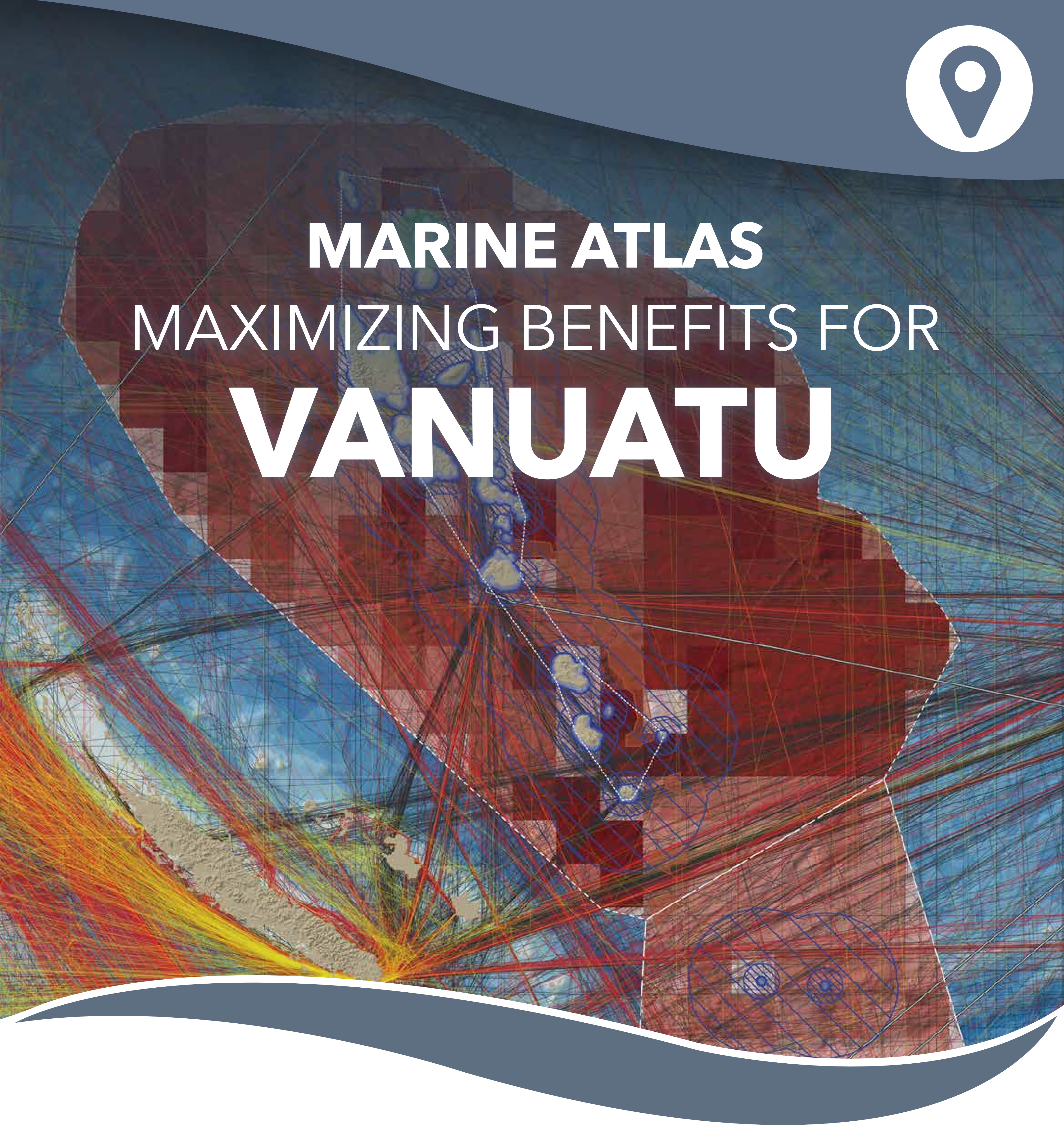
MARINE ATLAS

MAXIMIZING BENEFITS FOR

VANUATU



MACBIO

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MARINE SPATIAL PLANNING

Marine Spatial Planning is an integrated and participatory planning process and tool that seeks to balance ecological, economic, and social objectives, aiming for sustainable marine resource use and prosperous blue economies.

The MACBIO project supports partner countries in collecting and analyzing spatial data on different types of current and future marine resource use, establishing a baseline for national sustainable development planning of oceans.

Aiming for integrated ocean management, marine spatial planning facilitates the sustainable use and conservation of marine and coastal ecosystems and habitats.

This atlas is part of MACBIO's support to its partner countries' marine spatial planning processes. These processes aim to balance uses with the need to effectively manage and protect the rich natural capital upon which those uses rely.

For a digital and interactive version of the Atlas and a copy of all reports and communication material please visit **www.macbio-pacific.info**

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MARINE ATLAS

MAXIMIZING BENEFITS FOR

VANUATU

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2019

MACBIO
Marine and Coastal Biodiversity Management in Pacific Island Countries

SPREP Secretariat of the Pacific Regional Environment Programme

IUCN

giz

On behalf of
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
of the Federal Republic of Germany

GRID ARENDAL

FOREWORD

While the ocean covers more than two thirds of the Earth's surface, the oceanic territory of Vanuatu is 57 times larger than its land territory. With an exclusive economic zone (EEZ) of 680,000 km², Vanuatu is a large ocean state.

This island nation contains many marine ecosystems, from globally significant coral reefs to mangroves, seagrass areas, seamounts and deep-sea trenches supporting at least 769 fish species, including sharks and rays, as well as whales, dolphins and sea turtles. We are committed to conserving this unique marine biodiversity.

Vanuatu's marine ecosystems are worth at least VUV 5.8 billion per year—comparable to the country's total export value. We are strongly committed to sustaining these values to build an equitable and prosperous blue economy.

The country's history, culture, traditions and practices are strongly linked to the ocean and its biodiversity. By sharing and integrating traditional and scientific knowledge, we are navigating towards holistic marine resource management.

Traditionally, Vanuatu's coastal villages manage inshore marine resources. We are striving to work together to sustainably manage all of Vanuatu's coastal marine areas (traditional fishing grounds) for the benefit of empowered and resilient communities.

At the same time, Vanuatu is experiencing the direct effects of climate change on its ocean and island environments.

By strengthening global partnerships, we are proudly taking leadership in climate change policy and global ocean governance. Further, through integrated and participatory planning, we are aiming to balance economic, ecological and social objectives in this EEZ for the benefit of current and future generations.

In doing so, we can maximize benefits from the ocean for Vanuatu, its people and its economy.

This is where the Vanuatu Marine Atlas comes into play. Improvements in research over the years have enabled us to better understand the ocean system and to develop solutions with a sustainable approach. A lot of data have become publicly available, with this atlas compiling over a hundred data sets from countless data providers to make this treasure trove of marine and coastal information accessible and usable for the first time—as maps with narratives, as data layers and as raw data.

In its three chapters, the atlas sets out to illustrate:

What values does the ocean provide to Vanuatu, to support our wealth and well-being?

How should we plan the uses of these ocean values and best address conflicts and threats?

On what levels and in which ways can we manage uses of, and threats to, our marine values?

The atlas can help decision makers from all sectors appreciate the values of marine ecosystems and the importance of spatially planning the uses of these values.

Practitioners can assist these planning processes by using the accompanying data layers and raw data in their Geographic Information Systems.

While the atlas provides the best data currently publicly available, information about Vanuatu's waters is constantly increasing. Therefore, the atlas is an open invitation to use, modify, combine and update the maps and underlying data.

Only by involving all stakeholders in a nationwide Marine Spatial Planning (MSP) process can we truly maximize benefits for Vanuatu.

The e-copy and interactive version of the Vanuatu Marine Atlas are available here: **http://macbio-pacific.info/marine-atlas/vanuatu**

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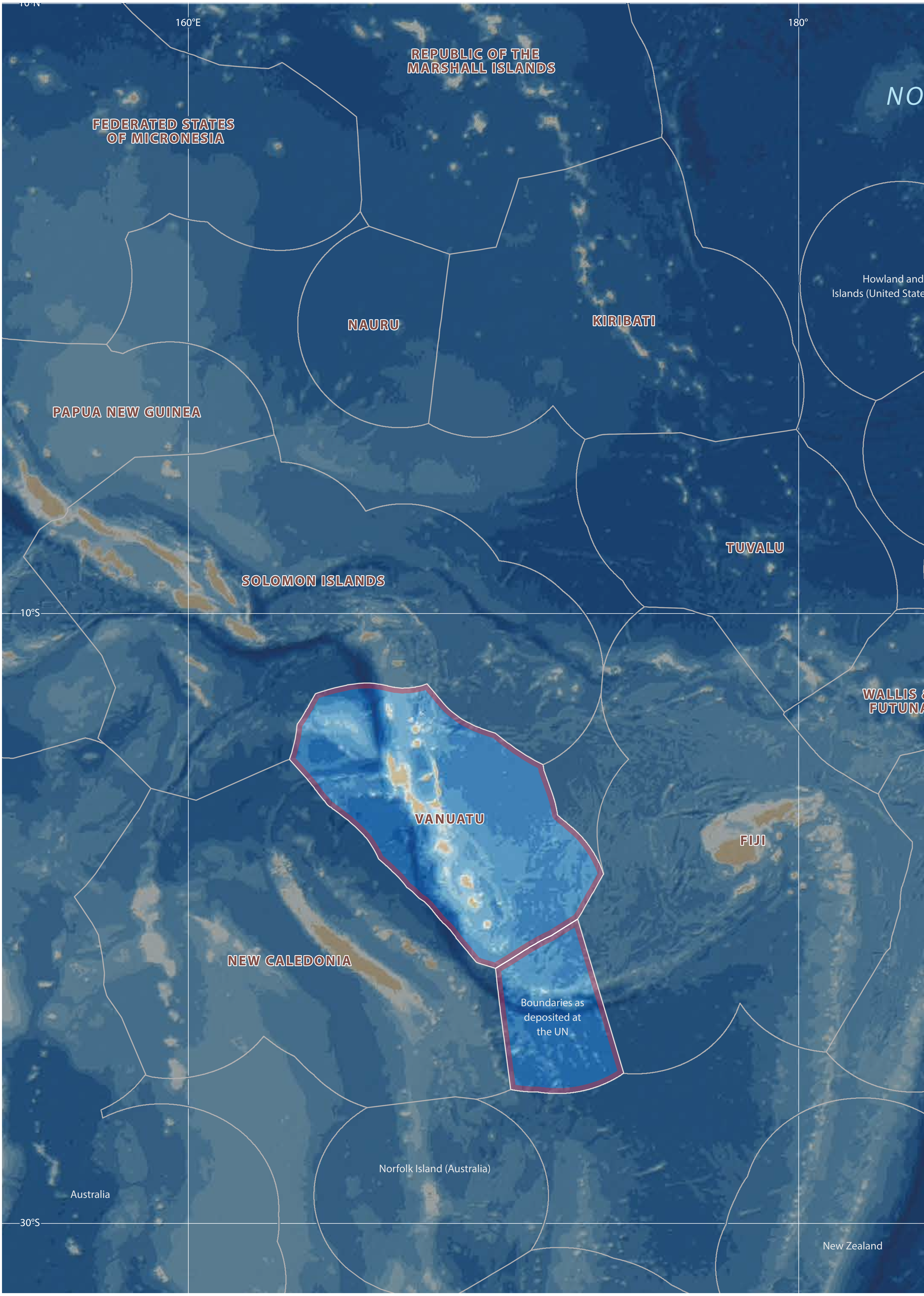
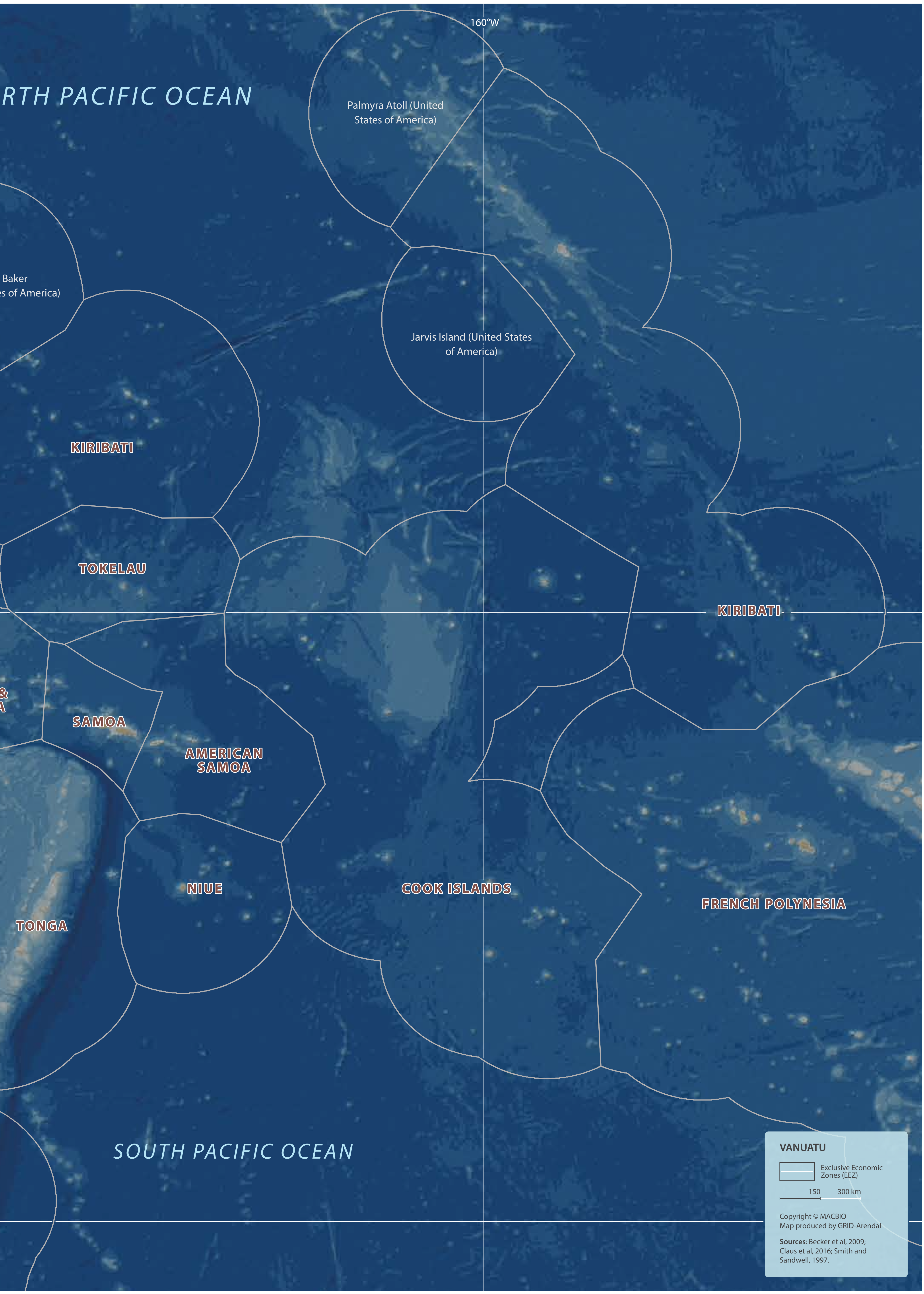
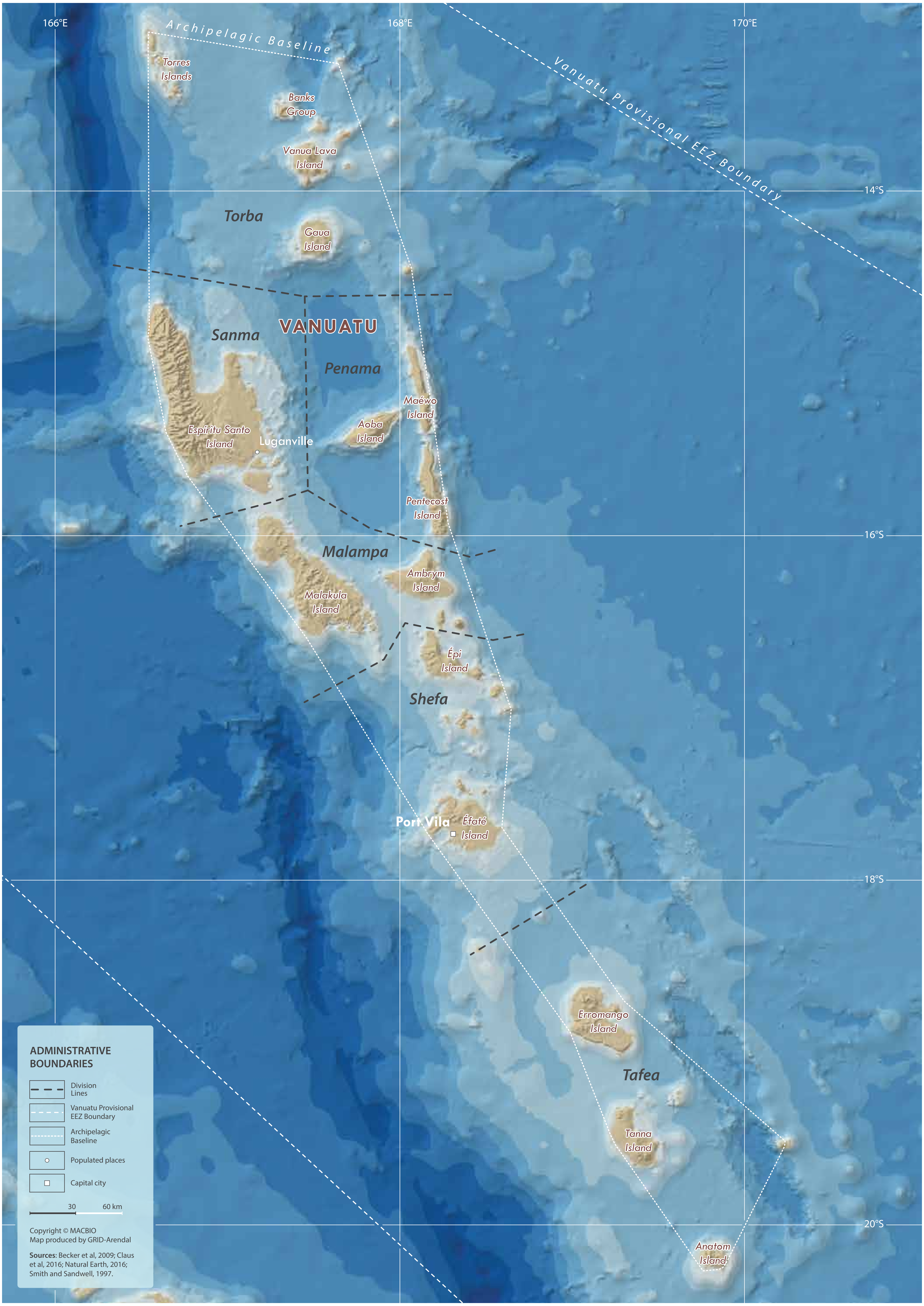


160°E
180°
REPUBLIC OF THE MARSHALL ISLANDS
FEDERATED STATES OF MICRONESIA
NAURU
KIRIBATI
Howland and
Islands (United State
PAPUA NEW GUINEA
TUVALU
SOLOMON ISLANDS
10°S
WALLIS &
FUTUNA
VANUATU
FIJI
NEW CALEDONIA
Boundaries as deposited at the UN
Norfolk Island (Australia)
Australia
30°S
New Zealand


160°W
RTH PACIFIC OCEAN
Palmyra Atoll (United States of America)
Baker
s of America)
Jarvis Island (United States of America)
KIRIBATI
TOKELAU
KIRIBATI
SAMOA
AMERICAN SAMOA
NIUE
COOK ISLANDS
FRENCH POLYNESIA
TONGA
SOUTH PACIFIC OCEAN
VANUATU
Exclusive Economic Zones (EEZ)
150
300 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; Claus et al, 2016; Smith and Sandwell, 1997.


166°E
168°E
170°E
14°S
16°S
18°S
20°S
Archipelagic Baseline
Vanuatu Provisional EEZ Boundary
Torres Islands
Banks Group
Vanua Lava Island
Torba
Gaua Island
VANUATU
Sanma
Penama
Maéwo Island
Aoba Island
Espiritu Santo Island
Luganville
Pentecost Island
Malampa
Ambrym Island
Malakula Island
Épi Island
Shefa
Port Vila
Éfaté Island
Erromango Island
Tafea
Tanna Island
Anatom Island
ADMINISTRATIVE BOUNDARIES
Division Lines
Vanuatu Provisional EEZ Boundary
Archipelagic Baseline
Populated places
Capital city
30
60 km
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Sources: Becker et al, 2009; Claus et al, 2016; Natural Earth, 2016; Smith and Sandwell, 1997.

A LARGE OCEAN STATE: ADMINISTRATION

Vanuatu's ocean provides a wealth of services to the people of Vanuatu, and beyond. The ocean and its resources govern daily life, livelihoods, food security, culture, economy and climate.

The South Pacific is a sea of islands (see previous map). While these Pacific Island countries are often referred to as small island states, the map shows that they are in fact large ocean states, with Vanuatu's marine area covering 680,000 km^2.

Vanuatu's waters are home to countless environmental, social, cultural and economic values and to more than 80 islands, with a total land area of around 12,200 km^2. This makes Vanuatu a relatively large island nation, in terms of land area, compared with some of its neighbours. Each of Vanuatu's islands have slight variations in vegetation, geography, lifestyle, language and traditions, but they are all closely connected to the sea.

The islands now known as Vanuatu have been inhabited since 500 B.C.E. European sailors first visited the archipelago in the seventeenth century and Captain James Cook named it New Hebrides in 1774. French and English Christian missionaries, as well as some traders and planters, settled on various parts of New Hebrides, and the islands became an Anglo-French condominium ruled by separate French and British administrations. The archipelago gained independence as Vanuatu in 1980 before being divided into six provinces in 1994, each with their own provincial councils. There were more than 270,400 people living in Vanuatu in 2016.

Vanuatu is sometimes divided into northern, central and southern regions. The northern region contains the Torba, Sanma and Penama Provinces. Torba Province contains the Torres and Banks Island chains; Sanma Province contains the islands of Espíritu Santo and Malo; and Penama Province contains the islands of Pentecost, Ambae and Maewo. The northern division is home to some of the most remote and, consequently, pristine areas in Vanuatu. Luganville on Espíritu Santo is Vanuatu's second largest city. It has a population of more than 16,300 people, is a hub for tourism and shipping, and is serviced by Vanuatu's second largest airport – Santo-Pekoa International Airport.

The central division contains the Shefa and Malampa Provinces. Shefa Province contains the Shepherd Islands and Efaté, which is the largest island in Shefa and the most populous in Vanuatu. Efaté had a population of nearly 66,000 in 2009, with more than 66 per cent of those living in the nation's capital and economic nucleus, Port Vila, where Vanuatu's main airport (Bauerfield International Airport) is located. Malampa Province includes the islands of Malekula, Ambrym and Paama. Malampa is one of the most culturally and linguistically diverse provinces in Vanuatu, while Malekula and the nearby Maskelyne Islands are home to some of Vanuatu's most extensive seagrass meadows and dugong herds. The island of Ambrym is a large, basaltic volcano—one of the most active inhabited volcanoes in the world.

The southern division contains a single province, Tafea Province. Its name derives from its five main islands—Tanna, Aneityum, Futuna, Erromango and Aniwa. Tanna is the most populous island with around 29,000 people. It is also one of the most popular tourist destinations in Vanuatu, largely due to Mount Yasur, which is one of the most accessible and spectacular active volcanoes in the world.

The national government of Vanuatu has three distinct and independent arms—the Legislature, the Executive and the Judiciary. The role of ocean governance under this structure is explained further in the chapter "Vanuatu's commitment to marine conservation". The Legislature of Vanuatu also involves the National Council of Chiefs (the Malvatumauri). This formal advisory body of elected chiefs was established under the Constitution of the Republic of Vanuatu. Members are elected by their fellow chiefs from various Island Councils of Chiefs and Urban Councils of Chiefs. The Malvatumauri advises government on all matters concerning Ni-Vanuatu culture, Kastom (traditional culture in Melanesia) and language.

Special rights

An exclusive economic zone (EEZ) is a sea zone that extends up to 200 nautical miles (nmi) from a country's baseline. Vanuatu's EEZ, prescribed by the United Nations Convention on the Law of the Sea (UNCLOS), gives Vanuatu special rights regarding the exploration and use of marine resources below the surface of the sea. The territorial sea, within 12 nmi from the baseline, is regarded as the sovereign territory of Vanuatu in which it has full authority.

Local government in Vanuatu is comprised of provincial and municipal councils. Provincial councils are primarily responsible for rural areas. Virtually independent of the provincial councils are three municipal councils, which serve the more densely populated areas of Port Vila, Luganville and Lenakel. Each provincial or municipal council has a central administration. Areas under the jurisdiction of provincial councils have local areas headed by an area secretary who reports to the secretary-general of their respective provincial council.

In all its diversity, from its administrative to geographic and biological features, Vanuatu is indeed a large ocean state.

Vanuatu Parliament, Port Vila

VALUING

Marine ecosystems in Vanuatu provide significant benefits to society, including food security and livelihoods for the people of Vanuatu, the Pacific and around the world. Limited land resources and the dispersed and isolated nature of communities make the Ni-Vanuatu people heavily reliant upon the benefits of marine ecosystems.

These benefits, or ecosystem services, include a broad range of connections between the environment and human well-being and can be divided into four categories.

1. Provisioning services are products obtained from ecosystems (e.g. fish).
2. Regulating services are benefits obtained from the regulation of ecosystem processes (e.g. coastal protection).
3. Cultural services are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences (e.g. traditional fishing and traditional marine resource management systems).
4. Supporting services are necessary for the production of all other ecosystem services (e.g. nutrient cycling, biodiversity).

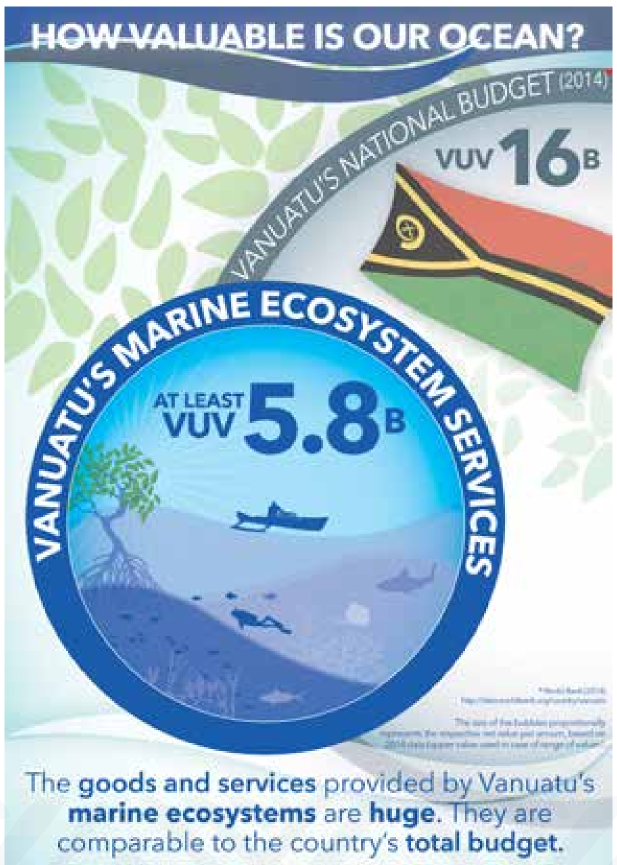
The maps in this chapter showcase, firstly, the biophysical prerequisites underpinning the rich values and benefits provided by marine ecosystems. These range from the volcanism at the depths of the ocean that formed the islands and atolls that now provide a home to many, to the prevailing flow of currents and the role of plankton in the ocean's life cycle, among many others.

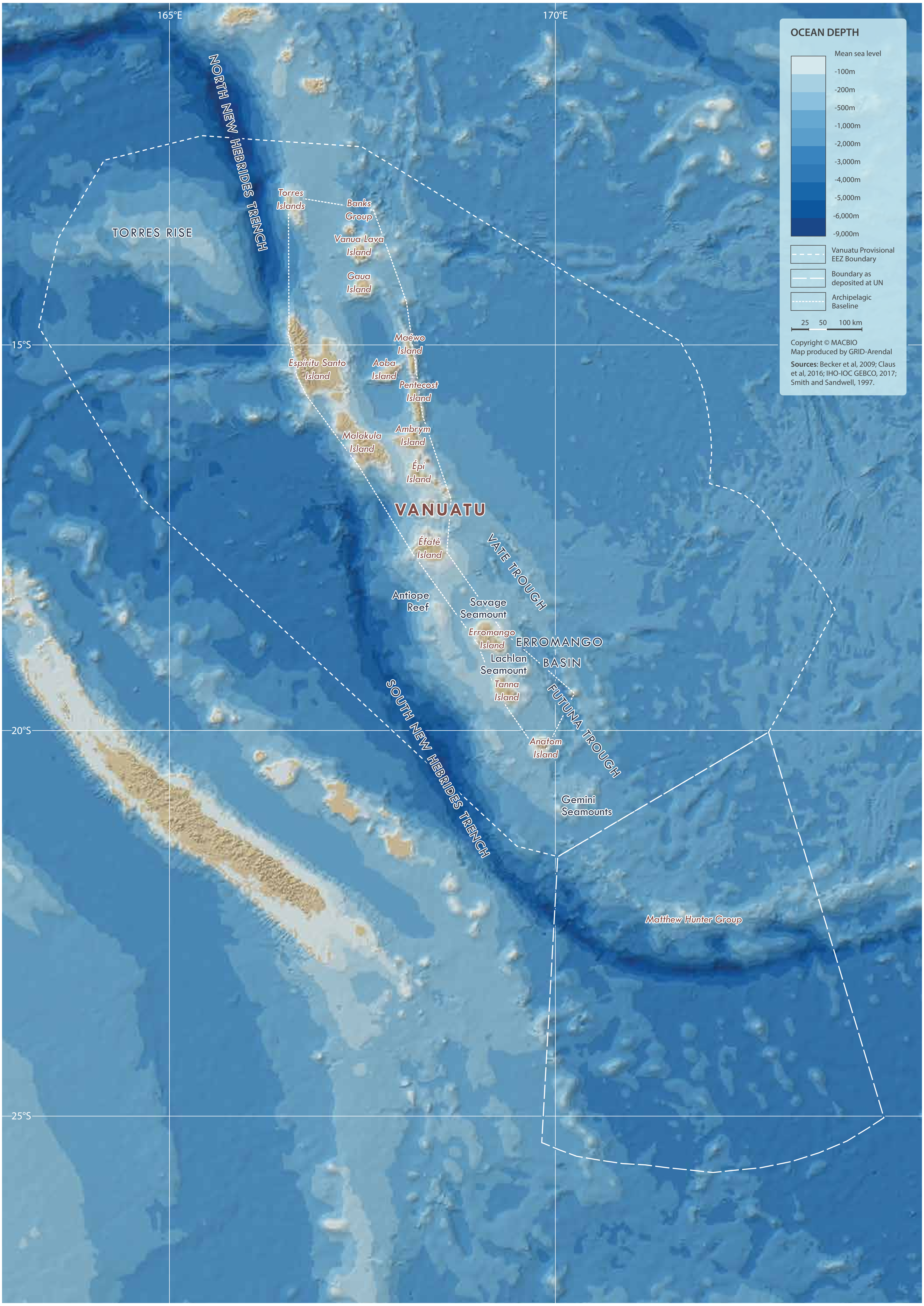
Based on the combinations of biophysical conditions, the ocean provides a home to many different species, from coral-grazing parrotfish on the reefs to the strange and mysterious animals of the deep. These and many other species and the unique marine ecosystems on which they rely are featured in the maps to follow.

Appreciating the rich diversity of marine ecosystems helps in understanding their importance to Vanuatu. Quantifying the benefits of marine ecosystems in the Pacific makes it easier to highlight and support appropriate use and sustainable management decisions. Despite the fact that more than 95 per cent of Pacific Island territory is ocean, the human benefits derived from marine and coastal ecosystems are often overlooked. For example, ecosystem services are usually not visible in business transactions or national economic accounts in Pacific Island countries. Assessments of the economic value of marine ecosystem services to Pacific Islanders can help make society and decision makers alike aware of their importance.

Vanuatu has therefore undertaken economic assessments of its marine and coastal ecosystem services, and is working on integrating the results into national policies and development planning. These economic values are also featured in the maps of this atlas, to help maximize benefits for Vanuatu.

For further reading, please see **http://macbio-pacific.info/marine-ecosystem-service-valuation/**




165°E
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15°S
20°S
25°S
OCEAN DEPTH
Mean sea level
-100m
-200m
-500m
-1,000m
-2,000m
-3,000m
-4,000m
-5,000m
-6,000m
-9,000m
Vanuatu Provisional EEZ Boundary
Boundary as deposited at UN
Archipelagic Baseline
25 50 100 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; Claus et al, 2016; IHO-IOC GEBCO, 2017; Smith and Sandwell, 1997.
NORTH NEW HEBRIDES TRENCH
TORRES RISE
Torres Islands
Banks Group
Vanua Lava Island
Gaua Island
Maéwo Island
Espiritu Santo Island
Aoba Island
Pentecost Island
Ambrym Island
Malakula Island
Épi Island
VANUATU
Éfaté Island
VATE TROUGH
Antiope Reef
Savage Seamount
Erromango Island
ERROMANGO BASIN
Lachlan Seamount
Tanna Island
FUTUNA TROUGH
Anatom Island
Gemini Seamounts
SOUTH NEW HEBRIDES TRENCH
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SUPPORTING VALUES

STILL WATERS RUN DEEP: OCEAN DEPTH

It is important to understand how ocean depth influences both the distribution of life below the surface and the management of human activities along the coasts of Vanuatu.

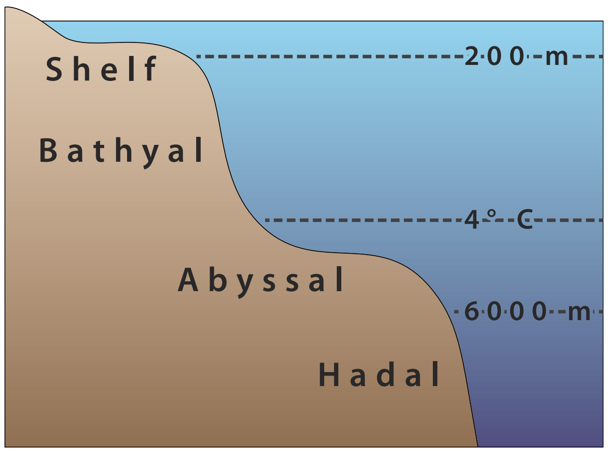
Vulnerable Vanuatu

Vanuatu is one of the most vulnerable countries in the world to natural hazards. The World Risk Report 2012 identified Vanuatu as having the highest natural risk exposure, while the Natural Hazards Risk Atlas 2015 identified Port Vila as the world's most exposed city. Vanuatu is at risk from a range of natural disasters including volcanoes, earthquakes, tsunamis and cyclones. For example, many of the earthquakes that commonly occur in Vanuatu (see chapter "Smoke underwater, fire in the sea") are above seven on the Richter scale, and at least 19 earthquakes are known to have generated tsunamis since 1950 . Since 1849, there have been 55 tidal waves classified as tsunamis in Vanuatu, with several of these resulting in loss of life and damage to coastal infrastructure. Knowledge about the depth of the ocean can help in understanding how tsunamis will propagate as they approach the coast and where they are likely to have the biggest impact.

Standing on Vanuatu's shore and gazing into an alluring turquoise lagoon, it is hard to imagine how deep the ocean truly is. Approximately 1 per cent of Vanuatu's national waters are shallower than 200 metres, while the other 99 per cent are up to 8,000 metres deep (in the North New Hebrides Trench). Changes in ocean depth, also known as bathymetry, affect many other dimensions of human life and natural phenomena.

Bathymetric maps were originally produced to guide ships safely through reefs and shallow passages (see chapters "Full speed ahead" and "One world, one ocean"). Since ocean depth is correlated with other physical variables such as light availability and pressure, it is also a determining factor in the distribution of biological communities, either those living on the bottom of the sea (benthic), close to the bottom (demersal) or in the water column (pelagic).

In addition, bathymetry significantly affects the path of tsunamis, which travel as shallow-water waves across the ocean. As a tsunami moves, it is influenced by the sea floor, even in the deepest parts of the ocean. Bathymetry influences the energy, direction and timing of a tsunami. As a ridge or seamount may redirect the path of a tsunami towards coastal areas, the position of such features must be taken into account by tsunami simulation and warning systems to assess the risk of disaster.

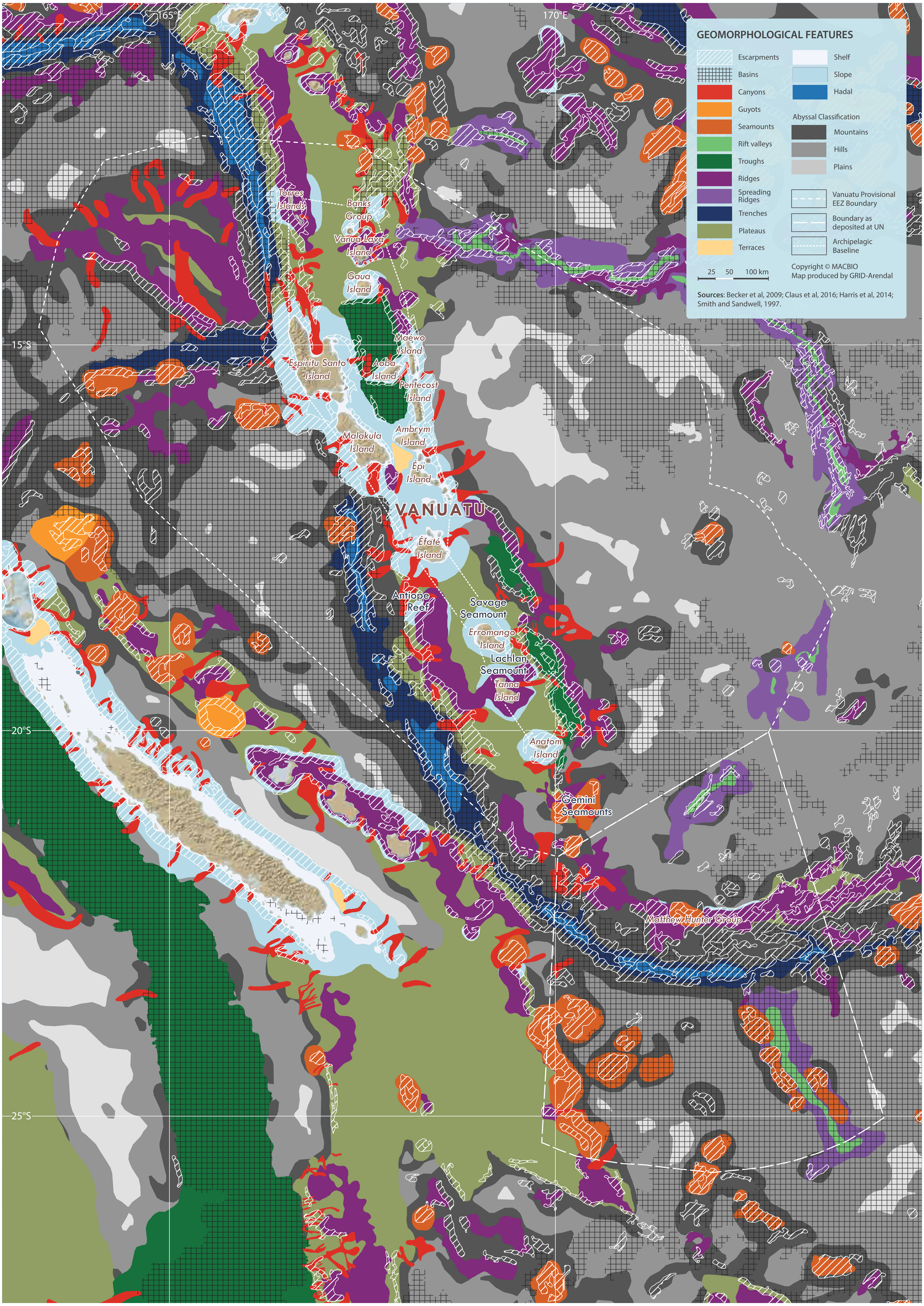


As the bathymetry map shows, Vanuatu's main islands are located on a raised plateau less than 2,000 metres deep, which runs in a north–south direction and extends beyond Vanuatu's EEZ to the north. To the immediate west of this plateau lies the South New Hebrides Trench and the North New Hebrides Trench. These two trenches have depths greater than 6,000 metres, with the North New Hebrides Trench reaching a maximum depth of over 8,800 metres within Vanuatu's EEZ.

In the north-west of Vanuatu's EEZ is a raised area of sea floor known as Torres Rise. This area rises several thousand metres above the surrounding sea floor, with its shallowest point only around 600 metres deep. To the west of the main Vanuatu islands is an area of abyssal sea floor between 4,000 and 5,000 metres deep. On the eastern side of the islands are several troughs and basins, including the Vate and Futuna Troughs and the Erromango Basin, which are separated from the adjacent abyssal area by areas of slightly raised sea floor. The abyssal plains to the east of the main islands are shallower than those to the west, with depths generally between 3,000 and 3,500 metres, but some areas shallower than 2,000 metres.

The sea floor can be divided into several different zones based on depth and temperature: the sublittoral (or shelf) zone, the bathyal zone, the abyssal zone and the hadal zone. The sublittoral zone encompasses the sea floor from the coast to the shelf break—the point at which the sea floor rapidly drops away. The bathyal zone extends from the shelf break to around 2,000 metres depth.

The lower limit of the bathyal zone is defined as the depth at which the temperature reaches 4°C. This zone is typically dark and thus not conducive to photosynthesis. The abyssal zone extends from the bathyal zone to around 6,000 metres. The hadal zone, the deepest zone, encompasses the deep-sea floor typically only found in ocean trenches, such as the North and South New Hebrides Trenches.


GEOMORPHOLOGICAL FEATURES
Escarpments
Basins
Canyons
Guyots
Seamounts
Rift valleys
Troughs
Ridges
Spreading Ridges
Trenches
Plateaus
Terraces
Shelf
Slope
Hadal
Abyssal Classification
Mountains
Hills
Plains
Vanuatu Provisional EEZ Boundary
Boundary as deposited at UN
Archipelagic Baseline
25 50 100 km
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Map produced by GRID-Arendal
Sources: Becker et al, 2009; Claus et al, 2016; Harris et al, 2014; Smith and Sandwell, 1997.
165°E
170°E
15°S
20°S
25°S
Torres Islands
Banks Group
Vanua Lava Island
Gaua Island
Maewo Island
Espiritu Santo Island
Aoba Island
Pentecost Island
Ambrym Island
Malakula Island
Epi Island
VANUATU
Efate Island
Antiope Reef
Savage Seamount
Erromango Island
Lachlan Seamount
Tanna Island
Anatom Island
Gemini Seamounts
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VOYAGE TO THE BOTTOM OF THE SEA: GEOMORPHOLOGY

Vanuatu's sea floor is rich in physical features that affect the distribution of biodiversity, fishing grounds, deep-sea minerals and even tsunamis and underwater landslides.

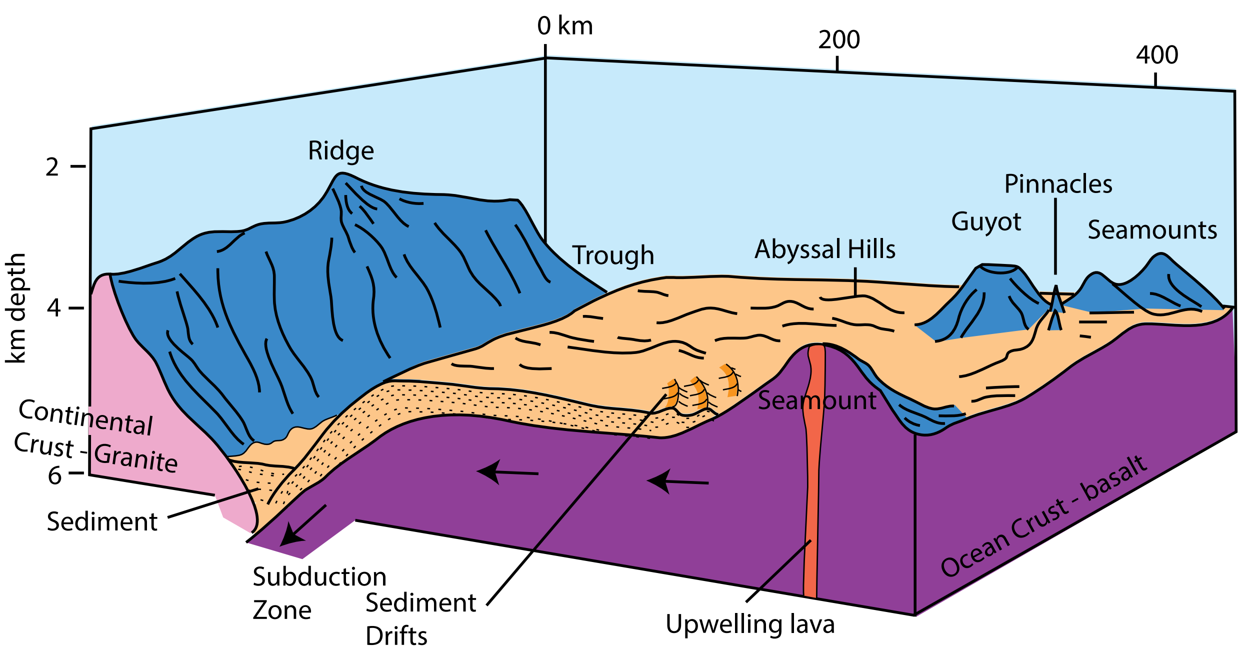
The nation's seascape is as diverse underwater as its landscape above, including towering underwater mountains (seamounts) that attract migratory species from hundreds of kilometres away, and deep-sea canyons that carry nutrient-rich water from the deep ocean to the shallow areas. Geomorphology (the study and classification of these physical features) reveals both the geological origin of the features as well their shape (morphology), size, location and slope.

The geomorphology of the sea floor influences the way the ocean moves (see also chapter "Go with the flow") and the distribution of water temperature and salinity (see also chapter "Hotter and higher"). These factors affect the distribution of biological communities, resulting in different biological communities being associated with different types of sea-floor geomorphology. For example, seamounts generally have higher biodiversity and a very different suite of species to the adjacent, deeper abyssal areas.

Similarly, different economic resources are often associated with different features. Many fisheries operate on certain features, such as the shelf, slope or over seamounts, based on where their target species occur. In Vanuatu, important deep-sea snapper is mostly found on outer reef slopes and around seamounts (mainly in depths from 100 to 400 metres; see chapter "Fishing in the dark"). Furthermore, different types of deep-sea mineral deposits are also associated with different features, such as the sea-floor massive sulfide deposits found along mid-ocean ridges (see chapter "Underwater Wild West").

