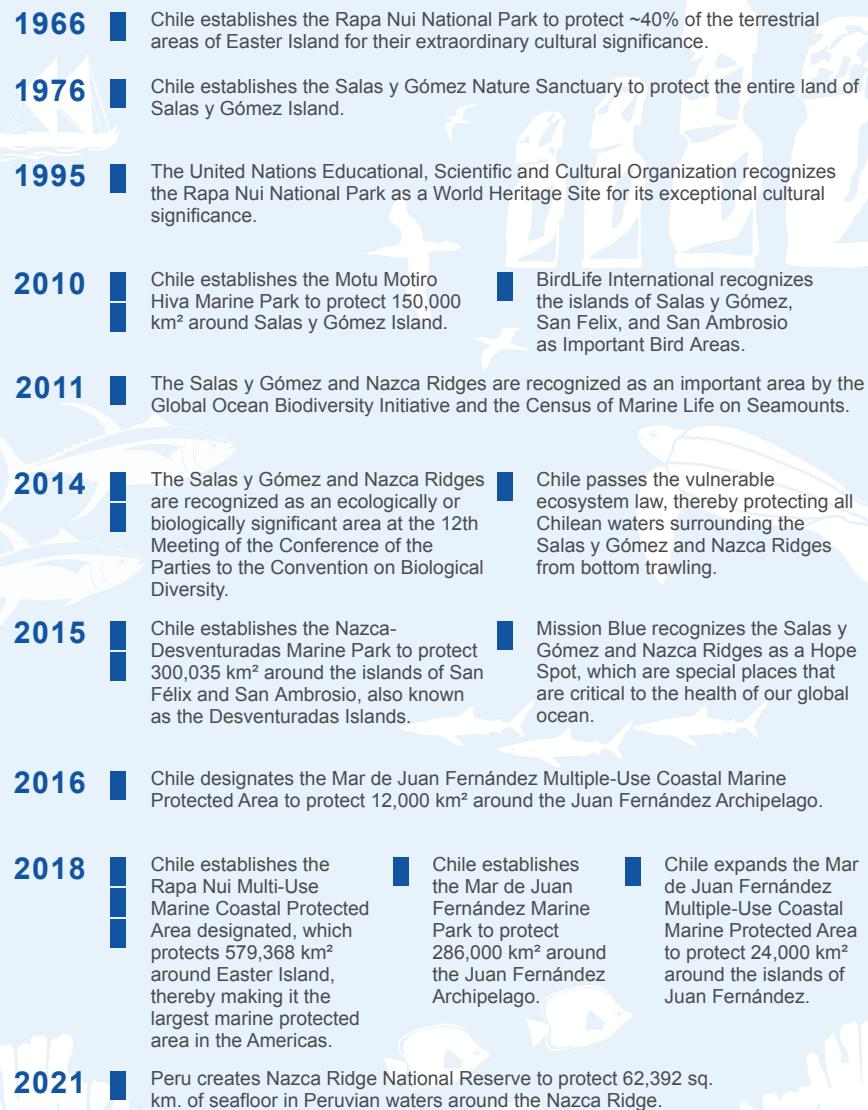
Excerpt from a Salas y Gómez and Nazca Ridges fact sheet.

The international distinctions and supporting scientific data prompted Chile and Peru to establish several marine protected areas in the portions of this region that fall under their jurisdiction.<sup>16</sup> These areas include the Rapa Nui Multiple-Use Coastal Marine Protected Area, the Motu Motiro Hiva Marine Park, the Nazca-Desventuradas Marine Park, and the Juan Fernández Multiple-Use Coastal Marine Protected Area, all established by Chile in the last decade. In June 2021, Peru created the Nazca Ridge National Reserve,<sup>17</sup> which protects the seafloor portion of the Nazca Ridge that falls in Peruvian national waters. Despite these important advances, more than 73% of the Salas y Gómez and Nazca Ridges lack any protected status.

