A porcelain crab (*Neopetrolisthes maculatus*) living inside an anemone at Santo Island // Joe Lepore

## Blue Prosperity Vanuatu

# 2023 Coral Reef Study

## FINAL SCIENCE REPORT

LONG GOD YUMI STANAP

BLUE PROSPERITY VANUATU

WAITT INSTITUTE

SCRIPPS INSTITUTION OF OCEANOGRAPHY

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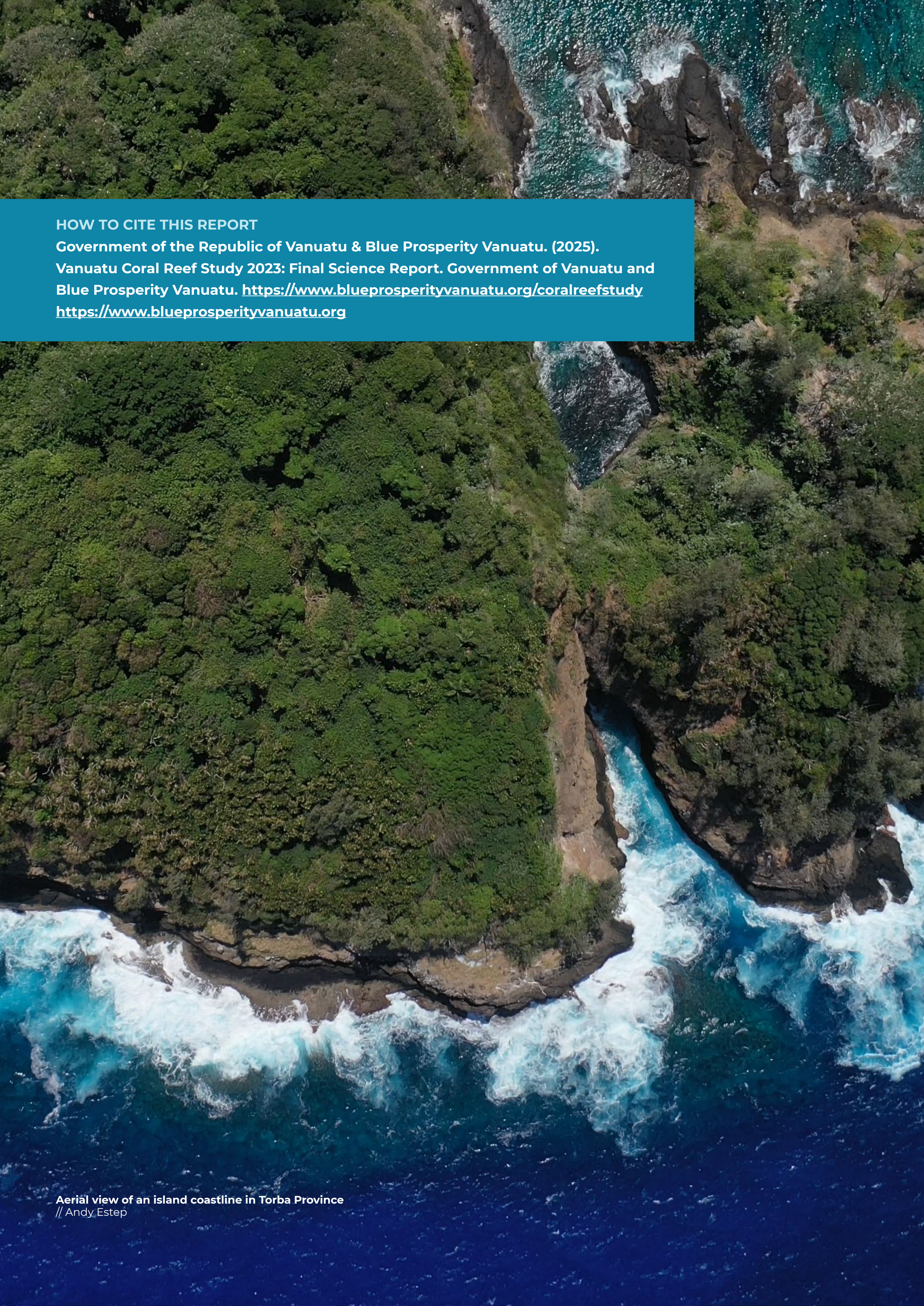

**Aerial view of an island coastline in Torba Province**
// Andy Estep

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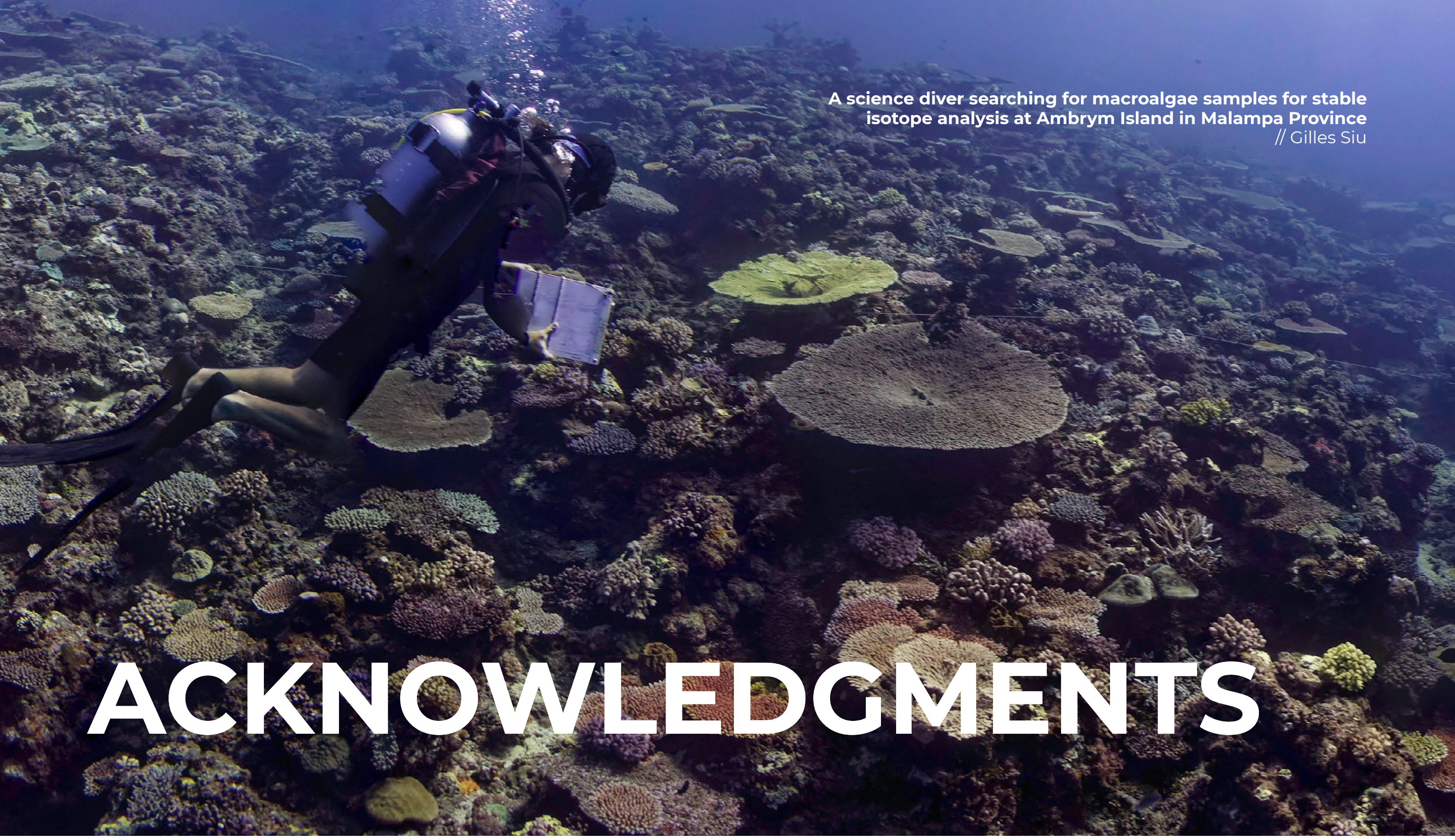

A science diver searching for macroalgae samples for stable isotope analysis at Ambrym Island in Malampa Province
// Gilles Siu

# ACKNOWLEDGMENTS


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**Sompert Gereva**
**June Brian-Molitaviti (Co-PI)**
**Ada Sokach**
**Hudson Feremaito**
**Jeremie Kaltavara**
**Rocky Kaku**

Vanuatu Fisheries Department

**Toney Tevi**
**Steve Hango (Co-PI)**
**Nastasia Shing**
**Nazymento Sine**

Maritime Boundaries and Ocean Affairs Division

**Rolenas Tavue Baereleo**
**Dean Wotlolan (Co-PI)**

Department of Environmental Protection and Conservation

**Ana Ciriyawa**
**Ellian Bangtor**
**Virana Bogiri**

Blue Prosperity Vanuatu

**Fabrice Billandon**

Big Blue Vanuatu

**Apete Dabea**

Lomani Gau

**Gilles Siu**

CRIOBE

**Karen Stone**

Vava'u Environmental Protection Association

**Teddy Fong**
**Rosemary Dautei**

USP Institute of Applied Sciences

**Elena Oussatcheva**

M/Y Plan b

**Gabriel Turner**

Blue Prosperity Coalition Consultant

**Andrew Estep (Co-PI)**
**Ellen Spooner**
**Jenny Lemmons**
**Joe Lepore**
**Laura Frank**
**Lorea Dandoy**
**Matt Pauvfe**
**Michael Dessner**
**Shayna Brody**

Waitt Institute

**Will McClintock**
**Peter Menzies**
**Abby Meyer**

UCSB McClintock Lab

**Katie Lubarsky**
**Anela Akiona**
**Stuart Sandin (Global Co-PI)**
**Jessica Levenson**
**Brian Zgliczynski**
**Chris Sullivan**
**Nicole Pedersen**
**McClaran Shirley**
**Emma Flattery**
**Kelly Tseng**
**Ahmi Cacapit**
**Lia Garvey**
**Woo Jae "Jimmy" Chung**

Scripps Institution of Oceanography

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**A science diver taking photos of the reef at Torres Islands in Torba Province**
// Joe Lepore

**Science divers at work: Hudson Feremaito (top), Ada Sokach (middle), Steve Hango (bottom)**
// Joe Lepore

# LIST OF KEY TERMS

***In alphabetical order***

**Anthropogenic stressors**: Human activities that can harm nature

**Baseline data**: Information collected at the beginning of a survey or project to serve as a reference point for future comparisons

**Belt transect**: A survey method where scientists record animals or plants found within a fixed-width area along a straight line.

**Benthic community composition (or benthic cover)**: What covers the ocean floor, such as sand, rocks, corals, or seaweed

**CCA (Crustose Coralline Algae)**: Hard, encrusting red algae that helps stabilize reefs and promote coral settlement

**CBFM (Community-Based Fisheries Management)**: A fisheries management model involving local governance with national support

**Coral bleaching**: A phenomenon when corals become 'sick' and lose their colors, appearing white or pale, often triggered by environmental stressors like warming water temperatures

**Coral cover**: How much of the ocean floor is covered by living corals

**Coral diversity**: Number of different types of corals in one place

**Coral genera**: Different groups or types of coral

**Corallivorous**: Animals that eat coral

**Coral recruitment**: When baby corals (tiny coral animals) start growing on the reef. Over time, baby corals can grow into larger colonies and help rebuild or expand coral reefs.

**Crown-of-Thorns Seastar (COTS)**: A coral-eating seastar known for causing large-scale reef degradation during outbreaks

**Detritivores**: Animals that eat dead plants and animals

**Endangered species**: Animals that face a very high risk of extinction in the wild

**Exclusive Economic Zone (EEZ)**: An area of ocean a country is in charge of, typically extending 200 nautical miles from the coast

**Export-based fisheries**: Catching sea animals to sell to other countries

**Fish density**: Number of fish in a certain area

**Fish diversity**: Number of different species of fish in a certain area

**Fish biomass**: Total weight of fish in a certain area

**Fleshy macroalgae**: Large, soft-bodied seaweeds that typically grow attached to the ocean floor

**Forereefs**: The part of the reef that faces the open ocean

**Fringing reefs**: Reefs that grow close to the shore

**Herbivores**: Animals that eat only plants or algae

**Hypoxia**: A condition where oxygen levels in the water become dangerously low, making it difficult for marine life to survive

**Juvenile corals**: Baby corals that are just starting to grow (typically 1-5 cm in diameter)

***Kastom***: Traditional knowledge and practices of Vanuatu

**Lagoon formations**: Shallow water areas inside reefs or islands

**Lower carnivores**: Smaller piscivores (fish that eat other fish) and invertivores (fish that primarily consume invertebrates) such as wrasses, triggerfish, etc.

**Macroinvertebrates**: Animals like sea cucumbers, clams, or crabs that do not have a backbone

**Marine spatial planning (MSP)**: A process used to plan the use and development of coastal and marine areas. This is a public, stakeholder-driven and science-based process that involves mapping out different activities and uses in a specific marine area, such as shipping lanes, fishing grounds, and renewable energy sites, and then determining how they can best coexist and be managed sustainably.

**Marine tenure**: Rules about who can use certain parts of the ocean

# LIST OF KEY TERMS (CONT.)

***In alphabetical order***

**Mass spectrometry**: Analysis by a machine that measures tiny parts of chemicals, identifying and quantifying molecules based on their mass-to-charge ratio

**Mosaic plot**: A big image made from many small photos of the reef

**Nitrogen sources**: Places where nitrogen comes from, like the atmosphere and/or fertilizers

**Nutrient runoff**: When rain washes nutrients from land into the ocean

**Overfishing**: Catching too many fish faster than the fish can reproduce or grow back.

**Restocking**: Putting animals back into the ocean to help their numbers grow

**Ribbon reefs**: Long, narrow reefs that look like ribbons

**Rugosity**: The structural complexity of the reef's surface, or how bumpy or rough the reef is.

**Rugosity ratio**: A number that shows the complexity of the reef surface. For example, the more cracks and caves a reef has (for fish to hide in), the higher the rugosity ratio.