1999 tsunami

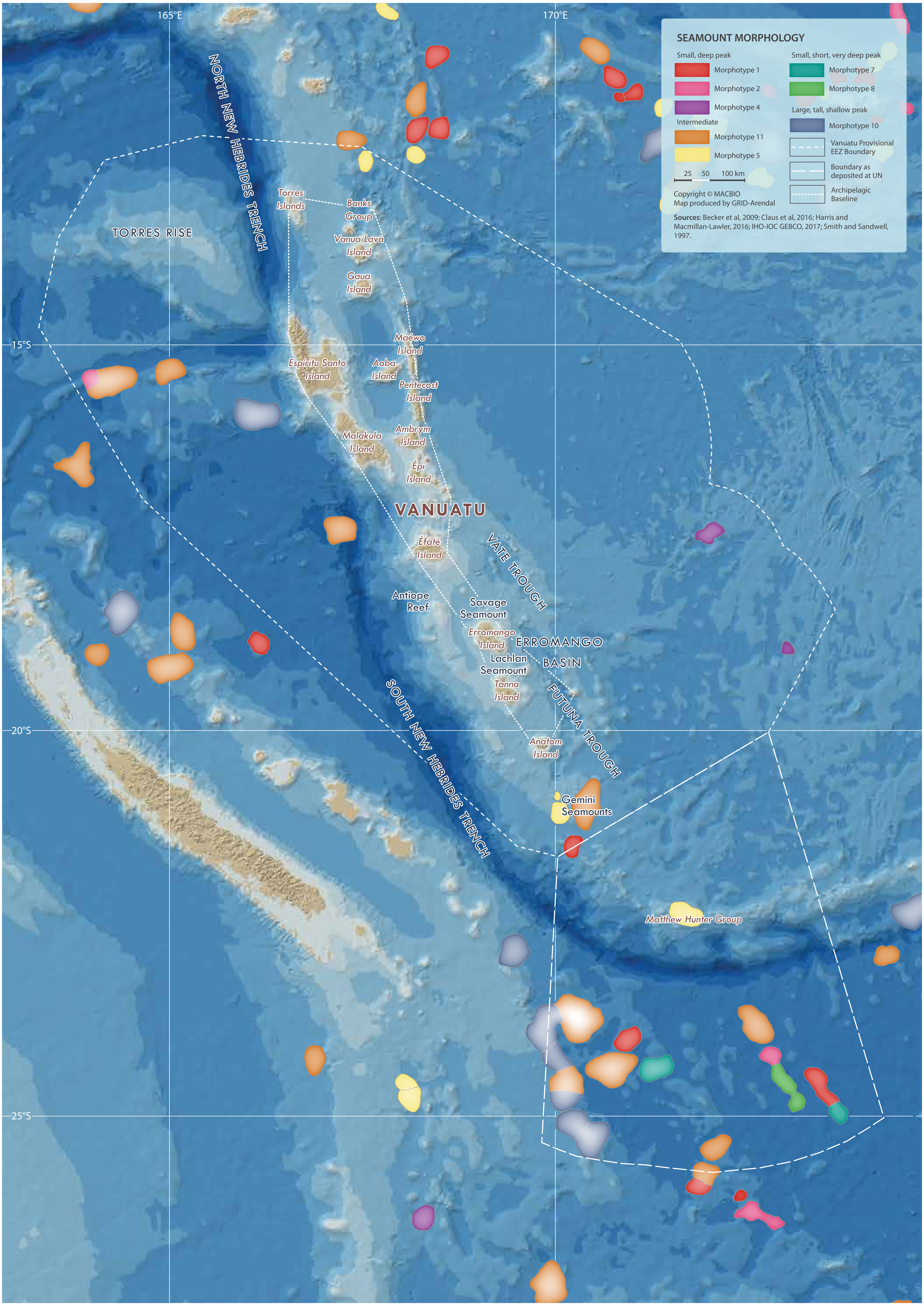
On 26 November 1999, central Vanuatu was struck by a 7.5 magnitude earthquake, generating a tsunami that killed five people and caused major damage to nearshore infrastructure. The tsunami is thought to have been generated by a submarine landslide in the Selwyn Strait (between Pentecost and Ambrym), highlighting the impact that these out-of-sight structures can have on life on land.



Vanuatu's waters harbour 18 different geomorphic features, which are presented in this map and associated figures. The distribution of geomorphology reflects many of the patterns observed in the bathymetry map, as geomorphology is primarily a classification of the shape of the sea-floor features. The main Vanuatu islands are perched on a raised plateau, surrounded by an area of generally narrow shelf, which supports extensive coral reefs. Ninety-three canyons incise the slope adjacent to the islands. These canyons are characterized as areas of high biodiversity due to their steep sides featuring rocky slopes, strong currents and enhanced access to food. They also act as a conduit between the deep-sea floor and the shallow shelf areas.

By Pacific Island standards, Vanuatu has relatively few seamounts, with only 13 found within its EEZ. Seamounts are large—over 1,000 metres high—conical mountains of volcanic origin, while guyots are seamounts with flattened tops (see also chapter "Underwater mountains"). There are also numerous ridges and chains of abyssal mountains rising up from the sea floor. On all these features, areas of steep sea floor (escarpments) are likely to contain hard substrate which, coupled with increased current flow, create ideal habitats for filter-feeding organisms such as sponges and cold-water corals.

Vanuatu's waters also have several deep ocean trenches, reaching depths greater than 6,000 metres. These trenches include the North and South New Hebrides Trenches, which reach over 8,000 metres at their deepest points. These deep ocean trenches are likely to support a suite of unique species.



SEAMOUNT MORPHOLOGY
Small, deep peak
Morphotype 1
Morphotype 2
Morphotype 4
Intermediate
Morphotype 11
Morphotype 5
Small, short, very deep peak
Morphotype 7
Morphotype 8
Large, tall, shallow peak
Morphotype 10
Vanuatu Provisional EEZ Boundary
Boundary as deposited at UN
Archipelagic Baseline
25 50 100 km
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Sources: Becker et al, 2009; Claus et al, 2016; Harris and Macmillan-Lawler, 2016; IHO-IOC GEBCO, 2017; Smith and Sandwell, 1997.
165°E
170°E
15°S
20°S
25°S
TORRES RISE
NORTH NEW HEBRIDES TRENCH
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Savage Seamount
Erromango Island
ERROMANGO BASIN
Lachlan Seamount
Tanna Island
FUTUNA TROUGH
Anatom Island
SOUTH NEW HEBRIDES TRENCH
Gemini Seamounts
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UNDER WATER MOUNTAINS: SEAMOUNT MORPHOLOGY

Vanuatu has 13 known submarine mountains (commonly known as seamounts). Seamounts enhance productivity and act as biodiversity hotspots, attracting pelagic predators and migratory species such as whales, sharks and tuna. Vulnerable to the impacts of fishing and mineral resource extraction, seamounts are becoming increasingly threatened.

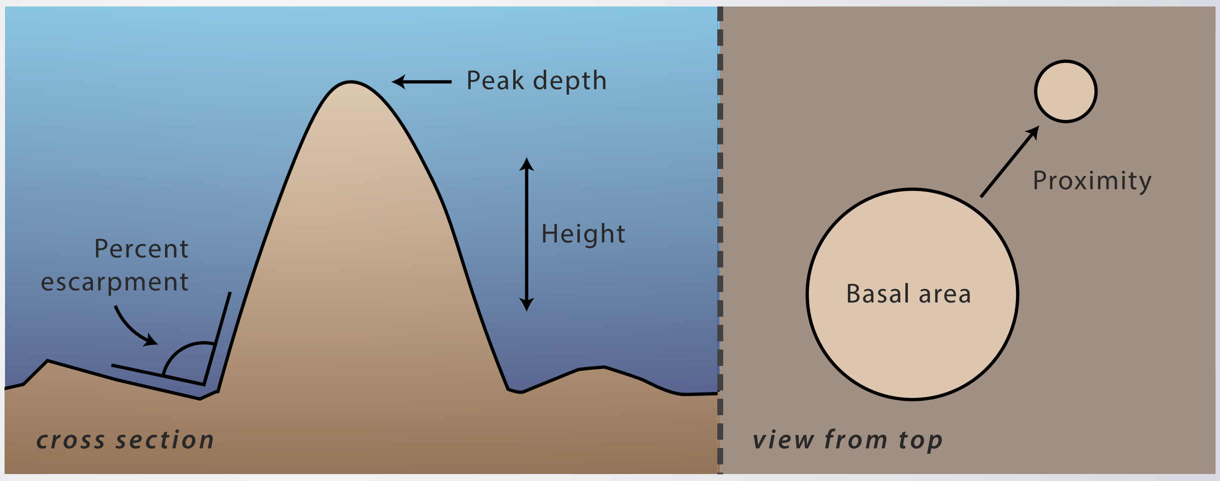
Seamount morphotypes found in Vanuatu's waters

Large and tall seamounts with a shallow peak – *Morphotypes 9 and 10*.

Medium-height seamounts with moderately deep peak depths – *Morphotypes 3, 5, and 11*.

Small seamounts with a deep peak – *Morphotypes 1, 2, and 4*.

Small and short seamounts with a very deep peak – *Morphotypes 7 and 8*.



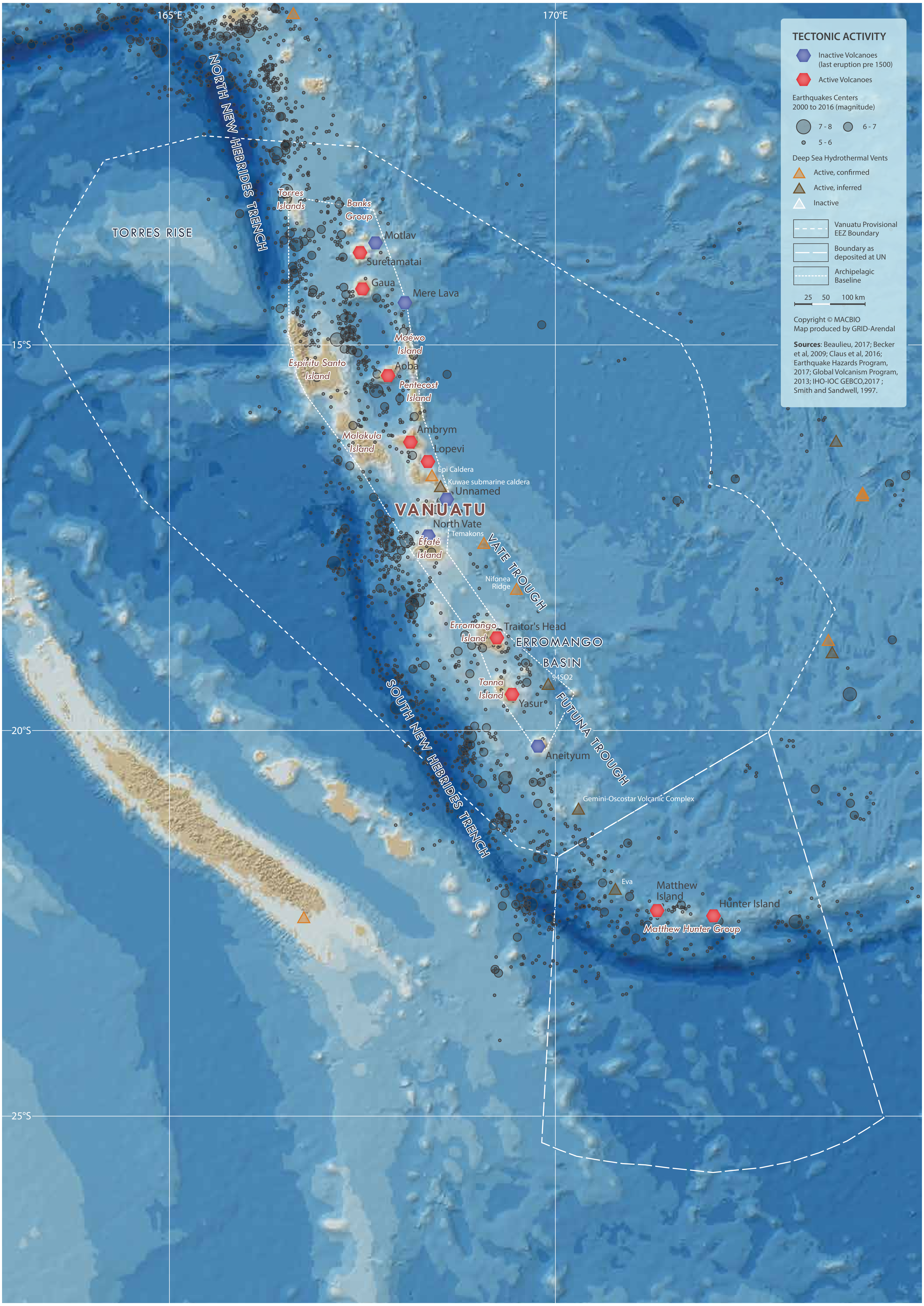
Seamounts are important features of the ocean landscape, providing a range of resources and benefits to Vanuatu. Many have elevated biodiversity compared to surrounding deep-sea areas. They can therefore function as stepping stones, allowing hard substrate organisms to disperse from one underwater island to another, thereby expanding their range across ocean basins. Seamounts are also key locations for many fisheries (see also chapter "Fishing in the dark") and are known to contain valuable mineral resources (see also chapter "Underwater Wild West"). As demand for these resources continues to grow, the need for focused management is increasing. The adverse impacts of mismanaged mineral resources extraction have the potential to severely impact seamount ecosystems.

Just like mountains above the sea, seamounts differ in size, height, slope, depth and proximity, with different combinations of these factors recognized as different morphotypes likely to have different biodiversity characteristics (Macmillan-Lawler and Harris, 2015). The map presents a classification of seamounts identified by Harris et al. (2014) into morphotypes within Vanuatu's waters. Physical variations such as depth, slope and proximity are known to be important factors for determining the structure of biological communities. For example, many species are confined to a specific depth range (Rex et al., 1999; Clark et al., 2010). Therefore both the minimum depth (peak depth) and the depth range (height) are likely to be strongly linked to the biodiversity of a given seamount.

Slope is also an important control in the structure of seamount communities, with steep slopes, which are current-swept, likely to support different communities to flat areas, which may be sediment-dominated (Clark et al., 2010). Seamounts in close proximity commonly share similar suites of species with one another and also with nearby areas of the continental margin.

The 13 seamounts in Vanuatu's waters represent six of the 11 global morphotypes. Understanding this distribution of the different morphotypes is important for prioritizing management actions. For example, seamounts with shallow peak depths that fall within the Epipelagic (photic) zone are hotspots for biodiversity. In Vanuatu's case, this includes a single large, tall and shallow peaked seamount (morphotype 10) to the west of the main islands. Over half the seamounts in Vanuatu's waters are part of the intermediate seamount group (morphotypes 5 and 11). These are small to medium in size, with medium heights and a gradation in peak depths from moderately shallow through to moderately deep.

Those with moderately shallow peak depths are more likely to be exposed to fishing impacts than deeper-peaked ones. The remaining seamount morphotypes are characterized by deep to very deep peak depths, so are less likely to be targeted directly by fishing. However, with the push to explore seabed mineral resources, seamounts—with their associated cobalt-rich crusts—are likely to come under increasing pressure.


165°E
170°E
15°S
20°S
25°S
TECTONIC ACTIVITY
Inactive Volcanoes (last eruption pre 1500)
Active Volcanoes
Earthquakes Centers 2000 to 2016 (magnitude)
7 - 8
6 - 7
5 - 6
Deep Sea Hydrothermal Vents
Active, confirmed
Active, inferred
Inactive
Vanuatu Provisional EEZ Boundary
Boundary as deposited at UN
Archipelagic Baseline
25 50 100 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Beaulieu, 2017; Becker et al, 2009; Claus et al, 2016; Earthquake Hazards Program, 2017; Global Volcanism Program, 2013; IHO-IOC GEBCO,2017 ; Smith and Sandwell, 1997.
NORTH NEW HEBRIDES TRENCH
TORRES RISE
Torres Islands
Banks Group
Motlav
Suretamatai
Gaua
Mere Lava
Maéwo Island
Espiritu Santo Island
Aoba
Pentecost Island
Ambrym
Malakula Island
Lopevi
Epi Caldera
Kuwae submarine caldera
Unnamed
VANUATU
North Vate
Temakons
Efaté Island
VATE TROUGH
Nifonea Ridge
Erromango Island
Traitor's Head
ERROMANGO BASIN
94SO2
Tanna Island
Yasur
FUTUNA TROUGH
Aneityum
SOUTH NEW HEBRIDES TRENCH
Gemini-Oscostar Volcanic Complex
Eva
Matthew Island
Hunter Island
Matthew Hunter Group

SMOKE UNDER WATER, FIRE IN THE SEA: TECTONIC ACTIVITY

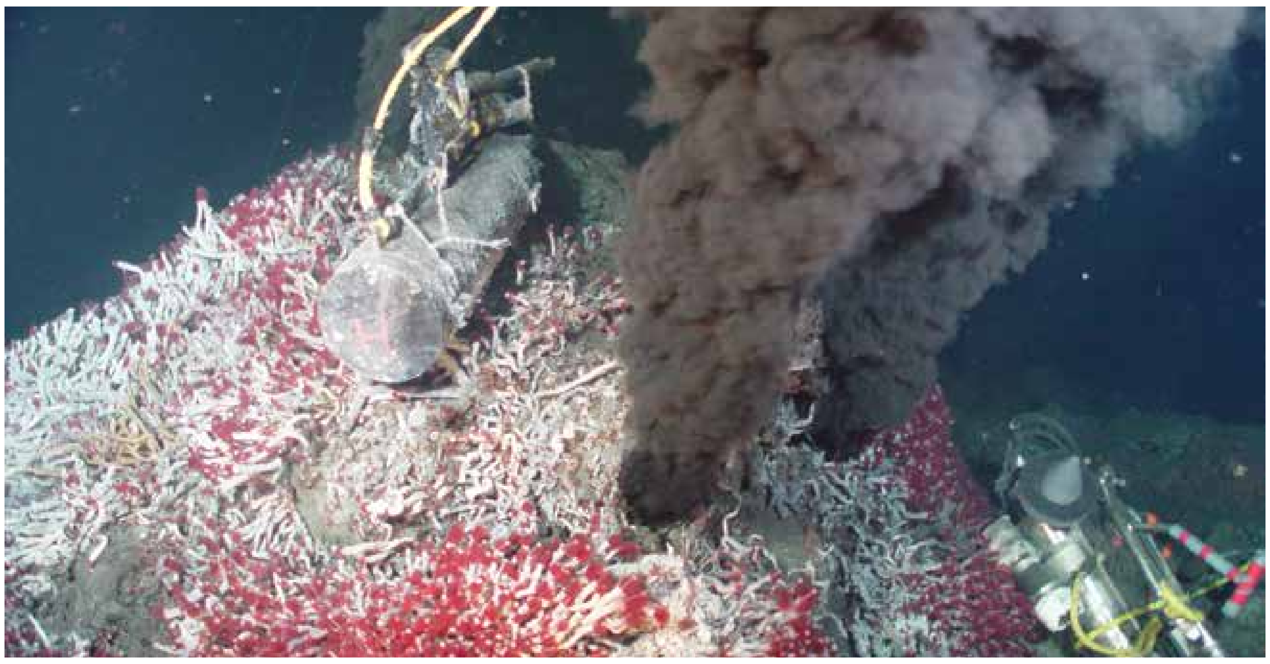
Vanuatu is located on the Pacific Ring of Fire, a highly active tectonic zone. Above water, this tectonic activity means that Vanuatu is under threat from possible earthquakes and tsunamis. Underwater, the tectonic activity produces magnificent underwater volcanoes and hydrothermal vents which, in turn, spawn unique complex but fragile ecosystems that contribute to Vanuatu's rich marine biodiversity. These features also deposit minerals, making them an attractive, if conflicting, target for deep-sea mining exploration and extraction.

Vanuatu's islands are young in geological terms and formed during four main periods of volcanic activity. While Maewo and Pentecost formed between 4 and 11 million years ago, Futuna and Mere Lava formed between 2 and 5 million years ago, and all remaining islands formed within the last 3 million years. It is believed that at least 20 per cent of Vanuatu's land mass formed within the last 200,000 years (Ministry of Lands and Natural Resources, 2014). These island-building processes continue, driven by plate tectonics. Vanuatu sits atop the Pacific Plate and has an active subduction zone to its west. This zone runs from Matthew and Hunter Islands in the south to the Tinakula volcano in the Solomon Islands to the north.

This tectonic activity shapes not only the islands of Vanuatu but also its undersea landscape. In these tectonically active areas of sea floor, features known as hydrothermal vents are often found. These are fissures in the Earth's surface from which geothermally heated water (up to 450°C) escapes. Under the sea, hydrothermal vents may develop black or white smokers. These roughly cylindrical chimney structures can reach heights of 60 metres, forming from either black or white minerals that are dissolved in the vent fluid.

The black and white smokers and their mineral-rich warm water attract many organisms and have unique biodiversity. Chemosynthetic bacteria and archaea, both single-celled organisms, form the base of a food chain supporting diverse organisms, including giant tube worms, clams, limpets and shrimp. Some scientists even suggest that life on Earth may have originated around hydrothermal vents. Along with their unique biodiversity, these vents are also a hotspot of minerals. Massive sulfides (including gold and copper), cobalt and rare earth metals occur in high concentrations in vent systems, which are increasingly being explored for their mineral resources (see also chapter "Underwater Wild West").

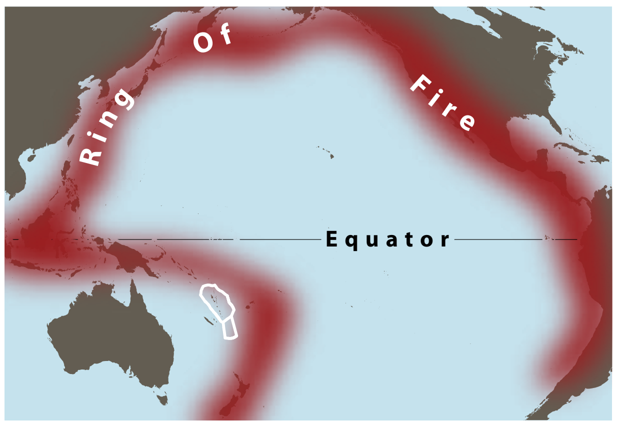
The Pacific region is one of the most tectonically active regions in the world. The Pacific Ring of Fire, stretching clockwise from New Zealand all the way around to South America, is home to around 90 per cent of the world's earthquakes. Pacific Island countries such as Vanuatu are part of the Pacific tectonic plate, thus subject to volcanic and seismic activity. The activity affecting Vanuatu is primarily centred on the eastern side of the large ocean trenches—the North and South New Hebrides Trenches. This means that many earthquakes are focused either near or directly on the main islands of Vanuatu. Numerous magnitude 6 earthquakes or above have occurred in this region, with several of the larger ones measuring over magnitude 8. Earthquakes can, under certain circumstances, generate tsunamis. For example, in 1999 a 7.5 magnitude earthquake near central Vanuatu generated a tsunami that killed five people and caused major damage to coastal infrastructure (see also chapter "Voyage to the bottom of the sea").



The Sully Vent in the north-eastern Pacific Ocean provides an example of the diverse communities around hydrothermal vents.

What's happening underwater?

In the late 1990s, a team of Australian scientists had a hunch that something special was happening in the waters off Vanuatu. They were proved right in September 2001, when an expedition led by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) discovered Vanuatu's first ever hydrothermal vent—a hot, powerful underwater spring that produces new, often valuable, minerals and supports one of the most remarkable ecosystems in the natural world.



As the map shows, Vanuatu's waters harbour not only numerous deep-sea hydrothermal vents, but also more than 20 volcanoes. At least five of these (Mt Yasur, Ambrym, Lopevi, Mt Garet and Manaro) are still active. Mt Yasur on Tanna Island is one of the most active and accessible volcanoes in the world, typically erupting several times an hour, making it one of Vanuatu's primary tourist attractions. To the north, the lesser known Manaro volcano may be becoming more active. After lying dormant for 120 years, its activity increased significantly in 2005, resulting in the displacement of half the island's population. In September 2017, a full evacuation of Ambae was undertaken as Manaro reached level 4 on the Vanuatu Volcanic Alert Scale, posing the threat of a very large eruption.

Tectonic activity is key to the creation of the Pacific Islands and atolls, many of which sit upon active or inactive volcanoes (see also chapter "Underwater mountains").

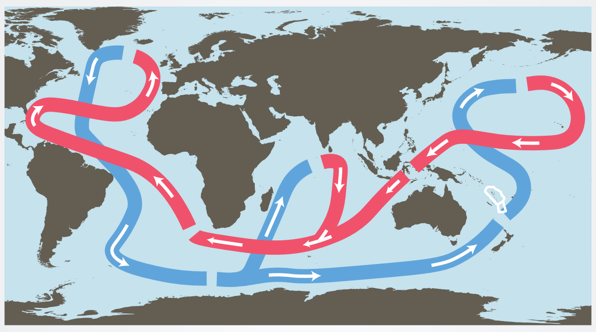
Many Anomuran crabs attached to a hydrothermal chimney at 2,397 metres depth.

GO WITH THE FLOW: SALINITY AND SURFACE CURRENTS

Ocean currents are driven by a combination of thermohaline currents (thermo = temperature; haline = salinity) in the deep ocean and wind-driven currents on the surface. Ocean currents affect climate, the distribution of biodiversity and the productivity of the seas, particularly during extreme El Niño years.

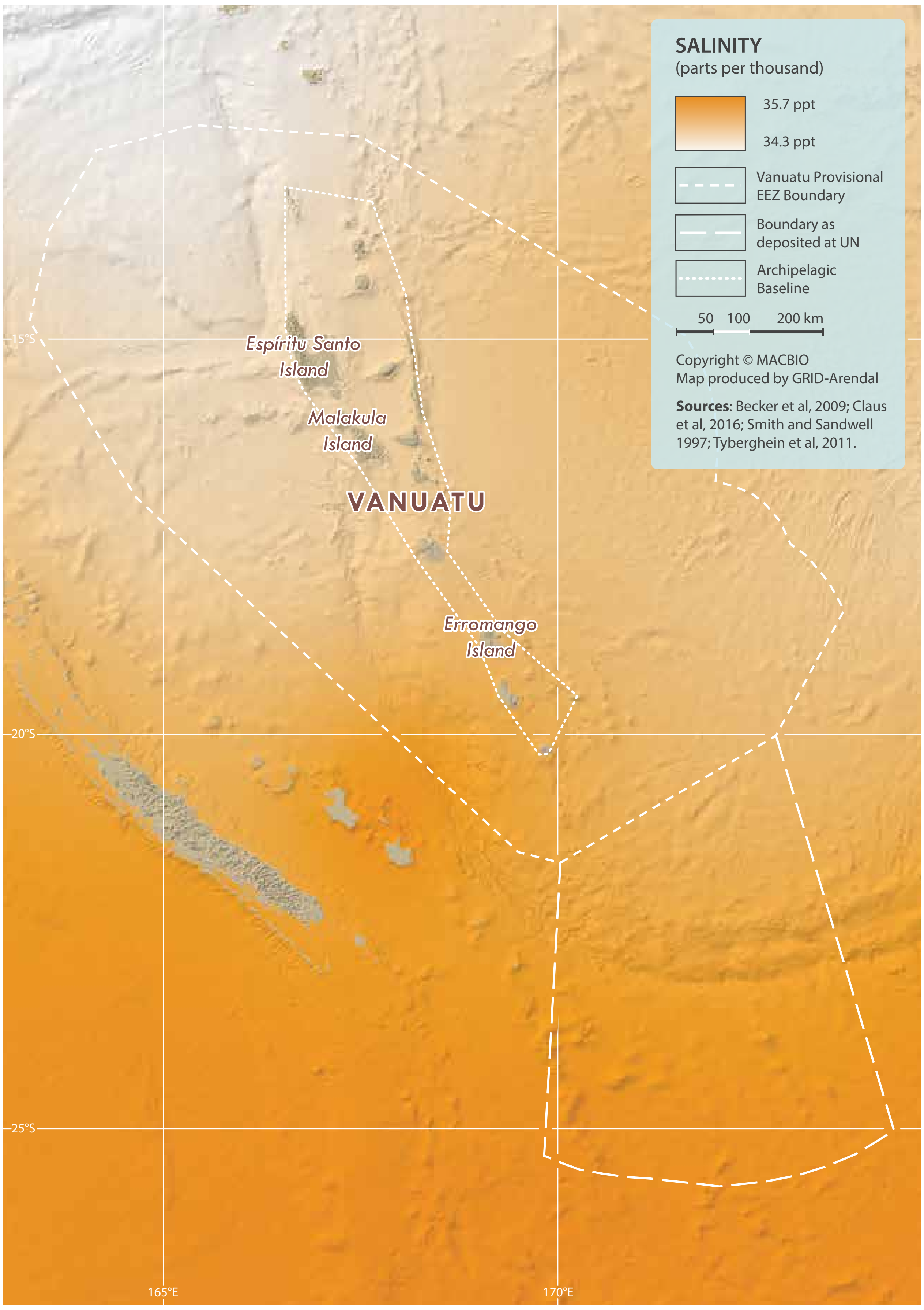
A trip around the world

It took Magellan more than three years (from 1519 to 1522) to be the first person to circumnavigate the Earth. The current record for this trip is 67 hours by plane and 50 days by sailboat. Water in the ocean is not in such a rush, taking much more time on its journey on the global ocean conveyor belt. Within this belt, the ocean is constantly in motion due to a combination of thermohaline currents in the deep, and wind-driven currents at the surface. Cold, salty water is dense and sinks to the bottom of the ocean, while warm water is less dense and remains at the surface.



The global ocean conveyor belt starts in the Norwegian Sea, where warm water from the Gulf Stream heats the atmosphere in the cold northern latitudes. This loss of heat to the atmosphere makes the water cooler and denser, causing it to sink to the bottom of the ocean. As more warm water is transported north, the cooler water sinks and moves south to make room for the incoming warm water. This cold bottom water flows south of the equator all the way down to Antarctica. Eventually, the cold bottom water returns to the surface through mixing and wind-driven upwelling, continuing the conveyor belt that encircles the globe (Rahmstorf, 2003), crossing the Pacific from east to west.

A full circle takes about 1,000 years. No rush at all!

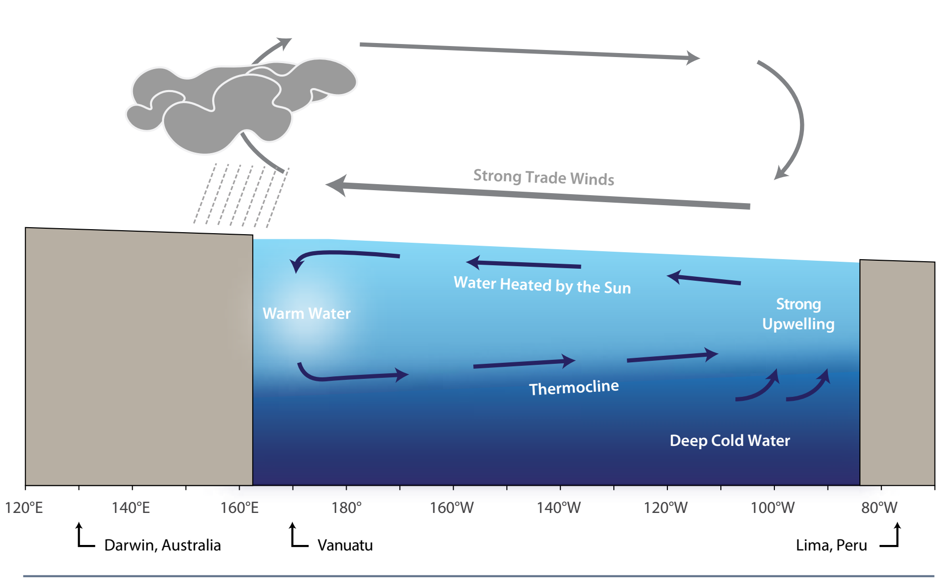


Salinity also greatly influences the distribution of marine life (Lüning, 1990; Gogina and Zettler, 2010). Salinity is the concentration of dissolved salt, measured as the number of grams of salt per kilogram of seawater. The salinity of the global oceans is generally around 35, with a maximum salinity of over 40 found in the Mediterranean and Red Seas, and a minimum salinity of less than five in parts of the Baltic and Black Seas. Generally, salinity is higher in the warmer low-latitude waters and lower in the cooler high-latitude waters. The salinity of Vanuatu's waters has a narrow range—between 34.5 in the northern part of the EEZ and 35.4 in the southern part of the EEZ. Salinity also varies by depth, with a strong salinity gradient forming in the upper layers, known as a halocline.

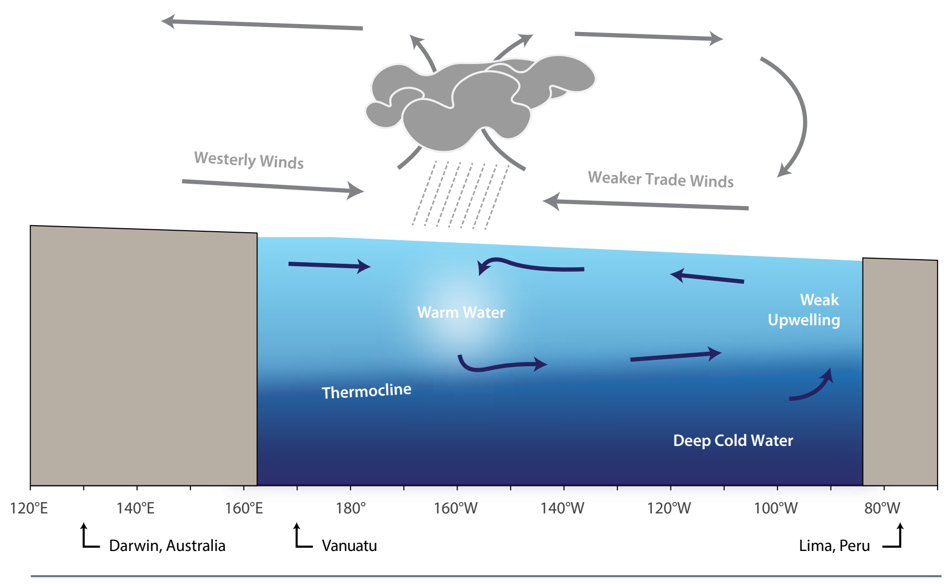
In contrast to the deep-sea currents, Vanuatu's surface currents are primarily driven by wind. Their direction is determined by wind direction, Coriolis forces from the Earth's rotation, and the position of landforms that interact with the currents. Surface wind-driven currents generate upwelling in conjunction with landforms, creating vertical water currents. The westward flowing South Equatorial Current, which is strongest north of Espíritu Santo, is driven by the south-east trade winds. Its general westward flow is broken into zonal jets (Webb, 2000), which are thought to be the result of a number of processes, including the structure of the mid-Pacific winds, which induce mid-basin bands of stronger flow, curl dipoles behind the islands, and the blocking of currents by the islands (Kessler and Gourdeau, 2006). Webb (2000) showed that the extensive shallow topography around Fiji, New Caledonia and Vanuatu resulted in the formation of prominent zonal jets at the northern and southern extremities of the islands. South of the South Equatorial Current, the currents weaken and turn into a generally southerly flowing current.

Both kinds of currents—the thermohaline ones in the deep water and the wind-driven one on the surface—are very important to Vanuatu. On their journey, water masses transport two things around the globe and through Vanuatu's waters.

Normal conditions



El Niño conditions



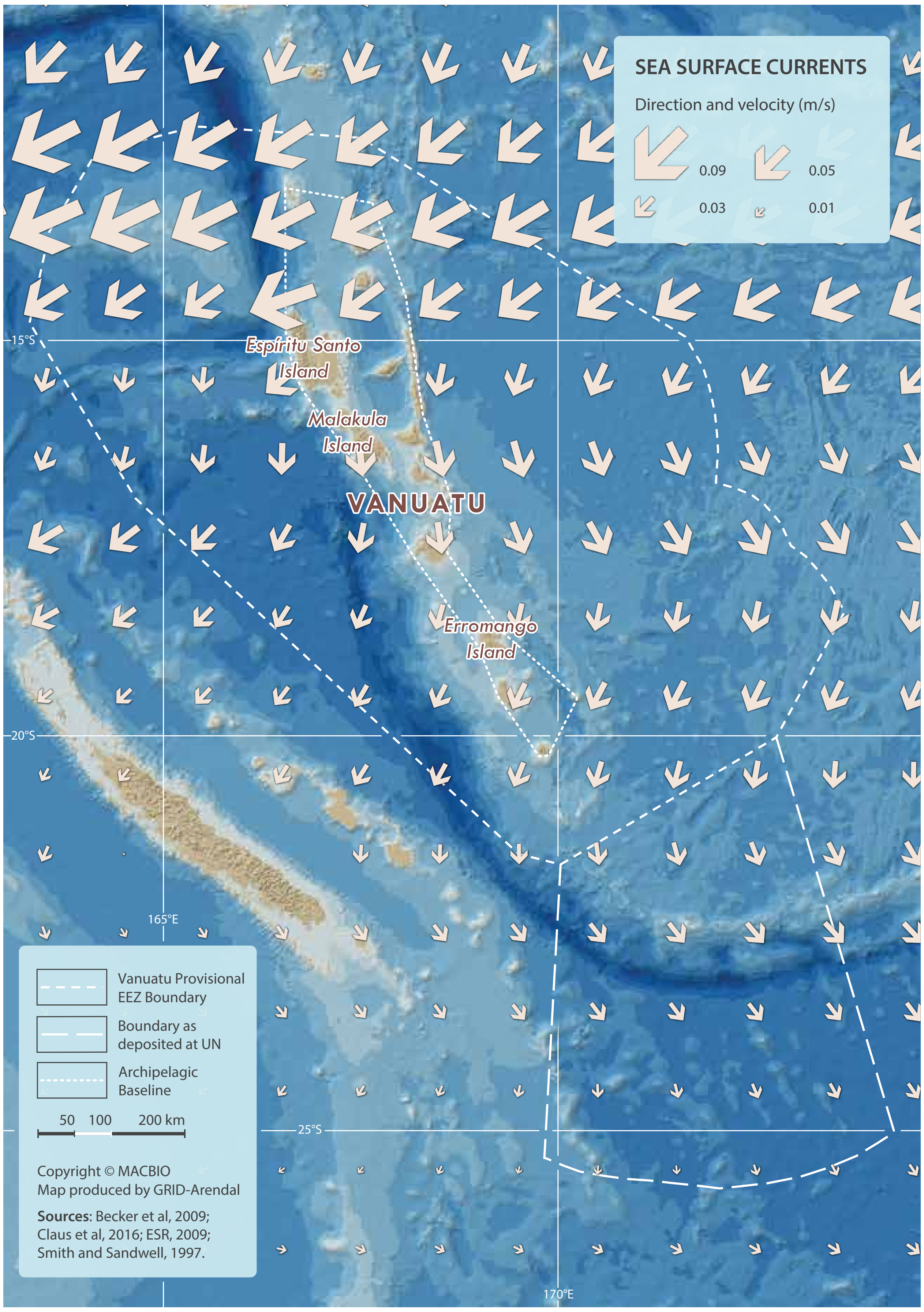
Firstly, matter such as solids, dissolved substances and gases are carried by the currents, including salt, larvae (see also chapter "Travellers or homebodies"), plastics and oil (see also chapters "Plastic oceans" and "Full speed ahead"). Secondly, currents transport energy in the form of heat. Currents therefore have a significant impact on the global climate.

El Niño is an example of the big impact that regional climate variability related to ocean currents has on Vanuatu (see graphs and chapter "Hotter and higher"). Normally, strong trade winds blow from east to west across the Pacific Ocean around the equator. As the winds push warm surface water from South America west towards Asia and Australia, cold water wells up from below in the east to take its place along the west coast of South America. This creates a temperature disparity across the Pacific, which also keeps the trade winds blowing. The accumulation of warm water in the west heats the air, causing it to rise and create unstable weather, making the western Pacific region warm and rainy. Cool, drier air is usually found on the eastern side of the Pacific.

In an El Niño year, the trade winds weaken or break down. The warm water that is normally pushed towards the western Pacific washes back across, piling up on the east side of the Pacific from California to Chile, causing rain and storms and increasing the risk of cyclone formation over the tropical Pacific Ocean (Climate Prediction Center, 2005) (see also chapter "Stormy times").

On the other side, the western Pacific experiences particularly dry conditions. The periods 1997–1998 and 2014–2016 witnessed some of the most extreme events on record in the region. Between 2015 and 2017, Vanuatu experienced its worst and most sustained drought in decades. Many of the worst affected areas were also those severely hit by Cyclone Pam, itself one of the worst natural disasters in the history of Vanuatu. Throughout this period, a food security crisis loomed that saw many communities struggle to survive, with young children the most acutely affected. Moreover, El Niño contributes to an increase in global temperatures. In the particularly hot year of 2015, El Niño was responsible for about 10 per cent of the temperature rise. In turn, rising global and ocean temperatures may intensify El Niño (Cai et al., 2014).

In summary, sea currents driven by wind, heat and salinity influence not only Vanuatu's marine biodiversity, but also its rainfall patterns and temperature on land.

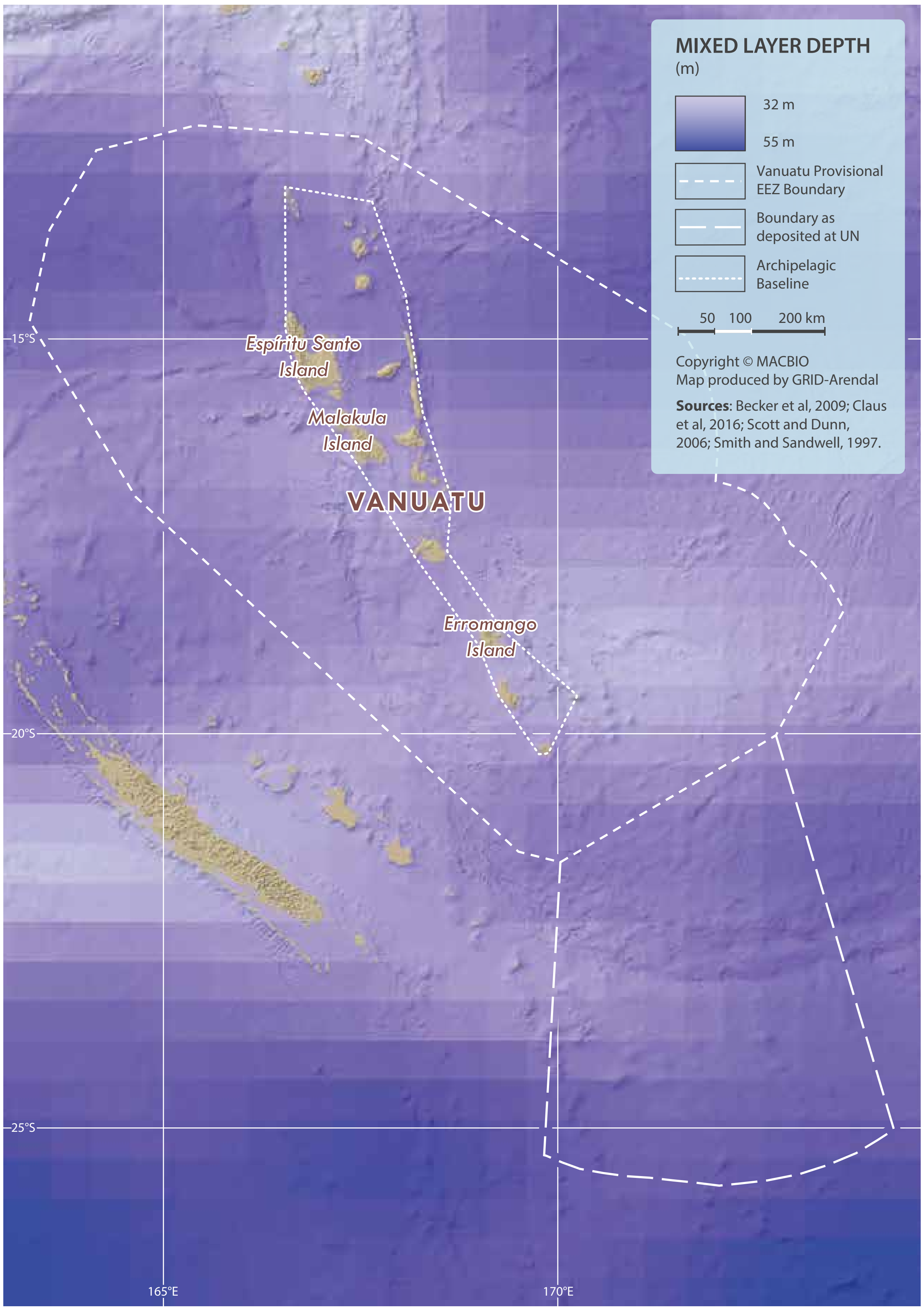


STIR IT UP: MIXED LAYER DEPTH

Vanuatu's waters are stirred by winds and heat exchange. How deep this disturbance goes influences both the climate and the marine food chain.

The waters surrounding Vanuatu are often choppy and turbulent, creating a 'mixed layer' in the upper portion of sea surface where active air–sea exchanges cause the water to mix and become vertically uniform in temperature and salinity, and thus density.

The mixed layer plays an important role in the physical climate, acting as a heat store and helping regulate global temperatures (see also chapter "Hotter and higher"). This is because water has a greater capacity to store heat compared to air: the top 2.5 metres of the ocean holds as much heat as the entire atmosphere above it. This helps the ocean buffer global temperatures, as the heat required to change a mixed layer of 25 metres by 1°C would be sufficient to raise the temperature of the atmosphere by 10°C. The depth of the mixed layer is thus very important for determining the temperature range in Vanuatu's waters and coastal regions.



In addition, the heat stored within the oceanic mixed layer provides a heat source that drives global variability, including El Niño (see also chapter "Go with the flow").

The mixed layer also has a strong influence on marine life, as it determines the average level of light available to marine organisms. In Vanuatu and elsewhere in the tropics, the shallow mixed layer tends to be nutrient-poor, with nanoplankton and picoplankton supported by the rapid recycling of nutrients (e.g. Jeffrey and Hallegraeff, 1990; see also chapters "Soak up the sun" and "Travellers or homebodies"). In very deep mixed layers, the tiny marine plants known as phytoplankton are unable to get enough light to maintain their metabolism. This affects primary productivity in Vanuatu's waters which, in turn, impacts the food chain. Mixed layer depth can vary seasonally, with consequential impacts on primary productivity. This is especially prominent in high latitudes, where changes in the mixed layer depth result in spring blooms.

The depth of the mixed layer in Vanuatu's waters ranges from 33 metres to a maximum of 43 metres, with a mean depth of around 38 metres. The shallowest mixed layer depths correspond to the sheltered areas to the immediate south and east of the main islands. The deepest mixed layer depths are found to the north of the main islands—an area that corresponds to the strongest sea surface currents from the South Equatorial Current. Globally, mixed layer depths range from 4 metres to nearly 200 metres depth. The deepest mixed layer depths are generally found in the sub-Antarctic regions and the high latitudes of the North Atlantic.