# HUMAN ACTIVITIES AND MANAGING AUTHORITIES

Within areas beyond national jurisdiction, the authority to regulate human activities belongs to various intergovernmental organizations, including the International Maritime Organization for shipping activities, the International Seabed Authority for seabed mining activities, and regional fishery management bodies, which regulate fishing activities for specific fishery species and geographic regions.

## CONSERVATION DISTINCTIONS



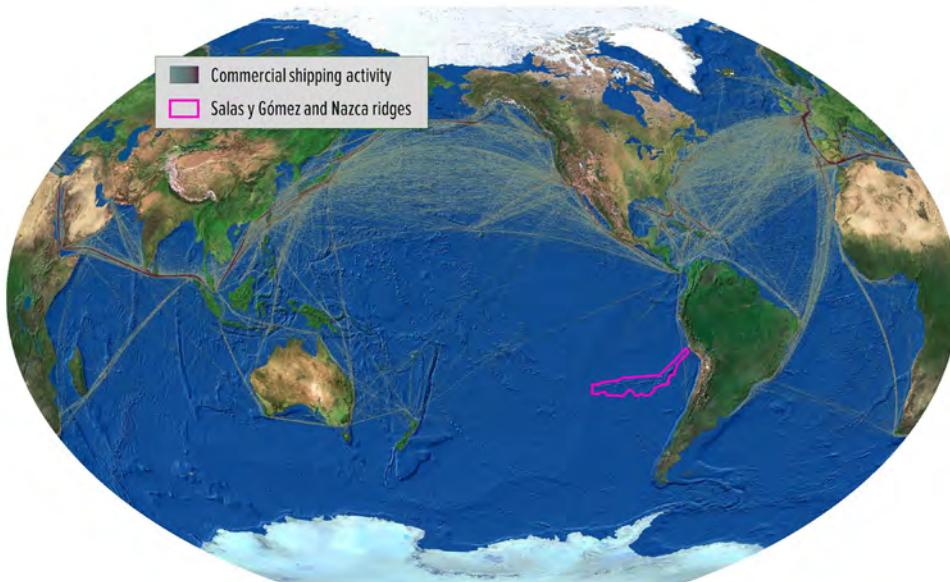
- 1966** Chile establishes the Rapa Nui National Park to protect ~40% of the terrestrial areas of Easter Island for their extraordinary cultural significance.
- 1976** Chile establishes the Salas y Gómez Nature Sanctuary to protect the entire land of Salas y Gómez Island.
- 1995** The United Nations Educational, Scientific and Cultural Organization recognizes the Rapa Nui National Park as a World Heritage Site for its exceptional cultural significance.
- 2010** Chile establishes the Motu Motiro Hiva Marine Park to protect 150,000 km<sup>2</sup> around Salas y Gómez Island.
- 2011** BirdLife International recognizes the islands of Salas y Gómez, San Félix, and San Ambrosio as Important Bird Areas.
- 2011** The Salas y Gómez and Nazca Ridges are recognized as an important area by the Global Ocean Biodiversity Initiative and the Census of Marine Life on Seamounts.
- 2014** The Salas y Gómez and Nazca Ridges are recognized as an ecologically or biologically significant area at the 12th Meeting of the Conference of the Parties to the Convention on Biological Diversity.
- 2014** Chile passes the vulnerable ecosystem law, thereby protecting all Chilean waters surrounding the Salas y Gómez and Nazca Ridges from bottom trawling.
- 2015** Chile establishes the Nazca-Desventuradas Marine Park to protect 300,035 km<sup>2</sup> around the islands of San Félix and San Ambrosio, also known as the Desventuradas Islands.
- 2015** Mission Blue recognizes the Salas y Gómez and Nazca Ridges as a Hope Spot, which are special places that are critical to the health of our global ocean.
- 2016** Chile designates the Mar de Juan Fernández Multiple-Use Coastal Marine Protected Area to protect 12,000 km<sup>2</sup> around the Juan Fernández Archipelago.
- 2018** Chile establishes the Rapa Nui Multi-Use Marine Coastal Protected Area designated, which protects 579,368 km<sup>2</sup> around Easter Island, thereby making it the largest marine protected area in the Americas.
- 2018** Chile establishes the Mar de Juan Fernández Marine Park to protect 286,000 km<sup>2</sup> around the Juan Fernández Archipelago.
- 2018** Chile expands the Mar de Juan Fernández Multiple-Use Coastal Marine Protected Area to protect 24,000 km<sup>2</sup> around the islands of Juan Fernández.
- 2021** Peru creates Nazca Ridge National Reserve to protect 62,392 sq. km. of seafloor in Peruvian waters around the Nazca Ridge.