**Photoquadrat**: An underwater photo of the ocean floor used to study what is living there

**Planktivores**: Animals that eat tiny organisms floating in the water called plankton

**Platform reefs**: Flat reefs that grow in the middle of the ocean.

**Point cloud**: A 3D image made from points that shows what the reef looks like

**Stable isotope**: A tiny part of a chemical that helps scientists figure out where pollution or nutrients come from

**$\delta^{15}N$**: A measurement that shows where nitrogen in the water comes from

**Sewage pollution**: Dirty or polluted water from toilets, sinks, and other sources that can end up in the ocean

**Size frequency distribution**: A chart showing how big or small animals are in a group

***Tabu erias* (or tabu areas)**: Places where people are not allowed to fish so nature can recover

**Tectonic uplift**: When the earth pushes land or reefs up from below

**Top predators**: Larger fish that eat other fish, such as larger groupers, snappers, and barracudas

**Transect**: A line used to study what is living along it

**Trophic group**: A group of animals that eat similar things

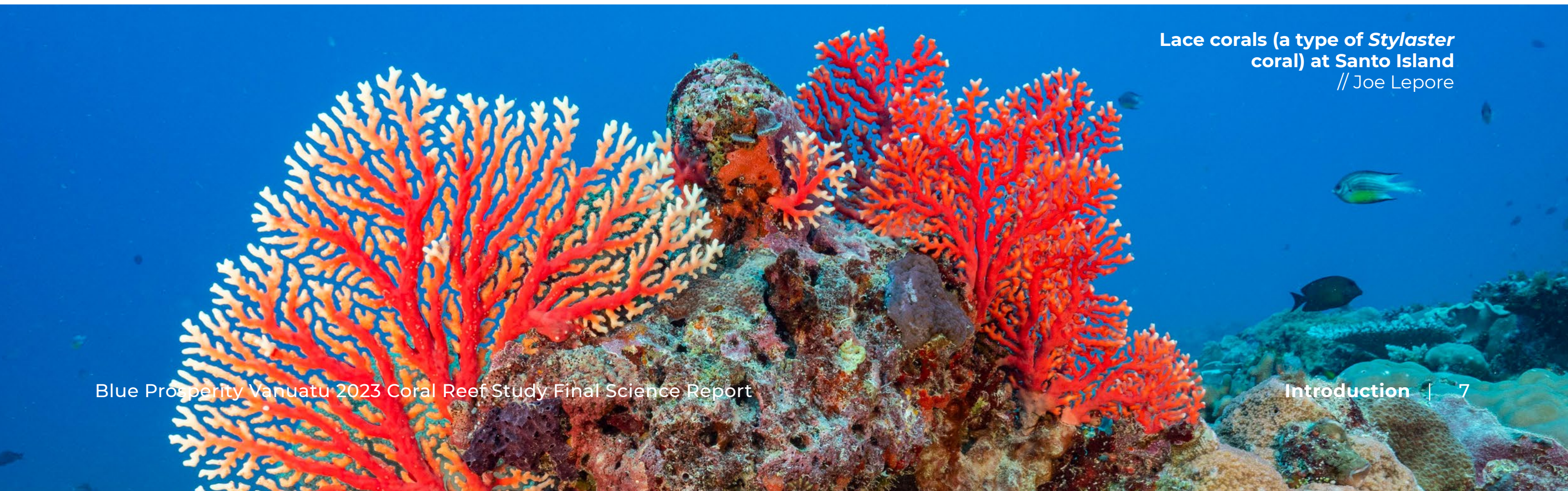
**Turbidity**: How cloudy or muddy the water is

**Turf algae**: Short, fuzzy seaweed that grows like grass on the reef

**Upwelling events**: When deep ocean water comes up to the surface and brings nutrients

**Volcanic atolls**: Ring-shaped islands made from coral growing around a volcano

**Vulnerable species**: Animals that are at risk of becoming endangered



**Lace corals (a type of *Stylaster* coral) at Santo Island**
// Joe Lepore

Community members on a traditional canoe at Epi Island // Andy Estep

# FOREWORD

As the Minister responsible for Fisheries, Oceans, and Maritime Affairs of the Republic of Vanuatu, I am proud to share this milestone report and results from one of the first comprehensive coral reef assessments ever undertaken across our nation. From 1–21 September 2023, the Government of Vanuatu, in partnership with Blue Prosperity Vanuatu, local NGOs, coastal communities, and international collaborators, conducted a nationwide Coral Reef Study to assess the health of our coral reefs, reef fish, invertebrates, and water quality across all six provinces.

This research effort reflects our deep commitment to protecting Vanuatu's most valuable asset—our ocean. Our nation comprises of more than 80 islands, but our identity, our economy, and our very survival are tied to the vast ocean that surrounds us. The ocean is our source of food, our connection between islands, and our foundation for *kastom* and cultural identity.

As part of the Blue Prosperity Vanuatu program, this study provides new tools to support what our people have always known: If we respect the ocean, the ocean will respect us.

The findings in this report will serve as a baseline to guide sustainable coastal planning. This baseline will further support the development of our Marine Spatial Plan (MSP)—a process that integrates the best available science with traditional knowledge and values. By basing marine decision-making in both ecological evidence and *kastom* practices, we can reinforce the role of chiefs, communities, and customary marine tenure in managing our marine resources.

Our traditional reef closures, or tabu erias, have long been a successful model of marine management. This study will strengthen these systems with new knowledge and a clearer picture of the state of our reefs, helping ensure that they remain healthy and abundant for the future.

I extend my deep appreciation to all those who made this expedition possible—the Ministry of Fisheries, Oceans, and Maritime Affairs, Waitt Institute, Blue Prosperity Vanuatu program, our community leaders, and all participating scientists and crew. Let this report be both a tool to guide us and a symbol of our shared responsibility to protect our ocean.

Together, we carry forward a legacy of ocean stewardship—guided by kastom, informed by science, and inspired by the needs of future generations.

**Hon. Jack Norris Kalmet**
Minister of Fisheries, Oceans, and Maritime Affairs for Vanuatu

Mi gat hona ia blong givim long yufala ol risal blong ripot we hemi kam out long wan saksesful stadi blong ol rif we e tekem ples long klosap evri aelan long kaontri. Olsem Minista risponsibol blong Fiseries, Osen mo Maritime Affairs, mi hapi tumas long bigfala wok ia we e bin tekem ples. Long Septemba 1st -21st long yia 2023, Gavman blong Vanuatu wetem Blue Prosperity Vanuatu, ol NGO blong Vanuatu, ol jifs mo komuniti, mo ol partner long pasifik oli wok tugeta blong mekem stadi ia long ol korel rif blong kaontri. Stadi ia e fokas long helt blong ol korel rif, ol rif fish, ol sel fis ol nara kaen marine laef , ol nara kaen laef lo solwora fis blong rif, ol invertebrate mo kwaliti blong wota long olgeta six provins.

Stadi ia i soem strong tingting blong yumi blong lukaot gud wan long ol impoten risos blong kaontri we hemi solwota blong yumi. Vanuatu i gat ova long 80 aelan, be yumi dipen bigwan long solwota blong givhan lo laef blong yumi, ekonomi blong yumi, mo fiuja blong yumi. Solwota hemi source blong kakae, hemi konektem ol aelan blong yumi mo hemi foundesen blong kastom mo kalja blong yumi.

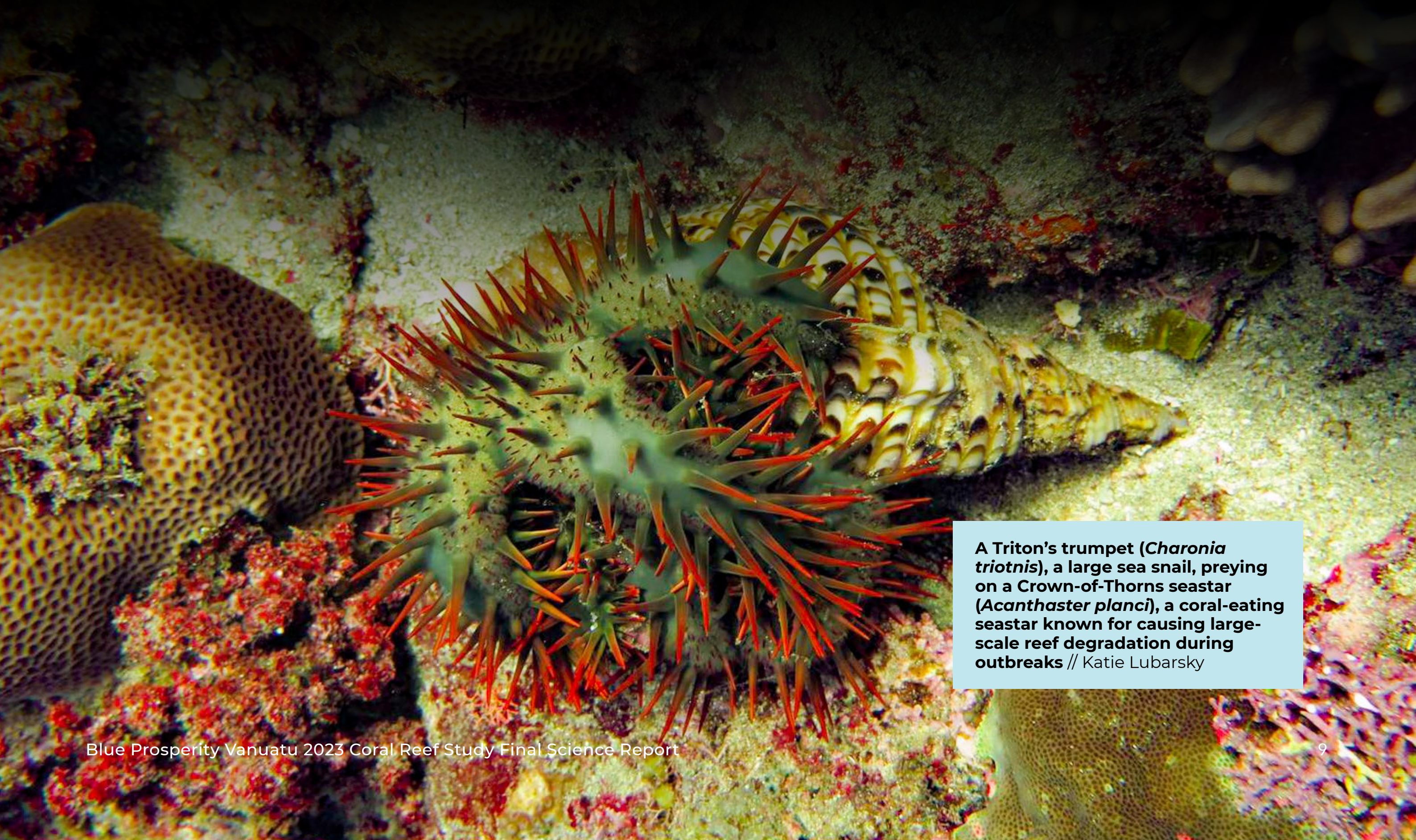
Stadi ia hemi part blong Blue Prosperity Vanuatu prokram we i provaedem ol niufala tul blong sapotem save blong ol man long solwota. Sipos yumi rispektem solwota, solwota bae i rispektem yumi tu.

Ol risal blong ripot ia bae e kam baseline blong sapotem planning blong coastal eria blong yumi. Baseline ia bae i sapotem tu developmen blong Marine Spatial Plan (MSP)—wan proses we i joinem saens wetem kastom save mo ol valiu blong yumi blong planem gud spes long solwota blong yumi.

Ol kastom tabu eria blong yumi oli ol saksesful model long manejmen blong spes long solwota. Stadi ia bae I givim plante niu infomesen long kondisen blong rif blong yumi blo e helpem yumi long fiuja.

Mi wantem talem bigfala tok tankiu blong mi long evriwan we oli mekem ekspedisen ia i saksesful—Ministri blong Fiseris, Osen mo Maritime Affairs, Waitt Institute, Blue Prosperity Vanuatu program, ol lida blong komuniti, mo olgeta saentis mo kru blong ship we oli pat blong stadi ia. Ripot ia bae e stap olsem wan tul blong givim rod long yumi mo olsem wan saen blong resposibiliti blong yumi evriwan blong lukaot gud long solwota blong yumi.

**Hon. Jack Norris Kalmet**
Minista blong Fiseris,
Osen mo Maritime Affairs



**A Triton's trumpet (*Charonia triotnis*), a large sea snail, preying on a Crown-of-Thorns seastar (*Acanthaster planci*), a coral-eating seastar known for causing large-scale reef degradation during outbreaks** // Katie Lubarsky

**A clownfish hiding behind bubbletip anemone in Maewo Island** // Gilles Siu

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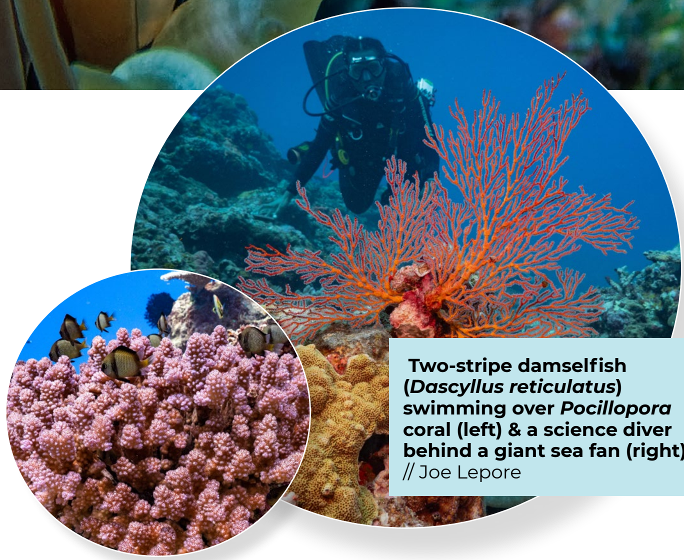
# EXECUTIVE SUMMARY

## (ENGLISH)

From 1–21 September 2023, the Government of Vanuatu, in partnership with the Waitt Institute through Blue Prosperity Vanuatu, conducted the most extensive coral reef survey in the nation's history.

**Covering 109 sites across all six provinces**, this study provides critical baseline data to guide Vanuatu's marine protection and sustainable ocean management efforts.



**Two-stripe damselfish (*Dascyllus reticulatus*) swimming over *Pocillopora* coral (left) & a science diver behind a giant sea fan (right)** // Joe Lepore

**Variety of coral at Santo Island in Sanma Province** // Joe Lepore

### Vanuatu is one of the most disaster-prone countries in the world.

Positioned on the edge of the Pacific tectonic plate and within the tropical cyclone belt, it frequently faces earthquakes, volcanic eruptions, and powerful storms. **Just six months before this survey, twin cyclones Judy and Kevin struck Vanuatu within 48 hours of each other**, passing directly over Tafea and Shefa Provinces at peak intensity. **During the study, scientists observed lower coral cover in Tafea and Shefa provinces**, which may be linked to those recent cyclones, though this cannot be confirmed. They also saw potential signs of storm damage, including fallen trees on reefs and overturned coral — highlighting the constant pressure these ecosystems endure.