PUMP IT: PARTICULATE ORGANIC CARBON FLUX

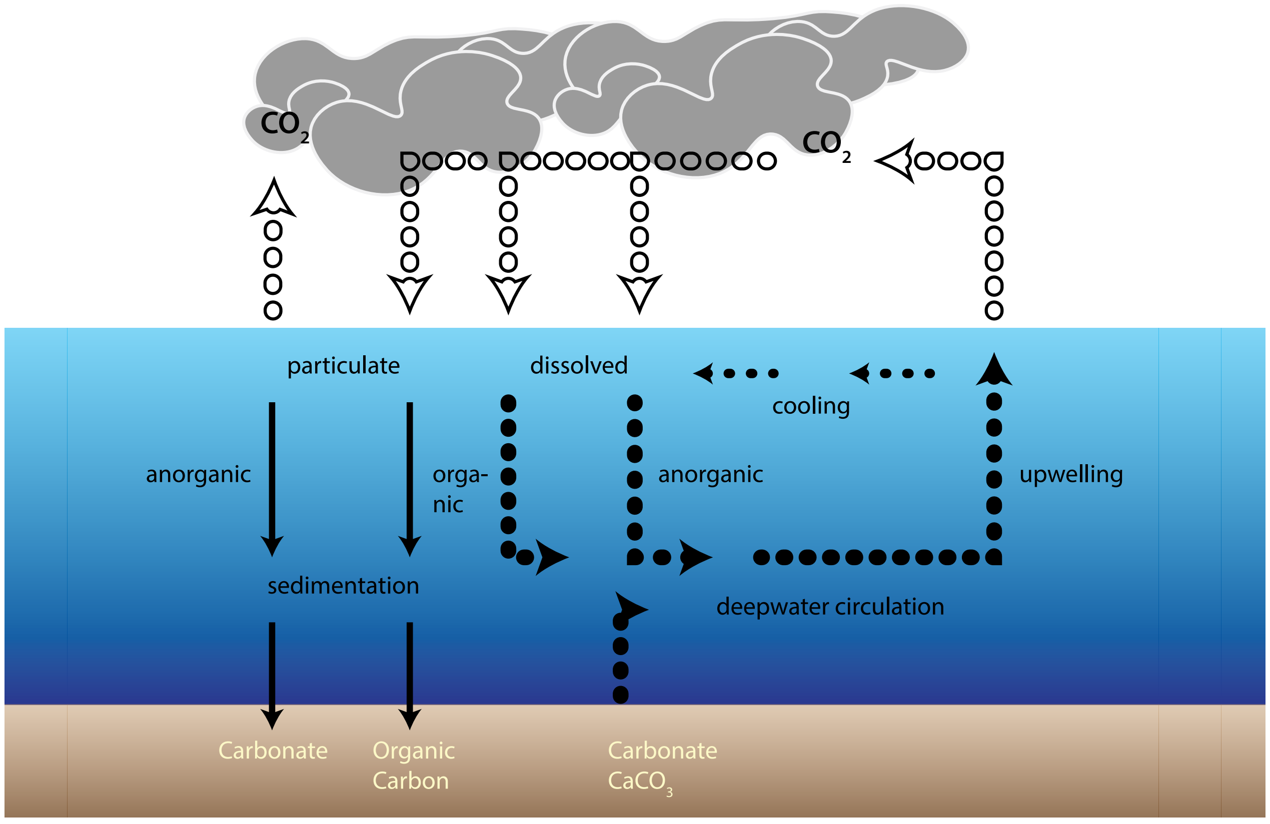
Vanuatu's sea has valuable ocean pumps that control nutrients, fuel marine life and affect carbon storage.

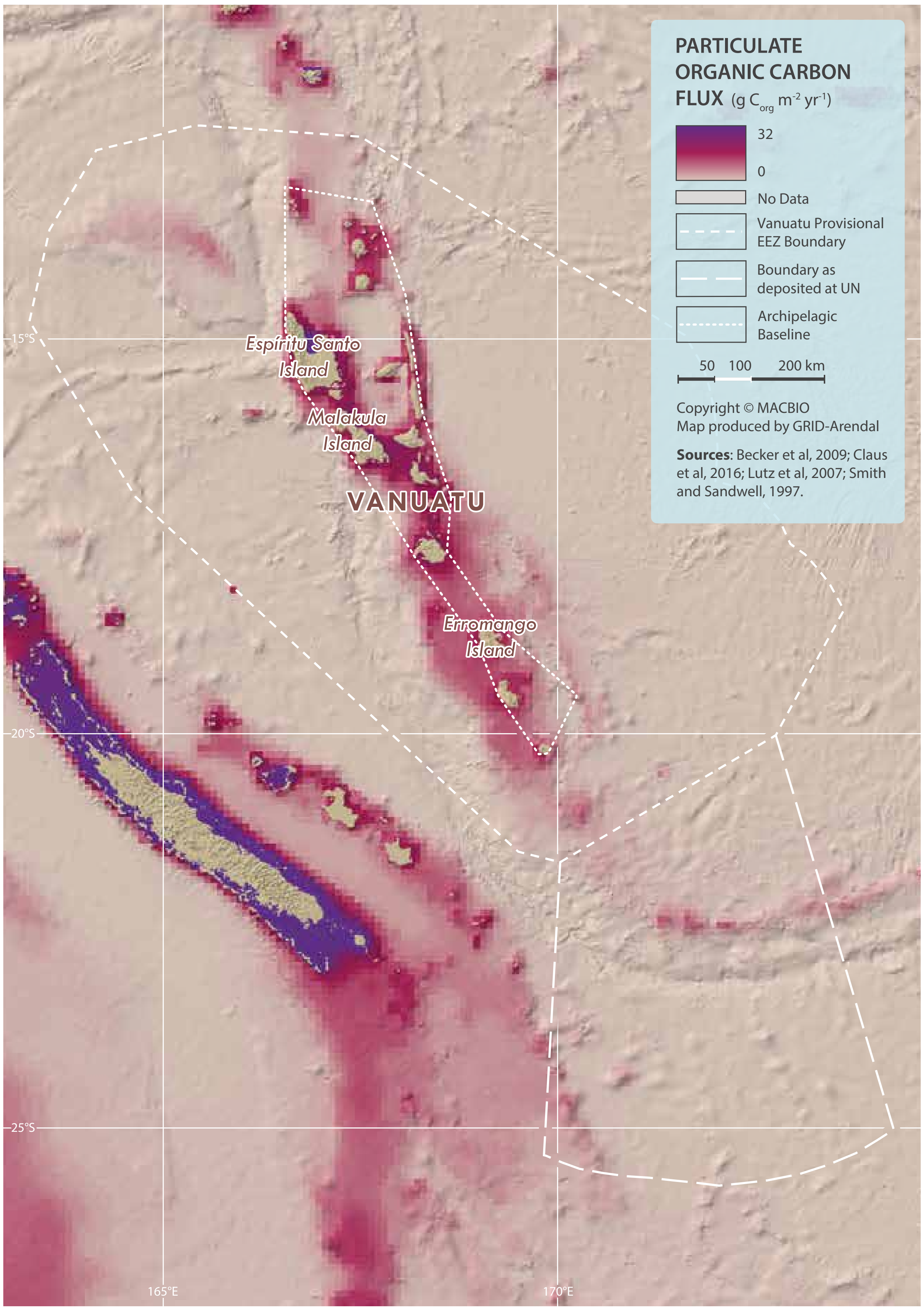
Oceanic carbon naturally cycles between the surface and the deep via two pumps of similar scale (see graphic). The solubility pump is driven by ocean circulation and the solubility of carbon dioxide (CO_2) in seawater. Meanwhile, the biological pump is driven by phytoplankton (see also chapter "Soak up the sun") and the subsequent settling of detrital particles or the dispersion of dissolved organic carbon.

Vanuatu's ocean pumps are measured by particulate organic flux (the total amount of organic carbon reaching the sea floor) as seen on the map. Organic detritus passing from the sea surface through the water column to the sea floor controls nutrient regeneration, fuels benthic life and affects the burial of organic carbon in the sediment record (Suess, 1980). As the ocean's biological pump is a direct pathway that allows carbon from the atmosphere to be sequestered in the deep-sea floor, it is one of the mechanisms that moderates climate change.

In fact, Vanuatu's ocean pumps are a key part of blue carbon—the carbon captured by the world's oceans and coastal ecosystems. The carbon captured by living organisms in the oceans is stored as biomass and can be trapped in sediment. Key carbon-capturing ecosystems include mangroves, salt marshes, seagrasses and potentially algae (see also chapter "Home, sweet home"). The social value of carbon sequestration by mangroves and seagrasses in Vanuatu has been estimated to be worth up to US$1.4 million per year (Pascal et al., 2015).

The patterns of particulate organic carbon flux in Vanuatu's waters closely reflect the depth of the sea floor, with higher rates in the shallow water compared with the deep. Particulate organic carbon flux is low throughout the majority of Vanuatu's waters, with rates of less than 1 gram of organic carbon/m2/year reaching much of the deep-sea floor. This is consistent with deep-sea rates globally. The maximum rates of particulate organic carbon flux occur in the shallow coastal zones, where rates are up to a maximum of 6 grams/m2/year.





Whale falls

Several whale species are commonly sighted in Vanuatu, and although they have less cultural importance than in, say, Fiji, their demise still plays a significant role in biogeochemical cycling. When a whale passes away, its carcass sinks to the bathyal or abyssal zone, deeper than 1,000 metres (Russo, 2004; see also chapter "Still waters run deep"). On the sea floor, it can create complex localized ecosystems that can sustain deep-sea organisms for decades. Moreover, a whale carcass contains a lot of carbon, which it transports to the bottom of the sea. This transport is part of the biological pump—the flux of organic material from the surface ocean to depth. Food falls (such as whale carcasses) may contribute up to 4 per cent of the total carbon flux to the deep ocean (Higgs et al., 2014).

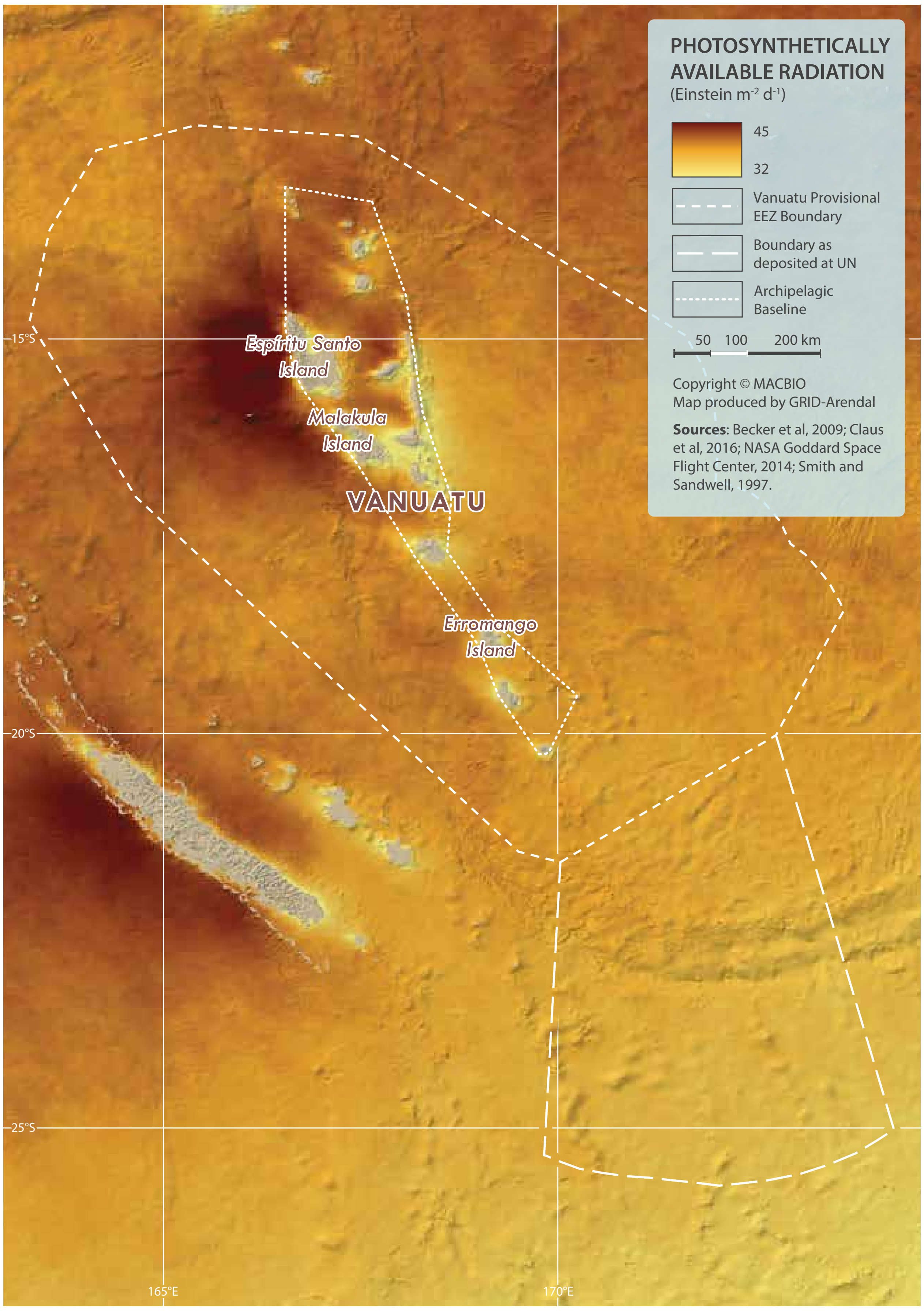
SOAK UP THE SUN: PHOTOSYNTHETICALLY AVAILABLE RADIATION

The amount of light available in Vanuatu's waters determines the growth of plants, including tiny phytoplankton—the basis of the marine food chain—and thus the rate of carbon capture.

However, in Vanuatu's coastal waters, increased nutrients from land-based activities, such as farming and wastewater treatment, can result in harmful algal blooms. These blooms can affect coastal habitats, for example the growth of macroalgae can smother coral reefs and limit light availability, both of which can lead to rapid declines in reef biodiversity (Fabricius, 2005). Blooms can therefore have a detrimental impact on living creatures and ecosystems, resulting in fish die-offs, water being unsafe for human consumption, or the closure of fisheries.

Marine phytoplankton, however, play a key role in the global climate system and in supporting Vanuatu's complex marine food webs. Understanding their spatio-temporal variability by analysing chlorophyll-a concentrations is therefore an important goal of present-day oceanography. Consequently, chlorophyll-a concentration is routinely measured in the ocean and is also considered to be an important parameter of global physical-biological oceanic models.

Globally, photosynthetically available radiation is highest in the tropics and decreases at high latitudes, with some variation due to cloud cover and other atmospheric conditions. As a result, photosynthetically available radiation is moderately high in Vanuatu's waters and mirrors the global pattern, with higher levels in the northern parts of Vanuatu's waters compared to further south. Within this overall trend, there are other variations: for example, photosynthetically available radiation is highest directly north and west of the main islands, and significantly lower to the direct south and east. This is a reflection of the local climatic conditions, with the predominantly easterly trade winds (see also chapter "Go with the flow") resulting in less cloud cover over the leeward side of the larger islands (Vanuatu Meteorological Service, 2016).



Ocean gardens

For plants to thrive, they need three things: water, sunlight and nutrients. In Vanuatu's sea, the first is obviously not an issue. The second is also not a problem, with the sun shining on Vanuatu's tropical waters year-round. Thus, there is always radiation available for photosynthesis—the process used by a plant to convert light energy into chemical energy that can later be released to fuel its activities. However, the third requirement, nutrients, is often the limiting factor in the seas of Vanuatu.

The energy from sunlight is absorbed by green chlorophyll pigments that transform sunlight into energy. Only sunlight of a specific wavelength range (400 to 700 nanometres) can be converted into energy. This wavelength range is referred to as photosynthetically available radiation, also known as photosynthetically active radiation.

Growing in Vanuatu's sunlit surface waters is a myriad of tiny plants called phytoplankton, which literally means drifter plants (see also chapter "Travellers or homebodies"). They are full of chlorophyll, which gives them their greenish colour. Chlorophyll absorbs most visible light, but reflects some green and near-infrared light. There are six different types of chlorophyll molecules, with chlorophyll-a the most common type in phytoplankton. Measuring chlorophyll-a concentration gives a good indication of primary productivity in the oceans.

Nevertheless, marine plants cannot live off water and light alone. They also require nutrients, including iron, nitrate and phosphate (see also chapter "The dose makes the poison"). Since these nutrients are generally low in Vanuatu's waters, phytoplankton quickly consume nutrients whenever they do become available. There is a school of thought that fertilizing areas of ocean may stimulate phytoplankton growth, capturing carbon which may sink to the ocean floor (see also chapter "Pump it"). Could this be the solution to climate change (see also chapter "Hotter and higher")? However, the many ocean fertilization experiments worldwide using iron, phosphate or nitrate have yet to show feasibility on a scale large enough to reduce global emissions (Matear, 2004).

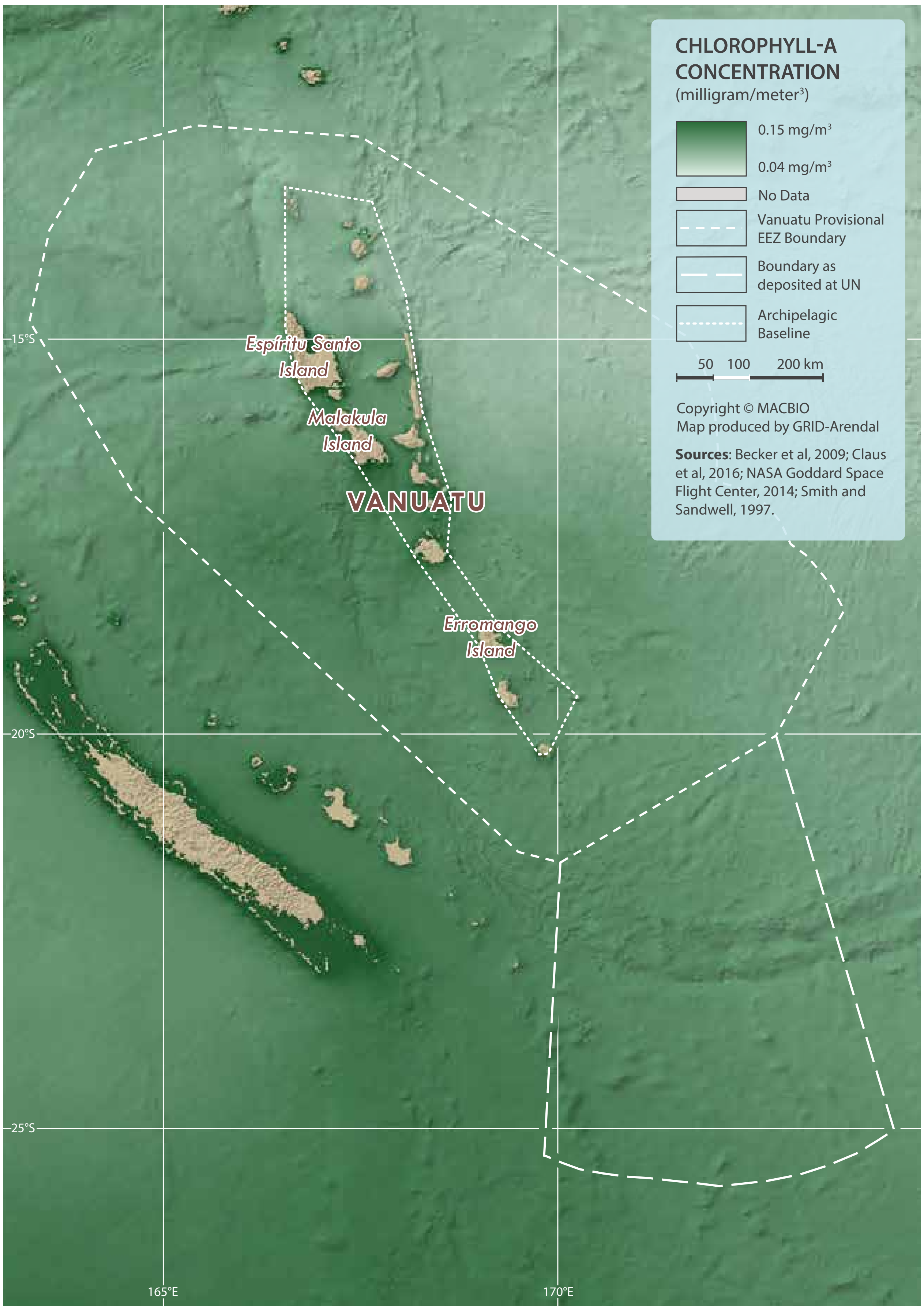
There is also seasonal variation in photosynthetically available radiation in Vanuatu. The greatest variation occurs in the very northern part of the Vanuatu's waters, where photosynthetically available radiation varies by up to 20 per cent throughout the year. This is in part due to changes in atmospheric conditions, such as cloud cover. In Port Vila, the average percentage of the sky covered by clouds experiences significant seasonal variation, with the cloudiest days occurring from December to March and the least cloudy days from June to September.

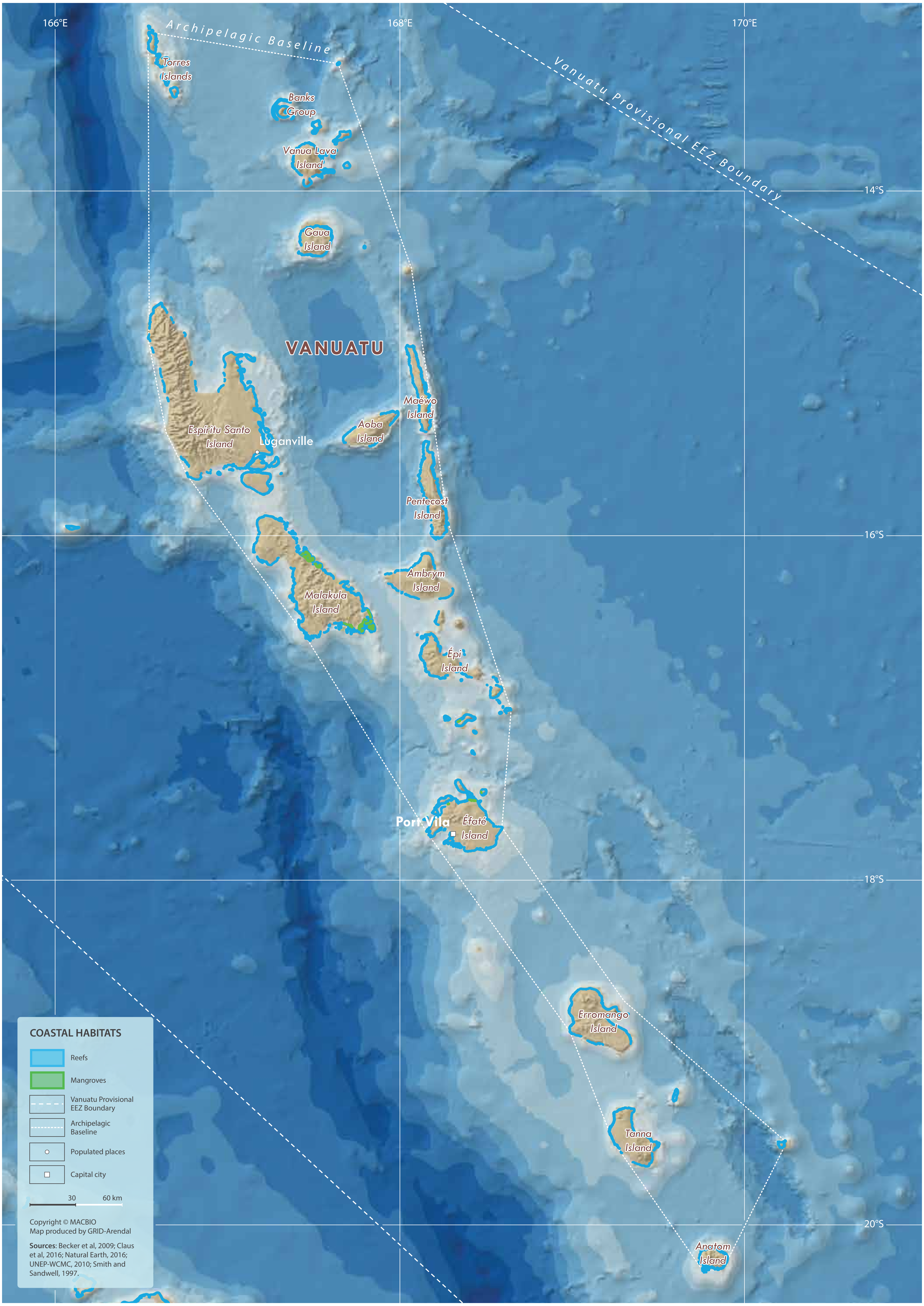
The chlorophyll-a concentration in Vanuatu's waters is generally very low, with concentrations in its offshore waters less than 0.1 gram per m3 of seawater. Most of the tropical regions of the open oceans have similarly low chlorophyll-a concentrations. In contrast, within temperate and arctic regions, these concentrations can approach 1 gram per m3 of seawater. The shallow coastal regions of Vanuatu have slightly increased chlorophyll-a concentrations, with up to 0.4 grams per m3 of seawater. Again, this is low compared to many coastal regions around the world, where chlorophyll-a concentrations can reach over 10 grams per m3 of seawater. The low concentrations of chlorophyll-a in Vanuatu's waters reflect the low availability of key nutrients. Compared to large continental landmasses, with large river discharges that can carry nutrients into the sea, Vanuatu is a small island nation with comparatively small nutrient inputs into the marine environment. However, at the local or bay scale, nutrient inputs may still be significant.

In the south-western tropical Pacific Ocean, strong seasonal and inter-annual variabilities in the chlorophyll-a concentration have been observed (Dupouy et al., 2004). Strong chlorophyll-a enrichments have been documented around the Solomon Islands, and between New Caledonia and Vanuatu, with weaker enrichments found around Fiji or Tonga. The annual variation in chlorophyll-a around Vanuatu is low, with variation of less than 2 grams per m3 of seawater in some coastal areas.

Euphausia superba, phytoplankton from the Antarctic, is an example of the basis of the marine food chain.

Bloom of Trichodesmium erythraeum in the South-West Pacific Ocean between New Caledonia and Vanuatu.




166°E
168°E
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14°S
16°S
18°S
20°S
Archipelagic Baseline
Vanuatu Provisional EEZ Boundary
Torres Islands
Banks Group
Vanua Lava Island
Gava Island
VANUATU
Espiritu Santo Island
Luganville
Aoba Island
Maéwo Island
Pentecost Island
Malakula Island
Ambrym Island
Épi Island
Port Vila
Éfaté Island
Erromango Island
Tanna Island
Anatom Island
COASTAL HABITATS
Reefs
Mangroves
Vanuatu Provisional EEZ Boundary
Archipelagic Baseline
Populated places
Capital city
30
60 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; Claus et al, 2016; Natural Earth, 2016; UNEP-WCMC, 2010; Smith and Sandwell, 1997.

HABITAT VALUES

HOME, SWEET HOME: COASTAL HABITATS

Vanuatu's famous hospitality extends to the thousands of species that call its coral reefs, mangroves and seagrasses home. These habitats house countless plants and animals that store carbon and help protect Vanuatu's coastal inhabitants.

The previous set of maps in the "Supporting values" section of the report took us on a journey from the ocean floor all the way to the surface, demonstrating the colourful biophysical features of Vanuatu's waters. While they are fascinating in their own right, the combination of features such as bathymetry, geomorphology, currents, nutrients and plankton are also important factors in the distribution and health of Vanuatu's coastal habitats.

Coastal protection is a key ecosystem service with two components: the prevention of erosion and the mitigation of storm surges. Coastal ecosystems prevent coastal erosion by reducing the effects of waves and currents and also helping regulate the removal and deposition of sediment (erosion and accretion). Furthermore, they provide increased short-term protection against episodic events, including coastal floods and storm surges. The benefits of this protection against extreme weather events include minimizing damage to homes, buildings and other coastal infrastructure and on important resources such as crops.

Residents of many of Vanuatu's islands came to realize these benefits in March 2015, when Cyclone Pam was the second most intense cyclone to ever affect the South Pacific and the most intense and devastating in Vanuatu's history. However, without the protection that coral reefs and mangroves provide to most of Vanuatu's islands, the damage could have been a lot worse. Every year, reefs and mangroves mitigate damage to houses and hotels across Efaté, Malekula and Espíritu Santo by up to US$23 million, demonstrating just how valuable marine and coastal ecosystem services are to Vanuatu.

Coastal habitats such as mangrove forests, seagrass beds and coral reefs play an important role in stabilizing shorelines. As human density increases however, so too does the impact on these important coastal habitats.

The role of mangroves in coastal stabilization is well known. They protect coastal areas from erosion, storm surges (especially during cyclones) and tsunamis. Their massive root systems are efficient at dissipating wave energy and slow down tidal water so that suspended sediment is deposited as the tide comes in, with only the fine particles resuspended as the tide recedes. In this way, mangroves help build their own environment. Given the uniqueness of mangrove ecosystems and the protection they provide against erosion, they are often the subject of conservation programmes and are commonly included in national biodiversity action plans.

Seagrasses are another important coastal habitat that form extensive meadows in the coastal areas they colonize. Their leaves can also slow currents, and their roots and rhizomes trap the sediments in which they grow, thereby enhancing the stability of the substrate. Seagrasses can also dissipate the energy of waves by up to 40 per cent, which can in turn increase the rate of sedimentation. As such, seagrass beds effectively help protect against waves and limit coastal erosion.

In addition to protecting the coast, Vanuatu's coastal habitats also act as nursery areas for fish and support food security, livelihoods, tourism and other human activities. Seagrass meadows and mangroves are also recognized as important carbon stores, with the preservation of healthy mangrove systems contributing to climate change action. The social benefit of carbon sequestration by mangroves in Vanuatu's EEZ is estimated to be worth up to US$4 million (Pascal et al., 2015). But while coastal habitats are some of the most productive and valuable marine habitats, they are by the same token some of the most vulnerable to human activities (see also chapters "Reefs at risk" and "Turning sour").

The map of coastal habitats presents the distribution of coral reefs and mangroves. Shallow coral reefs form some of the most diverse ecosystems on Earth. Despite occupying less than 0.1 per cent of the world's ocean surface, they provide a home for at least 25 per cent of all marine species, including fish, molluscs, worms, crustaceans, echinoderms, sponges, tunicates and other cnidarians. Coral reefs provide many benefits to people living in coastal areas, including food provision, supporting artisanal and commercial fisheries, tourism opportunities and coastal protection. The islands of Vanuatu are surrounded by fringing reefs, making this an important coastal habitat.

Mangroves are Vanuatu's most extensive wetland vegetation type (Bani & Esrom, 1993). They occur on nine different islands, but the most extensive stands are found off eastern Malekula and the Maskelyne Islands (Laffoley, 2013). Seagrass beds are highly diverse and productive ecosystems that can harbour hundreds of associated species from all phyla, for example, juvenile and adult fish, epiphytic and free-living macroalgae and microalgae, molluscs, bristle worms, and nematodes. These beds occur in the sheltered waters of many of Vanuatu's islands, with nine different species identified. However, seagrass maps have not been presented in the map of coastal habitats as there are currently no publicly available data that adequately capture the distribution of seagrass in Vanuatu.

Fringing reef south of Mota Lava

Barrier reef south of Aneityum Island

Rowa Island Atoll

Patch reef in front of Saraoutou, south-east of Espíritu Santo

SHAPING PACIFIC ISLANDS: CORAL REEFS

Vanuatu's reefs are not only important coastal habitats; they are also transforming and shaping Vanuatu's coastlines, islands and atolls.

Corals play a fundamental role in the development of island nations such as Vanuatu, with coral reefs having helped transform and shape the very outline of Vanuatu's coasts, islands and atolls. But how do coral reefs do this, especially considering that corals are tiny animals, belonging to a group of animals known as cnidaria, which also includes jellyfish and sea anemones?

Firstly, corals secrete hard calcium carbonate exoskeletons, which support and protect their coral polyps. The resulting calcium carbonate structures hold the coral colonies together. Most coral reefs are built from stony corals, which consist of polyps that cluster together and grow best in warm, clear, sunny, nutrient-poor, agitated water, which also needs to be shallow, as corals are dependent on light. But where does the shallow water come from in the middle of the ocean?

Charles Darwin was wondering the same. Following his voyage of the world on HMS Beagle in 1842, he set out his theory of the formation of atoll reefs. He theorized that uplift and subsidence of the Earth's crust under the oceans was responsible for atoll formation (see also chapter "Smoke underwater, fire in the sea"). Darwin's theory, which was later confirmed, sets out a sequence of three stages for atoll formation, starting with a fringing reef forming around an extinct volcanic island. As the island and ocean floor subsides, the fringing reef becomes a barrier reef, and ultimately an atoll reef as the island subsides below sea level.

A fringing reef can take 10,000 years to form, while an atoll can take up to 30 million years. When an island is undergoing uplift, fringing reefs can grow around the coast, but if the coral is raised above sea level, it will die and become white limestone. If the land subsides slowly, the fringing reefs keep pace by growing upward on a base of older, dead coral, forming a barrier reef enclosing a lagoon between the reef and the land. A barrier reef can encircle an island, and once the island sinks below sea level, a roughly circular atoll of growing coral continues to keep up with the sea level, forming a central lagoon. Barrier reefs and atolls do not usually form complete circles, but are broken in places by storms. Like sea level rise (see also chapter "Hotter and higher"), a rapidly subsiding bottom can overwhelm coral growth, killing the coral polyps and the reef through "coral drowning". Corals that rely on their symbiotic zooxanthellae can drown when the water becomes too deep for their symbionts to adequately photosynthesize due to decreased light exposure (Spalding et al., 2001).

According to Bell & Amos (1993), Vanuatu's inner reefs cover an area of 408 km^2. They are composed of around 300 different coral species and include fringing reefs, barrier reefs, platform reefs, drowned reefs and near-atolls (Naviti & Aston, 2000).

The maps show examples of the four prevailing reef types in Vanuatu.

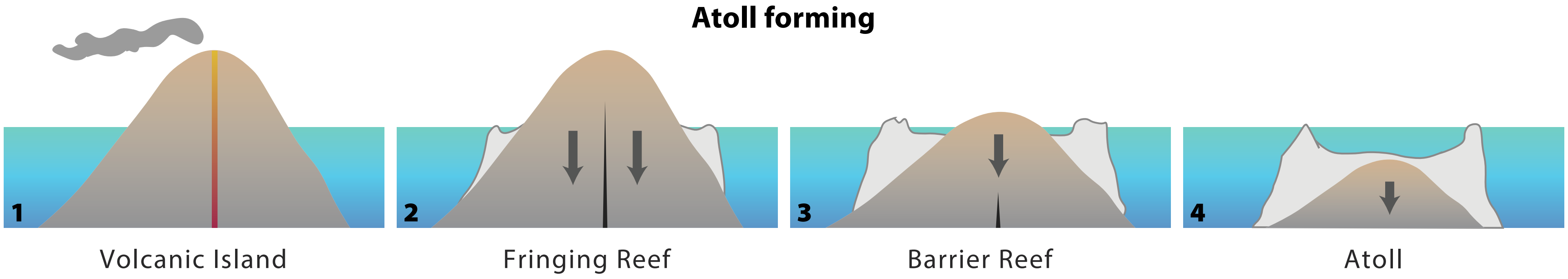
- Fringing reef (e.g. encircling most of the islands from Efaté southward. The predominant reef type in Vanuatu): Directly attached to a shore, or borders it with an intervening shallow channel or lagoon.
- Barrier reef: Separated from a mainland or island shore by a deep channel or lagoon.
- Atoll reef (e.g. Rowa Islands): More or less circular or continuous barrier reef that extends all the way around a lagoon without a central island.
- Patch reef (e.g. South Malekula): Common, isolated, comparatively small reef outcrop, usually within a lagoon or embayment, often circular and surrounded by sand or seagrass.

Important reefs include those around Efaté, Santo, Tanna, Malekula, Pentecost, Ambae and Ambrym, where almost 80 per cent of the population lives and where the vast majority of tourism is concentrated (Naviti & Aston, 2000).

Underwater rainforests

Around 36 per cent of Vanuatu's land is covered by forest and its sea also features the proverbial "rainforests of the sea", coral reefs. These reefs are rich in biodiversity and harbour many more plants and animals then the nation's forests above sea level. Such a diverse ecosystem is very valuable to Vanuatu, providing habitat, shelter and tourist destinations (see also chapters "Home, sweet home" and "Beyond the beach").

Atoll forming



TRAVELLERS OR HOMEBODIES: MARINE SPECIES RICHNESS

Vanuatu's marine environment hosts two types of animals: pelagic species and benthic species, both of which are important and biologically interconnected.

Pelagic species are those that live in the water column away from the sea floor and coast. Often these species migrate across vast areas of ocean, driven by oceanic conditions and seasonal food availability (see also chapter "Go with the flow"). On the other hand, benthic species are those that live on or close to the sea floor. Unlike pelagic species, which migrate large distances, benthic species are often associated with specific sea-floor features and are either attached to the substrate or very site-specific.

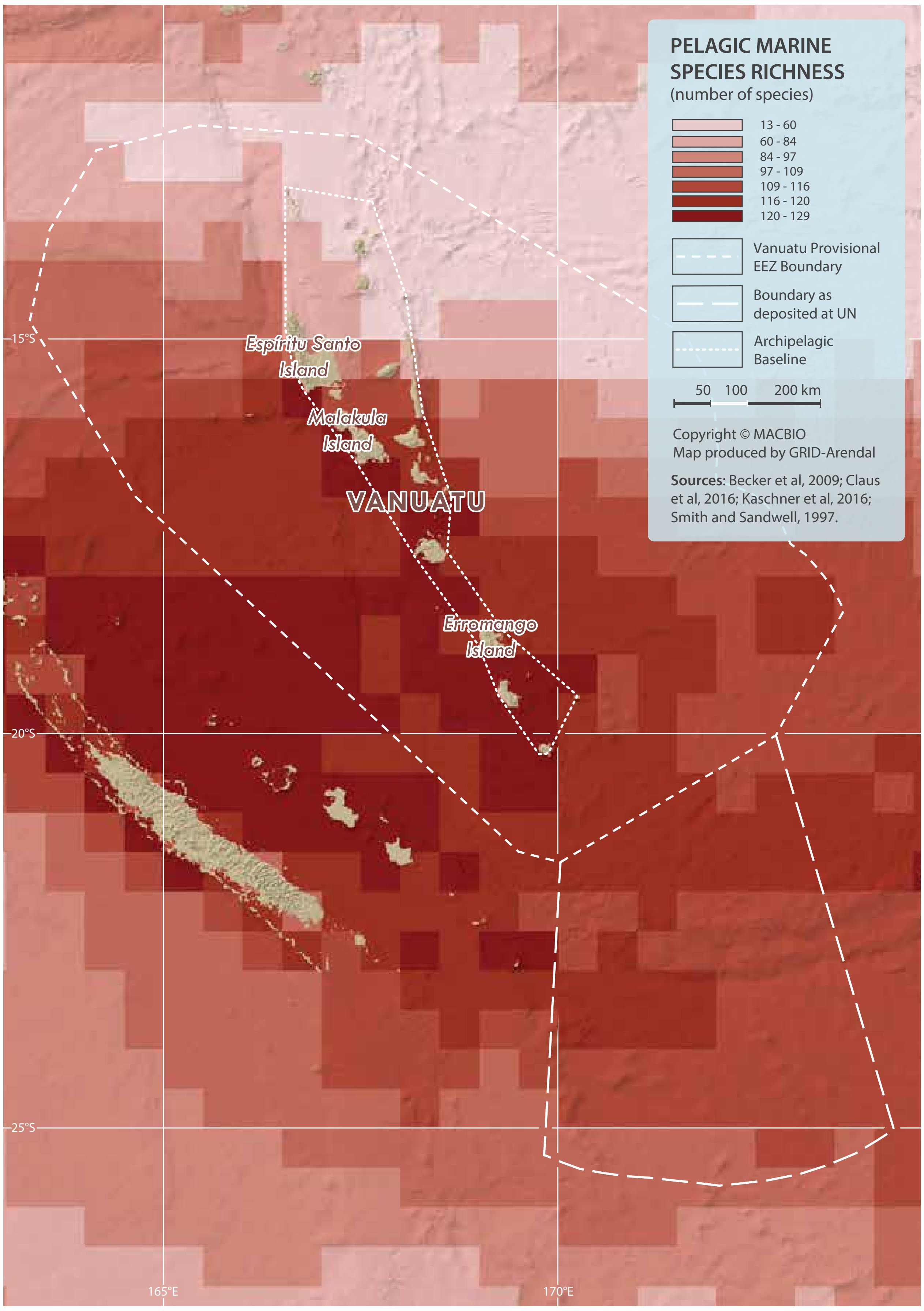
Both pelagic and benthic species contribute to Vanuatu's rich marine biodiversity, are part of complex food chains, and form important habitats. Furthermore, many commercially important species of both types are found in Vanuatu's waters. Commercially important pelagic species include several species of tuna, such as albacore (*Thunnus alalunga*), bigeye (*Thunnus obesus*), skipjack (*Katsuwonus pelamis*) and yellowfin (*Thunnus albacares*) tuna (FAO, 2010), and several important commercial billfish species, such as blue marlin (*Makaira nigricans*), black marlin (*Makaira indica*), striped marlin (*Kajikia audax*) and swordfish (*Xiphias gladius*) (Williams, 2002).

There are also some pelagic shark species, including the blue shark (*Prionace glauca*), oceanic whitetip (*Carcharhinus longimanus*), shortfin mako shark (*Isurus oxyrinchus*), longfin mako (*Isurus paucus*), and silky shark (*Carcharhinus falciformis*). Other sharks such as bull (*Carcharhinus leucas*) or tiger (*Galeocerdo cuvier*) sharks attract countless dive tourists and revenue to Vanuatu (see also chapter "Beyond the beach"). Pelagic species also include the smaller species that support these large commercially important species (see also chapter "Fishing in the dark"). The routes these species take to migrate, and thus the connectivity of their habitats, are an important consideration for marine management and conservation planning.

Pelagic or benthic?

Some marine species move from one place to another, while others tend to stay in the same location. These species are described as either "pelagic" or "benthic" (see also chapter "Still waters run deep").

As for Vanuatu's numerous benthic species, many invertebrates (those without a backbone) are found in soft sediment habitats and on rocky substrates. According to the Ocean Biogeographic Information System, Vanuatu has numerous marine invertebrates, including 210 species of hard and soft corals, 939 species of bivalves (such as oysters and mussels) and gastropods (such as snails and slugs), 361 crustaceans (such as crabs, lobsters and shrimps) and many echinoderm species (including starfish, sea urchins, and sea cucumbers). Sea cucumbers are particularly important to Vanuatu, with at least 23 species harvested commercially (see chapter "Small fish, big importance"). Many benthic species form habitats in Vanuatu's shallow waters,

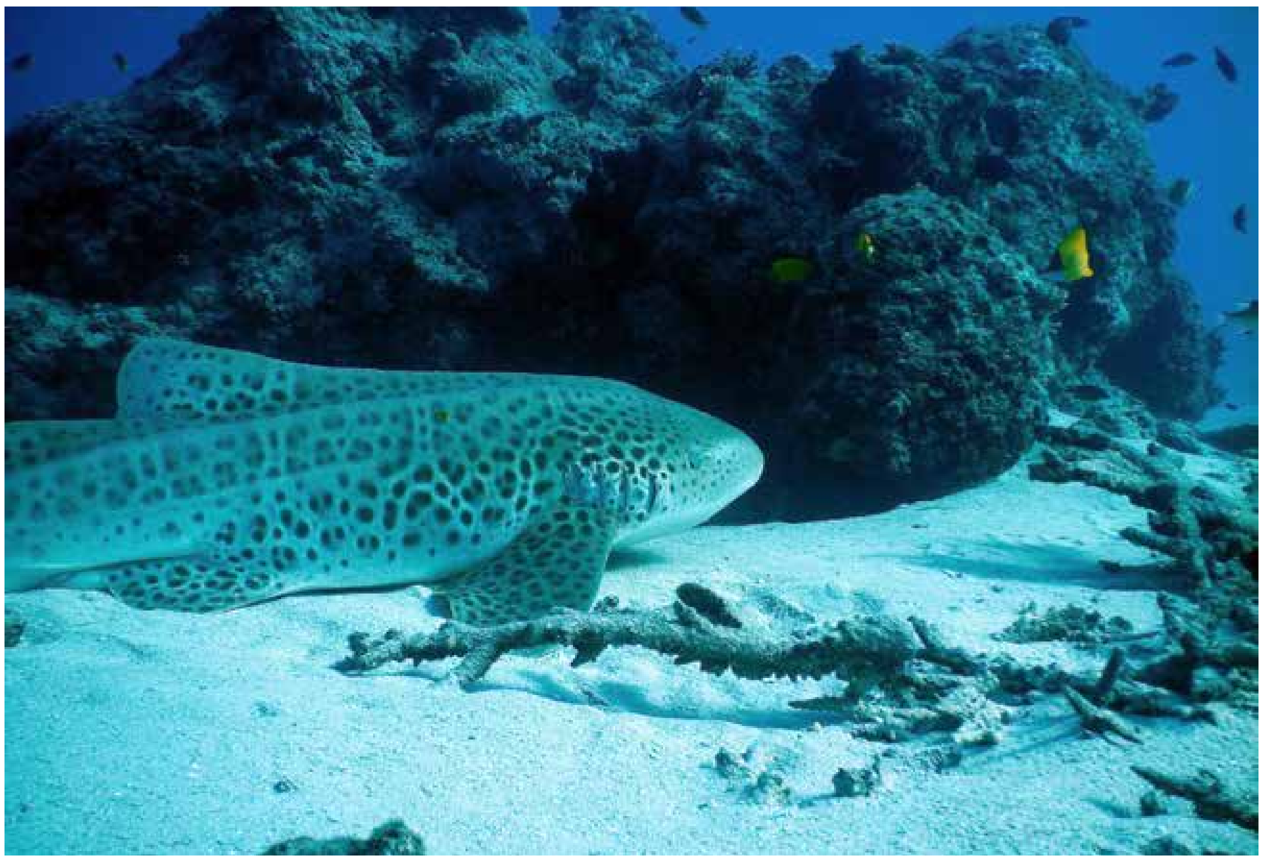


including corals, seagrass, mangroves and algae (see also chapter “Home, sweet home”).

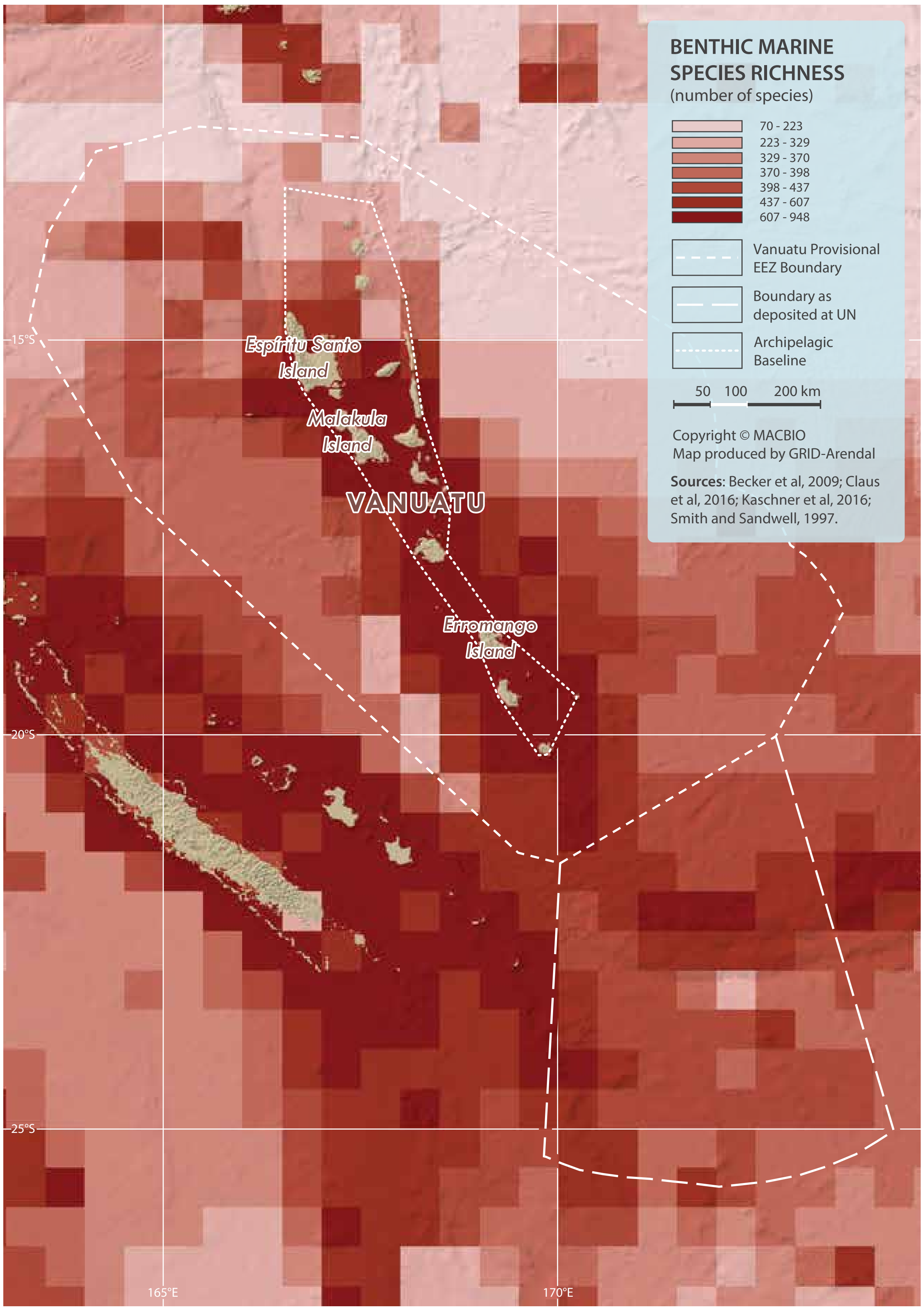
Globally, pelagic fish are generally more abundant in tropical waters and decrease as latitude increases. As the map shows, within Vanuatu’s waters, there is a trend for lower species richness in the northern part of Vanuatu’s waters, with higher pelagic richness to the south and west of the main islands; especially between New Caledonia and Vanuatu.