The International Maritime Organization is responsible for regulating international shipping activities on the oceans, which includes having the authority to implement conservation measures to prevent potential environmental impacts on fragile ecosystems. Specifically, the International Maritime Organization has the authority to designate particular sensitive sea areas, which may be protected by ship routing measures, such as areas to be avoided by all ships, or by certain classes of ships. There have been no particular sensitive sea area designations anywhere on the high seas, nor are there any shipping route limitations around the Salas y Gómez and Nazca Ridges. However, with the exception of the northern section of the Nazca Ridge, this region does not contain major commercial shipping routes.

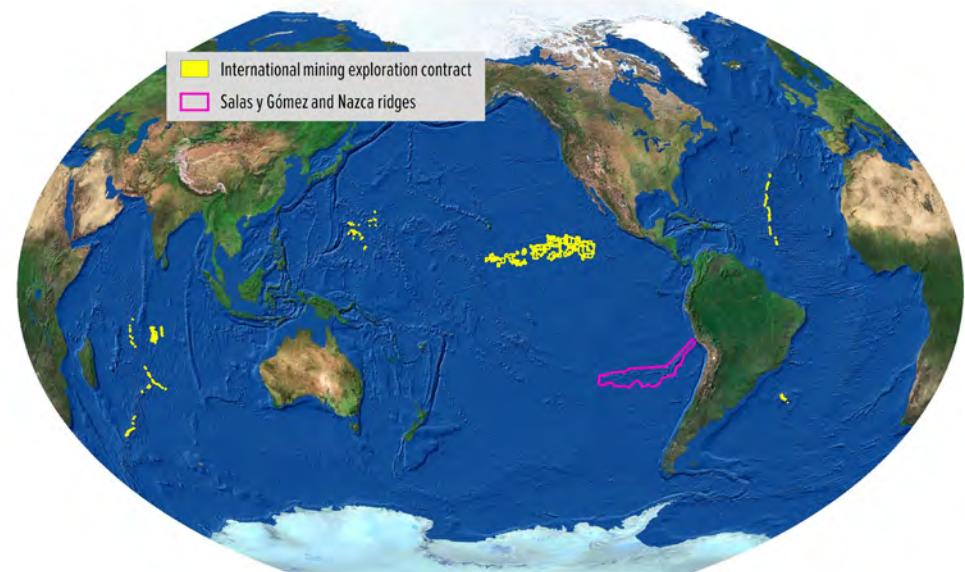
While deep-sea mining has not yet occurred, regulations for this developing industry are currently being created. The International Seabed Authority, an intergovernmental institution established under the 1982 UN Convention on the Law of the Sea, is mandated with developing deep-sea mining regulations in areas beyond national jurisdiction, commonly known as the mining code. The mining code is currently only applicable to the prospecting or exploration for deep-sea minerals, but not yet to the exploitation or collection of minerals for commercial purposes, regulations for the latter of which are still under development. To date, the International Seabed Authority has approved 31 licenses to explore for seabed minerals, which are located in the Clarion-Clipperton Zone, the North West Pacific, the Mid-Atlantic Ridge, the Rio Grande Rise (South Atlantic), and several areas in the Indian Ocean. No contracts have been issued for the exploration of deep-sea minerals in the South Pacific. While commercially valuable seabed minerals occur on seamounts of the Salas y Gómez and Nazca Ridges, the International Seabed Authority has not yet developed exploration regulations in this region. Thus, this area could be proactively closed to seabed mining without having any impact on this developing industry.