## REEF FISH

**The survey recorded 448 species of reef fish.** Fish were numerous (on average, about 3.7 individuals per square meter) indicating vibrant fish communities. However, fish biomass was moderate, with many small-bodied fish and very few top predators; only two sharks were recorded across all sites studied. Herbivores like parrotfish and surgeonfish were the most prevalent, playing a crucial role in keeping algae in check and supporting reef health.

***Octocoral* coral (left) & Whitebelly damsel (*Amblyglyphidodon leucogaster*) (right)**
// Gilles Siu

## WATER QUALITY

**No evidence of sewage pollution was detected on coral reefs at 10 meter depths, even near urban centers.** Vanuatu's reefs grow close to the shore and quickly drop off into deep water. This likely plays a role, as runoff is swept away by currents from the islands or into deep water. This is not to say urban and agricultural runoff are not having an impact on coastal ecosystems. Testing closer to shore is recommended.

**Full view of *Acropora* coral (top) & a close-up view (bottom)**
// Joe Lepore & Gilles Siu

## CORAL COVER

**Despite the damage from recent storms, Vanuatu's reefs showed remarkable signs of resilience.** Coral cover averaged about 20% across the country, which is considered moderate by regional standards. Coral diversity was high, with 51 genera recorded. Most encouraging was the abundance of juvenile corals (approximately 11 per square meter), signaling strong potential for natural recovery of Vanuatu's damaged reefs, if conditions remain favorable for coral growth. Vanuatu's reefs also have relatively high structural complexity (mean rugosity of 1.6), providing important habitat for fish and invertebrates and helping support reef resilience.

## INVERTEBRATES

**A green snail (*T. marmoratus*)**
// Ada Sokach

**Commercially important invertebrates such as sea cucumbers, trochus, and green snails were present but sparse.** Sea urchins, key grazers that help prevent algal overgrowth, were relatively abundant. The destructive crown-of-thorns seastar was rare nationwide.

**Importantly, Vanuatu's long tradition of community-based marine management provides a strong foundation for the future.**
With its history of kastom marine tenure or traditional governance and growing marine spatial planning efforts, Vanuatu is well-positioned to build resilience against climate change and natural disasters.

**By combining traditional knowledge with science, Vanuatu can protect its reefs for generations to come.**

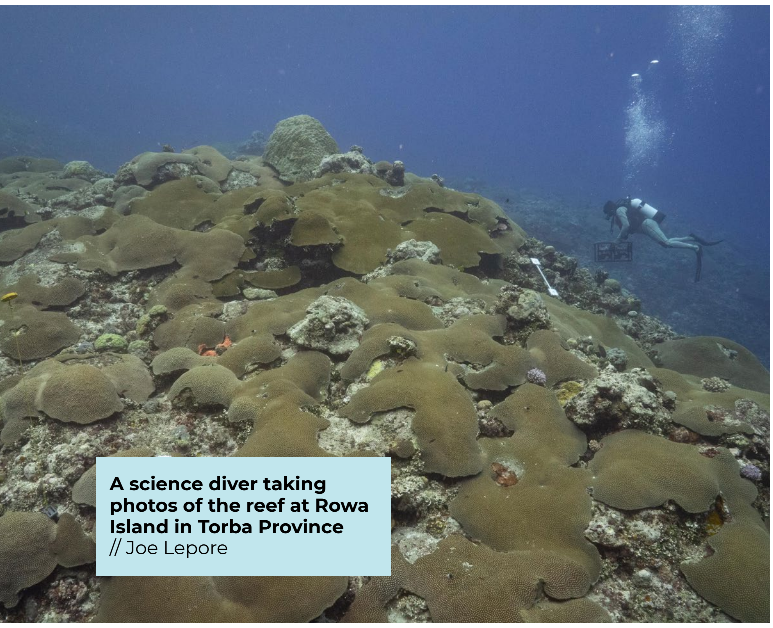
A Whitetipped nudibranch (*Coryphellina exoptata*) at Santo Island in Sanma Province
// Gilles Siu

# 01 EKSEKUTIF SAMARI
## (BISLAMA)

Long Septemba 1st -21st long yia 2023, Gavman blong Vanuatu wetem Blue Prosperity Vanuatu Program thru long sapot blong Waitt Institute oli wok tugeta blong mekem wan stadi long ol korel rif blong kaontri.

**Stadi ia kaveremap 109 sites long ol six provins.** Stadi ia e hemi givim baseline data mo infomesen long hao blong yumi protektem mo manejem ol risos long solwota blong yumi.

A crinoid, commonly known as a feather star, sitting on top of a *Pocillopora* coral
// Gilles Siu



A science diver taking photos of the reef at Rowa Island in Torba Province
// Joe Lepore

**Posisen blong Vanuatu long wol e soem se hemi vulnerable long ol natural disasta.** Vanuatu e staun antap lo end blong Pacific tectonic plet mo i stap insaed long belt blong tropikol saeklon, mo ie gat hae janis blong fesem ol etkwek, mo huriken. Six manis bifo long stadi ia, tufala saeklon Judy mo Kevin tufala ie hitim Vanuatu long 48 hour nomo mo eye blong tufala ie pas stret ova long Tafea mo Shefa Provins. Long taem blong stadi ia, ol saentis oli luk se korel cover ie low moa long Tafea mo Shefa provins. Hemia ie save gat link wetem tufala saeklon ia we ie bin kam pass ova long eria. Oli luk tu sam saen blong damej blong strong wind, olsem ol stampa blong bigfala wud we oli foldaon long rif, tu ol korel we oli tanem. Tufla exampol ya emi stap soem wanem kaen jalens nao we laef long solwota ie stap fesem.


Close-up view of Tree coral (*Dendronephthya spp.*)
// Gilles Siu

**Ol saentist oli recordem wan total blong 448 difren kaen blong rif fis.** Fis emi kat plante (long on ples we oli daeva ie kat kolosap 3.7 fis lo wan square mita). Emi stap soem se ie kat hae namba blo fis long ol ples ya.

**Ol saentis oli jekem kwaliti blong wota long evri site mo tu long ol eria klosap long town mo ripot i showem se i no gat toti wota or pollution long ol korel rif.** Emia emi from se ol rif long ol aelan blong yumi oli short mo dip ples emi stap kolosap tu, mekem se toti we ie kam long graon, solwota ie pusum ie ko long dip ples. Stadi ia i rekomendem blong i nid blong gat moa wok long sho long fiuja folem ol impakt blong agrikalja long solwota.

**Nomata long damej blong ol saeklon olsem tuflala twin saeklon Judy mo Kevin we e afektem full kaontri blong yumi, ol rif blong Vanuatu oli soem gudfala saen blong gro gud.** Laef korel emi kavremap plante ples lo kantri, minim se emi semak lo sam nara kantri lo region. Emi emi wan gudfala nius blong yumi we yumi stap fesem plante saeklon. Ie kat 51 difren kaen famle blo korel we oli bin finem.

Emi gud tumas tu blo finem plante pikinini blong korel (11 olgeta lo wan square mita), minim se rif blong Vanuatu ie stap gro gud mo olgeta rifs we ie damej emi gro gud tu. Be ie dipen tu spos kondisen blo solwata ie stap gud. Ol rif blo yumi oli kat diffren kaen shape mo size, emi minim se ie kat plante haos blong fis, selfis mo ol nara kaen laef long solwota.

**Ol saentis oli recordem wan low namba blong ol risos blong yumi olsem ol si kukamba, troka, mo grin snel.** Ie gat hae namba blong ol sea urchin, we oli ol impotan animol blong solwota from oli kakae nalumlum we ie gro long korel. Risal ie soem tu wan low namba blong posen sta fis– wan animol we ie save damejem ol rif.

**Emi impoten blo yumi andastan se ol kastom fasin mo practis blong manejem solwota blong yumi, hemi givim wan strong foundesen long ol komuniti blong manejem solwora iko lo fiuja ie stap kam.** From gudfala fasin blo ol kastom rod blo yumi, ie mekem se Vanuatu ie stap long wan gudfala ples blong save bildim risiliens agensem claemet jens mo ol natural disasta we ie save kam long fiuja.

**Tu, emi impoten blong fasem gud kastom save wetem science, blong mekem se kantri emi safe protectem ol rif blong ol pikinini blong fiuja we ie stap kam.**


Aerial view of Emae Island in Shefa Province
// Andy Estep

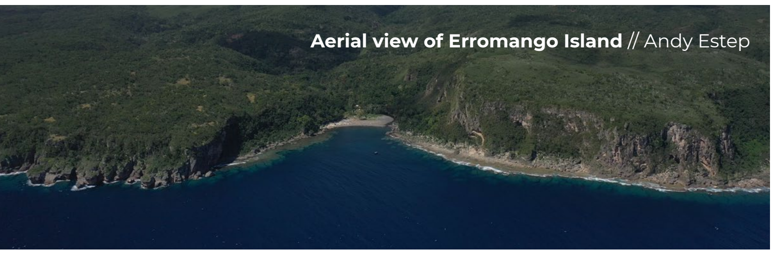
Aerial view of Maewo Island // Andy Estep

02

# INTRODUCTION

## GEOLOGY & DEMOGRAPHICS

Vanuatu is a South Pacific island nation comprising approximately 80 islands stretching over 1,300 km from north to south. With a land area of about 12,200 km² (Amos 2007), approximately 98% of its territory is ocean (Sustainable Fisheries Group 2019). Of this large marine area, 448 km² are coral reefs and lagoons (Amos 2007, Sustainable Fisheries Group 2019). Vanuatu has a variety of reef types (fringing, platform, ribbon reefs, volcanic atolls; Chin et al. 2011). Due to rapid tectonic uplift, many of the reef systems lack classical lagoon formations (Ducarme et al. 2023). Because of the country's location on the eastern margin of the Pacific plate, earthquakes and volcanic eruptions are common, and both have significant effects on the geomorphology of Vanuatu's reefs (Sustainable Fisheries Group 2019).



Aerial view of Erromango Island // Andy Estep

Of the country's roughly 300,000 inhabitants (Vanuatu National Statistics Office 2020a), about 94% live within 5 km of the coast (Bhardwaj & Kuleshov 2024) and 78% live in rural areas (Vanuatu National Statistics Office 2020b). Rural populations in Vanuatu rely heavily on fishing and farming for subsistence (Raubani & Arnason 2006, UNDP 2012, Nimoho et al. 2013, Vanuatu Fisheries Department 2019a).

**While traditional subsistence fishing practices have typically encouraged sustainable harvesting, recent demographic changes, such as increasing populations, a move towards cash economies, increased urbanisation, and migration of inland populations towards the coast, have increased pressure on coral reef resources** (David & Cillaurren 1992, David 1994, Léopold et al. 2013, Léopold et al. 2017, Vanuatu Fisheries Department 2019a). While management of Vanuatu's fisheries and marine resources is the responsibility of the Vanuatu Fisheries Department (Raubani et al. 2017, Vanuatu Fisheries Department 2019a), traditional marine tenure plays an important role in marine management. The right of communities to manage resources within their tenure areas is enshrined in several of Vanuatu's legislations, including the Constitution, and has given way to many co-management programs sponsored by the government, NGOs, and other stakeholders, building on science and other traditional management practices (Amos 2007, Raubani & Arnason 2006, Steenbergen et al. 2022).

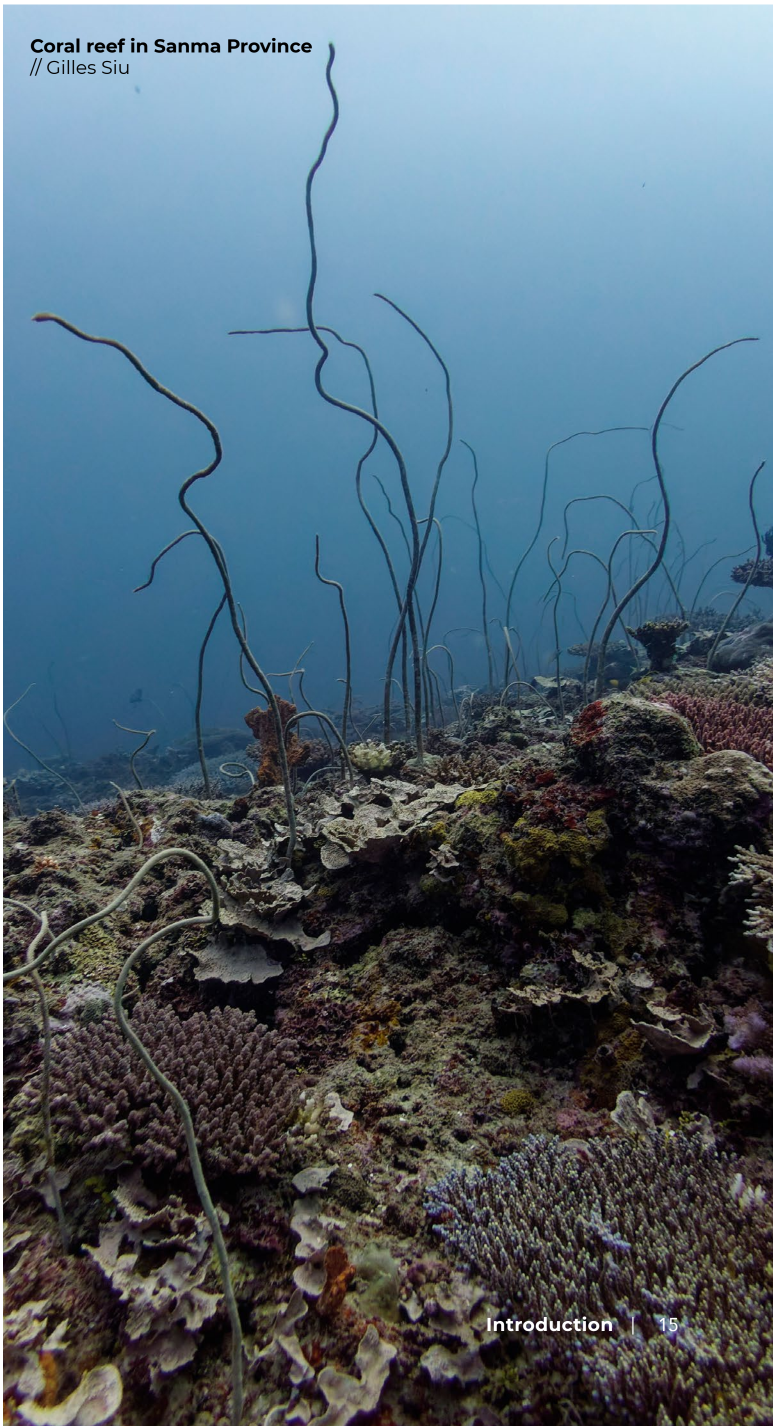
## REEF HEALTH & THREATS

**Coral reefs provide essential ecosystem services (e.g., coastal protection, fisheries habitat, economic opportunities) and nutrition for the citizens of Vanuatu; however, quantitative studies of reef health across the country are sparse.**

Estimates of coral cover are few, and are typically geographically restricted, making generalisations across the country difficult. Of those that exist, estimates of coral cover on Efate range from a low of 13.5%-25% (Dumas et al. 2017, Lovell et al. 2004) to a high of 60-75% at Devils Point (Hill 2004, Lovell et al. 2004). On Epi, coral cover was estimated between <20% to 33% (Pakoa et al. 2008). More commonly, however, reefs have been described using non-standardised qualitative terms such as “healthy,” “fair,” “degraded,” or “poor” (e.g., Amos 2007, Sustainable Fisheries Group 2019) or in comparison to other sites (e.g., “higher,” “lower” or “similar”; Bartlett et al. 2009, Dumas et al. 2010). Due to difficulty in accessing more remote areas of the country, the majority of studies to date have taken place near the urban centers of Port Vila on Efate and Luganville on Santo (e.g., Lovell et al. 2004, Maynard & Done 2008), meaning that the conditions of presumably less impacted reefs are highly understudied. Importantly, no published data on coral recruitment rates or structural complexity of reefs across the archipelago exist.