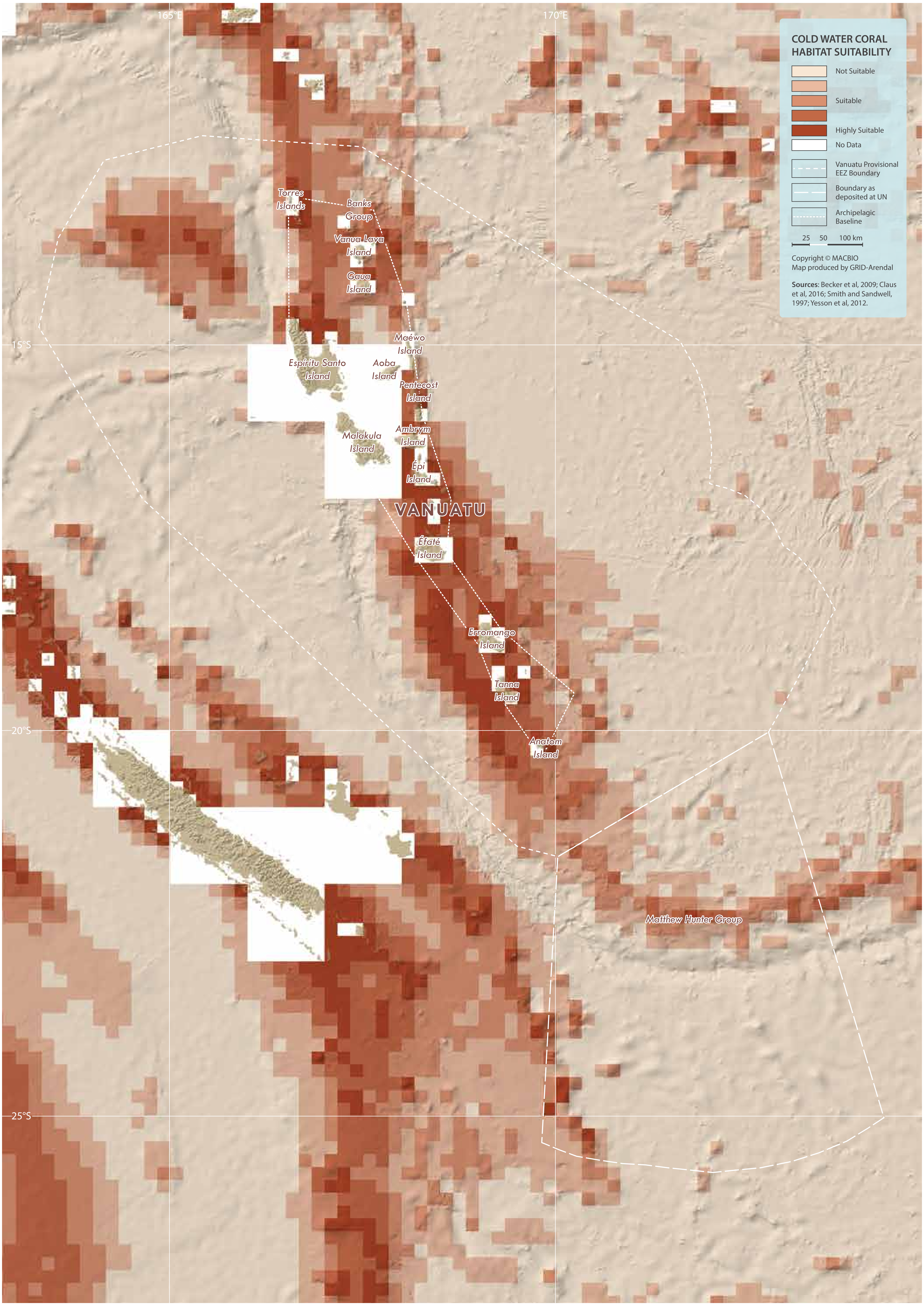
Similarly, tropical waters tend to have a higher benthic species richness than waters at higher latitudes. Again, in Vanuatu’s waters, there is a trend for higher benthic species richness in the south than in the north. Benthic species richness is higher in shallow water compared to deep water, both in Vanuatu and globally. The highest benthic species richness is found around Vanuatu’s main islands. Elevated benthic species richness is also associated with other shallow areas such as the Torres Rise.

In general, species richness can be used as an indicator of conservation significance. It does not, however, provide information on species composition, nor does it identify whether there are rare or priority species in an area. Further, areas with similar species richness may have very different species present, which would affect the conservation and management measures required.



The Zebra shark is found throughout the tropical Pacific, but listed as an endangered species.




COLD WATER CORAL HABITAT SUITABILITY
Not Suitable
Suitable
Highly Suitable
No Data
Vanuatu Provisional EEZ Boundary
Boundary as deposited at UN
Archipelagic Baseline
25 50 100 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; Claus et al, 2016; Smith and Sandwell, 1997; Yesson et al, 2012.
165°E
170°E
15°S
20°S
25°S
Torres Islands
Banks Group
Vanua Lava Island
Gaua Island
Maéwo Island
Espiritu Santo Island
Aoba Island
Pentecost Island
Ambrym Island
Malakula Island
Épi Island
VANUATU
Éfaté Island
Erromango Island
Tanna Island
Anatom Island
Matthew Hunter Group

HOW MUCH DO WE REALLY KNOW? COLD-WATER CORAL HABITATS

While quite a lot is known about Vanuatu's inshore environment, some habitats are hard to explore and map. For example, although cold-water corals can be common and important deep-sea species, little is known about their distribution and abundance in Vanuatu's waters. Their sensitivity to human impact and future climate change should be considered when assessing management options for deep-sea ecosystem conservation.

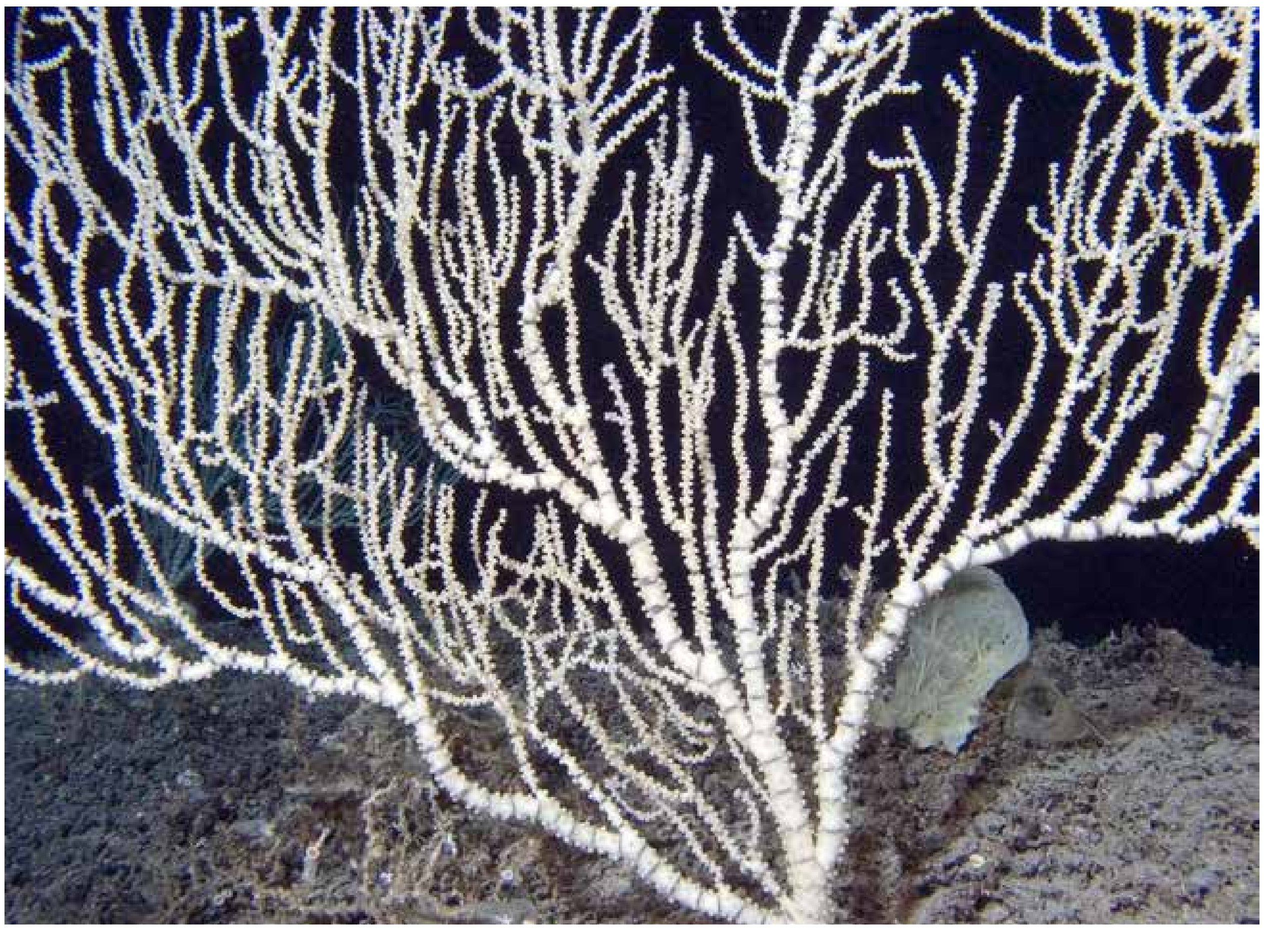
The Moon or the sea?

There is a common misconception that we know more about the surface of the Moon than the ocean floor and that 95 per cent of the ocean is unexplored. The chapter "Voyage to the bottom of the sea" showed that we actually know a lot about the ocean floor. The entire ocean floor has been mapped to a maximum resolution of around 5 kilometres, unveiling most features larger than 5 kilometres across (Sandwell, 2014). However, only 0.05 per cent of the ocean floor has been mapped to a high level of detail, meaning Vanuatu's waters undoubtedly hold a lot of secrets, including deep-water or cold-water corals. These corals have a depth range extending from around 50 metres to beyond 2,000 metres deep, where water temperatures may be as cold as 4°C (see also chapter "Still waters run deep"). While there are nearly as many species of cold-water corals as shallow-water corals, only a few cold-water species develop into traditional reefs. This is also why they are much harder to discover and map than their shallow-water counterparts. Nevertheless, scientists have created habitat suitability models that use information on the physical environment to predict their distribution and provide an understanding of their ecological requirements.

Corals are not restricted to shallow-water tropical seas. Deepwater or cold-water corals are regarded as occurring deeper than 50 metres, and include five taxa and over 3,300 more species than their better known tropical coral reef counterparts: order Scleractinia (hard, stony corals), order Zoanthidea (zoanthids, gold corals), order Antipatharia (black corals), subclass Octocorallia (soft corals, gorgonians, bamboo corals), and family Stylasteridae (lace corals) (Roberts et al., 2009). They are widespread throughout the Pacific Ocean.

At present, cold-water corals have no economic importance for Vanuatu. However, many of them have been recognized as playing important ecological roles in the deep sea, since they can form large reef-like structures or have complex growth forms which in turn provide habitat for many associated invertebrate and fish species.

Cold-water corals are widely regarded as being susceptible to damage from human activities, such as direct effects from fishing, deep-sea mining and submarine communication cables (see also chapters "Fishing in the dark" and "Underwater Wild West"), as well as more indirect impacts from pollution and climate change (see also chapters "The dose makes the poison" and "Turning sour"). Many species of cold-water coral are structurally fragile, and hence easily broken. They can also be long-lived and slow-growing, meaning that any recovery from damage is slow. Therefore, the presence of cold-water corals can be an important indicator of the need to manage human activities to avoid or minimize impacts on these deep-sea ecosystems. For instance, octocorals are one of the groups that FAO lists as potentially Vulnerable Marine Ecosystems (FAO, 2009), and which are required under United Nations resolutions to be protected from deep-sea fishing. They are fully protected in some countries (e.g. New Zealand).



The map shows the predicted suitability of habitat where octocoral species could occur. Octocorals are a highly diverse group, with soft corals, gorgonians, sea fans, sea whips, sea feathers, precious corals, pink coral, red coral, golden corals, bamboo corals, leather corals, horny corals, and sea pens among their estimated 2,000-plus species (Roberts et al., 2009). Globally accessible data for offshore corals are sparse in many Pacific Islands, including Vanuatu. In fact, data available through the Ocean Biogeographic Information System (OBIS) in 2015 supplemented with New Zealand regional records (NIWA) show only 15 records of cold-water octocorals in Vanuatu's waters (mainly primnoid corals and soft corals). This has led to the need for habitat suitability modelling to be used to predict the likely occurrence of corals in the area.

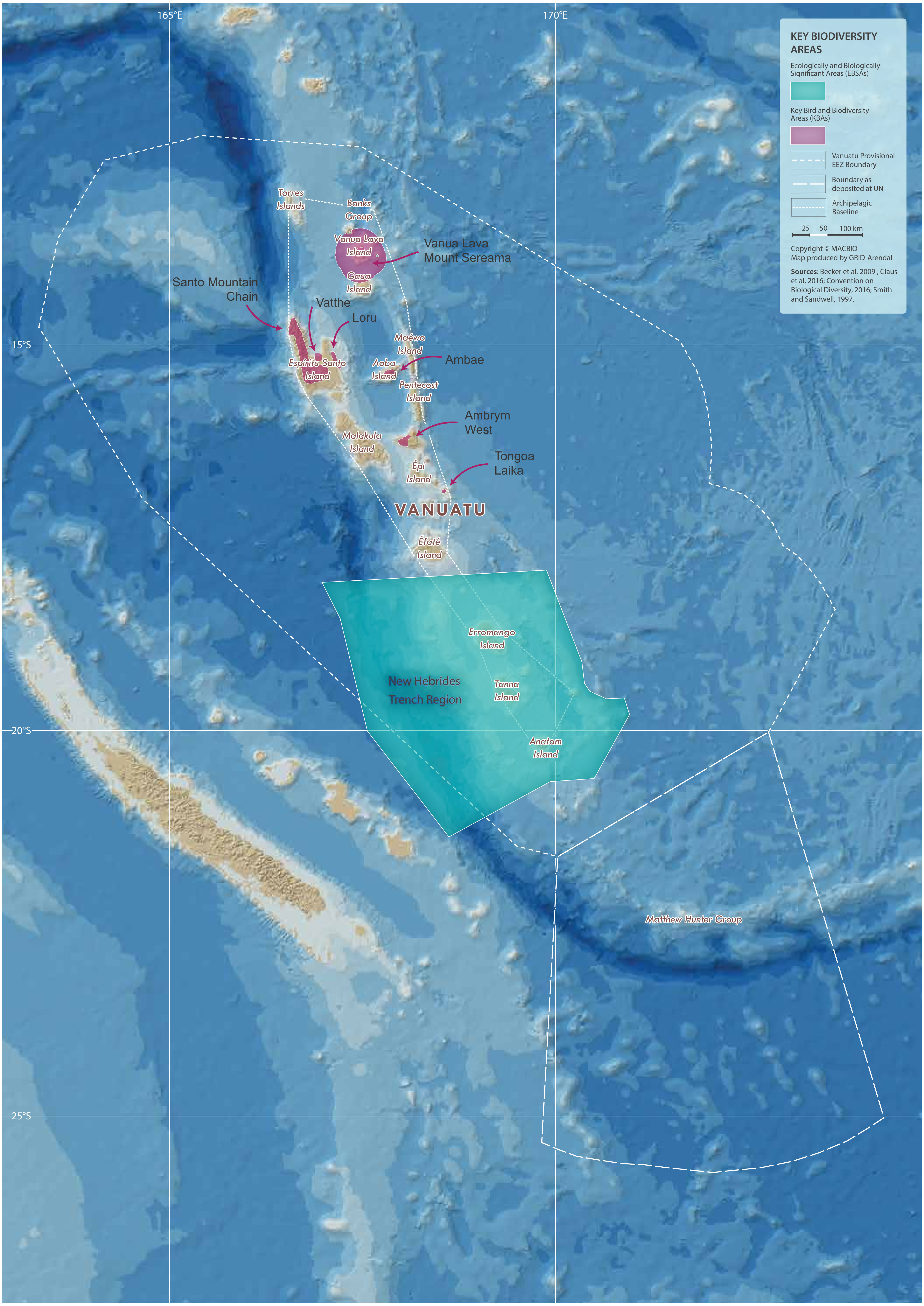
Habitat suitability was highest along the major bathymetric features in the EEZ, with high predicted occurrence in a nearly continuous band along the main island ridge and island slopes, as well as on the West Torres Plateau west of the Torres Islands and bordering the Torres Trench. The distribution largely follows depth, with topography also a factor. These ridge and bank features are shallower than many of the abyssal plains in the EEZ, with higher food availability. The steep topography provides hard rocky substrate which the corals need for attachment.

Although not presented, similar analyses have been carried out for five species of stony coral (order Scleractinia) (Davies and Guinotte, 2011). Depth, temperature, aragonite saturation state and salinity were the key environmental drivers for this taxonomic grouping. The published figures do not indicate high suitability for these corals around Vanuatu.

Habitat suitability modelling examines the relationship between where the corals are known to occur and key environmental conditions at that location. This relationship enables extrapolation into areas that have not been sampled, based on the suitability of a range of globally recognized environmental factors. For octocorals, temperature, salinity, slope of the sea floor, ocean productivity, dissolved oxygen levels, and calcite saturation state were important factors controlling habitat suitability (Yesson et al., 2012).

The presence of cold-water corals can be an important indicator for managing human activities to avoid or minimize impacts on deep-sea ecosystems. The habitat suitability map, although based on presence-absence rather than abundance, gives an indication of which areas may need protection from disturbance of the sea floor or climate change.

The bamboo coral Keratoisis grandiflora, which has been recorded in Vanuatu's waters.


165°E
170°E
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KEY BIODIVERSITY AREAS
Ecologically and Biologically Significant Areas (EBSAs)
Key Bird and Biodiversity Areas (KBAs)
Vanuatu Provisional EEZ Boundary
Boundary as deposited at UN
Archipelagic Baseline
25 50 100 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009 ; Claus et al, 2016; Convention on Biological Diversity, 2016; Smith and Sandwell, 1997.
Torres Islands
Banks Group
Vanua Lava Island
Vanua Lava Mount Sereama
Gaua Island
Santo Mountain Chain
Vatthe
Loru
Maéwo Island
Espíritu Santo Island
Aoba Island
Ambae
Pentecost Island
Ambrym West
Malakula Island
Épi Island
Tongoa Laika
VANUATU
Éfaté Island
Erromango Island
New Hebrides Trench Region
Tanna Island
Anatom Island
Matthew Hunter Group

NATURE'S HOTSPOTS: KEY BIODIVERSITY AREAS

The islands of Vanuatu and its surrounding waters host a large variety of habitats, which are important breeding or feeding grounds for a number of marine and seabird species. The characteristics of Key Biodiversity Areas (KBAs) and Ecologically or Biologically Significant Areas (EBSAs) mapped here can support the further development of management options to balance human needs and protect vulnerable species and ecosystems.

The previous maps show Vanuatu's impressive richness of natural wonders and their value to Vanuatu. However, as the ocean and the atmosphere do not have borders that restrict the migration of species or the flow of carbon (see also chapters "Go with the flow" and "Travellers or homebodies"), these high-value areas in Vanuatu's waters also have international significance. It is therefore important for Vanuatu to identify and designate hotspots that are key to global biodiversity and climate as part of a global effort to conserve biodiversity. Such hotspots are called Key Biodiversity Areas (KBAs), which extend the concept of the 13,000 Birdlife International Important Bird and Biodiversity Area (IBA) sites worldwide to other species and include EBSAs described under the Convention on Biological Diversity (CBD).

Marine conservation in Vanuatu is guided by the goals and objectives laid out in its Environmental Management and Conservation Act (2013), which links national action with these more global and regional initiatives. These areas (KBAs, IBAs and EBSAs) are defined as sites that contribute significantly to regional or global persistence of biodiversity, and consider attributes such as uniqueness or rarity; importance for life-history stages of key species; threatened, endangered or declining species; vulnerability to, or slow recovery from, disturbance; productivity; diversity and/or naturalness. These definitions can operate at all levels of biodiversity (genetic, species, ecosystem).

The determination of KBAs can bring a site into the conservation agenda that had not previously been identified as needing protection. It is important to note that while EBSAs identified under the CBD criteria have no official management status, KBAs can be recognized under national legislation. The New Hebrides Trench Region, encompassing the southern islands of Vanuatu, has been identified by the Secretariat of the Convention on Biological Diversity as an EBSA. While EBSAs have no official management status in Vanuatu, a number of marine protected areas, such as Mystery Island or Port Patrick Marine Reserve, are nestled within the New Hebrides Trench Region EBSA. As knowledge of the characteristics of such prospective areas develops, they can become critical elements of an integrated protected area network that can ensure key ecological sites are protected, yet still allow human activities to occur in an environmentally sustainable way.

The map shows the distribution of EBSAs and KBAs in island and offshore areas of Vanuatu, although it should be noted that there are also 23 localized coastal marine protected areas (MPAs) that are not included on the map.

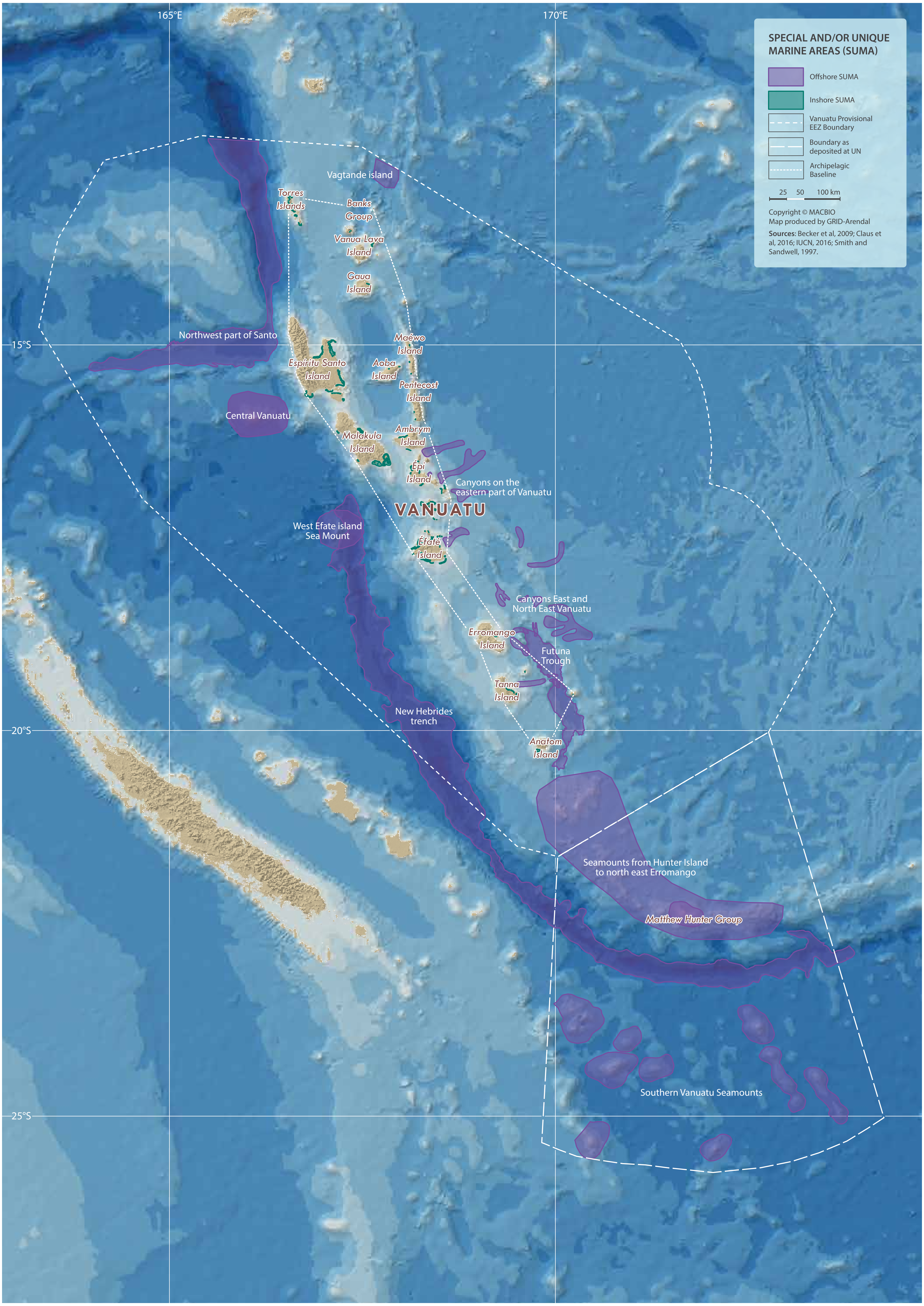
In 2011, the Secretariat of the Convention on Biological Diversity hosted a regional workshop to facilitate the description of EBSAs for the western South Pacific Ocean (CBD, 2012). One EBSA was identified, and subsequently approved by the CBD.

New Hebrides Trench Region: While the main feature of this EBSA is the New Hebrides Trench (a large oceanic trench between New Caledonia and Vanuatu), it also includes lower bathyal and abyssal depth features, seamounts, and hydrothermal venting sites. Extending beyond the provisional EEZ into part of New Caledonia, the region is notable for being the likely spawning ground of three species of freshwater eel that migrate from Australia and New Zealand (Jellyman & Bowen, 2009). The deep-sea fish fauna of this trench differs from the community structure of other South-West Pacific trenches (Linley et al., 2017), with trench environments generally recognized as hosting endemic species of snailfish, as well as other fauna that are unique to individual trenches due to their isolation (Jamieson, 2015).

There are 28 KBAs in Vanuatu (Birdlife International, 2018a), which include both terrestrial and marine species. Within these KBAs are 12 IBAs, which are largely defined on the basis of their importance for globally threatened species (defined in the IUCN Red List as critically endangered, endangered or threatened). Most of these areas are on the islands themselves, but have relevance for seabird species. These include Vanua Lava, which is a breeding ground for the white-necked petrel; Mount Sereama on Vanua Lava, a breeding site for collared petrel and white-necked petrel; Green Hill and Mount Tokusmera on Tanna which has a breeding colony of Polynesian storm petrel; Aneityum, also a breeding location for Polynesian storm petrel; Tongoa Laika, which hosts a large colony of wedge-tailed shearwaters; and the Vatthe Conservation Area, which has a very high diversity of both land and marine birds, and is a prospective World Heritage site on account of both its flora and fauna.

EBSAs and KBAs have no official management status, but are components of efforts by the CBD and International Union for Conservation of Nature (IUCN) to identify species that should be prioritized for conservation based on their ecological roles, cultural significance, uniqueness (e.g. endemics) and rarity (e.g. threat status on the IUCN Red List) and to describe the marine habitats in which these species are likely to be found, and which may therefore need protection.

Vanuatu's KBAs are important habitats, e.g. for bird nesting, benthic and pelagic species.


SPECIAL AND/OR UNIQUE MARINE AREAS (SUMA)
Offshore SUMA
Inshore SUMA
Vanuatu Provisional EEZ Boundary
Boundary as deposited at UN
Archipelagic Baseline
25 50 100 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; Claus et al, 2016; IUCN, 2016; Smith and Sandwell, 1997.
165°E
170°E
15°S
20°S
25°S
Vagtande island
Torres Islands
Banks Group
Vanua Lava Island
Gaua Island
Northwest part of Santo
Maewo Island
Espiritu Santo Island
Aoba Island
Pentecost Island
Central Vanuatu
Ambrym Island
Malakula Island
Epi Island
Canyons on the eastern part of Vanuatu
VANUATU
West Efate island Sea Mount
Efate Island
Canyons East and North East Vanuatu
Erromango Island
Futuna Trough
Tanna Island
New Hebrides trench
Anatom Island
Seamounts from Hunter Island to north east Erromango
Matthew Hunter Group
Southern Vanuatu Seamounts

SPECIAL AND UNIQUE MARINE AREAS

To prioritize management and/or protection of Vanuatu's waters, local marine experts came together to identify areas in Vanuatu's waters that are special and/or unique.

Vanuatu's KBAs (see previous chapter) emphasize not only the importance of marine biodiversity to Vanuatu, but also to the world. Much of Vanuatu's waters contain very diverse physical and ecological environments, which in turn support a huge range of marine life, yet a great deal of these environments remain undocumented. As the resources of both the nearshore and offshore marine environments are vital to the well-being and prosperity of the country and its people, their sustainable management and conservation are in the interests of both resource managers and the general population.

So how can sustainable management be achieved? One requirement is to set agreed management priorities, which allow for an incremental, inclusive and sustainable management and conservation approach to Vanuatu's valuable biodiversity. To help achieve this, the important concept of KBAs was complemented and extended by the identification of Special and Unique Marine Areas (SUMAs) and bioregions (see "Beyond the hotspots").

SUMAs are areas that are particularly important in maintaining Vanuatu's biodiversity. They can serve as priority areas for management actions within Vanuatu's marine environment. It is important that these areas are identified and agreed upon by a broad cross section of local users and experts to ensure they have validity in relevant decision-making processes. Therefore, in 2017, local users and subject experts were brought together to share their knowledge and identify and map 108 SUMAs. This effort built upon and updated previous efforts, including the information on EBSAs.

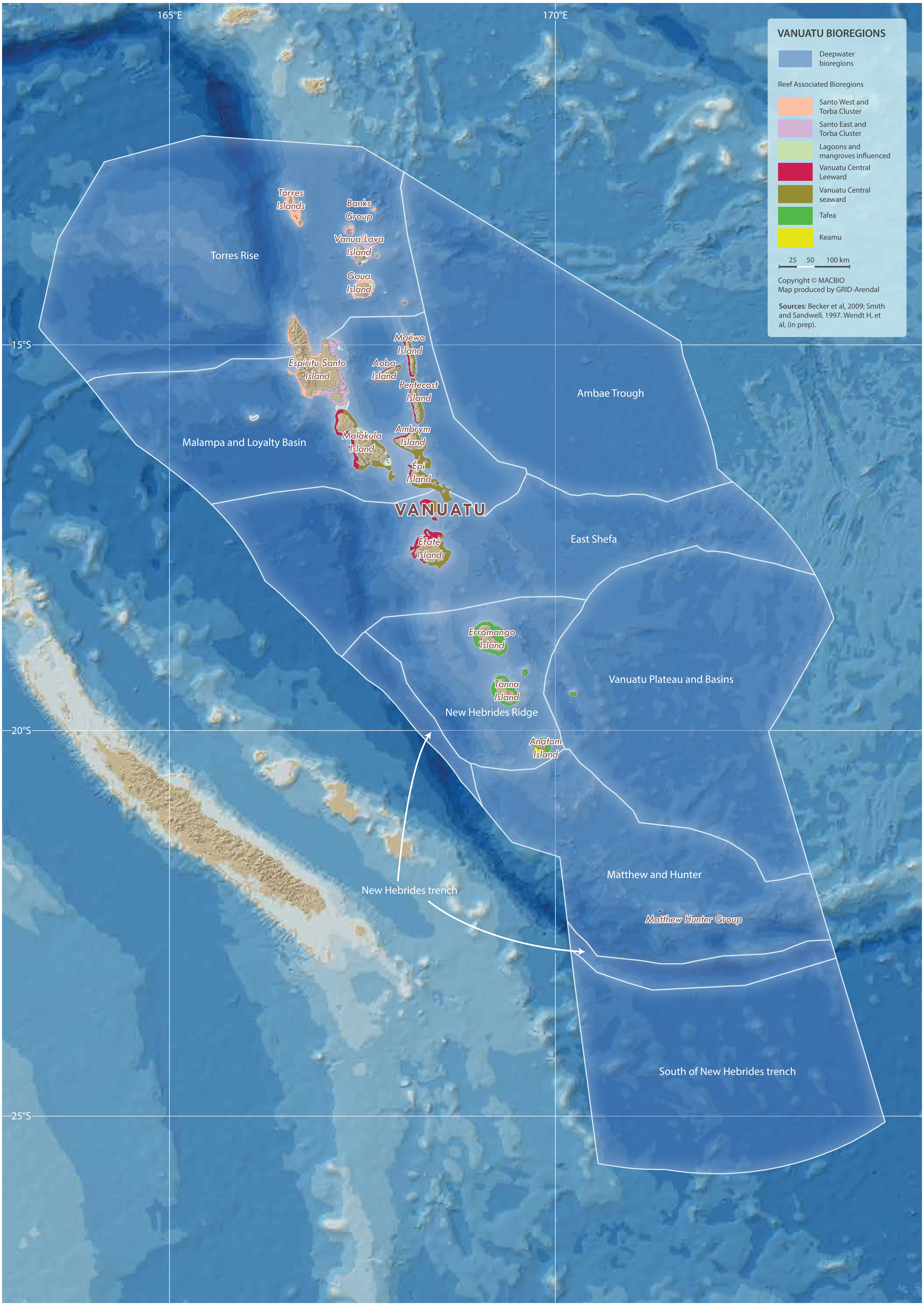
The local users and experts contributed their local knowledge of the area and were guided by four criteria in identifying SUMAs in Vanuatu's waters: biophysical justification, geographic explicitness, availability of information sources, and international and national obligations.

Ranging from mangroves and seagrasses to deep-sea trenches, canyons and seamounts, these marine areas are some of Vanuatu's most biologically important. These sites, together with the corresponding report "Biophysically Special, Unique Marine Areas of Vanuatu", will assist in the selection of marine managed protected areas, to achieve 10 per cent coverage of Vanuatu's waters (see also chapter "Vanuatu's commitment to marine conservation") (Sykes et al., forthcoming). Moreover, they provide site-specific information for local or national-level decisions, policies, plans or analyses that refer to marine places.

The maps show a total of 11 offshore and 89 inshore sites. These SUMAs reflect the immense variety of marine habitats within the Vanuatu islands, reefs and surrounding oceans. Much of this information has been published in formal papers and reports, but there is also a great vein of local knowledge held by the traditional resource owners themselves, which should be taken into account when describing what is special and unique.

Special and unique: Mystery Island

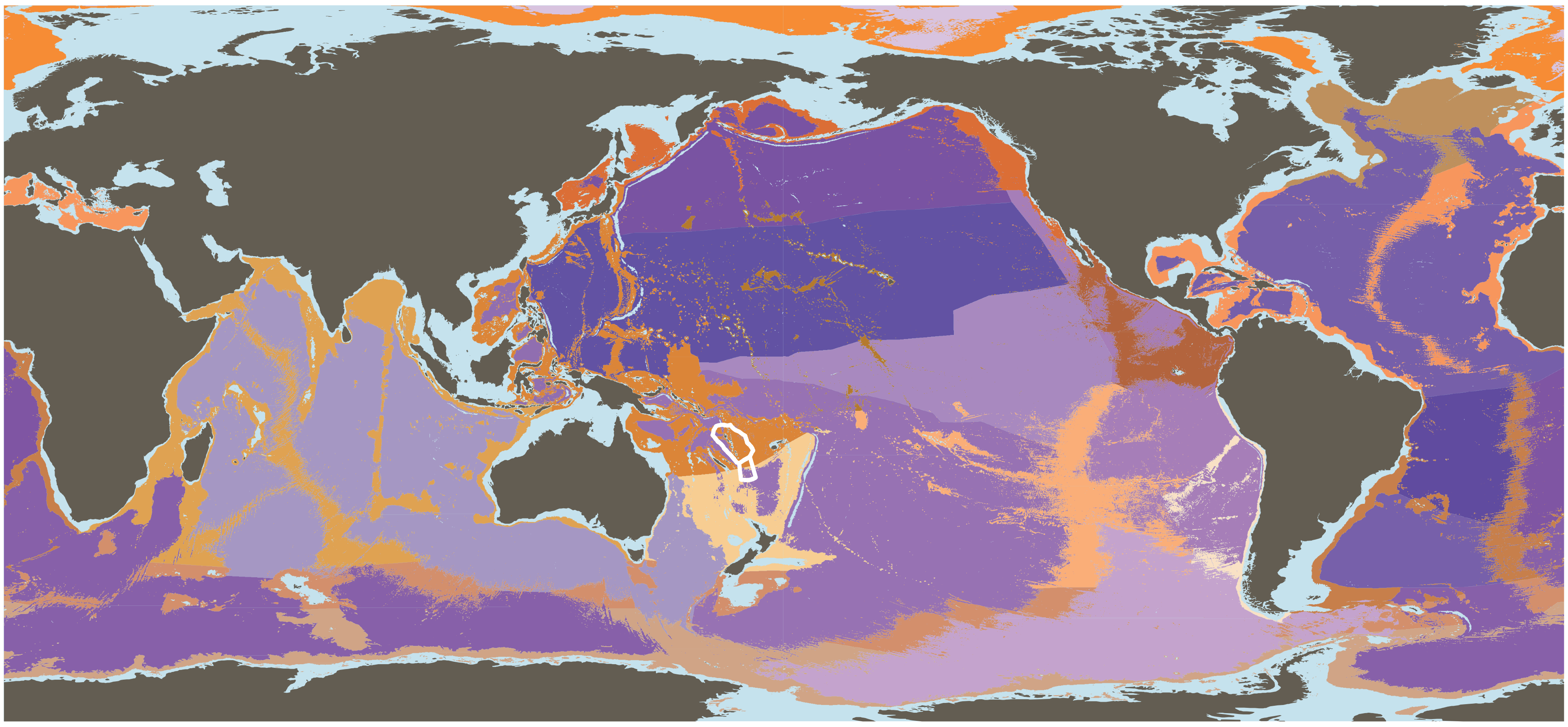
Located on the southernmost point of the Vanuatu archipelago, Mystery Island is one of the 100 Special and Unique Marine Areas (SUMAs) in Vanuatu's waters. This little jewel of the South Pacific is completely uninhabited. Locals come across the waters from mainland Aneityum to enjoy the island and are often joined by cruise ship tourists. It has benefited from its status as a popular tourism destination, with the waters surrounding the island protected from fishing. Therefore it has reefs in good condition, seagrass beds, more than 115 green sea turtles, populations of grazing fish and a giant clam garden. There has been a measurable increase in populations of exploited species and general reef condition since its protection from fishing. This shows how conservation and tourism (see also chapters "Beyond the beach" and "Space to recover") can go hand in hand to preserve places such as Mystery Island.



VANUATU BIOREGIONS
Deepwater bioregions
Reef Associated Bioregions
Santo West and Torba Cluster
Santo East and Torba Cluster
Lagoons and mangroves influenced
Vanuatu Central Leeward
Vanuatu Central seaward
Tafea
Keamu
25 50 100 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; Smith and Sandwell, 1997. Wendt H, et al, (in prep).
165°E
170°E
15°S
20°S
25°S
Torres Islands
Banks Group
Vanua Lava Island
Gaua Island
Torres Rise
Maéwo Island
Espiritu Santo Island
Aoba Island
Pentecost Island
Ambae Trough
Malampa and Loyalty Basin
Ambrym Island
Malakula Island
Epi Island
VANUATU
East Shefa
Efaté Island
Erromango Island
Tanna Island
Vanuatu Plateau and Basins
New Hebrides Ridge
Anatom Island
Matthew and Hunter
New Hebrides trench
Matthew Hunter Group
South of New Hebrides trench

BEYOND THE HOTSPOTS: BIOREGIONS

Ideally ecosystem-based marine planning should be based on comprehensive data that represents all of Vanuatu's marine plants and animals. This data, however is rarely available for any country. To overcome this limitation, surrogates can be used to classify the marine environment into spatial units, or bioregions, that host similar plants and animals.



The GOODS biogeographic classification from 2009 is an example of a global bioregionalization.

To sustainably manage and protect Vanuatu's rich marine recourses, its government is committed to delivering a comprehensive, ecologically representative network of managed and protected marine areas (see also chapter "Vanuatu's commitment to marine conservation"). Ideally ecosystem-based marine planning should be based on comprehensive biodiversity data that represent all of Vanuatu's marine plants and animals in its entire marine environment.

While a lot of data are accessible—as the maps in this atlas show—comprehensive data are not available for any country, including Vanuatu. To overcome this limitation, surrogates must be used to classify the marine environment into spatial units, or bioregions, that can host similar plants and animals. These surrogates include factors such as salinity (see also chapter "Go with the flow"), pH (see chapter "Turning sour") or phosphate concentration (see chapter "The dose makes the poison"). Analysing and c lustering such data results in spatial units, called marine "bioregions". These bioregions present comprehensive descriptions of the marine biodiversity of Vanuatu and can be used for conservation, management and planning.

Such marine classification and the use of bioregions is not a new concept, as bioregions have been produced before at various scales in other countries, regions and globally, including some that encompass Vanuatu. The graphic provides one example of a global bioregionalization, the Global Open Oceans and Deep Seabed (GOODS) biogeographic classification, undertaken by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2009.

Classifications such as GOODS are very useful on a global scale. However, Vanuatu's large EEZ is divided into merely three bioregions, making the existing classifications of the marine environments, both coastal and offshore, too coarse to inform most national marine planning processes in Vanuatu. This calls for more detailed bioregions to inform marine planning. In 2016, in-country experts came together to describe preliminary marine bioregions for Vanuatu, supported by the MACBIO project. These include nine deepwater and seven coastal bioregions (Wendt et al., forthcoming), as shown on the map.

Using these bioregions as substitutes to describe the suite of marine biodiversity in Vanuatu, an ecologically representative system of managed and protected areas can be built. This is done by representing an example of every bioregion within an area, as well as examples of all known habitats and ecosystems (see also chapters "Nature's hotspots" and "Special and Unique Marine Areas"). The bioregional approach assists planners with the fact that not all habitats and ecosystems are known and mapped.


Port Vila, Vanuatu
23 to 25 November 2016

PLANNING

The previous section on “Valuing” revealed the diversity and richness of Vanuatu’s biophysical features, the ecosystems they underpin, and the many goods and services they provide to Vanuatu. This section will look at how the many human uses of these values interact and how these uses can be planned.

More than 98 per cent of Vanuatu’s total jurisdiction is ocean. The ocean is vitally important to Vanuatu, providing food and income, coastal protection, carbon storage, and essential habitat for marine plants and animals. Furthermore, coasts and oceans are heavily intertwined with Vanuatu’s cultures, traditional knowledge and practices, while the economic, social and ecological benefits provided by marine ecosystems are worth billions of dollars to Ni-Vanuatu every year.

Despite the high value of the ocean to Ni-Vanuatu, to date, national development and conservation planning has largely focused on land. However, recent studies show that better planning for oceans can bring significant economic, social and environmental benefits. Marine Spatial Planning (MSP) can help Vanuatu realize and maintain these benefits.

MSP is most useful if countries:

- have (or expect) human activities that adversely affect biodiversity in marine areas
- have (or expect) competing human activities within a given marine area
- need to decide which marine spaces are most suitable for new or additional economic development activities such as tourism, deep-sea mining or mariculture
- want to prioritize marine resource management efforts in parts of, or all, marine areas or
- need a vision or scenarios of what marine areas could or should look like in another 10, 20 or 30 years

MSP can help address these issues. Similar to land-use planning but relating instead to the sea, it is a tool in the marine resource management toolbox that also includes input controls (e.g. on fishing effort), process controls (e.g. permits) and output controls (e.g. quotas). MSP is an intersectoral and participatory planning process that seeks to balance ecological, economic and social objectives, aiming for sustainable marine resource use and prosperous blue economies.

The concept of MSP is not new and countries are already applying aspects of it, such as designated shipping lanes, fishing areas, locally managed marine areas, or MPAs. However, some of these existing examples have, at times, been declared opportunistically without an overarching and integrated planning process. When declared in isolation, individual spatial planning tools may not secure the ecosystem services that people rely on in the medium and long term.

A more comprehensive and integrated MSP process can support and guide sectoral planning efforts, but does not replace sectoral planning. A more holistic MSP process will reduce the conflicts between the marine environment’s different users and uses, while maximizing the social, economic and ecological benefits people receive from the ocean.

The maps in this chapter show how Vanuatu can plan the uses of the rich values its marine ecosystems provide, be it fishing, tourism, mining or vessel traffic. At the same time, MSP is also a powerful tool for avoiding conflicts and managing threats, such as marine debris, pollution or impacts from climate change, as featured in the maps.