Fishing activities on the high seas surrounding the ridges are managed by two regional fishery management organizations: the Inter-American Tropical Tuna Commission, which manages highly migratory fishery species such as tuna, billfish, and sharks; and the South Pacific Regional Fisheries Management Organisation, which manages non-highly migratory fishery species, such as jack mackerel, giant squid, and orange roughy. Some historical fishing has targeted Chilean jack mackerel, giant squid, tuna, striped bonito, marlin, and swordfish on the ridges. However, today most of the fishing in this region targets pelagic species and is primarily focused on high seas waters outside Peru. For fisheries managed by the South Pacific Regional Fisheries Management Organisation, fishing is virtually nonexistent. The orange roughy fishery has been closed in this region since 2006, and total effort for giant squid and Chilean jack mackerel have collectively accounted for less than one day in eight years. Similarly, catch data for most species of billfishes and sharks have been zero in this region in the last 10 years, with the exception of black marlin, blue marlin, striped marlin, and swordfish. However, low catch rates for these species have cumulatively accounted for only 40 metric tons in the last 10 years. In contrast, tuna fisheries targeting skipjack, bigeye, and yellowfin tuna, are active in the region; however, these activities are strongly localized in the area just outside Peruvian national waters. These activities are all conducted by distant water fishing fleets, as more than 96% of the fishing effort in this region is conducted by vessels flagged by China, Spain, Japan, Taiwan, and the Republic of Korea. Importantly, these tuna fishing fleets are much more successful when operating in areas outside the ridges. Thus, closing the Salas y Gómez and Nazca Ridges to commercial fishing activities would have little or no impact on fishing industries.

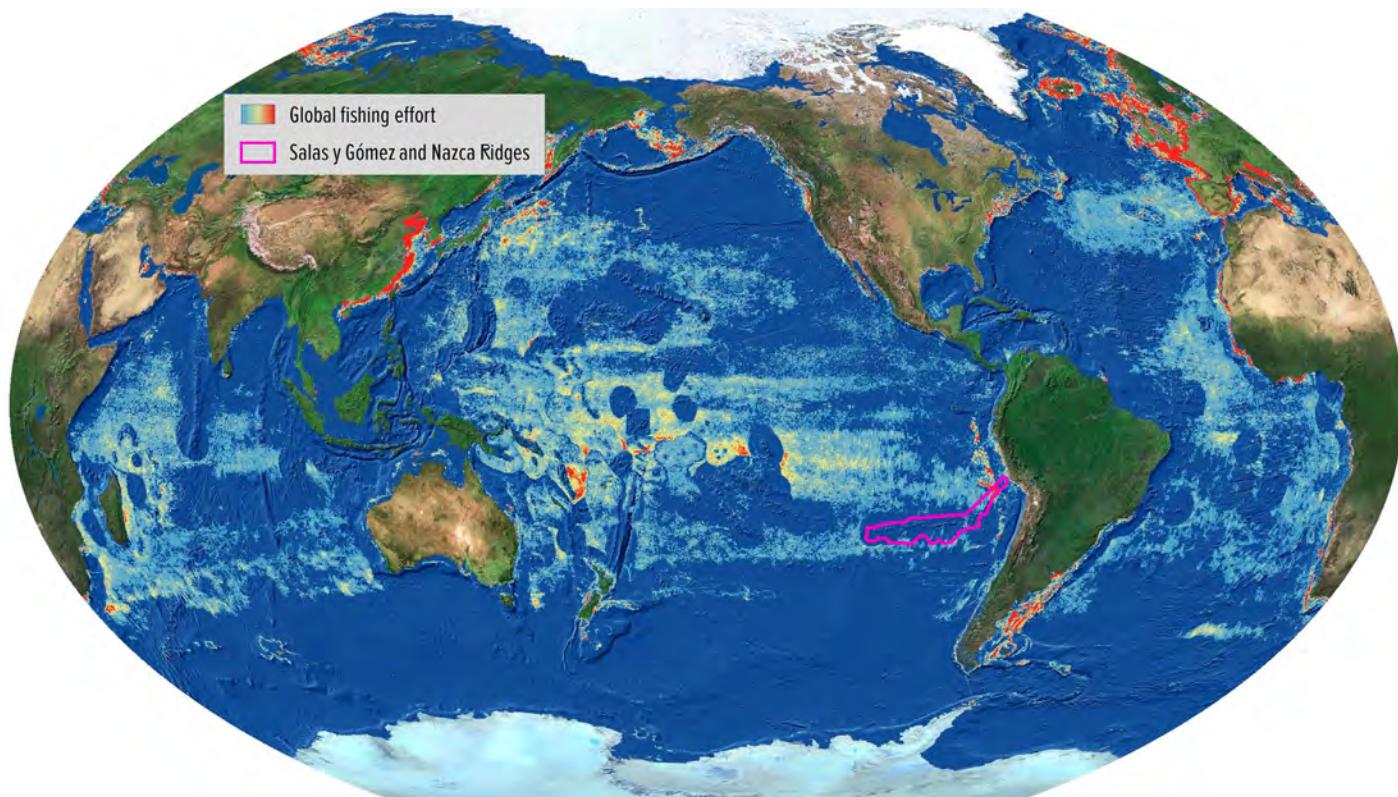
As a result of its unique collection of natural and cultural resources, the region has been acknowledged for its exceptional significance by numerous organizations.