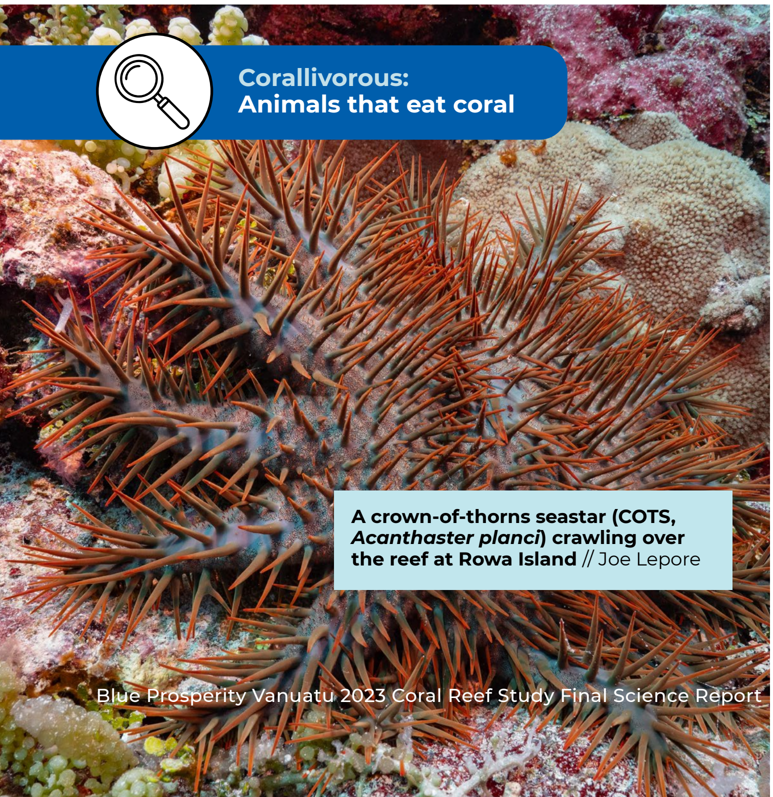
**CORAL RECRUITMENT: When baby corals (tiny coral animals) start growing on the reef. Over time, baby corals can grow into larger colonies and help rebuild or expand coral reefs.**

In contrast, the threats facing Vanuatu’s reefs have been more widely documented. Coral bleaching, caused by climate change and increased sea surface temperatures, was reported in Vanuatu in 1998, 2000-2002, 2008, and 2016 (Amos 2007, Bhardwaj & Kuleshov 2024, Maynard (Maynard & Done 2008). Other studies reference widespread partial or total coral mortality at several sites following bleaching events in the early 2000s (Amos 2007, Raubani & Arnason 2006), but quantitative data remain limited. There are also anecdotal accounts linking bleaching to other reef impacts; for example, the 2016 bleaching event was linked to sudden mass fish deaths and hypoxia in some regions of the country (Bhardwaj & Kuleshov 2024). Statistical modeling case studies from Tanna predict that the health and resilience of reefs in the area will be severely threatened by climate change by 2070 in the absence of effective adaptation measures (Hafezi et al. 2020); however, subsequent studies indicate that ecosystem services can be preserved by implementing sustainable community-based management strategies (Hafezi et al. 2021).



**Coral reef in Sanma Province**
// Gilles Siu

**In addition to these global threats, local threats, such as outbreaks of the corallivorous crown-of-thorns seastar (COTS, *Acanthaster planci*) have been noted on Vanuatu's reefs.** COTS outbreaks of over 4,000 individuals/ha (outbreak threshold = 15 – 300 individuals/ha) have been noted in several locations across the country at various points in time, and damage from these outbreaks has been reported to rival that from major cyclones (Dumas et al. 2015, Sustainable Fisheries Group 2019). For example, an outbreak in Santo killed approximately 15% of corals in Luganville Harbor (Lovell et al. 2004). In addition to causing damage to corals, COTS outbreaks have been reported to disrupt nearshore fishing by women and children in some areas, as fear of injury from COTS spines led to reduced excursions to reef flats (Dumas et al. 2015). However, several communities have mobilised or planned removal efforts in response to COTS outbreaks (Amos 2007, Klint et al. 2012, Tavue et al. 2016, Vanuatu Fisheries Department 2014, Dumas et al. 2015, Raubani et al. 2017, Vanuatu Fisheries Department 2022). In fact, immediately prior to this survey, two removal efforts had recently been completed in Pango and Ifira on Efate, during which hundreds of COTS were culled (Vanuatu Fisheries Department 2022). In some cases, these interventions have removed up to 3.7 tonnes of COTS over the course of a few days (Dumas et al. 2015). While the cause of COTS outbreaks is debated (e.g., Babcock et al. 2016), one Vanuatu-based study shows evidence that nutrients from periodic upwelling events may contribute to outbreaks in this region (Houk & Raubani 2010).



**Corallivorous:**
**Animals that eat coral**

**A crown-of-thorns seastar (COTS, *Acanthaster planci*) crawling over the reef at Rowa Island** // Joe Lepore

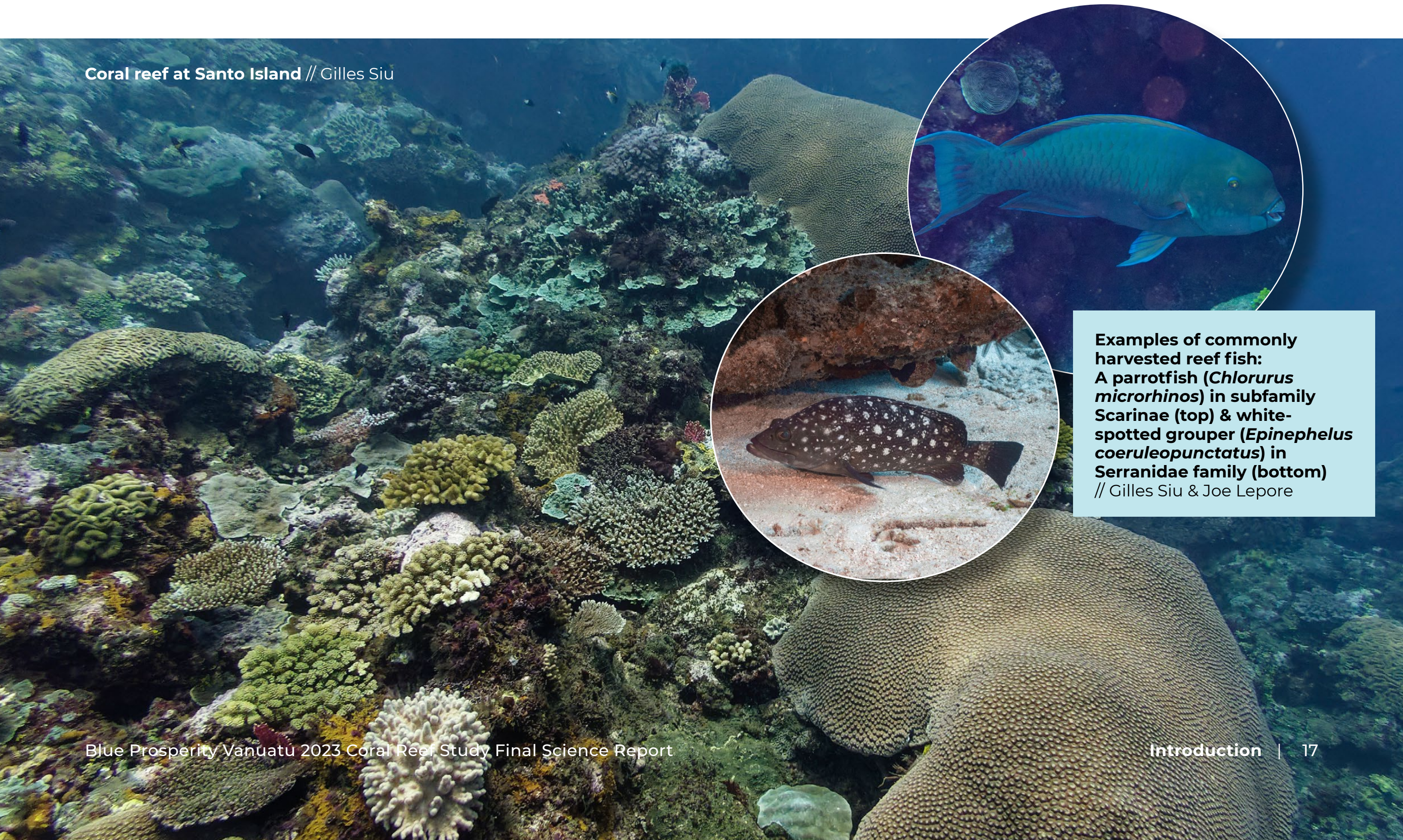
**Coastline of Ambrym Island in Malampa Province** // Andy Estep

**Anthropogenic stressors, such as decreased water quality and unsustainable fishing practices, have been known to affect reefs in Vanuatu as well.** In urban areas, such as Port Vila and Luganville, nutrient levels and turbidity have increased with increasing coastal development and urban populations (Carter 1990, Naviti & Aston 2000, GEF Pacific 2008, Komugabe-Dixson et al. 2019, Devlin et al. 2020, Faivre et al. 2021). For example, extremely high nutrient concentrations (e.g., nitrate >100 µmol/L, ammonium >10 µmol/L), high turbidity and chlorophyll-a concentrations (>30µg/L; Devlin et al. 2020), and strong microbial (e.g., E. coli) contamination frequently exceeding 1000 MPN/100ml have been found in the waters surrounding Port Vila (Faivre et al. 2021). However, these issues are not limited to urban areas, as runoff in rural areas that have been deforested and used for agriculture has also been linked to decreased water quality and reef degradation (Chin et al 2011, Wilkinson & Brodie 2011, Buckwell et al. 2020). Nevertheless, urban sites generally show poorer water quality than nearby rural areas (Lincoln et al. 2021).

# REEF FISH FISHERIES

**Fishing, particularly for subsistence and artisanal purposes, is an important food security, income generating, and livelihood activity across Vanuatu**, with inshore reef and lagoon fisheries providing the main source of protein for rural communities (Amos 2007). Subsistence fishing makes up almost 93% of total small-scale catches (~270,000 tonnes), while small-scale commercial catches make up the remaining 7% (Amos 2007, Léopold et al. 2017). The growth of the rural population in Vanuatu has led to an increase in small-scale catches over time, with a 480% increase from 1950-2014 (Léopold et al. 2017). **Commonly harvested reef fish** include species in the families Lutjanidae (snappers), Serranidae (groupers), Scarinae (parrotfish), Acanthuridae (surgeonfish), and Siganidae (rabbitfish) (Léopold et al. 2017, Komugabe-Dixson et al. 2019). **Export-based reef fisheries mostly focus on invertebrates** such as sea cucumbers and trochus. Green snails were historically part of an export fishery but their collection has been banned since 2005. Additionally, **Vanuatu has a small, export-based aquarium fishery**, targeting ornamental fish, corals, giant clams, and live rock (Raubani & Arnason 2006, Vanuatu Fisheries Department 2009, Léopold et al. 2017, Sustainable Fisheries Group 2019, Gillett et al. 2020).

**Despite the generally small-scale nature of reef fishing in Vanuatu, evidence of potential overfishing and unsustainable fishing practices exist**. Increased urban populations, a shift towards cash-based economies, and access to markets has led to overfishing in villages near urban centers such as Port Vila (Sulu et al. 2002, Lovell et al. 2004, Chin et al. 2011, Léopold et al. 2013, Komugabe-Dixson et al. 2019, Vanuatu Fisheries Department 2019a). In more remote areas, coral reef fishery resources are under less pressure (Naviti & Aston 2000, Lovell et al. 2004). However, with increasing rural populations, even these remote reefs are seeing effects of overfishing, with villagers noting decreased catches for increased effort and noticeable declines in the abundance of targeted fish and invertebrate resources (Johannes 1998, Nimoho et al. 2013, Sustainable Fisheries Group 2019, Andrew et al. 2020, Valentin et al. 2024). This trend is exacerbated by the adoption of newer, more efficient, and often more destructive fishing methods. These include the use of gillnets or mosquito nets, nighttime spearfishing, poison fishing in rare cases, and dynamite fishing historically (Naviti & Aston 2000, Sulu et al. 2002, Chin et al. 2011, Eriksson et al. 2017, Komugabe-Dixson et al. 2019). Importantly, few baseline surveys of reef fish abundance and biomass have been undertaken, so most reports of overfishing of reef fish are inferred from observational or effort-based data.