Further reading: **www.macbio-pacific.info/marine-spatial-planning**

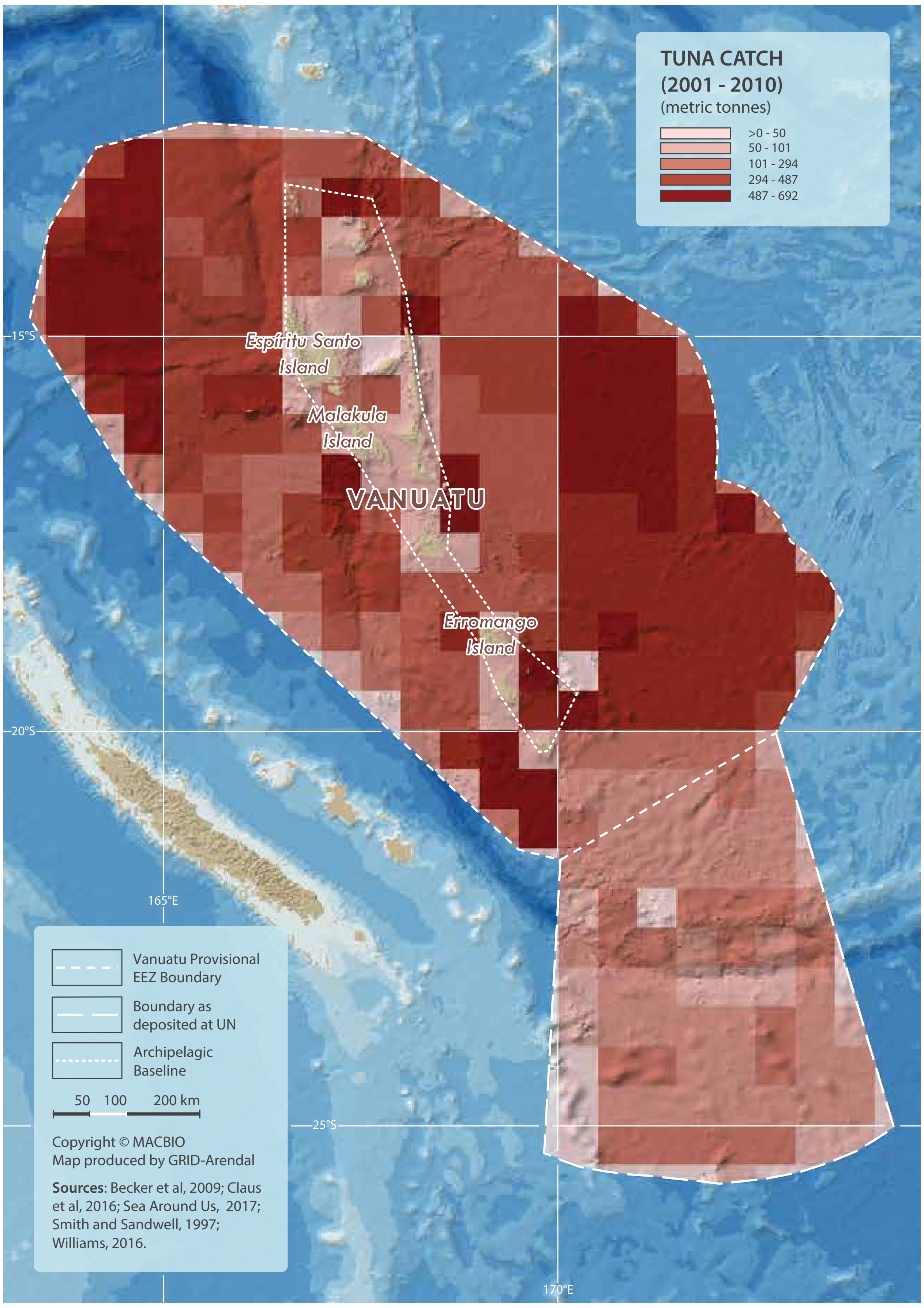
FISHING IN THE DARK: OFFSHORE FISHERIES

Large offshore fisheries are a very important resource for Vanuatu in terms of income and economic development, as well as local employment and food. Knowledge of the distribution and catch is crucial in ensuring these fisheries are sustainable.

A very important use of the ocean that immediately comes to the mind of every Ni-Vanuatu is fishing. There are two different types of fisheries in Vanuatu: those close to the shore (see also chapter "Small fish, big importance") and those offshore (see also chapter "Travellers or homebodies"). Commercial offshore fisheries are primarily based on tuna harvest and are worth VUV 208 million per year, compared to inshore fisheries with a total of VUV 995 million per year (Pascal, 2015).

Tuna are the basis of important commercial fisheries for many island nations in the South-West Pacific. Typically four main species are taken: skipjack (*Katsuwonus pelamis*), albacore (*Thunnus alalunga*), bigeye (*Thunnus obesus*), and yellowfin (*Thunnus albacares*). The abundance of these species varies throughout the region, as do fishing methods such as purse seine, longline and pole-and-line. The fisheries are managed by the Western and Central Pacific Fisheries Commission (WCPFC) and cover the entire western Pacific Ocean to longitudes of 150°W in the North Pacific and 130°W in the South Pacific. Typically, there are 3,000–4,000 vessels operating each year, and the total tuna catch exceeds 2 million tons per year.

Tuna fishing provides a major source of income to Vanuatu through the licencing of foreign and joint-venture vessels to catch tuna within Vanuatu's waters. Although tuna is generally landed in other countries for processing, it is nevertheless the largest marine export, and the highest contributor to fisheries-based revenue for the nation.



Knowledge of the catch composition, amounts and distribution is necessary to understand how best to balance the exploitation of such fishery resources with the conservation of stocks, while considering other marine resources and values for the islands. The map shows the distribution of all tuna catches over the period from 2001 to 2010 in the provisional EEZ of Vanuatu. A number of valuable non-target billfish species were also captured within tuna fisheries.

Longline fisheries were very active over the 2001–2010 period, with between 26 and 73 vessels per year reported to be involved in longlining (WCPFC, 2017), targeting albacore, bigeye and yellowfin tuna. Over this period, the total catch of albacore was approximately 82,000 tons, making up 78 per cent of the line-caught tuna catch, followed by bigeye (13 per cent) and yellowfin (9 per cent). Commercial billfish species taken in the fisheries include blue marlin (*Makaira nigricans*), black marlin (*Makaira indica*), striped marlin (*Kajikia audax*) and swordfish (*Xiphias gladius*). Reported catches of these species by the Pacific community over this period totalled over 6,000 tons, 6 per cent of the tuna catch.

The largest tuna fishery covered by vessels registered to Vanuatu is the purse seine fishery. Vessel numbers increased from two in 2001 to 10 in 2007, before reducing again, with only three vessels fishing in 2014–2016. Skipjack is the main species caught by purse seine (about 313,000 tons, 76 per cent of the total purse seine tuna catch between 2001 and 2010), followed by yellowfin (84,000 tons, 20 per cent), and bigeye (15,000 tons, 4 per cent). Skipjack catches exceeded 50,000 tons each year in 2005, 2006 and 2007, but have since declined to current catch levels below 10,000 tons per year (WCPFC, 2017).

Most of the tuna catch occurs in areas towards the edge of the provisional EEZ boundary, far from the main island ridge, with catches concentrated in the northwest and east. Unlike some other Pacific Island nations, catches do not appear to be closely correlated with seamounts, even though these are known to host higher catch rates of yellowfin and, to a lesser extent, bigeye tuna (Morato et al., 2010).

All the tuna species are widely distributed. Given the significant proportion of the fisheries based on albacore, it is important to note that a South Pacific stock of albacore is distributed between 10°S and 50°S, spawning between latitudes of 10°S and 25°S. More juveniles are found in surface waters at higher latitudes, while adults tend to be found deeper in subequatorial waters. Adults appear to have a seasonal migration pattern, moving south for feeding during early summer and north for spawning in winter. Skipjack spawning occurs in the central Pacific throughout the year, near the equator. Hence some skipjack can migrate long distances, but their movement patterns are not well understood. Both depth and seasonal distribution therefore need to be considered in the spatial management of tuna fisheries.

The distribution of tuna and their fisheries is influenced by oceanographic events, particularly the El Niño–Southern Oscillation (ENSO) period. Fish distribution is also expected to shift with climate change, potentially moving to the east and to higher latitudes (Lehodey et al., 2011). Climate change may also lead to a shift in skipjack spawning grounds. Climate change may negatively affect yellowfin, but have a positive effect on albacore fish stocks around Vanuatu. In short, environmental change should be a factor considered in longer-term management scenarios.

With much of the fish catch being taken by large foreign vessels, licence fees increased in 2015 in a bid to increase revenue while ensuring the fisheries' long-term sustainability. The importance of both purse seine and longline fisheries to different species means that national and regional conservation efforts must carefully manage different fishery characteristics to ensure they are sustainable in the long term.

While tuna is the main large-scale fishery resource in Vanuatu's waters, deepwater fisheries extending beyond the reef and onto the upper slope are a small but important resource for Vanuatu in terms of fishery employment (for small local operators and artisanal fishers) and local food. Over 100 small boats are involved in fishing for deepwater snapper, with several larger vessels fishing offshore and deepwater snapper continuing to be an important catch around the main islands, where they support domestic and some small export markets (SPC, 2013a). However, as deepwater species are often vulnerable to overfishing, careful management is required to ensure such fisheries are sustainable.

Deepwater snapper inhabit reef slopes and shallow seamounts that rise to between 100 metres and 400 metres below the surface. Commercial line fishing for these species has been undertaken around the Pacific Islands for several decades. Over 20 west-central Pacific countries and territories either have active deepwater snapper fisheries, have historically participated in deepwater snapper fishing, or have expressed some interest in developing this capacity (Williams & Nicol, 2014).

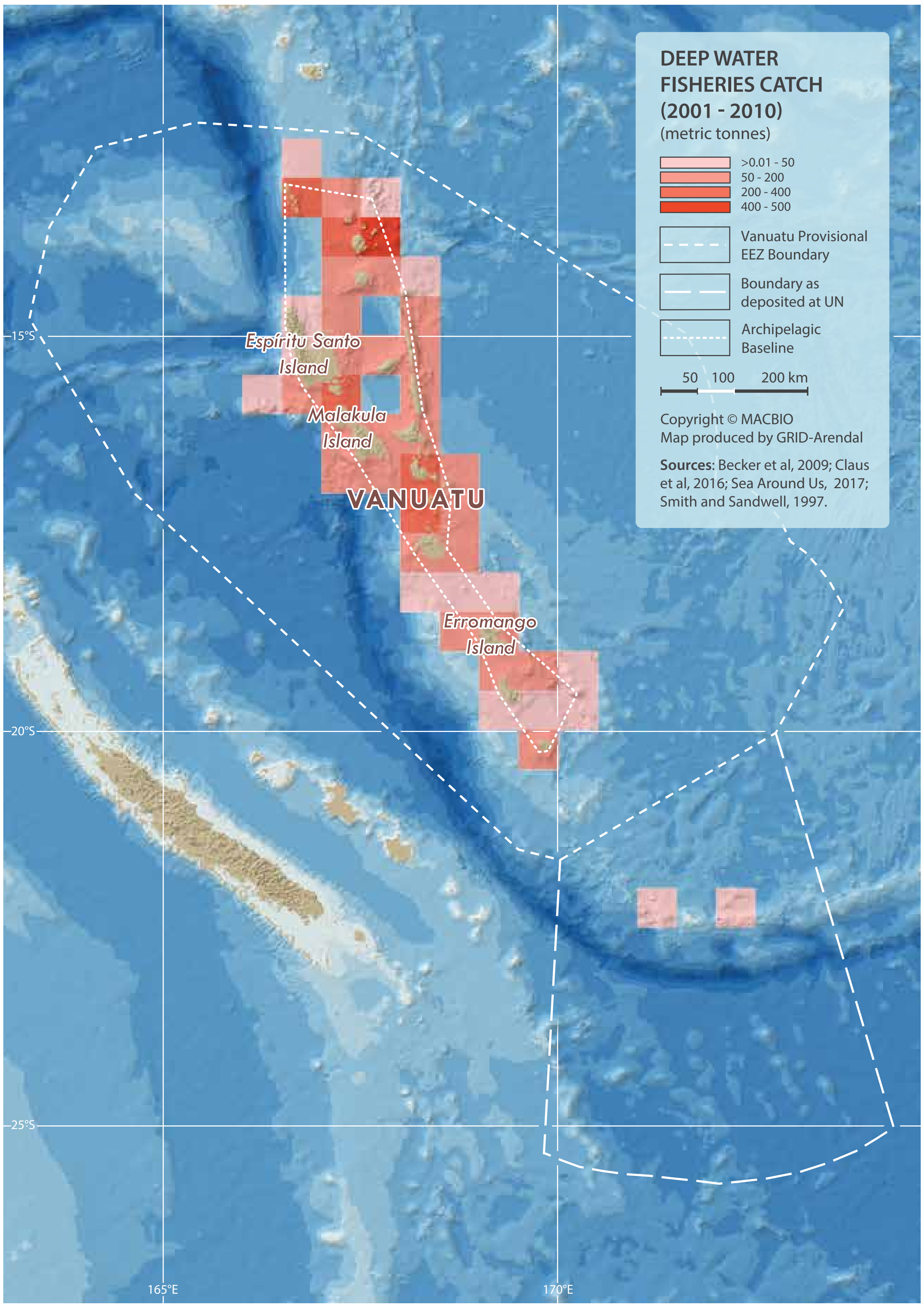
The map shows historical catches over the 2001–2010 period for deepwater fisheries around the islands of Vanuatu, based on FAO data and national reports. Of the 100-plus species caught in these deepwater demersal fisheries, the majority are snappers from the Lutjanidae family (primarily the genera *Etelis* and *Pristipomoides*, but also some *Lutjanus* species (around 100 metres depth)), Serranidae (groupers of the genera *Epinephelus* and *Variola*) and *Lethrinidae* (McCoy, 2010, SPC 2013b). Amberjacks (genus Seriola) also feature in the estimated catch records. The catches are dominated by the snappers *Pristipomoides filamentosus, Etelis coruscans* and *E. carbunculus*, which account for around 60 per cent of the total deepwater catch over the period mapped here, averaging around 400 tons per year. Most of the catch occurs close to the islands, on the deep slope as the bathymetry drops to abyssal depths, although some more isolated seamounts are also fished.

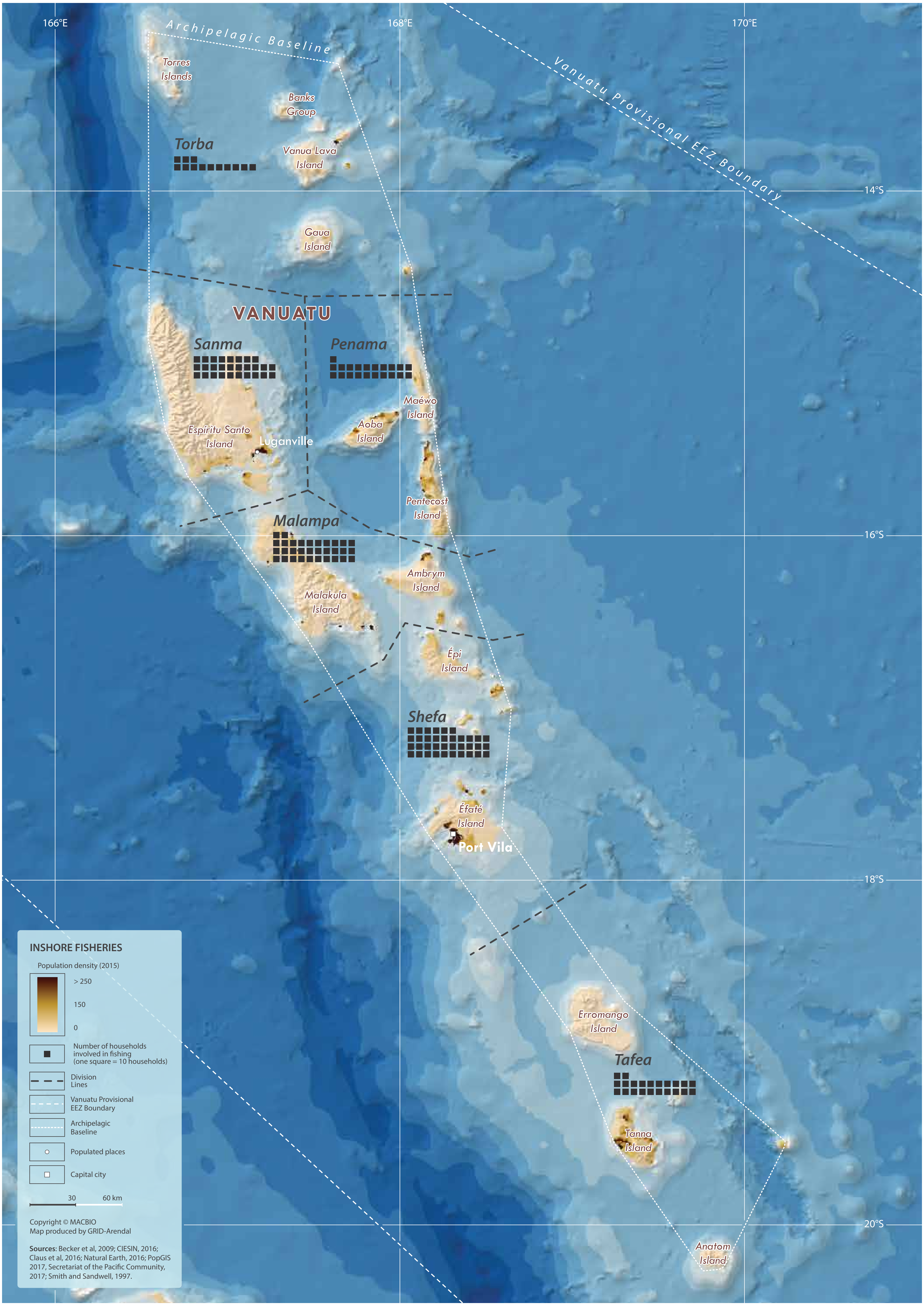
Line fishing is the main method used for these species. The gear used includes hand-reels and powered reels, with some commercial bottom longlining and trotlining. Deepwater snapper fishing was promoted in the 1980s by the SPC, and was also researched by ORSTOM in New Caledonia. Vanuatu was actively engaged in the deepwater snapper fishery (Dalzell & Preston, 1992), with the rapid development in the 1980s of many small fishery operations.

There have been several attempts to estimate maximum sustainable yield (see Dalzell & Preston, 1992), with annual tonnages ranging from 100 tons to 800 tons, although 300 tons is a more likely upper limit (SPC, 2013b). The data set on all known deepwater snapper location records compiled by Gomez et al. (2015) was used with fisheries and oceanographic data to model the distribution of 14 deepwater snapper species. Results were based largely on depth, and indicated a potential total biomass of 980 tons. However, there are currently no reliable estimates of sustainable levels of catch and effort, and a poor understanding of stock structure. Such fisheries in the region as a whole have struggled due to low catch rates following an initial fishing-down phase, variable export markets and prices, shipping costs and limited habitat area (McCoy, 2010). Deepwater snapper stocks are considered vulnerable to overfishing due to their localized seamount and slope distribution, high longevity, late maturity and slow growth (Williams et al., 2013).

Seamount features are recognized as important habitat for deepwater snappers, although typically around Vanuatu there is limited fishing effort offshore, with most catch being nearshore on the island slope. Snapper populations may be localized on slopes or seamounts, which can make them vulnerable to overfishing, as well as impacts from potential deep-sea mining for sea-floor massive sulfides or cobalt-rich crust (Clark et al., 2017). Improved knowledge of stock structure, and the degree of seamount-affinity, are issues of major relevance to management. The likelihood of restricted distributions of these deepwater species means there is a need to consider regulations specific to seamounts or to localized areas of suitable fish habitat, in order to reduce the risk of serial depletion that occurs when the fishery can move from one place to the next if total catch limits are set for a large area.

Deepwater fisheries over the period considered were a small but important resource for Vanuatu. However, little is known about stock structure, stock size, and productivity, thereby making the long-term sustainability of historic catch levels uncertain.

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VANUATU
Torres Islands
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Vanua Lava Island
Gaua Island
Torba
Sanma
Penama
Espíritu Santo Island
Luganville
Aoba Island
Maéwo Island
Pentecost Island
Malampa
Ambrym Island
Malakula Island
Épi Island
Shefa
Éfaté Island
Port Vila
Erromango Island
Tafea
Tanna Island
Anatom Island
INSHORE FISHERIES
Population density (2015)
> 250
150
0
Number of households involved in fishing (one square = 10 households)
Division Lines
Vanuatu Provisional EEZ Boundary
Archipelagic Baseline
Populated places
Capital city
30
60 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; CIESIN, 2016; Claus et al, 2016; Natural Earth, 2016; PopGIS 2017, Secretariat of the Pacific Community, 2017; Smith and Sandwell, 1997.

SMALL FISH, BIG IMPORTANCE: INSHORE FISHERIES

Catch from Vanuatu's inshore fisheries is eaten locally and sold on the market. While inshore fisheries are relatively small, they are much more valuable to Vanuatu than its offshore fisheries. However, to maintain these benefits, sustainable management of dwindling inshore resources is key.

Almost all of Vanuatu's 1.3 million km^2 of marine water is classed as offshore (99 per cent), as opposed to inshore (1 per cent) (see also chapter "Vanuatu's commitment to marine conservation"). It would therefore be easy to assume that most of Vanuatu's fish were caught in the vast offshore area, and would produce by far the highest value for the country. However, this is not the case, with over 80 per cent of fisheries value produced by inshore fisheries, to the tune of VUV 995 million per year (Pascal, 2015) (see also chapter "Fishing in the dark").

Vanuatu's inshore fisheries can be divided into two broad categories: subsistence fishing and commercial fishing. Subsistence fishing is the use of marine and coastal resources by local populations directly for food or trade, rather than for profit. It typically occurs when these products are consumed by the fisher or their family, given as a gift or bartered locally. In Pacific Island countries, coral reef fisheries are characterized by a strong predominance of subsistence fishing, with an estimated 80 per cent of coastal fisheries' catch consumed directly by the fisher and their communities. In Vanuatu, over 60 per cent of the inshore catch is taken directly by the community for subsistence, with rural households taking over 93 per cent of this catch (Table 1). This underlines how vital inshore fisheries are to the people of Vanuatu, particularly those in rural and remote areas, who often rely on them for nutrition and income.

Sadly, inshore fisheries are some of the most vulnerable to climate change, natural disasters and direct anthropogenic pressures. Vanuatu's reefs are at risk of serious degradation, and it is predicted that if the current trends continue, there will be a 20 per cent reduction in the productivity of Vanuatu's inshore fisheries by 2050 (NAB, n.d.). The ongoing deterioration of inshore fisheries will have severe implications for food security in Vanuatu and for the social order of many Ni-Vanuatu communities (ACIAR, 2012).

The inshore commercial fisheries target a range of different species including reef fish, deep slope fish, crabs, lobsters (which together constituted 63 per cent of the total value added catch for inshore commercial fisheries in 2014 (Table 1)), trochus and bêche-de-mer (sea cucumber). The game-fishing sector is also of high value, constituting 31 per cent of total commercial fisheries value in 2014 (Table 1). Only the offshore foreign-based fishing sector has a higher production volume and value than the inshore subsistence sector, with the inshore commercial sector following closely behind (Gillett, 2016). An unpublished Vanuatu Fisheries Department report showed that, for 2014, Vanuatu-sourced aquarium products had an export value of VUV 801,772 (Gillett, 2016).

Table 1. Vanuatu inshore fisheries statistics 2014

	Catch Volume (mt)	Annual Value-Added (US$)
Subsistence		
Rural	2,600	6,050,000
Urban	200	440,000
Total	**2,800**	**6,490,000**
Commercial		
Reef fish, deep slope fish, crabs and lobster	1,720	3,300,000
Trochus and similar	28	100,000
Bêche-de-mer	40	50,000
Aquarium trading	0	150,000
Game fishing	70	1,600,000
Total	**1,858**	**5,200,000**

Source: Pascal et al. (2015)

Table 2. Percentage and number of households involved in marine fishing activities by province

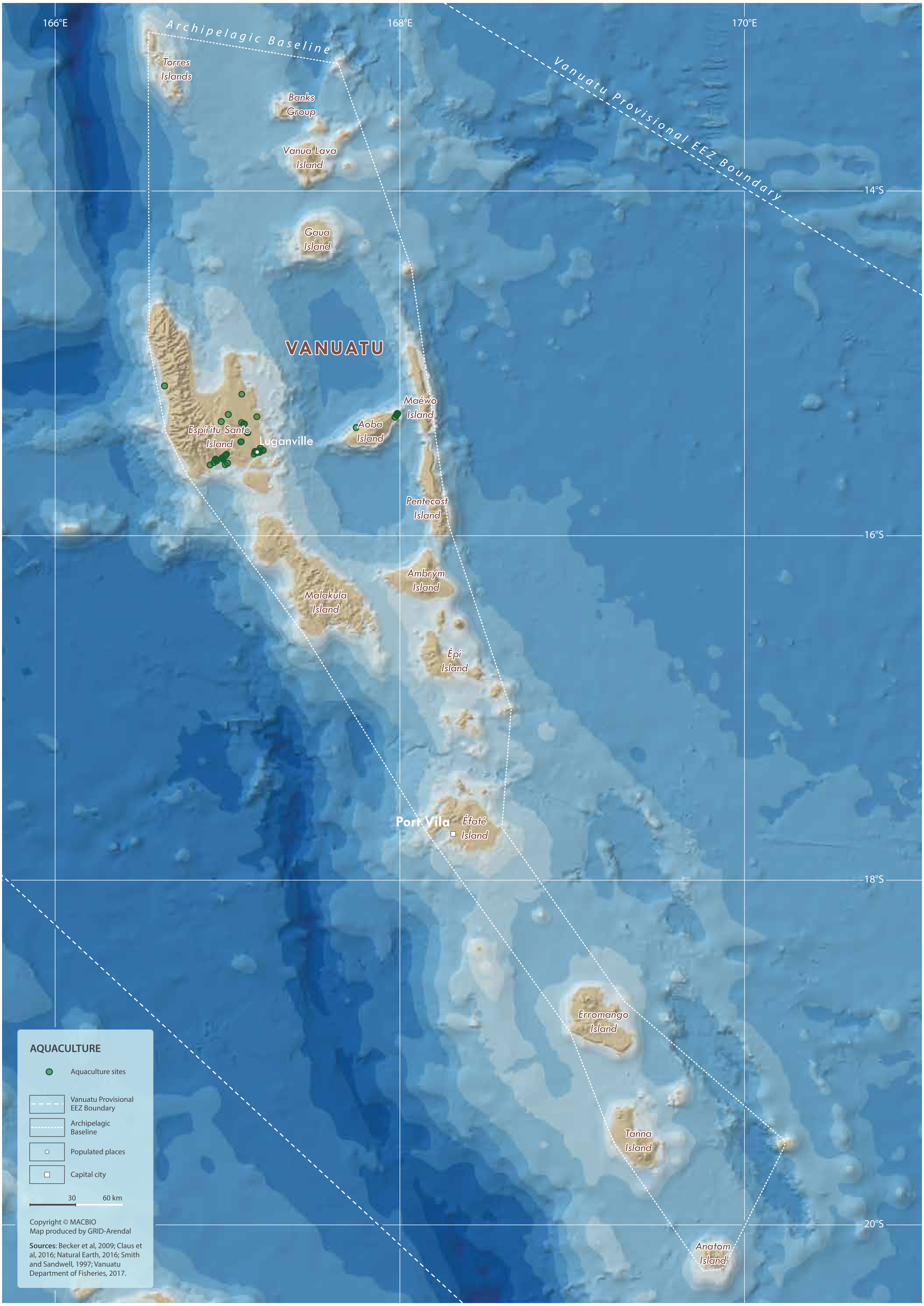
Province	Percentage	Number
Torba	76.8	1,332
Sanma	48.7	2,801
Malampa	46.1	3,250
Shefa	43.3	3,609
Tafea	43.1	2,243
Penama	36.1	2,125
Total		**15,360**

Source: PopGIS n.d.

Specific areas with particularly high numbers of people involved in fishing are Northwest Santo, South Maewo, South Malekula, North Erromango, South Erromango and Aneityum (Gillett, 2016). Conversely, Torba Province, which has the lowest number of households involved in fishing, has the highest percentage of households involved in activities related to marine fishing, at nearly 77 per cent (Table 2). The 2010 Vanuatu Household Income and Expenditure Survey found that 2 per cent of urban households and 12 per cent of rural households receive income from the sale of fisheries products. Pascal et al. (2015) showed that 15,500 households (approximately 30 per cent of all households in Vanuatu) and 74,000 individuals fish reefs and mangroves as a regular source of protein. In many areas, 100 per cent of households are involved in reef fisheries, which many consider to be their most important source of income (Gillett, 2016). Interestingly, around 60 per cent of the fish consumed on Efaté comes from other islands (Gillett, 2016).

Community-based management through traditional governance is common in Vanuatu, and its primacy typically increases with remoteness. There are examples throughout the country of community-implemented closed seasons and areas, taboo species, and gear and access restrictions (Vanuatu Kaljoral Senta, n.d.). Effective community-based management in Vanuatu is essential to ensuring the sustainability of many inshore subsistence fisheries. Since no significant revenue is generated, these fisheries often receive less policy attention than commercial fisheries. It is therefore important to support and strengthen these systems by introducing fisheries science in a way that they can accept and that can be useful to them.

Sea cucumber, or bêche-de-mer, is an important inshore fishery in Vanuatu.



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AQUACULTURE
Aquaculture sites
Vanuatu Provisional EEZ Boundary
Archipelagic Baseline
Populated places
Capital city
30
60 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; Claus et al, 2016; Natural Earth, 2016; Smith and Sandwell, 1997; Vanuatu Department of Fisheries, 2017.

FISH FROM THE FARM: AQUACULTURE

Aquaculture has faced many challenges in Vanuatu over the years. Although successful fish farms do exist, Vanuatu's aquaculture is declining and the true costs and benefits need to be carefully assessed.

The farming of seafood, known as aquaculture, can be practised in either fresh water or saltwater, the latter of which is also known as mariculture (see map).

The further development of aquaculture in Vanuatu could contribute to food security, sustainable livelihoods and economic growth for current and future generations. At present, the gap between the sustainable supply of seafood from wild fisheries and food security demands is growing. The Vanuatu Fisheries Department (VFD) is therefore focused on effective fisheries management, expanding aquaculture and improving the sector's efficiency.

Aquaculture can have negative impacts on Vanuatu's marine ecosystem, including pressure on wild fish used for fish feed, escape of introduced aquaculture species, interbreeding of farmed fish with wild fish, pollution and habitat loss. For example, mangroves are cut to develop shrimp farms, resulting in loss of this key coastal habitat (see also chapter "Home, sweet home"). There is therefore a need for clear priorities when expanding aquaculture to minimize any adverse environmental impacts.

A brief history of aquaculture in Vanuatu (SPC, 2011; Vanuatu Department of Fisheries, 2008):

Mangrove oysters were the first organisms to be farmed in Vanuatu. They were introduced from the US in the 1920s, and again from Japan and the US in 1972. This was terminated, however, due to then-unavoidable introductions of pests with US-imported spat.

In the 1980s, giant freshwater prawns (*Macrobrachium rosenbergii*), also known as naura, were introduced and trialled as a potential aquaculture species. No successful production was achieved, however, due to land disputes and a lack of technical expertise.

The VFD began operating a small-scale top-shell trochus (*Trochus niloticus*) hatchery in 1985 to assess the practicality of reseeding and enhancing wild populations, and to conduct research into nutrition, seed production and community participation in trochus management. The hatchery's average annual output is around 20,000 seeds. These are primarily supplied to communities for restocking purposes. Top-shell trochus are exported to be processed into buttons for the fashion industry.

In 1996, a feasibility study into black-lip pearl oyster (*Pinctada margaritifera*) culture was conducted at Peskarus in the Maskelyne Islands. It was determined that stocks were insufficient to support a commercial farm.

In 1997, the VFD, in association with private operators, established a turtle nursery programme in response to regional concerns about turtles' vulnerability. As well as being an educational initiative, the programme raises juvenile turtles until they are large enough for release into the wild. Several nurseries are now operating.

Cottonii seaweed (*Kappaphycus alvarezii*) farming trials commenced in Vanuatu in 2000 as part of a regional effort to promote seaweed as an alternative livelihood in small island developing states. Trials were undertaken on Efaté, Malekula and Santo. While the culturing process was successful, communities lost interest due to the low levels of revenue generated. To be economically viable, seaweed must be produced in large quantities, yet the VFD was unable to provide the funding required for mass production.

In 2002, giant clams (*Tridacna gigas*) were grown at the VFD hatchery after restrictions had been placed on harvests for the aquarium trade. Unfortunately, the VFD was unable to secure sufficient funding to continue the programme. Operators in the private sector, however, are now successfully exporting giant clams for the aquarium market.

From 2003, green snail (*Turbo marmoratus*) production trials were conducted to assess the feasibility of reseeding heavily depleted wild stocks. These were unsuccessful due to significant rates of mortality in early larval stages.

Genetically improved farmed tilapia (GIFT)—a faster-growing strain of the Nile tilapia, *Oreochromis niloticus*—were introduced to Vanuatu from Fiji in 2004. The species is now one of the most farmed in the country. This followed the introduction of Mozambique tilapia (*Oreochromis mossambicus*) to Vanuatu in the early 1980s, which instead of being cultured for food, were introduced to still water bodies to control mosquitos. They are, however, still eaten by some inland communities.

Blue shrimp (*Litopenaeus stylirostris*) were successfully harvested and sold in 2005 by a private company. The freshwater Tahitian prawn (*Macrobrachium lar*) was also successfully reared to market size in earthen ponds in the same year. This species is known to have been previously grown on a subsistence basis in water taro fields.

Ornamental coral culture, mainly of the Scleractinia order, is undertaken by aquarium operators as a best-practice alternative to harvesting coral from Vanuatu's reefs. Corals are also cultured in several areas for restoration purposes.

The figures in Table 3 equate to approximately 43 metric tons (mt) and 27,300 pieces, with a farm-gate value of VT 39.3 million (Gillett, 2016). Overall, aquaculture is estimated to contribute 11 per cent of the total value added from fishing to Vanuatu's gross domestic product (GDP).

Tilapia is the second most farmed fish globally, and GIFT (*Oreochromis niloticus*) is an auspicious species for aquaculture in tropical developing countries. This is largely due to its uncomplicated production cycle, capacity to withstand or adapt to a wide variety of conditions, high survival rates and ample economic yield.

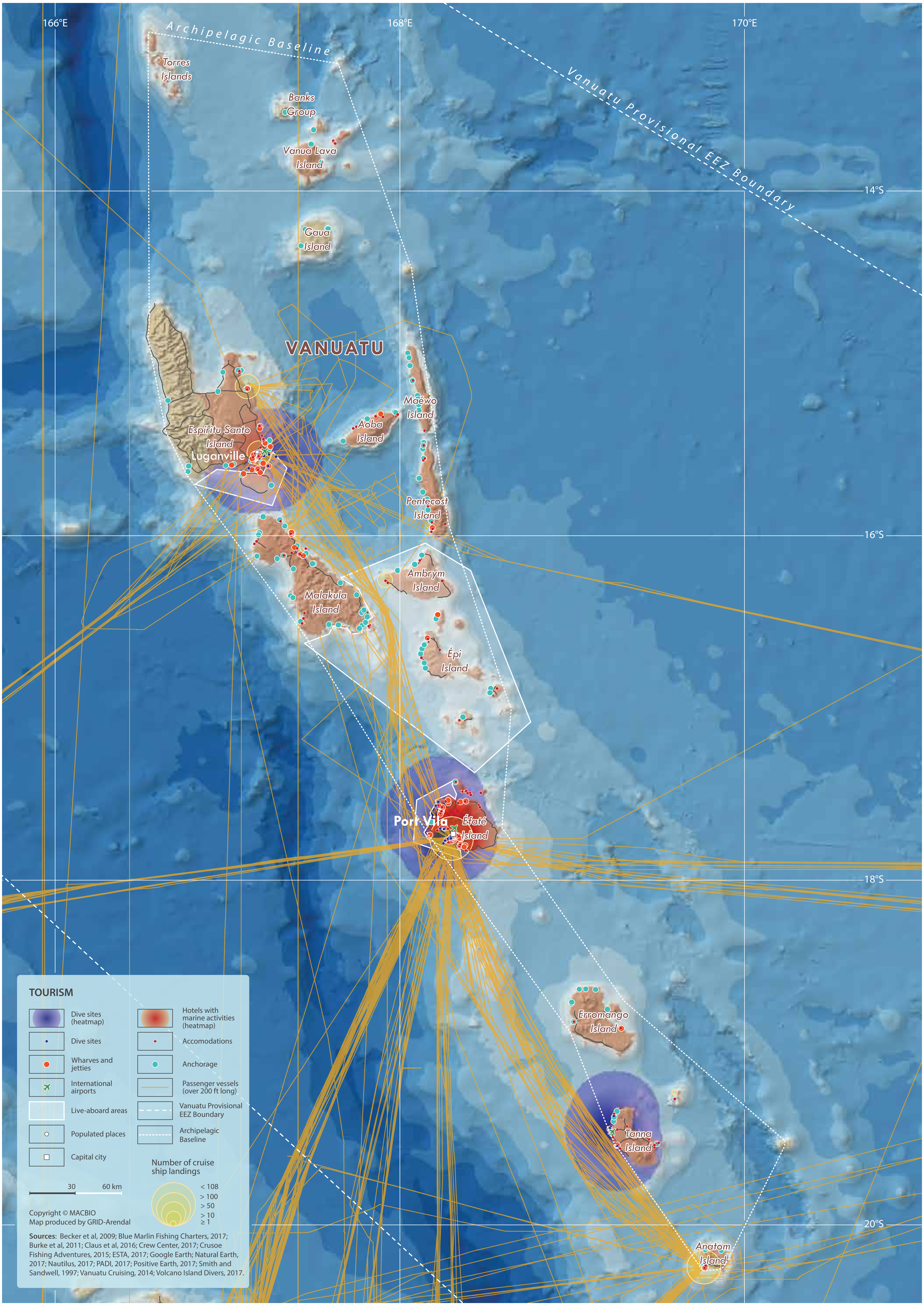
There are now many tilapia farms operating in Vanuatu across at least five provinces. The sector has grown substantially in recent years, a trend that the VFD and other agencies intend to see continue. For example, the northern VFD delivered more than 8,500 fry during the first half of 2017, compared to less than 4,300 in all of 2015 (Mr C Bosboom, pers. comm.). The continued expansion of tilapia aquaculture should relieve pressure on marine fish stocks, particularly those of frequently targeted nearshore and reef-associated species.

There are, however, some challenges and priority issues that must be addressed. These include the maintenance of genetic quality via, for example, regular complete harvests; the supply of sufficient water where not readily available, during the dry season and during El Niño periods; poor pond management practices lowering productivity and/or leading to ecologically harmful escapements; and the limited availability of hatchery facilities in particular regions (in northern VFD in 2016). For example, the El Niño-induced drought of 2015–2016 saw Sanma Province lose 40 per cent of its tilapia farms and Torba Province lose 95 per cent of its freshwater prawn farms.

Table 3. Current status of aquaculture production in Vanuatu

	Type of operation	Estimate of annual production	Farm-gate price	Annual production value (VT)
Tilapia	Commercial farms	30 mt	550 VT/kg	16,500,00
	Village ponds	1 mt	400 VT/kg	400,000
Prawns	Commercial farms	13 mt	1,700 VT/kg	22,100,000
	Village ponds	120 kg	1,500 VT/kg	180,000
Coral culture	One company	–	–	–
Giant clam	Govt. operation	300 pieces	300-500 VT/piece	120,000
Trochus	Govt. operation	25,000 pieces	–	–
Green snail	Govt. operation	2,000 pieces	–	–

Source: Gillett (2016)



166°E
168°E
170°E
14°S
16°S
18°S
20°S
Archipelagic Baseline
Vanuatu Provisional EEZ Boundary
VANUATU
Torres Islands
Banks Group
Vanua Lava Island
Gaua Island
Maéwo Island
Aoba Island
Espíritu Santo Island
Luganville
Pentecost Island
Ambrym Island
Malakula Island
Épi Island
Port Vila
Éfaté Island
Erromango Island
Tanna Island
Anatom Island
TOURISM
Dive sites (heatmap)
Hotels with marine activities (heatmap)
Dive sites
Accomodations
Wharves and jetties
Anchorage
International airports
Passenger vessels (over 200 ft long)
Live-aboard areas
Vanuatu Provisional EEZ Boundary
Populated places
Archipelagic Baseline
Capital city
Number of cruise ship landings
30
60 km
< 108
> 100
> 50
> 10
≥ 1
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Map produced by GRID-Arendal
Sources: Becker et al, 2009; Blue Marlin Fishing Charters, 2017; Burke et al, 2011; Claus et al, 2016; Crew Center, 2017; Crusoe Fishing Adventures, 2015; ESTA, 2017; Google Earth; Natural Earth, 2017; Nautilus, 2017; PADI, 2017; Positive Earth, 2017; Smith and Sandwell, 1997; Vanuatu Cruising, 2014; Volcano Island Divers, 2017.

BEYOND THE BEACH: MARINE TOURISM

Vanuatu's diverse and growing marine tourism sector is worth millions to the economy, accounting for around 20 per cent of GDP in 2012 (Ministry of Tourism, Industry, Commerce and Ni-Vanuatu Business, 2013). It requires careful management if it is to complement rather than endanger the very ecosystems it relies on.

Maintaining identity

Nguna and Pele have a strong traditional cultural identity surrounding turtle hunting. How can this identity be maintained while conserving these important marine species? And what role can tourists play? A turtle-tagging programme and awareness-raising activities have been established in the Nguna-Pele marine protected area, actively involving tourists. Over the years, many ecotourism visitors have sponsored sea turtles, contributing to increased household incomes and encouraging the younger generation to follow old customary practices of turtle hunting, but for conservation rather than consumption. This has resulted in the number of sea turtles consumed among all villages on the two islands dropping to under five per year. At the same time, the annual number of sea turtles tagged has quadrupled since this initiative was introduced, with hundreds of turtles now being monitored.

"Discover what matters" is Vanuatu's tourism slogan. The country's marine tourism and recreation activities include scuba diving, snorkelling, day boat charters, day tours and recreational boating, as well associated accommodation (Pascal et al., 2015). In 2012, 108,000 visitors arrived in Vanuatu by air and 213,000 by cruise ship (Ministry of Tourism, Industry, Commerce and Ni-Vanuatu Business, 2013). A moderate growth scenario predicted that annual arrivals may exceed 500,000 in 2018 (Ministry of Tourism, Industry, Commerce and Ni-Vanuatu Business, 2013). Outdoor activities and sightseeing are the focal points of tourism in Vanuatu, which directly supported 10,000 jobs (13.6 per cent of total employment) and contributed 44.5 per cent of GDP in 2016 (World Travel and Tourism Council, 2017).

The majority of tourism facilities are concentrated on Efaté, especially around Port Vila, Luganville and the east coast of Espíritu Santo, and on Tanna. There are also a smaller number of tourist facilities on Pentecost, Ambrym and Malekula, with very small operations on other islands. Visitors come to Vanuatu mainly through the three international airports: Bauerfield International Airport in Port Vila, Santo-Pekoa International Airport in Luganville, and Whitegrass Airport on Tanna. Bauerfield is the country's primary international airport, hosting direct flights to and from eight international locations, while there are smaller airports on many of the smaller islands, as seen on the map.

Cruise ships, ferries and yachts transport tourists through Vanuatu's waters, with eight cruise ship ports in Vanuatu. A total of 248 stops from 21 cruise ships occurred in 2017. Of these, 43 per cent were scheduled for Port Vila, 35 per cent for Mystery Island and 14 per cent for Champagne Beach (Crew Center, 2017). Over the past 10 years the number of cruise ship arrivals in Vanuatu has grown by an average of 15 per cent per year (Net Balance Management Group Pty Ltd, 2014). In 2013, more than 240,000 people came to Vanuatu by cruise ship, spending more than 490,000 passenger days on the islands (Net Balance Management Group Pty Ltd, 2014). In a 2014 report, Net Balance Management Group Pty Ltd found that cruise companies, their passengers and crew

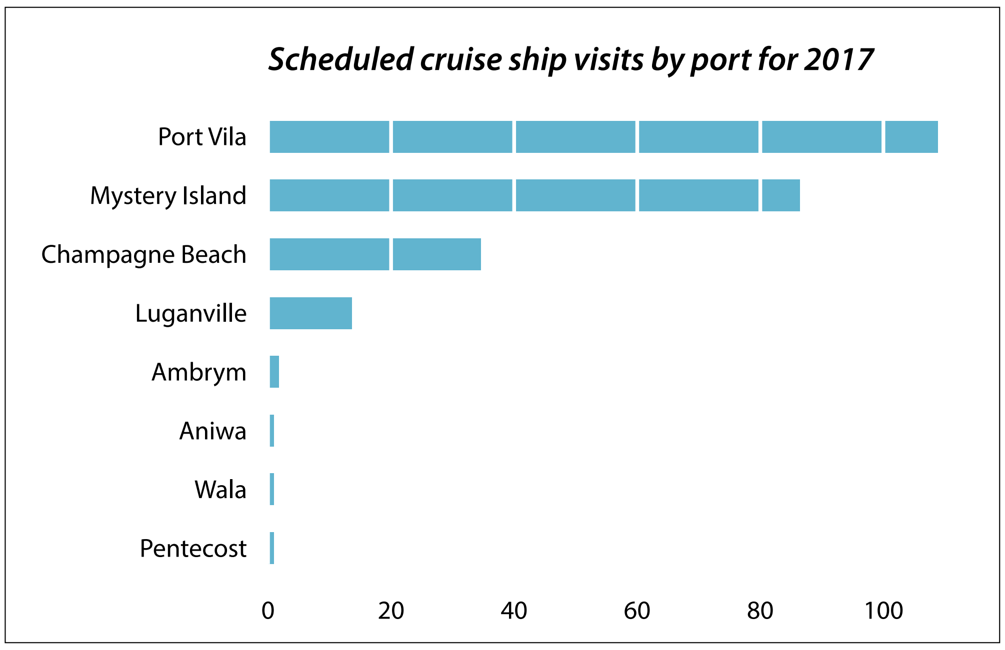
spent AUD $34.6 million in Vanuatu in 2013, estimated to increase to AUD $42.8 million in 2016.

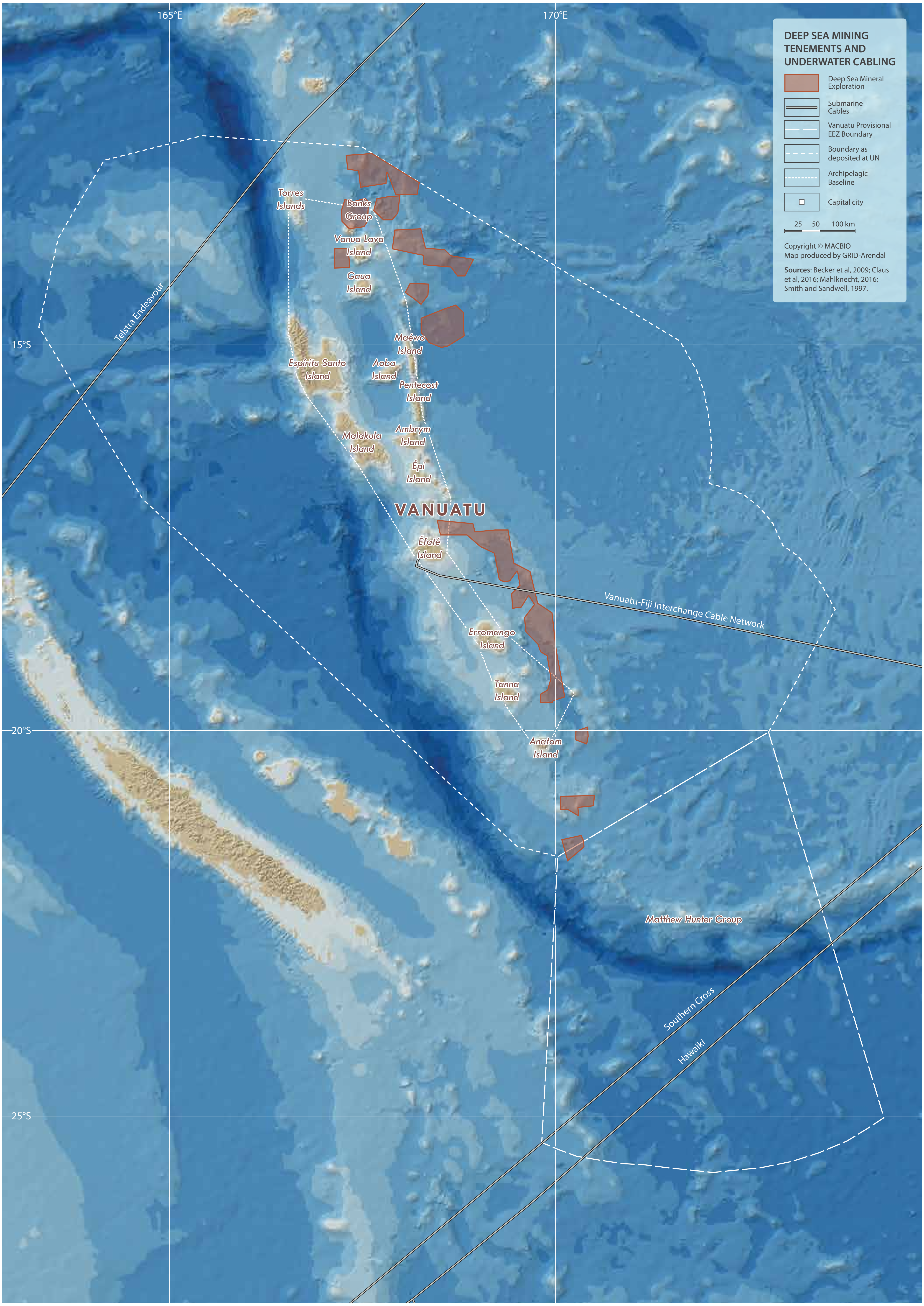
Private businesses receive 90 per cent of this expenditure. Additional indirect stimulus, resulting from second-round spending from those businesses benefiting directly from cruise-related activities, amounted to an estimated AUD $18.6 million. Each cruise ship voyage to Vanuatu brings an average of AUD $260,000 in spending, with each individual spending an average of AUD $125. Port Vila receives 85 per cent of this passenger expenditure. Additional economic benefits, such as destination development, are estimated at over AUD $30 million. In this way, the cruise ship industry is estimated to support up to 3,250 jobs in Vanuatu. The 2013 Vanuatu Cruise Survey showed that 90 per cent of cruise passengers to Vanuatu were from Australia.

