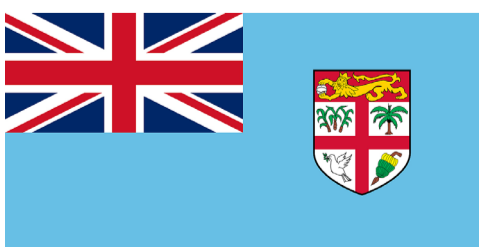




# MARINE ATLAS MAXIMIZING BENEFITS FOR FIJI





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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](http://www.macbio-pacific.info)

MARINE ECOSYSTEM SERVICE VALUATION

MARINE SPATIAL PLANNING

EFFECTIVE MANAGEMENT



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Project director: Jan Henning Steffen

Suggested citation: Gassner, P., Yakub, N., Kaitu'u, J., Wendt, H., Westerveld, L., Macmillan-Lawler, M., Davey, K., Baker, E., Clark, M., Fernandes, L. (2019) *Marine Atlas. Maximizing Benefits for Fiji*. MACBIO (GIZ/ IUCN/SPREP): Suva, Fiji. 88 pp.

ISBN: 978-82-7701-172-1



# MARINE ATLAS

## MAXIMIZING BENEFITS FOR

# FIJI

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2019



Marine and Coastal Biodiversity Management  
in Pacific Island Countries



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



# FOREWORD

While the ocean covers more than two thirds of the Earth's surface, the oceanic territory of Fiji is 70 times larger than its land territory. With an exclusive economic zone (EEZ) of 1.29 million km<sup>2</sup>, Fiji 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 more than 1,200 fish species, including sharks and rays, as well as whales, dolphins and sea turtles. We are committed to conserving this unique marine biodiversity.

Fiji's marine ecosystems are worth FJ\$2.5 billion per year—exceeding 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, Fiji's coastal villages manage inshore marine resources. We are striving to work together to sustainably manage all of Fiji's iqoliqoli (traditional fishing grounds) for the benefit of empowered and resilient communities.

At the same time, Fiji 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 Fiji, its people and its economy.

This is where the Fiji 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 Fiji, 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 Fiji'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 Fiji.

The e-copy and interactive version of the Fiji Marine Atlas are available here: <http://macbio-pacific.info/marine-atlas/fiji>



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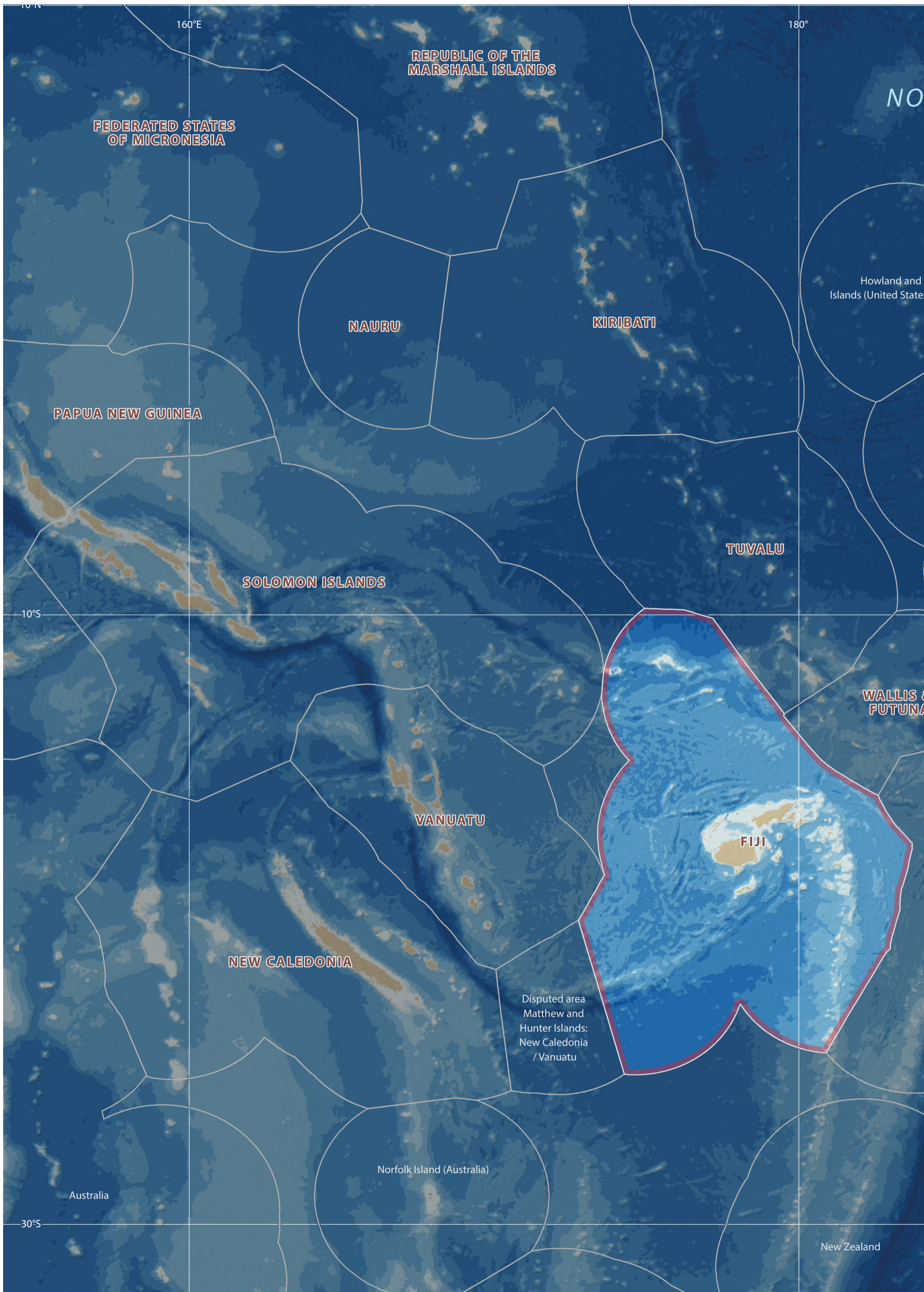


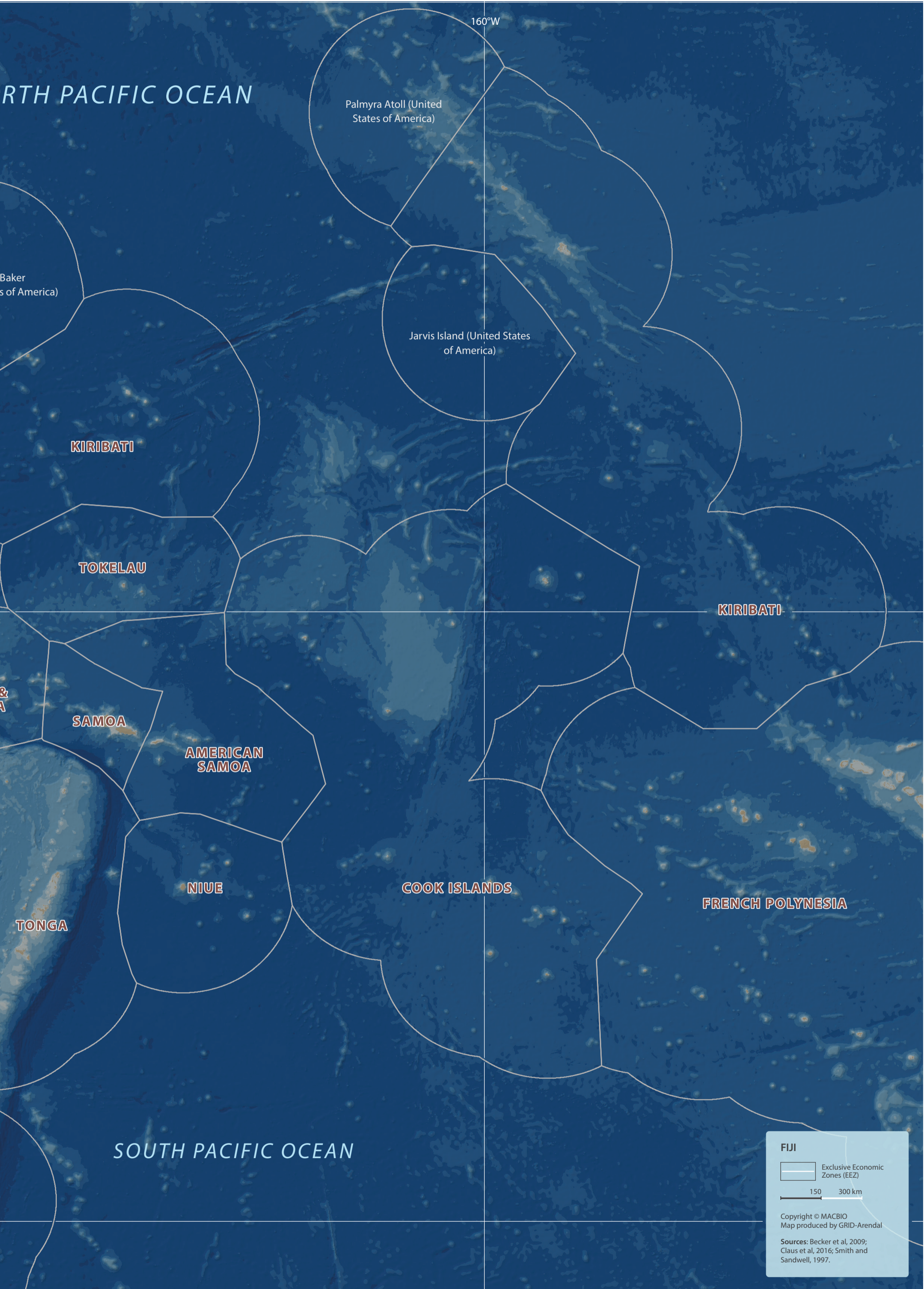
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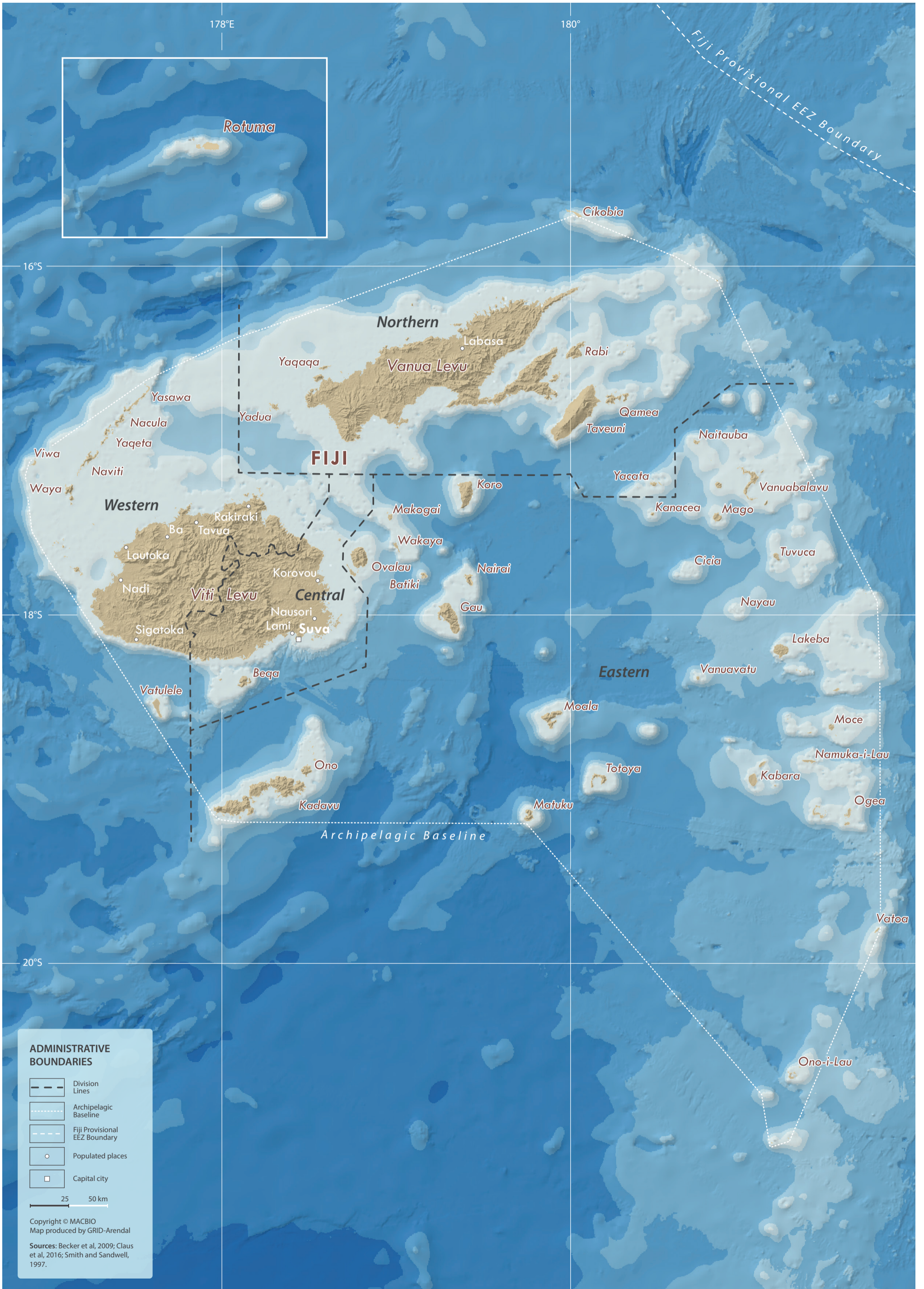
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# A LARGE OCEAN STATE: ADMINISTRATION

Fiji's ocean provides a wealth of services to the people of Fiji, 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 Fiji's marine area covering 1,290,000 km<sup>2</sup>. Boasting more than 330 islands, Fiji is relatively large in terms of land area compared with some of its neighbours. Each of these islands and the waters that surround them are rich in terms of their geography, biodiversity, lifestyles, languages and traditions.

One third of Fiji's islands are inhabited, with the two largest islands—Viti Levu and Vanua Levu—constituting three quarters of the country's total land area and 90 per cent of its population. Fiji is home to almost 900,000 people, comprising approximately 57 per cent indigenous Fijians (iTaukei), 38 per cent of Indian descent and 5 per cent 'other', including other Pacific Islanders, Rotuman, Chinese and those of European descent.

Religion plays an important role in Fijian culture, with the predominantly Christian population comprising

64 per cent of the total. Hindus represent 28 per cent, Muslims 6 per cent and other religions 2 per cent.

Fiji is divided into four divisions—Central, Western, Northern and Eastern—and 14 provinces. Suva, the capital of Fiji, is in the Central Division. The Central Division is the smallest yet most populated division in Fiji.

The Western Division, often described as the "Burning West", is Fiji's largest and hottest region and includes the Yasawa and Mamanuca island groups and the majority of Viti Levu. The Western Division is Fiji's second most populous division and houses Nadi airport, Fiji's primary international airport.

The Northern Division, or "Friendly North", is made up primarily of the islands of Vanua Levu and Taveuni and harbours large areas of pine and sugar plantations. The north is also home to the world's third largest barrier reef system, the Great Sea Reef (see

also "Shaping Pacific Islands") and Fiji's deepest river, the Dreketi river. Both these features are home to an array of endemic species. Taveuni, described as the "Garden Isle of Fiji", is home to Fiji's largest reserve—the Bouma National Heritage Park—which covers over 80 per cent of the island and protects many of the country's endemic birds and plants.

The Eastern Division is often described as "the way Fiji used to be". It is home to Fiji's old capital, Levuka town, which is Fiji's only UNESCO world heritage site. In terms of land area, this is Fiji's smallest division; however, it is home to the majority of Fiji's islands, which are spread over more than 50 per cent of Fiji's archipelagic waters, making it the division with the largest marine area. Owing to its isolation and lack of urbanization, it is considered one of Fiji's more pristine divisions.

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

## Tradition meets administration—managing Fiji's marine resources

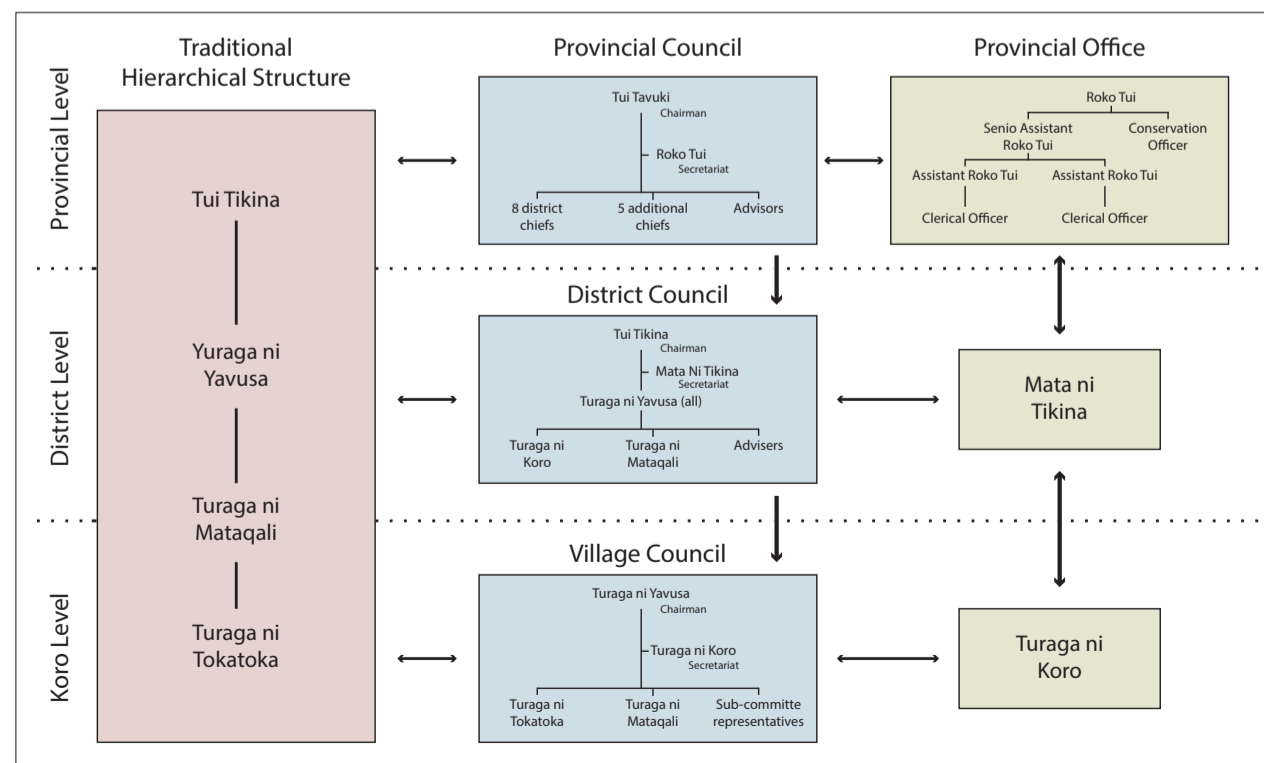
Traditionally, Fiji was ruled by many different warring tribes until Ratu Seru Epenisa Cakobau created a united Fijian kingdom in 1871. Fiji is now grouped into four divisions (see above) to ease the task of administrative oversight, including the administration of marine resources. Each division is overseen by a government-appointed commissioner; however, the divisions have few administrative functions, with their primary objective being to foster cooperation among the member provinces.

The government of Fiji has three distinct, independent arms: the Legislature (or Parliament), the Executive and the Judiciary. Ocean governance, in this context, is explained in more detail in the chapter "Fiji's commitment to marine conservation".

Understanding government representation is key to understanding the processes of marine resource management at the provincial level. Kadavu Province, south of Viti Levu, is used here as an example. At this level, the divisional commissioners are represented by the Provincial Administrator (PA) and his office. The PA acts as the head of government within the provinces. All ministries represented in the province report in some way to the PA, although individual ministerial representation varies between provinces. Among a number of other functions, the PA's office is in charge of administering the development of the province, issuing business licences and acting as a voice for all Fijians by representing them at divisional and national meetings.

However, traditional hierarchy also plays a significant role in Fijian governance. To effectively

acknowledge the rights of iTaukei and to align traditional and national governance, each province has its own council—the Provincial Council. The Provincial Council is the core of the iTaukei administrative system within the provinces and is headed by the Provincial Chief. Other members of the council include heads of the different clans that have pledged fealty to the Provincial Chief and advisers from various ministries, public organizations and the private sector. The Provincial Office, headed by the Roko Tui, represents the Ministry of iTaukei Affairs in the provinces and acts as the Secretariat to the Provincial Council. Together, the Provincial Council and Provincial Office work towards effectively administering the affairs, upholding the traditional rights and ensuring the general well-being of the iTaukei, including their benefits from marine values.



*iTaukei administrative system based on the Kadavu Province. It should be noted that, unlike most provinces, Kadavu does not instate a Tui Kadavu (provincial chief) but rather, the Tui Tavuki (one of nine district chiefs assumes the position as Chairperson in the Provincial Council). The general structure remains the same throughout the 14 provinces of Fiji.*





# VALUING

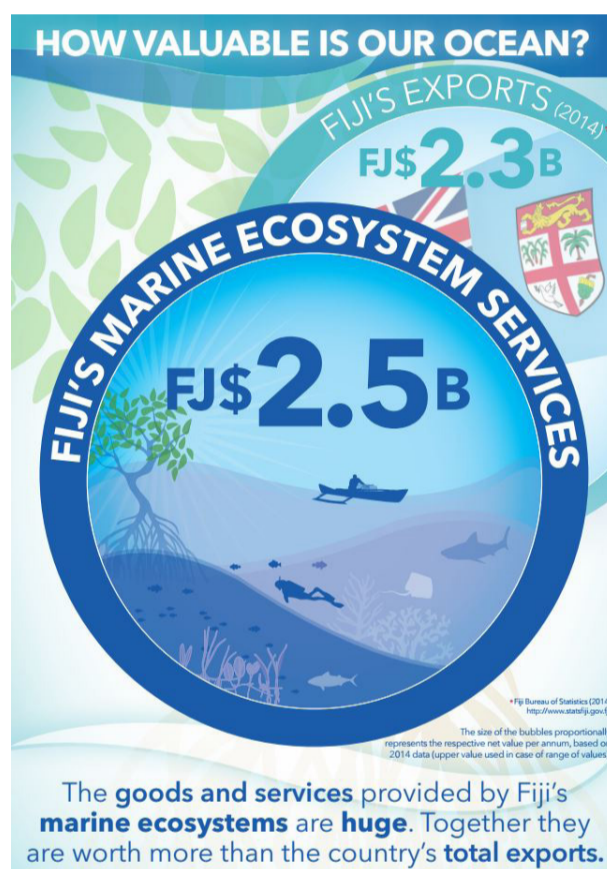
Marine ecosystems in Fiji provide significant benefits to society, including food security and livelihoods for the people of Fiji, the Pacific and around the world. Limited land resources and the dispersed and isolated nature of communities make the Fijian people heavily reliant upon the benefits of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

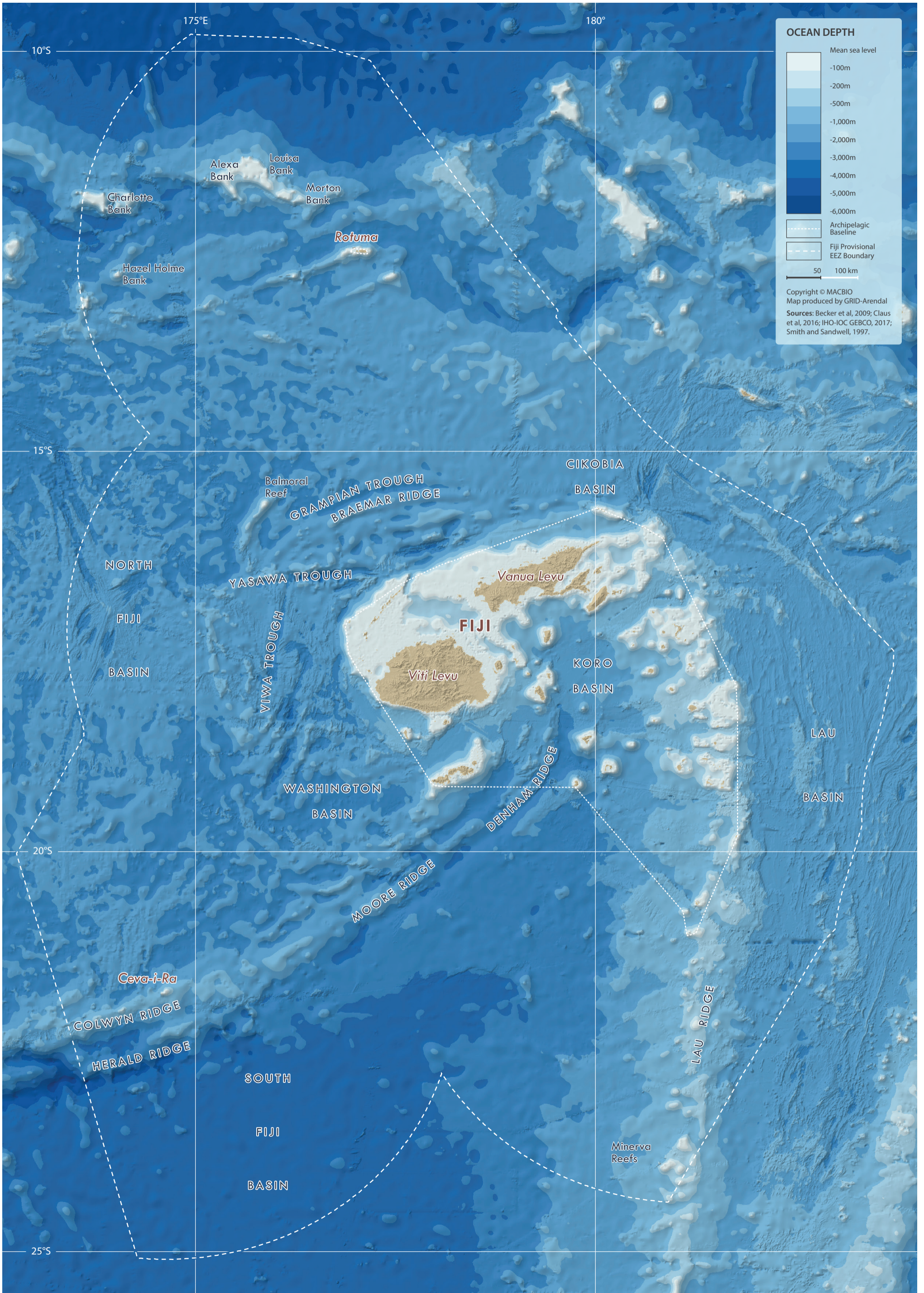
Appreciating the rich diversity of marine ecosystems helps in understanding their importance to Fiji. Quantifying the benefits of marine ecosystems in the Pacific makes it easier to highlight and support appropriate use and sustainable management decisions. Despite the fact that more than 95 per cent 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.

Fiji 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 Fiji.

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



Fiji's marine ecosystem services are **valuable** and **diverse**, yet often **hidden**.



## SUPPORTING VALUES

# STILL WATERS RUN DEEP: OCEAN DEPTH

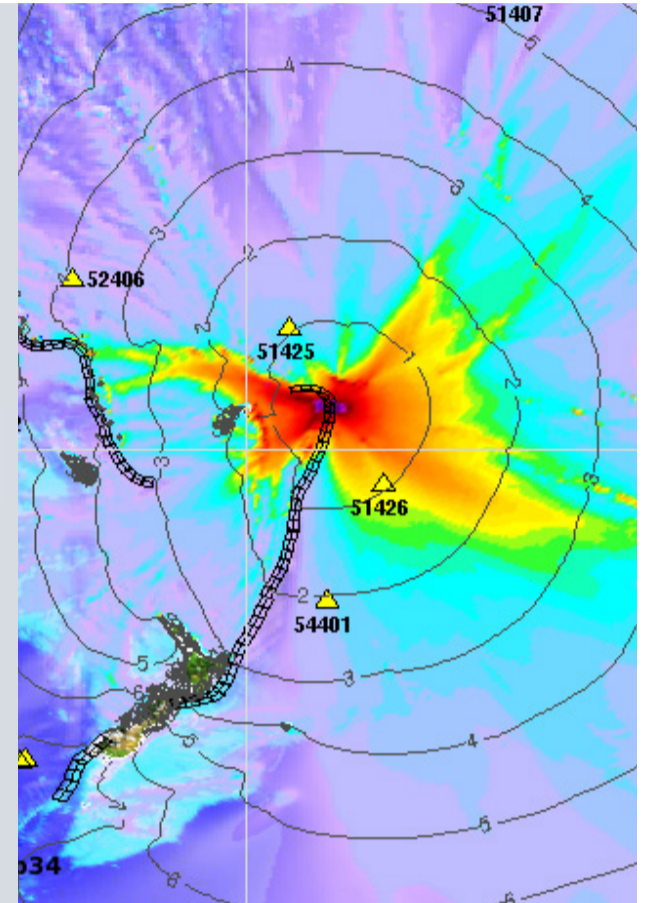
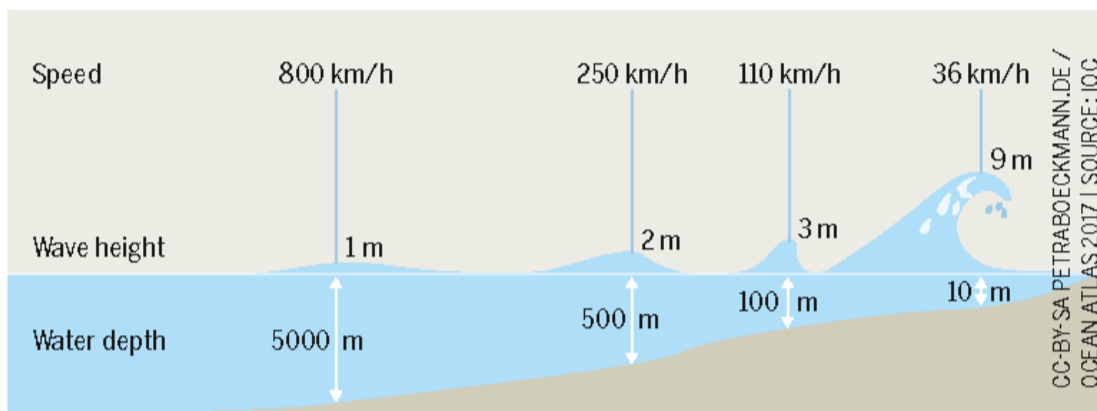
It is important to understand how ocean depth influences both the distribution of life below the surface and the management of human activities along the coast.

### The Samoa tsunami

One recent example was the 2009 Samoa Tsunami, which caused substantial damage and the loss of 189 lives in Samoa, American Samoa and Tonga (see graphics). A 76 millimetre rise in sea level near the earthquake's epicentre

turned into a wave up to 14 metres high when it hit the shallow Samoan coast. Owing to its submarine ridges to the east, Fiji merely experienced large waves with no major damage caused, highlighting the influence of bathymetry (ISC, 2015).

#### Emerging Giant – A Tsunami Races across the Ocean



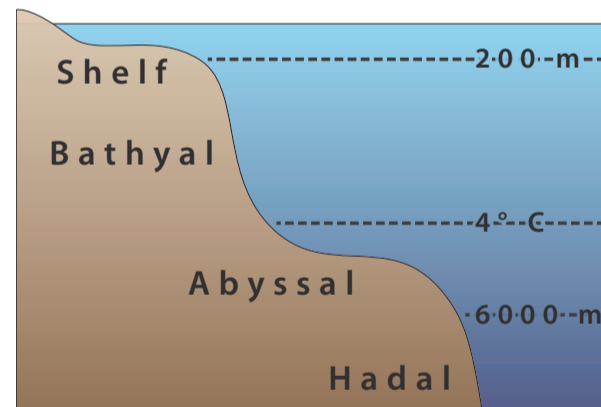
Standing on Fiji's shore and gazing into an alluring turquoise lagoon, it is hard to imagine how deep the ocean truly is. Less than 3 per cent of Fiji's national waters are shallower than 200 metres, while the other 97 per cent are up to 6,000 metres deep. Changes in ocean depth, also known as bathymetry, 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).

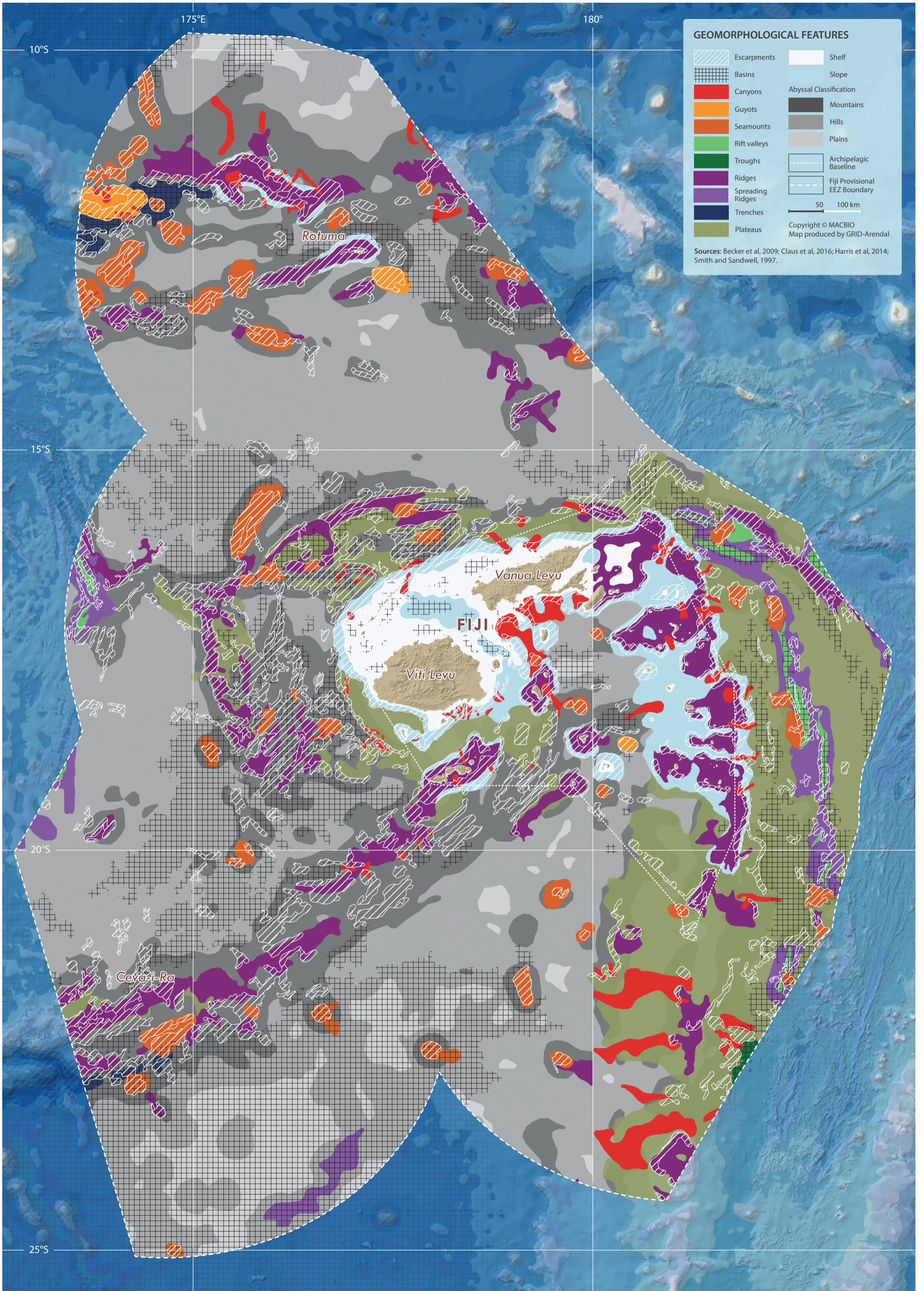
In addition, bathymetry significantly affects the path of tsunamis, which travel as shallow-water waves across the ocean. As a tsunami moves, it is influenced by the sea floor, even in the deepest parts of the ocean. Bathymetry influences the energy, direction and timing of a tsunami. As a ridge or seamount may redirect the path of a tsunami to-

wards 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, Fiji's main islands are located on a raised plateau less than 2,000 metres deep, which extends to the south as the Lau Ridge. There are several other extensive ridges that run south-west from the main Fijian islands, including the Denham, Moore, Colwyn and Herald Ridges. Just like mountain ridges, these submarine ridges rise several thousand metres above the deep ocean floor. To the north-west of Viti Levu is a series of small ridges and troughs, and to the west of Rotuma is a series of shallow banks that rise from the deep. These include Charlotte, Alexa, Louisa, Morton and Hazel Holme Banks. Aside from these shallower areas, the majority of the Fijian national waters are deeper than 2,000 metres, with a mean depth of around 2,700 metres, extending down to the deep ocean floor to exceed 6,000 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.



# VOYAGE TO THE BOTTOM OF THE SEA: GEOMORPHOLOGY

Fiji'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.

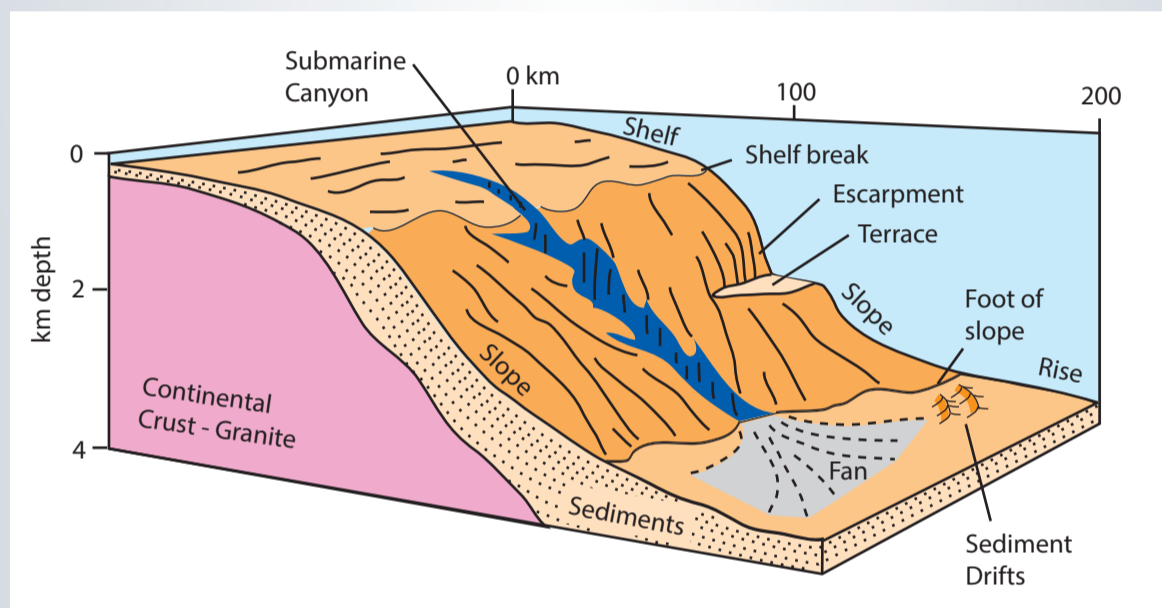
Similarly, different economic resources are often associated with different features. Many fisheries operate on certain features, such as the shelf, slope or over seamounts, based on where their target species occur. In Fiji, important deep-sea snapper is mostly found on outer-reef slopes and around 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: cobalt-rich ferromanganese crusts are found on the flanks of seamounts, massive sulfide deposits occur along the mid-ocean ridges and nodule deposits are found on some deep abyssal plains (see chapter "Underwater Wild West").

Fiji's waters harbour 16 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. Some notable features in Fiji's waters include 59 seamounts and three guyots. Sea-

## 1953 earthquake

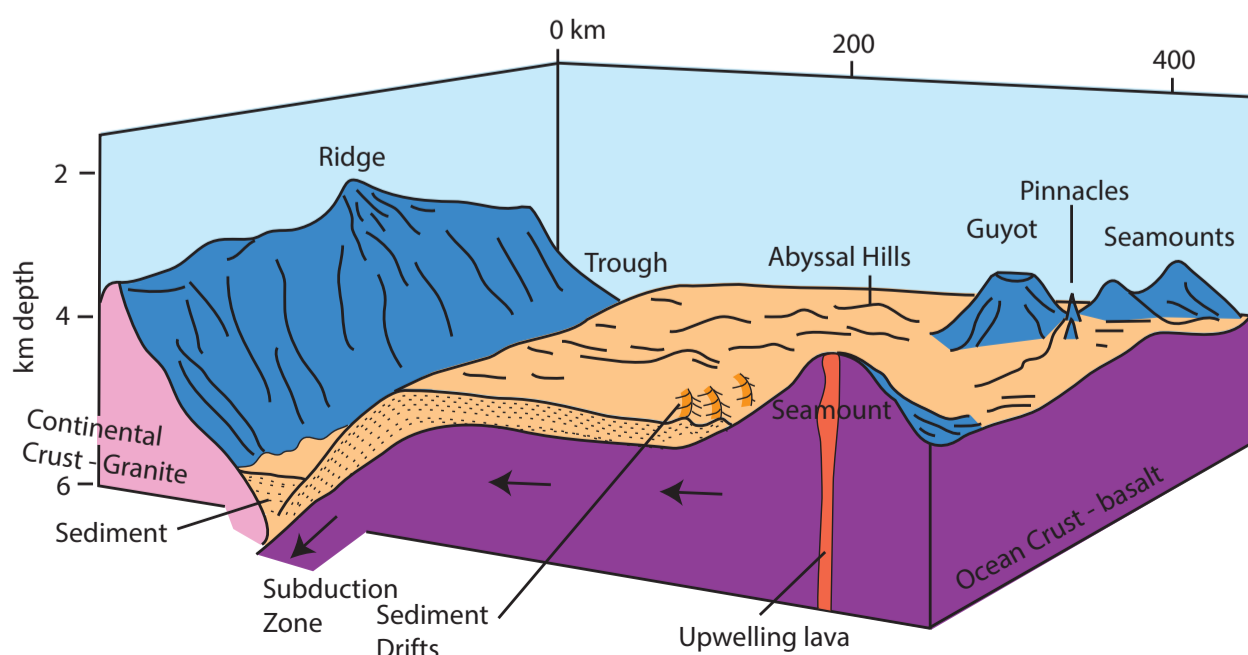
The slope of physical underwater features is hugely significant, as can be illustrated by an event that happened 1953. On 14 September, Fiji's capital, Suva, was struck by a nearby earthquake (see also chapter "Smoke underwater, fire in the sea"). Unlike the 2009 Samoan earthquake (see chapter "Still waters run deep"), this earthquake did not create a direct tsunami that threatened Fiji or other Pacific Island countries. However, it did cause a coral reef platform to collapse, which induced a submarine landslide. Sixty million m<sup>3</sup> of mud,

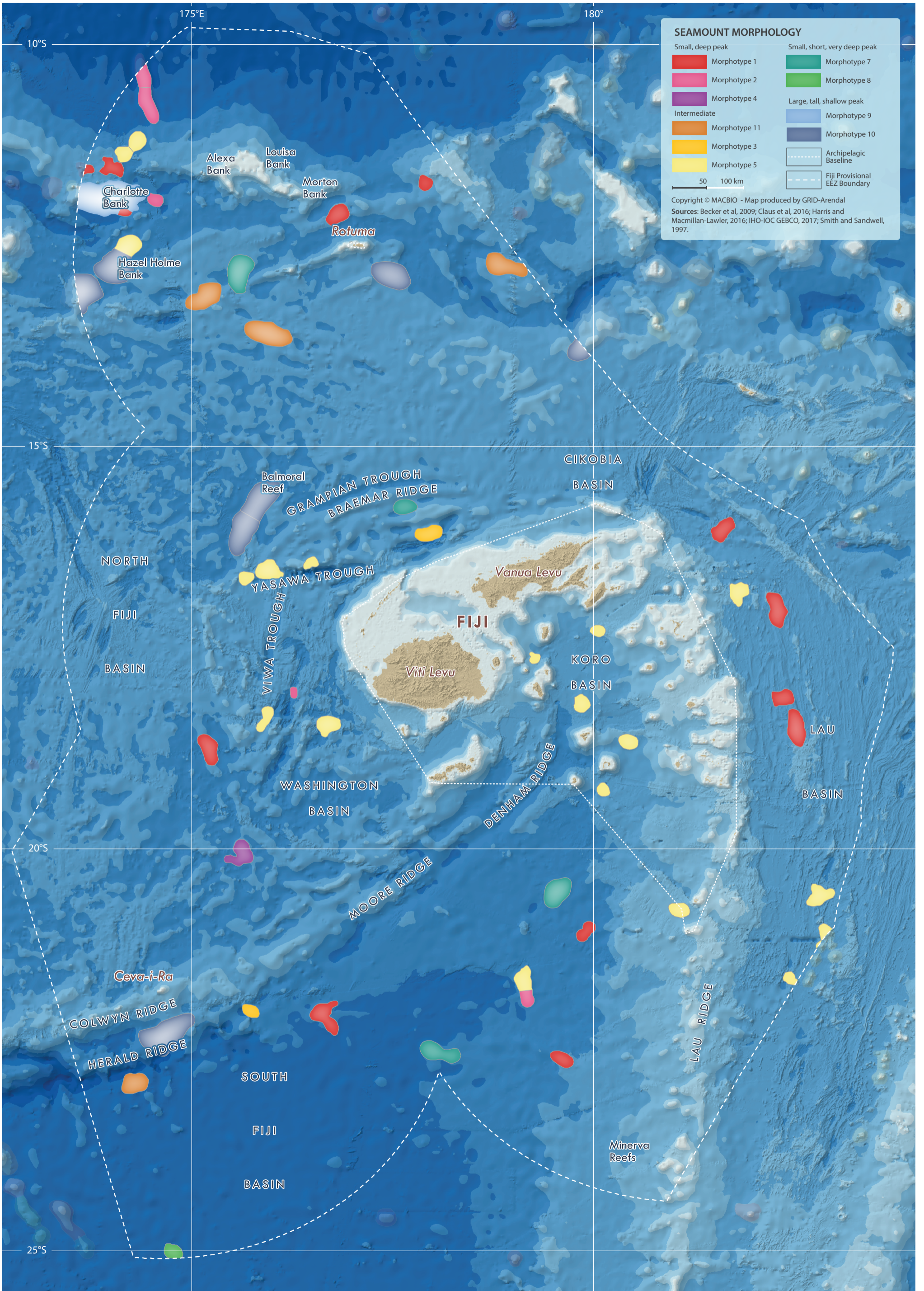
stone and part of a long-wrecked vessel hurtled to the depths of the Suva Canyon, at the western end of the entrance to the harbour. It was this event that triggered a tsunami, devastating the villages of Nakasaleka and Makaluva, as well as parts of Suva. The tsunami resulted in five deaths and caused a total estimated damage of US\$500,000 (at 1953 values), making it the most destructive earthquake in Fiji's recorded history (Rahiman, 2007; Pacific Disaster Center, 2011). Had the tsunami occurred at high tide, it would have been even more damaging.



mounts 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, all of which rise up from the sea floor. The steep sides of all these features interact with currents and create important habitats for many species. The main islands of Fiji are perched on a raised plateau, which extends to the east and the south. Surrounding the islands is an area of generally narrow shelf, which supports extensive coral reefs.