**Coral reef at Santo Island** // Gilles Siu

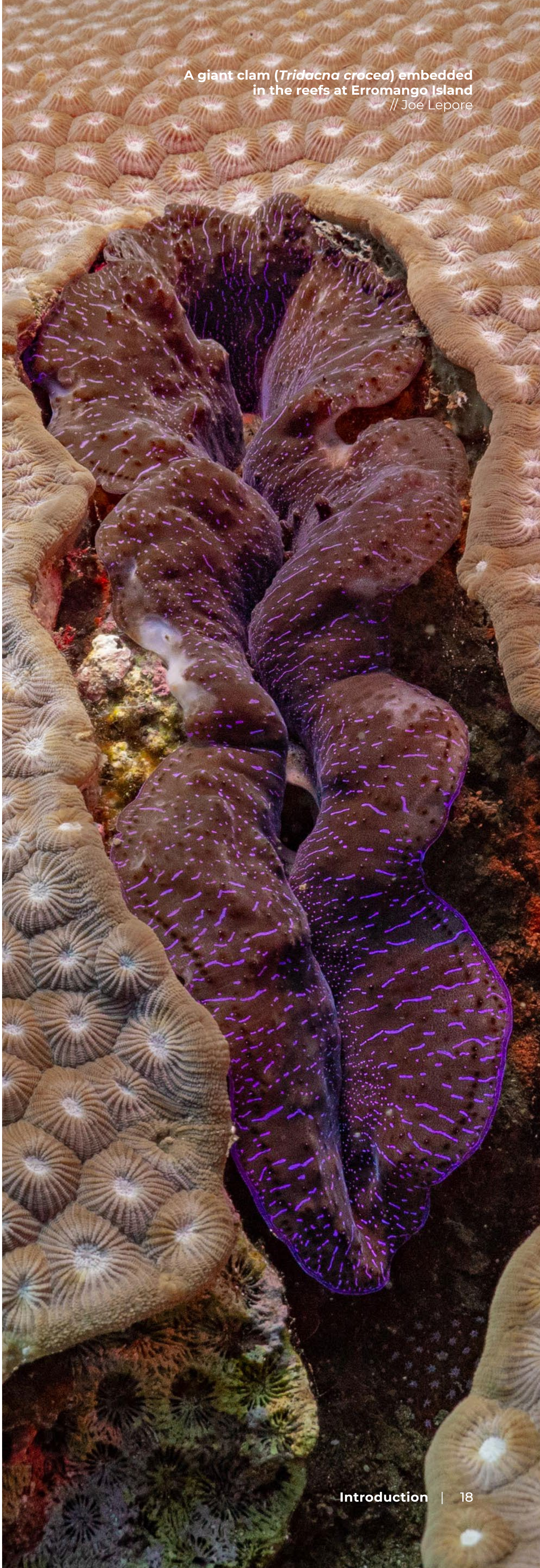
**Examples of commonly harvested reef fish: A parrotfish (*Chlorurus microrhinos*) in subfamily Scarinae (top) & white-spotted grouper (*Epinephelus coeruleopunctatus*) in Serranidae family (bottom)** // Gilles Siu & Joe Lepore

# INVERTEBRATE FISHERIES

**While fishing of reef fish in Vanuatu is mostly for subsistence, coral reef invertebrates support sizable export-based fisheries and are important cash generators for rural communities.**

However, these species are often relatively sedentary and easy to harvest, meaning **overexploitation is common** (Naviti & Aston 2000, Raubani & Arnason 2006, Vanuatu Fisheries Department 2009, Chin et al. 2011, Léopold et al. 2017, Komugabe-Dixson et al. 2019, Sustainable Fisheries Group 2019). The major invertebrate exports are **trochus shell** (*Rochia nilotica*), which is prized for button making and handicrafts, and **sea cucumbers** (exported as bêche-de-mer), which are considered a delicacy in some East Asian countries (Lovell et al. 2004, Raubani & Arnason 2006, Pakoa et al. 2008, Chin et al. 2011, Pakoa et al. 2013, Komugabe-Dixson et al. 2019, Ducarme et al. 2023). **Cultured giant clams** were exported in the early 2000s as part of the aquarium trade; however, harvesting wild specimens for export is banned (Vanuatu Fisheries Department 2009, Mies et al. 2017, Gillett et al. 2020). Similarly, **green snail** (*Turbo marmoratus*), the shell of which is used for decorative inlays, was previously an important export species until harvest was banned in 2005 (Pakoa et al. 2014, Terashima et al. 2018).

In addition to export fisheries, invertebrates also support subsistence fisheries (Sulu et al. 2002, Amos 2007, Valentin et al. 2024), with organisms such as lobsters making up >20% and shellfish making up >30% of the total small-scale catch (David & Cillaurren 1992, David 1994, Naviti & Aston 2000, Léopold et al. 2017). Other invertebrates such as octopus, giant clams and mollusks are common targets of reef gleaning, and are particularly targeted by women for subsistence and small-scale income generation (David & Cillaurren 1992, David 1994, Hickey 2008, Nimoho et al. 2013, Léopold et al. 2017, Andrew et al. 2020, Valentin et al. 2024).



**A giant clam (*Tridacna crocea*) embedded in the reefs at Erromango Island** // Joe Lepore

# CORAL REEF FISHERIES MANAGEMENT IN VANUATU

**Because of their importance and propensity for overharvest, coral reef invertebrates have significantly shaped the landscape of modern coral reef fisheries management in Vanuatu.**

Vanuatu is geographically extensive and culturally diverse, with several remote islands and villages, creating challenges for centralised management of fisheries resources (Hickey 2008, Vanuatu Fisheries Department 2019a). Traditionally, reef management was primarily conducted at the village level, where local communities had tenure over marine resources and managed them as they found appropriate. As western influence increased through the arrival of Christian missionaries, some customary beliefs became eroded, and management slowly transitioned to a more centralised regime (Hickey 2006).

When Vanuatu gained independence from the United Kingdom and France in 1980, the Fisheries Act was issued, further centralising marine management responsibilities (Raubani et al. 2017). For example, in 1982, the Government of Vanuatu, in collaboration with NGOs, launched the Village Fisheries Development Programme (VFDP), which incentivized deep bottom-fish fishing and the development of village fishing cooperatives for the purpose of shifting from subsistence fishing to income generation fisheries (David and Cillaurren 1992). Despite the devotion of millions of dollars in aid to the project, many of the cooperatives dissolved soon after their inception, but pockets of successful deep-bottom fisheries still exist throughout the archipelago (David & Cillaurren 1992, Johannes 1998). Outcomes such as this, along with issues related to the remoteness of communities and the strength of customary tenure traditions, promoted a shift towards **Community-Based Fisheries Management (CBFM)** in Vanuatu, where communities manage their traditional tenure areas with technical and legal support from the central government (Raubani et al. 2017).

**Reef invertebrates were some of the first resources to be managed under CBFM.**
In response to communities noting decreasing stocks of important invertebrates, the Vanuatu Fisheries Department launched an outreach campaign, initially focused on trochus, which provided communities with technical information about sustainable management of this fishery (Johannes 1998, Hickey 2006).

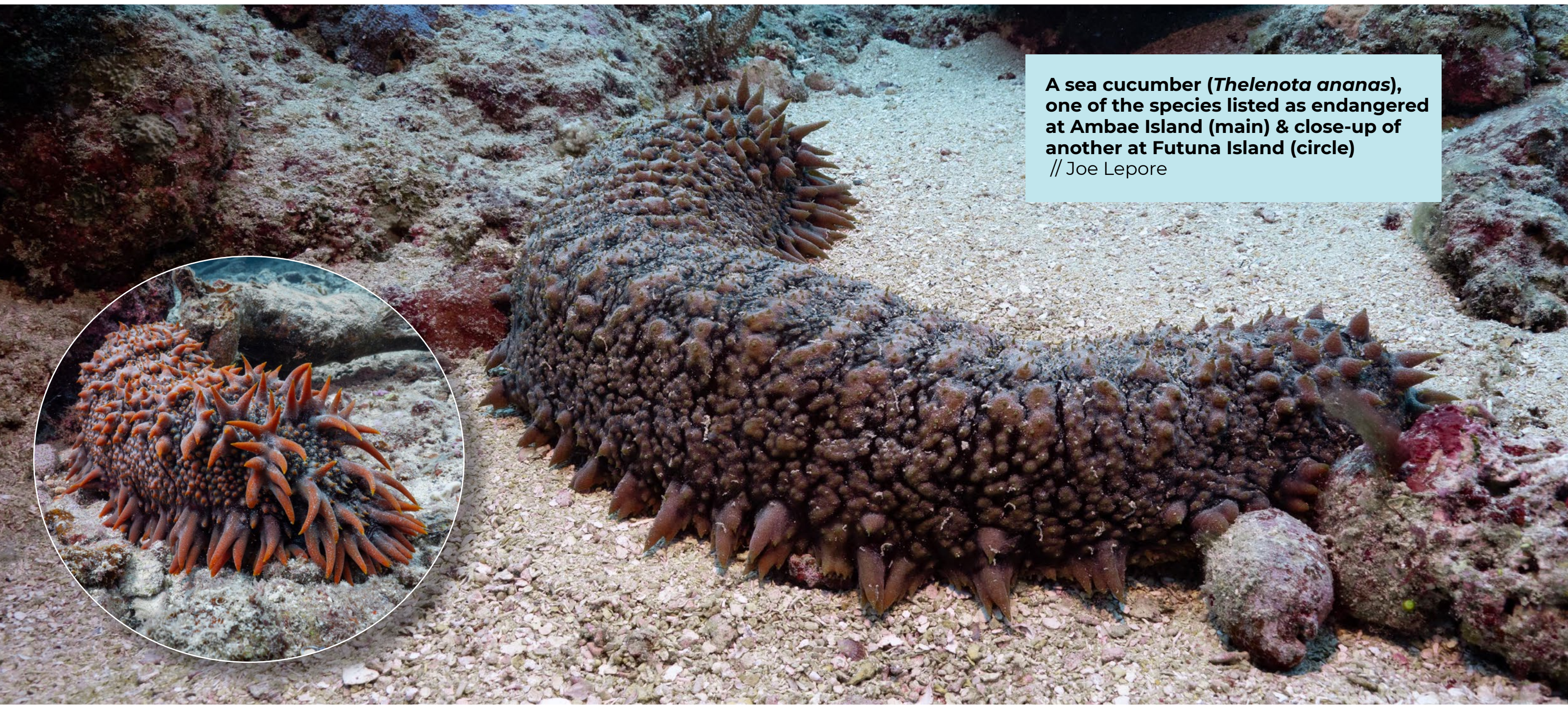
Around the same time, other groups, such as the "Wan Smol Bag" traveling theater group, toured the country with performances about the importance of marine conservation (Nimoho et al. 2013). This information inspired many communities to implement temporary or permanent *tabu erias* (traditional reef closures) in order to conserve important invertebrate species (Johannes 1998, Nimoho et al. 2013).


A Hairy red hermit crab (*Dardanus lagopodes*) at Ambae Island
// Joe Lepore

More recently, the Vanuatu Fisheries Department began formally collaborating with communities to develop official management plans, in which the community outlines management actions formulated based on traditional resource management (TRM), traditional ecological knowledge (TEK) from community elders, and technical expertise provided by the central government (e.g., Vanuatu Fisheries Department 2014). In addition, several nationwide regulations and management plans have been developed for important species, such as sea cucumbers, sea turtles, sea birds, sharks, deep-bottom snappers, tuna, and coconut crabs (*Birgus latro*), to provide consistency across all tenure areas (Tavue et al. 2016, Raubani et al. 2017, Vanuatu Fisheries Department 2019b, Steenbergen et al. 2022).

**Trochus was the first species formally managed under village-based closures, leading the way for other species-specific management measures and future CBFM programs** (Johannes 1998, Hickey & Johannes 2002, Raubani et al. 2017, Steenbergen et al. 2022). Implementation of trochus tabu areas is widespread in Vanuatu, and has been supported by technical advice from the Vanuatu Fisheries Department. In some cases, restocking efforts have been paired with tabu areas to further increase trochus stocks (Hickey & Johannes 2002, Purcell et al. 2004), and CBFM plans have been developed with trochus-specific catch limits (e.g., Vanuatu Fisheries Department 2014). The ecological effects of these interventions have been mixed, with some showing increases in trochus size and density (Purcell et al. 2004, Dumas et al. 2010, Nimoho et al. 2013, Vanuatu Fisheries Department 2014), and others showing little noticeable effect (Lovell et al. 2004, Bartlett et al. 2009, Dumas et al. 2010, Dumas et al. 2017). Nonetheless, these various strategies have helped pave the way for further species-specific management measures. For example, **green snails, which had been fished nearly to extinction in Vanuatu, are often co-managed with trochus in community-based closures**, have been restocked in similar manners, and have been subject to multi-year national harvesting bans in efforts to increase stocks (Johannes 1998, Dumas et al. 2010, Nimoho et al. 2013, Pakoa et al. 2014, Vanuatu Fisheries Department 2014, Terashima et al. 2018, Sustainable Fisheries Group 2019).

**Management of the sea cucumber fishery has also evolved over time.** Sea cucumbers have been harvested in Vanuatu for centuries. This is evidenced by the fact that the name "Bislama," one of the official languages of Vanuatu, is thought to have been derived from the term "bêche-de-mer" (the name for sea cucumbers processed for consumption), which was used in conversations between early European colonists and ni-Vanuatu (Ducarme et al. 2023). **Sea cucumbers are not consumed locally, but are an important export income source** (Raubani 2006, Ducarme et al. 2023). Of the 36 sea cucumber species present in Vanuatu (Ducarme et al. 2023), 23 are commercially harvested through quota management systems (Vanuatu Fisheries Department 2019b). Out of the 23 species, one has been under moratorium (*Holothuria scabra*) and four are currently listed under Appendix 2 of the CITES listings, which recognizes commercial species that may become threatened with extinction unless trade is closely controlled (CITES 2023). Catches peaked in the 1990s but collapsed as stocks were overfished in the early 2000s, prompting a five-year ban on harvesting sea cucumbers in 2008 (Léopold et al. 2013, Pakoa et al. 2013). Surveys conducted at the end of the moratorium found that while some species were showing signs of recovery, many species remained below reference densities for healthy stocks, and a second five-year closure was recommended (Pakoa et al. 2013). The fishery was temporarily reopened in 2015 following Cyclone Pam to allow



**A sea cucumber (*Thelenota ananas*), one of the species listed as endangered at Ambae Island (main) & close-up of another at Futuna Island (circle)** // Joe Lepore communities to generate needed post-disaster income; however, this resulted in a catch volume that was three times the allowable amount, necessitating a revised management strategy (Eriksson et al. 2017, Vanuatu Fisheries Department 2019b, Gillett et al. 2020). In 2019, the Vanuatu Fisheries Department issued the Vanuatu National Sea Cucumber Fishery Management Plan 2019-2024, which aims to manage stocks using a quota-based, adaptive co-management system (Vanuatu Fisheries Department 2019b). Following the inception of the management plan, surveys found that rare and endangered species previously reported as depleted (e.g., *Holothuria fuscogilva*, *Holothuria whitmaei*) were observed in localised dense populations, suggesting some positive effect from closures and management efforts (Ducarme et al. 2023).