There is also an abundance of yacht anchorages in all provinces of Vanuatu. These are shown on the accompanying map, which was compiled using information from Vanuatu Cruising (2014). There are also two established marinas in Vanuatu: the Point and the Yachting World Sea Wall, both of which are located in Port Vila.

Vanuatu is a world-renowned dive destination. The islands of Efaté, Santo and Tanna are home to the country's best and most visited dive sites. The variety of diving in Vanuatu is enormous, with reefs, wrecks and caves aplenty and all with an abundance of marine life. The wreck of the SS President Coolidge is consistently ranked as one of the best dive sites in the world. Approximately 47,000 dives by more than 9,000 divers were undertaken in Vanuatu in 2013 (Pascal et al., 2015), 65 per cent of which took place in Efaté (Pascal et al., 2015). Around 9,000 snorkelling trips were also undertaken. Although there are no live-aboard dive charters that consistently operate in Vanuatu, five companies run live-aboard fishing charters. These primarily operate around Efaté, South Malekula, the Maskelynes, Epi and the Shepherd Islands. The recent annual catch from game-fishing boats ranges from 48 mt to 64 mt (McCoy, 2013).

All of these activities make marine tourism an important sector for the Vanuatu economy, accounting for a total gross value of VUV 1.1 billion per year.



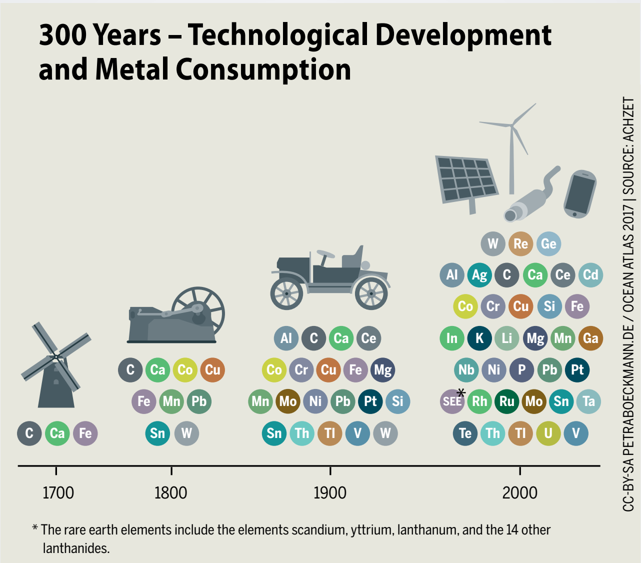

DEEP SEA MINING TENEMENTS AND UNDERWATER CABLING
Deep Sea Mineral Exploration
Submarine Cables
Vanuatu Provisional EEZ Boundary
Boundary as deposited at UN
Archipelagic Baseline
Capital city
25 50 100 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; Claus et al, 2016; Mahlknecht, 2016; Smith and Sandwell, 1997.
165°E
170°E
15°S
20°S
25°S
VANUATU
Torres Islands
Banks Group
Vanua Lava Island
Gaua Island
Maéwo Island
Espiritu Santo Island
Aoba Island
Pentecost Island
Ambrym Island
Malakula Island
Épi Island
Éfaté Island
Erromango Island
Tanna Island
Anatom Island
Matthew Hunter Group
Telstra Endeavour
Vanuatu-Fiji Interchange Cable Network
Southern Cross
Hawaiki

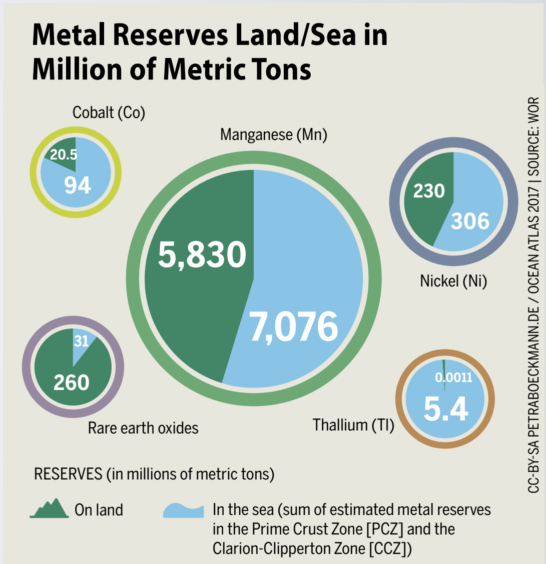
UNDER WATER WILD WEST: DEEP-SEA MINING AND UNDER WATER CABLING

Vanuatu's sea and coasts are rich with deep-sea minerals, petroleum, sand and gravel. These all need to be sustainably managed and a balance found between their overlapping uses.

Gold rush

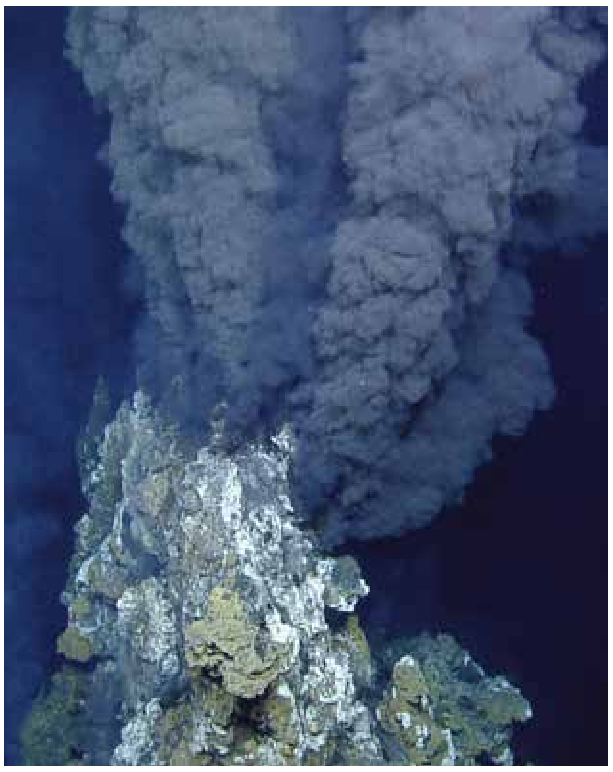
Is Vanuatu about to experience a gold rush, like California did in the 1850s, when over 300,000 people rushed to the Wild West with dollars signs in their eyes? While Vanuatu's land may be rich in many ways, gold is much scarcer. Instead, Vanuatu's gold rush could take place underwater to satisfy the world's hunger for minerals, given that many metal reserves are found in the sea (see graphic).





There are three main types of deep seabed mineral deposits: sea-floor massive sulfides, polymetallic manganese nodules and cobalt manganese crusts (rich in platinum and rare earth elements) found throughout the Pacific Ocean basin, including in the maritime jurisdictions of many Pacific Islands countries. Due to limited opportunities for economic growth in these countries, there is considerable interest from the leaders of these nations to develop this as a potential new industry to boost their economic development.

But Vanuatu is still waiting for its gold rush. In 2012, 154 prospecting licences for deep-sea minerals were granted within Vanuatu's waters, for mining companies to explore for seabed mineral deposits and collect samples to estimate their magnitude: 113 were held by Bismarck Corporation (Vanuatu) Ltd and 41 by Nautilus Minerals. Prospecting licences covering the exploration phase are granted for a period of three years, but can be renewed twice for a period of two years each time. Vanuatu has not accepted any new applications or renewals, and all seabed mining exploration licences expired in 2016, while deep-sea mineral extraction costs are still unknown.

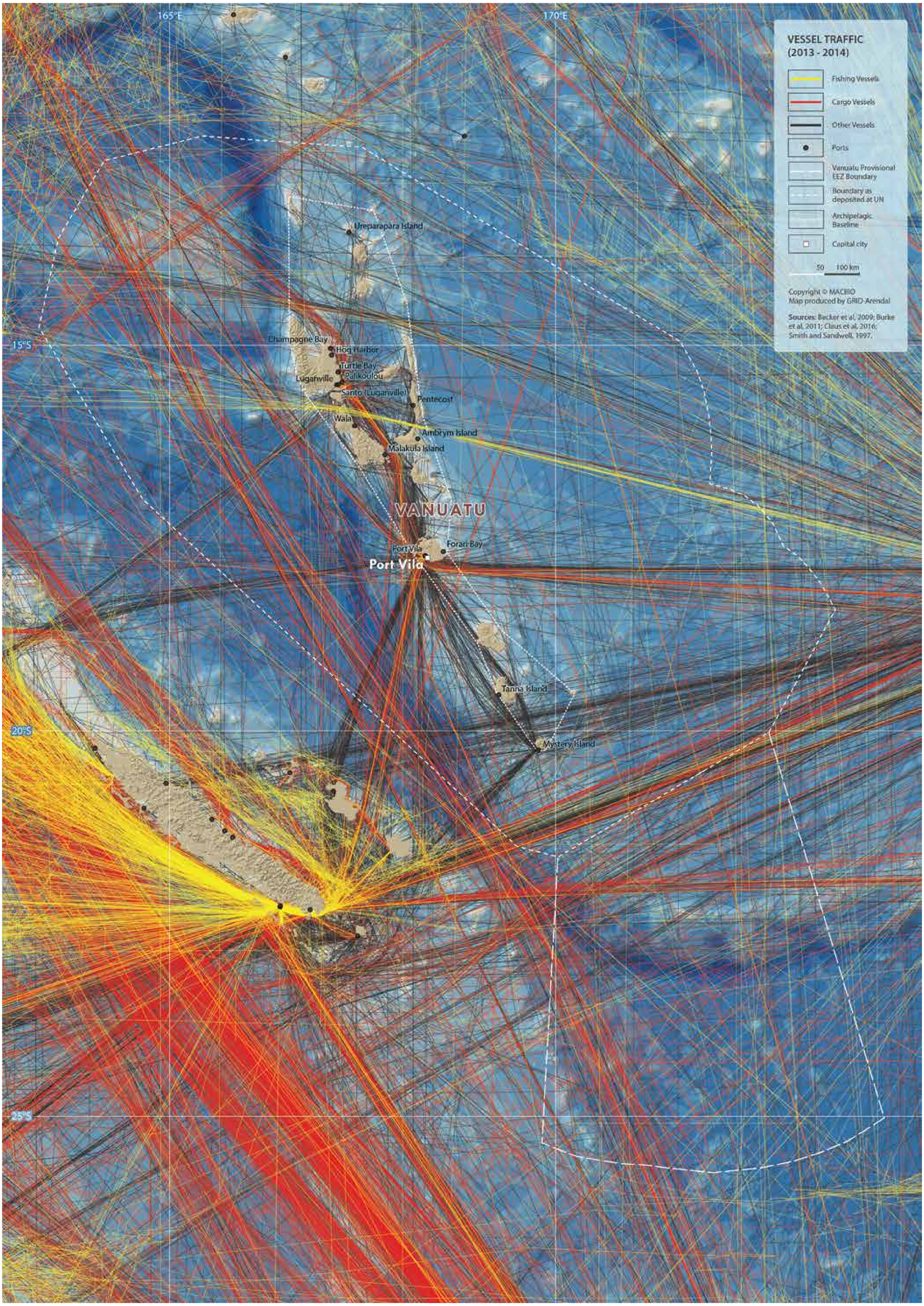


Hydrothermal vent deposits.

While Vanuatu has a Petroleum (Exploration and Production) Act 1993 and a designated Petroleum Licencing Area, no petroleum exploration has been, or is currently being, undertaken. Since neither metals nor petroleum are currently being exploited, it seems Vanuatu's gold rush is more of a sand rush. Aggregates (gravel and sand) are extracted from rivers and coastal zones, such as Teouma Bay, and are used for construction and in cement production.

In addition to resource exploration, Vanuatu's ocean floor is used as a well-established submarine cable hub with connections to a number of cable networks. The Fiji-Vanuatu Telecommunications Cable System (FINTEL) connects Port Vila to Suva in Fiji, and subsequently to Australia, New Zealand, the USA, Tonga and Samoa via the Trans-Pacific Southern Cross Cable's access point in Suva. In shallow waters, the fibre-optic cables are generally thicker and laid beneath the sea floor for protection. At the shoreward end of the cables, where they cross the intertidal zone, the cables are protected by piping and are bolted to the substrate. In deeper water, the thinner cables are laid on the sea floor.

These different and overlapping uses clearly need to be well planned and managed. For example, as the map shows, sea-floor massive sulfides are found on or close to hydrothermal vents, which are biodiversity hotspots (see also chapter "Smoke underwater, fire in the sea"). Deep-sea mining has the potential to impact on these important ecosystems. However, because deep-sea mining is a relatively new field, the complete consequences of full-scale mining operations on this ecosystem are unknown. Direct risks include disturbances to the benthic layer, increased toxicity of the water column and sediment plumes from tailings with unknown long-term effects, while indirect risks are leakage, spills and corrosion. As mining involves the extraction of a non-renewable resource, it should be managed using the precautionary approach and, technically, cannot be considered sustainable. Given the limited scientific knowledge and high demand for technology in exploring and mining deep-sea areas, marine-based mineral extraction should be treated with caution. Equally, sand and gravel mining, as well as petroleum exploitation, comes with risks that need to be managed. Finally, cable routes have to avoid hazardous conditions and sensitive marine areas, such as deep-sea vents and seamounts.



VESSEL TRAFFIC
(2013 - 2014)
Fishing Vessels
Cargo Vessels
Other Vessels
Ports
Vanuatu Provisional EEZ Boundary
Boundary as deposited at UN
Archipelagic Baseline
Capital city
50 100 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; Burke et al. 2011; Claus et al, 2016; Smith and Sandwell, 1997.
165°E
170°E
15°S
20°S
25°S
Ureparapara Island
Champagne Bay
Hog Harbor
Turtle Bay
Palikoulou
Luganville
Santo (Luganville)
Pentecost
Wala
Ambrym Island
Malakula Island
VANUATU
Port Vila
Forari Bay
Port Vila
Tanna Island
Mystery Island

FULL SPEED AHEAD: VESSEL TRAFFIC

Vanuatu's waters are a highway for thousands of domestic and international vessels that are lifelines for many Ni-Vanuatu who rely on the regular delivery of important goods and food items. Minimizing potential environmental and safety risks is a high priority for all.

The tree and the canoe

Bonnemaison (1985) pondered "Can the tree, symbol of rootedness and stability, be reconciled with the canoe, symbol of journeying and unrestricted wandering? At first sight, apparently not. Nevertheless, Melanesian civilization uses this dual metaphor, this apparent contradiction, to define traditional identity. On the island of Tanna in Vanuatu, they say that man is a tree that must take root and stay fixed in its place. The local group, on the other hand, is a canoe that follows roads and explores the wide world". This shows the great traditional importance seafaring has always had to Ni-Vanuatu. To make a traditional outrigger canoe, also known as Kenu, Ni-Vanuatu felled and hollowed out trees. The living tree in some sense underwent a process of death and rebirth.

Ships coming in and out of Vanuatu ports, from fishing vessels to cargo vessels, cruise ships and ferries, serve many different purposes. Vanuatu has about 700 registered ships. Fishing vessels operate in a range of fisheries, including artisanal and subsistence inshore fisheries and commercial offshore fisheries for tuna and billfish (see also chapters "Fishing in the dark" and "Small fish, big importance"). The main freight ships operate out of Port Vila, with several other ports for the transport of bulk goods. The main commercial shipping routes include lines to other Pacific Island countries, Australia and New Zealand, and destinations in Asia.

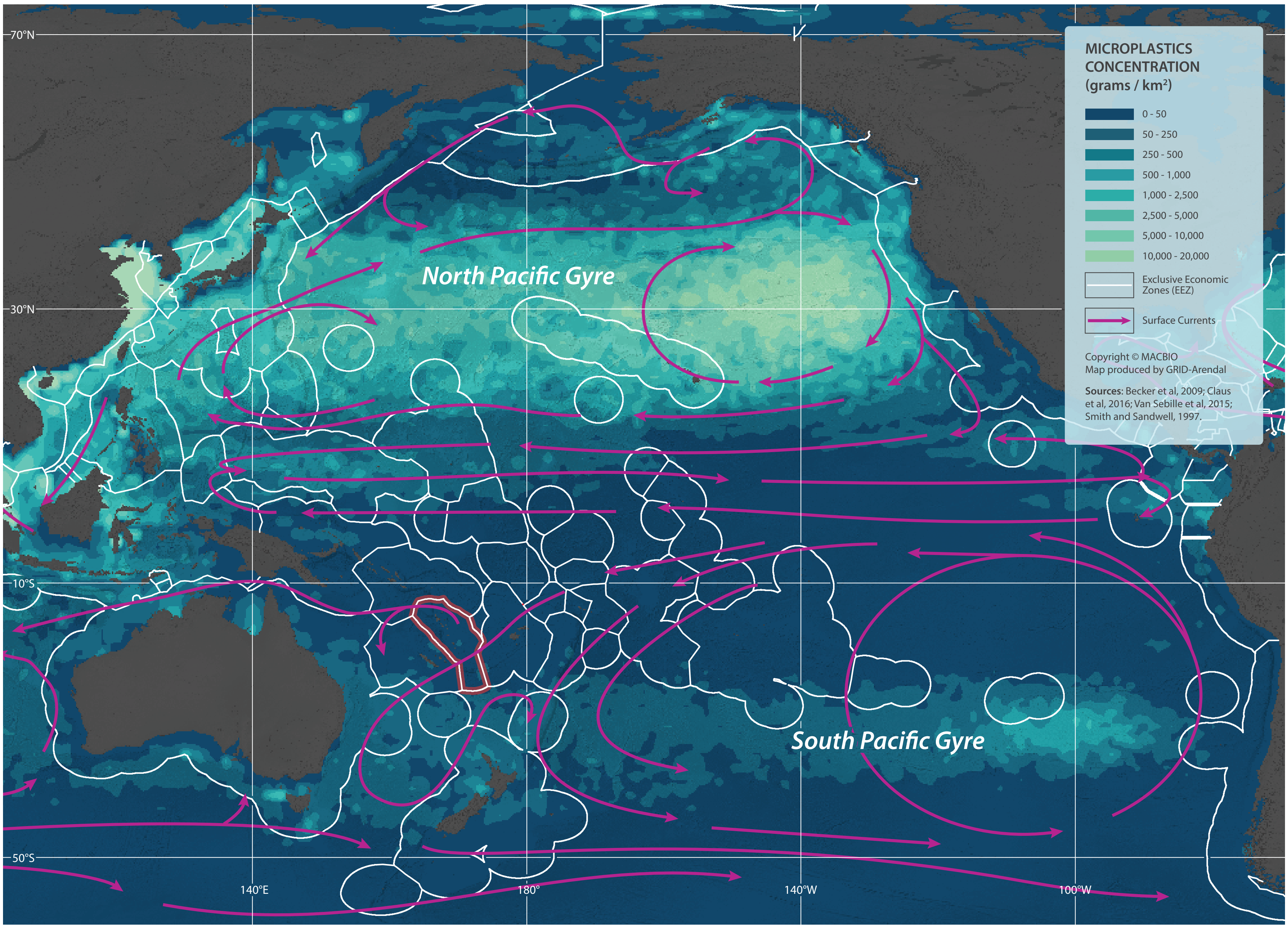
In addition, cruise ships have been visiting Vanuatu for many years now. Over the past 10 years, the number of cruise ship arrivals in Vanuatu has grown by an average of 15 per cent per year (Net Balance Management Group Pty Ltd, 2014). In 2013, more than 240,000 people came to Vanuatu by cruise ship, spending more than 490,000 passenger days on the islands (Net Balance Management Group Pty Ltd, 2014). There are also many yachts cruising Vanuatu's waters (see also chapter "Beyond the beach").

Alongside the two major government-managed ports, Port Vila and Santo, are smaller ports catering for inter-island ferries and cargo. Port Vila is the largest and busiest port in Vanuatu, accommodating large numbers of cruise ships, cargo carriers and inter-island vessels. The Port of Santo is small by international standards but caters for significant copra (dried coconut kernels) exports.

From the map of different types of vessels crisscrossing Vanuatu's waters, it is clear that MSP is key not only for navigational safety, but also to minimize conflicts with Vanuatu's many other marine values that are threatened, be it by fishing or oil spills. In order to avoid the negative impacts of oil transporters and shipping emissions in general, and to decrease Vanuatu's fossil fuel dependence, more sustainable forms of sea transport are being explored. As a seafaring nation, Ni-Vanuatu can look to their ancestors, who were advanced sailors following the stars in their traditional canoes, for inspiration.

PLASTIC OCEAN: MICROPLASTICS CONCENTRATION

Like the rest of the world's oceans, Vanuatu's waters are overflowing with plastic. Only 5 per cent of plastics are recycled effectively and forecasts expect that by 2050 there will be more plastic than fish in the world's ocean.



The world produces 300 million tons of plastic each year. About 2 per cent of it—around 8 million metric tons—ends up in the ocean. It is a staggering amount, yet only 1 per cent of this plastic is actually found on the surface of the ocean. Half of this 1 per cent becomes caught in large gyres (see map); the other half is more widely dispersed. The other 99 per cent (7.92 million metric tons) of plastics in the ocean worldwide are unaccounted for each year.

Science has only just begun to unravel the riddle of where this unaccounted-for plastic ends up. At the turn of the millennium, scientists uncovered a previously unknown phenomenon: microplastic. Eighty per cent of plastic waste enters the ocean via rivers and the other 20 per cent is tossed overboard from ships (see graphic). A portion of the plastic waste is carried great distances by ocean currents and gathers in large trash vortices such as the Great Pacific Garbage Patch in the North Pacific Gyre. On this journey, which can take up to 10 years, large pieces of plastic are progressively eroded, broken down by sunlight and eaten by bacteria, fragmenting into many smaller pieces. The result is microplastic—plastic particles that are smaller than 5 millimetres.

Thus the Great Pacific Garbage Patch is not the massive islands of trash that one might first imagine. Large bits of plastic are relatively rare, and one could actually swim through a gyre without noticing the microplastic that composes it. The remaining 99 per cent of the waste that begins its journey on the coasts never reaches garbage patches. It also breaks down into microplastic and disperses through the ocean, before finally sinking into the depths. In fact, the plastic concentration on the ocean floor is 1,000 times greater than on the surface. In light of this, Vanuatu's comparably low concentration of microplastic at the ocean surface (see the map) is not necessarily good news.

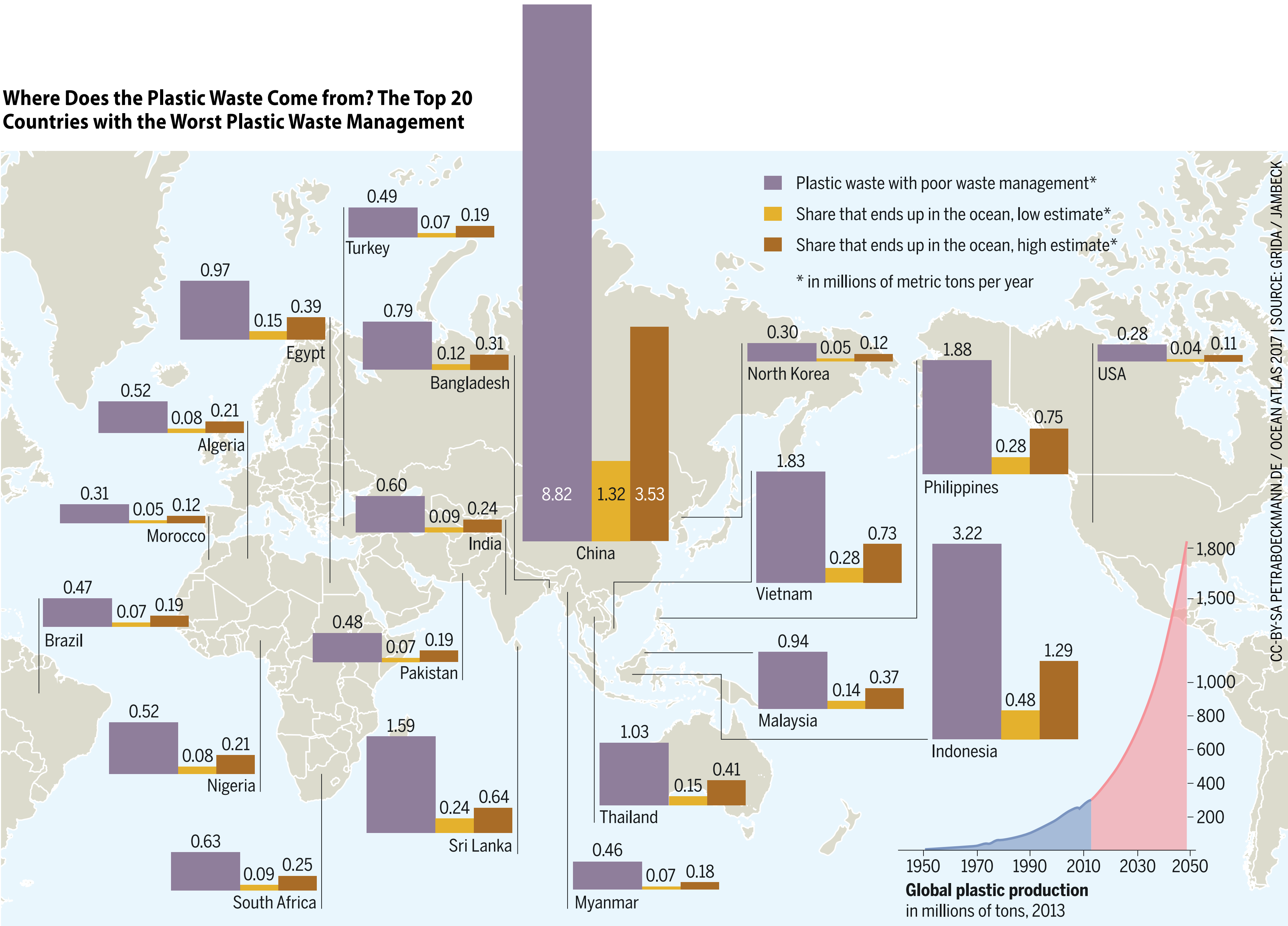
The microplastic is trapped on the ocean floor, embedded in the sediment. It is gradually forming a new geological layer, the "plastic horizon", which researchers of the future will attribute to our era. The sad truth is that we use the deep sea as a gigantic dustbin and benefit from the fact that the majority of the waste seemingly disappears forever, rather than washing up at our feet again.

While the portion of microplastic that remains afloat may seem small, it is the cause of a large problem with far-reaching effects. It is no wonder that fish mistake microplastic for plankton and eat it, since there is six times as much plastic as plankton in some parts of the ocean. Very small pieces of plastic can penetrate the fish's intestinal walls and become trapped in the surrounding tissue. The microplastic then enters the food chain and eventually winds up on our plates and in our own stomachs. The consequences of consum-

Walk the talk

"I'm a fisherman from Vanuatu, but these days I caught more plastics than fish when fishing" says John Managawi, a Ni-Vanuatu fishermen who supports the Vanuatu government's move towards banning plastic in the country. And the government is walking the talk: Vanuatu is the first nation in the world to have legally banned the use of plastic straws in legislation passed on 1 July 2018 that also saw the end of single-use plastic bags and polystyrene takeaway boxes. The First Lady of Vanuatu, Estella Moses Tallis, welcomed this ban: "The Mamas of Vanuatu can bring to the frontline the use of traditional baskets which are part of our culture. The more we use them, the more we encourage our cultural art of weaving, in turn strengthening the cultural heritage of Vanuatu."

Where Does the Plastic Waste Come from? The Top 20 Countries with the Worst Plastic Waste Management



How Does All That Plastic Get Into the Ocean?

1. *A poor waste management/recycling system (or none at all) is the leading cause.*
2. *Plastic garbage from cities and industrial centers flows directly into rivers and seas with untreated wastewater.*
3. *Microplastic used as additives in cosmetic products is not filtered out by water treatment plants.*
4. *Fishing nets and lines lost or intentionally abandoned at sea.*
5. *Lost loads and ship materials.*
6. *Garbage illegally dumped at sea.*
7. *Catastrophic waste: wreckage and garbage swept out to sea by hurricanes, floods, and tsunamis.*

ing microplastic have yet to be studied—after all, microplastic itself has only been a research topic since 2007. One finding is already cause for concern: the surface of microplastic acts like a sponge that soaks up toxins, including environmental poisons such as PCB and disease-causing germs, helping them spread and threatening entire fish populations.

Once plastic gets into the ocean, there is currently no way to retrieve it. Most becomes microplastic, which is so small that filtering it out of the water would filter out the aquatic life as well and would still leave larger pieces of plastic that are dangerous to larger animals. Many technical solutions aimed at ocean cleanup are under development and must consider the ecological consequences as well as the benefits. For instance, plans to scoop rubbish out of large areas of the sea could unintentionally catch fish and other organisms. The benefits must therefore be compared with the resulting damages.

The solution to the problem actually lies on dry land: on coasts and river deltas, at markets and in households. The good news is, it is within our grasp. As a significant portion of the plastic waste in the ocean comes from the packaging and products we use, we can have a direct influence by changing our consumption patterns. Governments can also ban the use of microplastics in cosmetics. But the most effective step that we can take is to build a globally functioning recycling economy, or circular economy, so that fewer new plastics are created and fewer are disposed of in an uncontrolled manner. Political engagement is a powerful lever for setting the right incentives for change, and developing a circular economy is just a matter of political will.

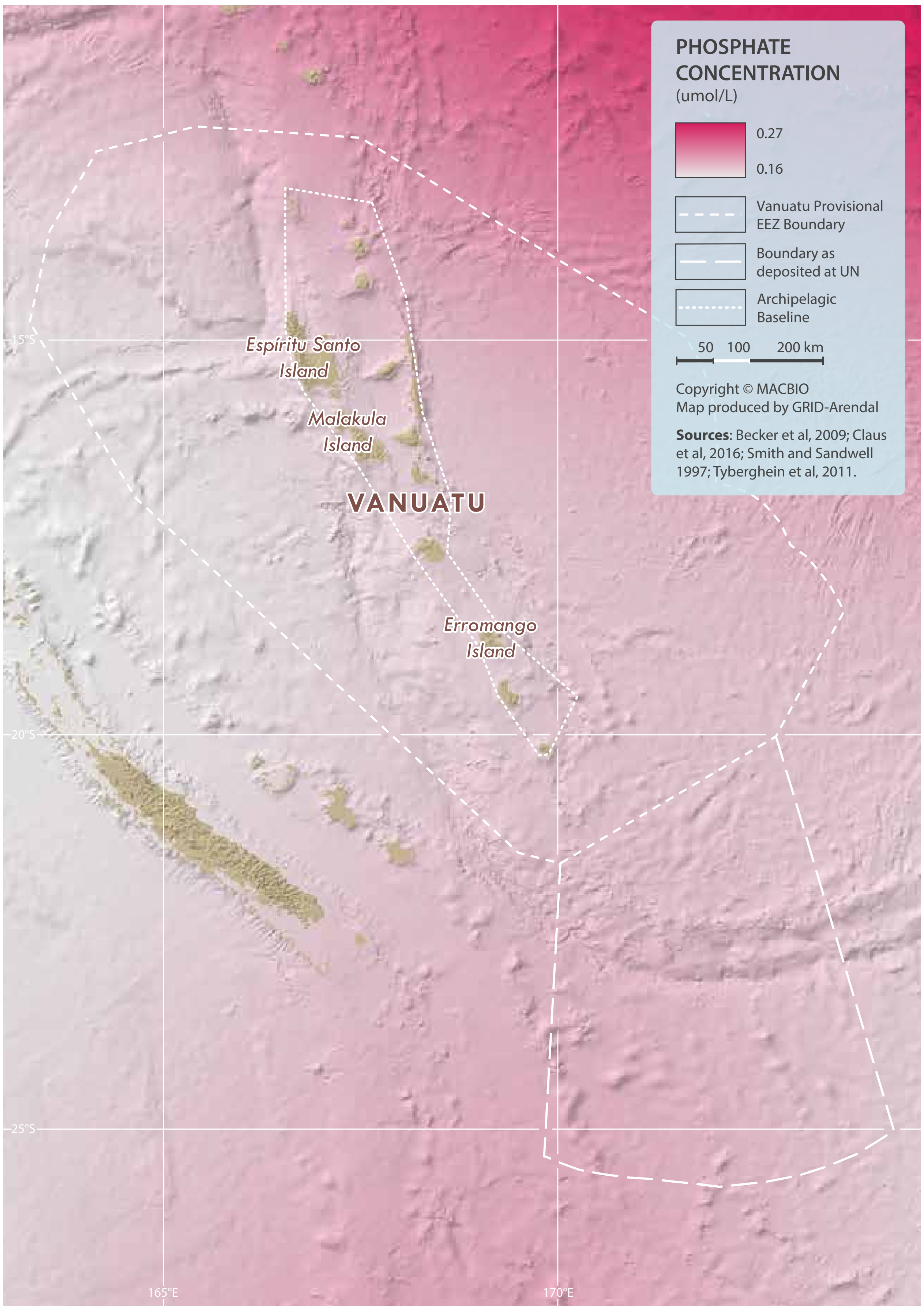
As a first step, Vanuatu has legally banned the use of some single-use plastics (see text box) and many Ni-Vanuatu are involved in coastal cleanup activities, helping keep Vanuatu's waters from turning into a plastic ocean.

THE DOSE MAKES THE POISON: PHOSPHATE AND NITRATE CONCENTRATION

While nutrients including phosphate and nitrate provide much-needed nutrients for the marine food chain, too much from agricultural run-off and other sources negatively affect Vanuatu's coastal ecosystems.

On a global scale, Vanuatu's waters have a moderately low phosphate concentration, ranging from 0.17 to 0.20 umol/L. The highest concentrations are observed in the north-eastern waters and gradually decrease to the south and west. At the global level, nitrate concentrations in seawater are generally low, with the highest concentrations found in high latitudes and some areas of coastal upwelling. Within Vanuatu's waters, the nitrate concentration ranges from 0.3 to 0.7 mmol m3, which is very low compared with global levels. The highest concentrations of nitrate in Vanuatu occur in the south-west, but the South-West Tropical Pacific (SWTP) is generally considered a nitrogen-limited area.

Phosphate and nitrate concentrations can be higher in the waters close to the main islands due to land and coastal inputs, which can include inorganic fertilizers, wastewater treatment from municipal sources, and soaps and detergents. This is where the dose makes the poison: while phosphate and nitrate are important nutrients, too much of them can be bad for marine and coastal ecosystems. In Vanuatu's waters, there is certainly no shortage of sun, and thus photosynthetically available radiation, but there is a general limit of phosphate and nitrate. Once these nutrients are added from the land-based activities such as farming and wastewater treatment, primary productivity increases dramatically. The impact of too many nutrients (eutrophication) is especially significant in coastal waters, where increased nutrients can result in algal blooms. These blooms can affect coastal habitats such as coral reefs by smothering, in the case of macro-algae, or limiting light availability, which can lead to rapid declines in reef biodiversity (Fabricius, 2005).



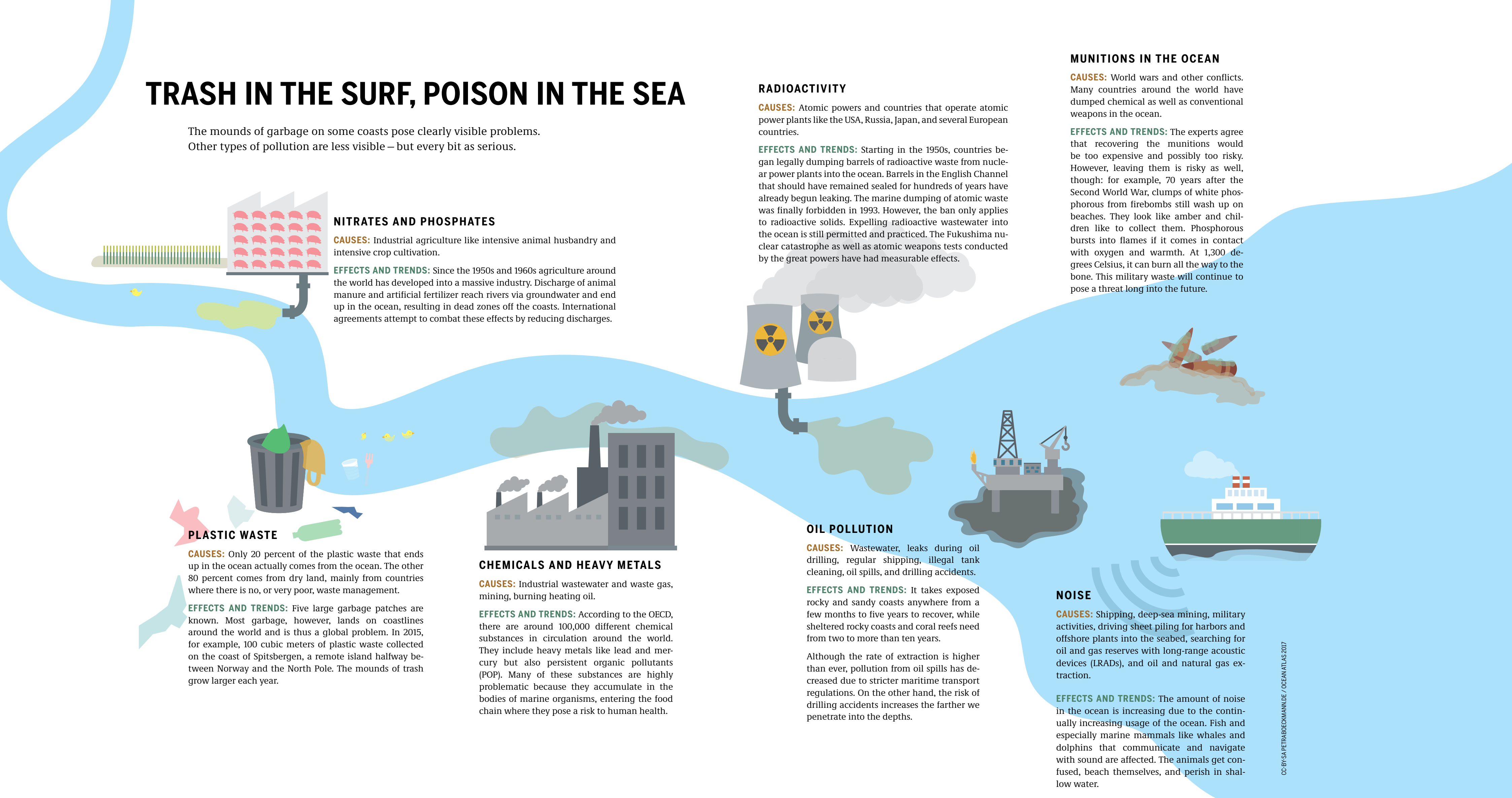
Sea food

"All things are poison and nothing is without poison; only the dose makes a thing not a poison", stated the Swiss physician Paracelsus 500 years ago. And indeed, the dose makes the poison.

Marine organisms need food and nutrients, with tiny plants known as phytoplankton forming the basis of many marine food chains (see also chapter "Soak up the sun"). These phytoplankton rely on the nutrients phosphate and nitrogen, principally in the form of nitrate (see map).

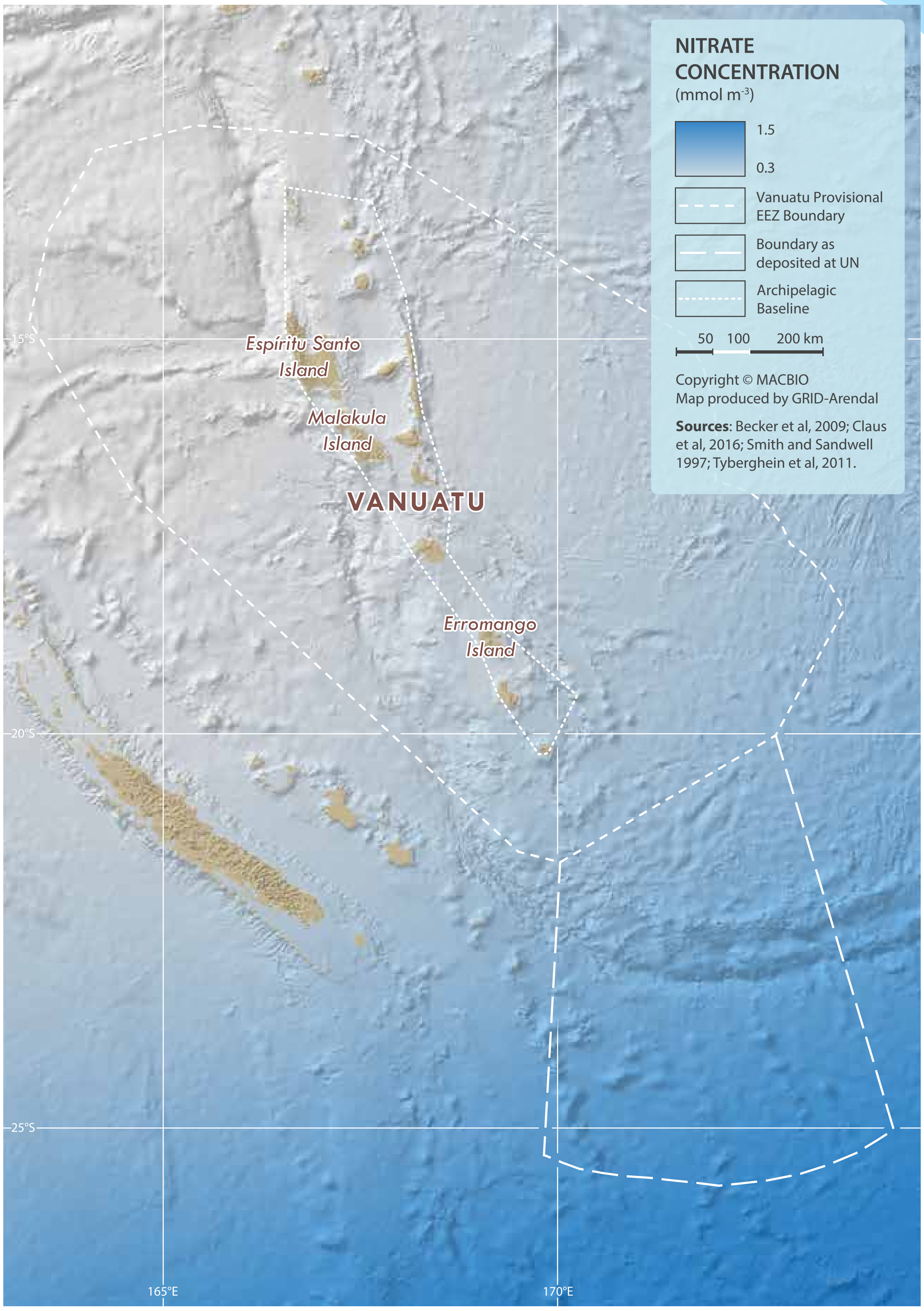
Phytoplankton productivity at the surface of the ocean is often limited by the amount of available fixed inorganic nitrogen (Falkowski et al., 2009). However, where there is too much of these nutrients, algal blooms can occur, which can have negative impacts on the environment.

As the chapter "Plastic oceans" as well as the graphic show, excess nutrients are only one type of pollution and threat to Vanuatu's marine values. To keep Vanuatu's coastal habitats healthy (see also chapter "Home, sweet home"), it is important to



manage both point-source pollution, which comes from a single identifiable source such as a factory, as well as non-point pollution, for example from agricultural run-off. The MARPOL Convention (see also chapter "One world, one ocean") is one international instrument to regulate pollution. MSP can help spatially identify sources and areas of pollution to guide sustainable ecosystem management, ensuring the dose does not make the poison.

Wastewater is one of the main sources of nitrate and phosphate in Vanuatu's waters.



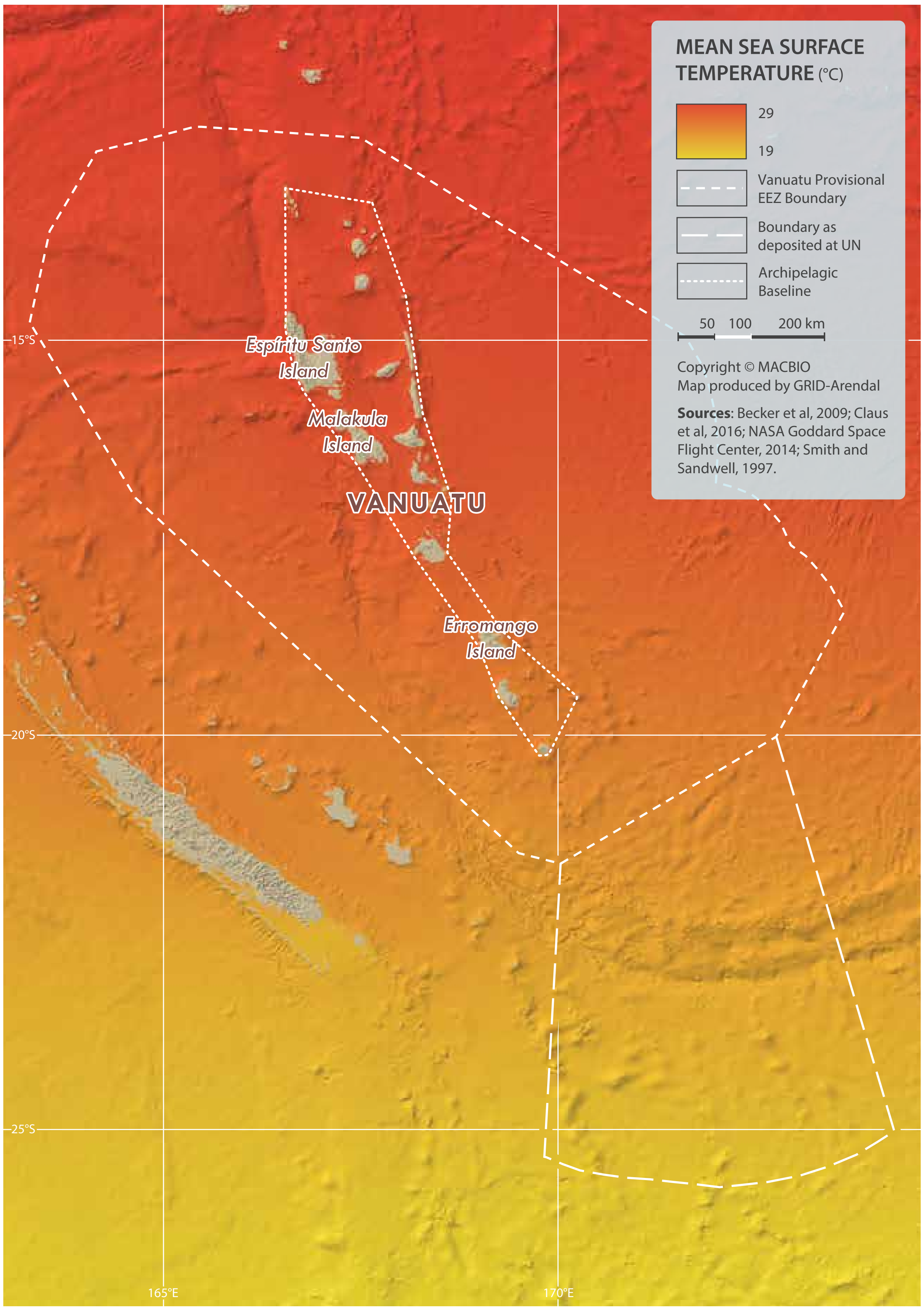
HOTTER AND HIGHER: MEAN SEA SURFACE TEMPERATURE AND PROJECTED SEA LEVEL RISE

Sea surface temperature (SST) is a limiting factor for much marine life. Climate change is leading to higher sea temperatures, as well as sea levels, thus compromising Vanuatu's marine values.