The adjacent areas of slope and the margins of the plateau are incised with numerous large submarine canyons. 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. 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.





# UNDER WATER MOUNTAINS: SEAMOUNT MORPHOLOGY

Fiji has 59 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.

## Newborn islands

Imagine the shock of the captain who, in 2005, ran his submarine, the USS San Francisco, at full speed (35 knots) into an unknown solid object at a depth of 160 metres (Doehring, 2014). It was neither a whale nor a hostile submarine. The mysterious object in fact turned out to be an island. However, at 160 metres deep, it wasn't the kind of island with beaches and palm trees! Vessels on the surface can easily look out for islands, either visually or using bathymetric maps (see chapter "Still waters run deep"), and the same applies for submarines. Unfortunately, at the time, the charts did not show the seamount near Guam that the submarine ran into. The fact that this feature was not on the charts is due to the nature of seamounts—mountains rising from the ocean floor that do not quite reach the water's surface.

But, how quickly this can change!

By January 16, 2015, after a large eruption and ash plumes reaching 10 kilometres high, a former seamount became a new Tongan island—Hunga Ha'apai—now two kilometres long and 100 metres high (NASA, 2015).

While some islands are newly born and others disappear amid rising sea levels (see chapter "Hotter and higher"), there is a third kind that seems to come and go. Home Reef, created by another Tongan seamount, surfaced in 2006, sending vast rafts of floating pumice drifting over to Fiji. And yet, by 2008, Home Reef was already gone. A new eruption in 2015 did not bring Home Reef back, but the seamount may yet have another chance to metamorphose into an island (Smithsonian Institution, 2017).



Seamounts are important features of the ocean landscape, providing a range of resources and benefits to Fiji. 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 Fiji'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 59 seamounts in Fiji's waters represent 10 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 Fiji's case, this includes the large, tall and shallow peaked seamount (morphotypes 9 and 10), the majority of which are found north-west of the main islands. Nearly half the seamounts in Fiji's waters are part of the intermediate seamount group (morphotypes 3, 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.

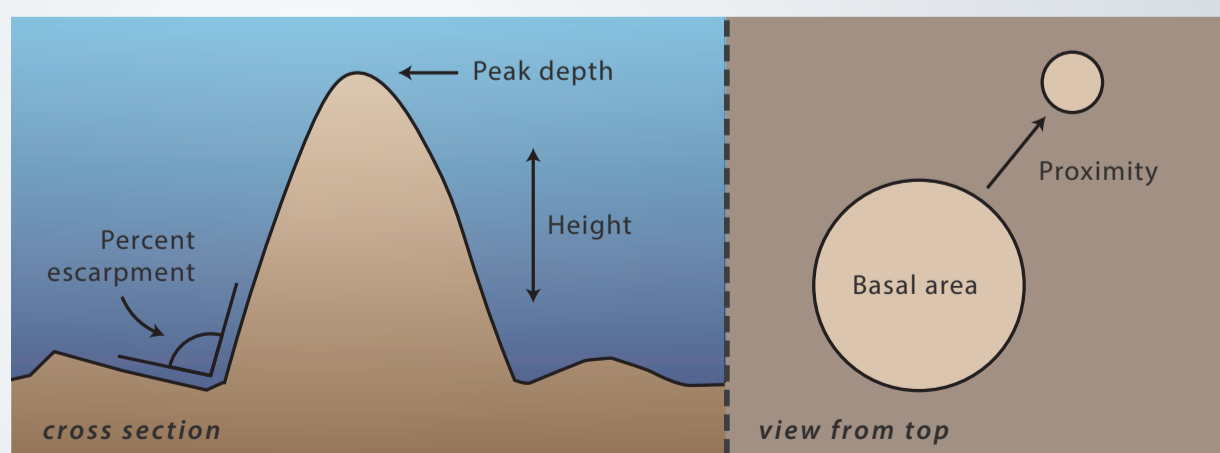
## Seamount morphotypes found in Fijian waters

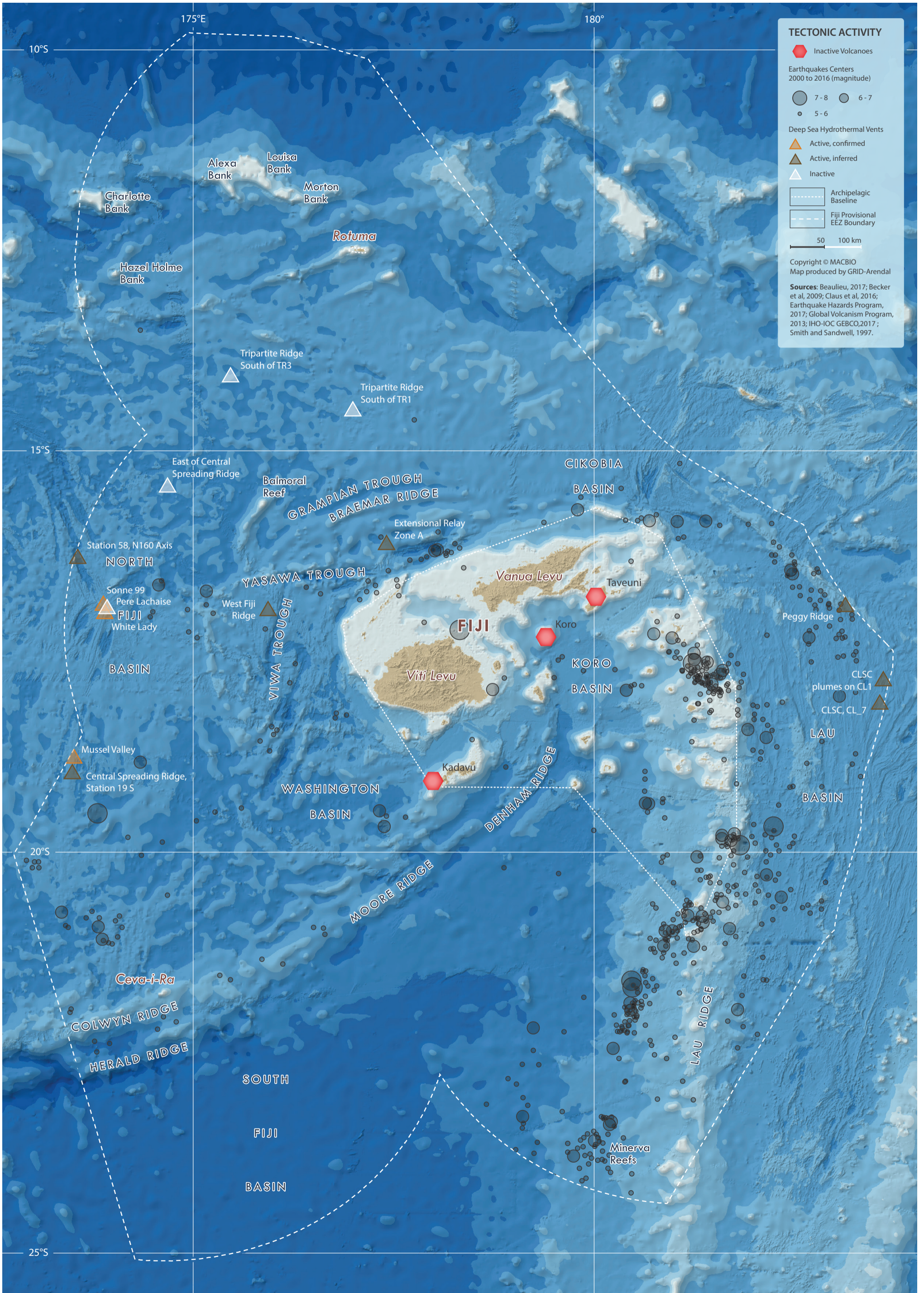
Large and tall seamounts with a shallow peak – *Morphotypes 9 and 10.*

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.*





# SMOKE UNDER WATER, FIRE IN THE SEA: TECTONIC ACTIVITY

Fiji is located on the Pacific Ring of Fire, a highly active tectonic zone. Above water, this tectonic activity means that Fiji 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 Fiji's rich marine biodiversity. These features also deposit minerals, making them an attractive, if conflicting, target for deep-sea mining exploration and extraction.

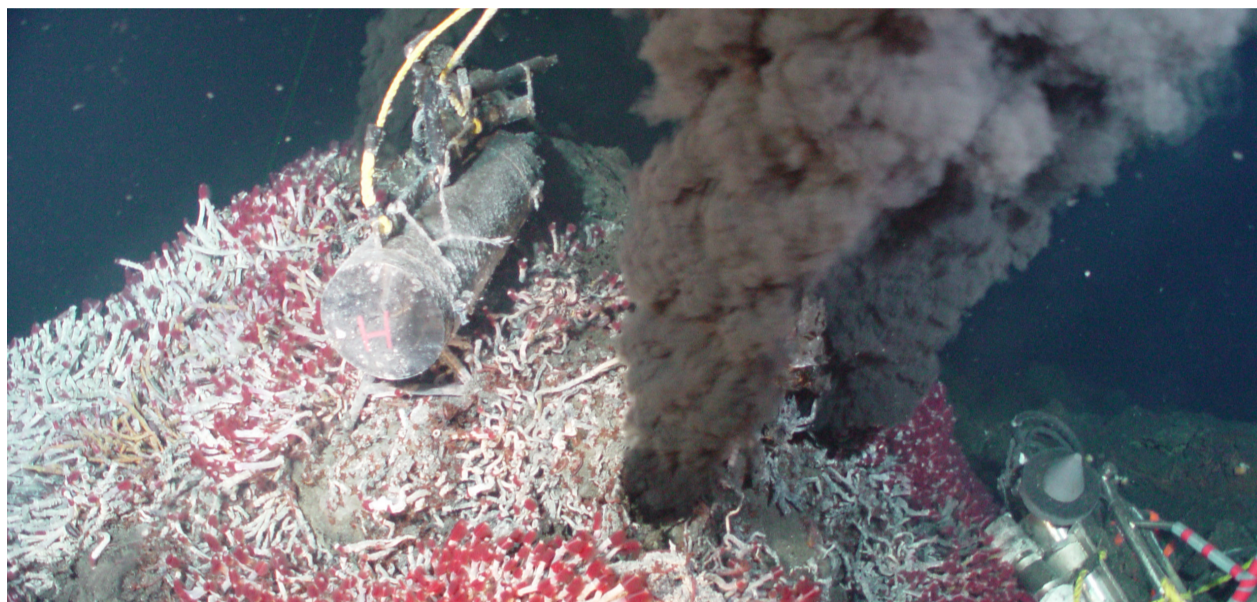
There are still many mysteries around sea-floor hydrothermal vent systems, with their complicated biological, chemical and geological relationships. Only by exploring, recording and monitoring deep-sea hydrothermal systems is there a chance to protect them and the benefits they provide.

Hydrothermal vents are fissures in the Earth's surface from which geothermally heated water (up to 450°C) escapes. Vents are commonly found in volcanically active areas, such as areas between tectonic plates. 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").

As the map shows, Fiji's waters harbour not only numerous deep-sea hydrothermal vents, but also three inactive volcanoes: Nabukelevu on Kadavu Island, Koro Island and Taveuni Island. These volcanoes have been dormant for several hundred years, with the last known eruption (Nabukelevu) occurring in 1660. The island of Rotuma does not have an active volcano, but is also volcanic in origin.

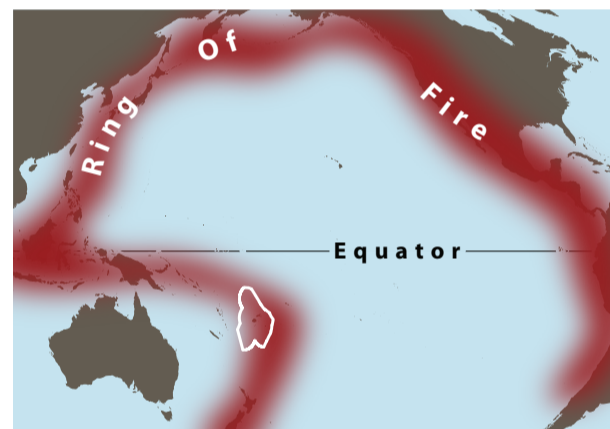


The Sully Vent in the north-eastern Pacific Ocean provides an example of the diverse communities around hydrothermal vents.

## 3D vents

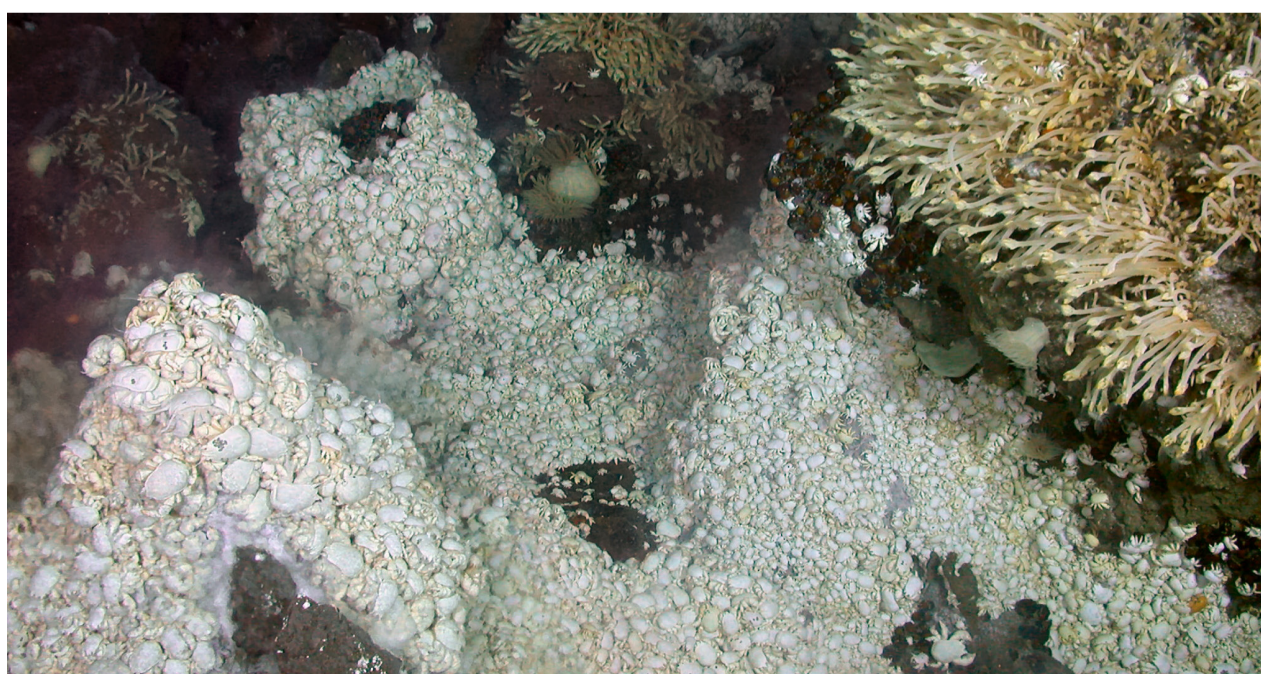
In 2016, 16,000 online viewers from around the world watched a unique event in Fiji. It wasn't the rugby finals at the Rio Olympics or the World Rugby Sevens Series—both won by Fiji! Nevertheless, it was an important event for Fiji. It took place in the Northern Lau Basin, at the bottom of the ocean, filmed by a robot for spectators' viewing pleasure. The robot live-streamed a visit to the hydrothermal vent field at the Niua volcano, which lasted more than 48 hours. This way, viewers could witness the exploration of this unique underwater world first-hand. At the same time, the exploration team reconstructed the vent site in 3D using virtual reality technology, allowing scientists all over the world to study this unknown environment without having to leave their labs (Schmidt, 2016).

Who would have thought deep-sea geology could be a spectator sport too!



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").

But where does all the heat fuelling vents and volcanoes come from? The Pacific region is one of the most tectonically active regions in the world. The Pacific Ring of Fire, which stretches clockwise from New Zealand all the way around to South America, experiences around 90 per cent of the world's earthquakes. Pacific Island countries such as Fiji are on the south-western edge of the Pacific tectonic plate and are therefore subject to volcanic and seismic activity. The activity affecting Fiji is primarily centred on and around the Lau Ridge to the south-east of the main islands. Numerous earthquakes of magnitude 6 and above have occurred in this region, with several of the larger ones measuring above magnitude 8. A smaller number of earthquakes happen to the immediate north, west and south of the islands. Earthquakes can, under certain circumstances, generate tsunamis. The most destructive of these occurred in 1953, when an earthquake south-east of Suva generated a tsunami that caused particular damage to areas not protected by barrier reefs (see also chapters "Still waters run deep" and "Voyage to the bottom of the sea").



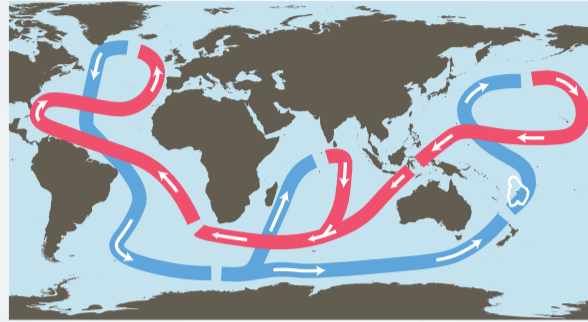
Many Anomuran crabs attached to a hydrothermal chimney at 2,397 metres depth.

# 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

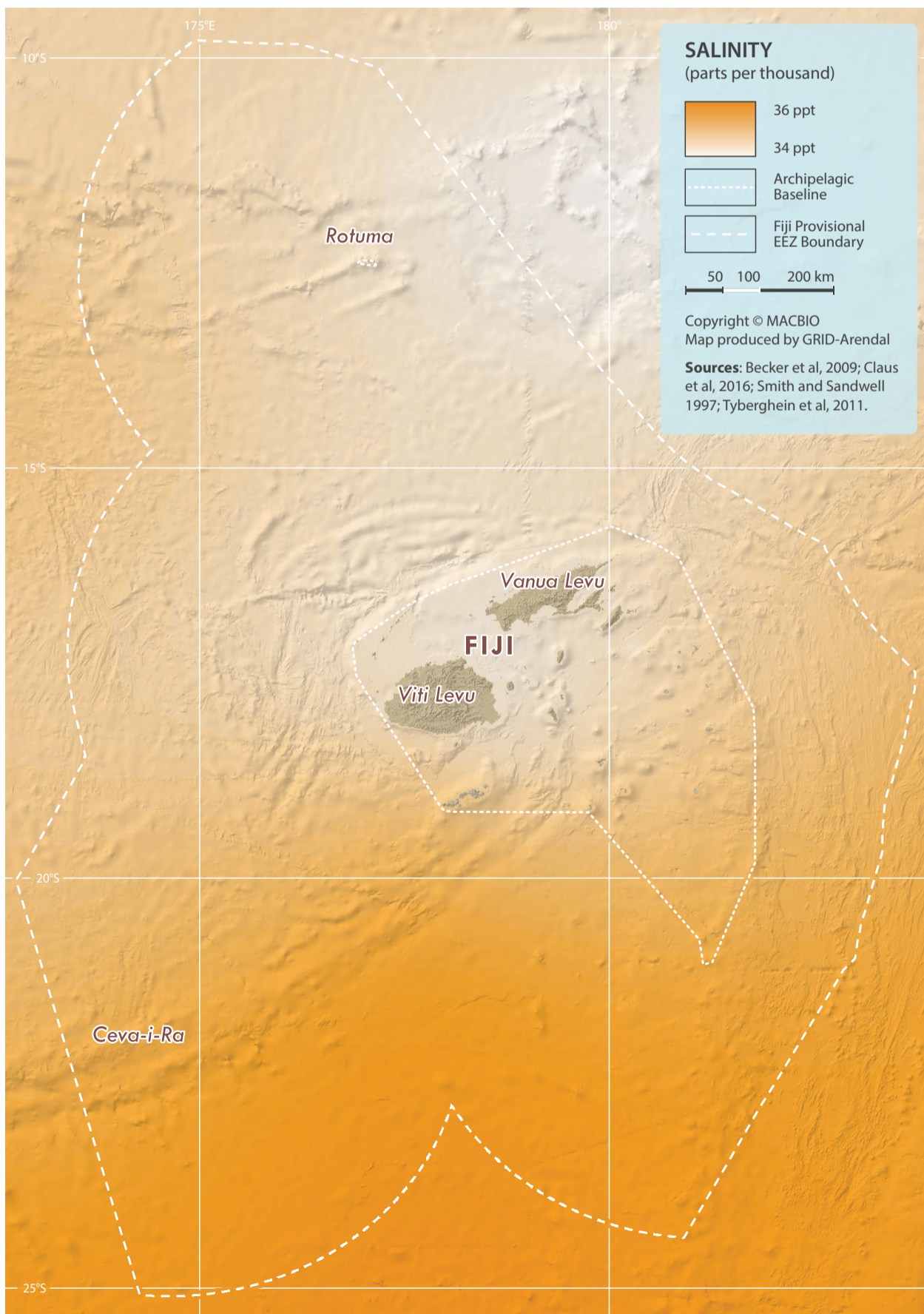
It took Magellan more than three years (from 1519 to 1522) to be the first person to circumnavigate the Earth. The current record for this trip is 67 hours by plane and 50 days by sailboat. Water in the ocean is not in such a rush, taking much more time on its journey on the global ocean conveyor belt. 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.

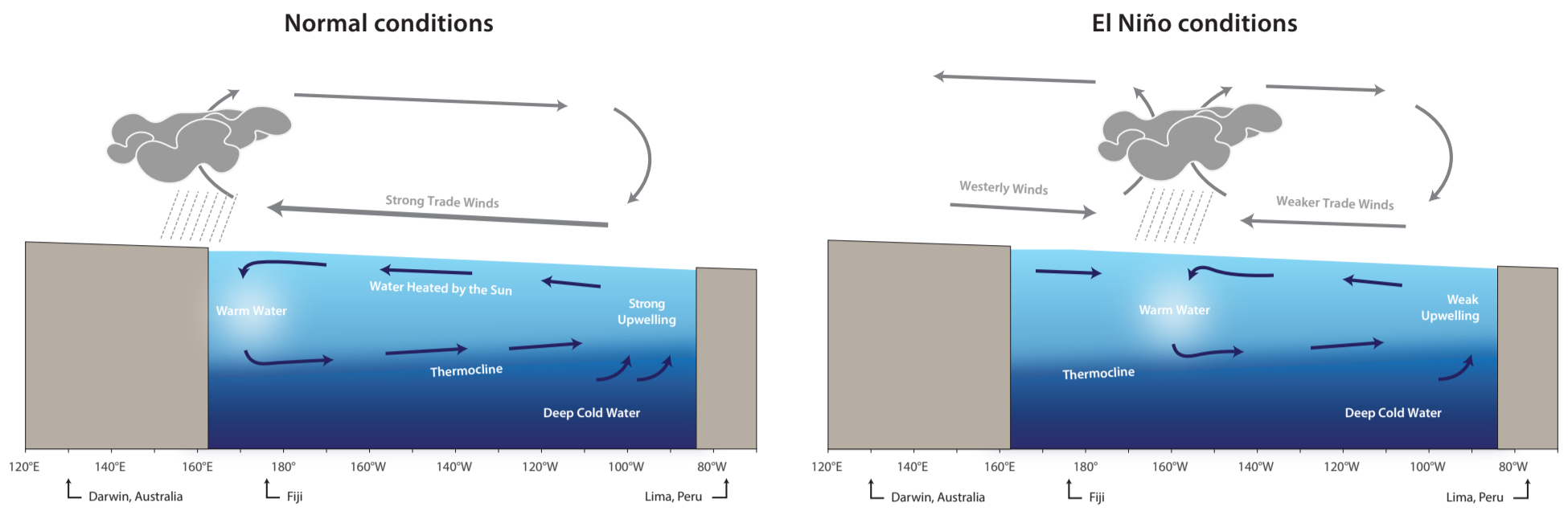
A full circle takes about 1,000 years. No rush at all!



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 Fiji's waters has a narrow range—between 34.6 in the northern part of the EEZ and 35.6 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, Fiji'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 the main islands of Fiji, is driven by the southeast 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.

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

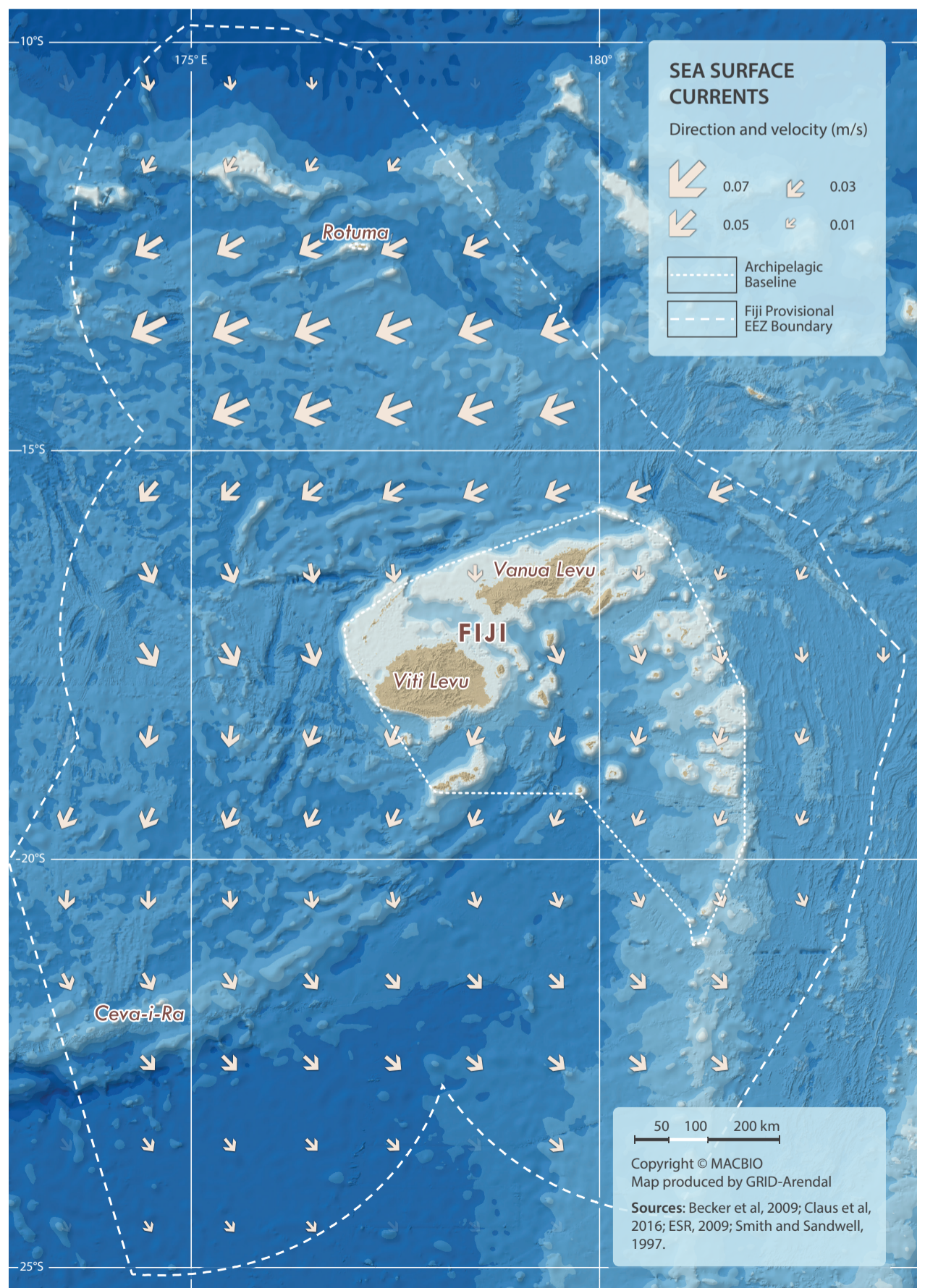
In an El Niño year, the trade winds weaken or break down. The warm water that is normally pushed towards the western Pacific washes back across, piling up on the east side of the Pacific from California to Chile, causing rain and storms and increasing the risk of cyclone formation over the tropical Pacific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

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. In the 1997–1998 wet season, Fiji recorded the lowest ever rainfall at almost all recording sites across the country. The drought led to food and water shortages across Fiji. The western sides of Viti Levu and Vanua Levu, as well as the Yasawa Islands, were the worst-hit regions, where 90 per cent of the population received food and water rations. The drought drove Fiji’s economy into the worst recession in its history, hitting food and cash crops hard, with the sugarcane harvest slashed by nearly 50 per cent, causing a FJ\$104 million loss in revenue in the sugarcane industry alone (UNOCHA, 2016).

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 Fiji’s marine biodiversity, but also its rainfall patterns and temperature on land.

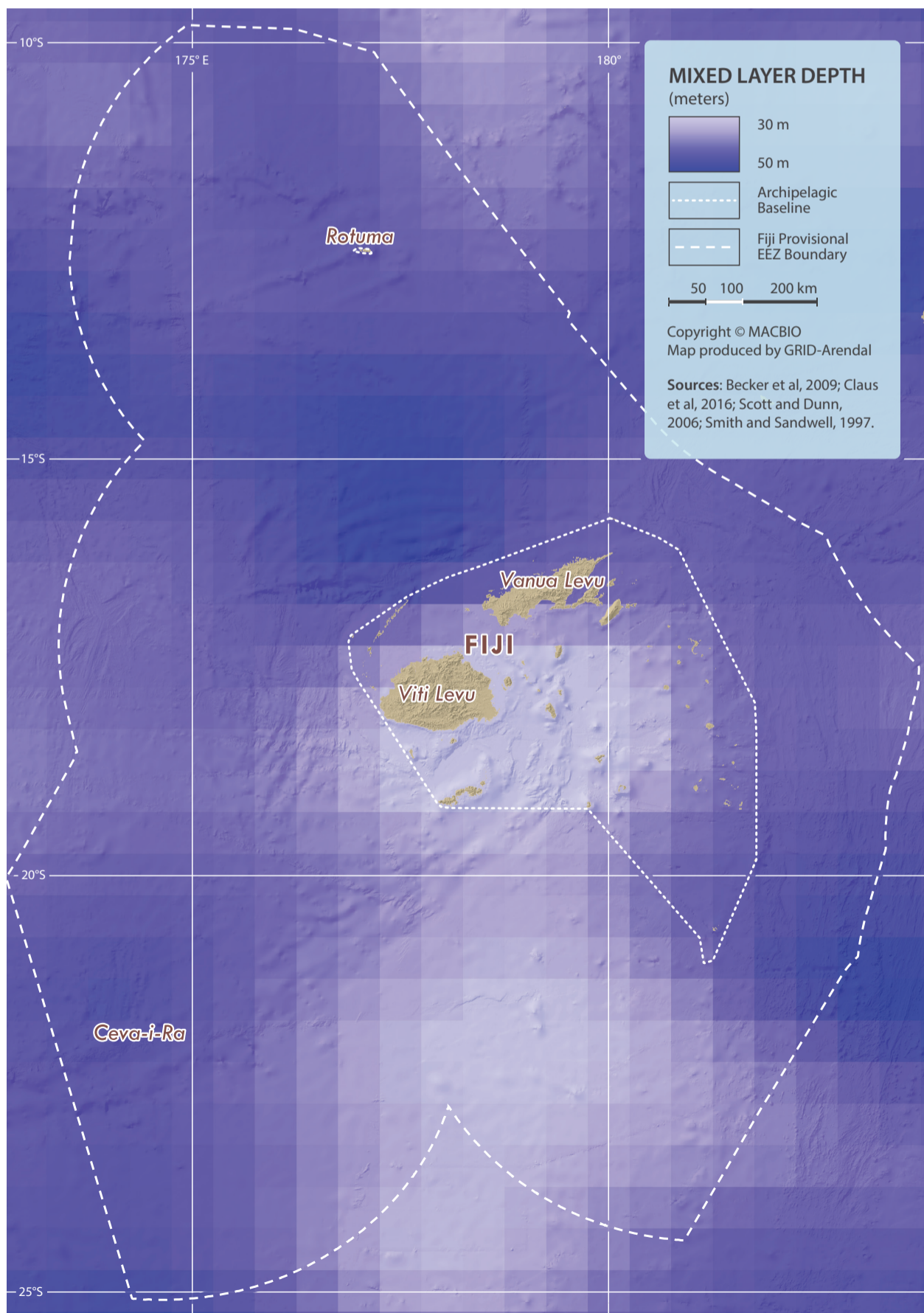


# STIR IT UP: MIXED LAYER DEPTH

Fiji'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 Fiji 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 Fiji'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 Fiji 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 Fiji'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 Fiji's waters ranges from 26 metres to a maximum of 47 metres, with a mean depth of around 37 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

Fiji'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<sub>2</sub>) 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.

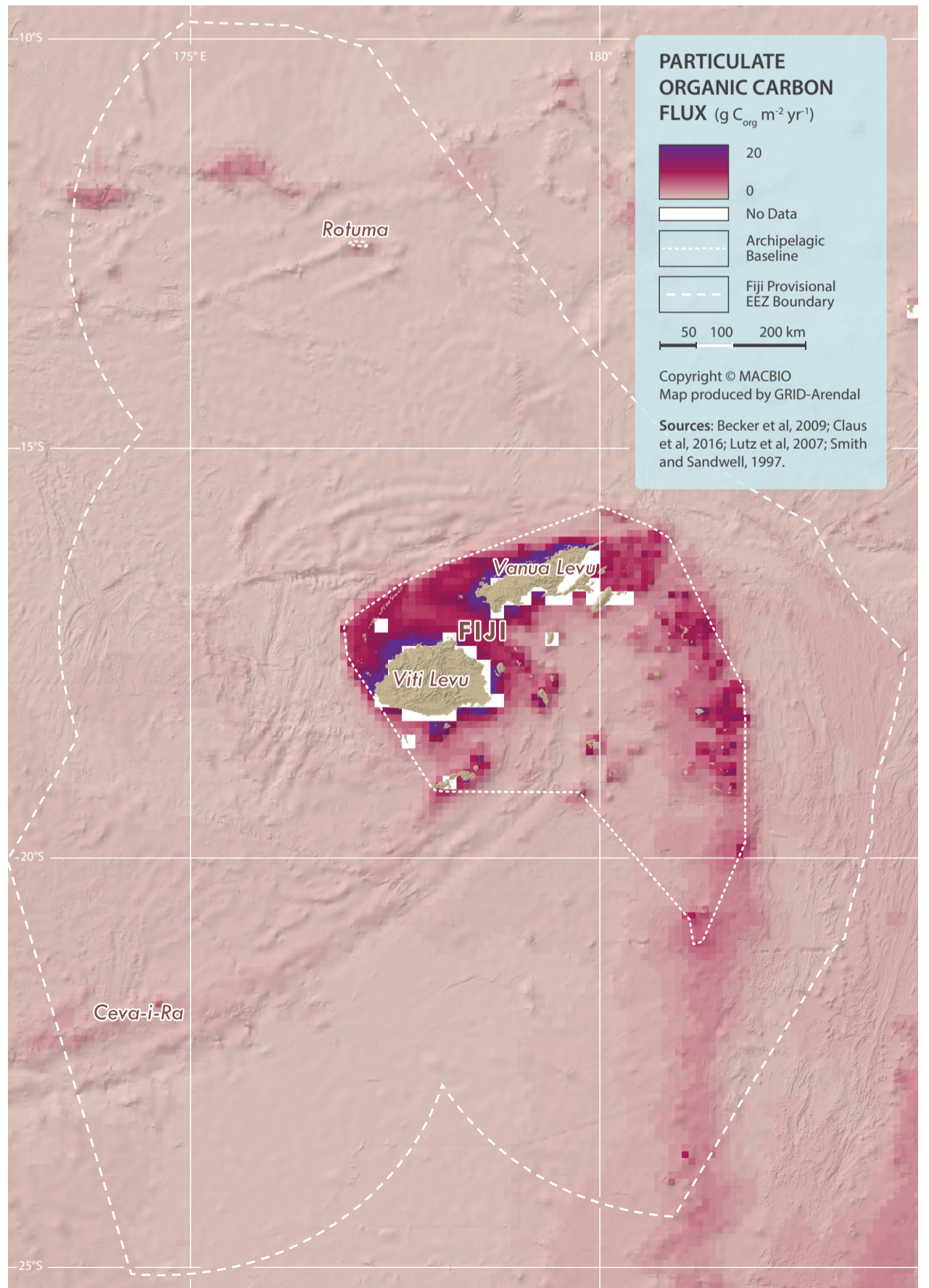
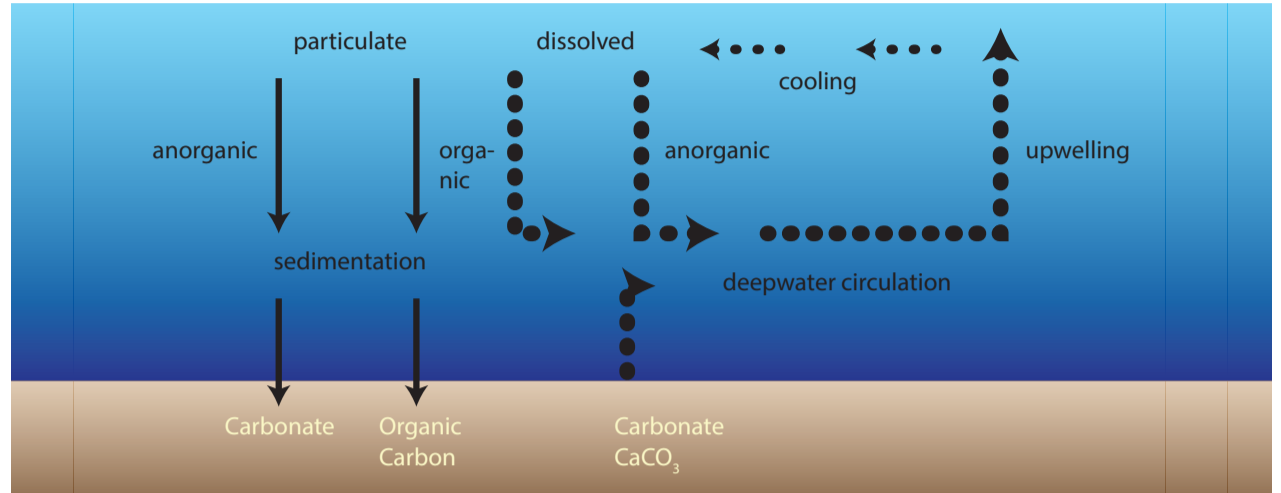
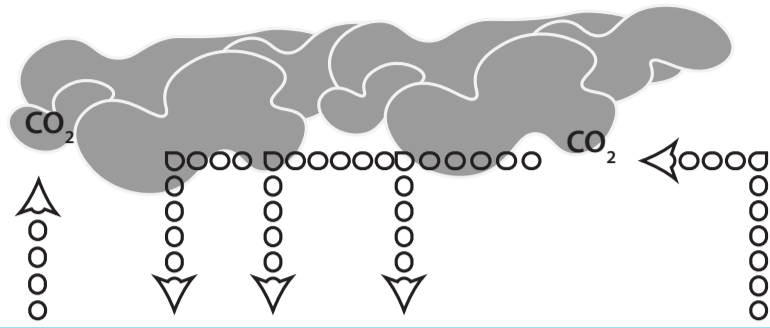
Fiji's ocean pumps are measured by particulate organic flux (the total amount of organic carbon reaching the sea floor) as seen on the map. Organic detritus passing from the sea surface through the water column to the sea floor controls nutrient regeneration, fuels benthic life and affects the burial 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, Fiji'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, plus the avoided emissions in the oceanic waters of Fiji's EEZ, is estimated to be worth about FJ\$873 (US\$437) million per year (Gonzalez, 2015).

The patterns of particulate organic carbon flux in Fiji'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 Fiji's waters, with rates of less than 1 gram of organic carbon/m<sup>2</sup>/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 generally above 10 grams/m<sup>2</sup>/year and up to a maximum of 22 grams/m<sup>2</sup>/year.

## Whale falls

Whales have cultural significance in Fiji. Just take the tabua, a sperm whale's tooth that is often presented at major ceremonies such as weddings or funerals. Whales also play an important role in the marine food chain, even after they have died. 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 Fiji'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 Fiji's coastal waters, increased nutrients from land-based activities, such as farming and wastewater treatment, can result in harmful algal blooms (see also chapter "From ridge to reef"). 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 Fiji'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 Fiji's waters and mirrors the global pattern, with higher levels in the northern parts of Fiji'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 (Fiji Meteorological Service, 2016).

There is also seasonal variation in photosynthetically available radiation in Fiji. The greatest variation occurs around the islands and in the very

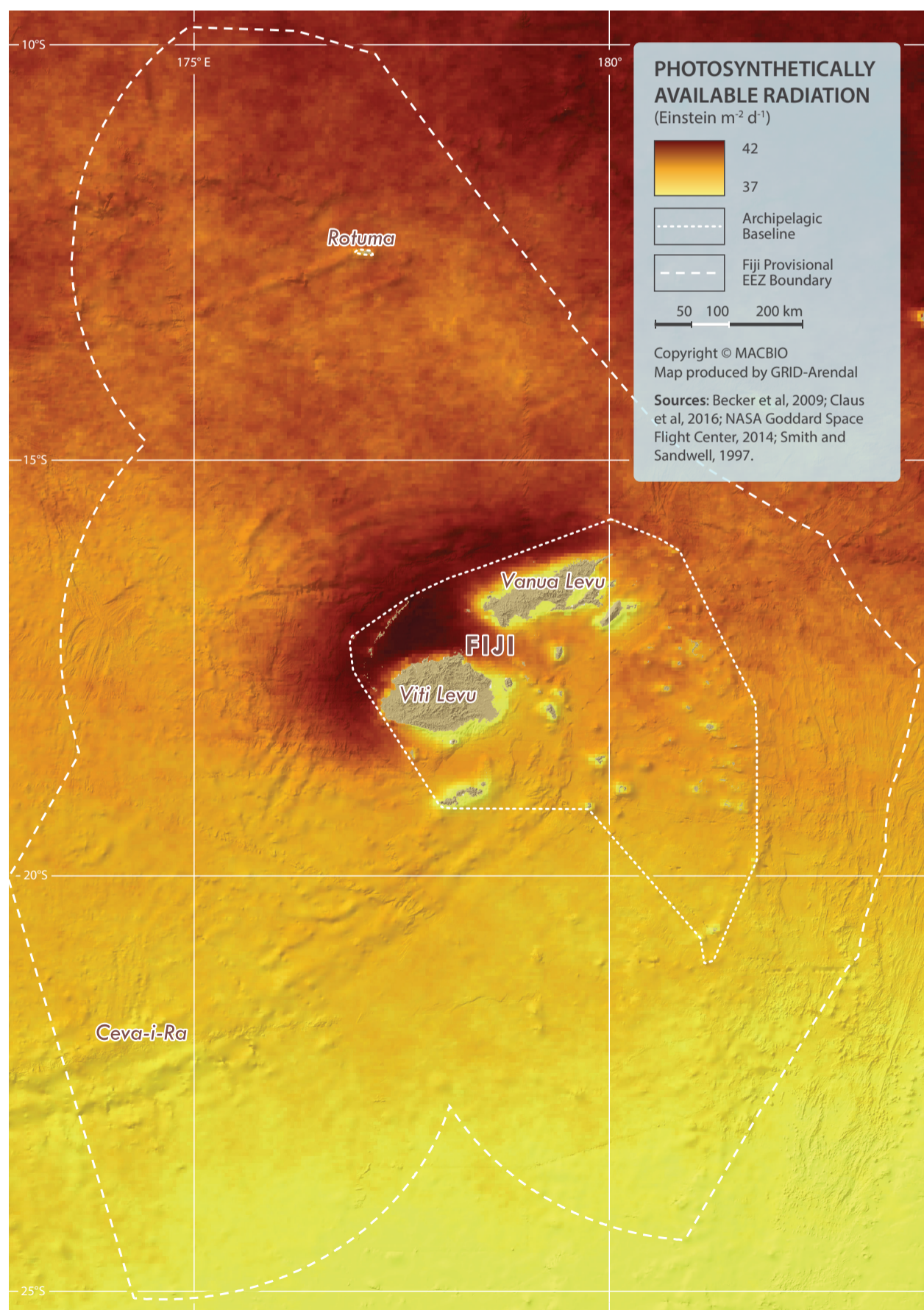
## Ocean gardens

For plants to thrive, they need three things: water, sunlight and nutrients. In Fiji's sea, the first is obviously not an issue. The second is also not a problem, with the sun shining on Fiji'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.

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 Fiji'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.