**Coral reef at Vanua Lava Island in Torba Province**
// Gilles Siu

**Close-up view of soft tree coral at Pentecost Island**
// Gilles Siu

**Vanuatu has a rich history of marine management, in which local communities are heavily dependent on and involved with the health of their local reefs. Marine protection in the form of local tabu areas is ingrained in Vanuatu's tradition**, and has been modernised to target species important for subsistence and export fisheries. The CBFM approach to reef management is a useful way to incorporate traditional tenure and knowledge principles along with the technical expertise and national reach of the central government, and has shown some promising results. However, limited and sporadic baseline data makes it difficult to assess the efficacy of management interventions or the abundance of key marine resources. Additionally, the small-scale and often temporary nature of local tabu closures limits their efficacy in some cases.

The Government of Vanuatu, in collaboration with the Waitt Institute, University of the South Pacific, and Scripps Institution of Oceanography, conducted a nationwide coral reef assessment survey aimed at collecting baseline data on reef health across the archipelago, with the intent of using this information to support government programming on managing all marine resources Vanuatu. This survey, for which this was generated, was the most geographically extensive, standardised reef assessment conducted in Vanuatu to date, and provides data on the health of benthic, fish, and invertebrate communities and water quality across all six provinces. The data collected during this survey will serve to fill in gaps in understanding regarding reef health in Vanuatu and to support decision-making for future coral reef management initiatives.

# 03

# SURVEY METHODOLOGY

**A science diver gathering photos of the reef for 3D reef model production** // Joe Lepore

The data presented in this report were collected during the field expedition, undertaken from September 1-21, 2023.

During the expedition, researchers conducted surveys of reef fish populations, benthic coral reef communities, marine macroinvertebrates, and water quality parameters. A total of **109 sites were surveyed** across 21 islands, spanning all six of Vanuatu's provinces (Figure 1).

**A detailed summary of survey methods can be found in Appendix 1**, and a summary of the sites surveyed with associated metadata can be found in Appendix 3.

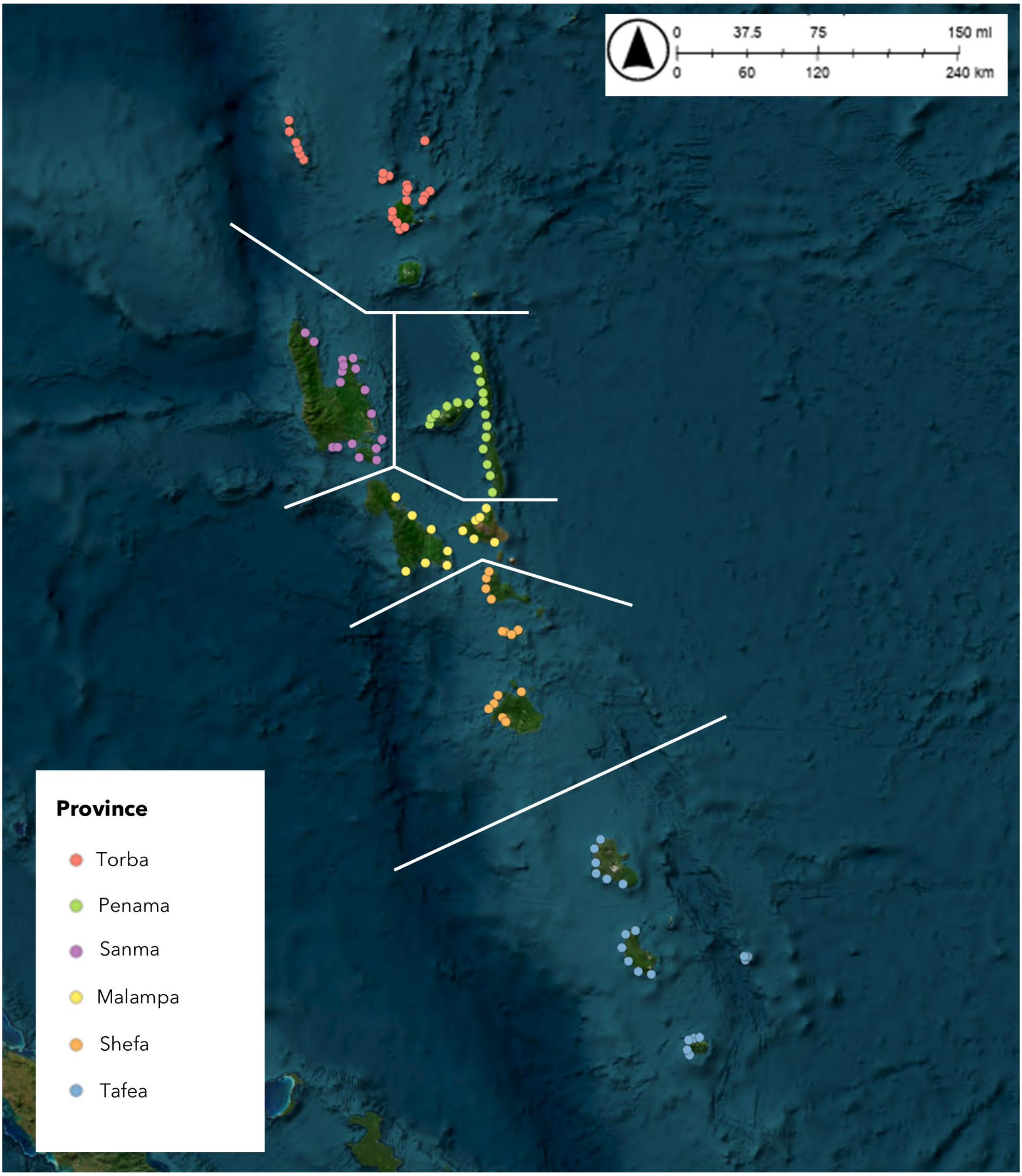



**FIGURE 1:** *Map of survey sites*

**Sites were selected with the goal of maximising coverage across Vanuatu**, while including priority sites identified by the Ministry of Foreign Affairs, Vanuatu Fisheries Department, and the Department of Environmental Protection and Conservation. Sites were selected to include **various locations within each province**, and leeward sites were selected in order to **maintain safe diving conditions and to minimise variability**.

No surveys were undertaken in lagoons. River outfalls and estuaries were avoided. Sites were spaced at least 2km from one another to avoid psuedoreplication. On larger islands, a minimum sample size of six sites was targeted, and on smaller islands, at least three sites were surveyed when possible. Communities were consulted prior to surveys being conducted within traditional tenure areas.

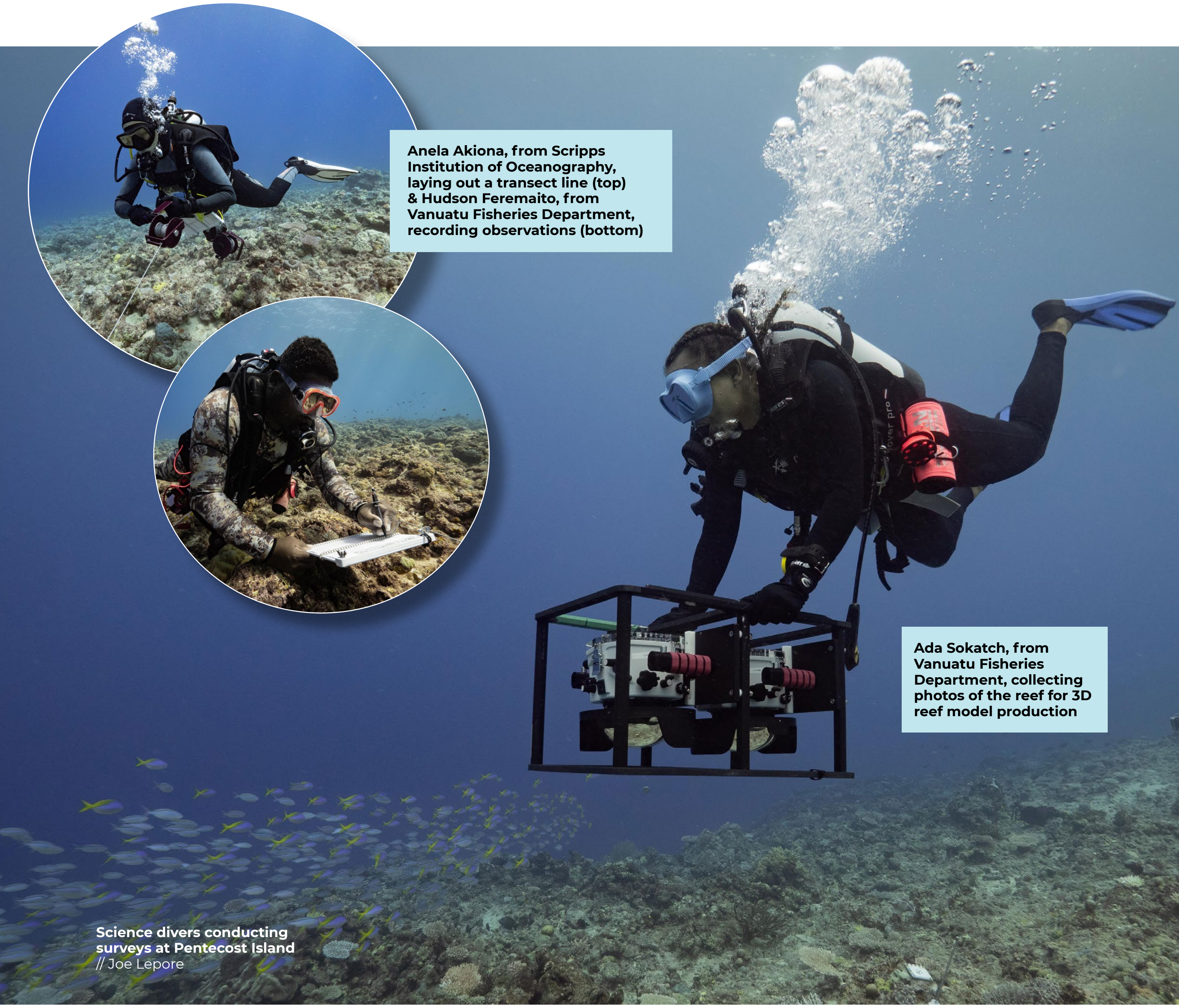
**At each site, the following indicators of reef health were surveyed:**

- reef fish density, diversity, and biomass;
- benthic community composition, including percent cover and diversity of benthic taxa;
- the density and diversity of juvenile corals (coral recruitment);
- reef rugosity (structural complexity); and
- the abundance and diversity of benthic macroinvertebrates.

**Algal samples** were also collected (when present) at each site to be utilised for stable isotope analysis, which provides information on the origin of nutrients at the collection sites.

**Survey methods were designed to collect data for each indicator, and in some cases to gather specific information regarding species of ecological and/or economic significance.** **All surveys were undertaken at a depth of 10 metres (m)**, and sites with continuous or nearly continuous hard bottom were prioritised where possible in order to minimise variability in community composition between sites. A brief summary of the survey methods used can be found in Table 1, and full methods can be found in Appendix 1.

**Temperature loggers** were deployed at a subset of sites (Appendix 3) for collection at a later date. No temperature data is included in this report.



**Anela Akiona, from Scripps Institution of Oceanography, laying out a transect line (top) & Hudson Feremaito, from Vanuatu Fisheries Department, recording observations (bottom)**

**Ada Sokatch, from Vanuatu Fisheries Department, collecting photos of the reef for 3D reef model production**

**Science divers conducting surveys at Pentecost Island**
// Joe Lepore

**TABLE 1**: Summary of key metrics, units, and methods used to measure reef health in this study.

| KEY METRIC | DEFINITIONS | UNITS | METHOD | SIGNIFICANCE TO REEF HEALTH |
|---|---|---|---|---|
| **Reef fish density, diversity, biomass** | Density: Number of reef fish per unit area<br><br>Diversity: Number of different species of reef fish<br><br>Biomass: Total weight of reef fish in a certain area | Density: Individuals/$m^2$<br><br>Diversity: Number of species<br><br>Biomass: g/$m^2$ | Belt transect surveys | Healthy reefs are able to support diverse, abundant fish communities, as well as higher fish biomass. Overfished reefs will tend to have lower biomass and diversity. Herbivores promote reef health by removing macroalgae and creating space for coral recruitment. |
| **Benthic community composition** | What makes up the sea floor | Percent cover | Photo-quadrats | Corals are the building blocks of coral reefs, so higher coral cover is indicative of healthier reefs. Too much algae can crowd out corals and reduce reef health. |
| **Juvenile coral density** | Number of young, newly settled corals (1-5cm diameter) on a reef | Individuals/ $m^2$ | Large-area imagery | Young corals indicate the reef is growing and rcovering well. More juveniles suggest better chances for long-term reef health. |
| **Reef rugosity** | A number that shows the structural complexity of the reef (how rough or smooth the reef is) | Rugosity ratio (ratio of surface distance [measured at 10 cm intervals]/ linear distance) | Large-area imagery | More complex (higher rugosity) reefs provide more habitat for important coral reef species, such as fish and invertebrates. |
| **Macroinvertebrate density, diversity and size frequency distribution** | Density: Number of macroinvertebrates per unit area<br><br>Diversity: Number of different species of macroinvertebrates<br><br>Size frequency distribution: A chart showing how big or small animals are in a group. | Density: Individuals/site (300 $m^2$) | Belt transect surveys | Macroinvertebrates such as herbivorous urchins can clear reefs of macroalgae. Other invertebrates, such as sea cucumbers, crustaceans, and bivalves are important food/ fisheries resources. |
| **Stable isotope analysis for water quality** | Source of nutrients delivered to a reef (e.g., sewage pollution, agriculture, atmospheric/natural sources) | Stable isotope ratio (‰) | Stable isotope approaches | Poor water quality can stress reefs by causing macroalgal blooms, promoting coral disease, increasing bioerosion, etc. |

# 04

# RESULTS

Layers of table coral in Sanma Province // Gilles Siu

All results are presented as province-level means with standard error (SE), unless otherwise specified. Standard error is a measure of variance, or uncertainty, in an estimate.