The following chapters explain how observed and predicted climate change will affect Vanuatu's marine values, starting with SST, which is the water temperature close to the ocean's surface. The very hot temperatures in 2012 were not only uncomfortable for people, but for the ocean's inhabitants too. Warm water holds less dissolved oxygen than cooler water and once the level of dissolved oxygen drops below a critical threshold, fish and invertebrates suffocate. This is especially bad in shallow-water habitats, which can rapidly heat up and lose dissolved oxygen, resulting in thousands of dead fish.

Corals also find hot water uncomfortable. Shallow-water corals grow optimally between 23°C and 29°C, hence they are confined to tropical regions of the globe. When the water temperature falls outside this range, they can become stressed and expel their symbiotic algae (see also chapter "Home, sweet home") in a process known as bleaching. Coral bleaching is an increasing threat to coral reefs in tropical regions and can have a negative impact on ecosystems, fisheries and tourism. An increase in SST of only 1°C for four weeks can trigger a bleaching event. When increased temperatures last for longer periods (eight weeks or more), corals begin to die. This shows how SST is an important factor in the distribution of ocean life, with many species confined to specific temperature ranges.

Moreover, air masses in the Earth's atmosphere are highly modified by SST. Warm SST is known to be a cause of tropical cyclones over the Earth's oceans, with a threshold temperature of 26.5°C being a trigger mechanism (see also chapter "Stormy times"). At the same time, tropical cyclones can also cause a cool wake, due to turbulent mixing of the upper 30 metres of the ocean. SST changes diurnally, like the air above it, but to a lesser degree due to its higher specific heat. There is less SST variation on windy days than on calm days. In addition, ocean currents can affect SST on multi-decadal timescales. Coastal SST can cause offshore winds to generate upwelling, which can significantly cool or warm nearby land masses, and additionally shallower waters over a continental shelf are often warmer. Onshore winds can cause a considerable warm-up even in areas where upwelling is fairly constant.



The annual mean SST in Vanuatu's waters ranges from 22°C in the south to nearly 30°C in the north, as the map shows. Across the year there is relatively little variation in the SST, with up to ±3.5°C in the south and less than ±2°C in the north. Vanuatu is strongly influenced by the North Vanuatu and South Vanuatu Jets, both of which bring warm water westward from the South Equatorial Current, which itself brings warm water from the eastern tropical Pacific Ocean.

Sea level rise has the potential to negatively impact the low-lying coastal areas of Vanuatu, through flooding and wave inundation, with consequent shoreline

Blame it on the weatherman?

In February 2012, Vanuatu recorded its highest ever water temperature, 37.2°C in Lamap on Malekula. Such high temperatures heat the water in shallow reefs to uncomfortable temperatures for many of the inhabitants.

Was it just a few hot sunny days or global warming that warmed the water way above its average temperature?

To understand this, we need to look at two different things. On one hand climate variability, which refers to shorter term (daily, seasonal, annual, inter-annual, several years) variations in climate, including the fluctuations associated with El Niño (dry) or La Niña (wet) events (see also chapter "Go with the flow"). On the other hand climate change, which refers to long-term (decades or longer) trends in climate averages such as the global warming that has been observed over the past century, and long-term changes in variability (e.g. in the frequency, severity and duration of extreme events) (see also chapter "Stormy times"). There may always be particularly rainy weather in Sola, or a particularly hot week in Lamap. Only by observing trends in the long term can we show how the climate is changing.

erosion and groundwater salinization. These impacts could lead to a loss of infrastructure and productive land, thereby posing a challenge to livelihoods in the region. Improved data and information on sea level rise are necessary in order to plan effectively for these changes.

Sea level rise, as a consequence of global warming, threatens many low-lying regions of the world. The Fifth International Panel on Climate Change assessment projects a global rise in mean sea level for 2081–2100 relative to 1986–2005 of between 0.2 and 0.98 metres, depending on different emissions scenarios. Furthermore, the western tropical Pacific Island region is considered one of the most vulnerable regions under future sea level rise (Nicholls and Cazenave, 2010). Sea level rise is not uniform across the western Pacific and is affected by ENSO events. These have a strong modulating effect on inter-annual sea level variability, with lower than average sea level during El Niño and higher than average during La Niña events (of ±20–30 cm). In addition, there is also an observed low-frequency (multi-decadal) variability, which in some areas adds to the current global mean sea level rise due to ocean warming and ice melting (Becker et al., 2012).

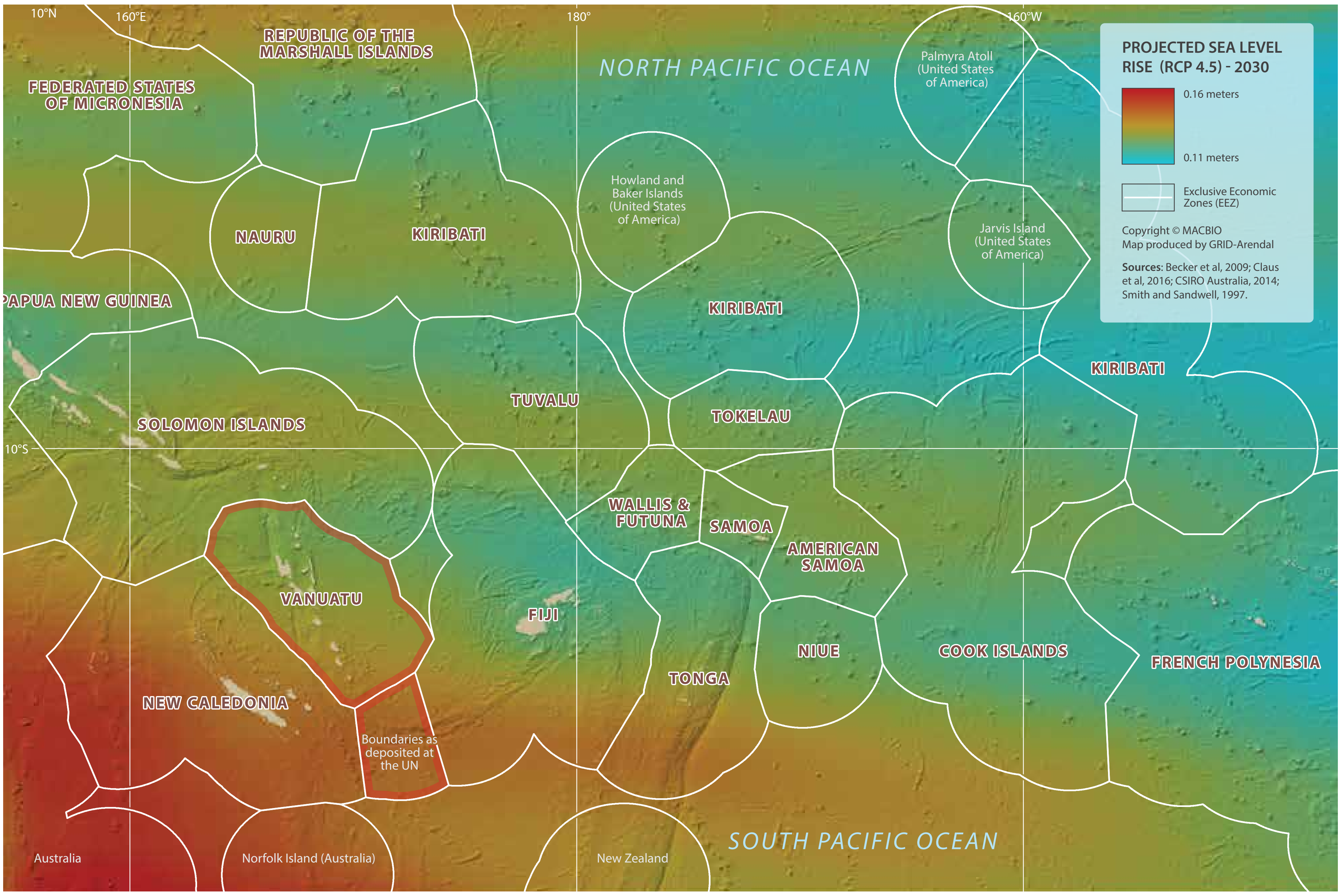
Vanuatu is a mix of predominantly high volcanic islands and several low-lying coral atolls. Vulnerability to sea level rise is influenced by coastal geography and prevailing ocean currents. Islands exposed to higher wave energy in addition to sea level rise can experience higher rates of erosion than their more sheltered counterparts. However, the coral atolls of Vanuatu may be able to adjust their size, shape and position in response to sea level rise, as has been suggested for other reef islands such as Funafuti Atoll in Tuvalu (Kench et al., 2015). Vertical reef accretion that occurs in response to sea level rise may be able to prevent the significant increases in shoreline wave energy and wave-driven flooding that are predicted in the absence of reef growth (Beetham et al., 2017).

The map indicates that by 2030, Vanuatu will experience a minimum rise in sea level of 0.15 metres. This is likely to be accompanied by increases in episodes of flooding and wave inundation in some coastal areas. The southernmost islands in the archipelago will experience slightly greater sea level rise than those of the northern islands, but the overall difference between these two areas will be minimal. Pacific Island nations are therefore focused on developing adaptation strategies to address the predicted continued rise in sea level.

It is becoming clear that in a warming world, Vanuatu's sea will become hotter and higher, with drastic consequences for coastal habitats and their inhabitants.

Visualizing sea level rise

For the first time, Ni-Vanuatu can visualize how their homes, neighbourhoods and even popular tourist spots will be inundated by sea level rise caused by global climate change. The Coastal Risk Vanuatu website, launched in 2016, charts the low-lying coastline of a number of Vanuatu islands. The free platform incorporates Google Maps technology, local tidal data and nationwide elevation data to map exactly how rising sea levels will encroach on homes, villages and beaches under three scientific scenarios.

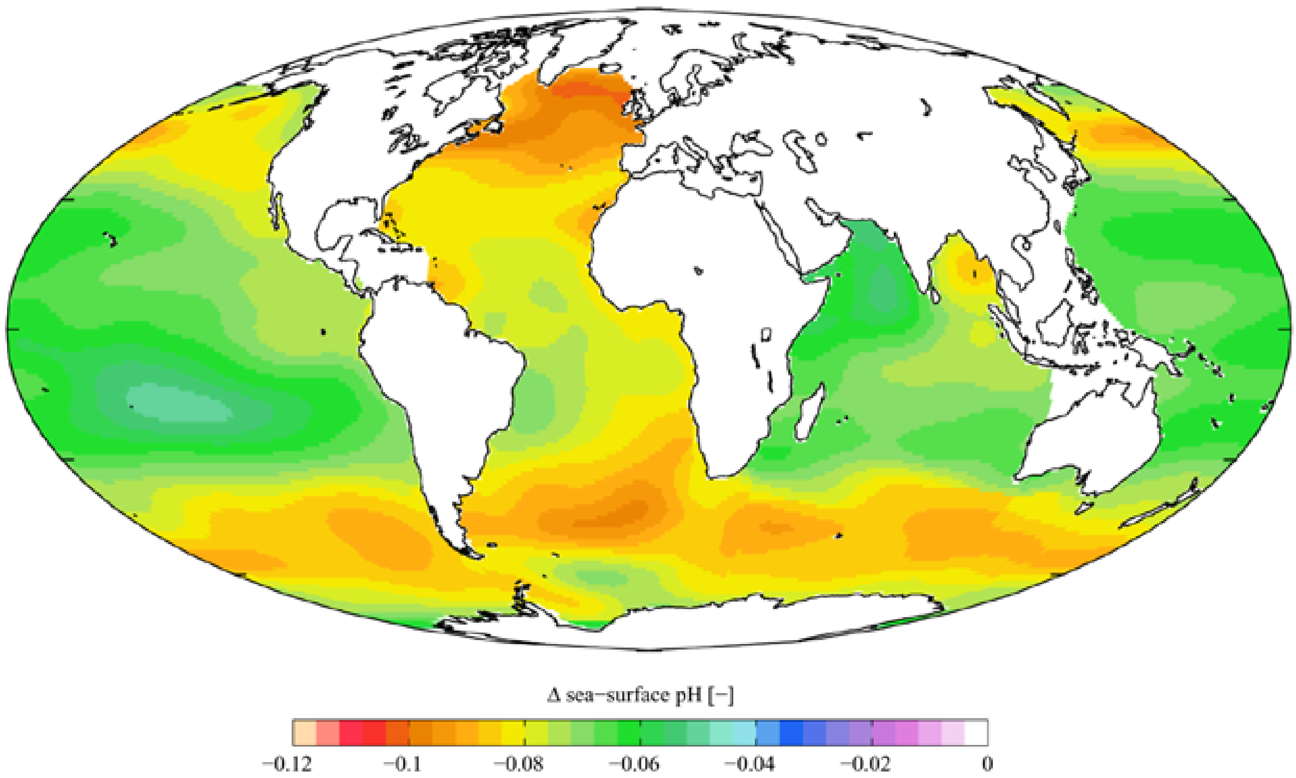


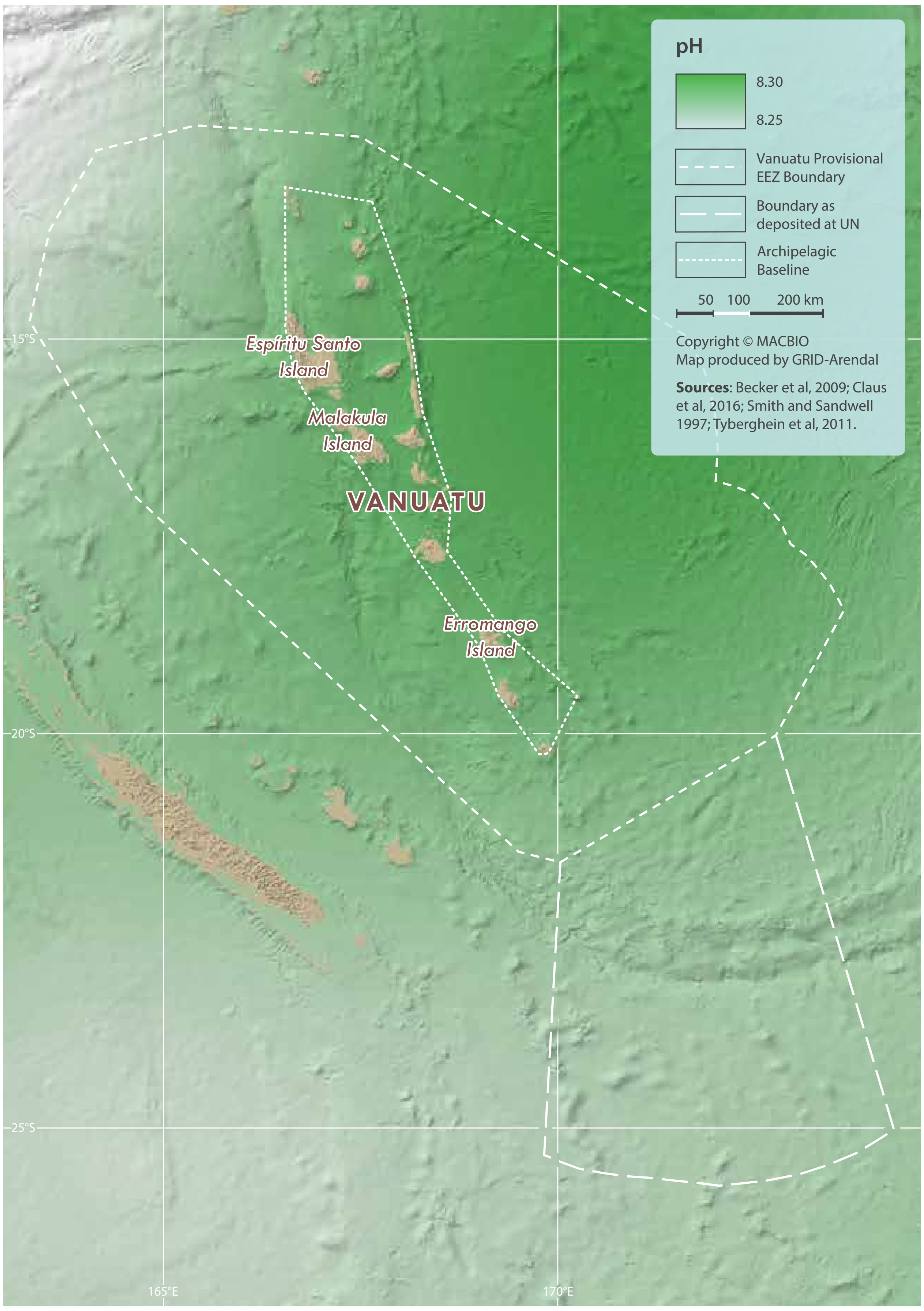
TURNING SOUR: OCEAN ACIDITY

Climate change is not only causing sea temperatures and levels to rise but also its acidity, which causes serious problems for many marine organisms.

Seawater acidity can be measured using the pH, a numeric scale to specify the acidity or basicity of a solution; a pH of 7 is neutral—neither acidic nor basic. A decrease in pH by one means a solution is twice as acidic, whereas an increase by one means a solution twice as basic (see graphic). The pH of the global oceans ranges from around 7.5 to 8.4. Vanuatu's waters are at the higher end of this range, with pH between 8.26 and 8.30. Increasing CO_2 in the surface water leads to increased acidification (lower pH). Already, CO_2 emissions have resulted in a 26 per cent increase in the acid content in the ocean (see small map).

In this context, it is important to look at calcite, which is another vital element found in seawater (see map on the right), as calcium carbonate is a building block of the skeletons of most marine organisms, including corals. Globally, calcite concentrations are highest in the high latitudes and in coastal areas. The calcite concentrations in Vanuatu's oceanic waters are low, with the coastal areas around the islands having a higher concentration (see calcite map).





How does acidification affect calcite levels? Firstly, CO_2 in the water transforms into carbonic acid and the carbonate saturation decreases. This is problematic for all animals that use carbonate to make their shells, such as mussels, snails, corals and sea urchins, among many others (see also chapter "Travellers or homebodies"). The less carbonate there is in the water, the more difficult it is for them to make suitable shells. The effects can already be seen among foraminifera: tiny calcifying creatures that make up an important part of the plankton. The shell-thickness of animals in the Southern Ocean has noticeably decreased compared to specimens from the pre-industrial period. The effect on oysters is slightly different: it has been observed that the thickness of their shells does not decrease, but only because they invest so much energy into shell production that it stunts their overall growth. This makes them easier prey for predators, such as murex snails.

The situation is particularly critical for calcifying species in zones in which carbonate saturation drops too far. In that case, the water actually begins

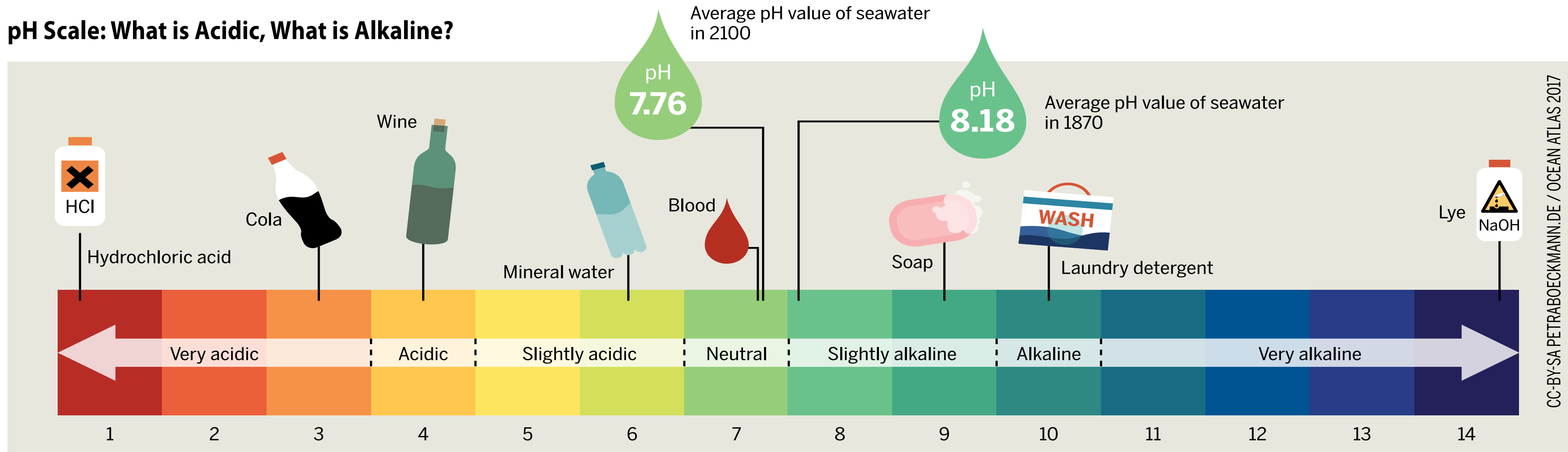
Ocean acidification

Vanuatu is suffering the effects of global warming, with greenhouse gas emissions not only heating the nation's sea, but also ending up in it. In fact, worldwide the oceans have absorbed about one third of the carbon dioxide (CO_2) produced by human activities since 1800 and about half of the CO_2 produced by burning fossil fuels (Sabine et al., 2004).

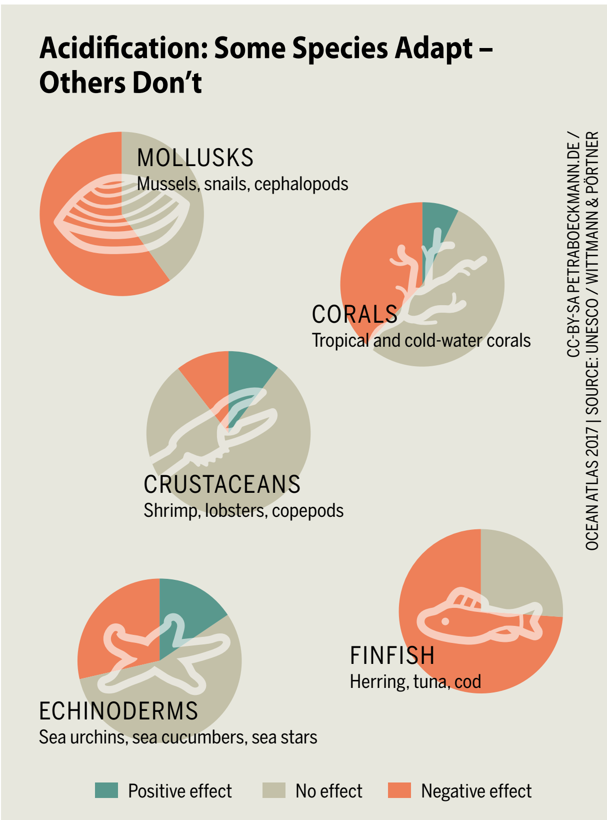
As CO_2 in the ocean increases, ocean pH decreases, resulting in the water becoming more acidic. This is called ocean acidification, the "evil twin" of sea temperature and sea level rise, described in the previous maps.

to draw carbonate out of their shells and corrodes them. This is already happening in some regions in Antarctica and in the North Atlantic. The cold-water corals that live there cannot maintain their skeletons and will eventually collapse.

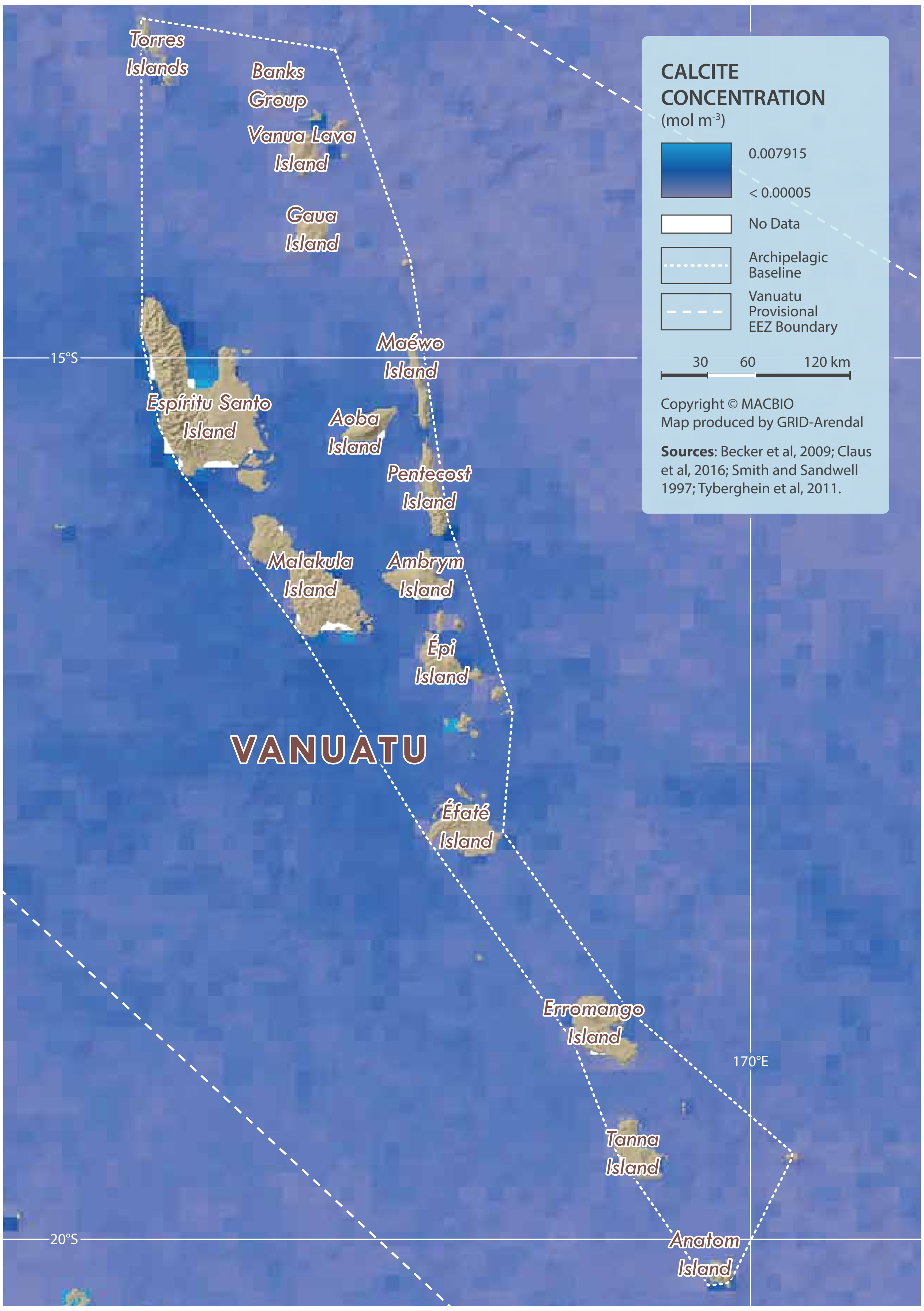
Vanuatu's shallow-water corals are also at risk from increasing acidity. For example, it has been predicted that ocean acidity will decrease from a current pH of around 8.6 to a pH of 7.9 by 2100. This level of decrease has been shown to result in a 50 per cent reduction in coral productivity, and increased acidity makes coral bleaching more likely. Moreover, other non-calcium carbonate-skeleton-producing species, such as fish, are threatened, as their eggs can be corroded in more acidic water.

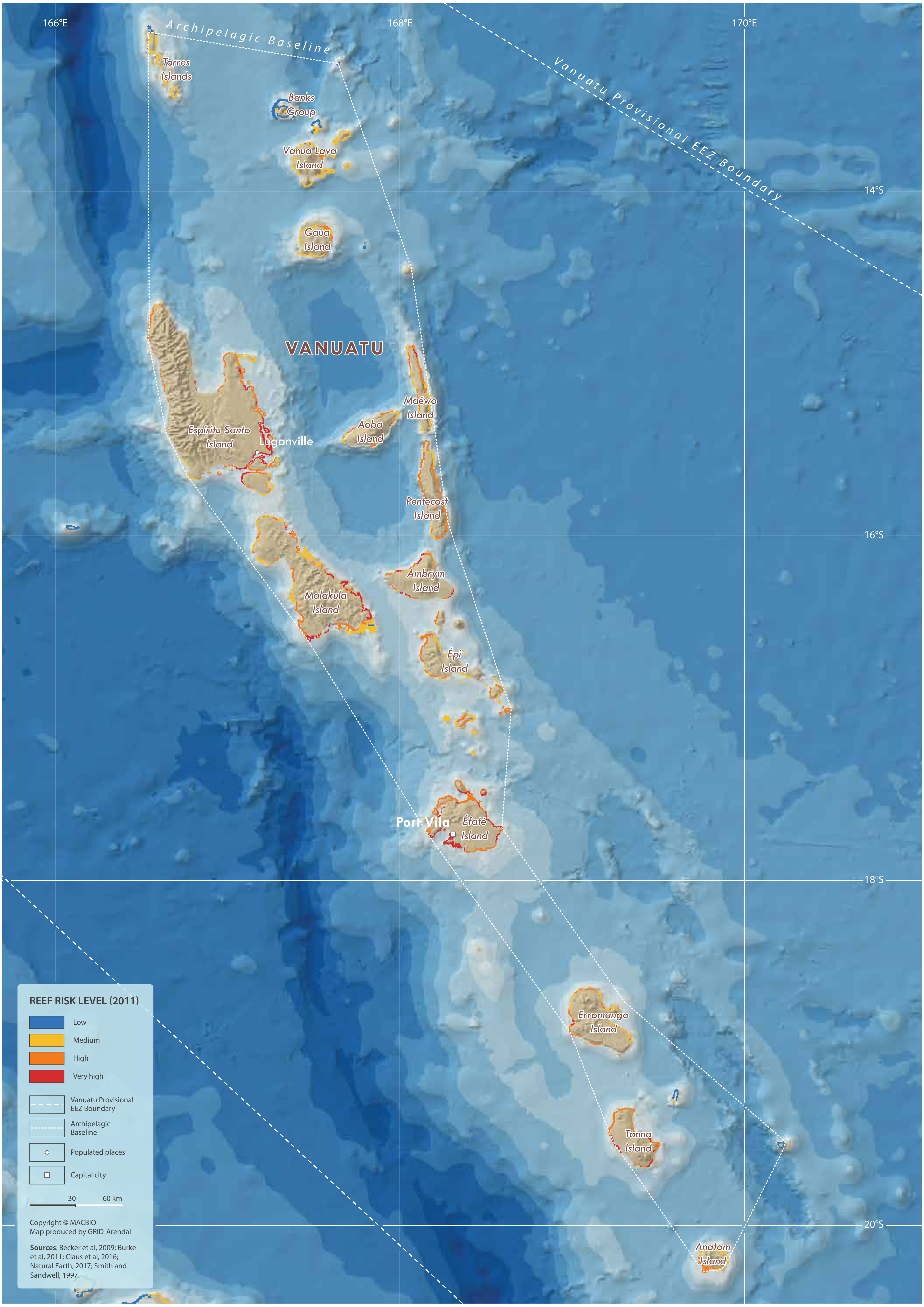


The difference may seem small, but the decline in the pH value from the year 1870 (pH 8.25) to 2100 (pH of 7.9) would mean a 170 per cent increase in acidity. Much smaller changes already pose problems for many sea creatures.



Many animals, including fish and snails, are negatively affected by acidification. Only a few actually benefit from it.




166°E
168°E
170°E
14°S
16°S
18°S
20°S
Archipelagic Baseline
Vanuatu Provisional EEZ Boundary
Torres Islands
Banks Group
Vanua Lava Island
Gaua Island
VANUATU
Espiritu Santo Island
Luganville
Aoba Island
Maéwo Island
Pentecost Island
Ambrym Island
Malakula Island
Épi Island
Port Vila
Éfaté Island
Erromango Island
Tanna Island
Anatom Island
REEF RISK LEVEL (2011)
Low
Medium
High
Very high
Vanuatu Provisional EEZ Boundary
Archipelagic Baseline
Populated places
Capital city
30
60 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; Burke et al, 2011; Claus et al, 2016; Natural Earth, 2017; Smith and Sandwell, 1997.

REEFS AT RISK: REEF RISK LEVEL

Vanuatu's reefs are at risk and the direct and indirect impacts of climate change are exacerbating a system already under threat, jeopardizing marine values worth billions of dollars.

Coral bleaching is the silent reef killer, caused by rising sea temperature as well as ocean acidification. The earliest recorded coral bleaching events in Vanuatu occurred in 2001 (Erakor Island) and 2002 (Vila Harbour, Hat Island and Moso Island) (Sulu et al., 2002). While there have been fewer recorded bleaching episodes in Vanuatu than in some other locations in the Pacific, episodic warming events are known to cause stress to reefs (see also chapter "Hotter and higher"). There are also high numbers of crown-of-thorns starfish (Acanthaster planci), with up to 7,000 per hectare recorded by the Vanuatu Fisheries Department. While these starfish naturally occur in low densities, when their populations rapidly increase, they can cause significant damage to reef communities. Crown-of-thorns starfish outbreaks are common in the region (Wilkinson, 2008), and spikes in their numbers often occur when their natural predators are overfished, including humphead wrasse, puffer fish and grouper (Vuki et al., 2000).

Crown-of-thorns starfish damage Vanuatu's reefs. Outbreaks often occur when their natural predators are overfished.

This interaction shows the cumulative impact of climate change and local human activities on Vanuatu's reefs; threats that will increase over time. The risk of these threats is shown on the map of Vanuatu's reefs, classified by estimated present threat from local human activities, according to the Reefs at Risk integrated local threat index. Threats considered in the index include coastal development, including coastal engineering, landfilling, run-off from coastal construction, sewage discharge (see also chapter "The dose makes the poison"), and impacts from unsustainable tourism (see also chapter "Beyond the beach"); watershed-based pollution, focusing on erosion and nutrient fertilizer run-off from agriculture entering coastal waters via rivers; marine-based pollution and damage, including solid waste, nutrients, toxins from oil and gas installations and shipping, and physical damage from anchors and ship groundings (see also chapter "Full speed ahead"); and overfishing and destructive fishing, including unsustainable harvesting of fish or invertebrates, and damaging fishing practices such as the use of explosives or poisons (see also chapters "Fishing in the dark" and "Small fish, big importance").

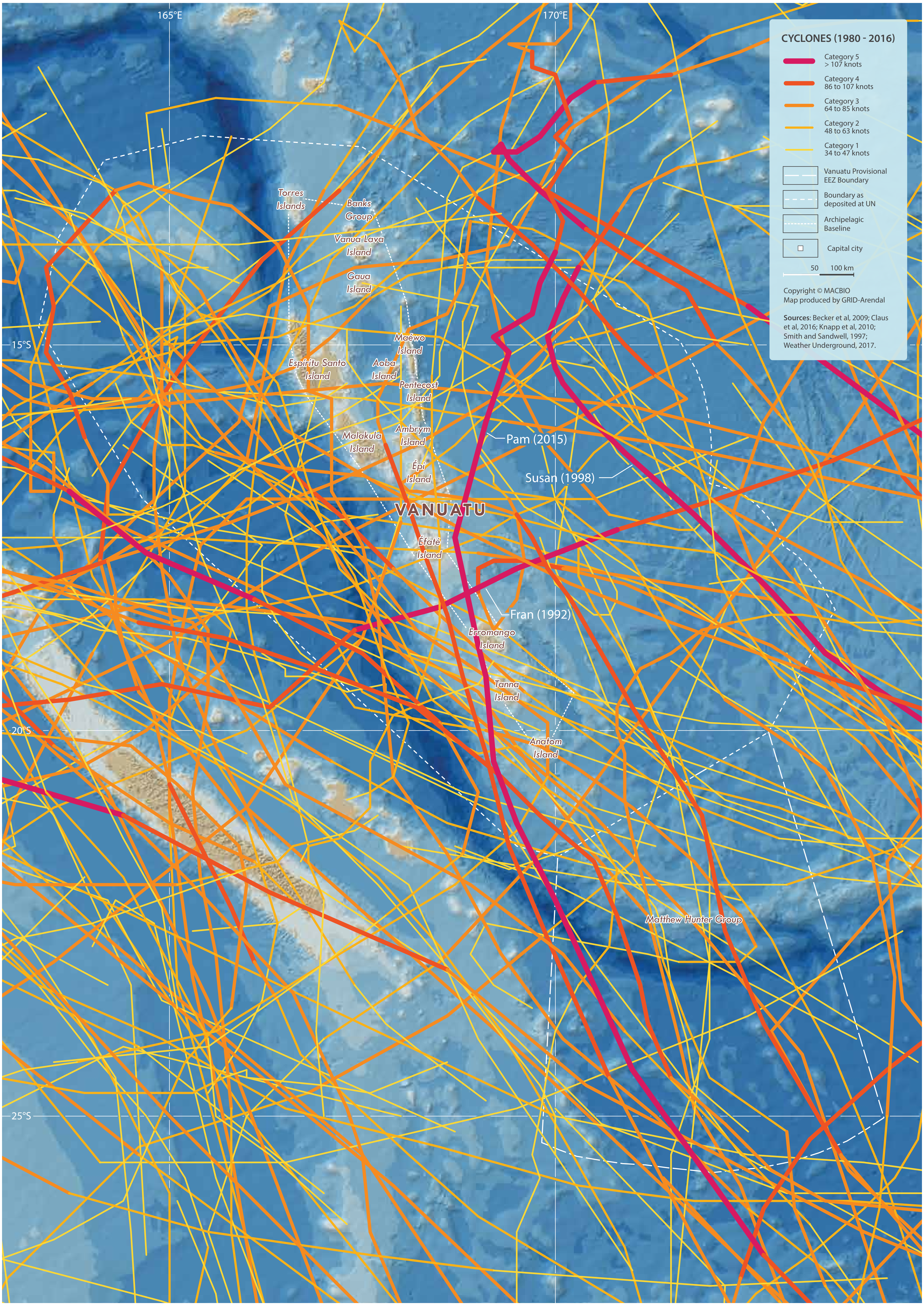
This multitude of man-made threats leaves Vanuatu's reefs at risk. Analysis of the threat index indicates that 7.6 per cent of the reef area is classified as facing a low risk, 37.7 per cent a medium risk, 40.9 per cent a high risk and 13.8 per cent a very high risk. The areas of very high risk (red) are often concentrated around urban centres such as Port Vila and Luganville. Vanuatu was identified as one of nine countries most vulnerable to coral reef degradation, due to the high socioeconomic importance of these reef systems for the local people (Burke et al., 2011). It is predicted that by 2030, 90 per cent of reefs globally will be in one of the threatened categories. In Vanuatu, the combined impacts of acidification and thermal stress are projected to push many reefs into the very high or critical threat categories by 2030 if no action is taken (Burke et al., 2011).

Luckily, there are many initiatives aiming to facilitate the necessary changes. The Vanuatu National Ocean Policy, released in 2017, identifies the protection of naturally resistant or resilient areas including coral reefs that still have high coral cover as a key policy. Further, Vanuatu prohibited the export of wild-harvested corals in 2009 (Vanuatu Department of Fisheries, 2009). Meanwhile, in neighbouring Fiji it has also been shown that relative coral reef condition could be improved by between 8 and 58 per cent if all remnant forest was protected rather than deforested (Klein et al., 2012). Clearly, good management of the human threats to coral reefs can help build resilience in the face of climate change.

Reef risks

With 280 km/h winds, Tropical Cyclone Pam was the second most intense tropical cyclone on record in the South Pacific Ocean. At least fifteen people lost their lives, making it one of the worst natural disasters in the history of Vanuatu. The storm not only resulted in damage to people and infrastructure on land; it also damaged coral reef by dislodging massive corals and moving boulders along the reef flat and down the reef slope. This is a stark example of how climate change effects such as the increasing intensity of tropical cyclones threaten reefs. Other effects that put reefs at risk, such as coral bleaching, are much more subtle, but nonetheless lethal to Vanuatu's vast reef system—the largest in the South-West Pacific (Spalding et al., 2001; see also chapter "Shaping Pacific Islands").

Acropora coral field in Vanuatu exposed to multiple impacts, including a crown-of-thorns outbreak and cyclone damage.



CYCLONES (1980 - 2016)
Category 5
> 107 knots
Category 4
86 to 107 knots
Category 3
64 to 85 knots
Category 2
48 to 63 knots
Category 1
34 to 47 knots
Vanuatu Provisional EEZ Boundary
Boundary as deposited at UN
Archipelagic Baseline
Capital city
50
100 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; Claus et al, 2016; Knapp et al, 2010; Smith and Sandwell, 1997; Weather Underground, 2017.
165°E
170°E
15°S
20°S
25°S
Torres Islands
Banks Group
Vanua Lava Island
Gaua Island
Maéwo Island
Espiritu Santo Island
Aoba Island
Pentecost Island
Ambrym Island
Malakula Island
Épi Island
VANUATU
Éfaté Island
Erromango Island
Tanna Island
Anatom Island
Matthew Hunter Group
Pam (2015)
Susan (1998)
Fran (1992)

STORMY TIMES: CYCLONES

Tropical cyclones pose direct threats to Vanuatu, its people and its marine life. Marine and coastal habitats including mangroves, seagrasses and coral reefs play an important role in offering effective protection and therefore need to be sustainably managed and conserved.

While being the strongest, the category 5 Cyclone Pam is but one track on the map showing all category 1 to 5 cyclones that occurred in the period from 1980 to 2016. Pam formed east of the Solomon Islands on 6 March 2015 and tracked slowly south, most heavily impacting the southern islands of Vanuatu before beginning to weaken on 14 March.

Cyclones are monitored by the Vanuatu Meteorology and Geohazards Department and categorized according to the Australian and South Pacific Category System from category 1 (90 km/h gusts) to category 5 (280 km/h gusts). The cyclone season is considered to run from the beginning of November to the end of April, but destructive cyclones can occur outside this period. The formation of cyclones in the region is strongly influenced by the El Niño–Southern Oscillation (ENSO; see also chapters “Go with the flow” and “Hotter and higher”). During El Niño years, cyclones are more likely to form between 6°S and 18°S and 170°E and 170°W. During La Niña years, slightly fewer tropical cyclones form and the origin moves to the south (Chand and Walsh, 2009). On average, Vanuatu receives 2–3 cyclones per season, with around 3–5 cyclones per decade causing severe damage (VMGD, 2017).

In the past decade, there has been increasing attention on the relationship between climate change and the frequency and intensity of cyclones in the region. Diamond et al. (2013) found a statistically significant increase in the number and intensity of cyclones in the period 1991–2010 compared with the period 1970–1990. Rising SSTs are fuelling cyclones (see also chapters “Hotter and higher”) that are resulting in increasing damage, including to Vanuatu’s valuable coastal habitats.

At the same time, conserving habitats such as coral reefs and mangroves offers a very effective form of protection against storms. In this way, Vanuatu can strengthen its defences against cyclones.

A trail of destruction

Grounded yachts were not the only wreckage Cyclone Pam left in its wake. Residents around the country, particularly those in the southern islands, were shocked to witness the toll that Pam had taken on the coral reefs. Over large areas, the force of the waves had dislodged large coral formations and moved heavy boulders great distances, greatly changing the structure of the ecosystem (see also chapter “Reefs at risk”).

Cyclone Pam, gusting at 280 km/h, killed at least 15 people, left another 75,000 homeless and destroyed 90 per cent of food crops. The financial toll amounted to approximately AUD $590 million—more than half of Vanuatu’s gross domestic product (GDP).

Graveyard of the yachts after Cyclone Pam at the old BP wharf in Port Vila.

MANAGING

The marine and coastal ecosystems of Vanuatu's waters provide benefits for people in and beyond Vanuatu. To better understand and improve the effective management of these values on the ground, Pacific Island countries, including Vanuatu, are increasingly building institutional and personal capacities for planning and management.

However, there is no need to reinvent the wheel, as Pacific Islanders possess centuries of traditional management knowledge. Coupled with scientific approaches and lessons learned, this knowledge can strengthen effective management of the region's rich natural capital.

The maps in this chapter showcase marine management in Vanuatu that starts at the local level, based on the management of traditional fishing grounds. In addition, Vanuatu has made strong national commitments to effectively manage its marine resources, which are embedded in regional and international efforts and commitments, such as the Aichi Biodiversity Targets, the United Nations Oceans Conference in support of the 2030 Agenda for Sustainable Development and the Pacific Oceanscape Framework. These management efforts can be effectively supported by marine planning efforts.

To maximize benefits from these marine values for Vanuatu, national and regional stakeholders are working together to document effective approaches to sustainable marine resource management and conservation. This chapter encourages stakeholders to share tried and tested concepts and instruments more widely throughout the Oceania region.

For further reading, please see: **http://macbio-pacific.info/effective-management**

SPACE TO RECOVER: MARINE MANAGEMENT

Marine managed and protected areas are key to maintaining Vanuatu's valuable marine resources. To effectively implement these areas, it is important to combine traditional marine management with national and international efforts.

Taking into account every type and category of protected area globally, only 3.5 per cent of the ocean is currently protected. Environmental organizations and scientists recommend that between 20 and 50 per cent of the ocean should be protected. The goal is not to preserve things as they are — even protected areas harbour only a tiny fraction of the biodiversity that once existed — but to allow life to recover.

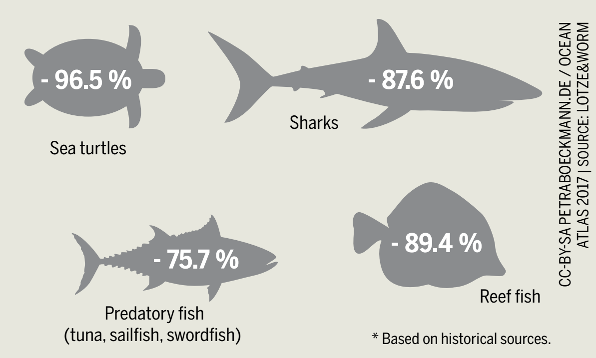
This is crucial, given the decline of global marine populations (see graphic). For this reason, the world wants to protect at least 10 per cent of coastal and marine areas by 2020, as formulated in an international CBD target (see also chapter "Vanuatu's commitment to marine conservation"). Indeed, marine managed areas are steadily increasing.