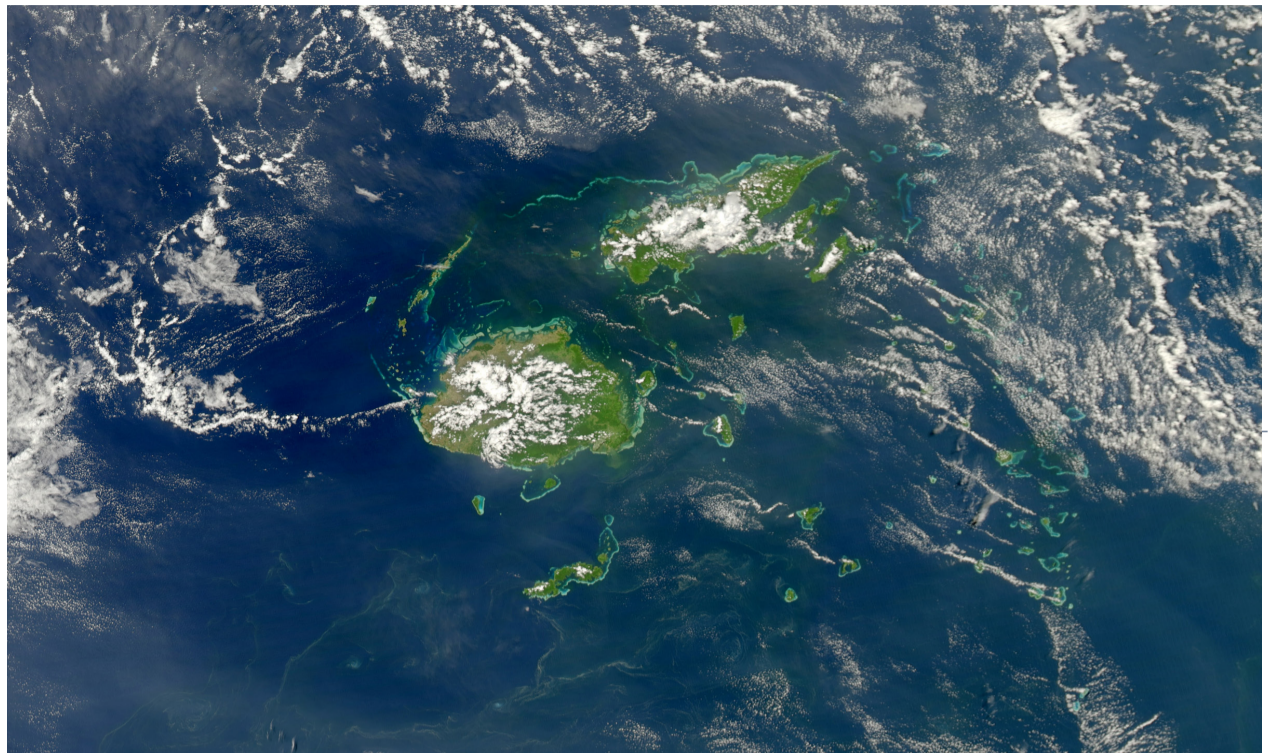
Nevertheless, marine plants cannot live off water and light alone. They also require nutrients, including iron, nitrate and phosphate (see also chapter "The dose makes the poison"). Since these nutrients are generally low in Fiji's waters, phytoplankton quickly consume nutrients whenever they do become 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).



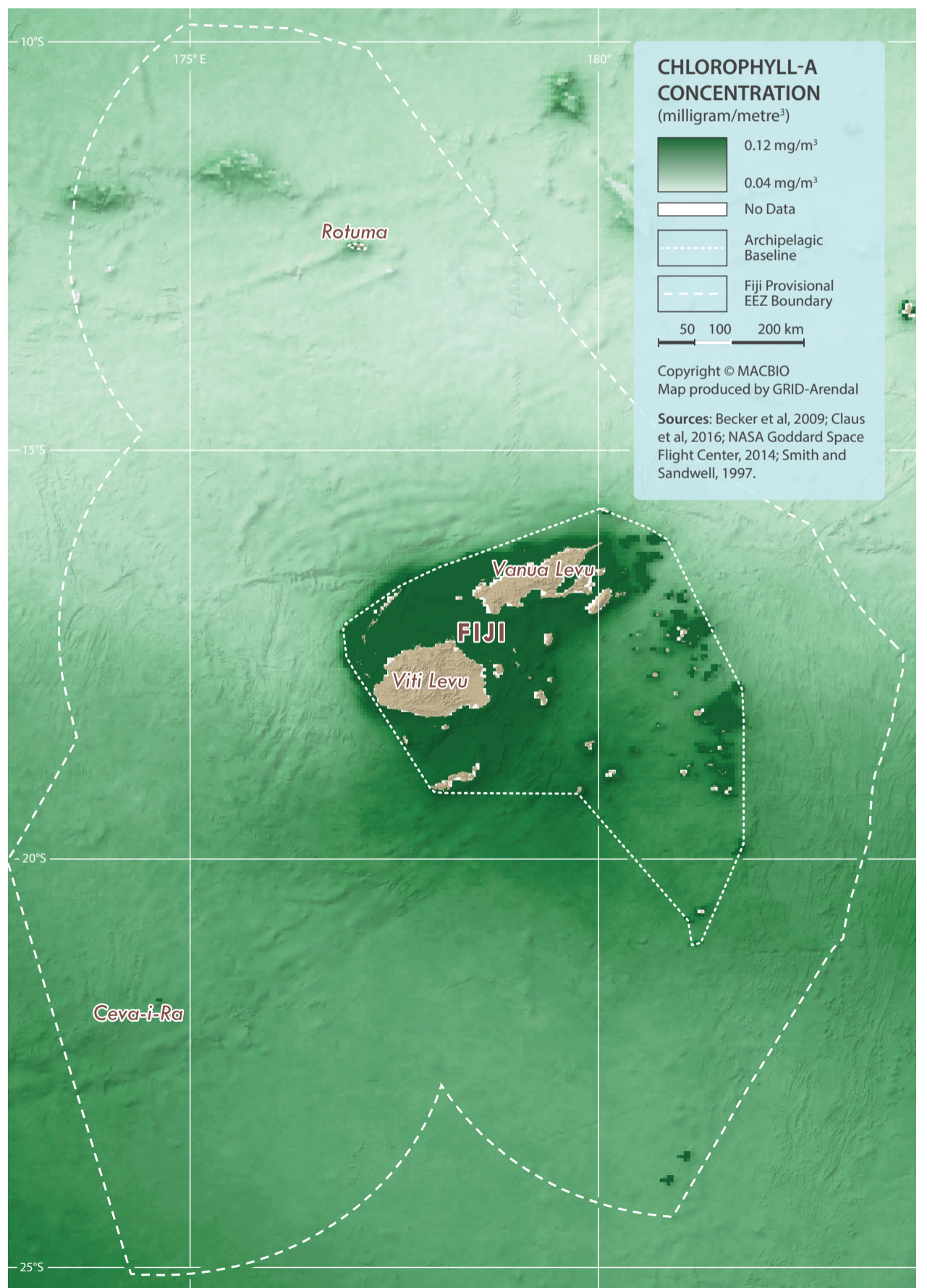
northern part of the Fiji's waters, where photo-synthetically available radiation varies by up to 15 per cent throughout the year. This is in part due to changes in atmospheric conditions, such as cloud cover. In Suva, the average percentage of the sky covered by clouds experiences significant seasonal variation, with the cloudiest days occurring from December to March and the least cloudy days from July to September.

The chlorophyll-a concentration in Fiji's waters is generally very low, with concentrations in its off-shore waters less than 0.1 gram per m<sup>3</sup> 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 m<sup>3</sup> of seawater. The shallow coastal regions of Fiji have increased chlorophyll-a concentrations, with up to 3–4 grams per m<sup>3</sup> of seawater. Again, this is low compared to many coastal regions around the world, where chlorophyll-a concentrations can reach over 10 grams per m<sup>3</sup> of seawater. The low concentrations of chlorophyll-a in Fiji'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, Fiji 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 (see also chapter "From ridge to reef").

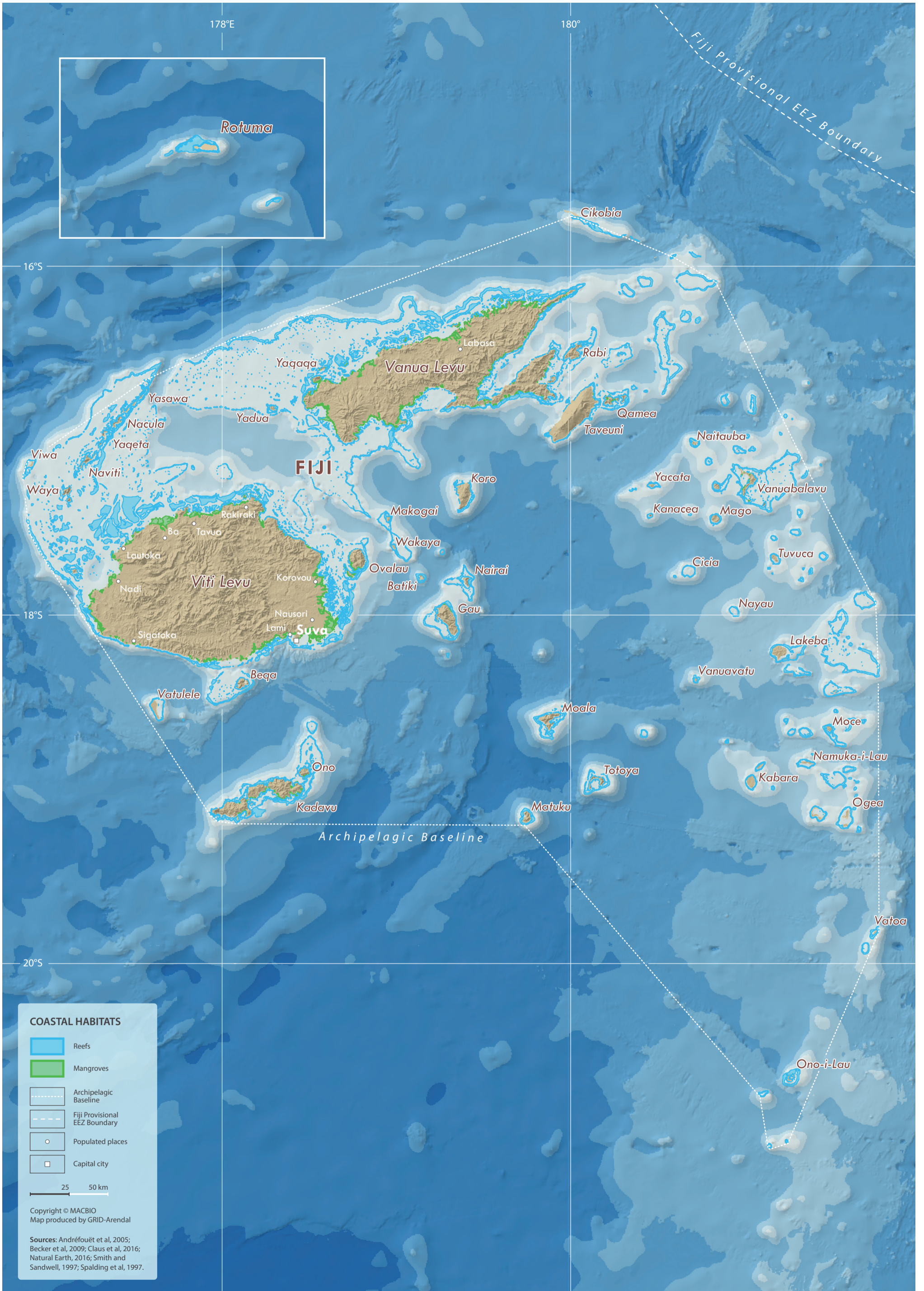
In the south-western tropical Pacific Ocean, strong seasonal and inter-annual variabilities in the chlorophyll-a concentration have been observed (Dupouy et al., 2004). Strong chlorophyll-a enrichments have been documented around the Solomon Islands, and between New Caledonia and Vanuatu, with weaker enrichments found around Fiji or Tonga. The annual variation in chlorophyll-a around Fiji is up to 20 grams per m<sup>3</sup> of seawater in some coastal areas.



Bacterial bloom south of Fiji on 18 October 2010. Though it is impossible to identify the species from space, it is likely that the yellow-green filaments are miles-long colonies of *Trichodesmium*, a form of cyanobacteria often found in tropical waters. NASA Earth Observatory.



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



## HABITAT VALUES

# HOME, SWEET HOME: COASTAL HABITATS

Fiji'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 Fiji's coastal inhabitants.

### Protecting coasts

Coastal habitats can be highly valuable, as residents of the island of Ovalau experienced when they awoke to a 70-metre long ferry in their backyard. It had been pushed onto a shallow reef by Cyclone Winston (see also chapter "Stormy times"), which generated waves of up to 10 metres. Luckily, like most other Fijian islands, Ovalau is protected by reefs and mangroves that shelter the coast and its inhabitants. The effects of the cyclone would have been much worse without this coastal protection, and much costlier. Every year, reefs and mangroves mitigate damage to houses and hotels on the north and south sides of Fiji's two main islands (Viti Levu and Vanua Levu), with an estimated worth of this mitigated damage of FJ\$12.7–21.2 million (US\$6.4–10.6 million) (Gonzalez, 2015).



A ferry beached by Cyclone Winston close to Levuka on the island of Ovalau.

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 Fiji'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 Fiji's coastal habitats.

Marine and coastal ecosystems provide a number of valuable services to Fiji, a key one being coastal protection. This has 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.

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 pro-

grammes 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, Fiji'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. Mangroves are found on many of Fiji's islands, with extensive areas of mangroves on both Viti Levu and Vanua Levu. The social value of carbon sequestration by mangroves in Fiji's EEZ is estimated to be worth about FJ\$147.67 million (US\$73.93 million) (Gonzalez, 2015).

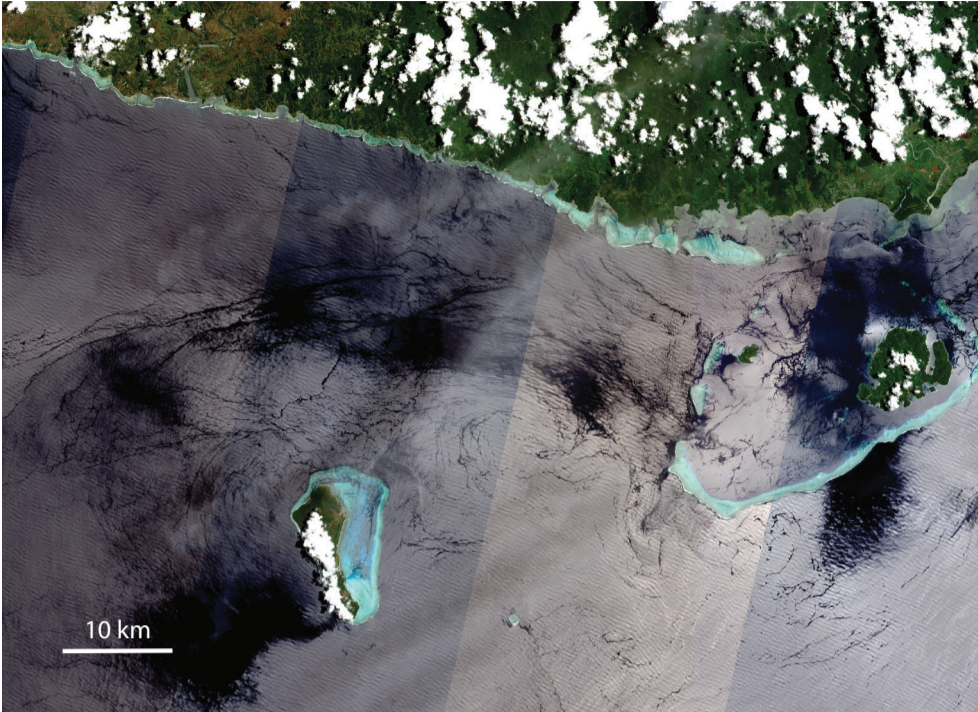
But while coastal habitats are some of the most productive and valuable marine habitats, they are by the same token some of the most vulnerable to human activities (see also chapters "Reefs at risk", "From reef to ridge" and "Turning sour").



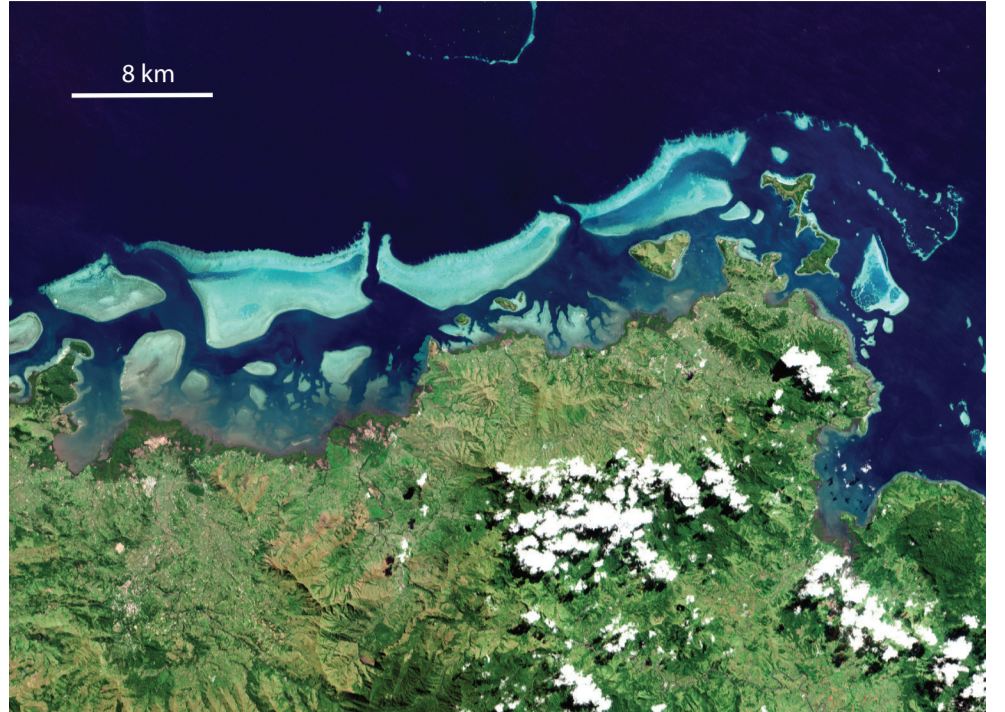
As described, three of the key coastal habitats in Fiji are coral reefs (see also chapter "Shaping Pacific Islands"), seagrasses and mangroves. The map of coastal habitats presents the distribution of coral reefs and mangroves. Shallow coral reefs form some of the most diverse ecosystems on Earth. Despite 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. Fiji is surrounded by a combination of fringing and barrier reefs. The Great Sea Reef, locally known as Cakaulevu, occurs along the north coast of Fiji and is the world's third longest continuous barrier reef system.

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 Fiji's islands. 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 Fiji.

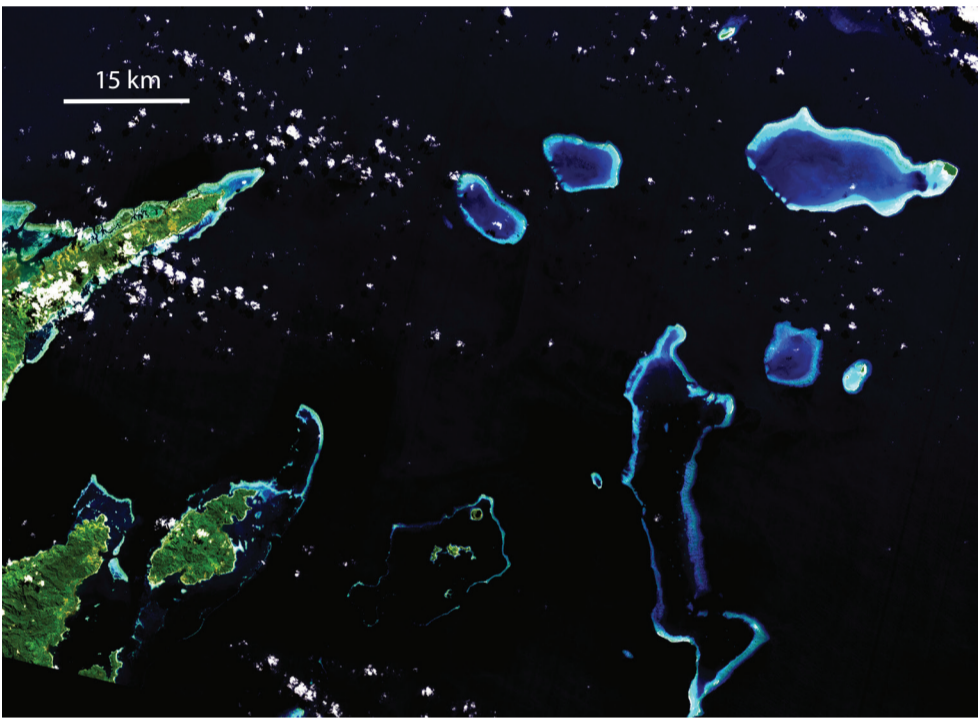




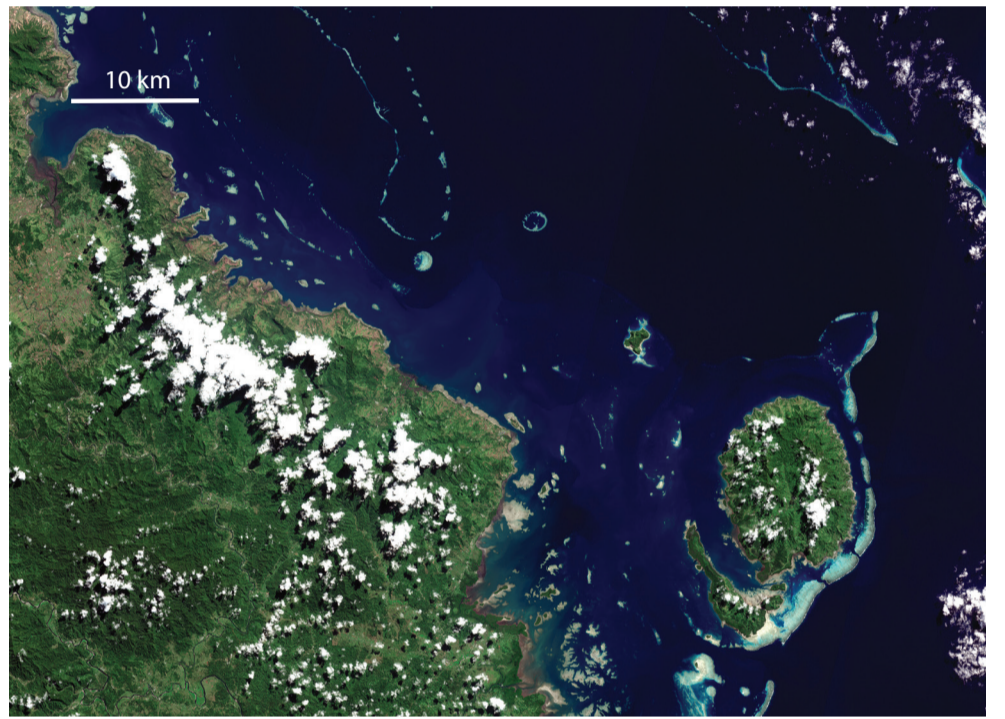
*Fringing reef along the Coral Coast*



*Barrier reef, North Viti Levu*



*Atolls east of Vanua Levu*



*Patch reef between Rakiraki and Natovi*



*Combination of different reef types at the Great Sea Reef*

# SHAPING PACIFIC ISLANDS: CORAL REEFS

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

Corals play a fundamental role in the development of island nations such as Fiji, with coral reefs having helped transform and shape the very outline of Fiji'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).



There are around 1,000 coral reefs in Fiji according to Zann (1994) and they have a relatively high level of biodiversity compared with other Pacific Island reefs (Lovell and Sykes, 2007), with over 350 species of coral having been documented (Lovell and McLardy, 2008).

Fiji's reefs include fringing reefs, barrier reefs, platform reefs, oceanic ribbon reefs, drowned reefs, atolls and near-atolls (Zann, 1992). Spalding et al. (2001) describe the Fijian coral reefs as the largest reef system in the South-West Pacific.

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

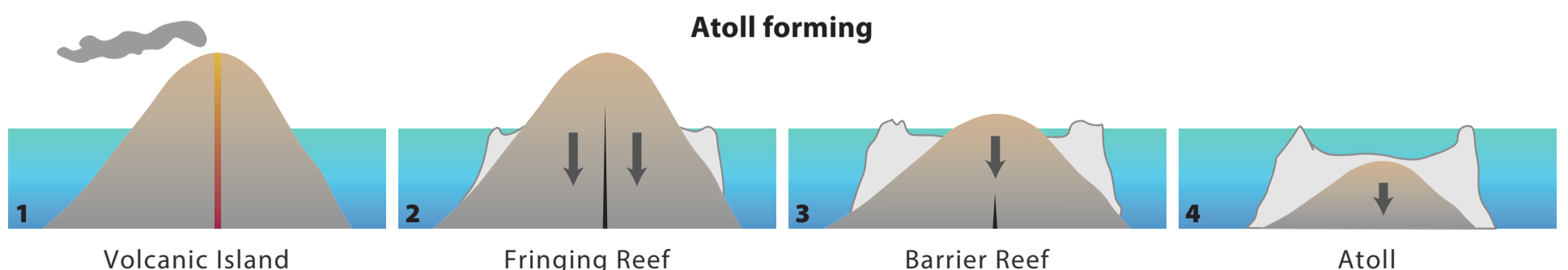
- Fringing reef (e.g. Coral Coast): Directly attached to a shore, or borders it with an intervening shallow channel or lagoon.
- Barrier reef (e.g. North Viti Levu): Separated from a mainland or island shore by a deep channel or lagoon.
- Atoll reef (e.g. east of Vanua Levu): More or less circular or continuous barrier reef that extends all the way around a lagoon without a central island.
- Patch reef (e.g. between Rakiraki and Natovi): Common, isolated, comparatively small reef outcrop, usually within a lagoon or embayment, often circular and surrounded by sand or seagrass.

## Underwater rainforests

Around half of Fiji'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 than the nation's forests above sea level. Such a diverse ecosystem is very valuable to Fiji, providing habitat, shelter and tourism opportunities (see also chapters "Home, sweet home" and "Beyond the beach").

- Combination of different reef types (e.g. the Great Sea Reef).

The major reef types are fringing reefs, which surround almost all high islands, and barrier reefs, which lie at the edges of island shelves (Vuki et al., 2000). Among Fiji's important reefs are: the fringing reefs that surround the two main islands, Viti Levu and Vanua Levu; the 200-kilometre-long Great Sea Reef, a barrier reef that runs along the shelf edge of the Yasawa group of islands to Vanua Levu; the fringing reefs around the large island of Kadavu and the 95-kilometre-long barrier reef running along its southern and eastern coasts, which extends into the Great Astrolabe and North Astrolabe Reefs.



# TRAVELLERS OR HOMEBODIES: MARINE SPECIES RICHNESS

Fiji'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 Fiji'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 Fiji'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, and several important commercial billfish species, such as blue marlin (*Makaira nigricans*), black marlin (*Makaira indica*) and swordfish (*Xiphias gladius*).

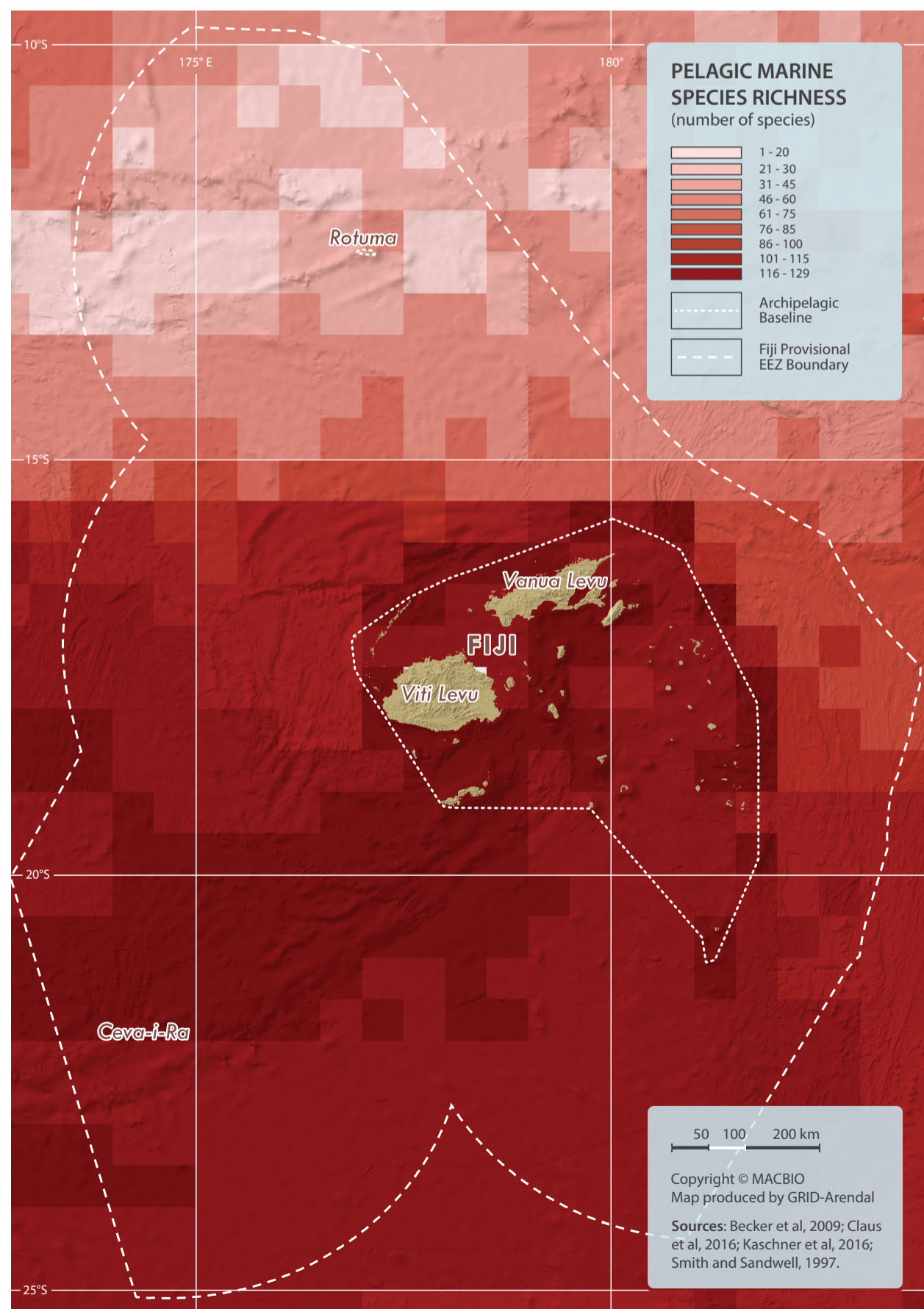
There are also some pelagic shark species, including the blue shark (*Prionace glauca*), oceanic whitetip (*Carcharhinus longimanus*), shortfin mako shark (*Isurus oxyrinchus*) and silky shark (*Carcharhinus falciformis*). Other sharks such as bull (*Carcharhinus leucas*) or tiger (*Galeocerdo cuvier*) sharks attract countless dive tourists and revenue to Fiji (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 Fiji's numerous benthic species, many invertebrates (those without a backbone) are found in soft sediment habitats. According to its 2016 National Biodiversity Strategies and Action Plan, Fiji has numerous marine invertebrates, including 342 species of hard corals, 760 species of bivalves (such as oysters and mussels) and gastropods (such as snails and slugs), 26 crustaceans (such as crabs, lobsters and shrimps) and many echinoderm species (including starfish, sea urchins, and sea cucumbers). Sea cucumbers are particularly important to Fiji, with at least 28 species harvested commercially (see graphic and chapter "Small fish, big importance"). Many benthic species form habitats in Fiji's shallow waters, including corals, seagrass, mangroves and algae (see also chapter "Home, sweet home").

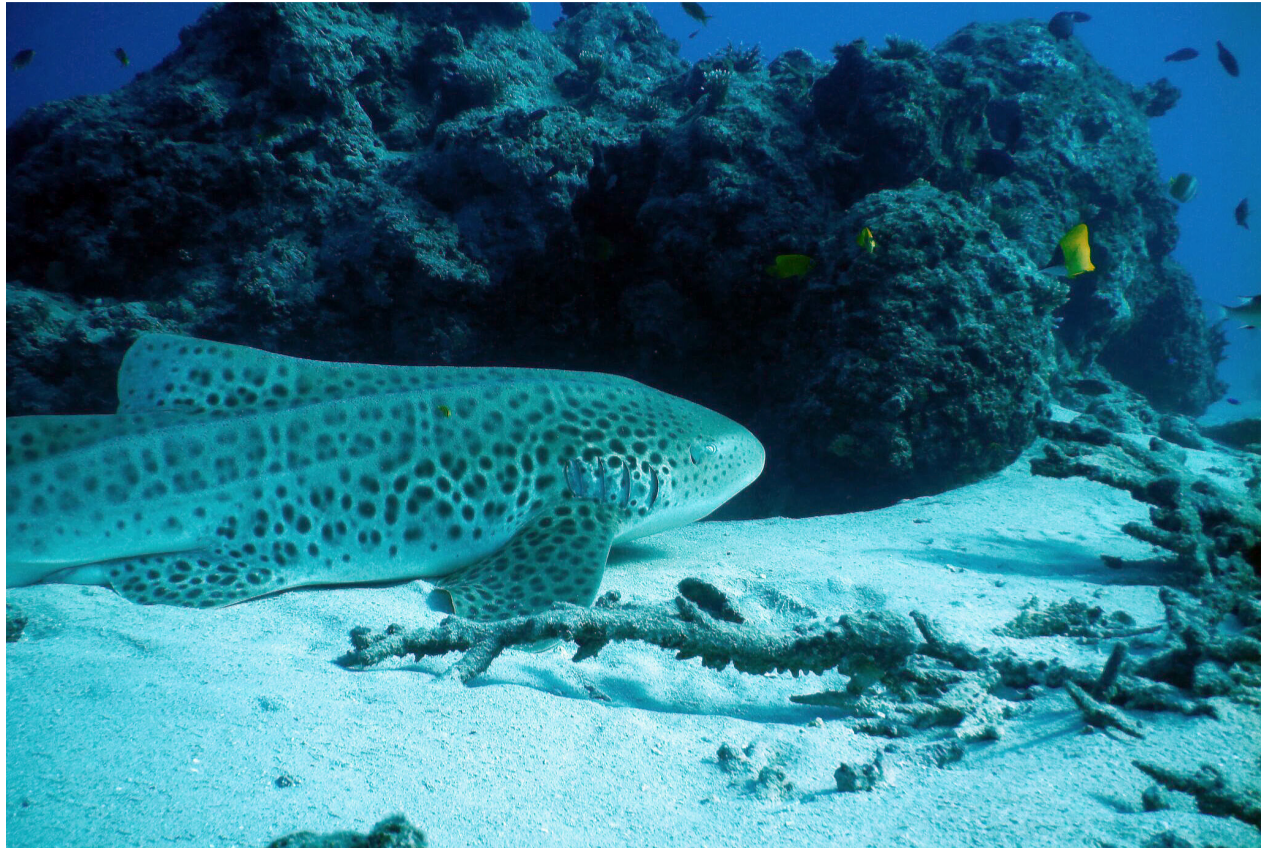
In general, species richness can be used as an indicator of conservation significance. It does not, however, provide information on species composition, nor does it identify whether there are rare



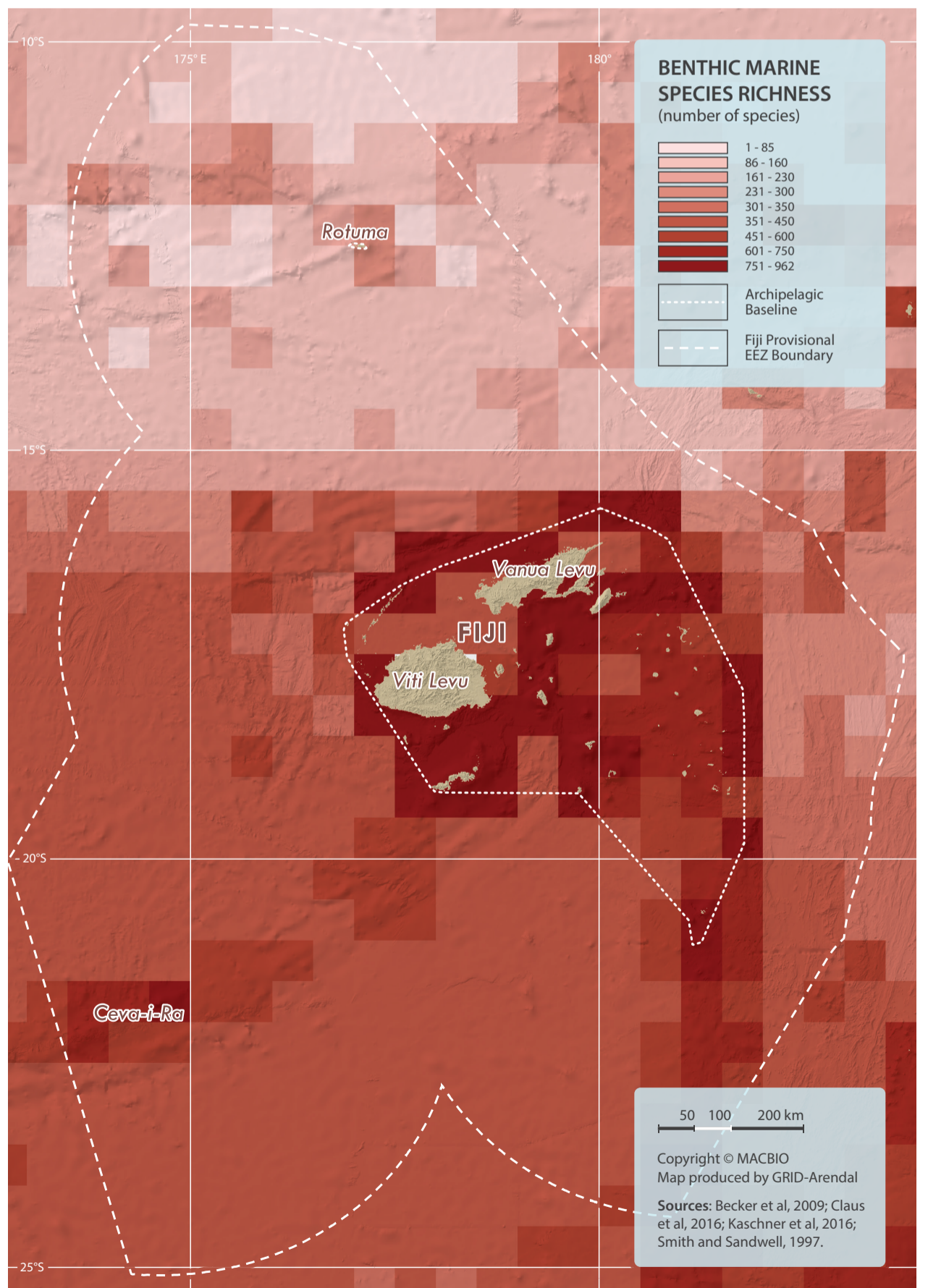
or priority species in an area. Further, areas with similar species richness may have very different species present, which would affect the conservation and management measures required.

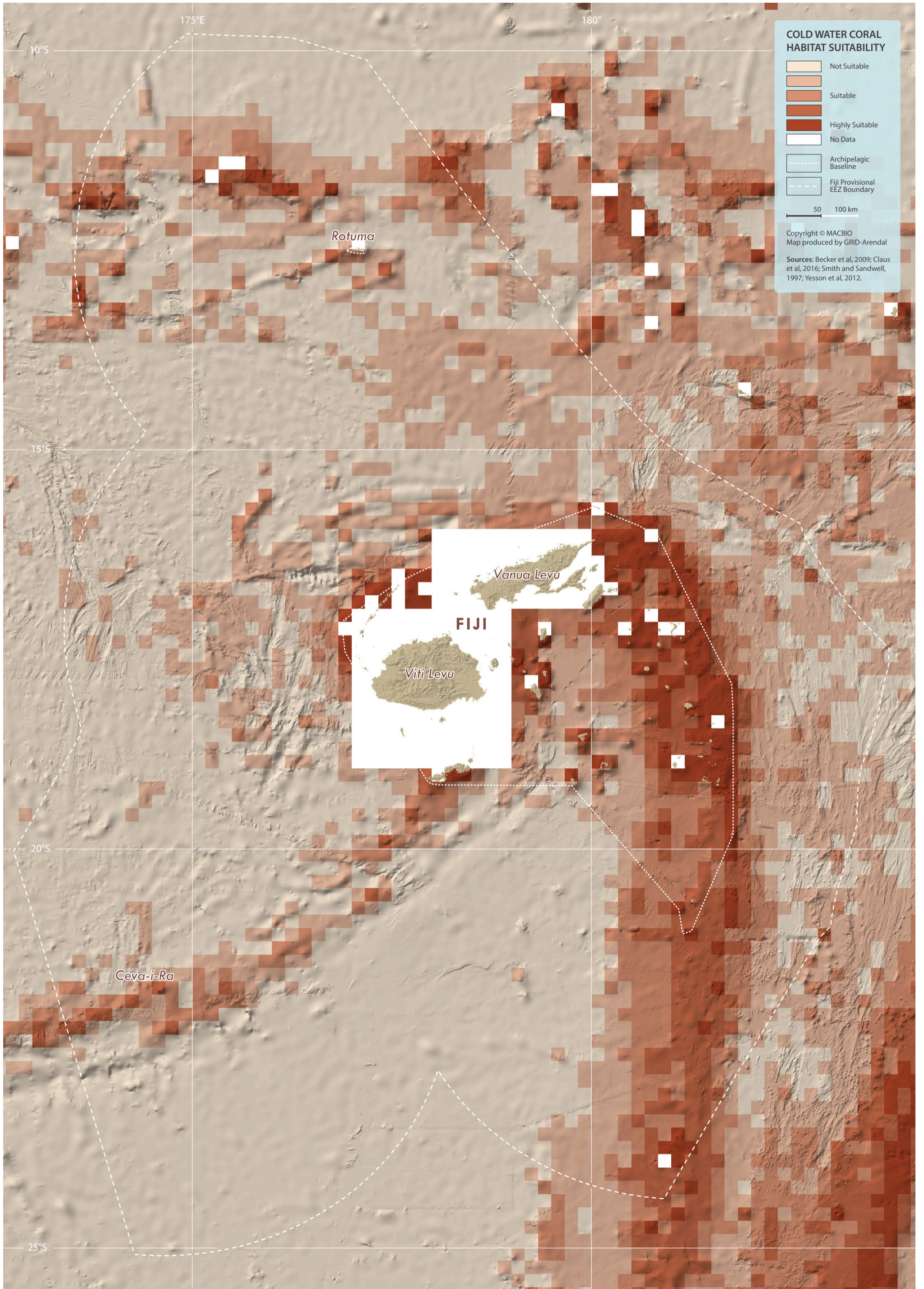
Globally, pelagic fish are generally more abundant in tropical waters and decrease as latitude increases. As the map shows, within Fiji's waters, there is generally lower species richness in the northern part of Fiji's waters, with higher pelagic richness to the south and south-west of the main islands, especially over the Denham and Moore Ridges and northern parts of the Lau Ridge (see also chapter "Voyage to the bottom of the sea"). Large geographic features that rise off the sea floor interact with currents (see also chapter "Go with the flow"). Pelagic fish abundance and biomass can, therefore, peak deep in the water column in association with abrupt bathymetric features such as seamounts and mid-ocean ridges (Sutton et al., 2010). Furthermore, migrating species, including whales, frequently pause over seamounts and other shallow geographical features (Garrigue et al., 2015).

Similarly, tropical waters tend to have a higher benthic species richness than waters at higher latitudes. Again, in Fiji's waters, there is generally higher species richness in the south than in the north. Benthic species richness is higher in shallow water compared with deep water, both in Fiji and globally. The highest benthic species richness is found around the main islands and extending south along the Lau Ridge. There is also elevated species richness along the Colwyn and Herald Ridges to the south-west of Fiji, and on the banks and seamounts west of Rotuma.



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





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

While quite a lot is known about Fiji's inshore environment, some habitats are hard to explore and map, especially those found deep below the surface where conducting research is both expensive and complicated. To map Fiji's important cold-water coral communities, scientists use habitat suitability models that guide us to where they are likely to be found.

## 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 Fiji's waters undoubtedly hold a lot of secrets, including deepwater 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.

Cold-water corals include five taxa and over 3,300 more species than their better known tropical coral reef counterparts: order Scleractinia (hard, stony corals), order Zoanthidea (zoanths, gold corals), order Antipatharia (black corals), subclass Octocorallia (soft corals, gorgonians, bamboo corals), and family Stylasteridae (lace corals) (Roberts et al., 2009).