White-freckled surgeonfish (*Acanthurus maculiceps*) in the Torba Province // Gilles Siu

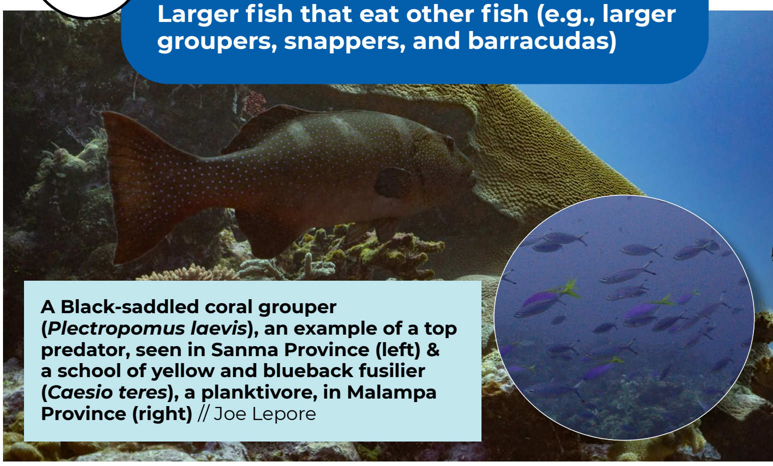
## REEF FISH

In total, **448 reef fish species were recorded** in belt transect surveys (Appendix 4). *Acanthurus nigrofuscus* was the most widely distributed species and was recorded at 107 of the 109 sites surveyed. *Pycnochromis margaritifer* had the highest mean density of all species surveyed (0.41 individuals/m$^2$), and *Ctenochaetus striatus* had the highest mean biomass (8.2 g/m$^2$). Labridae was the most diverse family, with 75 species recorded (not including species in the subfamily Scarinae (parrotfish), which are reported separately in this report; with scarids included, the total number of labrid species recorded increases to 104).

Mean fish density across Vanuatu was 3.7 individuals/m$^2$ (Figure 2, Map 1) and mean fish biomass was 151.9 g/m$^2$ (Figure 3, Map 2). Fish density was highest in Penama and lowest in Malampa. **Planktivores made up the largest proportion of fish density across all provinces**, with a high of 3.1 individuals/m$^2$ (± 1.0 SE) in Penama and a low of 1.7 individuals/m$^2$ (± 0.2 SE) in Malampa. **Density of top predators and sharks was very low across all provinces (Maps 3 and 4)**; the highest top predator density was found in Torba with a mean of 0.02 individuals/m$^2$ (± 0.003 SE), and sharks were only recorded in Torba and Tafea.

**PLANKTIVORES:**
**Animals that eat tiny organisms floating in the water called plankton**

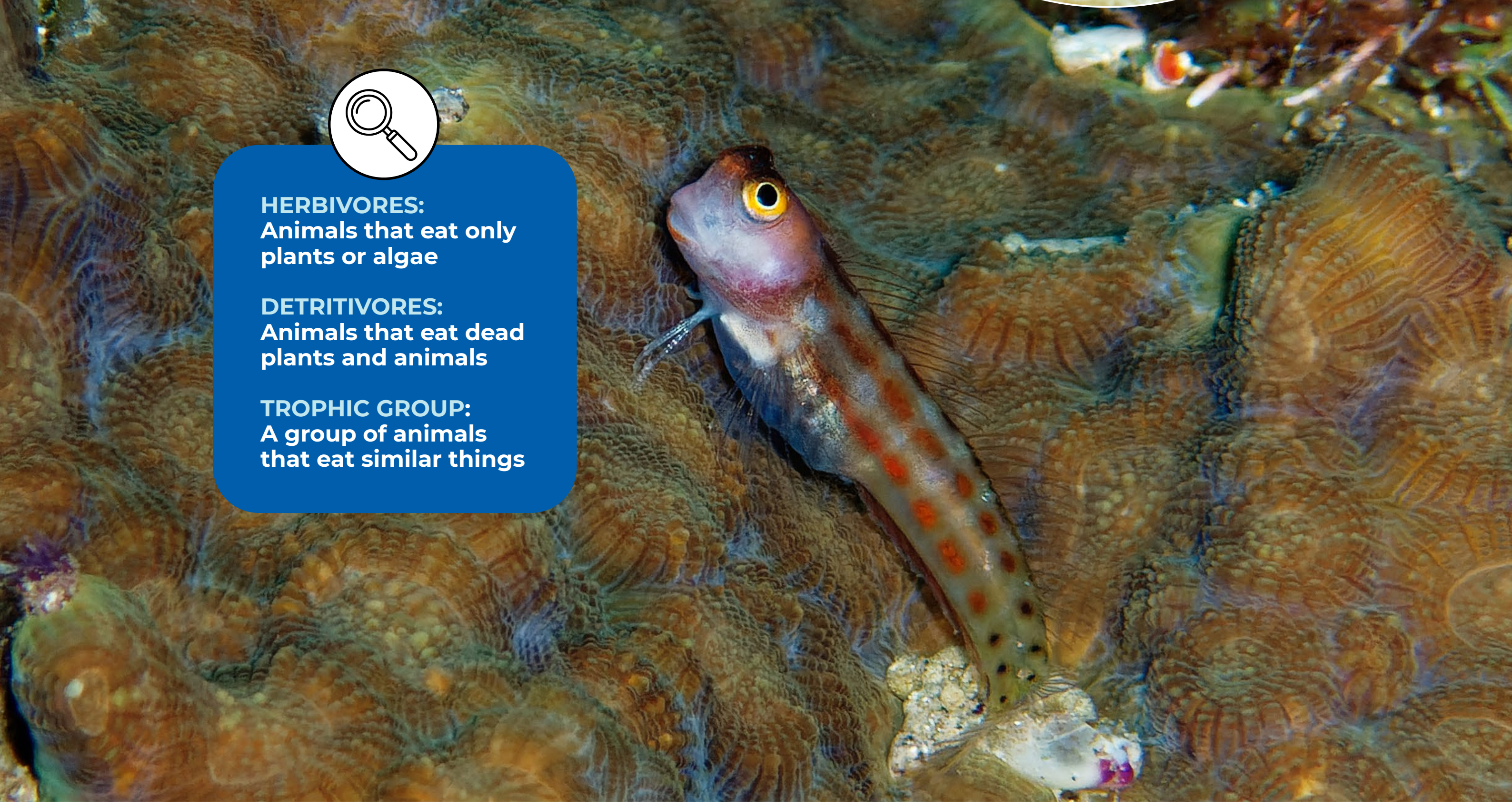
**TOP PREDATORS:**
**Larger fish that eat other fish (e.g., larger groupers, snappers, and barracudas)**



**A Black-saddled coral grouper (*Plectropomus laevis*), an example of a top predator, seen in Sanma Province (left) & a school of yellow and blueback fusilier (*Caesio teres*), a planktivore, in Malampa Province (right)** // Joe Lepore

**While herbivore/detritivore density was relatively uniform across provinces** (ranging from 0.4 individuals/m$^2$ ± 0.04 SE in Tafea to 0.6 individuals/m$^2$ ± 0.08 SE in Shefa; Map 5), **biomass in this trophic group varied more widely across provinces**, indicating differences in herbivore size across the country. Similar patterns can be seen when comparing overall mean density and biomass of individual provinces. For example, Malampa province had the lowest mean fish density of all provinces, but the highest biomass, indicating larger fish across trophic groups in this province. Conversely, Penama, Sanma and Tafea had lower mean biomass compared to abundance, particularly for planktivores, suggesting smaller fish on average in these provinces. Top predator and shark biomass was relatively low across all provinces due to consistently low densities, with the highest top predator biomass in Torba (10.5 g/m$^2$ ± 2.2 SE) and the highest shark biomass in Tafea (0.9 g/m$^2$ ± 0.9 SE).

**Acanthurids (surgeonfish) had the highest mean biomass of any family surveyed**, with a maximum of 46.8 g/m$^2$ (± 2.6 SE) in Malampa province and a minimum of 25.4 g/m$^2$ (± 1.1 SE) in Sanma (Figure 4). Mean scarid (parrotfish) biomass (reported separately from other labrids here due to the different ecological roles played by parrotfish) was relatively high across provinces, with a high in Malampa (32.0 g/m$^2$ ± 1.3 SE) and the lowest value in Tafea (17.3 g/m$^2$ ± 1.3 SE). Other common foodfish families, such as Lutjanidae (snappers) and Serranidae (groupers), generally had lower biomass, with a few exceptions; for example, lutjanid biomass was high in Malampa (29.1 g/m$^2$ ± 5.2 SE) and, to a lesser extent, in Torba (20.2 g/m$^2$ ± 5.2 SE).



**A camouflage grouper (*Epinephelus polyphekadion*) in Sanma Province (top) & a blackstriped combtooth blenny (*Ecsenius fourmanoiri*), an example of a detritivore (bottom)**
// Joe Lepore & Gilles Siu

**HERBIVORES:**
**Animals that eat only plants or algae**

**DETRITIVORES:**
**Animals that eat dead plants and animals**

**TROPHIC GROUP:**
**A group of animals that eat similar things**

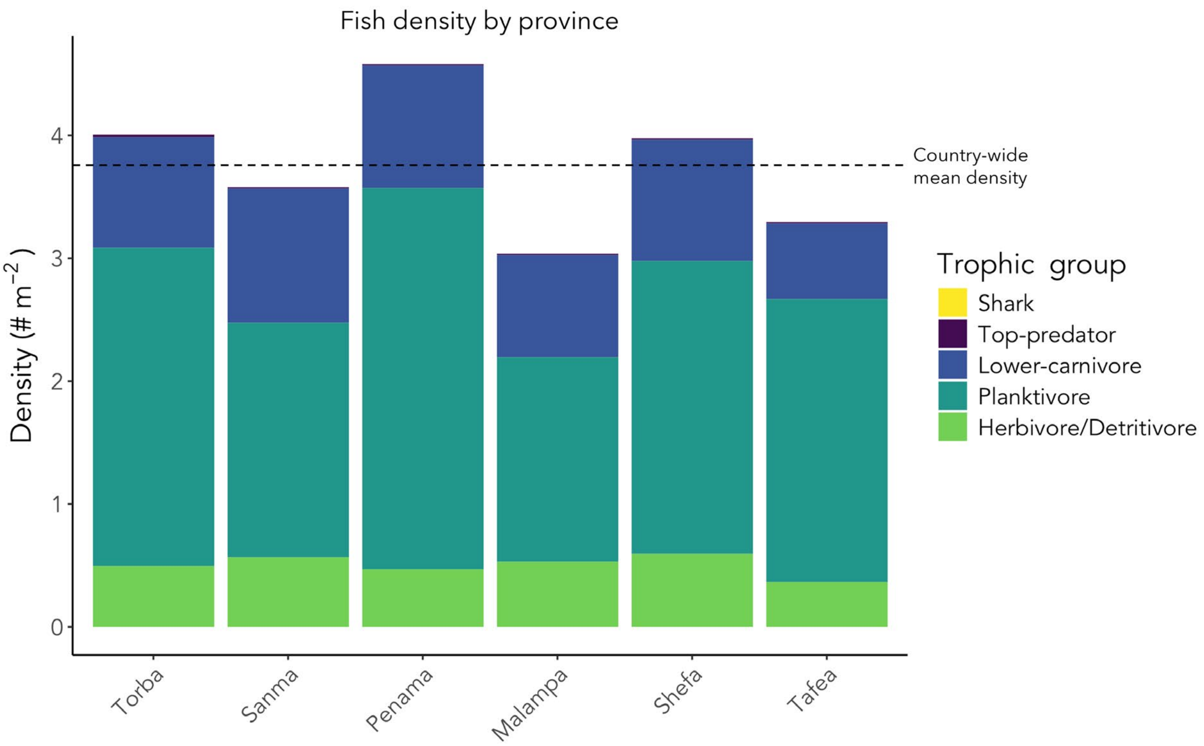



**FIGURE 2**: *Mean fish density at each province surveyed, by trophic group. The horizontal dashed line represents the overall mean fish density across provinces. Provinces are listed from north to south on the x-axis.*

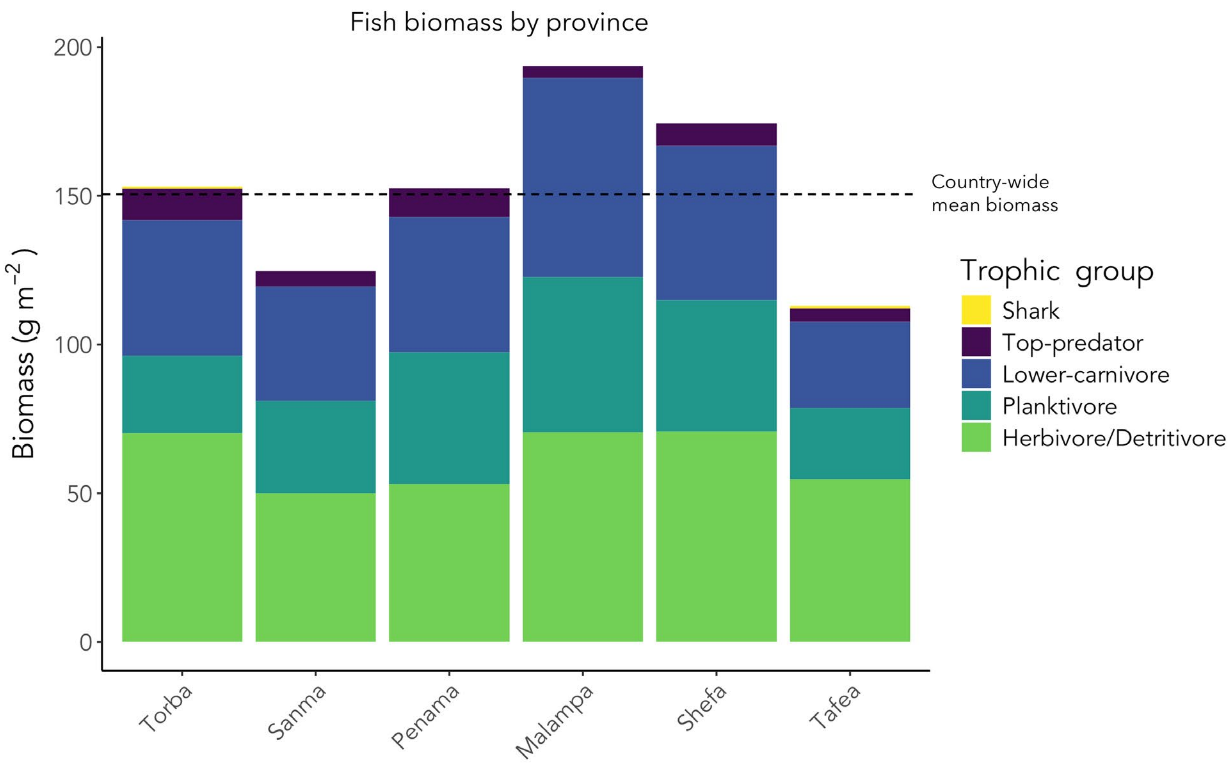



**FIGURE 3**: *Mean fish biomass at each province surveyed, by trophic group. The horizontal dashed line represents the overall mean fish biomass across provinces. Provinces are listed from north to south on the x-axis.*