Marine managed areas are areas of the ocean that are managed for specific purposes, which can include protection of biodiversity or sustainable use of the resources. These areas are summarized in the World Database on Protected Areas (WDPA), which is a global compilation of both terrestrial and marine protected areas produced by IUCN and UNEP-WCMC (Protected Planet, 2016). For protected areas to be included in this database, they must align with one of six IUCN protected area management categories, which provide international standards for defining protected areas and encourage conservation planning according to their management aims. Only one of these categories is "no take", and they are often placed at the core of a protected area. However, holistic, sustainable marine management on a large scale is key to conserving the marine values.

Recognizing the role that MPAs play in allowing marine life to recover, Vanuatu has committed to protecting 10 per cent of its sea (see also chapter "Vanuatu's commitment to marine conservation") by 2020, using Vanuatu-specific categories of protection. While this is an ambitious goal, Vanuatu has a rich tradition of marine management upon which to build. Traditional fisheries management is common in Vanuatu, where community leaders (particularly chiefs) implement management initiatives for the betterment of their marine resources. Known examples include closed seasons, closed areas and size limit restrictions.

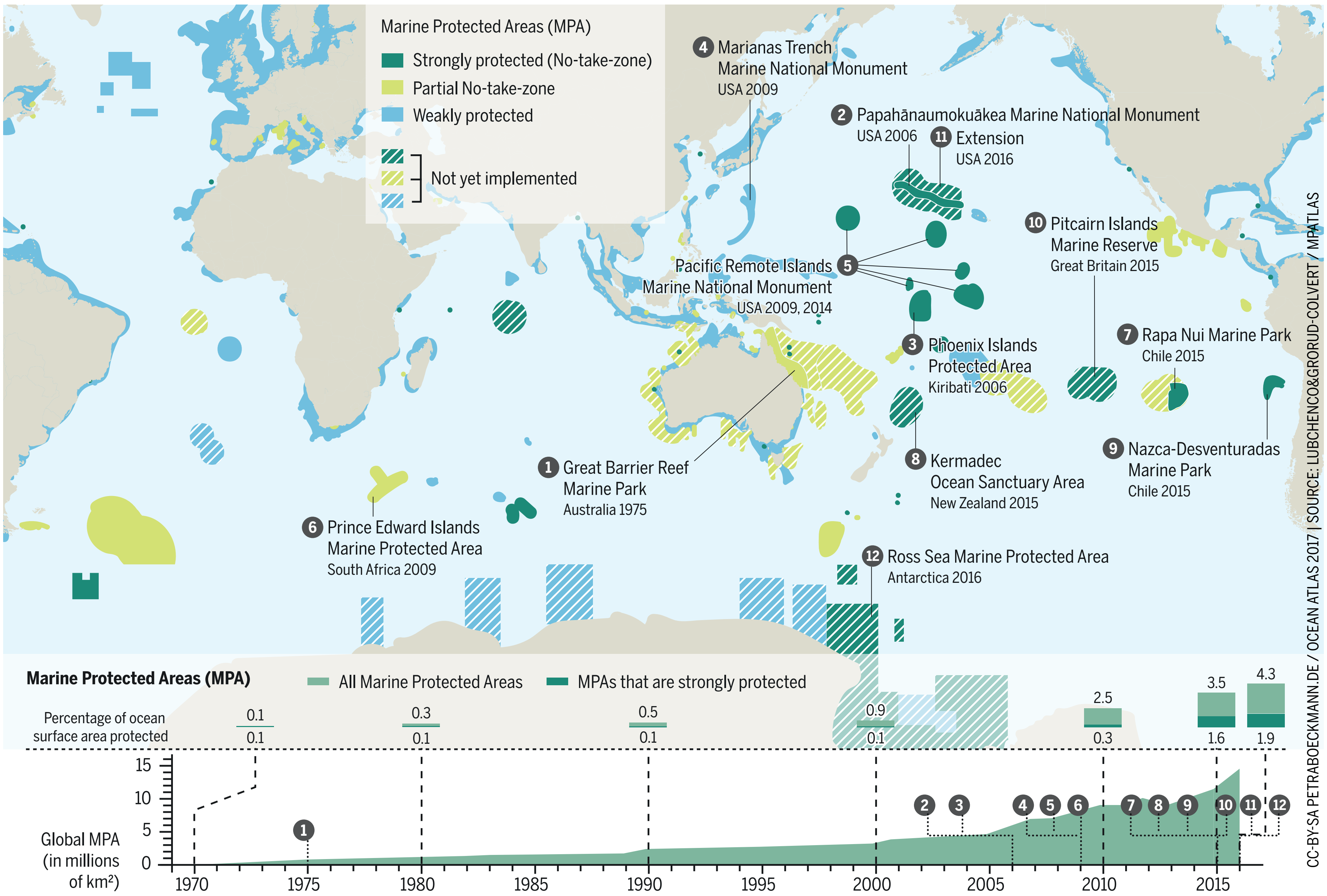
MPAs and locally managed marine areas (LMMAs) can improve human well-being by increasing human resilience to short and long-term threats (thus supporting objectives for community resilience under the National Climate Change Policy) and protecting ecosystems and vulnerable species from ridge to reef, thereby assisting Vanuatu in meeting its commitments under the CBD.

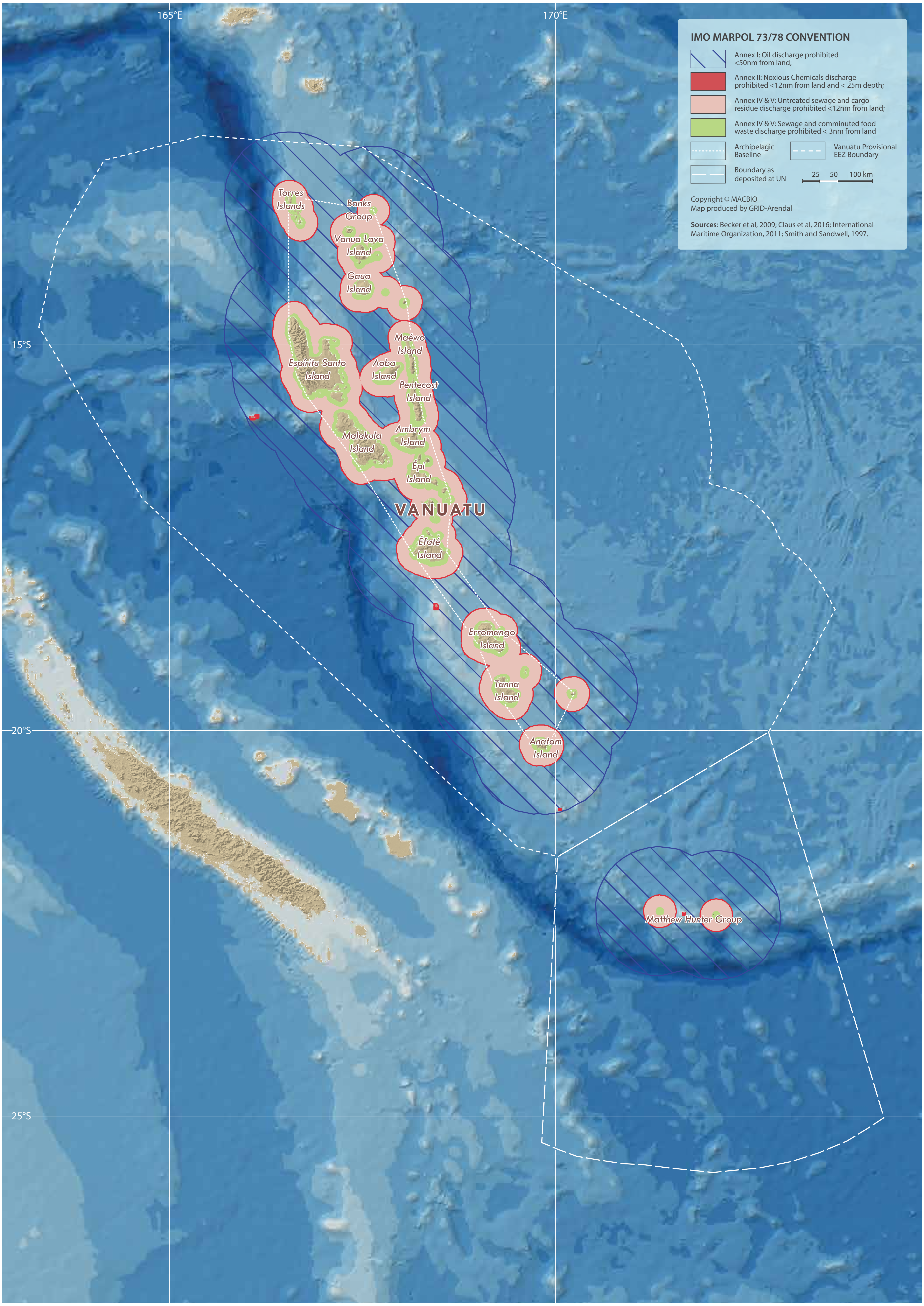
Declining Populations* (Percentage Change)



All the MPAs and LMMAs in Vanuatu are found in the shallow coastal zone, which is the area of greatest human use, from commercial and artisanal fishing to tourism and transport. The marine managed areas in this area contribute to sustainable local livelihoods.

Marine Protected Areas – Space to Recover





165°E
170°E
15°S
20°S
25°S
IMO MARPOL 73/78 CONVENTION
Annex I: Oil discharge prohibited <50nm from land;
Annex II: Noxious Chemicals discharge prohibited <12nm from land and < 25m depth;
Annex IV & V: Untreated sewage and cargo residue discharge prohibited <12nm from land;
Annex IV & V: Sewage and comminuted food waste discharge prohibited < 3nm from land
Archipelagic Baseline
Vanuatu Provisional EEZ Boundary
Boundary as deposited at UN
25 50 100 km
Copyright © MACBIO
Map produced by GRID-Arendal
Sources: Becker et al, 2009; Claus et al, 2016; International Maritime Organization, 2011; Smith and Sandwell, 1997.
Torres Islands
Banks Group
Vanua Lava Island
Gaua Island
Maéwo Island
Espiritu Santo Island
Aoba Island
Pentecost Island
Malakula Island
Ambrym Island
Epi Island
VANUATU
Éfaté Island
Erromango Island
Tanna Island
Anatom Island
Matthew Hunter Group

ONE WORLD, ONE OCEAN: INTERNATIONAL MARITIME ORGANIZATION (IMO) MARPOL CONVENTION

Vanuatu's marine values do not stop at national borders. This makes international cooperation increasingly important for effective management of values and their uses, such as mining, fisheries and shipping.

Vanuatu has sovereign rights over a vast marine area of 680,000 km². This area is rich in marine values and managed through various local, national and international instruments (see also chapter "Space to recover"). However, nearly half the Earth is covered by areas of the ocean that lie beyond national jurisdictions. Marine Areas Beyond National Jurisdiction (ABNJ), commonly called the high seas, are those areas of ocean for which no one nation has sole managerial responsibility. In the Pacific and around Vanuatu (see map "A sea of islands"), there are many high sea pockets that are connected to very important ecosystems and fisheries. Yet, marine species and ecosystems do not abide by the country borders shown on the map, as everything is connected in the ocean (see also chapter "Go with the flow" and "Travellers or homebodies"). Similarly, threats to marine values go beyond national boundaries. Hence, holistic, sustainable and effective marine management calls for appropriate international instruments.

Vanuatu is therefore part of the international governance structures for the ocean, which follow a multisectoral approach and involve a plethora of organizations (see graphic) dedicated to different uses, be it mining (see also chapter "Underwater Wild West"), fisheries (see also chapter "Fishing in the dark") or shipping (see also chapter "Full speed ahead").

Addressing the latter, the Convention for the Prevention of Pollution from Ships (MARPOL 73/78; see map) is an important international instrument that applies to Vanuatu's waters. Developed by the IMO in an effort to preserve the marine environment, it attempts to completely eliminate pollution by oil and other harmful substances, to minimize accidental spillages of such substances and to prevent air pollution from ships. The MARPOL 73/78 Convention contains six technical annexes, most of which include Special Areas with strict controls on operational discharges:

- Annex I Regulations for the Prevention of Pollution by Oil (entered into force 2 October 1983)

  Covers prevention of pollution by oil from operational measures as well as from accidental discharges.

- Annex II Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk (entered into force 2 October 1983)

  Details the discharge criteria and measures for the control of pollution by noxious liquid substances carried in bulk. No discharge of residues containing noxious substances is permitted within 12 miles of the nearest land.

- Annex III Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form (entered into force 1 July 1992)

  Contains general requirements for the issuing of detailed standards on packing, marking, labelling, documentation, stowage, quantity limitations, exceptions and notifications.

- Annex IV Prevention of Pollution by Sewage from Ships (entered into force 27 September 2003)

  Contains requirements to control pollution of the sea by sewage; the discharge of sewage into the sea is prohibited, except when the ship has in operation an approved sewage treatment plant or when the ship is discharging comminuted and disinfected sewage using an approved system at a distance of more than three nautical miles from the nearest land; sewage which is not comminuted or disinfected has to be discharged at a distance of more than 12 nautical miles from the nearest land.

- Annex V Prevention of Pollution by Garbage from Ships (entered into force 31 December 1988)

  Deals with different types of garbage and specifies the distances from land and the manner in which they may be disposed of; the most important feature of the annex is the complete ban imposed on the disposal into the sea of all forms of plastics.

- Annex VI Prevention of Air Pollution from Ships (entered into force 19 May 2005)

  Sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances; designated emission control areas set more stringent standards for SOx, NOx and particulate matter.

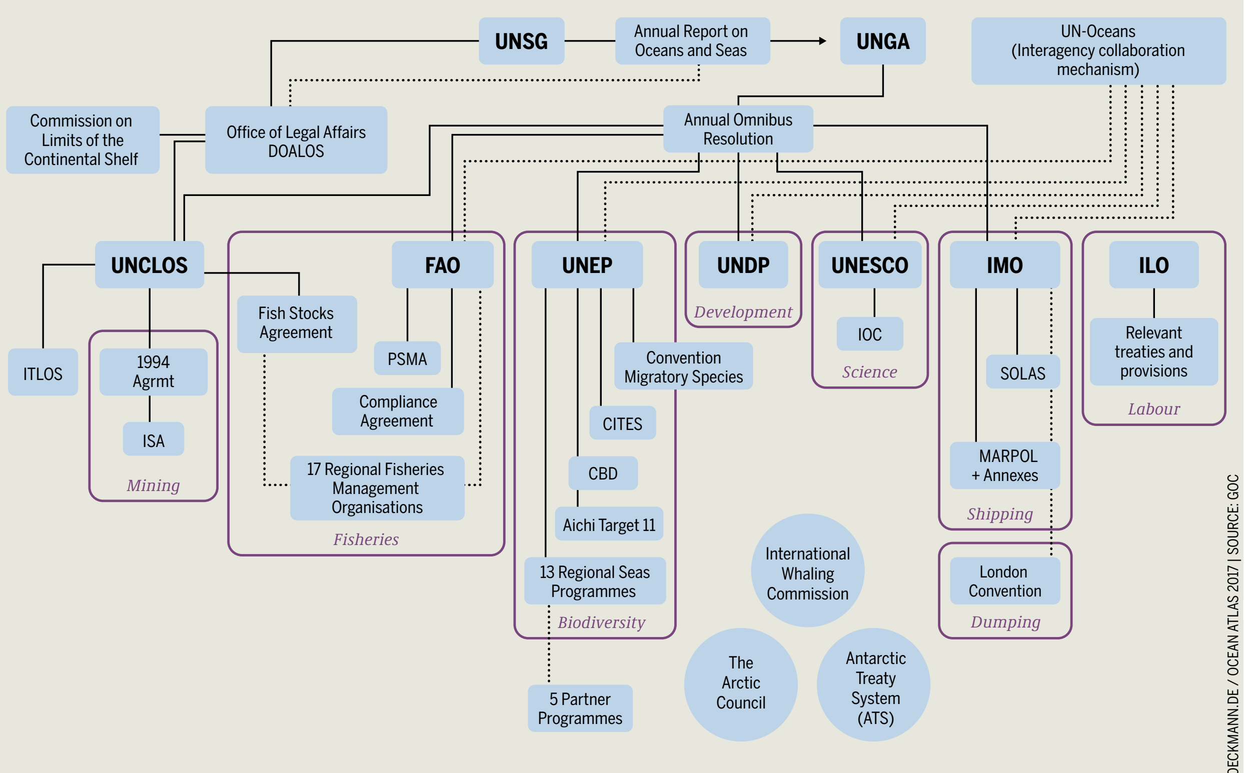
Under invasion

In addition to pollution, international shipping routes pose another threat to Vanuatu's marine values in the form of invasive species. Since the arrival of humans on the Pacific Islands, they have deliberately brought with them species that are useful for their survival, yet unwanted species have also been accidentally introduced. One of the major vectors for introduced species is the ballast water of ships. Some of the unwanted species get out of control and can cause enormous ecological, economic or health problems. These "invasive" species are also known as "pest" species. In response, the Pacific has developed the Pacific Invasives Partnership (PIP) as a coordinating body for international agencies that provide services to Pacific countries and territories.

In addition, one of the key aims of Vanuatu's National Ocean Policy is to reduce the impact of all sources of pollution (including land-based, solid waste, shipwrecks and shipping pollution) on the marine environment.

Beyond addressing pollution and invasive species, the Pacific Oceanscape Framework provides orientation at the regional level for sustainable marine management.

International Governance Structures for the Ocean – Multi-sectoral Approach and a Plethora of Organizations



CBD Convention on Biological Diversity; **CITES** The Convention on International Trade in Endangered Species of Wild Fauna and Flora; **DOALOS** Division for Ocean Affairs and the Law of the Sea; **FAO** Food and Agriculture Organization [of the United Nations]; **ILO** International Labour Organization; **IMO** International Maritime Organization; **IOC** Intergovernmental Oceanographic Commission; **ISA** International Seabed Authority; **ITLOS** International Tribunal for the Law of the Sea; **MARPOL** International Convention for the Prevention of Pollution from Ships; **PSMA** Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing; **RFMOs** Regional Fisheries Management Organisations; **SOLAS** International Convention for the Safety of Life at Sea; **UNDP** United Nations Development Programme; **UNEP** United Nations Environment Programme; **UNESCO** United Nations Educational, Scientific and Cultural Organization; **UNGA** United Nations General Assembly; **UNSG** United Nations Secretary-General

VANUATU'S COMMITMENT TO MARINE CONSERVATION

Vanuatu is committed to sustainably managing and conserving its marine values, so much so that its efforts in this respect extend beyond its international obligation of conserving 10 per cent of its waters by 2020.

Voluntary commitments

Voluntary Commitments for The Ocean Conference are initiatives voluntarily undertaken by key stakeholders individually or in partnership that aim to help implement Sustainable Development Goal (SDG) 14.

Vanuatu has long realized the many values it derives from its sea, and the importance of sustainably managing and planning its uses (see also previous chapter). Thus, in 1993, Vanuatu joined many other countries in signing and ratifying the international Convention on Biological Diversity (CBD), under which Vanuatu has accepted international responsibilities and obligations, including Aichi Target 11:

"By 2020, at least 17 per cent of terrestrial and inland water areas and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape."

However, considering the great importance of its marine resources, Vanuatu has gone even further. It is the first Pacific Island country to have a National Ocean Policy, which frames the overarching structure of the management of the ocean around the traditional meeting house, the Nakamal. The country has voluntarily committed to establishing a national, multiple-use Marine Spatial Plan and ecologically representative, climate-resilient network of MPAs. Vanuatu will also establish a National Ocean Office within its Ministry of Foreign Affairs to implement the National Ocean Policy.

This shows how seriously Vanuatu takes the role of maintaining its rich marine values for all Ni-Vanuatu, including future generations to come.

In 2015, the National Committee on Maritime Boundary Delimitation, through the Ministry of Foreign Affairs, International Cooperation and External Trade, established the Ocean Policy Subcommittee. This Subcommittee is continuing its work as the Ocean Policy Implementation Subcommittee, comprising the Prime Minister's Office and six ministries that have a vested interest in the ocean:

- Ministry of Foreign Affairs, International Cooperation and External Trade (Department of Foreign Affairs, Maritime Division) (Co-Chair of the Ocean Policy Implementation Subcommittee)
- Ministry of Climate Change, Meteorology, Environment, Geohazards, Energy, Environment and Disaster Risk Management (Department of Environmental Protection and Conservation, National Advisory Board on Climate Change and Disaster Risk Reduction)(Co-Chair of the Ocean Policy Implementation Subcommittee)
- Ministry of Agriculture, Livestock, Forestry, Fisheries and Biosecurity (Department of Fisheries)
- Ministry of Lands and Natural Resources (Department of Geology and Mines)
- Ministry of Infrastructure and Public Utilities (Department of Ports and Harbour)
- Ministry of Finance and Economic Management (Department of Finance and Treasury)
- Prime Minister's Office

The Ocean Policy Implementation Subcommittee works closely with other ministries such as the Ministry of Trade, Commerce, Tourism and Industry (Department of Tourism), Ministry of Internal Affairs and Community Services (Department of Provincial Affairs) and the Malvatumauri Council of Chiefs, as well as other non-governmental stakeholders and experts.

The Ocean Policy Subcommittee produced the Pacific's first National Ocean Policy, which the Ocean Policy Implementation Subcommittee will continue to implement.

The vision of the Ocean Policy is to conserve and sustain a healthy and wealthy ocean for the people and culture of Vanuatu, today and tomorrow. This shows that Vanuatu is committed to sustainably managing and conserving its marine values. In this spirit, Vanuatu submitted six Voluntary Commitments to the United Nations Ocean Conference in June 2017, focusing on ecosystems management and conservation, as well as integrated area-based governance.

"The Ocean Conference has changed our relationship with the ocean. Henceforth none can say they were not aware of the harm humanity has done to the ocean's health. We are now working around the world to restore a relationship of balance and respect towards the ocean," said the President of the United Nations General Assembly Peter Thomson, from Fiji, at the closing of the United Nations Ocean Conference.

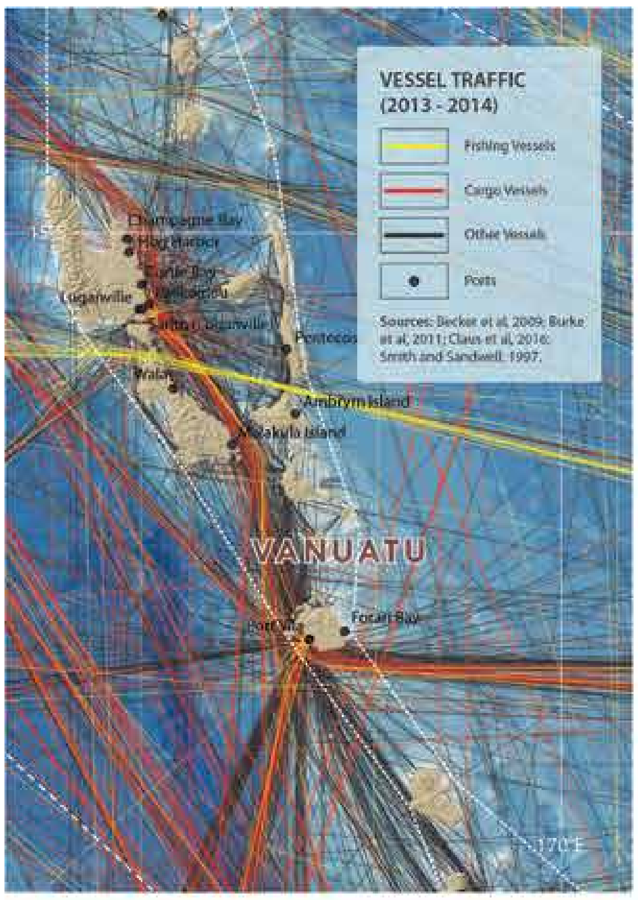
The 193 Member States of the United Nations unanimously agreed to a set of measures that aim to reverse the decline of the ocean's health. The "Call for Action" outcome document, together with more than 1,300 commitments to action, marks a breakthrough in the global approach to the management and conservation of the ocean. Recognizing that the well-being of present and future generations is inextricably linked to the health and productivity of the ocean, countries collectively agreed in the Call to Action "to act decisively and urgently, convinced that our collective action will make a meaningful difference to our people, to our planet and to our prosperity."

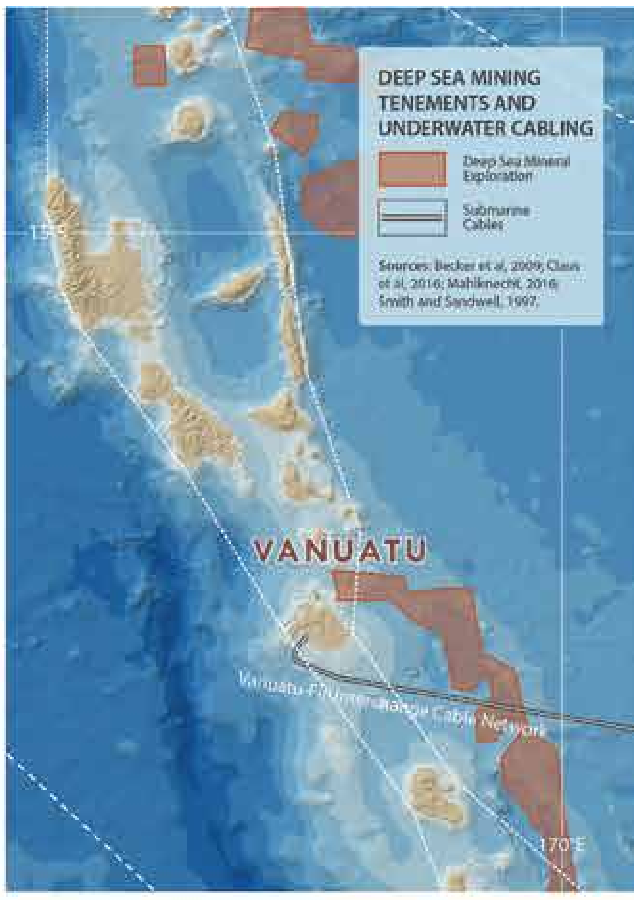
The second highest number of commitments come from the South Pacific, highlighting not only the importance of the ocean to Pacific Island countries, but also their commitment to "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" (SDG 14).

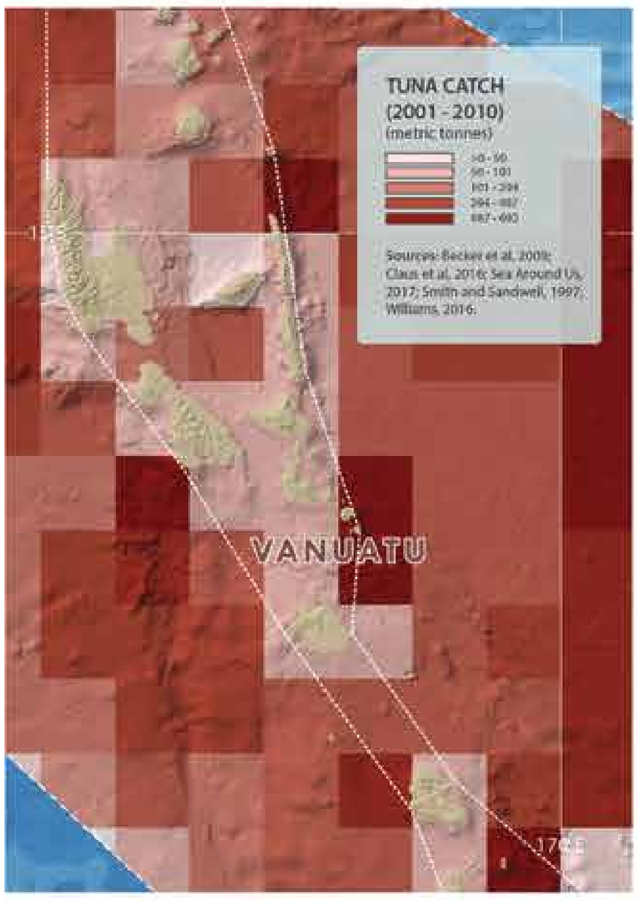
Vanuatu is calling for action to conserve valuable life below the surface, within its own waters and beyond.

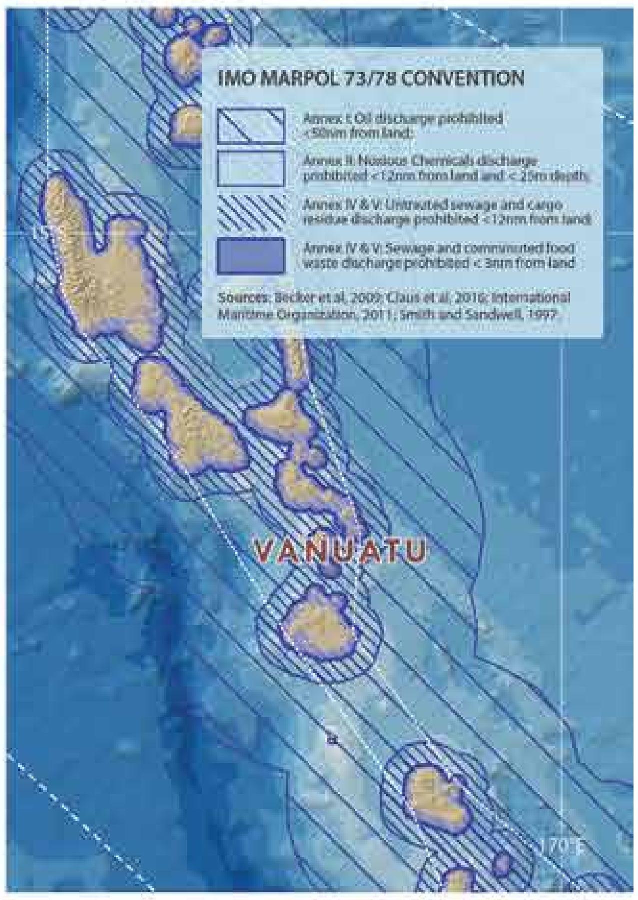
Voluntary Commitment Title	ID	Description and focus
National Marine Spatial Plan for Vanuatu	21632	To develop and implement a national, multiple-use Marine Spatial Plan with a wide range of objectives.
Network of marine protected areas for Vanuatu	21628	To develop a national, ecologically representative, climate-resilient network of MPAs, including highly protected areas.
Establishment of the National Ocean Office	21616	To institutionalize the National Ocean Office within the Ministry of Foreign Affairs to implement the National Ocean Policy of Vanuatu.

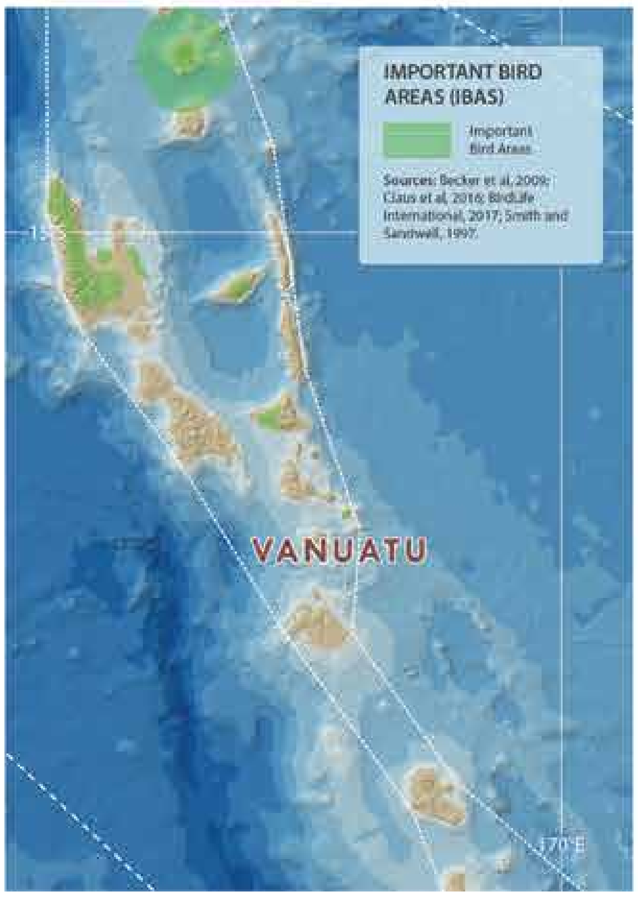
A MARINE LAYER CAKE

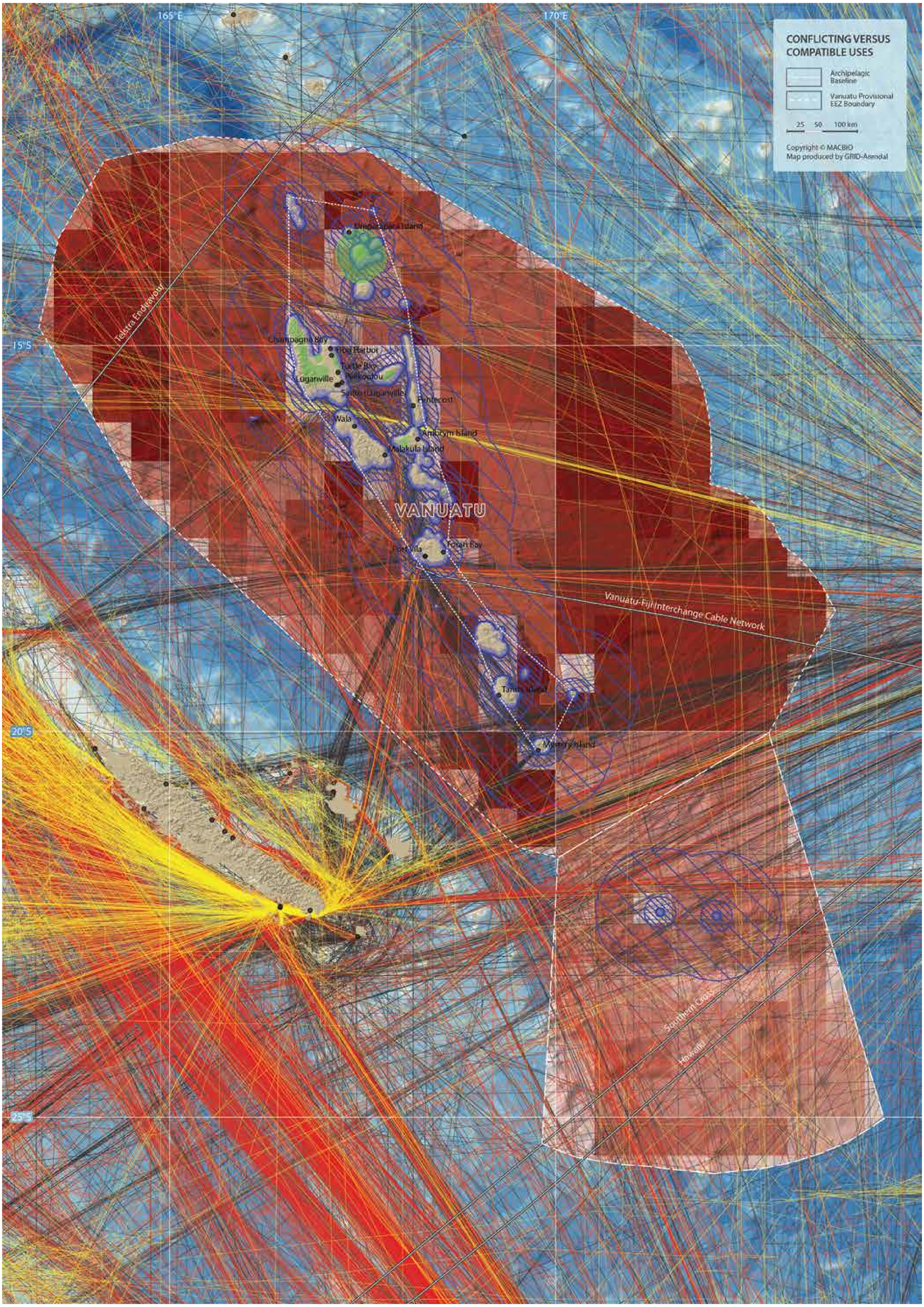











CONFLICTING VERSUS COMPATIBLE USES
Archipelagic Baseline
Vanuatu Provisional EEZ Boundary
25 50 100 km
Copyright © MACBIO
Map produced by GRID-Arendal
165°E
170°E
15°S
20°S
25°S
Telstra Endeavour
Champagne Bay
Hog Harbor
Luganville
Pentecost
Wala
Ambrym Island
Malakula Island
VANUATU
Port Vila
Forari Bay
Vanuatu-Fiji Interchange Cable Network
Southern Cross

CONFLICTING VERSUS COMPATIBLE USES

In an increasingly crowded seascape, MSP helps avoid conflict and maximize benefit between overlapping uses.

The six map close-ups on vessel traffic (see also chapter "Full speed ahead"), mining (see also chapter "Underwater Wild West"), fisheries (see also chapter "Fishing in the dark") and management (see also chapter "Space to recover") show snapshots of the many marine uses detailed in the previous chapters. On its own, each looks manageable. However, zooming out and looking at the big picture of all uses, it is clear that many overlap. Some of these may be complementary, such as conservation and tourism, while other uses impact each other and may lead to conflicts, such as pollution from shipping in an important fishery, or deep-sea mining on a biologically diverse seamount.

How can Vanuatu address these conflicts?

Marine Spatial Planning (see text box) holds the key to sharing marine uses fairly, and one of the key tools used to implement MSP is a zoning plan. This is a tool that divides the ocean into zones, where each zone includes different activities that are or are not permitted.

The main purpose of a zoning plan (Ehler and Douvere, 2009) is to:

- separate conflicting human activities or to combine compatible human activities
- protect the natural values of the marine management area while allowing reasonable human uses of the area
- allocate areas for reasonable human uses while minimizing the effects of these human uses on each other and nature
- provide protection for biologically and ecologically important habitats, ecosystems, and ecological processes and
- preserve some areas of the marine managed area in their natural state, undisturbed by humans except for scientific or educational purposes

There is no need to reinvent the wheel, as zoning of Vanuatu's waters is not a new concept and there are already a large number of different types of zones—although they may not be called zones. These include shipping lanes, IMO regulations regarding pollution at sea (see also chapter "One world, one ocean"), fisheries closures, and marine protected or managed areas, including LMMAs (see also chapter "Space to recover"). Each of these different zones stipulate different areas within which particular activities are permitted or not permitted.

In the past, however, these zones have been largely designated within single sectors, with little consideration of other human uses in the same area. Instead, a zoning plan that is derived through comprehensive MSP process takes into account how human uses impact each other and the environment. MSP can occur at a site level (such as a bay), across an entire marine managed area, within an EEZ, or between neighbouring countries (transboundary). It should aim to achieve clear ecological, economic and social goals and objectives.

Marine Spatial planning

Marine Spatial Planning (MSP) is an intersectoral and participatory planning process and tool that seeks to balance ecological, economic, and social objectives, aiming for sustainable marine resource use and prosperous blue economies.

Each marine zone should have an assigned objective that permits a range of activities to occur, provided that each activity complies with the relevant zone objective. All zones should contribute to the overall goals and objectives of the Marine Spatial Plan. For example, if the objective of a zone is to protect the sea-floor habitat, then activities such as trawling, mining or dredging should not be permitted, while other zones where the objective is to allow for a broad range of industrial uses may allow industrial tuna, shipping or even mining to occur.

Preparing a zoning plan is not an easy task, and is best achieved through considerable consultation, including across government departments at all levels, users, other stakeholders and the community. Zoning plans must accommodate and balance the cultural, economic, social and biological needs of the community.

MPAs are primarily established to meet biodiversity objectives, but can also have sociocultural and economic objectives that are consistent with national, regional and local needs. To meet these different objectives, MPAs can contain one or more zones to provide for different levels of protection.

The IUCN Protected Area Categories classify protected areas according to their management objectives. The categories are recognized by international bodies, such as the United Nations, and by many national governments as the global standard for defining and recording protected areas, and as such are increasingly being incorporated into government legislation.

However, the process of aligning standardized categories to individual MPAs is not an easy one and not without a degree of controversy. For example, protected areas that are culturally appropriate for Vanuatu may not always fit neatly into any one of the seven IUCN categories. If they are to be applied effectively, therefore, any categories used by a nation must be interpreted and adapted to meet the country's biophysical, sociocultural and economic needs.

This is a very promising way to share and manage Vanuatu's rich and complex marine environment in a fair and sustainable manner, while maximizing benefits.

CONCLUSION

Vanuatu's vast ocean supports a myriad of marine values. To successfully conserve and manage these values, the island nation is strongly committed to holistic planning and effective management of its ocean.

Vanautu's national vision for its ocean is:

> *"To conserve and sustain a healthy and wealthy ocean for the people and culture of Vanuatu, today and tomorrow."*

Vanuatu has developed an Ocean Policy that provides the framework for integrated ocean management, including national MSP. Stakeholders across Vanuatu are working together to implement the Ocean Policy to secure a healthy, productive, resilient and biodiverse ocean for all. At present, Vanuatu is also initiating national consultations for a national Marine Spatial Plan to ensure that it is a truly participatory and inclusive process that generates nationwide ownership across sectors.

We thank everyone who participated in meetings regarding this atlas and who, through their involvement, contributed input, guidance, data and/or information to this atlas and identified its utility to policy and decision-making (see list of data providers listed in the References).

In particular we thank the Ministry of Foreign Affairs, International Cooperation and External Trade, the Ministry of Climate Change, Meteorology, Environment, Geohazards, Energy, Environment and Disaster Risk Management and other relevant ministries for providing the project with data and support.

We are grateful for the contributions of text and graphical elements from the Ocean Atlas 2017 of the Heinrich Böll Foundation to this atlas.

We also thank the professionals of the MACBIO team, in alphabetical order: Mia Avril, Jasha Dehm, Marian Gauna, Jimaima Le Grand, Thomas Malone, Jan Steffen, Jonah Sullivan for their support, as well as the GRID-Arendal team: Kaja Lønne Fjærtoft, Georgios Fylakis, Elsa Lindeval, Petter Sevaldsen and Janet Fernandez Skaalvik, and Christopher Bartlett from GIZ.

While the atlas provides the best data currently publicly available, the information about Vanuatu's waters is constantly increasing. In this way, the atlas is an open invitation to use, modify, combine and update the maps and underlying data.

The e-copy and interactive version of the Vanuatu Marine Atlas are available here: **http://macbio-pacific.info/marine-atlas**

Timeline of the Vanuatu Marine Spatial Planning process

2012

APRIL
The government of Vanuatu, through the Ministry of Foreign Affairs, International Cooperation and External Trade, hosted an intragovernmental, cross-ministerial national workshop on ocean governance.

2014

NOVEMBER
The Council of Ministers (Decision No. 172/2014) approved the report arising from the 2012 national workshop on ocean governance as a framework to guide integrated ocean management in Vanuatu. They also decided to ask MACBIO to support key areas of ocean management (recommendations 2, 3, 4, 5, 7 and 8 from the report), including marine ecosystem service valuation, legal analysis, development of an Ocean Policy, capacity-building and MSP

2015

FEBRUARY
The National Committee on Maritime Boundary Delimitation, through the Ministry of Foreign Affairs, International Cooperation and External Trade, established a cross-Ministerial Ocean Policy Sub-Committee.

APRIL
The Ocean Policy Subcommittee prepared a first draft of a National Ocean Policy for Vanuatu.

An analysis of the legislative basis for an Ocean Policy and Marine Spatial Plan was conducted (contributing to COM Decision 172/2014, Item 3)..

MAY – *MARCH 2016*
Over 1,000 people were involved in national consultations held on the draft Ocean Policy in 32 locations across the country. A consultation report was prepared.

2016

***MAY 2015* – MARCH**
Over 1,000 people were involved in national consultations held on the draft Ocean Policy in 32 locations across the country. A consultation report was prepared.

MAY
A national marine ecosystem service valuation was presented to the National Committee (COM Decision 172/2014, Item b).

JUNE
The draft Ocean Policy was substantially revised based upon input from the national consultations.

SEPTEMBER
The Council of Ministers approved the revised Ocean Policy (see COM Decision 172/2014, Item 2).

2017

APRIL
The Acting Prime Minister launched the Ocean Policy at Vanuatu's inaugural national Ocean Summit.

JUNE
At the United Nations Ocean Conference, Vanuatu shared its intentions with the global community to have in place, by 2020, a national Marine Spatial Plan including a national ecologically representative network of MPAs and a National Oceans Office.

JULY
First steps were taken to implement the most novel part of the Ocean Policy—the national Marine Spatial Plan. A workshop was held to describe the range of ocean zones to use in the Marine Spatial Plan.

OCTOBER
National experts described 109 draft biophysically special, unique areas of Vanuatu for use in MSP. A report is being prepared.

2018

Marine bioregions that describe the entire marine environment of Vanuatu were defined by Vanuatu's marine experts for use in designing an ecologically representative network of MPAs.

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A Marine Layer Cake

MAPS

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Conflicting Versus Compatible Uses

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APPENDIX 1. DATA PROVIDERS

Organisation Name	Organisation Website
AquaMaps	http://www.aquamaps.org/search.php
Commonwealth Scientific and Industrial Research Organisation	http://www.csiro.au/
Convention on Biological Diversity	https://www.cbd.int/
Earth & Space Research (ESR)	http://www.esr.org/
Ecologically or Biologically Significant marine Areas	https://www.cbd.int/ebsa/
exactEarth	http://www.exactearth.com/
Government of The Kingdom of Tonga	http://www.gov.to/
Government of Vanuatu	http://governmentofvanuatu.gov.vu/
GRID-Arendal	http://www.grida.no/
Institute for Marine Remote Sensing	http://imars.marine.usf.edu/
Interridge	http://www.interridge.org/
Khaled bin Sultan Living Oceans Foundation	https://www.livingoceansfoundation.org/
Marine Ecology Consulting	http://marineecologyfiji.com/
National Aeronautics and Space Administration	http://www.nasa.gov/
National Oceanic and Atmospheric Administration	http://www.noaa.gov/
Oregon State University	http://oregonstate.edu/
Pacific community	http://gsd.spc.int/
Ports Authority Tonga	http://portsauthoritytonga.com/
Reef Life Survey	http://reeflifesurvey.com/
Republic of Kiribati	http://www.pso.gov.ki/
Sea Around Us is a research initiative at The University of British Columbia	http://www.seaaroundus.org/
Secretariat of the Pacific Regional Environment Program	http://www.sprep.org/
Solomon Islands Government	
The University of Queensland	http://www.uq.edu.au/
The Fijian Government	http://www.fiji.gov.fj/
The General Bathymetric Chart of the Oceans (GEBCO)	http://www.gebco.net/
The Nature Conservancy	http://www.nature.org/
Tonga Cable Limited	http://tongacable.to/
Tourism Tonga	https://plus.google.com/110982421797787387797
U.S. Geological Survey	https://www.usgs.gov/
University of South Florida	http://www.usf.edu/
Vava'u Environmental Protection Association	http://www.vavauenvironment.org/
Vlaams Instituut voor de Zee	http://www.vliz.be/
Western & Central Pacific Fisheries Commission	https://www.wcpfc.int/
Wildlife Conservation Society	https://www.wcs.org/
World Wildlife Fund	http://www.worldwildlife.org/
Zoological Society of London	https://www.zsl.org/

APPENDIX 2. PHOTO PROVIDERS

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25	NASA Earth Observatory
25	Uwe Kils
27	iStock/holgs
27	GRID-Arendal/Glenn Edney
27	GRID-Arendal/Lawrence Hislop
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45	MACBIO
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51	Ocean Exploration Trust
53	iStock/rweisswald
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56	22Kartika
61	iStock/ValentynVolkov
63	David Burdick
63	CSIRO/Matt Curnock
65	Wikimedia/Humans of Vanuatu/Graham Crumb
66	MACBIO
68	iStock/LifeofRileyDesign
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