Many of these corals 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 pol-

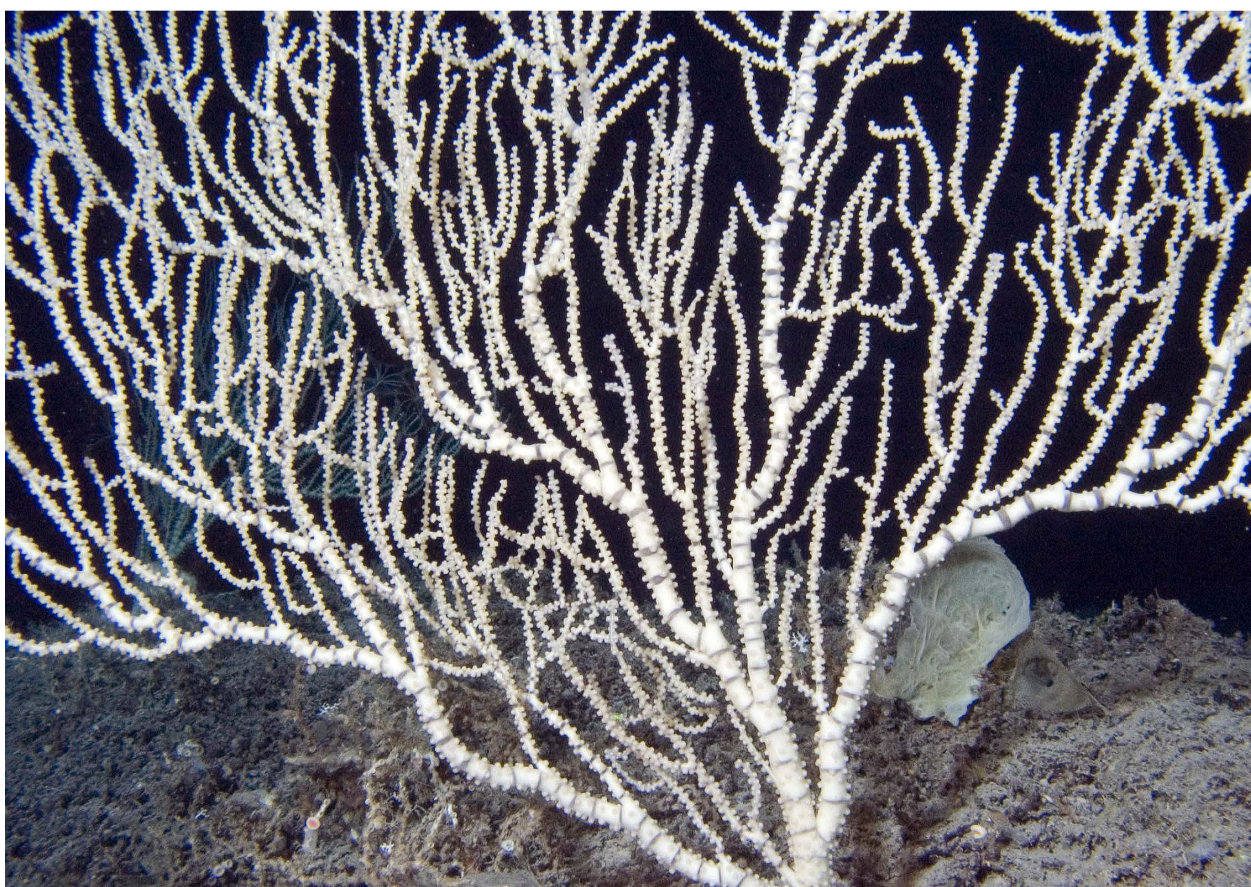
lution and climate change (see also chapters "The dose makes the poison" and "Turning sour"). Many species of cold-water coral are structurally fragile, and hence easily broken. They can also be long-lived and slow-growing, meaning that any recovery from damage is slow. Therefore, the presence of cold-water 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 an important group because they are known to be very widespread throughout the Pacific Ocean. Habitat suitability modelling has been used

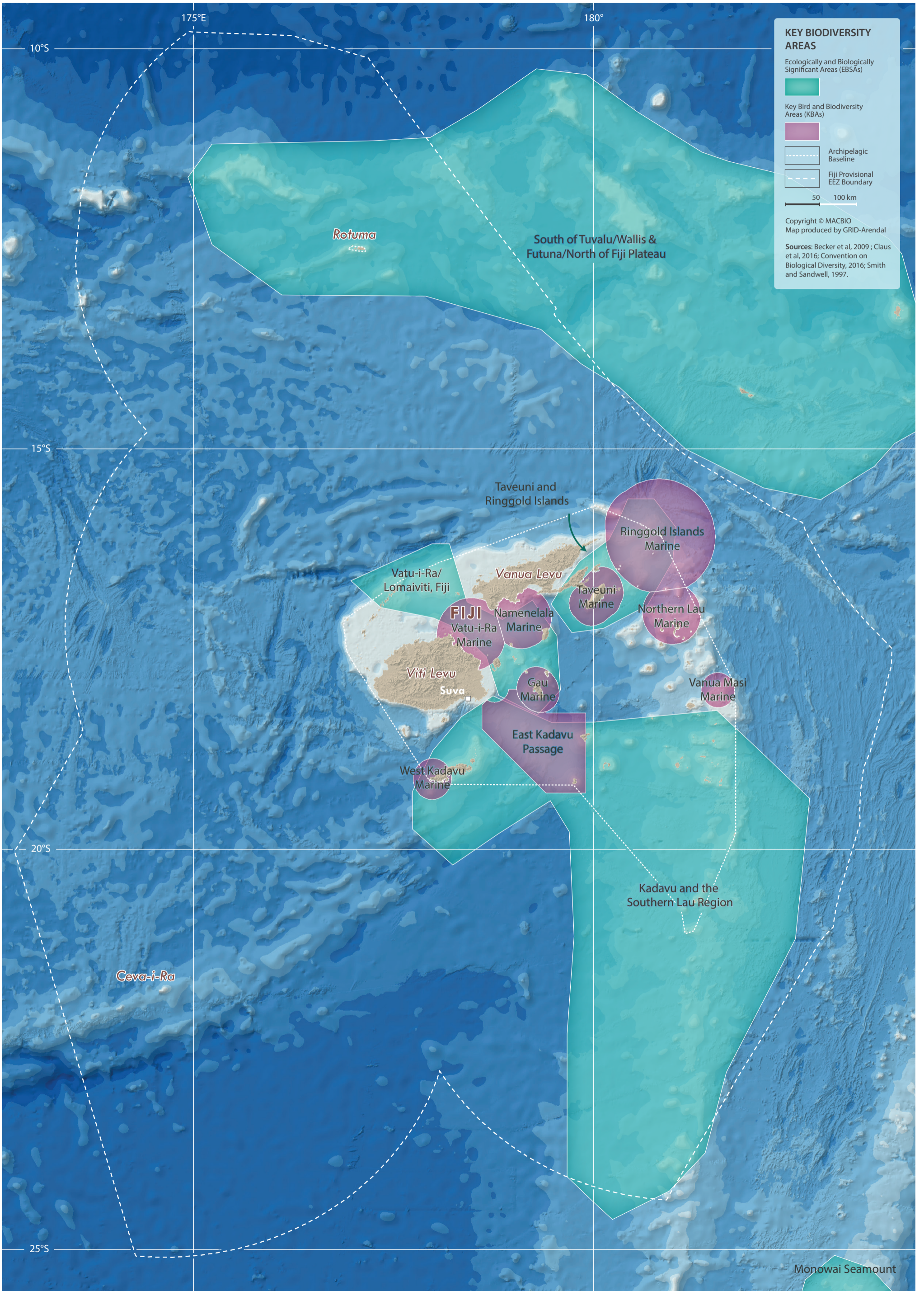
because actual species records are sparse. Data available through the Ocean Biogeographic Information System supplemented with New Zealand regional records (NIWA) show only 19 records of cold-water octocorals, comprising nine species, in Fiji's waters. The relationship between where the corals are known to occur and key environmental conditions in these locations has been used in these models to extrapolate into areas that have not been sampled, based on 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).

Habitat suitability was highest along the major bathymetric features in Fiji's waters, with high predicted occurrence continuously along the Lau Ridge (running north-south), the Moore and Denham Ridges to the south-west and Charlotte, Alexa, Louisa and Morton Banks in the north. These ridge and bank features are shallower than much of the abyssal plains in Fiji's waters (with greater food supply by the sea floor), and have higher slopes associated with steep topography. The latter is also associated with a greater amount of hard rocky substrate, which the corals need for attachment.

Although not presented in a figure, 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 (see also chapter "Go with the flow"). The published figures do not show the area north of the main islands of Fiji, but predict high suitability for at least one of the species (*Enallopsammia rostrata*) along the Lau Ridge, similar to the octocorals.



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



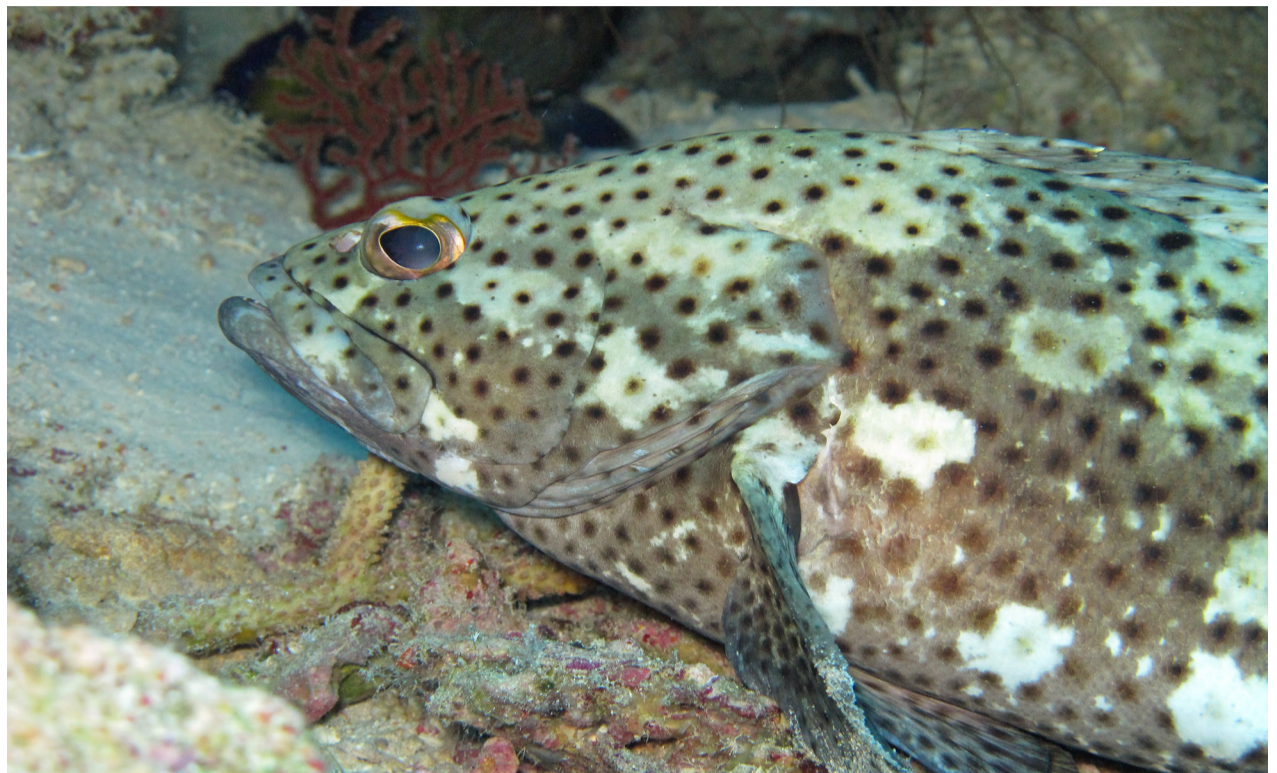
# NATURE'S HOTSPOTS: KEY BIODIVERSITY AREAS

Fiji's rich biodiversity is a gift to the world. Hotspots that are of particular international importance have been designated as Key Biodiversity Areas to ensure that the protection of their unique values is on Fiji's marine management and conservation agenda.

The previous maps show Fiji's impressive richness of natural wonders and their value to Fiji. 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 Fiji's waters also have international significance. It is therefore important for Fiji 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 Ecologically or Biologically Significant Areas (EBSAs) described under the Convention on Biological Diversity (CBD).

Marine conservation in Fiji's waters is governed by the goals and objectives set out in its National Biodiversity Strategy and Action Plan and an implementation framework developed in 2010. This plan links national action with more global and regional initiatives such as the CBD, process for EBSAs, IUCN protected areas, KBAs and Birdlife International's IBAs. 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).

In Fiji, as elsewhere around the world, 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. In Fiji, many of the KBAs identified are within or close to a number of marine reserves, typically centred around islands, such as the Namenalala Resort Marine Reserve, the Northern Lau group, Gau and Taveuni. Further KBAs and focal marine habitats and biodiversity targets have been identified, based on discussions and workshops that have been under way since 2009, to determine species that warrant priority conservation due to their ecological roles, cultural significance, uniqueness (e.g. endemics)



*Coral grouper populations are declining in Fiji due to their high value as food fish and popularity in the aquarium trade.*

and rarity (e.g. threat status on the IUCN Red List), as well as the marine habitats they are likely to be found in. 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 a number of these in offshore areas of Fiji, although it should be noted that there are over 100 locally managed marine protected areas, which are generally very localized and coastal. In November 2011, the CBD hosted a regional workshop to facilitate the description of EBSAs for the western South Pacific Ocean. Four EBSAs have subsequently been approved by the CBD:

**1) Kadavu and the Southern Lau region:** This large EBSA encompasses Kadavu and a number of other central islands, and extends southward towards Tonga. It covers diverse topography, extending from shallower waters around the islands to 1,000–2,000 metres along the Lau Ridge and to 4,000 metres on the abyssal plains. The region is an important nesting and foraging ground for Kadavu's endemic seabird species (Fiji petrel), hawksbill and green turtles. It is also a migration corridor for several species of whale and contains endangered shark breeding areas and a large variety of reef-associated fish and invertebrate species.

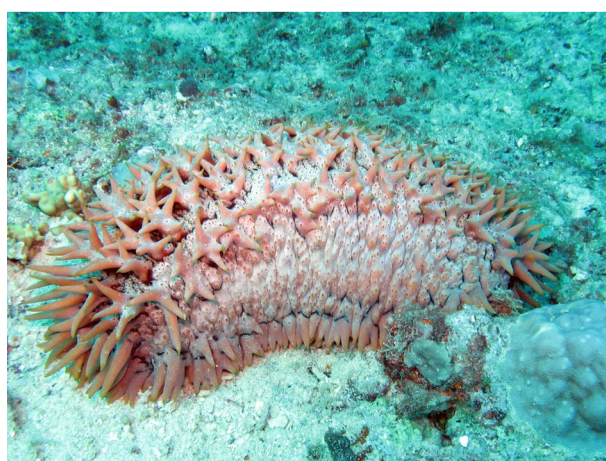
**2) South of Tuvalu/Wallis and Futuna/North of Fiji Plateau:** This EBSA encompasses an estimated total area of more than 325,000 km<sup>2</sup> and falls within three national jurisdictions. It has a number of distinct topographic features, such as seamounts, knolls, large submarine canyons, trenches, basins, plateaus, ridges, volcanic islands and fringing reefs. This topographic diversity supports high species richness.

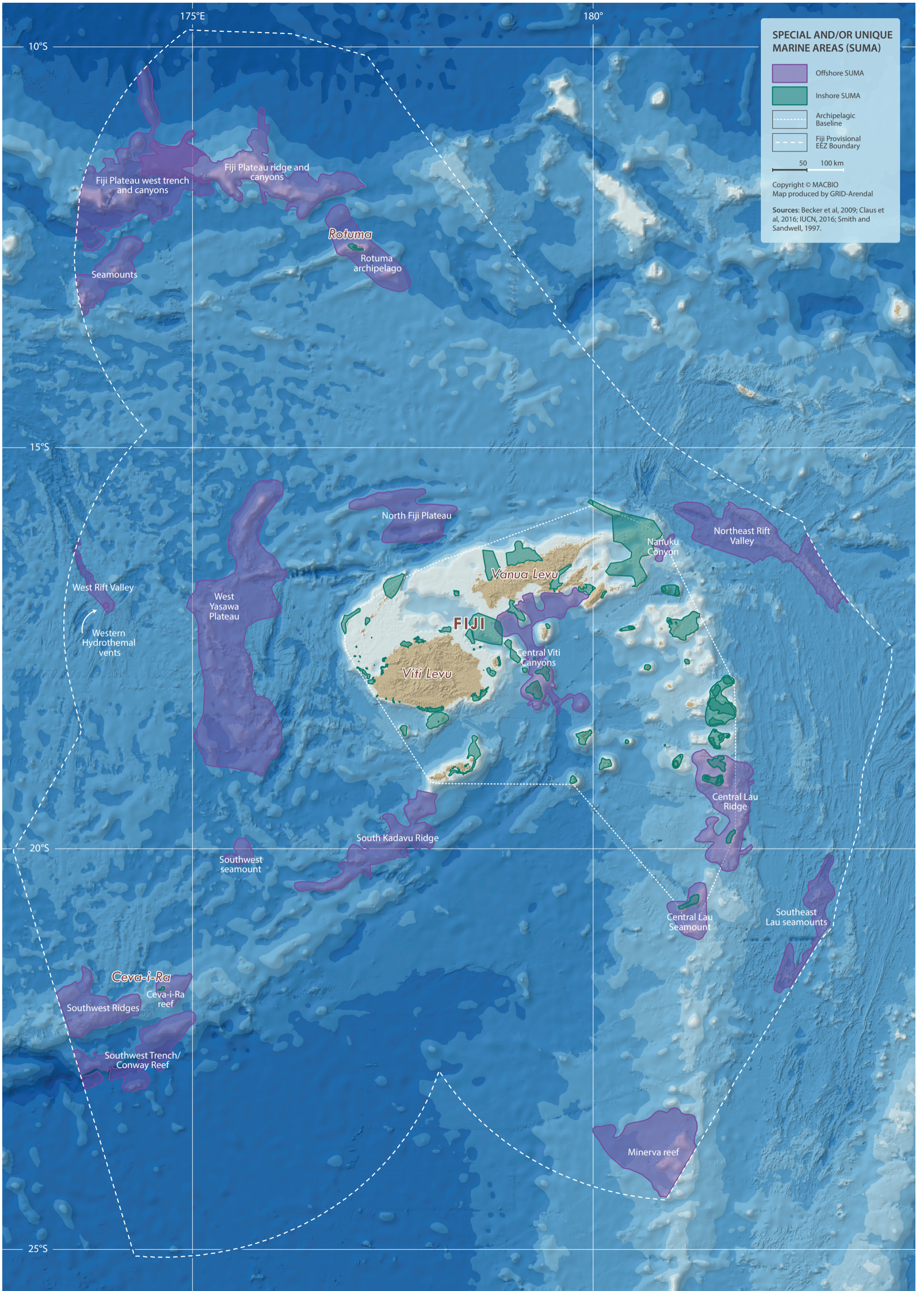
**3) Vatu-i-Ra/Lomaiviti:** Located close to the main islands of Viti Levu and Vanua Levu, this area contains a diverse benthic geomorphology, including channels, submarine canyons and seamounts. Coral reef biomass is very high, there are many significant seabird colonies—including the only breeding site for the endemic and critically endangered Fiji petrel—and the area is a hotspot for humpback whales and other cetaceans, sea turtles and sharks.

**4) Taveuni and Ringgold Islands:** This site combines a number of habitats, important communities and priority species in a compact area that includes deep channels, sheltered areas, small islands and sand cays. The area is a key breeding and foraging area for hawksbill and green turtles, and supports migratory movements of humpback whales and resident spinner dolphins. The EBSA encompasses four marine IBAs.



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





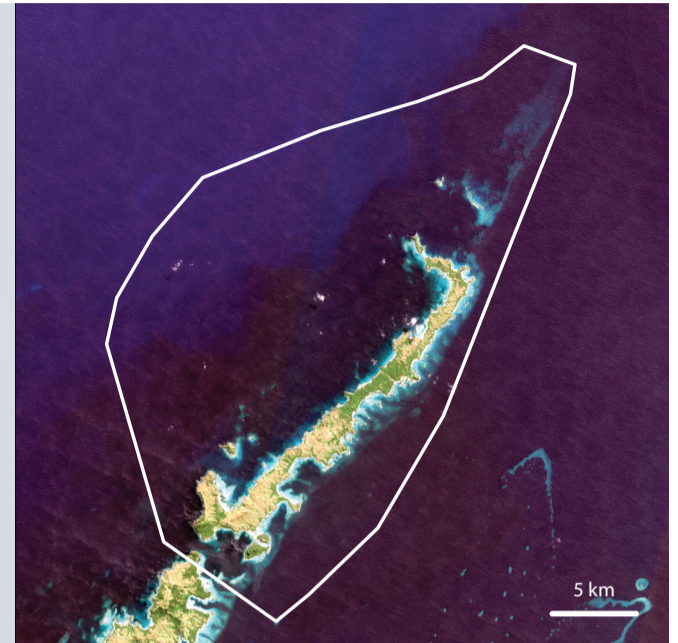
# SPECIAL AND UNIQUE MARINE AREAS

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

## Special and unique: Yasawa Islands

One of the 98 special and unique areas in Fiji's waters is the Yasawa chain of islands. Its northernmost island in the north-west of Fiji received an overall rating of 10/10 during the Special, Unique Marine Areas (SUMA) identification process. This long, narrow volcanic island about 23 kilometres long and 1–2 kilometres wide has steep cliffs of black volcanic rock and long white sand beaches. There are seven villages or settlements and a luxury resort for guests attracted by the fringing and patch reefs around the island that have high levels of coral cover in the

shallower areas. The western side of the barrier reef comes closer to shore than anywhere else in the Yasawa chain of islands, making the fringing and barrier reefs closely connected. Great hammerhead sharks (*Sphyrna mokarran*) have been sighted off these deep reefs, while there are green turtle foraging areas and hawksbill turtle nesting sites along the coast. Within the lagoon and back-reef areas, there are very productive seagrass beds and sites where grouper breeding occurs between June and September every year.



Fiji's KBAs (see previous chapter) emphasize not only the importance of marine biodiversity to Fiji, but also to the world. Much of Fiji'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 Fiji'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 also chapter "Beyond the hotspots").

SUMAs are areas that are particularly important in maintaining Fiji's biodiversity. They can serve as priority areas for management actions within Fiji'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 2016, local users and subject experts were brought together to share their knowledge and identify and map 98 SUMAs. This effort built upon and updated previous efforts, including the 2004 Fiji Islands Marine Ecoregion report, the Fiji Protected Area Committee's Marine Ecological Gap Analysis and the information on EBSAs.

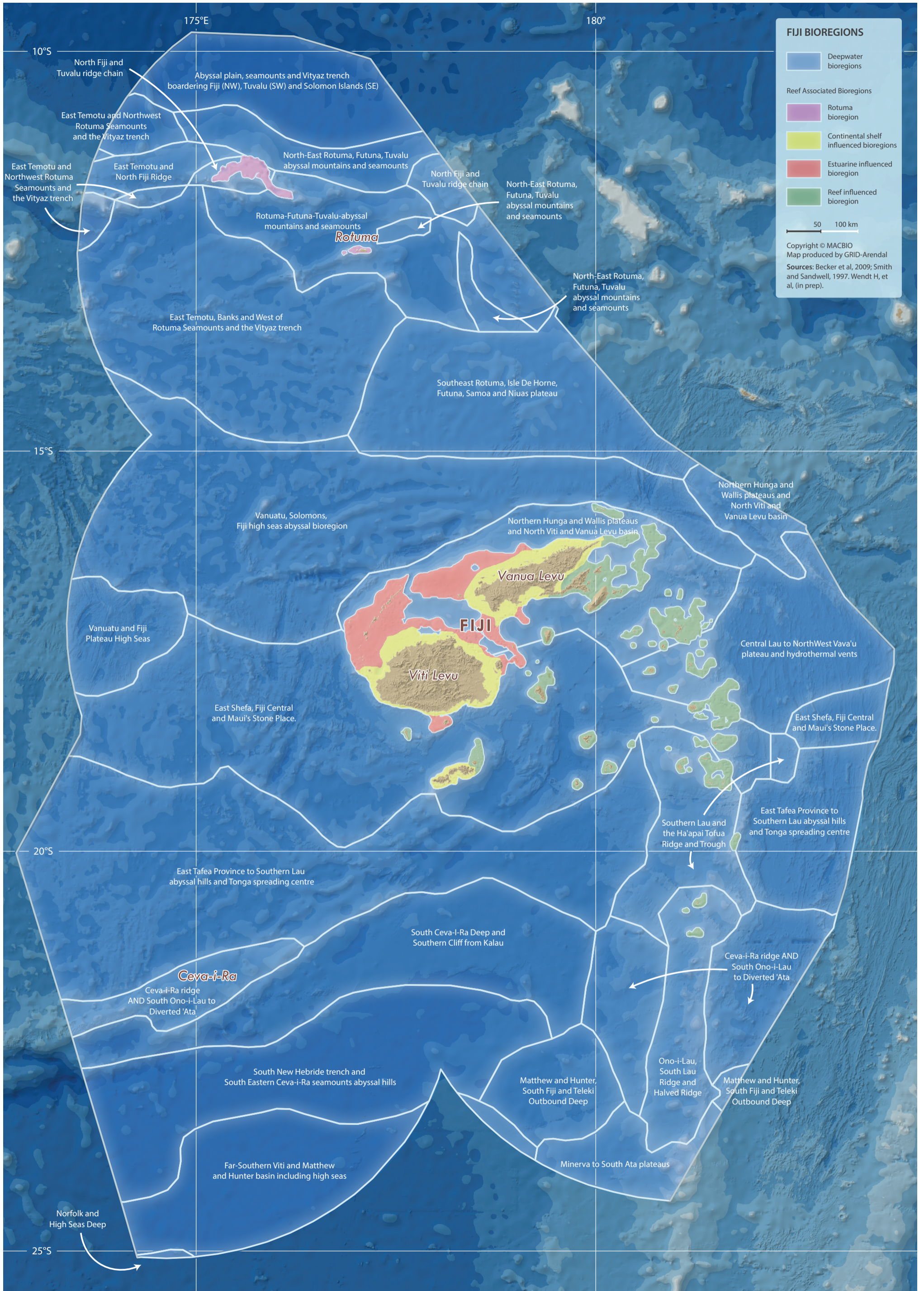
The local users and experts contributed their local knowledge of the area and were guided by four criteria in identifying SUMAs in Fiji's waters: biophysical justification, geographic explicitness, availability of information sources, and international and national obligations.

Ranging from mangroves and seagrasses to deep-sea trenches, canyons and seamounts, these marine areas are some of Fiji's most bi-



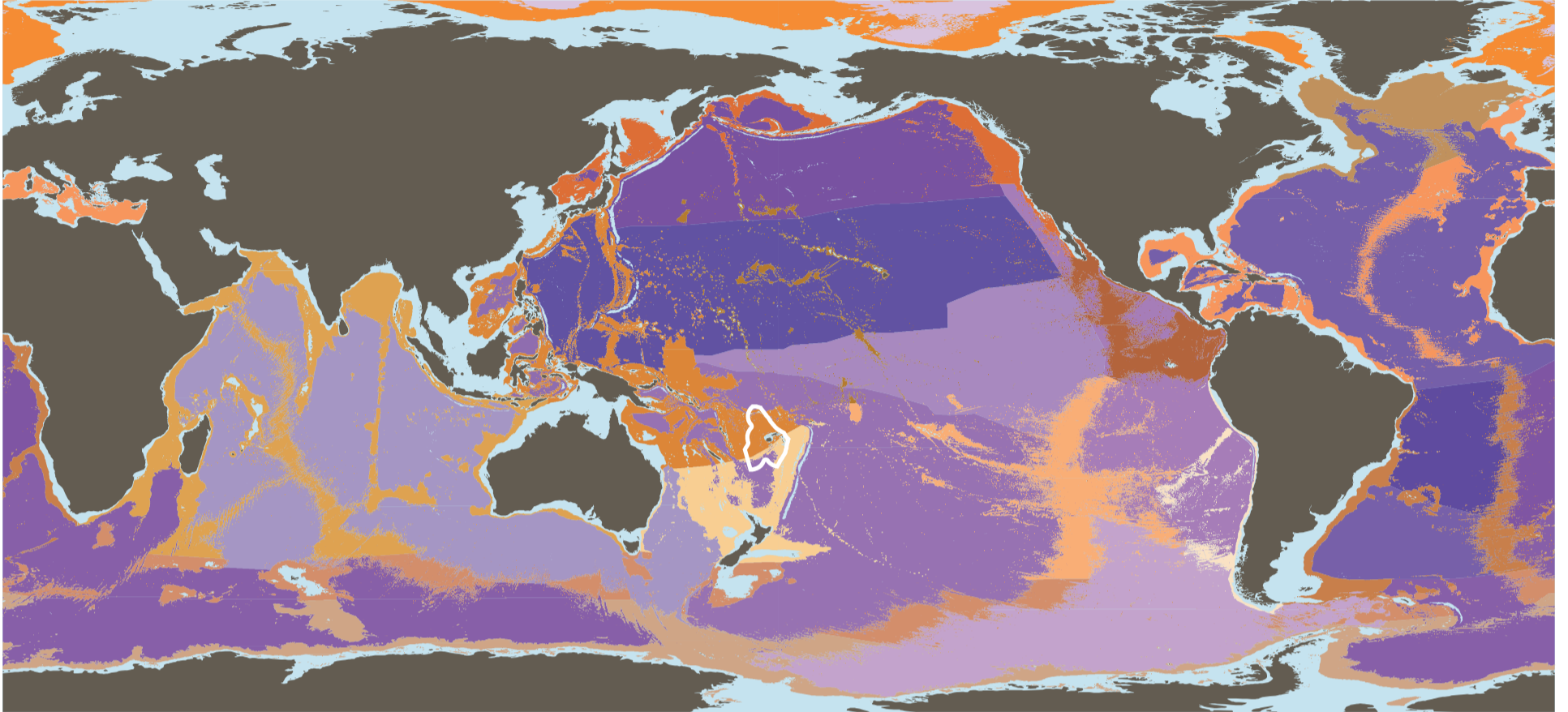
ologically important. These sites, together with the corresponding report "Biophysically Special, Unique Marine Areas of Fiji", will assist in the selection of marine managed protected areas, to achieve 30 per cent coverage of Fiji's waters (see also chapter "Fiji's commitment to marine conservation") (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 98 offshore and inshore SUMAs. Within these, the experts identified 33 subsites of interest as special, unique marine environments, reflecting the immense variety of marine habitats within the Fijian 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.



# BEYOND THE HOTSPOTS: BIOREGIONS

Ideally ecosystem-based marine planning should be based on comprehensive data that represents all of Fiji'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.

Fiji's waters are full of valuable marine biodiversity. To sustainably manage and protect this richness, the Fijian government is committed to delivering a comprehensive, ecologically representative network of managed and protected marine areas (see also chapter "Fiji's commitment to marine conservation"). Ideally ecosystem-based marine planning should be based on comprehensive biodiversity data that represent all of Fiji'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 Fiji. 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 clustering such data results in spatial units, called marine "bioregions". These bioregions present comprehensive descriptions of the marine biodiversity of Fiji and can be used for conservation, management and planning.

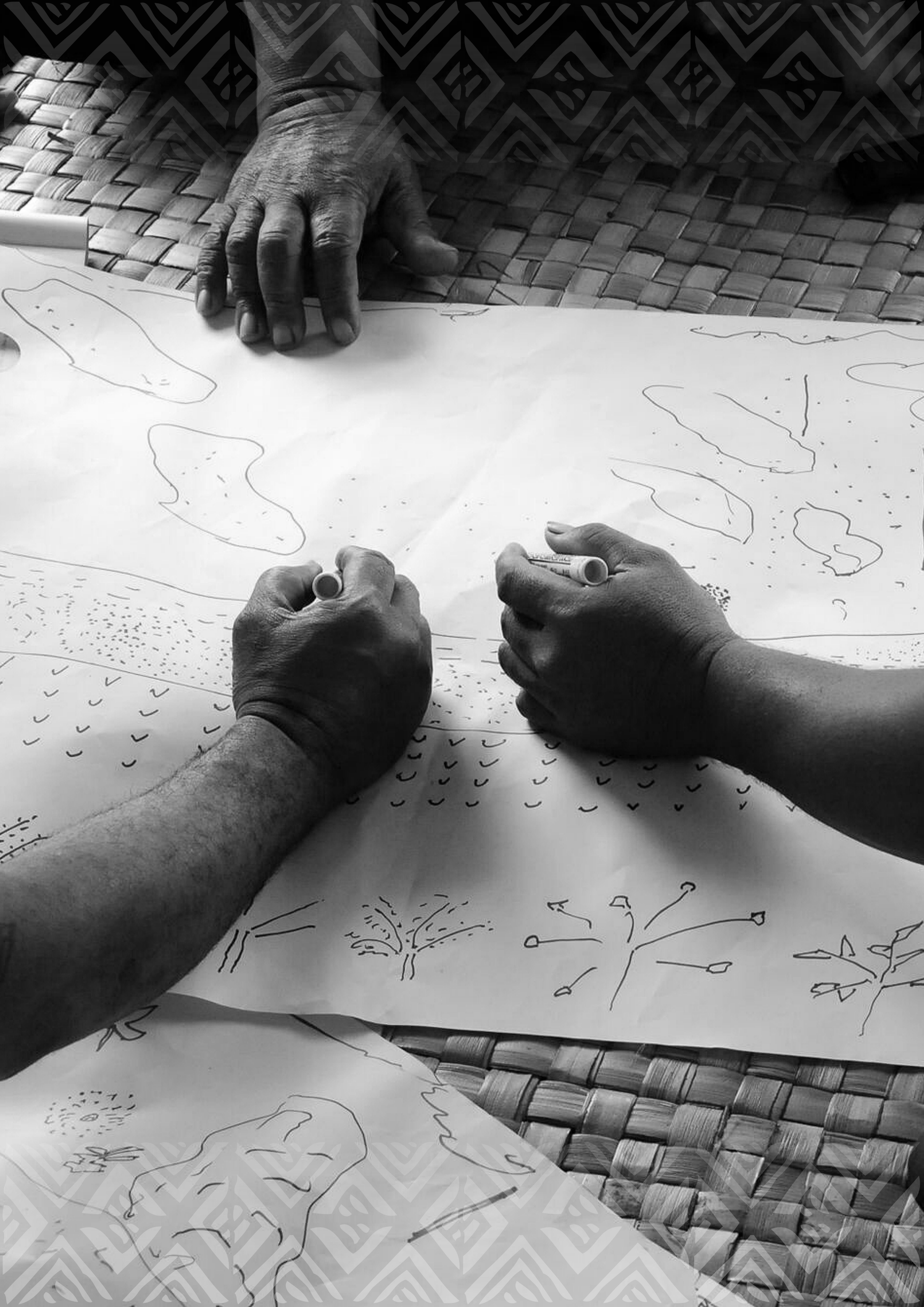
Such marine classification and the use of bioregions is not a new concept, as bioregions have been produced before at various scales in other countries, regions and globally, including some that encompass Fiji. The graphic provides one example of a global bioregionalization, the Global Open Oceans and 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, Fiji'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 Fiji. This calls for more detailed bioregions to inform marine planning. In 2016, in-country experts came together to describe preliminary marine bioregions for Fiji, supported by the MACBIO project. These include 23 deepwater and four reef-associated bioregions (Wendt et al., forthcoming), as shown on the map.

Using these bioregions as substitutes to describe the suite of marine biodiversity in Fiji, 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.



Navakavu is part of the estuarine-influenced bioregion in Fiji.





# PLANNING

The previous section on “Valuing” revealed the diversity and richness of Fiji’s biophysical features, the ecosystems they underpin, and the many goods and services they provide to Fiji. 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 Fiji’s total jurisdiction is ocean. The ocean is vitally important to Fiji, providing food and income, coastal protection, carbon storage, and essential habitat for marine plants and animals. Furthermore, coasts and oceans are heavily intertwined with Fiji’s cultures, traditional knowledge and practices, while the economic, social and ecological benefits provided by marine ecosystems are worth billions of dollars to Fijians every year.

Despite the high value of the ocean to Fijians, 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 Fiji 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 (LMMAs), or marine protected areas (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 Fiji 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](http://www.macbio-pacific.info/marine-spatial-planning)

## USES

# FISHING IN THE DARK: OFFSHORE FISHERIES

Underpinned by Fiji's ecosystems, offshore fisheries are an important contributor to the country's economy. As is the case with all human use of the ocean, offshore fisheries need to be planned and sustainably managed.

A very important use of the ocean that immediately comes to the mind of every Fijian is fishing. There are two different types of fisheries in Fiji: those close to the shore (see also chapter "Small fish, big importance") and those offshore (see also chapter "Travelers or homebodies").

Commercial offshore fisheries mostly catch tuna and produce a gross value around FJ\$55 million per year. In terms of net value, this translates to around FJ\$20 million in direct benefits to Fiji's economy (Gonzalez, 2015). Interestingly, inshore fisheries yield substantially more with a total of FJ\$113 million per year.

In Fiji's waters, commercial tuna fishing is carried out using longline, and pole-and-line methods. Longline fisheries target albacore (*Thunnus alalunga*), bigeye (*Thunnus obesus*), and yellowfin (*Thunnus albacares*)

tuna, comprising, on average, 60–70 per cent, 15–25 per cent and 10 per cent of annual catches respectively. Around 100 vessels are involved in this fishery (mostly Fijian), which in the last five-year period has produced a catch of 15,000–20,000 tons per year. Commercial billfish species taken in the fisheries include blue marlin (*Makaira nigricans*), black marlin (*Makaira indica*), striped marlin (*Kajikia audax*) and swordfish (*Xiphias gladius*), with combined catches of 300–400 tons each year. Several hundred tons of sharks, especially blue shark (*Prionace glauca*), oceanic whitetip (*Carcharhinus longimanus*), shortfin mako shark (*Isurus oxyrinchus*) and silky shark (*Carcharhinus falciformis*) are also caught as by-catch.

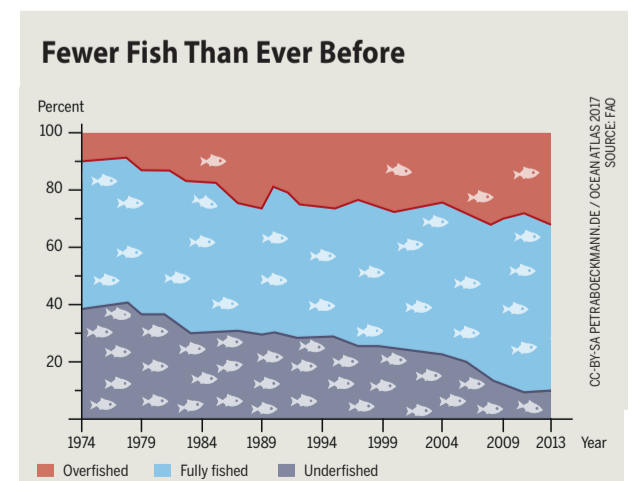
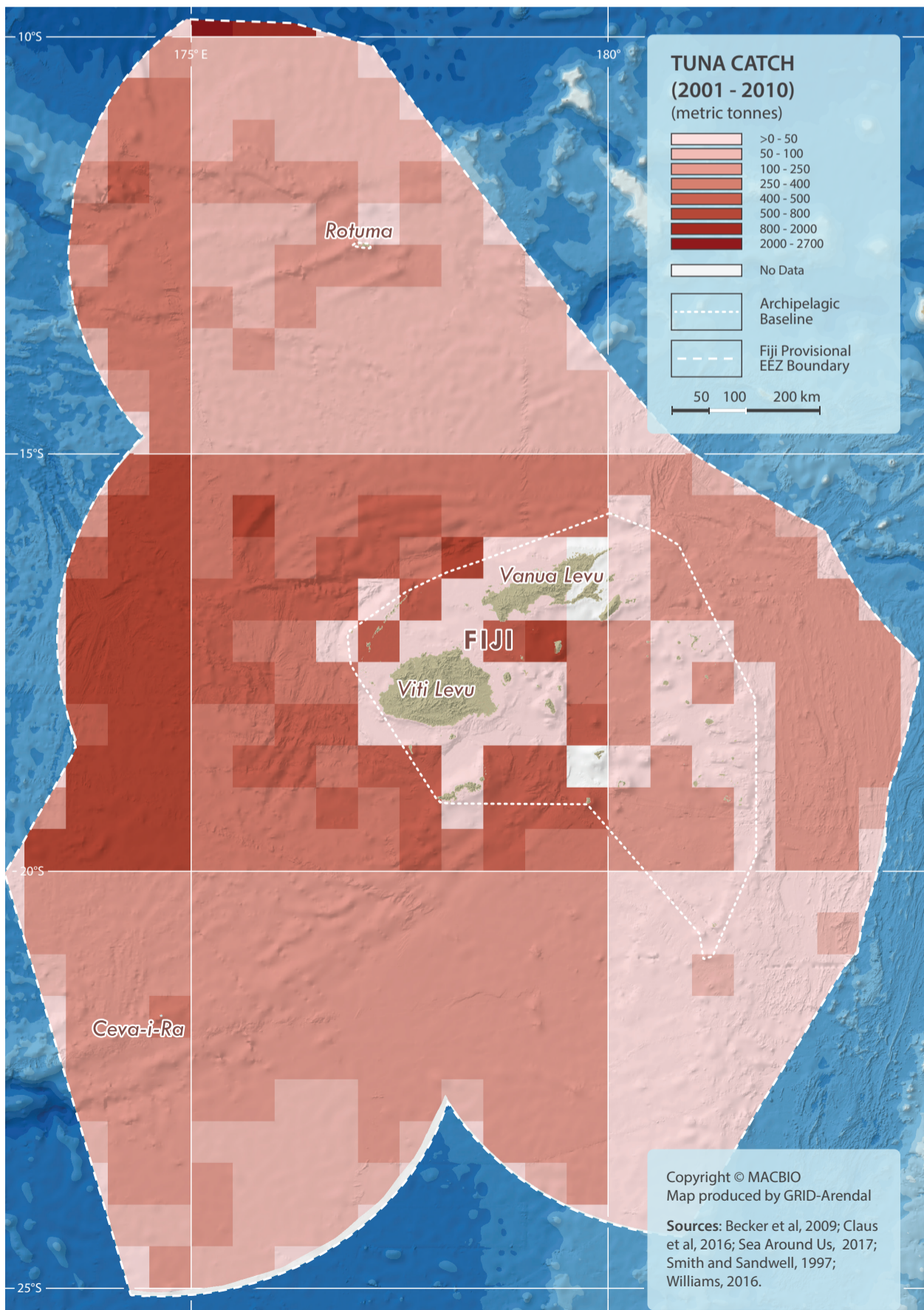
The pole-and-line fishery is much smaller, with only one or two vessels active per year. Skipjack tuna (*Katsuwonus pelamis*) comprises over 90 per cent

of the annual catch, with around 300–400 tons. Yellowfin tuna is also caught but in small quantities (less than 50 tons per year). No bigeye or albacore tuna are caught using this method.

The distribution of tuna catch on the map reflects the mixed sizes of vessels in the tuna fleet. Small boats (less than 20 metres long) often work close to the islands within territorial waters and land fresh fish on ice. Larger freezer vessels are able to undertake longer trips and work further offshore, especially along the western margin of the Fijian EEZ. Offshore catches are less in northern, southern and eastern sectors of the EEZ. Yellowfin tuna, and to a lesser extent, bigeye tuna catches are often higher on seamounts (Morato et al., 2010), which are relatively common to the west and northwest of the main islands. In some situations, seamounts and similar topographic features can enhance localized productivity, which can help support higher densities of fish species. The management of such habitats can be important for fisheries.

The Review of Fiji's National Tuna Management and Development Plan (FFA and SPC, 2012) clearly outlines the concerns of the domestic tuna industry. A provisional total allowable catch (TAC) of 15,000 tons has been determined by SPC. However, the TAC has not been reached within Fiji's EEZ and licence numbers for vessels remain low. Catches of high-value bigeye tuna, which was previously the target species for the sashimi market, have diminished because the fishery has become unviable, leading fishers to focus more on albacore and other tuna species. In addition, there has also been criticism about the large number of licences issued to highly subsidized Chinese vessels that compete against unsubsidized, locally-owned vessels (Gonzalez, 2015).

Other than tuna, fish caught in deepwater demersal (see also chapter "Voyage to the bottom of the sea") fisheries around Fiji and other Pacific Islands are mainly snappers from the families Serranidae (groupers of the genera *Cephalopholis*, *Epinephaus*, *Saloptia* and *Variola*; see graphic), Lutjanidae (snappers, primarily of the genera *Etalis*, *Aphareus*, *Pristipomoides* and *Lutjanus*) and Lethrinidae (emperors of the genera *Gymnocranius*, *Lethrinus* and *Wattsia*; see graphic and McCoy, 2010; SPC, 2013). In addition, catches off Fiji that sometimes extend into deeper waters may



Fifty-eight per cent of global marine fish stocks are fully fished and 31 per cent are overfished: only 10 per cent are not at or over their limits.

include parrotfish (family Scaridae), surgeonfish (family Acanthuridae) and rabbitfish (Siganidae). However, over 100 species are reported in the deep waters off Fiji, and in recent years interest has developed in medusafish (family Centrolophidae, primarily bluenose (*Hyperoglyphe antarctica*)), blue warehou (*Seriola lalandi*) and alfonsino (*Beryx spp.*) on seamounts (see also chapter “Underwater mountains”).

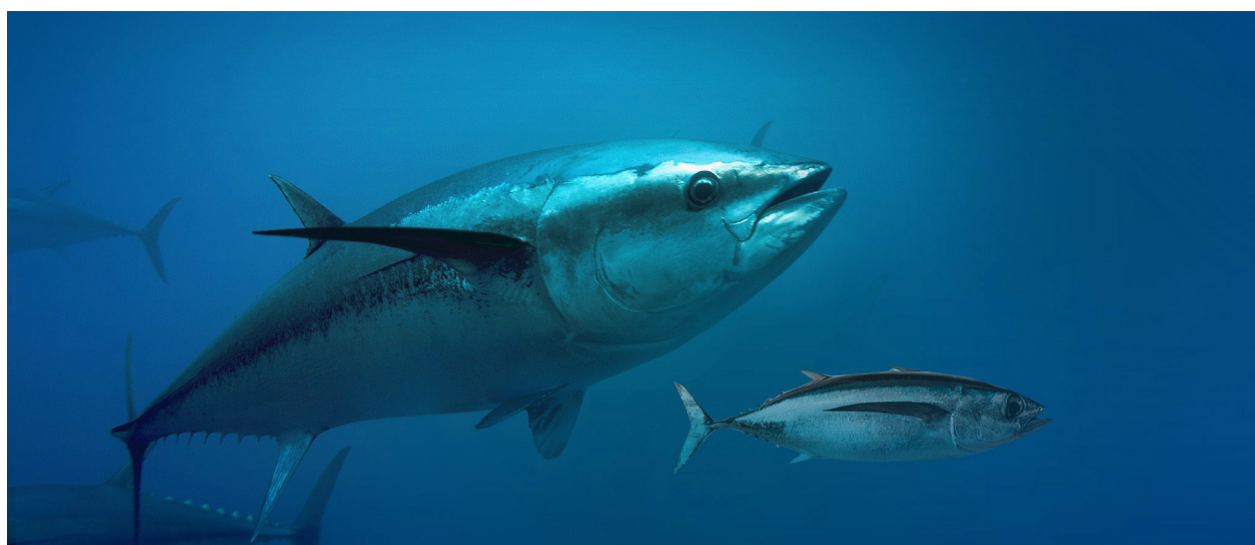
Line fishing for these species has been carried out commercially for several decades. Deepwater snapper fishing was promoted in the 1980s by SPC and Fijian fishers were actively engaged in this fishery (Dalzell and Preston, 1992). The fisheries occur on the outer-reef slope and around seamounts (mainly in depths from 100 to 400 metres; see also chapter “Underwater mountains”). The gear used includes hand reels and powered reels, with some commercial bottom longlining and trotlining. A regional assessment of the fisheries potential was made in 1992, largely based on seafloor area around 200 metres deep. Following this assessment, Fiji’s waters were estimated as having a sustainable yield of between 400 and 1,200 tons per year (SPC, 2013). However, although there have been up to seven licensed vessels fishing off Fiji, such fisheries in the region have struggled as a whole, due to low catch rates following an initial fishing-down phase, variable export markets and prices, and limited habitat area (McCoy, 2010).