Close to 90% of the world trade is carried out through international shipping<sup>18</sup> on the high seas, activities that are regulated by the International Maritime Organization. International shipping currently does not have a major footprint on most of the Salas y Gómez and Nazca Ridges. With the exception of the northern section of the Nazca Ridge, this region does not intersect major shipping routes.



Mining activities in the international seabed are regulated by the International Seabed Authority, which by 2021 has issued 31 contracts allowing for the exploration of seabed minerals<sup>19</sup> and is in the process of developing regulations that would allow exploitation of these resources. Deep-sea mineral exploration has not yet occurred on the ridges, despite having commercially valuable minerals, thus providing a window of opportunity to proactively protect this area without significantly impacting the developing mining industry.



Commercial fishing activities are minimal to nonexistent on the Salas y Gómez and Nazca Ridges.<sup>20</sup> The only exception are tuna fisheries concentrated just outside Peruvian national waters. However, these fisheries targeting skipjack, bigeye, and yellowfin tuna are much more successful when operating outside this area. Consequently, closing the Salas y Gómez and Nazca Ridges to commercial fishing activities would have minimal to nonexistent impacts on fishing industries.

# CONCLUSION

The Salas y Gómez and Nazca Ridges have been identified as one of the most important places to protect on the high seas by numerous international organizations and scientific studies. These assessments concluded that the ridges are among the most ecologically and culturally important areas on the high seas globally. To date, commercial fishing in this region has been limited, and deep-sea mineral exploration has not occurred, providing a narrow window of opportunity to proactively protect this unique region without significantly impacting industries. Such protection measures would, however, provide this region with a much greater chance to withstand impending impacts from global climate change, which are forecast to be substantial in this region. Additionally, protecting these areas would provide a global example for conservation—one that unites countries with shared interests and ecosystems. Furthermore, it would showcase the global leadership of the countries in this region and accelerate implementation of the high seas treaty for the benefit of present and future generations. With less than 8% of our ocean under protection, the high seas provide our greatest hope to achieve global protection targets and thereby limit the impending impacts of climate change and biodiversity decline.

250 miles

*Close-up of the Nazca Ridge—one of Earth's most dramatic undersea mountain ranges. The underwater geography creates unique biozones that are home to many threatened (and even undiscovered) marine species. The shaded relief visualization was created from an image service stewarded by NOAA in ArcGIS Online. The bright areas popping out in yellow are islands; most of this "landscape" is underwater.*

# NOTES AND DATA SOURCES

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Photos on page 97 courtesy of Rodolphe Holler, Matthias Gorny, Enric Sala, Jeff Yonover, Daniel Wagner, and Maël Iimirizaldu.