In 1987, Fiji put management guidelines in place for deepwater snappers, though these have not been updated given the lack of a consistent fishery. In 2011, SPC hosted an international workshop, where it was recommended that biological sampling and studies be undertaken across the Pacific Islands for deepwater snapper and other deepwater demersal fisheries, since these species are believed to be long-lived (20+ years), slow-growing and late to mature, thus making them susceptible to overfishing (Williams et al., 2013). Overfishing, from Fijian and international fishers, in both the inshore and offshore fisheries, is a big concern in Fiji and worldwide, with only 10 per cent of global fish stocks not yet at their limits (see graphic).

The tuna catch map shows the general distribution of all tuna catches from 2001 to 2010. All species are widely distributed, though there is limited information on the stock or substock structure. Fishery catches need to be managed on a regional basis, rather than at the national level; albacore tuna is a good example of this. A South Pacific stock is distributed between 10°S and 50°S, spawning between latitudes of 10°S and 25°S (Nikolic et al., 2016). Juveniles occur more in surface waters at higher latitudes compared with adults, which are found in deeper subequatorial waters. Adults appear to have a seasonal migration pattern, moving south during early summer (December – January) and north in winter (June – August). Depth and seasonal distribution therefore need to be considered in the spatial management of tuna fisheries.

The distribution of tuna and their fisheries is expected to shift with climate change, potentially moving to the east and to higher latitudes (Lehodey et al., 2011). While this is not expected to affect Fiji much at the large spatial scale of the current models, it is a factor that should be considered in longer-term management scenarios. The deepwater fisheries map shows historical catches around Fiji based on FAO data and national reports.

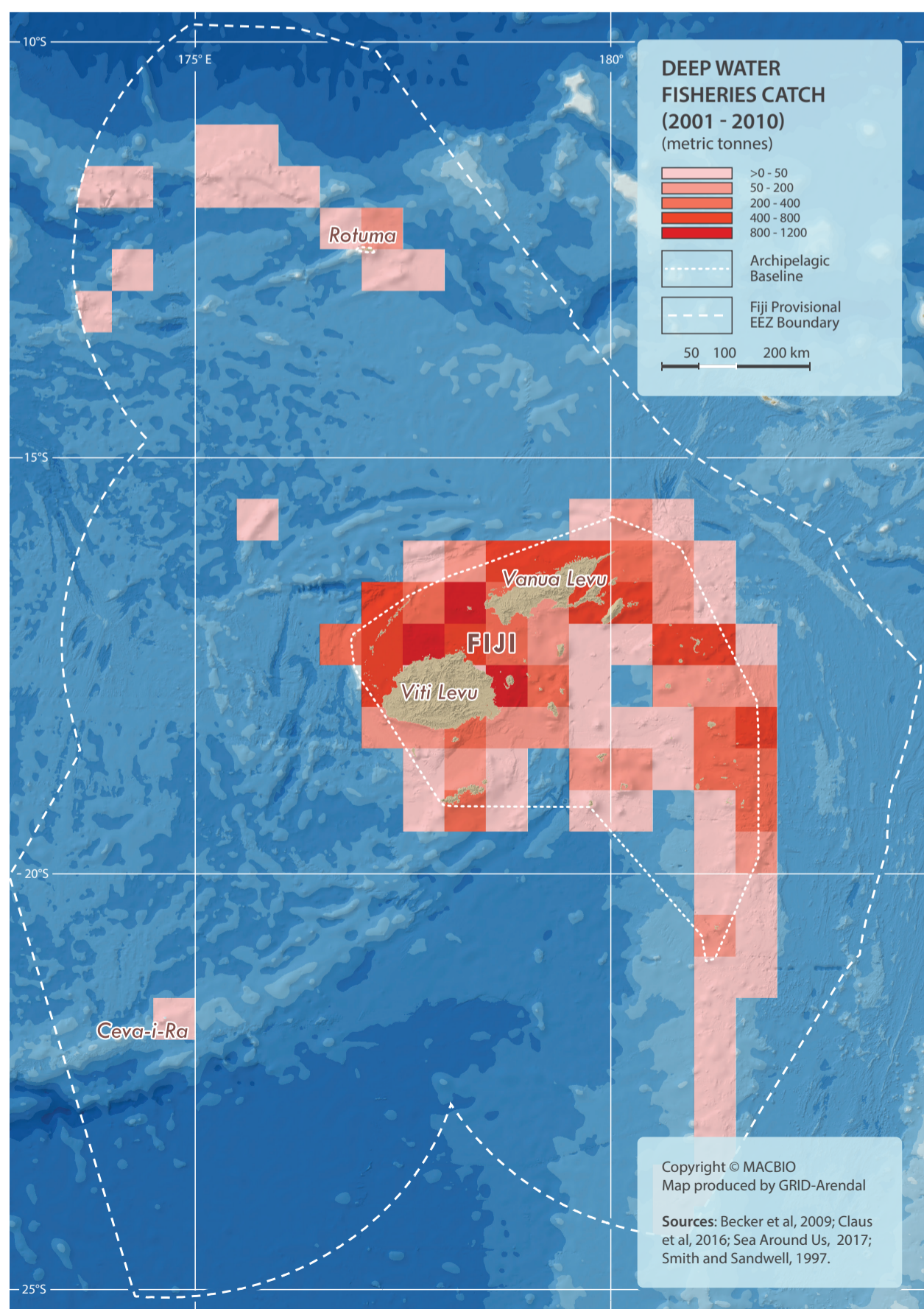
As regards the distribution of deepwater snapper, information is also limited. Gomez et al. (2015) estimated the distribution of 14 deepwater snapper

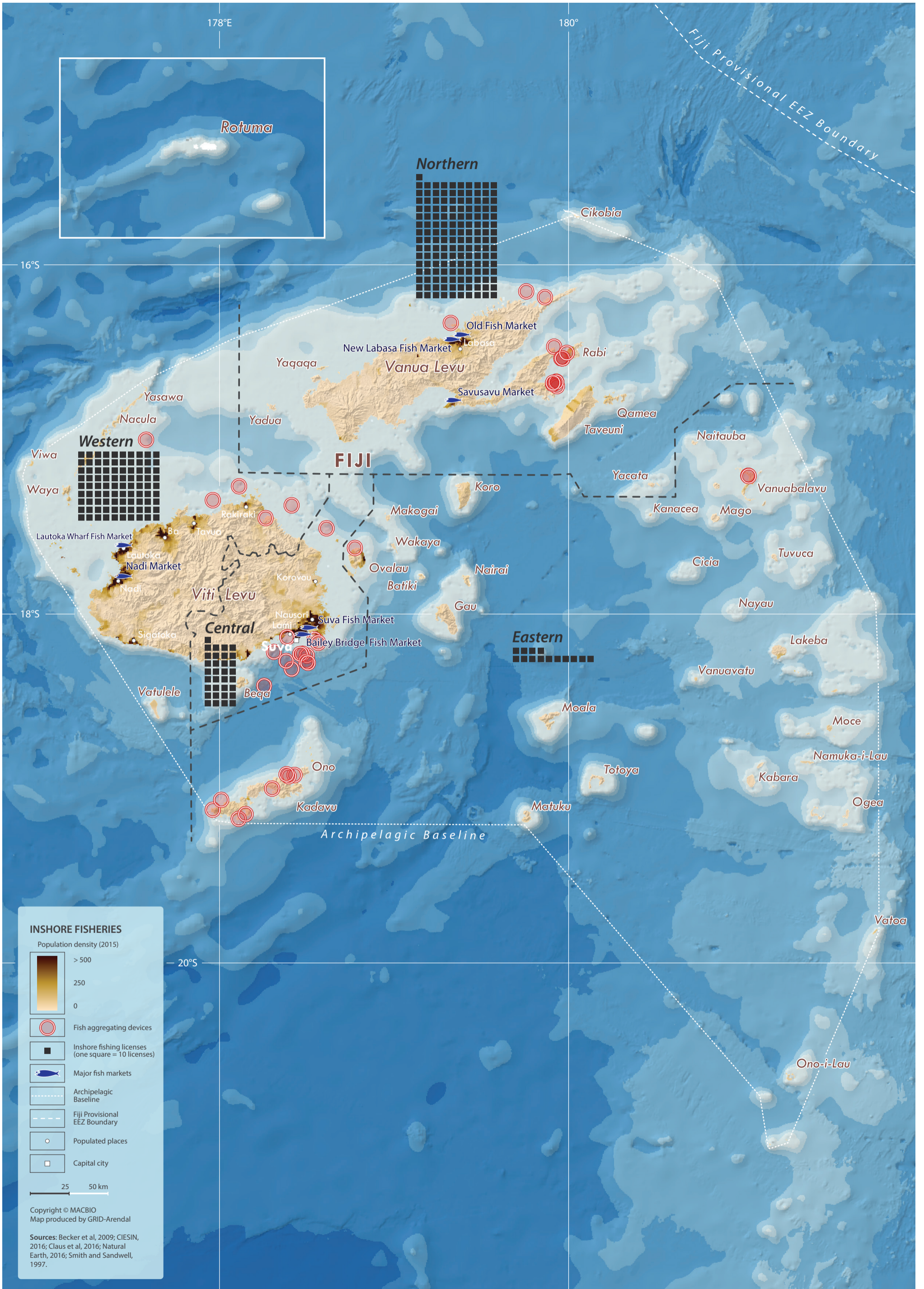


species, using available fisheries and oceanographic data. Depth was the most influential predictor and there were strong regional patterns in the modelled distributions of snapper. Seamount features are recognized as important habitats for deepwater snappers. If there are resident populations of fish on seamounts, it can make them vulnerable to localized overfishing, as well as detrimental impacts from deep-sea mining (Clark et al., 2016). Improved knowledge of stock structure, and the degree of seamount-affinity, are issues of major relevance to management. The likelihood of restricted distribu-

tions 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.

Fiji’s offshore fisheries are evidently important, providing economic benefits, employment and food additional to that provided by its valuable inshore fisheries. In order to maintain these values for generations of Fijians to come, MSP and evidence-based, sustainable fisheries management is crucial to preventing us from fishing in the dark.





# SMALL FISH, BIG IMPORTANCE: INSHORE FISHERIES

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

Almost all of Fiji's 1.3 million km<sup>2</sup> of marine water is classed as offshore (98 per cent), as opposed to inshore (2 per cent) (see also chapter "Fiji's commitment to marine conservation"). It would therefore be easy to assume that most of Fiji'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 as outlined below (see also chapter "Fishing in the dark").

Fiji'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 Fiji, coral reef fishery occurs in a nearshore area of around 6,700 km<sup>2</sup> only. In Viti Levu, an estimated 45 per cent of rural households live less than 5 kilometres from the coast, with 99.3 per cent of the total population consuming marine products at least once a week. The map shows how population density is concentrated along the coast, especially in the north-west and south-east of Viti Levu and around Labasa and Savusavu on Vanua Levu. High coastal population density means a high pressure on marine resources for subsistence. The available information indicates that the inshore and nearshore finfish and invertebrates in many coastal areas of Fiji are overexploited. Such a threat to subsistence fisheries is a major concern in terms of the fishery's ability to meet Fiji's nutritional and food security needs.

There are also commercial fisheries operating within Fiji's waters that fish for marine products to sell in markets for profit. These fisheries occur both inshore and offshore. Large-scale commercial offshore fisheries in Fiji primarily focus on tuna (see previous chapter), while small-scale commercial inshore fisheries (artisanal fishing) are more diverse. Commercial fishing in Fiji requires a fishing licence. The map and the table show the inshore fishing licences issued in 2014, with a majority in the Western and Northern Division.

## Division Inshore Fishing Licenses

Eastern .....	144
Central .....	331
Western .....	903
Northern .....	1509

Small-scale commercial fishing can be divided into fishing for local markets or fishing for export. As the map shows, the main fish markets in Fiji are close to urban centres. The Great Sea Reef (see also chapter "Shaping Pacific Islands") along the north of Vanua Levu provides fish for a large part of Fiji, including the capital Suva, and is thus called the "seafood basket" of Fiji.

Production of artisanal fishing based on market surveys collected by divisions are not currently compiled in Fiji on a national level due to resource constraints. However, the information available indicates that inshore and nearshore finfish and invertebrates are overexploited in many areas of Fiji. The decline in artisanal fishing in general has been attributed to overexploitation, destruction of habitats and pollution.

One example of such overexploitation is the sea cucumber, or *bêche-de-mer*, fishery. Nationally, the sea cucumber (live or unprocessed) fishery is Fiji's second most important commercial fishery after tuna, and has been operating intermittently for 200 years. From 2003 to 2012, the annual volume and value of sea cucumber production varied significantly, from a low of 130 tons in 2009 to a peak of 340 tons in 2005, giving an annual gross value of FJ\$5.5 million and FJ\$17 million respectively. This demonstrates a typical boom-and-bust cycle, evident even within a short period of time. In response to this, the Fijian Ministry of Fisheries introduced a ban on commercial sea cucumber fisheries in 2017.

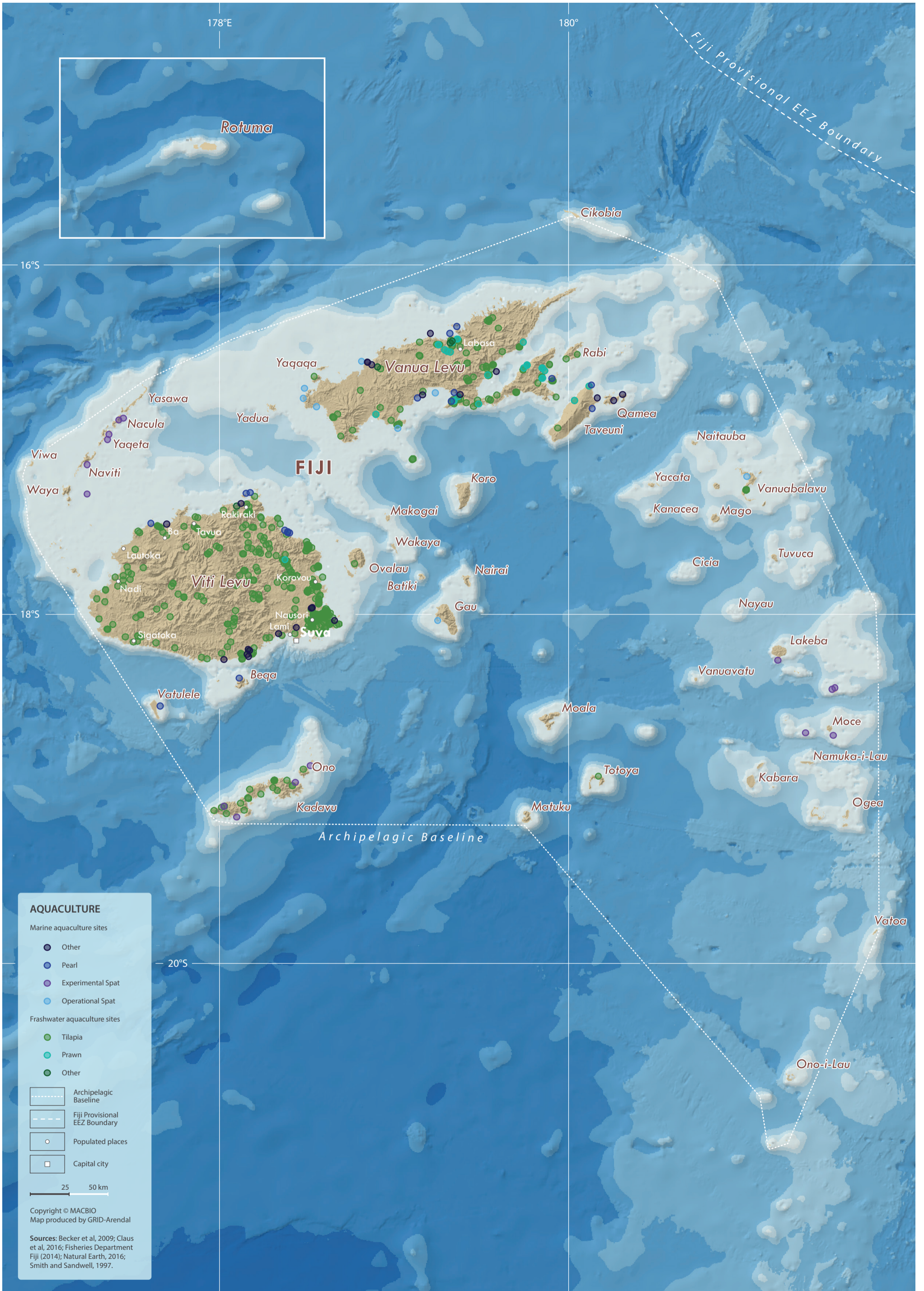
To address the country's fish availability, Fiji is adopting different management strategies. One such strategy is the placement of nearshore-anchored fish aggregating devices (FADs; see map) beyond reefs, which will give communities greater access to offshore species, such as tuna. This effort aims to improve local food security and livelihoods, reduce fishing pressure on vital reef fisheries and increase community resilience to tropical cyclones and climate change (see also chapters "Hotter and higher" and "Stormy times").

The importance of sustainably managing Fiji's offshore fisheries, as well as its valuable inshore fisheries is becoming increasingly apparent. Subsistence food provision from inshore fisheries and coastal resources has been valued at a total national gross value of FJ\$59 million (US\$30 million) per year, while small-scale inshore commercial fisheries produce a total value of up to FJ\$54 million (US\$27 million) per year.

The combined inshore fisheries value of FJ\$113 million per year dwarfs commercial offshore tuna fisheries considerably, which are worth around FJ\$20 million (US\$10 million) per year (see graphic and previous chapter), proving that small inshore fisheries have a big importance for Fiji.



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



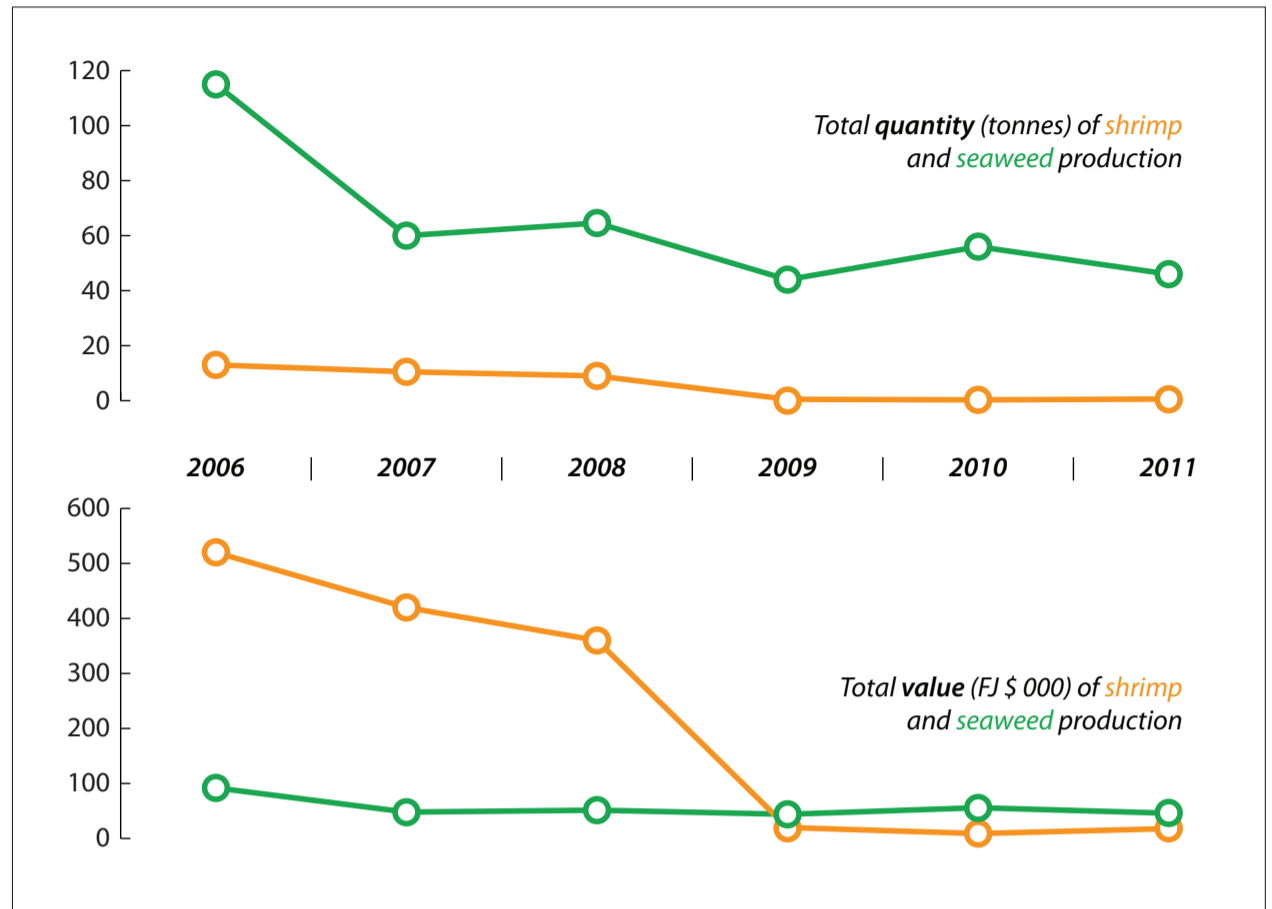
# FISH FROM THE FARM: AQUACULTURE

Aquaculture has faced many challenges in Fiji over the years. Although successful fish farms do exist, Fiji's aquaculture is declining and needs to be carefully assessed and supported to add true value.

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). Farmed fish is growing in popularity in Fiji, with the local consumer increasingly preferring tilapia and prawns. However, various species have been grown in Fijian aquaculture, including carp (grass and silver), milkfish, seaweed, pearl oysters, clams, trochus and sea cucumbers. Research is currently being done to determine whether other fish species found in Fiji's waters can also be farmed. Furthermore, there Fiji has an aquarium trade market, for which corals and other ornamental species are grown in aquaculture.

With 70 times more ocean than land, the question arises as to why Fiji needs to farm fish. As is the case with all global fisheries, wild fish stocks are declining in Fiji's waters, while the demand for fish protein continues to grow. Given the inevitable effects of climate change and other human factors on fisheries, aquaculture has been identified as a means to enhance Fiji's economy and help achieve food security. Aquaculture was first introduced to Fiji in 1953, with tilapia grown as a source of protein for pig farms. Production was later expanded by the Department of Fisheries in 1967. Aside from food, Fiji is known for its unique pearls, which is the country's most lucrative aquaculture product and contributes significantly to its economy. In addition, seaweed production is found in some coastal areas.

However, aquaculture has not always been as successful as hoped. There are many reports of failed aquaculture ventures of different species and at different scales of operation. A common thread in unsuccessful aquaculture ventures is the lack of technical support. In many cases, projects are started at community levels with little or no follow-up from the establishing bodies, resulting in a growing list of short-lived schemes. Farm operators are often not adequately trained to make informed farm management decisions.



Production costs are another factor commonly seen to reduce the success of aquaculture in Fiji. For example, feed can make up to 30 per cent of total production costs on tilapia farms. In attempts to reduce cost, farmers may compromise the quality of their product, resulting in farm failure. Regardless of the reason for failure, aquaculture production has been declining over the past decade (see graphic).

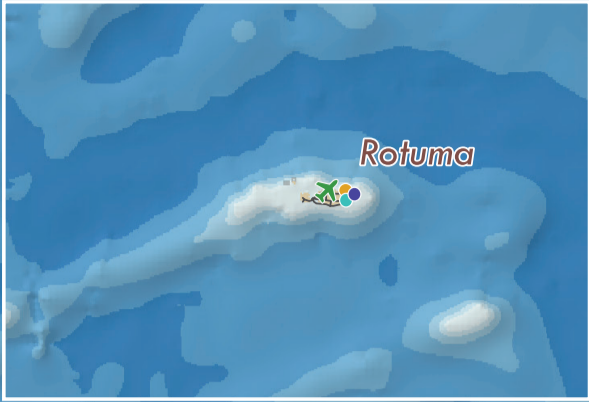
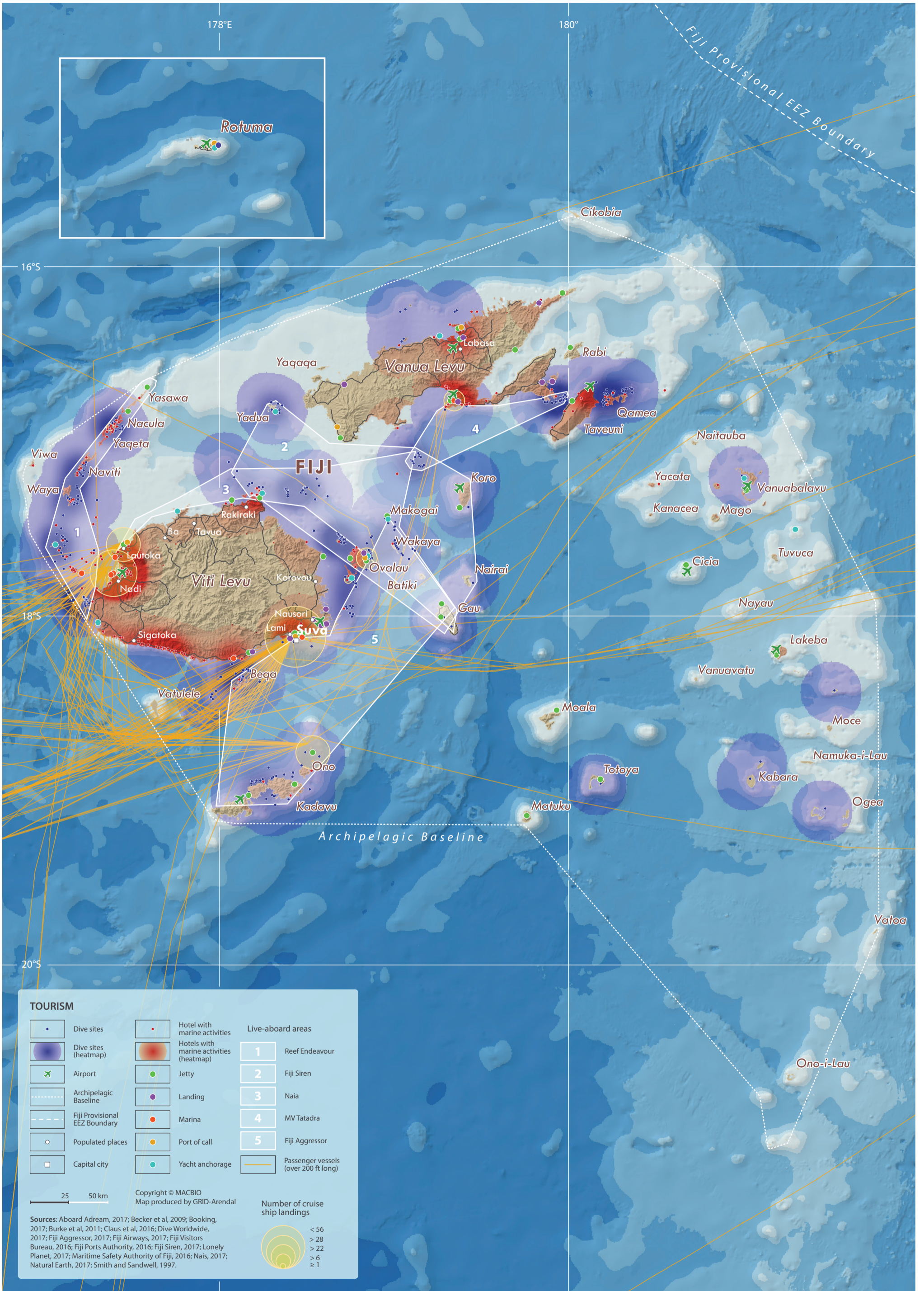
Aquaculture can have negative impacts on Fiji's marine ecosystem, including pressure on wild fish used for fish feed, escape of introduced aquaculture species, interbreeding of farmed fish with wild fish, pollution and habitat loss. For example, mangroves are cut to develop shrimp farms, resulting

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.

The current distribution of most of the fresh and saltwater aquaculture activities throughout Fiji is shown on this map. Pearl and mabe (half pearl) farms are mostly found in the coastal regions of Fiji's Northern Division. The production of oyster spat is currently widespread, though most spat farms are experimental in order to determine whether regular production can be established in these locations. Viable spat farms will then supply larger pearl farms. Other mariculture activities included on the map are seaweed and crab production on Viti Levu. The Fiji Crab Company operates two commercial farms, producing mud crabs and marine prawns. Throughout the country, there are also several small-scale freshwater farms for tilapia and freshwater prawns.

There is potential to expand mariculture and freshwater aquaculture in parts of Fiji with abundant freshwater. However, careful assessments and strategic technical and financial support is required to increase the benefits for Fiji and successfully supply farmed fish.





**TOURISM**

	Dive sites		Hotel with marine activities		Reef Endeavour
	Dive sites (heatmap)		Hotels with marine activities (heatmap)		Fiji Siren
	Airport		Jetty		Naia
	Archipelagic Baseline		Landing		MV Tatadra
	Fiji Provisional EEZ Boundary		Marina		Fiji Aggressor
	Populated places		Port of call		Passenger vessels (over 200 ft long)
	Capital city		Yacht anchorage		

Copyright © MACBIO  
Map produced by GRID-Arendal

Number of cruise ship landings

	< 56
	> 28
	> 22
	> 6
	≥ 1

Scale: 25 km, 50 km

Sources: Aboard Adream, 2017; Becker et al, 2009; Booking, 2017; Burke et al, 2011; Claus et al, 2016; Dive Worldwide, 2017; Fiji Aggressor, 2017; Fiji Airways, 2017; Fiji Visitors Bureau, 2016; Fiji Ports Authority, 2016; Fiji Siren, 2017; Lonely Planet, 2017; Maritime Safety Authority of Fiji, 2016; Nais, 2017; Natural Earth, 2017; Smith and Sandwell, 1997.

# BEYOND THE BEACH: MARINE TOURISM

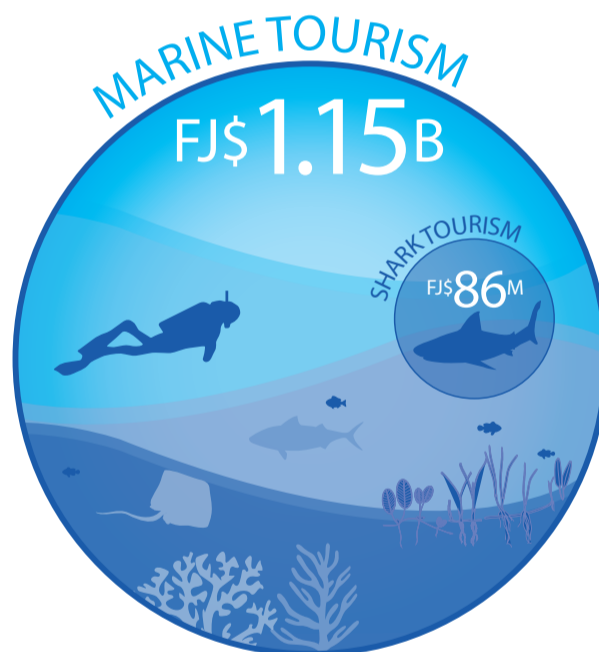
Fiji's diverse and growing marine tourism sector is worth billions to the economy. It requires careful management if it is to complement rather than endanger the very ecosystems it relies on.



Humphead parrotfish can grow to 1.3 metres and are one of the many underwater tourist attractions in Fiji.

“Where happiness finds you” is Fiji’s tourism slogan, which attracted more than 750,000 international visitors in 2015, as well as many domestic tourists. Visitors to the country are not only looking for happiness, but also the opportunity to explore the marine and coastal ecosystems beyond its sandy beaches. Fiji’s coral reefs, coastlines, sparkling blue waters and shoreline mangrove forests offer beautiful views and spaces for leisure. Tourists engage in countless activities in marine ecosystems, such as diving, snorkelling, swimming, jet-skiing, surfing, parasailing, water skiing, stand-up paddling, game fishing, cruising and yachting (see pie chart).

Visitors mainly arrive through Fiji’s two international airports at Nadi and Suva, though there are also airports on many of the smaller islands, as shown on the map. Cruise ships, ferries and yachts move tourists through Fiji’s waters, with major cruise ship ports located in Suva, Nadi and Lautoka. Popular yacht anchorages are found in the Yasawas, the Lau group and around Savusavu, and there are many jetties, marinas and landings throughout Fiji’s islands. Dive boats go



out to countless, world-class dive sites concentrated around the Rainbow Reef between Taveuni and Vanua Levu, the Yasawas and the Vatu-i-Ra seascape, east of Viti Levu. Some operators offer tourists the opportunity to live aboard their dive boats, allowing them to cover large areas around the main islands.

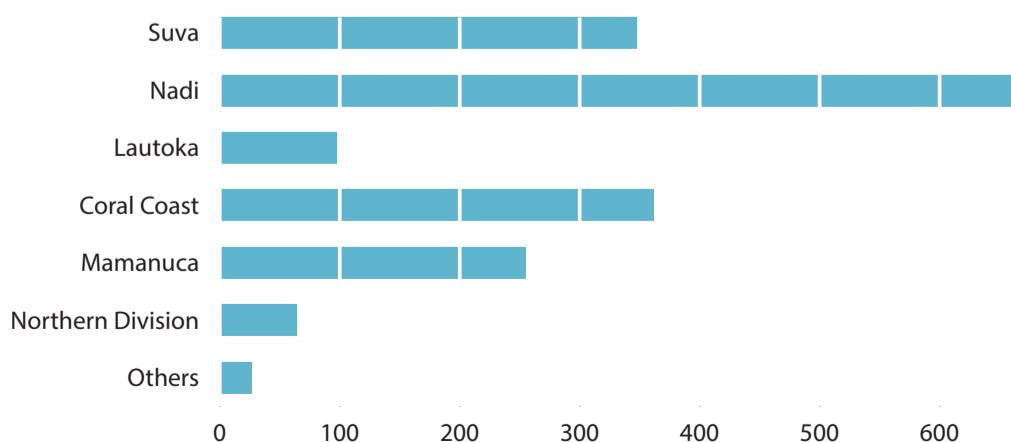
Most tourism facilities are found on Viti Levu, particularly along the Coral Coast, an 80-kilometre stretch between the capital Suva and Nadi—the main tourist town (see bar chart). The Coral Coast is named for the extensive fringing coral reef found along this coastline. There are also numerous hotels in and around Nadi and on the islands to the west and north. A smaller number of tourist facilities are found on Vanua Levu, Kadavu, Ovalau, Rotuma and Taveuni.

Marine tourism is therefore an important sector for Fiji’s economy, accounting for a total gross value of FJ\$1.15 billion (US\$574 million) per year and 41,500 jobs in 2014 (12.3 per cent of total jobs). Shark tourism alone was worth FJ\$86 million per year, coral reefs and lagoons, FJ\$917 million per year and mangroves FJ\$459 million per year, while yachting brought in FJ\$30 million per year (see also chapter “Home, sweet home”).

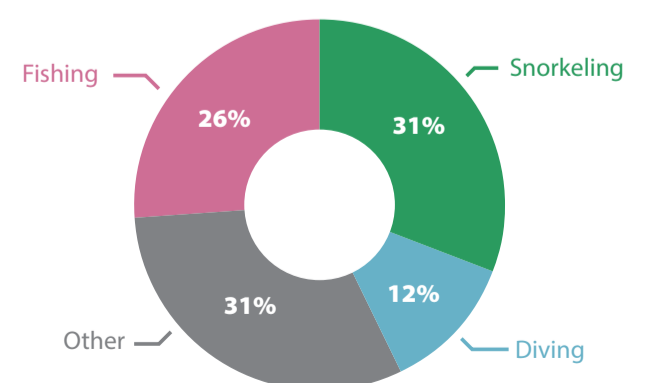
However, Fiji does not currently retain the full value of marine tourism and much leaks out of the country as revenue expatriated to foreign hotels and tourism operators and suppliers of imported goods for resorts and hotels. Conflict between tourist activities and local fishing on traditional fishing grounds (see also chapter “Space to recover”) is another issue, particularly on Tavarua Island and in Solevu (Malolo Island) and Nabila (Viti Levu Island). Due to the fast growth of the sector, it is becoming increasingly challenging for Fiji to maintain the state of its natural resources on which its tourism relies. Issues include pollution, overexploitation and habitat degradation, and loss of coral reefs, mangroves and other coastal ecosystems; many of these issues are on the verge of causing irreversible environmental damage.

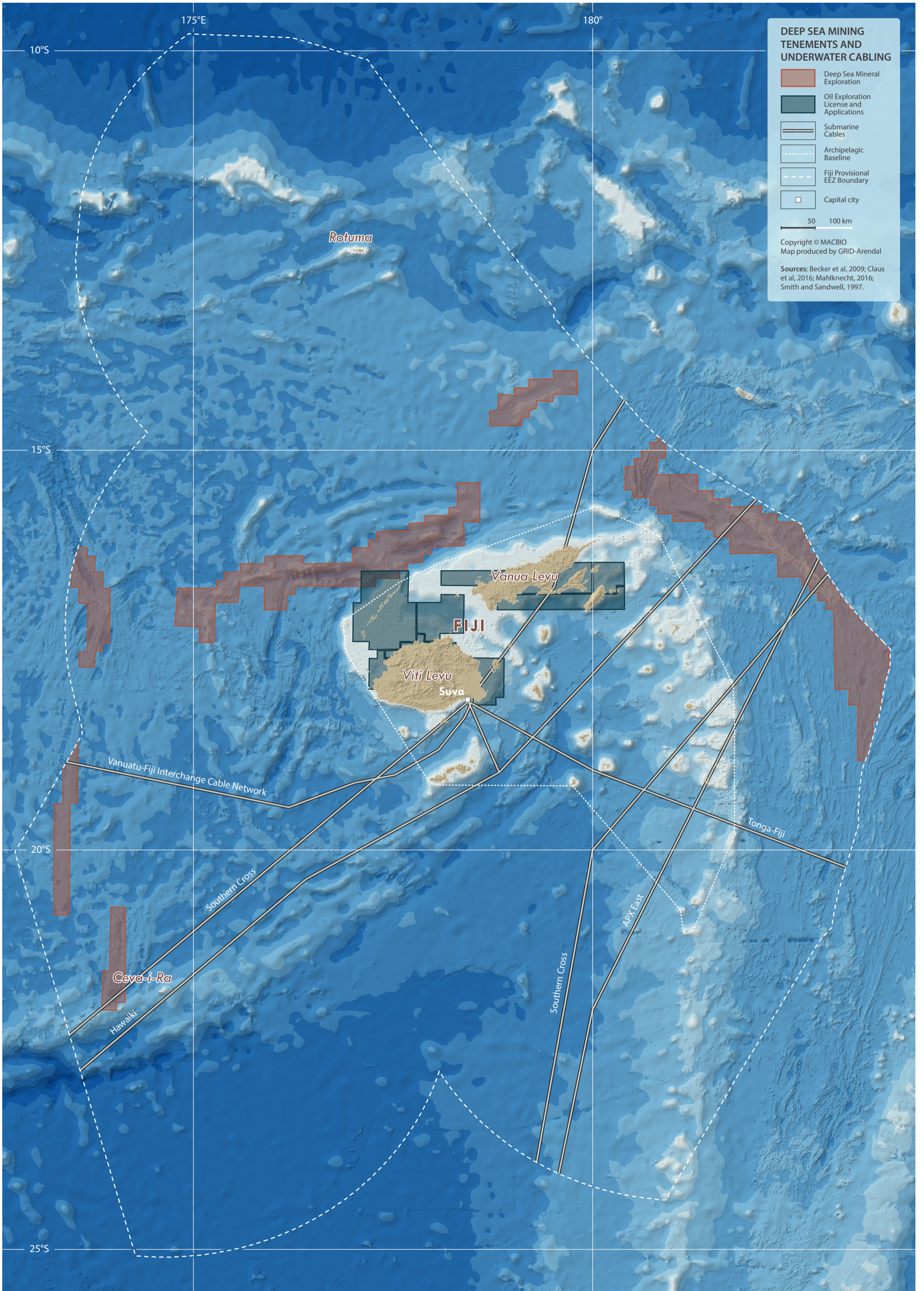
In light of this, the Tourism Development Plan 2007–2016 strongly emphasizes the need for sustainable tourism and to address issues related to social and environmental aspects of tourism. Managers of tourism operations should therefore aim to add value to the environment, communities, entrepreneurs and tourists on which they rely. Promoting small-scale, eco-friendly, village-based tourism can provide rural Fijians with opportunities to participate in the cash economy, while maintaining the country’s valuable marine and coastal ecosystems.

Room nights sold by region (in thousands '000) (2016)



Marine activities offered by hotels



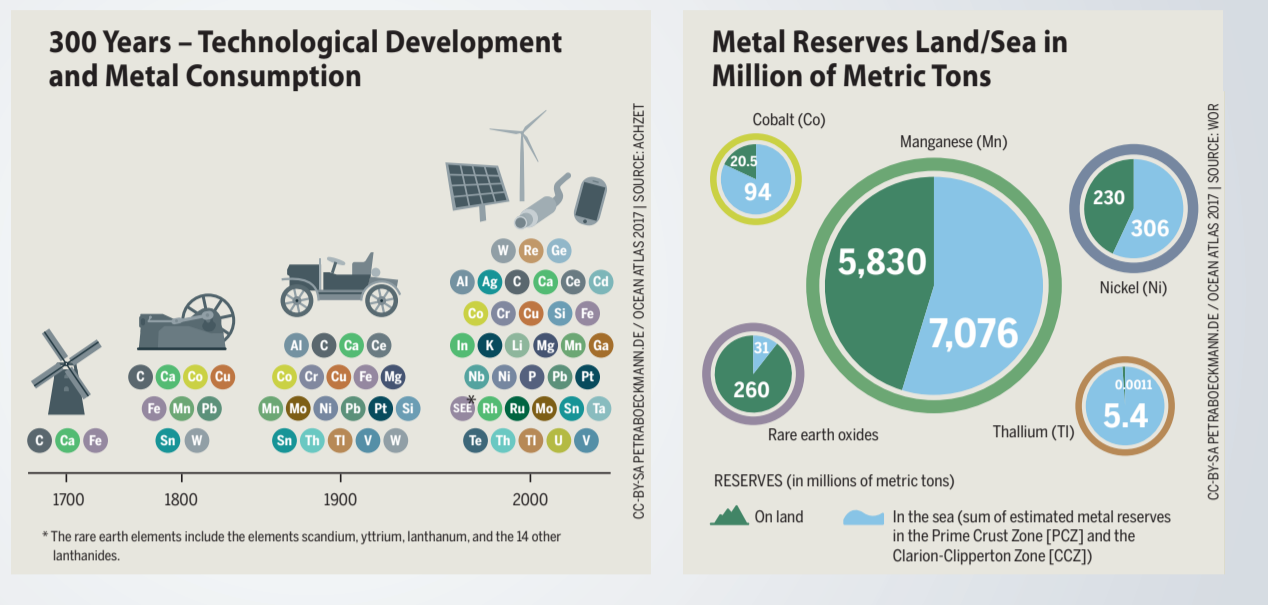


# UNDER WATER WILD WEST: DEEP-SEA MINING AND UNDER WATER CABLING

Fiji's sea and coasts are rich with deep-sea minerals, petroleum, sand and gravel, and support underwater cabling. These all need to be sustainably managed and balanced with other overlapping values and uses.

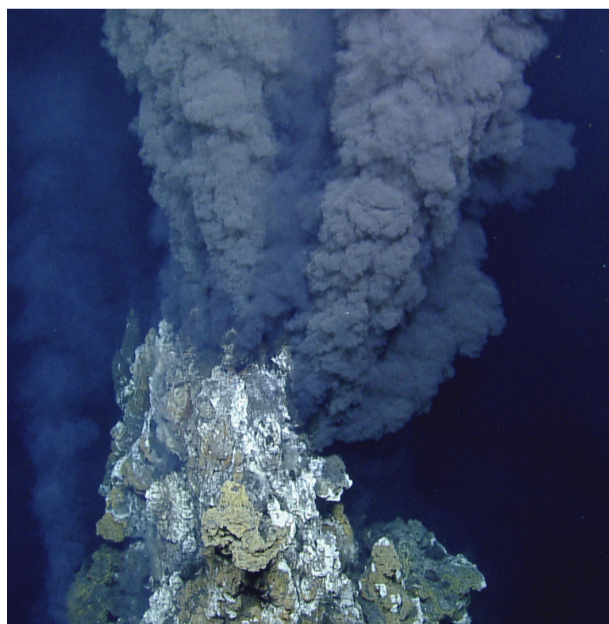
## Gold rush

Is Fiji 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 Fiji's land may be rich in sun and ample sugar cane fields, gold is much scarcer. Instead, Fiji'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).



In Fiji, mining interest in the ocean includes the potential sulfide and sulfate minerals that contain metals, including copper, lead, zinc, gold and silver. Hydrothermal vents concentrate and deposit these minerals (see also chapter “Smoke underwater, fire in the sea”) as sea-floor massive sulfides. As shown on the map, sea-floor massive sulfides in the North Fiji Basin, an intra-oceanic back-arc basin, are located along a spreading ridge.

But Fiji is still waiting for its gold rush. In 2013, the Mineral Resources Department issued 17 deep-sea mineral licences for mining companies to explore the seabed for mineral deposits and to collect samples to estimate their magnitude. These were granted to the Korean Institute of Ocean Science and Technology (KIOST, formerly KORDI), Nautilus Minerals and Bluewater Minerals. Most of these licences have expired and currently there are only three licences active, all held by KIOST (Mineral Resources Department, pers. comm.). The Government of Fiji is currently reviewing their Mining Act and draft policy on deep-sea minerals. Although deep-sea mineral extraction costs are still unknown and there are no estimates on the value of seabed mineral deposits in Fiji's EEZ, the government has established exploration fees, resulting in an estimated annual value of deep-sea mining in Fiji of FJ\$1.5 million per year (Gonzalez, 2015).



Hydrothermal vent deposits.

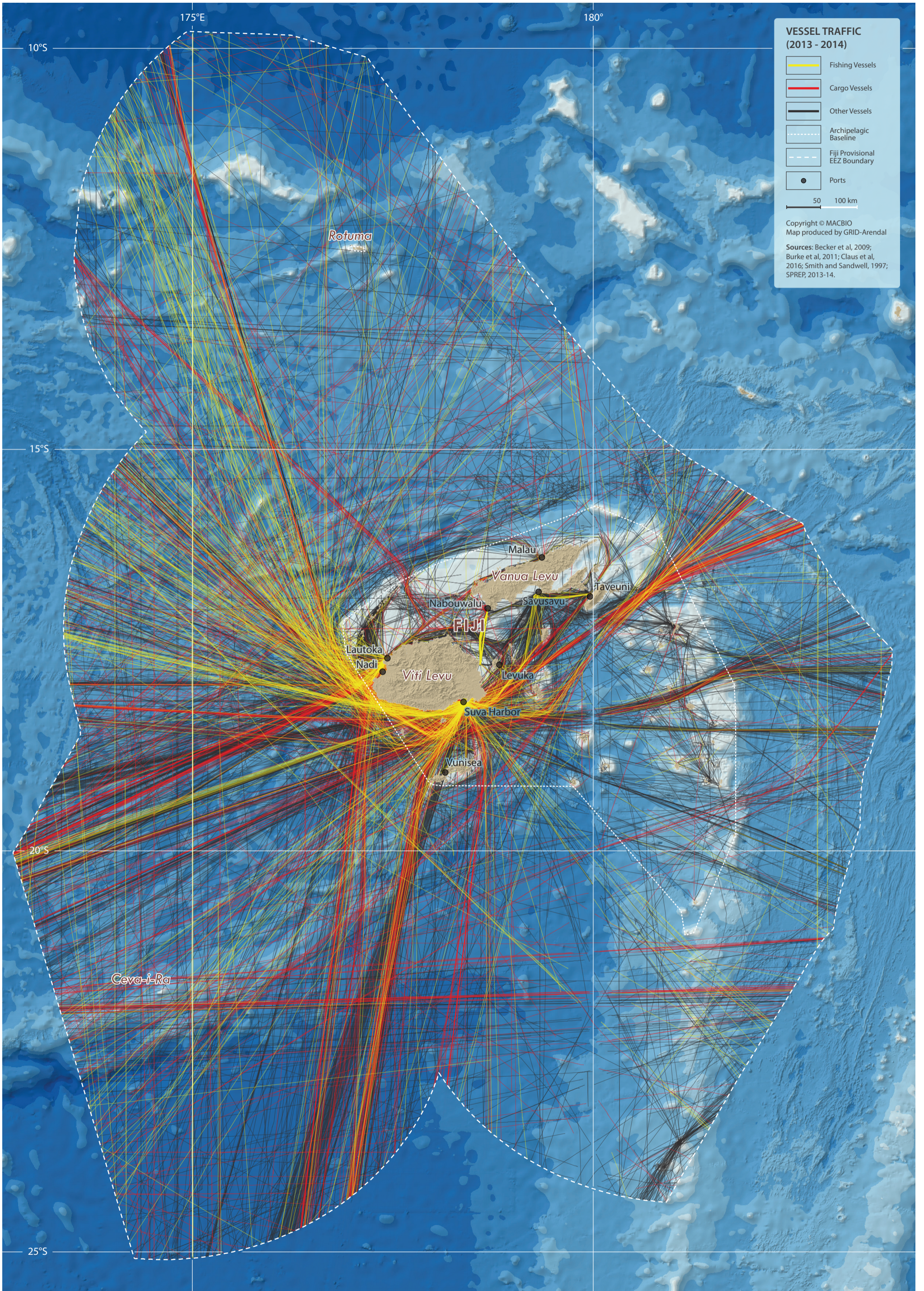
Exploration activities are not only limited to Fiji's metals, but also extend to petroleum, with several petroleum exploration licences having been issued in the past. However, these licences are currently inactive (Mineral Resources Department, pers. comm.). Petroleum exploration was most active in the 1970s to mid-1980s, during which time more than 14,000 kilometres of seismic data were collected and seven exploration wells were drilled (Rodd, 1993). Two tertiary sedimentary basins have been identified as potentially containing hydrocarbons: the Bligh Water Basin (located between Viti Levu and the Great Sea Reef), which has a sediment thicknesses of more than 5 kilometres, and the Bau Waters Basin (between Viti Levu Vanua Levu), where there is a potential area with sediments up to 4 kilometres thick (Rodd, 1993).

Given that neither metals nor petroleum are currently exploited in Fiji, it seems more fitting to term the “gold rush” as a “sand rush”, since roughly FJ\$1.5 million worth of aggregates (gravel and sand) are extracted per year. These come from rivers and coastal zones and are used in construction and as an ingredient for cement production.

In addition to resource exploration, Fiji's ocean floor is used as a well-established submarine cable hub with connections to several cable networks. The FINTEL (Fiji International Telecommunications Limited) cable landing station in Suva operates the international telecommunications into and out of Fiji. In shallow waters, the fibre-optic cables are generally thicker and laid beneath the sea floor for protection. At the shoreward end of the cable, where it crosses the intertidal zone, piping connects the cables, which are bolted to the substrate. In deeper waters, thinner cables are laid on the sea floor. The Southern Cross trans-Pacific network is the largest network and has an access point in Suva, which connects cable segments G1 to Australia and G2 to the United States (Hawaii). There is also an 826-kilometre segment to Tonga, a 1,230-kilometre segment (the Vanuatu–Fiji Interchange) to Vanuatu and a 1,470-kilometre segment to Samoa, all of which link to the Southern Cross network via the Suva access point. A branch of the Hawaiki cable network connects Fiji to the

Australia-New Zealand-United States trans-Pacific cable. The APX-East cable between Australia and the United States traverses Fiji's EEZ, as does the direct New Zealand-Hawaii segment of the Southern Cross network.

These different and overlapping uses clearly need to be well planned and managed. Since 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 raising questions about its environmental impacts. 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.



# THREATS

## FULL SPEED AHEAD: VESSEL TRAFFIC

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

### Shipwrecked

On May 6 2017, local fishers came across shipping containers that had fallen off the 90-metre cargo vessel MV Southern Phoenix which had capsized in the port (see picture). The Phoenix is one example of a shipwreck occurring in Suva harbour and Fiji's waters, which are highly frequented by countless domestic and international vessels. Given that these vessels are the lifeline of Fiji's central and remote islands, spatial planning crucial for navigation at sea.



Ships coming in and out of Fijian ports, from fishing vessels to cargo vessels, cruise ships and ferries, serve many different purposes. Fiji has about 2,000 registered ships that are less than 15 metres in length and about 250 that are more than 15 metres in length (see table). 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 the Port of Suva, though there are several other ports for transporting bulk goods, including sugar, molasses, wood products, petroleum and gas. The main commercial shipping routes include other Pacific Island countries, Australia and New Zealand, and destinations in Asia and North America. Cruise ships have been visiting Fiji since the 1990s, which has steadily increased over the following decades. In 2014, 88,000 cruise ship visitors arrived in Fiji. Many yachts also cruise Fiji's waters (see also chapter "Beyond the beach").

Fiji Ports Corporation Ltd, a government-owned company, manages Fiji's major ports. The coun-

try has two main ports, Suva and Lautoka, and several secondary ports in Levuka, Vuda, Malau, Rotuma and Wairiki. The Port of Suva, located in Suva Bay, is the largest and busiest port in Fiji. The Port of Lautoka, which is situated on Vitu Levu to the north of Nadi, is Fiji's largest port for handling bulk cargo, specifically bulk sugar, molasses, woodchips, petroleum and gas, and also serves as a base for cruise tourism. The Port of Levuka on Ovalau, Fiji's sixth largest island, is mainly a fishing port, while the Port of Malau, located on the north-western side of Vanua Levu, serves as a smaller bulk port, primarily for molasses. On the opposite side of Vanua Levu in the south-east is the Port of Wairiki, which services the logging industry, primarily as a woodchip port. The Port of Vuda is first and foremost a marina, largely used by the yachting community. The Port of Rotuma on the northern Fijian island of Rotuma is a minor port, established to facilitate trade between the island and other part of Fiji, as well as other island countries.

From the map of different types of vessels criss-crossing Fiji's waters, it is clear that MSP is key

not only for navigational safety, but also to minimize conflicts with Fiji'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 Fiji's fossil fuel dependence, more sustainable forms of sea transport are being explored. As a seafaring nation, Fijians can look to their ancestors, who were advanced sailors following the stars in their traditional wind-powered druas, for solutions.

Fiji Registered Ships Data, 2017

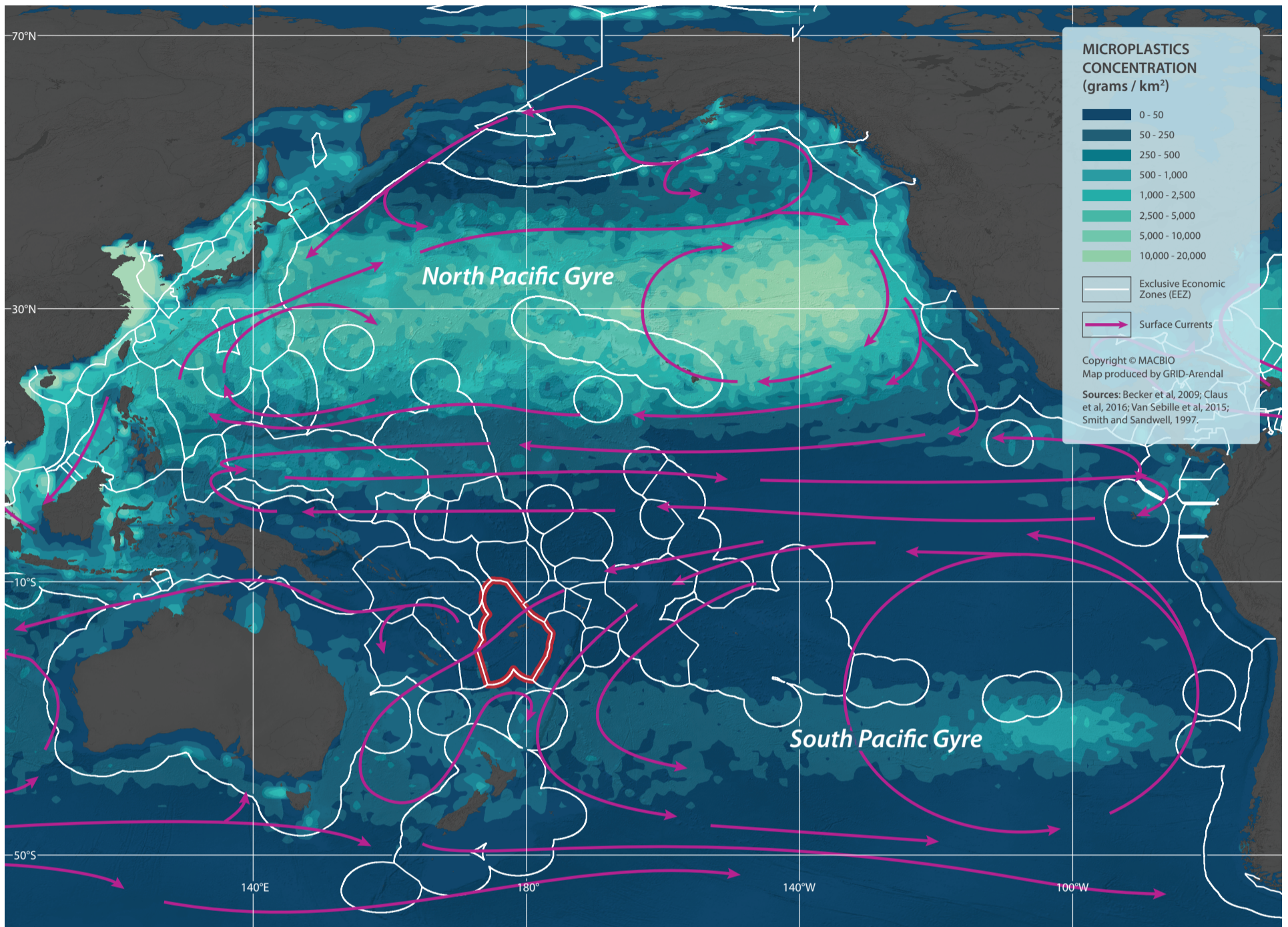
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1	Cargo	2
5	Dregder	9
391	Fishing	114
4	Lines Boat	0
14	Medical	0
985	Passengers	38
4	Pilot Boat	3
72	Pleasure Craft	3
16	Police Vessel	1
4	Private Use	0
9	Research Boat	0
0	Ro-Ro Ferries	8
366	Tourist	33
9	Tug	15
4	Yachts	0
8	Others	3
<b>1906</b>	<b>Total</b>	<b>256</b>



Tuna longliners in Suva harbour are one example of vessels that cruise Fiji's EEZ.

# PLASTIC OCEAN: MICROPLASTICS CONCENTRATION

Like the rest of the world's oceans, Fiji'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, Fiji's comparably low concentration of microplastic at the ocean surface (see the map) is not necessarily good news.

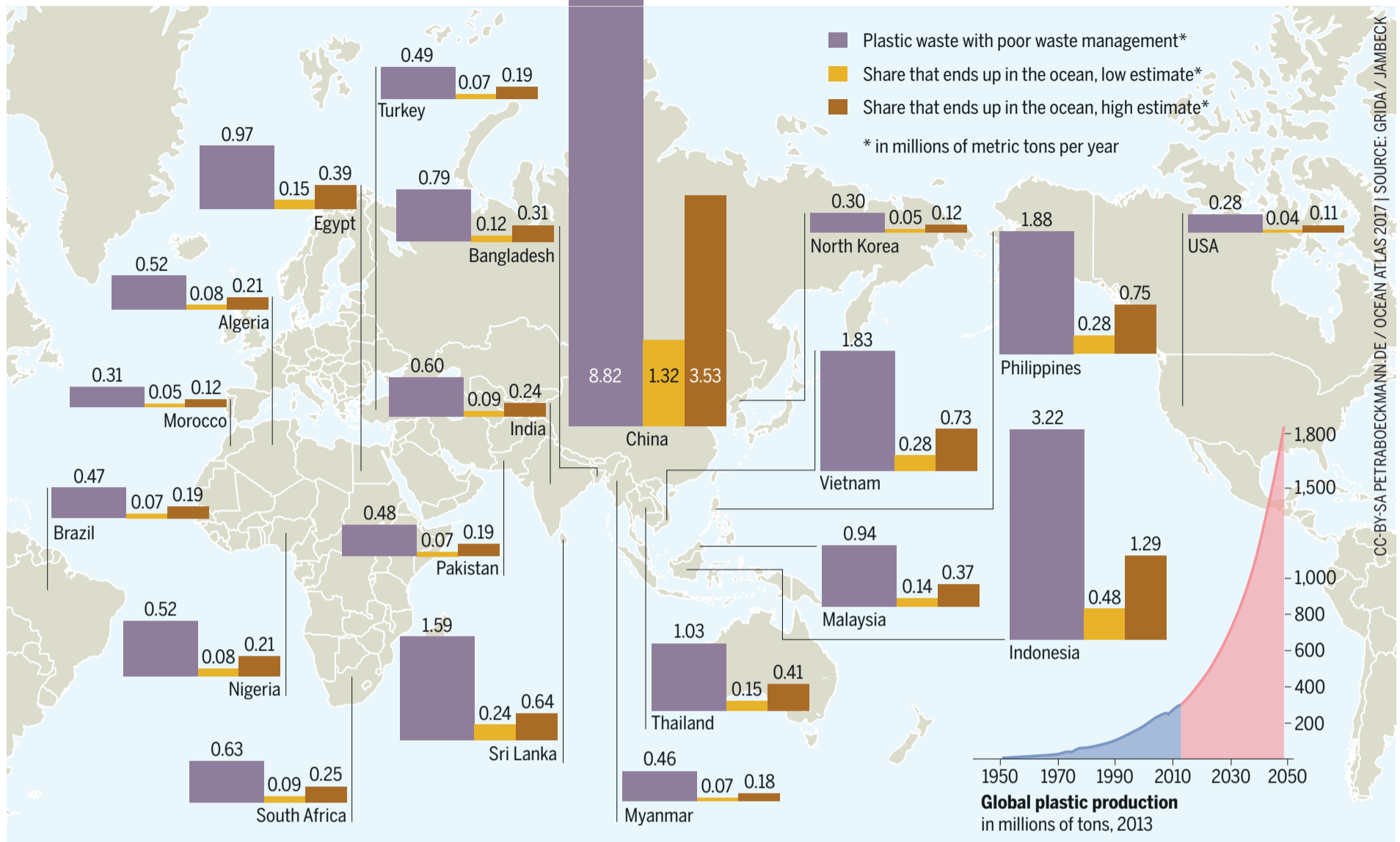
The microplastic is trapped on the ocean floor, embedded in the sediment. It is gradually forming a new geological layer, the "plastic horizon", which

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 consuming 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

## 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?



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- 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.

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 prod-

ucts 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.

Fiji's government has recognized the importance of reducing plastic waste and dedicated two of its Voluntary Commitments to this cause: the Plastic

Pollution Free Fiji Campaign and a levy to reduce plastic shopping bags (see also chapter "A call for ocean action"). As a first step, many Fijians are engaging in coastal cleanup activities, helping keep Fiji'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 Fiji’s coastal ecosystems.

On a global scale, Fiji’s waters have a moderately low phosphate concentration, ranging from 0.15 to 0.28  $\mu\text{mol/L}$ . The highest concentrations are observed in the northern waters and gradually decrease to the south. 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 Fiji’s waters, the nitrate concentration ranges from 0.7 to 1.3  $\text{mmol m}^3$ . The highest concentrations of nitrate in Fiji occur in the south-west, but the South-West Tropical Pacific (SWTP) is generally considered a nitrogen-limited area.

Phosphate and nitrate concentrations are slightly 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 Fiji’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).

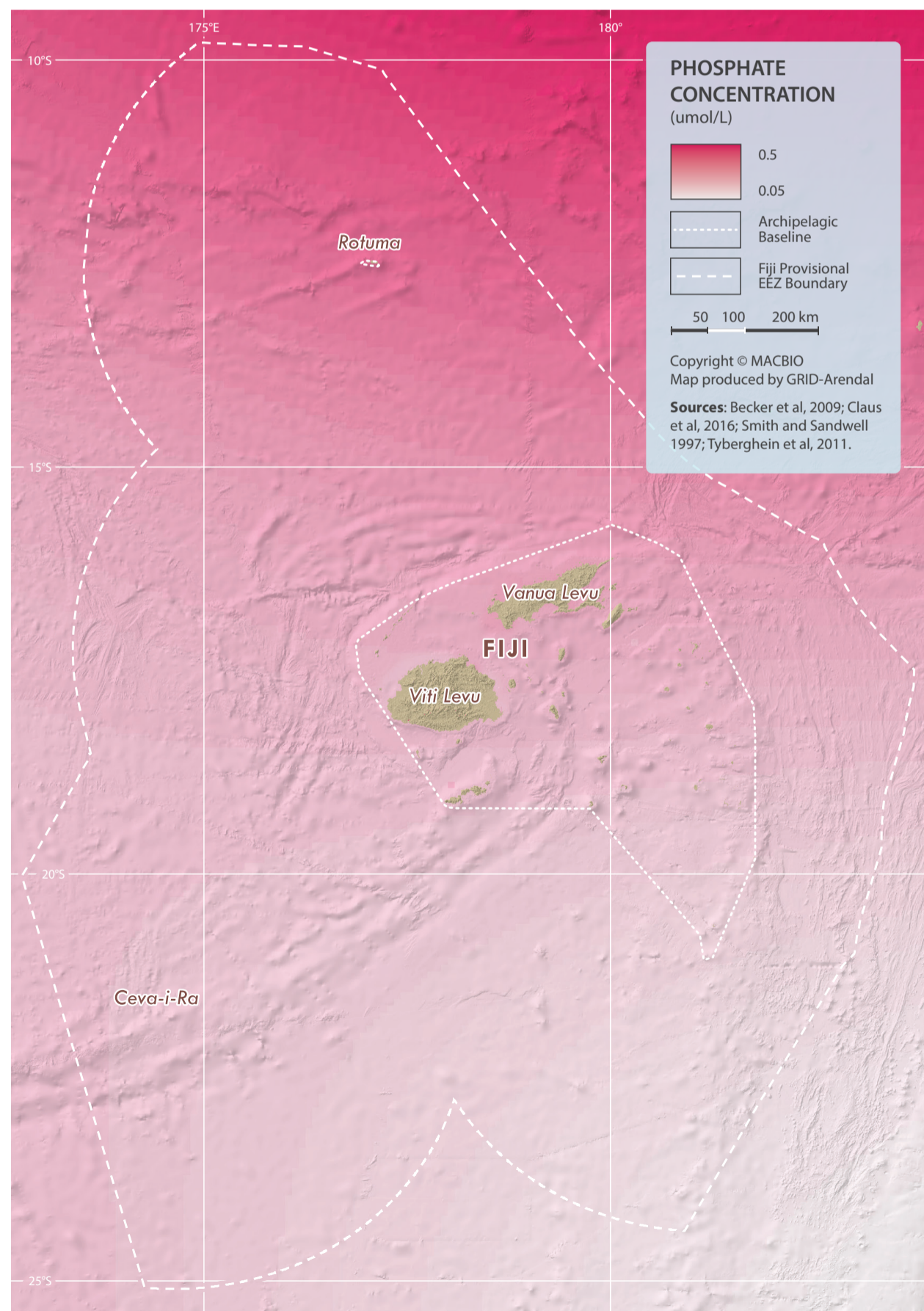
## Seafood

“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. Humans need to eat food to survive, though only in moderation, since too much food can undoubtedly do more harm than good.

Similarly marine organisms need food and nutrients. Phosphate (see map) is one such important nutrient that supports biological activity and is needed for the growth of tiny plants known as phytoplankton, which are the basis of many marine food chains (see also chapter “Soak up the sun”).

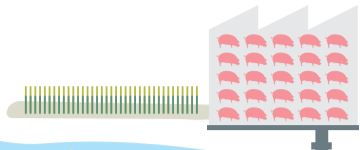
Another food source is nitrogen (see map), which exists in various forms in the marine environment, with nitrate the principal form used by organisms. Phytoplankton productivity at the surface of the ocean is often limited by the amount of available fixed inorganic nitrogen (Falkowski et al., 2009).

As the chapter “Plastic oceans” and “From ridge to reef” as well as the graphic show, excess nutrients are only one type of pollution and threat to Fiji’s marine values. To keep Fiji’s coastal habitats



# TRASH IN THE SURF, POISON IN THE SEA

The mounds of garbage on some coasts pose clearly visible problems. Other types of pollution are less visible – but every bit as serious.



## NITRATES AND PHOSPHATES

**CAUSES:** Industrial agriculture like intensive animal husbandry and intensive crop cultivation.

**EFFECTS AND TRENDS:** Since the 1950s and 1960s agriculture around the world has developed into a massive industry. Discharge of animal manure and artificial fertilizer reach rivers via groundwater and end up in the ocean, resulting in dead zones off the coasts. International agreements attempt to combat these effects by reducing discharges.

## PLASTIC WASTE

**CAUSES:** Only 20 percent of the plastic waste that ends up in the ocean actually comes from the ocean. The other 80 percent comes from dry land, mainly from countries where there is no, or very poor, waste management.

**EFFECTS AND TRENDS:** Five large garbage patches are known. Most garbage, however, lands on coastlines around the world and is thus a global problem. In 2015, for example, 100 cubic meters of plastic waste collected on the coast of Spitsbergen, a remote island halfway between Norway and the North Pole. The mounds of trash grow larger each year.



## CHEMICALS AND HEAVY METALS

**CAUSES:** Industrial wastewater and waste gas, mining, burning heating oil.

**EFFECTS AND TRENDS:** According to the OECD, there are around 100,000 different chemical substances in circulation around the world. They include heavy metals like lead and mercury but also persistent organic pollutants (POP). Many of these substances are highly problematic because they accumulate in the bodies of marine organisms, entering the food chain where they pose a risk to human health.

## RADIOACTIVITY

**CAUSES:** Atomic powers and countries that operate atomic power plants like the USA, Russia, Japan, and several European countries.

**EFFECTS AND TRENDS:** Starting in the 1950s, countries began legally dumping barrels of radioactive waste from nuclear power plants into the ocean. Barrels in the English Channel that should have remained sealed for hundreds of years have already begun leaking. The marine dumping of atomic waste was finally forbidden in 1993. However, the ban only applies to radioactive solids. Expelling radioactive wastewater into the ocean is still permitted and practiced. The Fukushima nuclear catastrophe as well as atomic weapons tests conducted by the great powers have had measurable effects.

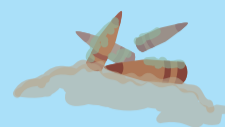


## OIL POLLUTION

**CAUSES:** Wastewater, leaks during oil drilling, regular shipping, illegal tank cleaning, oil spills, and drilling accidents.

**EFFECTS AND TRENDS:** It takes exposed rocky and sandy coasts anywhere from a few months to five years to recover, while sheltered rocky coasts and coral reefs need from two to more than ten years.

Although the rate of extraction is higher than ever, pollution from oil spills has decreased due to stricter maritime transport regulations. On the other hand, the risk of drilling accidents increases the farther we penetrate into the depths.



## NOISE

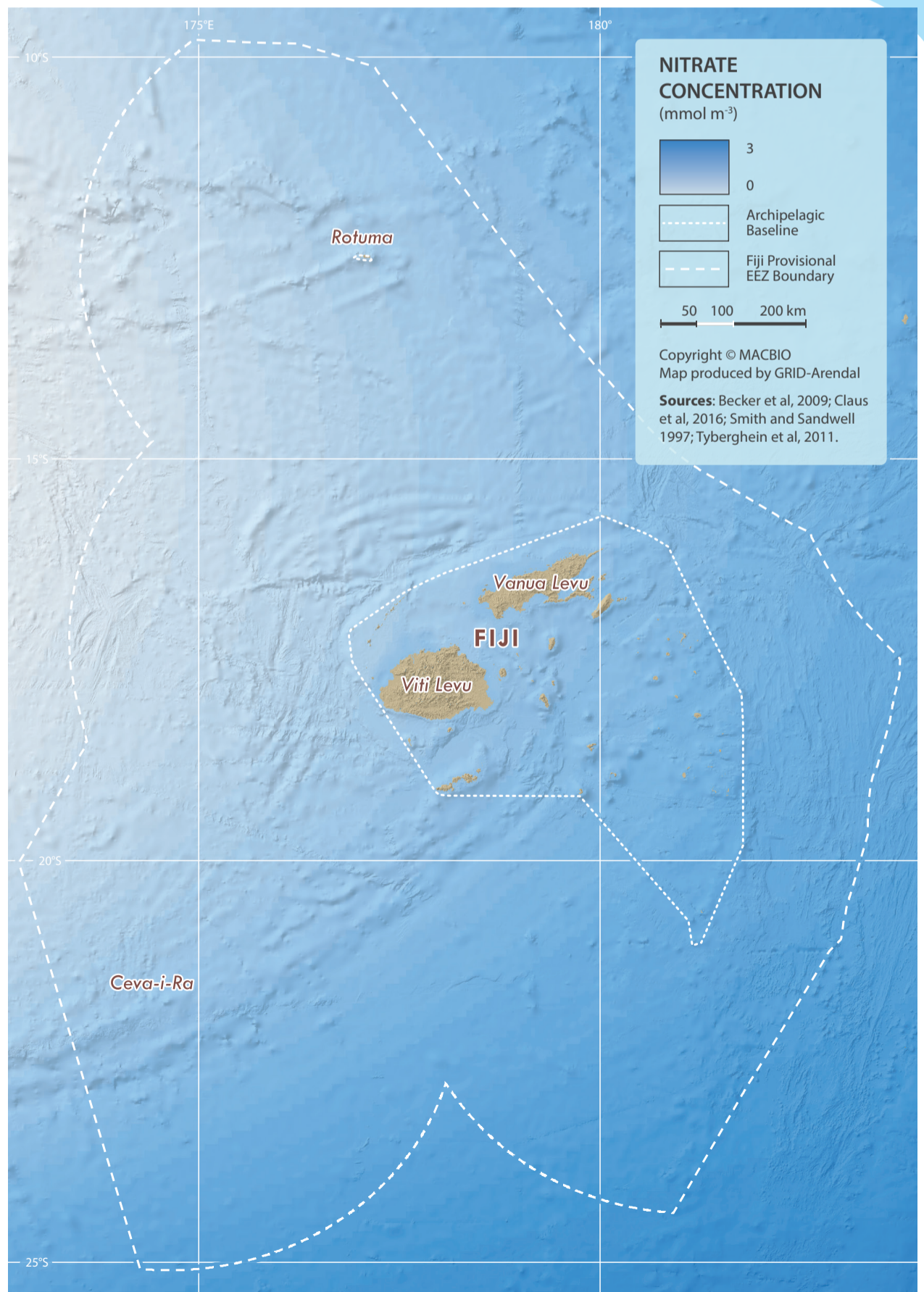
**CAUSES:** Shipping, deep-sea mining, military activities, driving sheet piling for harbors and offshore plants into the seabed, searching for oil and gas reserves with long-range acoustic devices (LRADs), and oil and natural gas extraction.

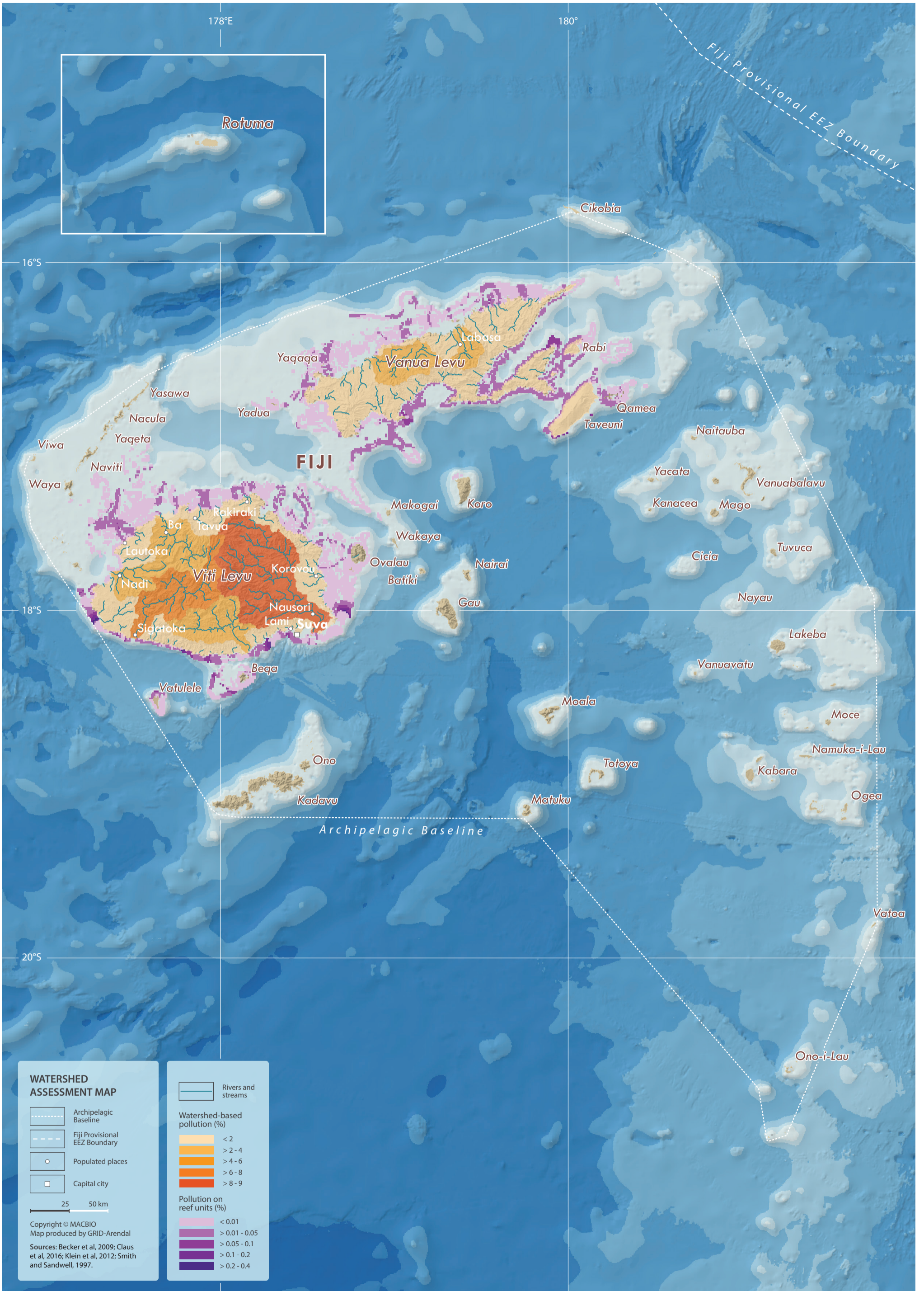
**EFFECTS AND TRENDS:** The amount of noise in the ocean is increasing due to the continually increasing usage of the ocean. Fish and especially marine mammals like whales and dolphins that communicate and navigate with sound are affected. The animals get confused, beach themselves, and perish in shallow water.

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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 Fiji’s waters.*





# FROM RIDGE TO REEF: WATERSHED ASSESSMENT

Healthy reefs depend on clean rivers, which in turn depend on intact healthy catchments. To maintain healthy coastal and marine ecosystems, Fiji must ensure that sustainable management practices are in place from ridge to reef.

As the previous chapters show, everything is connected to the ocean, though this connection does not end at the shore. On the contrary, activities on land have a big influence on adjacent and downstream coastal and marine ecosystems. It is therefore important to follow water from its source to the sea, from ridge to reef. Based on this, the term “watershed” should be used, since this refers to the catchment area where precipitation (rain) collects and drains into a common outlet, such as a river or bay.

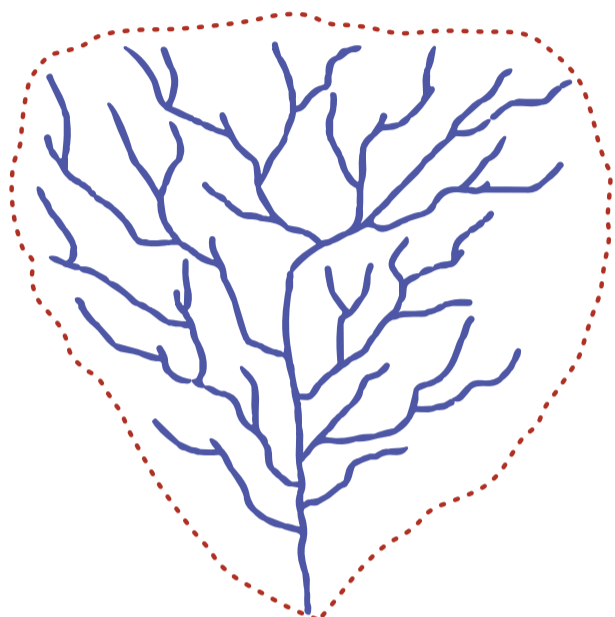


Illustration of a drainage basin. The dashed line is the watershed's main water divide.

Altered watersheds degrade reef and freshwater ecosystems primarily through increasing the amount of sediments and nutrients well beyond natural levels, as shown in the previous chapter. Sediments smother and shade out corals and other invertebrates, while higher levels of nutrients cause an imbalance in ecosystems that often results in blooms of algae. Sedimentation and nutrient-loading are known to reduce fish abundance, species diversity and coral cover in nearshore reef ecosystems. Although corals can survive heavy sedimentation events for short periods, longer-term stress induced by extended periods of low-level sedimentation causes significant damage to reef ecosystems.

In Fiji, agriculture—especially sugarcane farming, cattle grazing and logging—are the major sources of sedimentation and nutrient-loading. Even after logging activities have ended, logging roads continue to bleed sediments for over a decade. Sediments are therefore likely to seep into adjacent marine and freshwater ecosystems, particularly in higher rainfall areas, for long, continuous periods. In addition, the burning of grasslands, also particularly in higher rainfall areas, for cattle grazing or sugar cane plantations, for example, greatly contributes to erosion within watersheds.

The map shows, the percentage of watershed-based pollution and the percentage of pollution affecting reef units. Watershed based pollution is highest in eastern Viti Levu (up to 10 per cent), mainly due to high rainfall and logging. Watershed pollution is generally a reflection of the level of erosion due to biophysical conditions (e.g. soil, rainfall, slope, level of development), with its impact relative to the importance of the adjacent reef systems. Critical watersheds important for reef conservation are mostly found along the northeast coast of Viti Levu (Ra Province), the south-eastern coast of Vanua Levu (Bua Province), and the western and north-central coast of Vanua Levu (Macuata Province). However, all watersheds in Fiji should be well-managed in order to sustain local freshwater and marine fisheries, maintain clean water and reduce flood damage.

To this end, erosion mitigation practices should be implemented in all watersheds. Key actions include closing unused logging roads and their subsequent revegetation, building erosion berms, particularly on stream crossings, and reforesting stream sides. Logging code practices should also be adhered to more strictly, since these intend to prevent logging on slopes and along streams. The Wildlife Conservation Society (WCS) recommends that logging should be entirely prohibited in critical watersheds, particularly those that are adjacent to reefs with high conservation value or that have forests with high conservation value. Watersheds

in southern Bua Province, Macuata Province and Ra Province should remain unlogged. Taveuni and Kadavu, both well-forested islands, should also prohibit logging as their broader ecosystems, from ridgetops to reefs, are largely intact.

Coordinating the use and management of land and water, from source to sea, offers solutions to tackle water pollution. By implementing actions in river basins and along coasts, ecosystem services can be supported and riparian and coastal livelihoods improved. The Pacific Ridge to Reef (R2R) programme, which is funded by the Global Environment Facility, follows this approach and includes Fiji and 13 other Pacific Islands countries. The programme aims to preserve biodiversity and ecosystem services, sequester carbon, improve climate resilience and sustain livelihoods through a ridge-to-reef management of priority water catchments on Fiji's two main islands. Selected priority catchments include Ba River, Tuva River and Waidina River/Rewa Delta on Viti Levu and Labasa River, Vunivia River and Tunuloa district on Vanua Levu.

As the graphic shows, it is only by addressing vegetation and soil upslope that rivers and ultimately reefs can stay clean and healthy, sustaining their fish population. To maintain its marine values, Fiji must consider its ridges through to its reefs.



To maintain its healthy coastal and marine ecosystems Fiji has to implement sustainable management practices from ridge to reef.



Sugarcane farming is a major source of sedimentation and nutrient-loading on Fiji's reefs.

## CLIMATE CHANGE THREATS

# 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 Fiji's marine biodiversity.

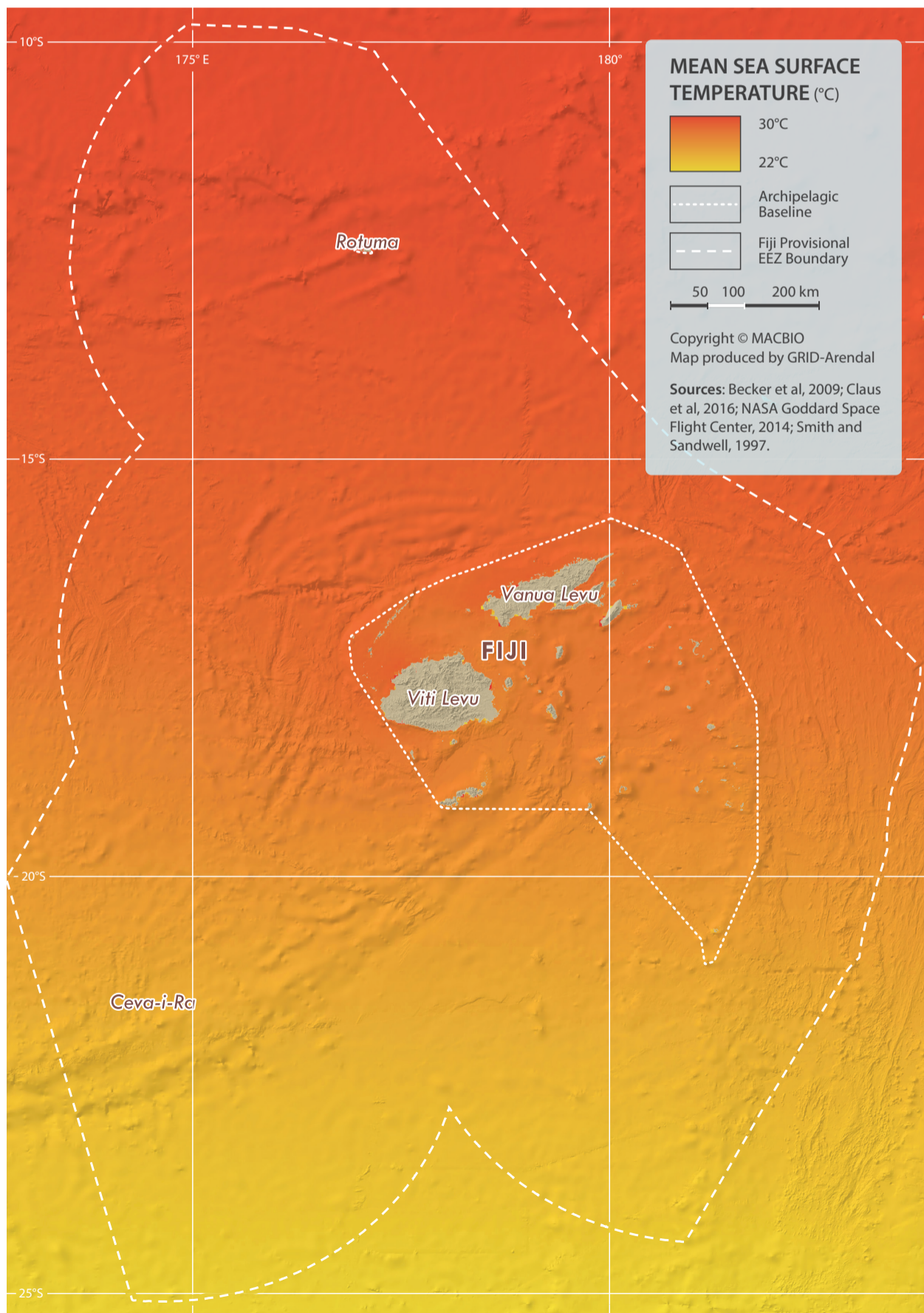
The following chapters explain how observed and predicted climate change will affect Fiji's marine values, starting with SST, which is the water temperature close to the ocean's surface. The very hot waters in 2016 at the Coral Coast and elsewhere in Fiji were not only uncomfortable for visitors, but 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 at the Coral Coast in 2016.

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 Fiji's waters ranges from just under 24°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 2.5°C in the south and less than 1°C in the north. The northern parts of Fiji's waters are strongly influenced by the South Equatorial Current (see also chapter "Go with the flow"), which brings warm water from the eastern tropical Pacific Ocean. This



### Blame it on the weatherman?

In early 2016, water in the shallow reefs along Fiji's Coral Coast rose to an uncomfortable 36°C.

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 Suva, or a particularly hot week on the Coral Coast. Only by observing trends in the long term can we show how the climate is changing.

current moves southward and cools within Fiji's waters resulting in the lower temperatures in the southern areas. The warm waters of the South Equatorial Current are one of the major drivers in the formation of cyclones in this part of the Pacific Ocean.

In fact, in 2016, the high SST fuelled the development of Cyclone Winston. Although the cyclone devastated Fiji's islands, it had a positive impact on corals, such as those found on the Coral Coast, as it cooled down the SST, thus helping the corals survive warm water stress.

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

## Sea level rise has many effects

Fortunately for Fiji, its islands have a higher elevation than many of its low-lying Pacific neighbours, meaning that sea level rise is not an issue for much of its land area. However, rising sea levels are still a threat for many coastal communities in Fiji, as evidenced by the low-lying village of Narikoso on Kadavu Island, where seawater has encroached onto

the land by 15 metres in the last 30 years. Many buildings located close to the sea therefore need to be relocated, with the seven houses closest to the sea a priority. A further 47 houses and other structures will also need to be moved soon due to the rising sea level and risk of floods, especially during cyclones or spring tides.

areas adds to the current global mean sea level rise due to ocean warming and ice melting (Becker et al., 2012).

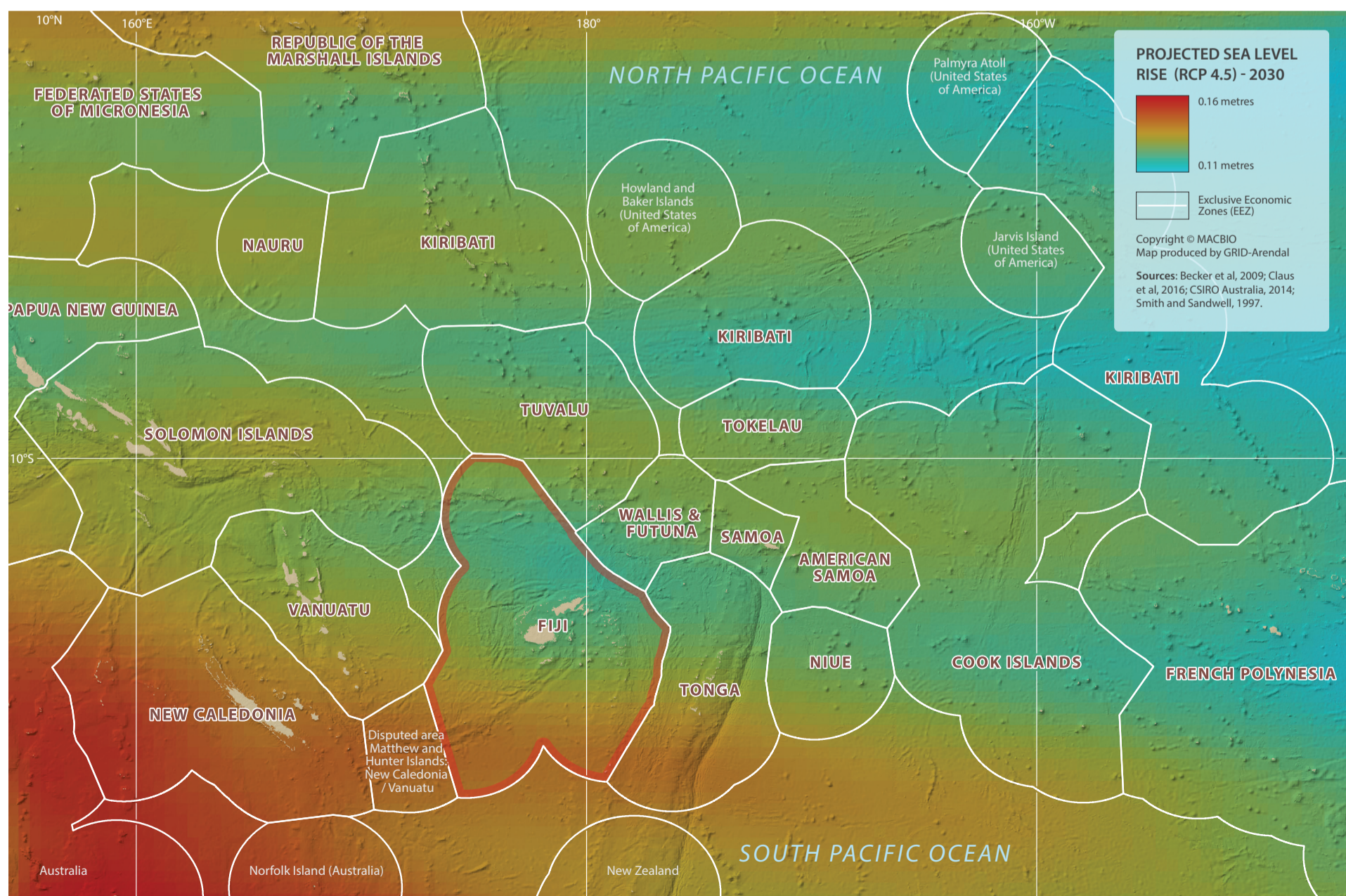
Fiji is a mix of high volcanic islands and low-lying coral atolls. Vulnerability to sea level rise is influenced by coastal geography and prevailing ocean currents. Islands exposed to higher wave energy in addition to sea level rise can experience higher rates of erosion than their more sheltered counterparts. However, the coral atolls of Fiji 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).

An assessment on the vulnerability of mangroves in Suva found that mangrove areas in Tikina Wai showed inherent vulnerability to rising sea levels, partly due to their location on subsiding coastline with low tidal range. However, the area has not experienced significant spatial change in the last few decades (Ellison, 2015).

The map indicates that by 2030, Fiji will experience a minimum rise in sea level of 0.11 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, the Lau group, will experience the highest increase in sea level rise of 0.16 metres. In general, the Fiji's main islands are in a zone of lower sea level rise, with bands of increasing sea level rise to the north and south. Pacific Island nations are therefore focused on developing adaptation strategies to address the predicted continued rise in sea level.

In the past, atolls and islands, which often rise only a metre above the waves, were flooded by the ocean every couple of decades. That trend has since changed, with an increased frequency in these flooding events. When these flooding events become too frequent, it is difficult for islands to recover, as the land becomes too salty, freshwater reserves in lagoons become undrinkable, and the islands themselves can no longer support human habitation.

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

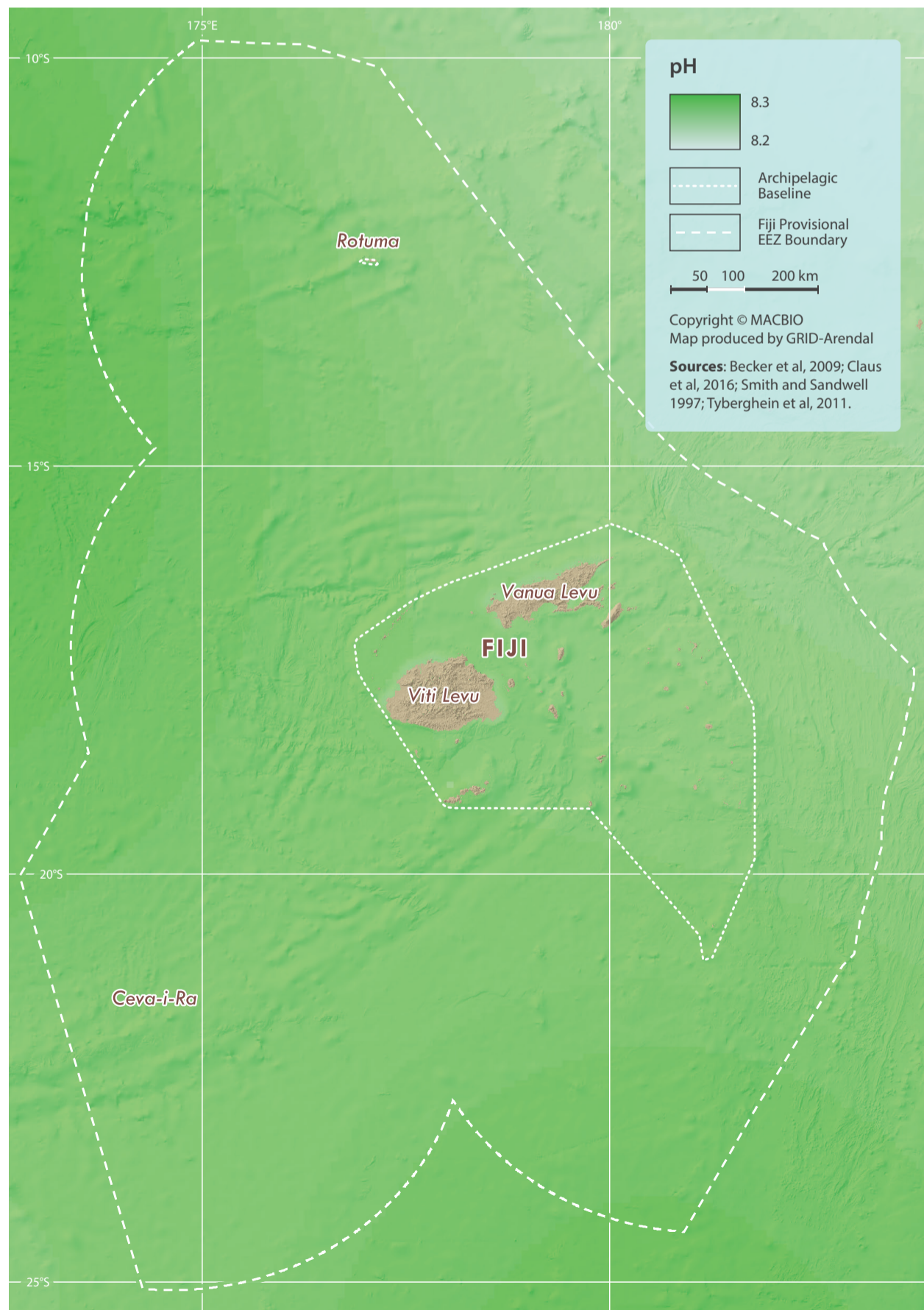
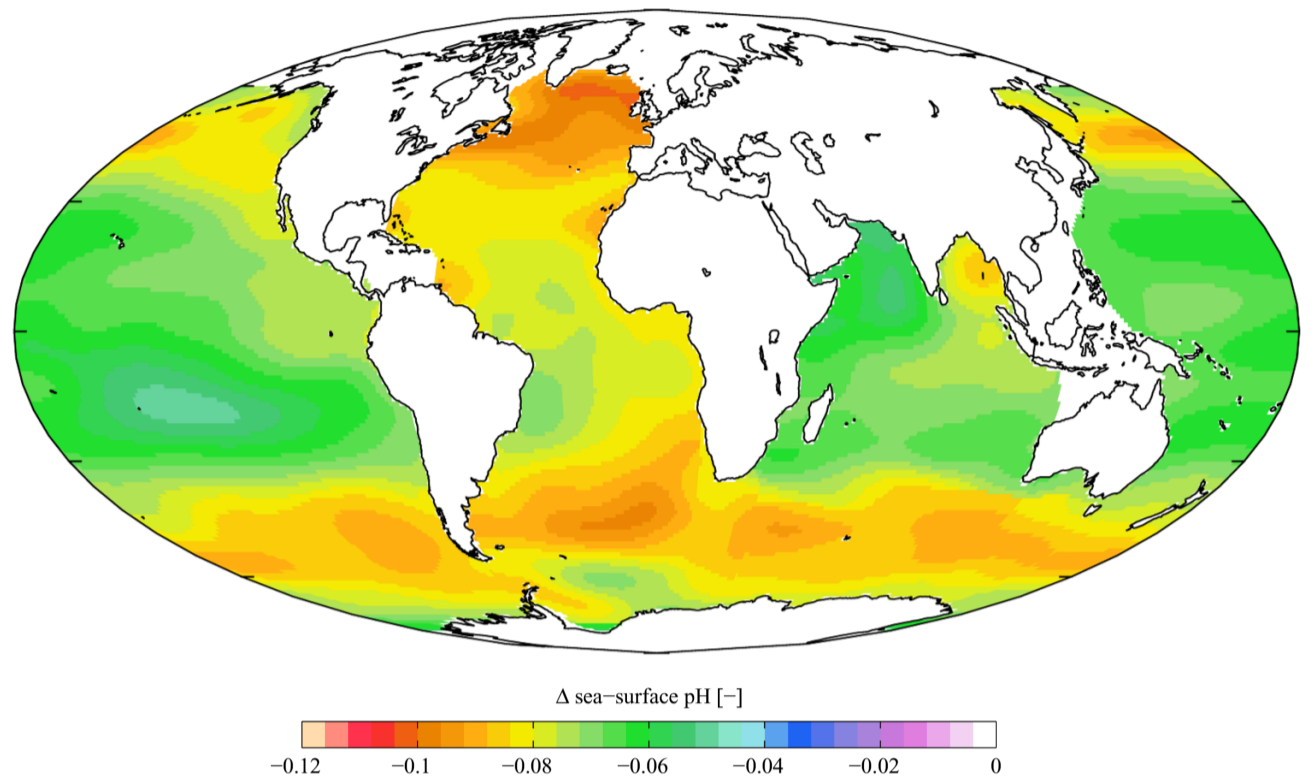


# TURNING SOUR: OCEAN ACIDITY

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. Fiji's waters are at the higher end of this range, with pH between 8.25 and 8.23. Increasing CO<sub>2</sub> in the surface water leads to increased acidification (lower pH). Already, CO<sub>2</sub> 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 Fiji's oceanic waters are low, with the coastal areas around the islands having a higher concentration.

How does acidification affect calcite levels? Firstly, CO<sub>2</sub> 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

## Ocean acidification

Fiji 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<sub>2</sub>) produced by human activities since 1800 and about half of the CO<sub>2</sub> produced by burning fossil fuels (Sabine et al., 2004).

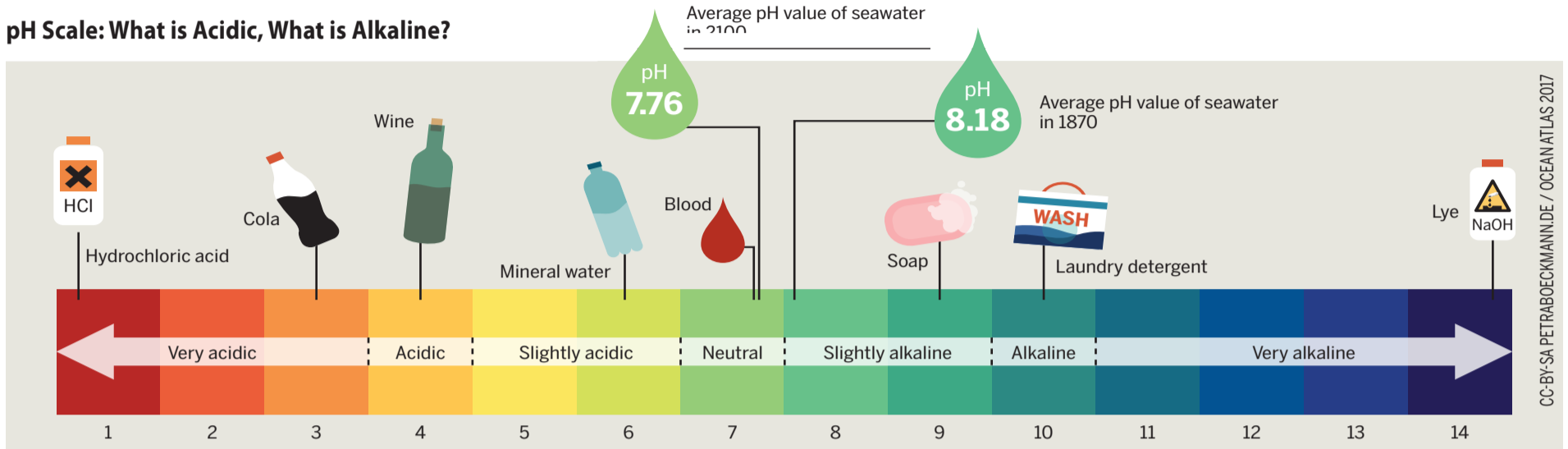
As CO<sub>2</sub> in the ocean increases, ocean pH decreases, resulting in the water becoming more acidic. This is called ocean acidification, the "evil twin" of sea temperature and sea level rise, described in the previous maps.

drops too far. In that case, the water actually begins 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.

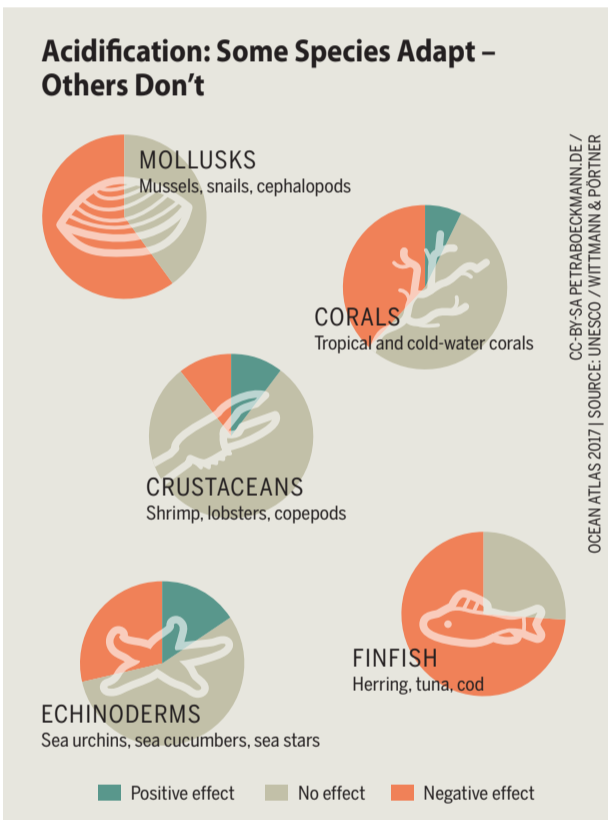
Fiji's shallow-water corals are also at risk from increasing acidity. For example, it has been predicted that ocean acidity will decrease from a current pH of around 8.3 to a pH of 7.9 by 2100. This level of decrease has been shown to result in a 50 per cent reduction in coral productivity, and increased

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.

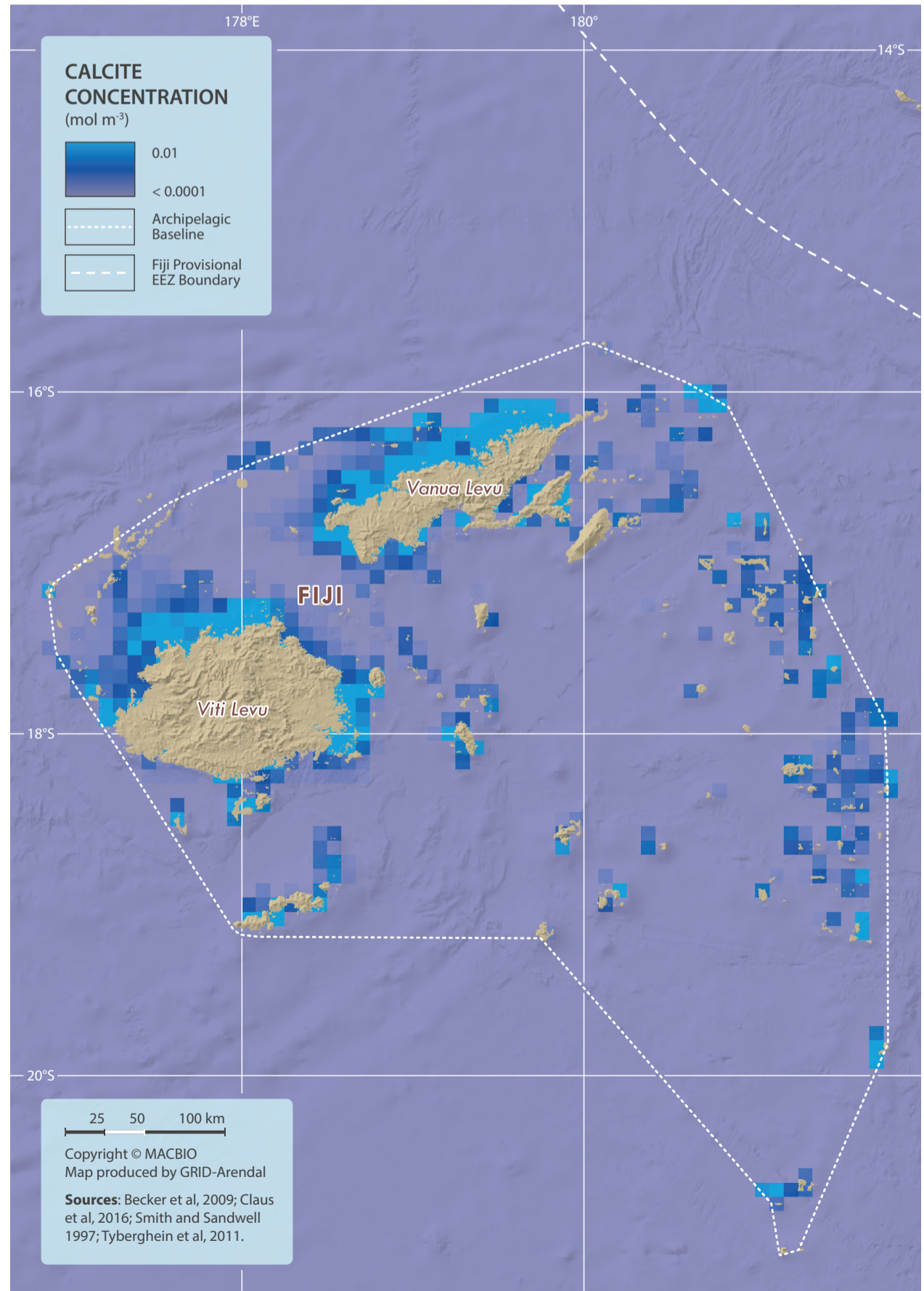
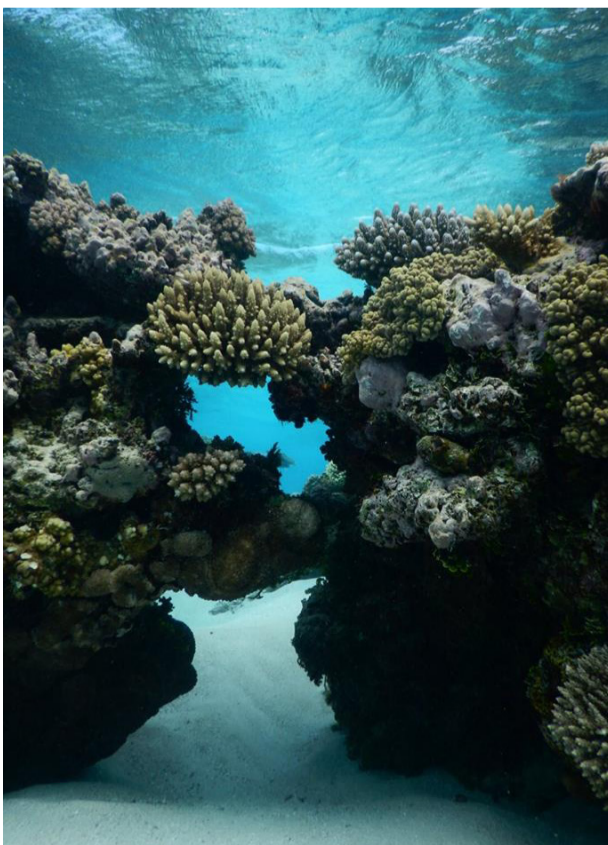
**pH Scale: What is Acidic, What is Alkaline?**

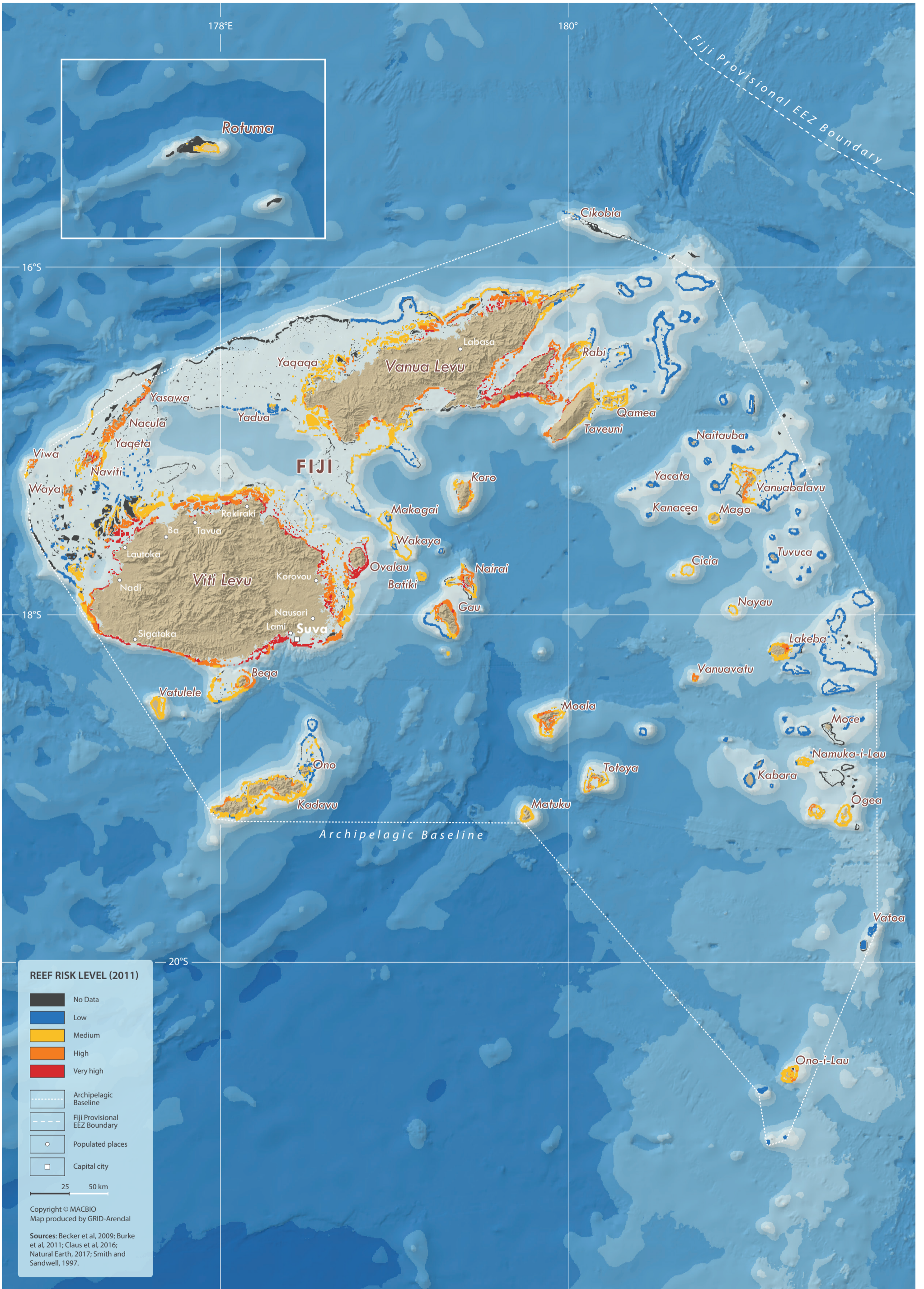


The difference may seem small, but the decline in the pH value from the year 1870 (pH 8.25) to 2100 (pH of 7.9) would mean a 170 per cent increase in acidity. Much smaller changes already pose problems for many sea creatures.



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

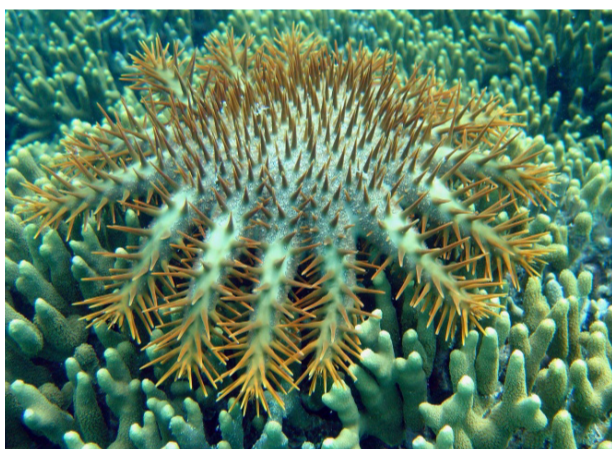




# REEFS AT RISK: REEF RISK LEVEL

Fiji'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.

As seen in the previous maps, coral bleaching is the silent reef killer, caused by rising sea levels and ocean acidification. The first bleaching events in Fiji were reported in 2000 and 2002, resulting in an estimated 40–80 per cent coral mortality, with outer-reef slopes most affected (Lovell et al., 2004). A more serious bleaching event was observed more recently in 2016, with 80 per cent of different coral species reported as damaged in the Great Astrolabe Reef, Beqa Lagoon, Suva Barrier Reefs, Northern Vanua Levu Reefs and Ovalau Reefs (Reefbase, 2017). During February 2016, shallow reef areas along the Coral Coast suffered from high fish mortality and bleaching of most hard and soft corals (see also chapter “Hotter and higher”). At the end of February 2016, Cyclone Winston cooled the seawater temperature by several degrees, allowing a small number of corals to recover. However, most of the affected corals and associated fish failed to survive (Mission Blue, 2017). Following the coral bleaching, a survey was conducted by Reef Explorer divers who observed an influx of crown-of-thorns starfish (*Acanthaster planci*) (Mission Blue, 2017). Outbreaks of this species 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 Fiji'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 Fiji's reefs; threats that will increase over time. The risk of these threats is shown on the map of Fiji'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 (see also chapter “From ridge to reef”); 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”).

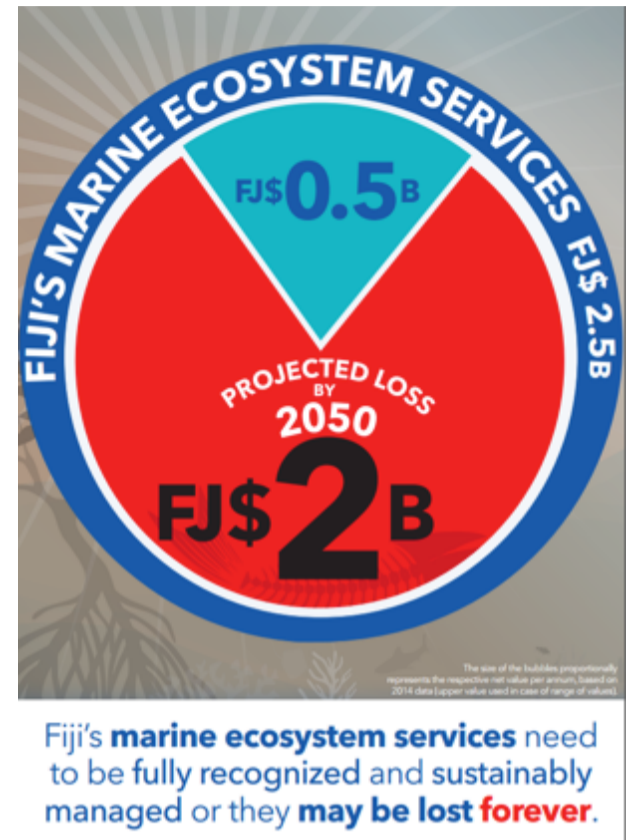
## A trail of destruction

Beached ferries (see chapter “Home, sweet home”) were not the only souvenir Cyclone Winston left behind. Villagers in Ra Province and along the Vatu-i-Ra seascape, among others, were surprised to find that the force of the waves had dislodged massive corals and moved boulders along the reef flat and down the reef slope (WCS, 2016). This is a stark example of how climate change effects such as the increasing intensity of tropical cyclones threaten reefs, largely through sheer physical force. Other effects that put reefs at risk, such as coral bleaching, are much more subtle, but nonetheless lethal to Fiji's vast reef system—the largest in the South-West Pacific (Spalding et al., 2001; see also chapter “Shaping Pacific Islands”).

This multitude of man-made threats leaves Fiji's reefs at risk. Analysis of the threat index indicates that 27.51 per cent of the reef area is classified as facing a low risk, 37.69 per cent a medium risk, 23.51 per cent a high risk and 11.28 per cent face a very high risk. Very high risk areas (red) are concentrated around urban centres such as Suva, and heavily fished locations such as the Yasawa Islands. Wilkinson (2008) identified the major human disturbances as overfishing, pollution, sedimentation, eutrophication and coastal development. Reefs are important to the economies of local communities, especially through tourism. They are also important for subsistence and coastal protection. As the largest coral exporter in the Pacific region (Cumming et al., 2002), it is estimated that around 10 per cent of the international coral trade (2000–2020) comes from Fiji (Wood et al., 2012). Much of Fiji's coastal fishery is carried out in its reefs and lagoons. In the past, destructive fishing practices, such as dynamiting and poisoning, caused serious damage in some places (Cumming et al., 2002). However, there is little information on the current prevalence of these practices.

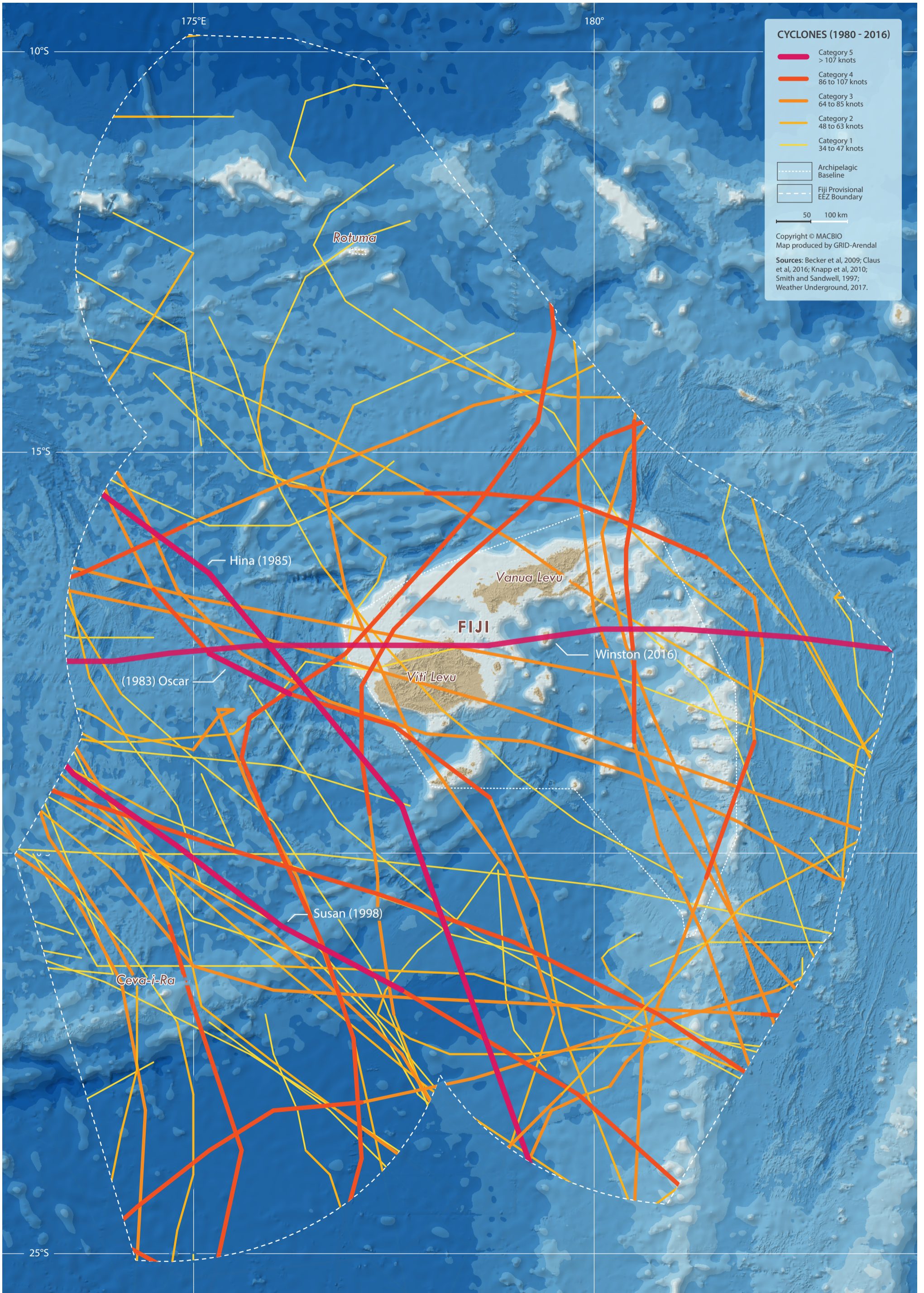


Acropora coral field in Fiji exposed to multiple impacts, including a crown-of-thorns outbreak and cyclone damage.



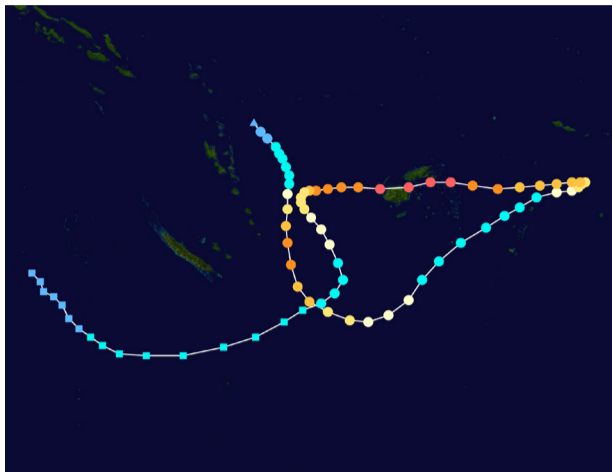
These many threats not only impact the country's reefs, but also have serious consequences for Fiji and its economy. Without change, Fiji could lose an astounding FJ\$2 billion in benefits from ecosystem services provided by reefs and mangroves by 2050 (see graphic; Brander et al., 2016).

Luckily, there are many initiatives aiming to facilitate the changes needed. The University of the South Pacific and other institutions are supporting capacity development for monitoring and conservation. An integrated approach to conserving coral reefs is needed that acknowledges land–sea connections and has an understanding of how and where terrestrial conservation actions influence reefs (see also chapter “From ridge to reef”). Klein et al. (2012) examined the impact and cost effectiveness of protecting forests as a reef conservation measure, finding that coral reef conditions could be improved by 8–58 per cent if all remnant forests were protected rather than deforested.



# STORMY TIMES: CYCLONES

Tropical cyclones pose direct threats to Fiji, 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 Winston is but one track on the map showing all category 1 to 5 cyclones that occurred in the period from 1980 to 2016. Cyclone Winston formed on 7 February north-west of Vanuatu and moved towards Tonga, before turning 180 degrees and heading for Fiji on 20 February.

Cyclones are monitored by the Regional Specialized Meteorological Centre of the Fiji Meteorological Service in Nadi 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. The highest density is centred over the northern part of Fiji’s islands, where low-level relative vorticity, an upper-level divergent atmosphere and weak environmental wind shear are very conducive to genesis. During La Niña years, slightly fewer tropical cyclones form, originating in the south of Fiji (Chand and Walsh, 2009). Although there is not much difference between El Niño and La Niña years, Fiji’s northern islands have less cyclone incidences during La Niña conditions than the country’s southern islands (Chand and Walsh, 2009). The average number of cyclones impacting Fiji from 1969 to 2017 was 7.3 per year. For El Niño years, the average is 8.7 per year, while for La Niña years the average is 6.5 per year. During neutral seasons, the average is slightly less at 6.4 per year (Fiji Meteorological Service, 2016/17).

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”)

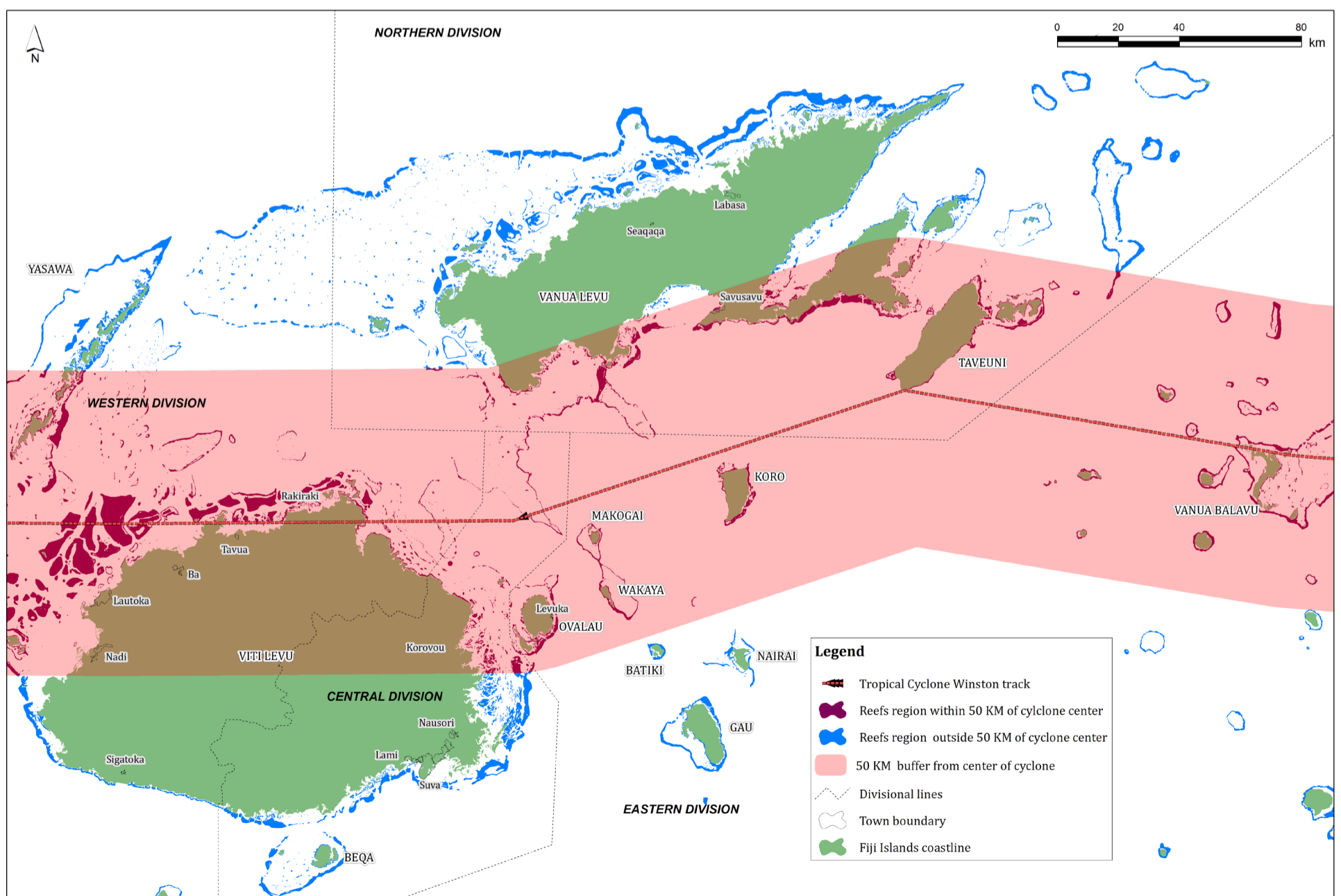
## Stronger than Cyclone Winston

As a symbol of their strength following the most powerful storm to have made landfall in the southern hemisphere and the devastation that it caused throughout Fiji, the villagers of Navitilevu named their youngest child Salomi Winston after the cyclone.

Reaching a maximum speed of 306 km/h, Cyclone Winston killed 44 people, damaged and destroyed 40,000 homes, and cost a total of FJ\$2.98 billion (US\$1.4 billion; Tuilevuka, 2016).

that are resulting in increasing damage, including to Fiji’s valuable coastal habitats (see small map).

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







# MANAGING

The marine and coastal ecosystems of Fiji's waters provide benefits for people in and beyond Fiji. To better understand and improve the effective management of these values on the ground, Pacific Island countries, including Fiji, 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 Fiji that starts at the local level, based on the management of iqoliqoli (traditional fishing

grounds). In addition, Fiji 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 Fiji, 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

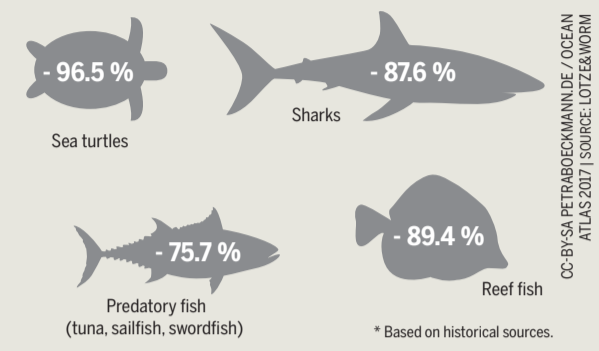
Marine managed and protected areas are key to maintaining Fiji's valuable marine resources. To effectively implement these areas, it is important to combine traditional marine management with national and international efforts.

## Vatu-i-Ra seascape

Stretching across the channel that links Fiji's two main islands is Vatu-i-Ra—a blue-green jewel of forest and reef. The island's vibrant seas are laced with coral reefs, masses of colourful reef fish, and sea turtles, while its coastal forests are alive with crested iguanas, tree frogs and sea birds. With the support of the Wildlife Conservation Society (WCS), local partners are undertaking ambitious efforts to

conserve this seascape, using science and traditional knowledge. In Kabulau district, a locally managed network is being implemented to protect the area. The network includes 20 community-managed MPAs that only permit sustainable fishing, as well as Fiji's first no-fishing protected zone. The network is currently the only one in Fiji to protect 30 per cent of its traditional management area.

## Declining Populations\* (Percentage Change)



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 “Fiji'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 in-

ternational 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.

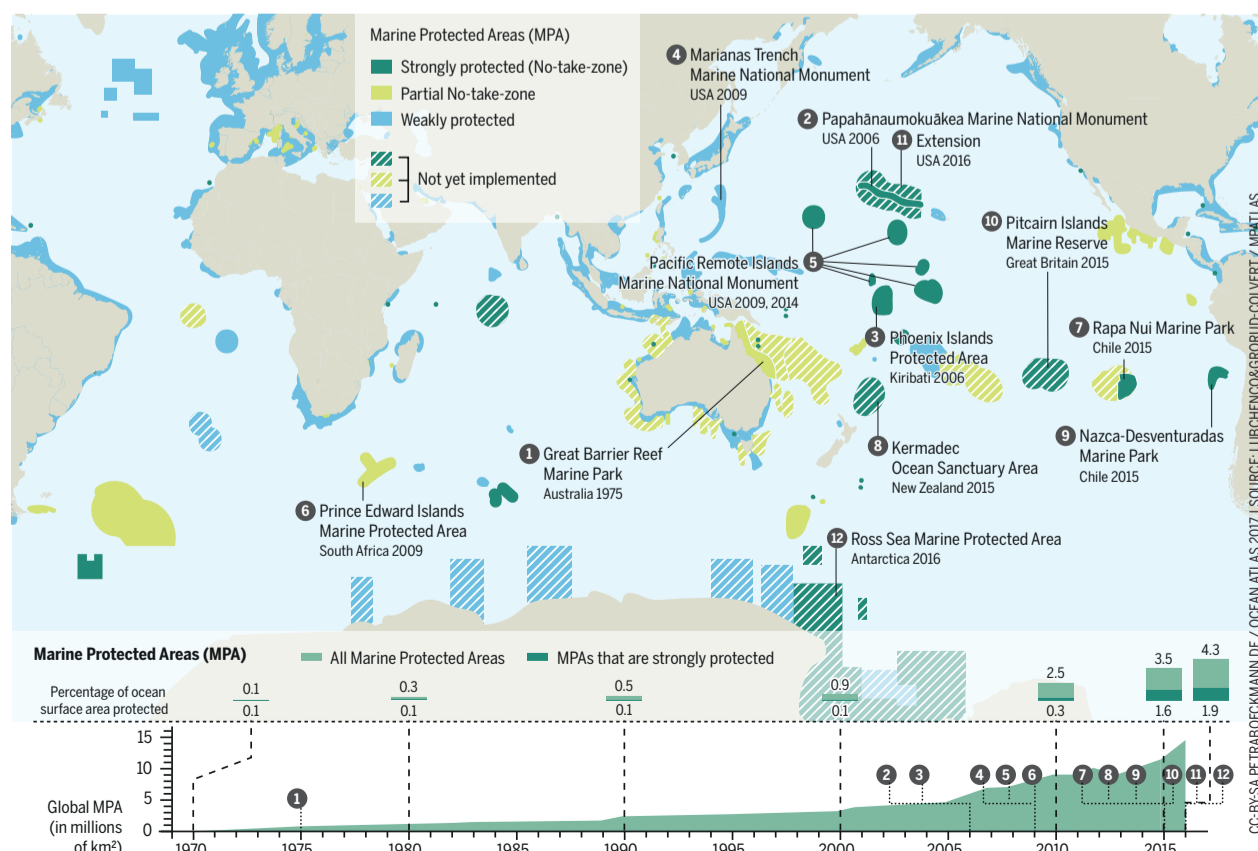
Recognizing the role that these areas play in allowing marine life to recover, Fiji has committed to protecting and sustainably managing 30 per cent of its sea (see also chapter “Fiji's commitment to marine conservation”) by 2020, using Fiji-specific categories of protection. While this is an ambitious goal, Fiji has a rich tradition of marine management upon which it can build. Local traditional Fijians have control over access to iqoliqoli (see map), which are traditional fishing grounds with customary fishing rights. Rights owners of a iqoliqoli are registered in the iTaukei Customary Fishing Rights Register, which is maintained by the iTaukei Lands and Fisheries Commission.

While some iqoliqoli may have no control or management procedures in place, many have some level of management, with their area either fully or partly designated a LMMA. It is estimated that 78 per cent of inshore areas (all within iqoliqoli) were LMMAs in 2010.

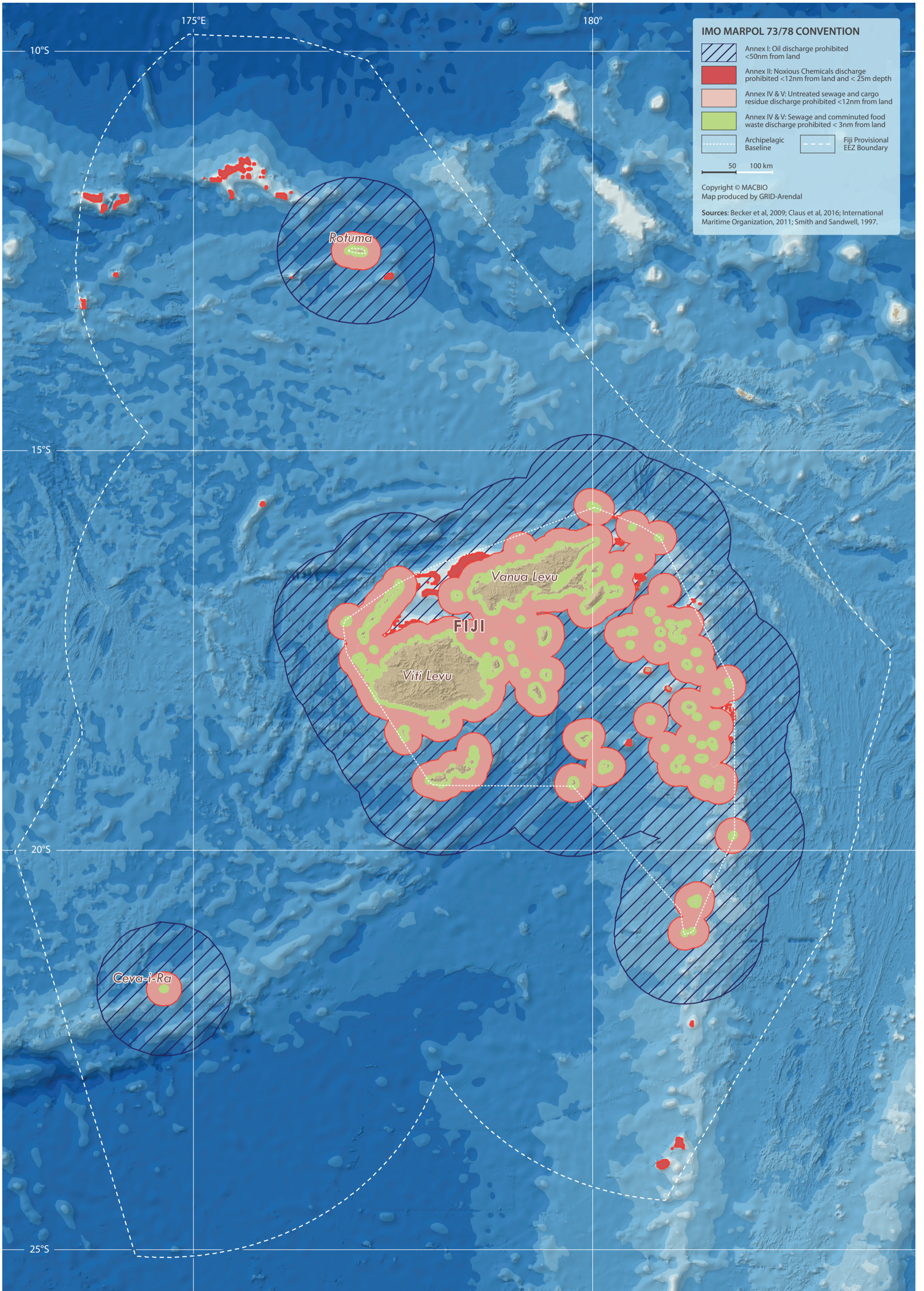
An LMMA may contain various input or output controls, including permanent or temporary no-fishing areas (tabu). At present, 135 of Fiji's marine iqoliqoli are being managed and have around 465 fishing reserves or tabu areas covering around 1,000 km<sup>2</sup>. All LMMAs in Fiji are found in the coastal waters surrounding the main islands of Viti Levu and Vanua Levu, as well as many of the smaller islands to the south and east. This shallow coastal zone is the area of greatest human use, from commercial and artisanal fishing to tourism and transport. The marine managed areas in these parts contribute to sustainable local livelihoods (see also chapter “Small fish, big importance”).

In Fiji, LMMAs are organized through the Fiji Locally Managed Marine Area network, a non-profit association of resource conservation non-governmental organizations (NGOs), government departments, academic institutions and over 400 communities, working together to promote and encourage the preservation, protection and sustainable use of marine resources in Fiji by the stewards of these marine resources. This is part of the international LMMA network of natural resource management practitioners working in Asia and the Pacific, who have joined together to share best practices and lessons learned, and to amplify their community voices.

## Marine Protected Areas – Space to Recover



This regional network is a good example of how local efforts can be integrated with national and international efforts to create spaces for marine recovery (see also the following chapter).



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

Fiji'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.

Fiji has sovereign rights over a vast marine area of 1.3 million km<sup>2</sup>. 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 Fiji (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.

Fiji 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 Fiji'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, label-*

*ling, 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 SO<sub>x</sub>, NO<sub>x</sub> and particulate matter.*

In addition, Fiji is in the process of declaring Particularly Sensitive Sea Areas (PSSA), which due to

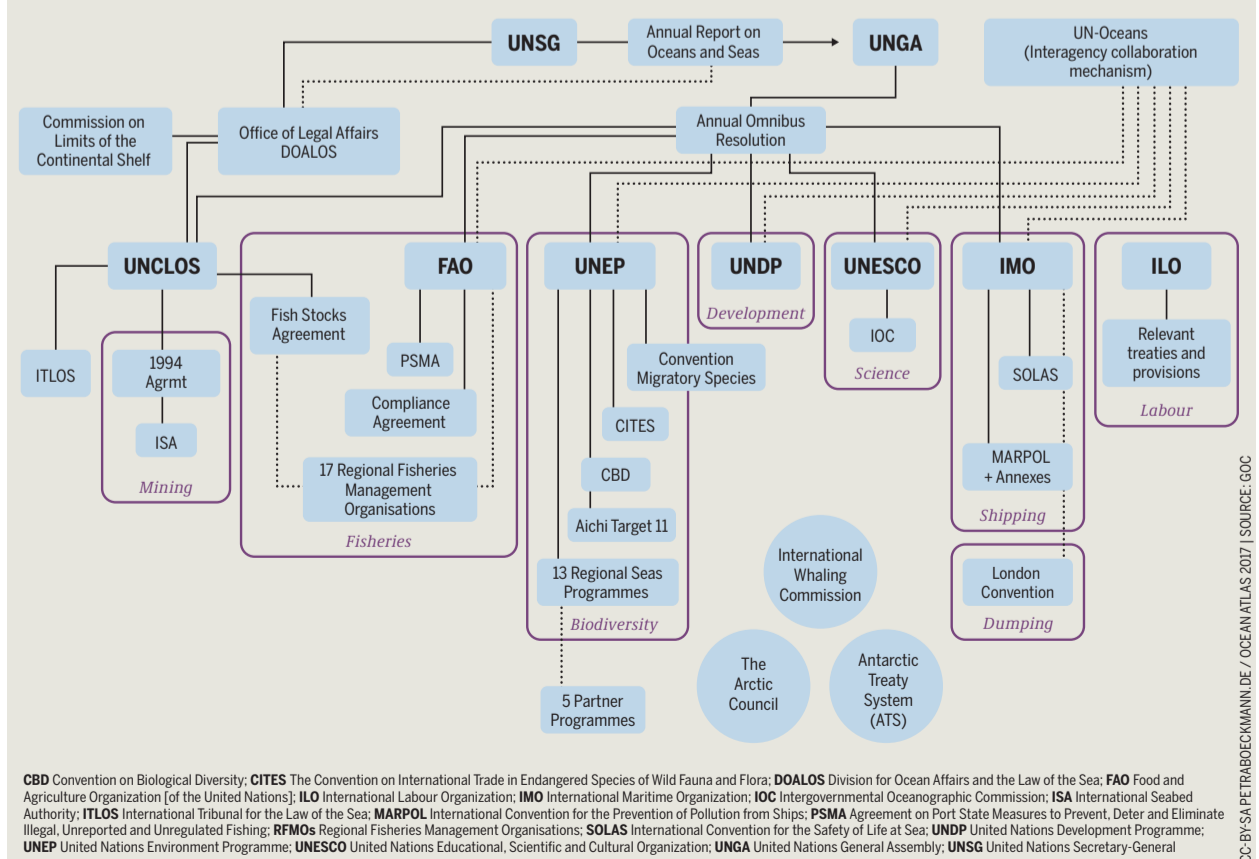
## Under invasion

In addition to pollution, international shipping routes pose another threat to Fiji'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.

their ecological, socioeconomic or scientific significance, or vulnerability to harm from maritime activities, require special protection from IMO. A PSSA can be protected, for example, by implementing routing measures, which prevent ships from entering the area.

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



# FIJI'S COMMITMENT TO MARINE CONSERVATION

Fiji 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.

Fiji 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 1994, Fiji joined many other countries in signing and ratifying the international Convention on Biological Diversity (CBD), under which Fiji 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, Fiji has gone even further. The Government of Fiji has enshrined the protection of its ocean values within its Green Growth Framework, which builds upon its commitment made through the

Ministry of Foreign Affairs at the 2005 Small Island Developing States (SIDS) Conference in Mauritius, to protect 30 per cent of its seas as marine managed and protected areas by 2020. This commitment was reconfirmed at the 2014 SIDS Conference in Samoa, through its then Ministry of Strategic Planning, National Development and Statistics.

Through the Environment Management Act, the Government of Fiji has established the high-level, cross-ministerial National Environment Council, which is responsible for setting up technical advisory groups, such as the Protected Area Committee (PAC). The PAC is harnessing the expertise of the Marine Working Group to help implement a national network of MPAs.

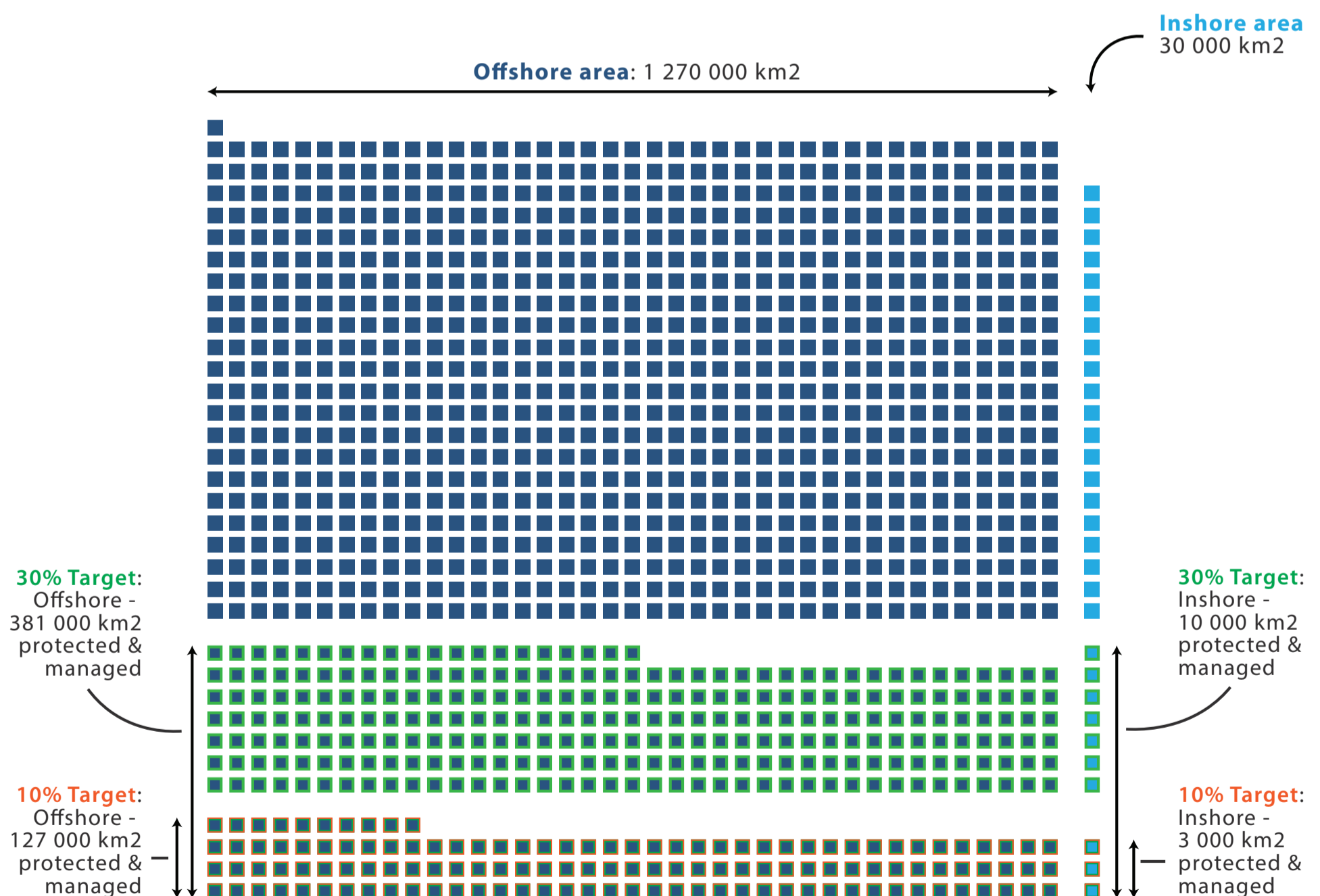
The vision for Fiji's MPA network is:

*“A comprehensive, ecologically representative network of MPAs that restores and sustains the health, productivity, resilience, biological diversity and ecosystem services of coastal and marine systems, and promotes the quality of life for our communities that depend on them.”*

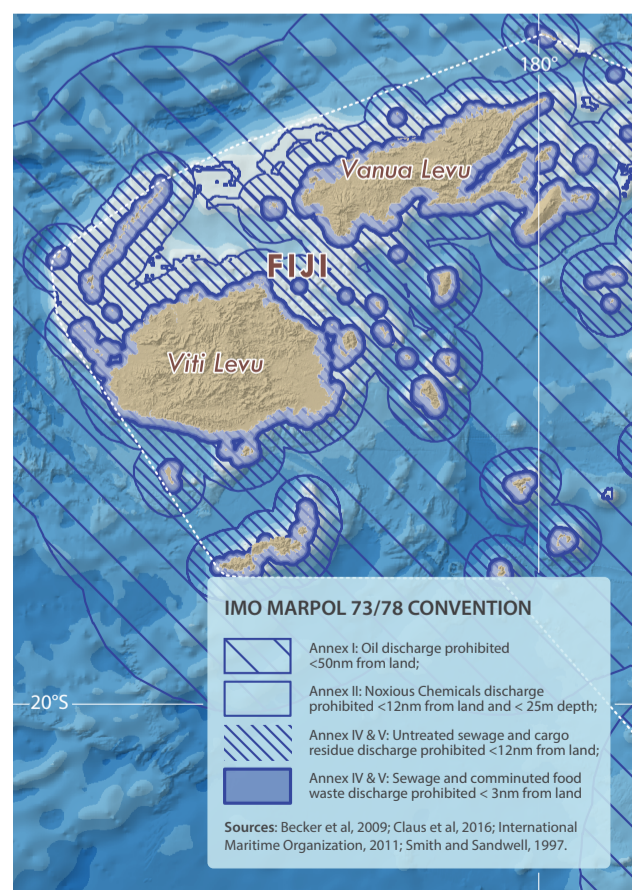
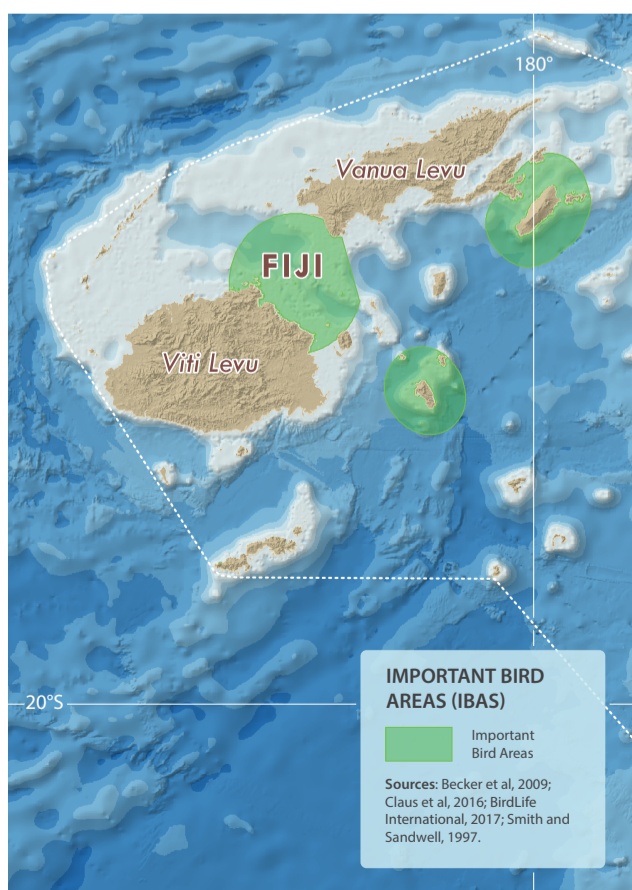
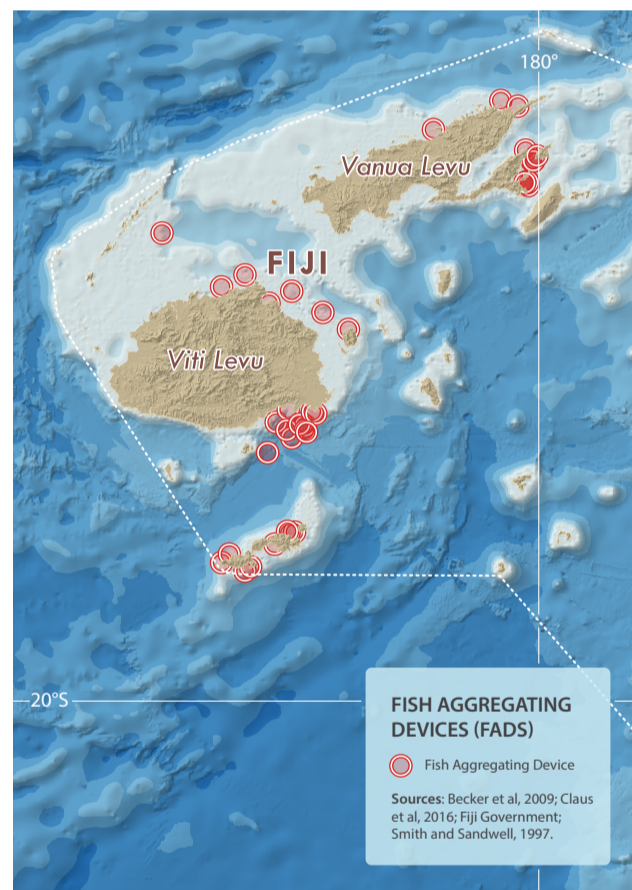
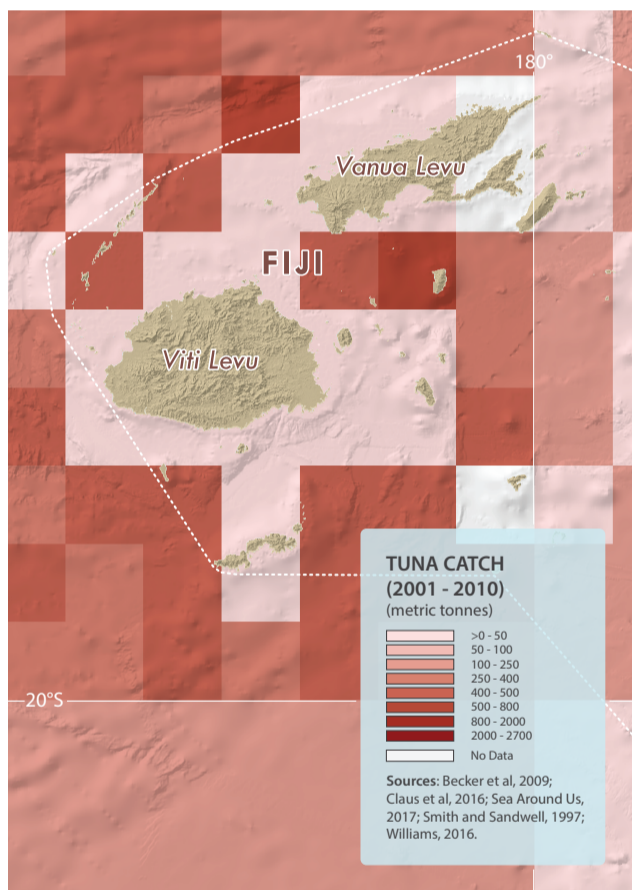
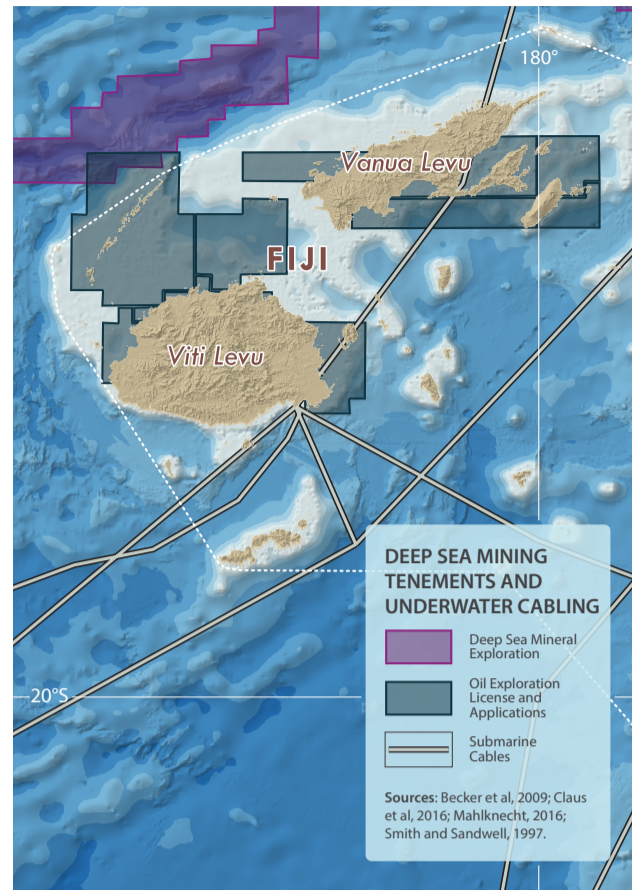
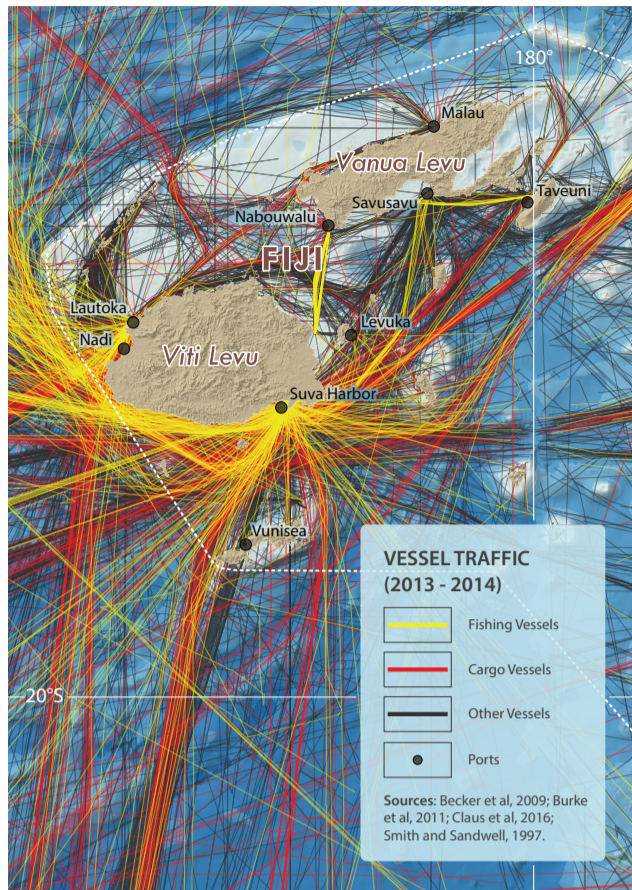
There are six objectives that Fiji's MPA network aims to achieve:

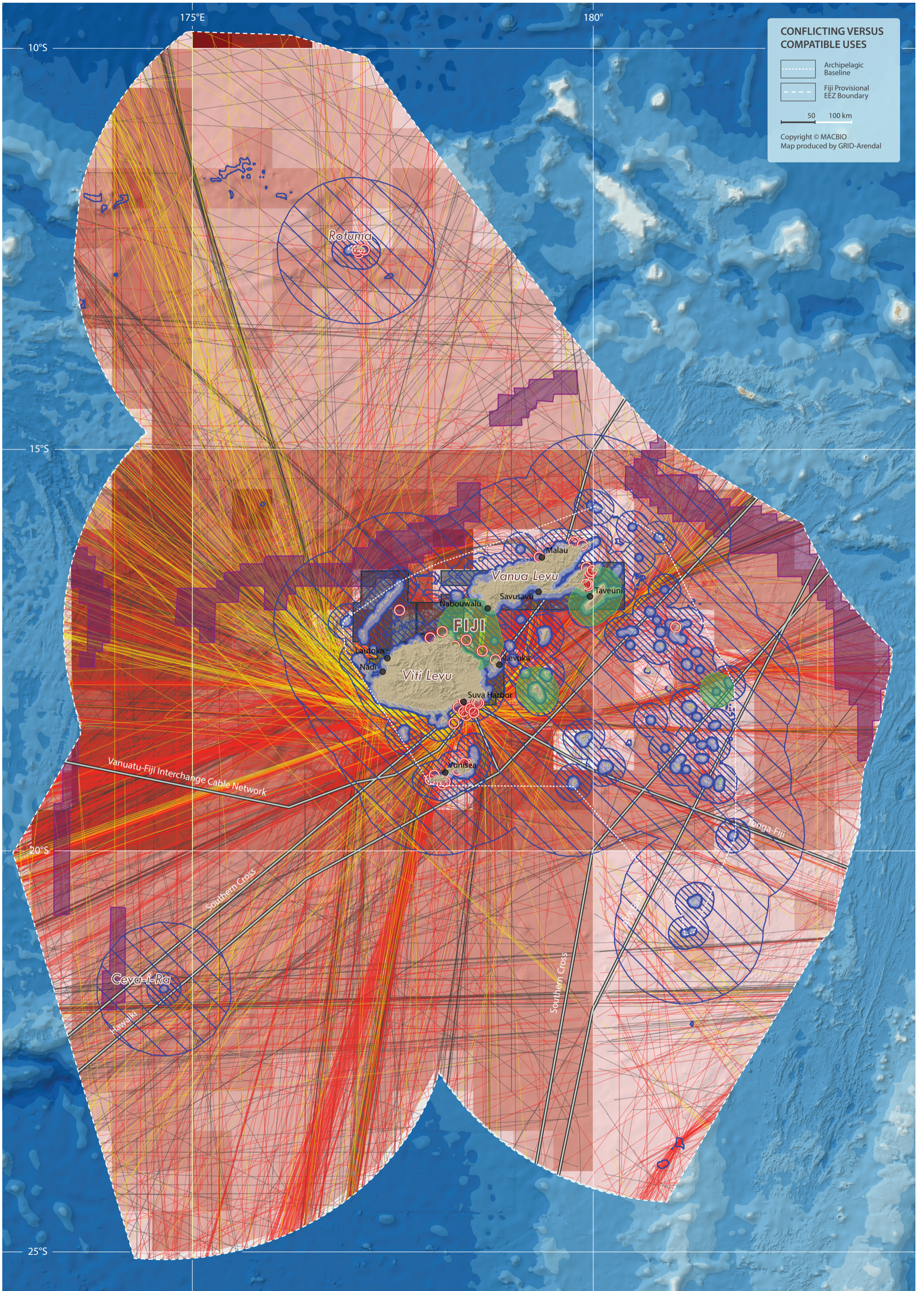
1. Ensure food security
2. Sustain livelihoods
3. Restore and sustain the health and productivity of marine resources
4. Minimize conflicts between uses
5. Build resilience to climate change and disasters
6. Restore and conserve biological diversity and ecosystem services

Fiji's total waters extend over 1.3 million km<sup>2</sup>, with inshore areas comprising roughly 2 per cent and offshore areas 98 per cent (see graphic).



# A MARINE LAYER CAKE





# CONFLICTING VERSUS COMPATIBLE USES

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

## Marine Spatial planning

Marine Spatial Planning (MSP) is an inter-sectoral 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 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 Fiji 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 Douvère, 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 Fiji’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



MSP can be applied on different scales, from local to regional levels.

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.

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.

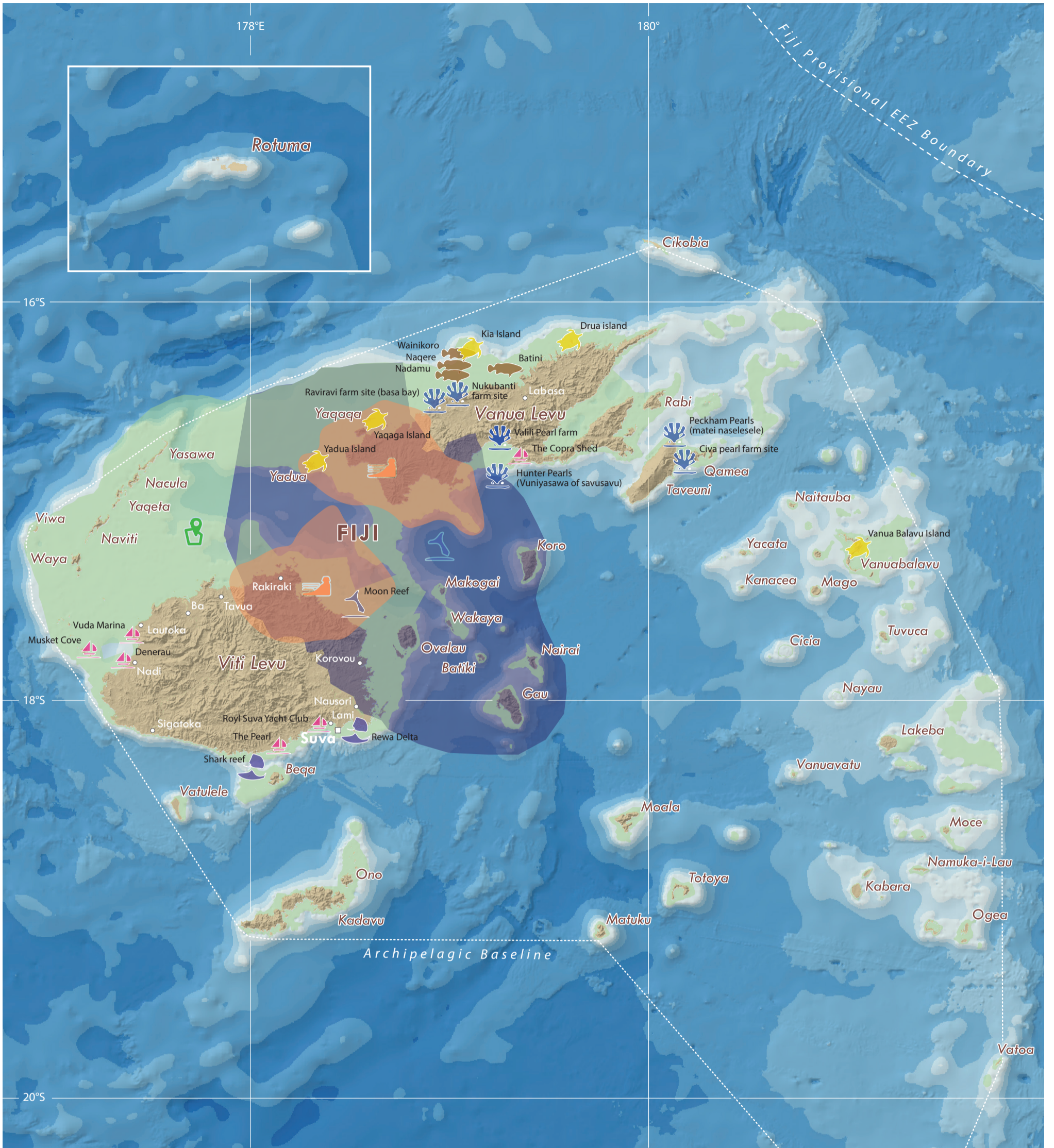
Preparing a zoning plan is not an easy task, and is best achieved through considerable consultation, including across government departments at all levels, users, other stakeholders and the community. Zoning plans must accommodate and balance the cultural, economic, social and biological needs of the 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 Fiji 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 Fiji’s rich and complex marine environment in a fair and sustainable manner, while maximizing benefits.



VOLUNTARY COMMITMENTS				
	General and EEZ wide voluntary commitments	Site specific voluntary commitments	Example sites	
	Archipelagic Baseline		One Pearl Farm in Fiji to review practices for better sustainability	Main pearl farms
	Fiji Provisional EEZ Boundary		Conservation & Management of all Species of Sharks and Rays and their Critical Habitats within Fijian Waters	Shark Reef and corridor (Bull and Tiger Sharks) Rewa Delta (Scalloped Hammerhead Sharks)
	Populated places		Fiji Clean Boating Program, Level 3 International Clean Marina Certification & International Fish Friendly Accreditation	Main marinas
	Capital city		The Conservation and Management of Sea Turtles within Fijian waters	High density examples of more than 40 main turtle nesting sites
	25 50 km		Protection of Groupers and Coral Trouts Spawning Aggregation Sites across Fijian Reef Systems	Example main Grouper and Coral Trout spawning aggregation sites
Copyright © MACBIO Map produced by GRID-Arendal				
Sources: Becker et al, 2009; Brunnschweiler, 2010; Claus et al, 2016; Jupiter S, et al, 2012; Merewalesi L, et al, 2011; Natural Earth, 2016; Oremus, et al, 2013; Cara M, et al, 2016; Pollett S, 2015; Sadovy Y & Ramoica M, 2015; Smith and Sandwell, 1997; UNOC, June 2017; WCS, 2009.				
	Plastic Pollution - Free Fiji Campaign		Integrated Coastal management to Preserve Ecosystems Services, Climate Resilience and Sustain Livelihoods in Fiji	Provincial model trials of Integrated Coastal Management in RA and Bua Provinces
	The Incorporation of Ocean Information into the VanuaGIS Platform		Protection and Management of all Marine Mammal Species in Fiji	Vatu-i-Ra Seascape as main breeding and calving area for humpback whales Moon Reef as example of dolphin sites
	Introduction of a Plastic Shopping Bag Reduction		Scaling up locally managed marine areas to 100% of Fiji's customary marine areas	Extent of qoliqoli (traditional fishing grounds)
	Promoting Gender Equality in Sustainable Fisheries Mgt and Development in Fiji			
	Prohibition of Destructive Offshore Fishing Practices in Fijian waters			
	Sustainable Tourism Development Framework			
	Eco-labelling/Catch Certification improved in Fiji			
	Expansion of Large Scale Marine Managed Areas in Fiji			
	The Fiji Pearl Development Plan - Creating a Blue Industry			
	Delivering Improved Coastal Fisheries Management Services in Fiji			

# A CALL FOR OCEAN ACTION: VOLUNTARY COMMITMENTS

Fiji is committed to sustainably managing and conserving its marine values, so much so that it has become a global leader in this area. From 5–9 June 2017, Fiji co-hosted the United Nations Ocean Conference in New York to support the implementation of Sustainable Development Goal (SDG) 14.

## 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.

In addition to the Aichi Biodiversity Targets (see previous chapter), and regional efforts such as the Pacific Oceanscape Framework, SDG 14 focuses on life below the surface.

“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 man-

agement 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).

Together, Fiji’s government and its non-government partners identified and drafted 17 Voluntary Commitments (see textbox and table) aimed at protecting and sustainably managing its ocean. These cover a wide range of topics from marine managed areas, including LMMAs, integrated coastal management, coastal fisheries, gender and fisheries, grouper spawning aggregations, turtles, sharks, and whales. These commitments fit into Fiji’s existing policy framework and national priorities on ocean governance, and may help gain new momentum to overcome limited funding, resources and thematic gaps.

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



Josaia Voreqe Bainimarama, prime minister of Fiji, addressing the UN Ocean Conference.



# CONCLUSION

Fiji's vast ocean has billions of dollars' worth of marine value. To successfully conserve and manage these values, the island nation is strongly committed to holistic planning and effective management of its ocean.

Fiji's national vision for these efforts is:

*"A comprehensive, ecologically representative network of MPAs that restores and sustains the health, productivity, resilience, biological diversity and ecosystem services of coastal and marine systems, and promotes the quality of life for our communities that depend on them."*

Fiji is initiating a participatory, national MSP process to implement their national network of MPAs. Stakeholders across Fiji are working together to build this MPA network in order to secure a healthy, productive, resilient and biodiverse ocean for all.

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 Department of the Environment of the Ministry of Local Government, Housing and Environment, the Fisheries Department of the Ministry of Fisheries and Forests, the Fiji Bureau of Statistics 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, Riibeta Abeta, Mia

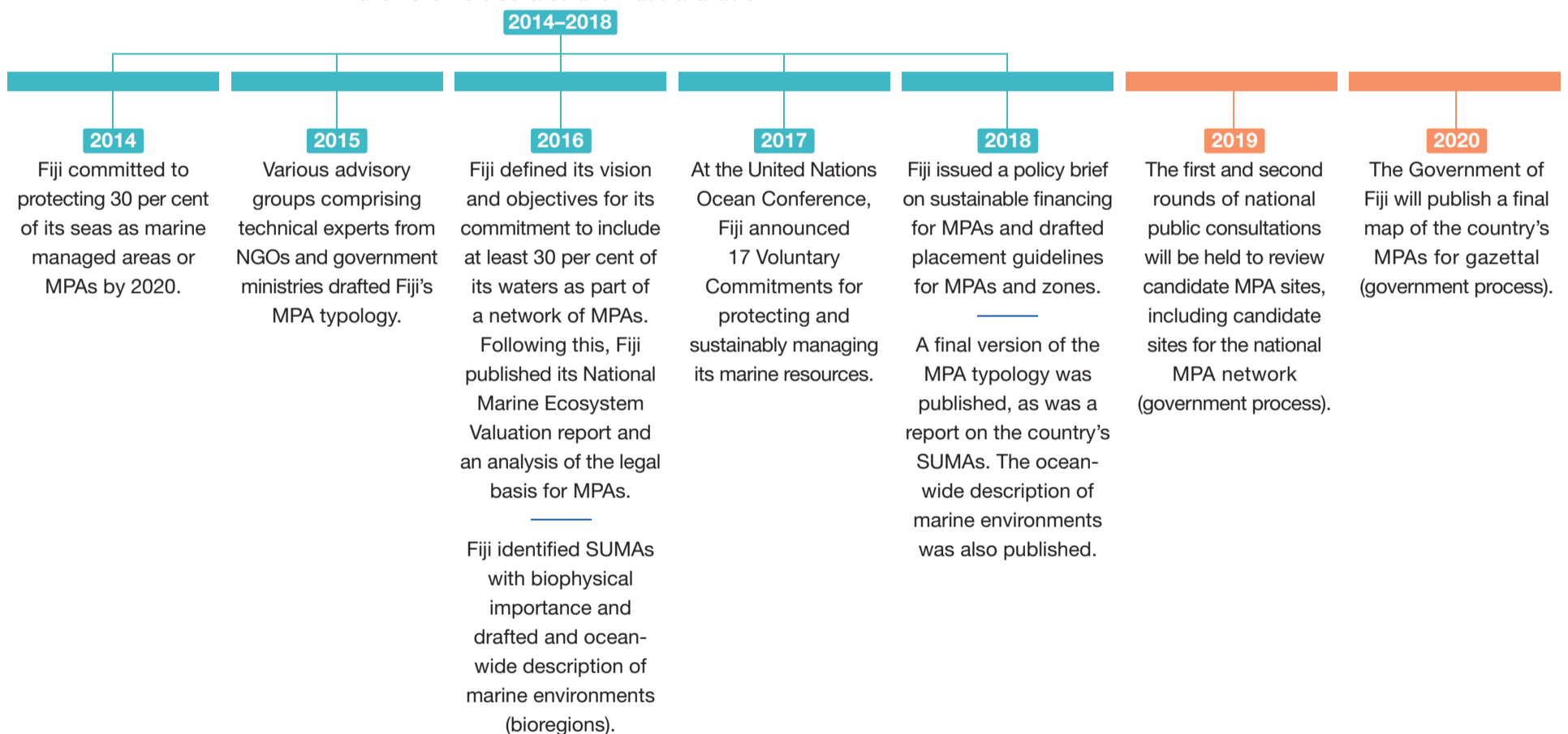
Avril, Jasha Dehm, Marian Gauna, Jimaima Le Grand Thomas Malone, Anja Nicolay-Grosse Hokamp, Jan Steffen, Jonah Sullivan, Naushad Yakub for their support, as well as the GRID-Arendal team: Kaja Lønne Fjærtøft, Georgios Fylakis, Elsa Lindeval, Petter Sevaldsen and Janet Fernandez Skaalvik.

While the atlas provides the best data currently publicly available, the information about Fiji'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 Fiji Marine Atlas are available here: <http://macbio-pacific.info/marine-atlas>

## Timeline of the Fiji Marine Spatial Planning process

Around 130 spatial data sets on uses, biodiversity, environmental conditions and risks were collated and made available.



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### A Marine Layer Cake

#### MAPS

For map data, please check references for chapters: "Fishing In The Dark – Tuna Catch", "Full Speed Ahead – Vessel Traffic", "One World, One Ocean – IMO MARPOL Convention", "Underwater Wild West – Deep Sea Mining And Underwater Cabling."

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### Conflicting Versus Compatible Uses

#### MAP

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# APPENDIX 1. DATA PROVIDERS

## Organisation Name

AquaMaps  
 Commonwealth Scientific and Industrial Research Organisation  
 Convention on Biological Diversity  
 Earth & Space Research (ESR)  
 Ecologically or Biologically Significant marine Areas  
 exactEarth  
 Government of The Kingdom of Tonga  
 Government of Vanuatu  
 GRID-Arendal  
 Institute for Marine Remote Sensing  
 Interridge  
 Khaled bin Sultan Living Oceans Foundation  
 Marine Ecology Consulting  
 National Aeronautics and Space Administration  
 National Oceanic and Atmospheric Administration  
 Oregon State University  
 Pacific community  
 Ports Authority Tonga  
 Reef Life Survey  
 Republic of Kiribati  
 Sea Around Us is a research initiative at The University of British Columbia  
 Secretariat of the Pacific Regional Environment Program  
 Solomon Islands Government  
 The University of Queensland  
 The Fijian Government  
 The General Bathymetric Chart of the Oceans (GEBCO)  
 The Nature Conservancy  
 Tonga Cable Limited  
 Tourism Tonga  
 U.S. Geological Survey  
 University of South Florida  
 Vava'u Environmental Protection Association  
 Vlaams Instituut voor de Zee  
 Western & Central Pacific Fisheries Commission  
 Wildlife Conservation Society  
 World Wildlife Fund  
 Zoological Society of London

## Organisation Website

<http://www.aquamaps.org/search.php>  
<http://www.csiro.au/>  
<https://www.cbd.int/>  
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<https://www.livingoceansfoundation.org/>  
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