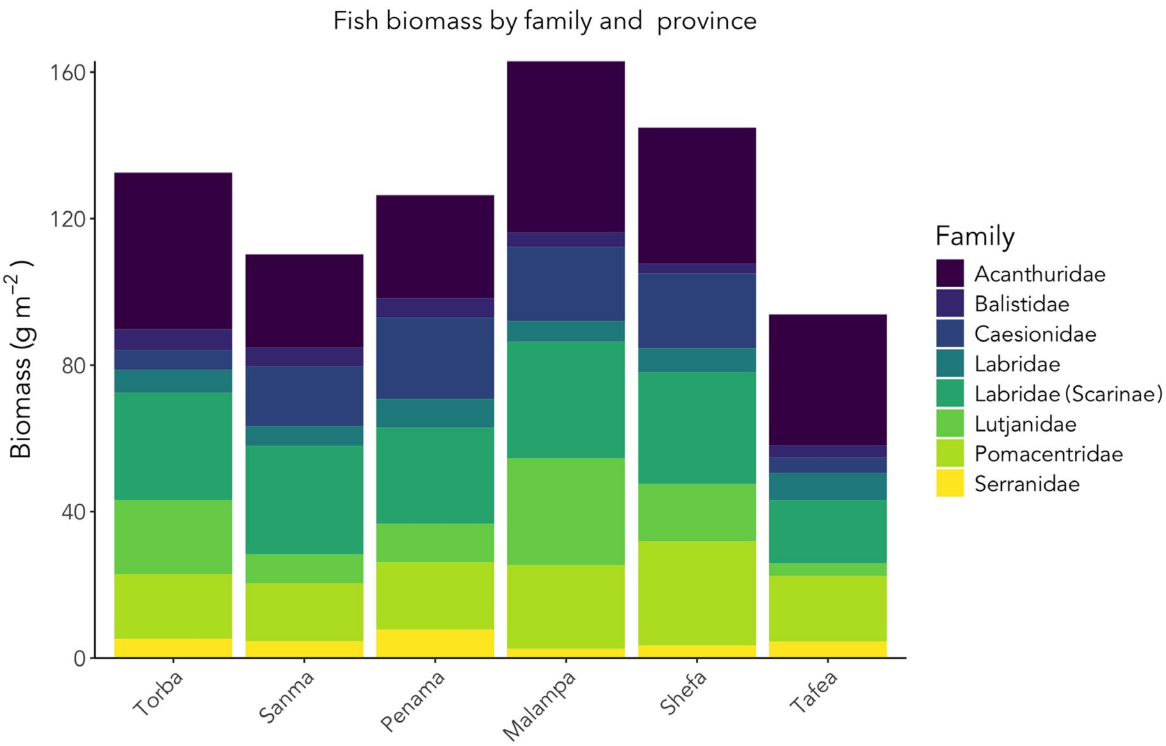
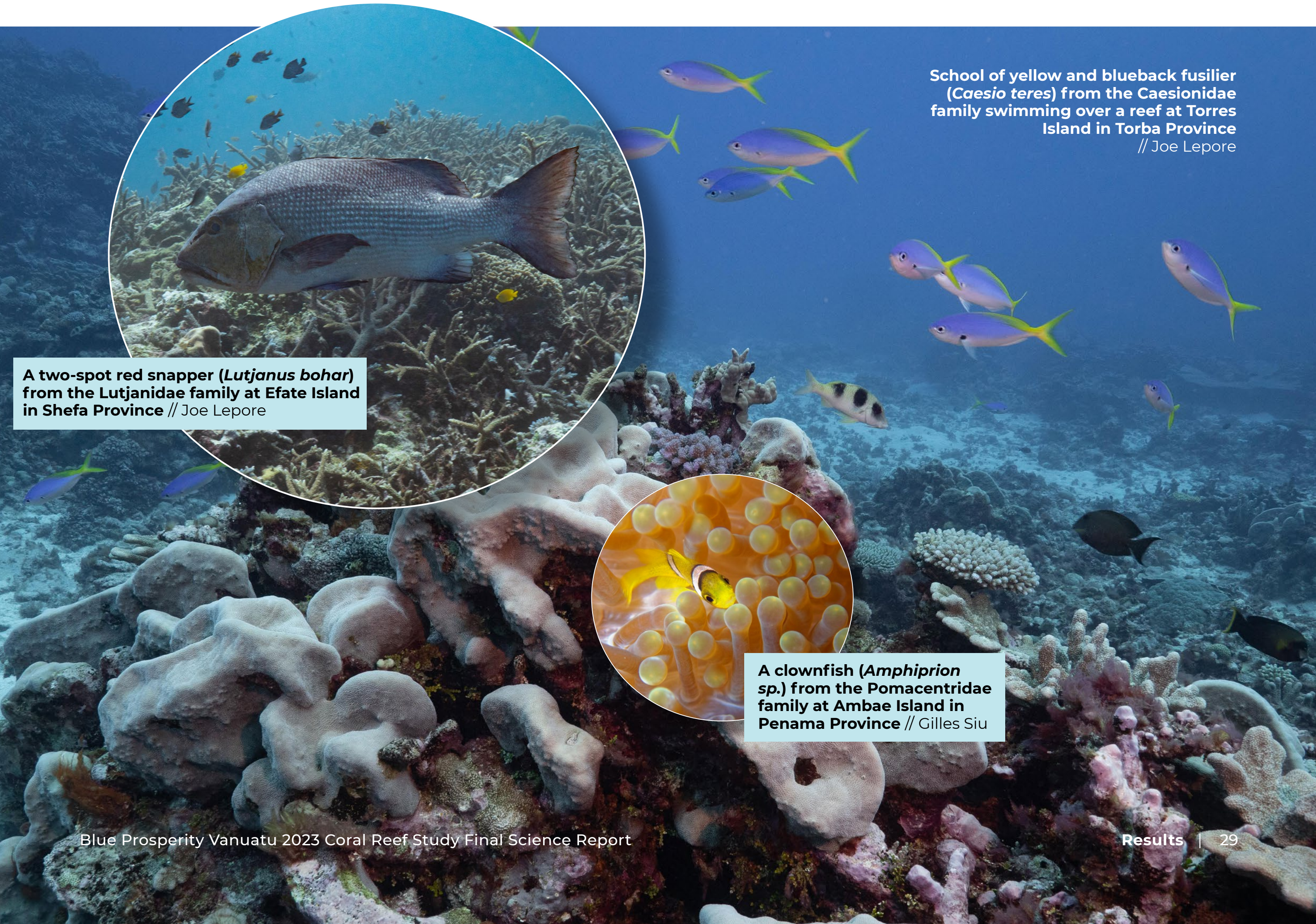



**FIGURE 4**: *Mean biomass of the fish families with the highest mean biomass by province. Note that the subfamily Scarinae is listed separately from Labridae in order to highlight the contribution of parrotfishes to mean biomass. Provinces are listed from north to south on the x-axis.*

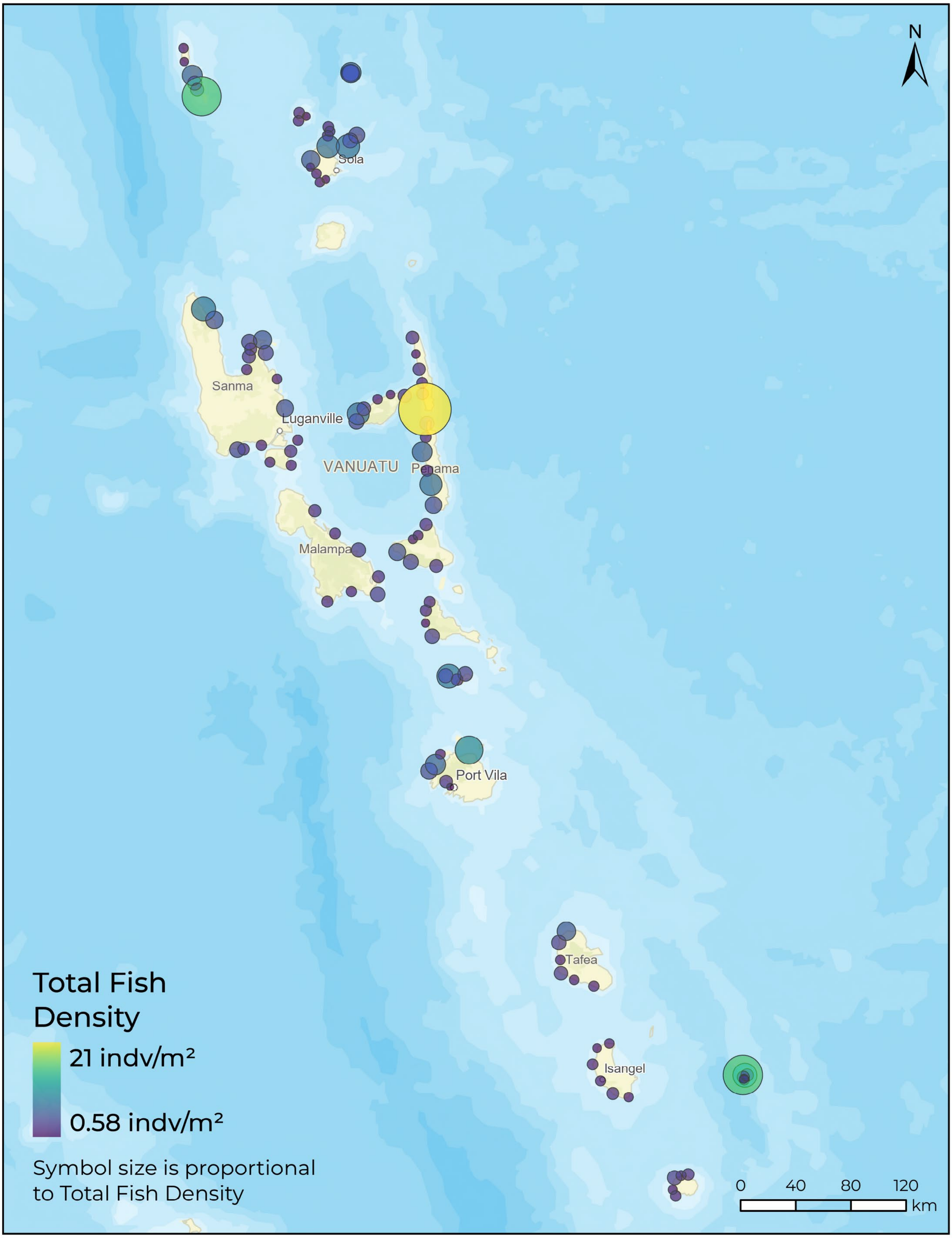


**School of yellow and blueback fusilier (*Caesio teres*) from the Caesionidae family swimming over a reef at Torres Island in Torba Province** // Joe Lepore

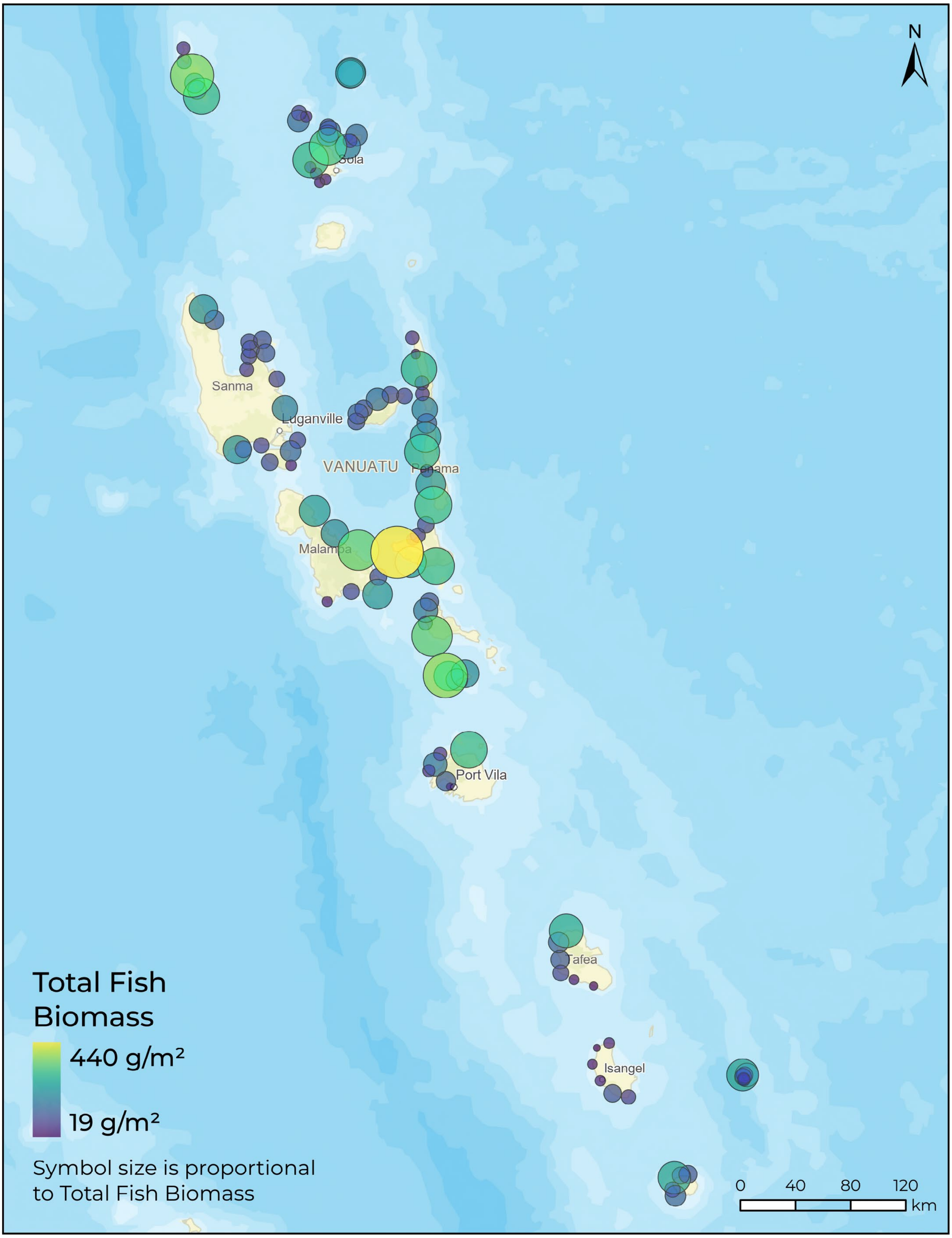
**A two-spot red snapper (*Lutjanus bohar*) from the Lutjanidae family at Efate Island in Shefa Province** // Joe Lepore

**A clownfish (*Amphiprion sp.*) from the Pomacentridae family at Ambae Island in Penama Province** // Gilles Siu

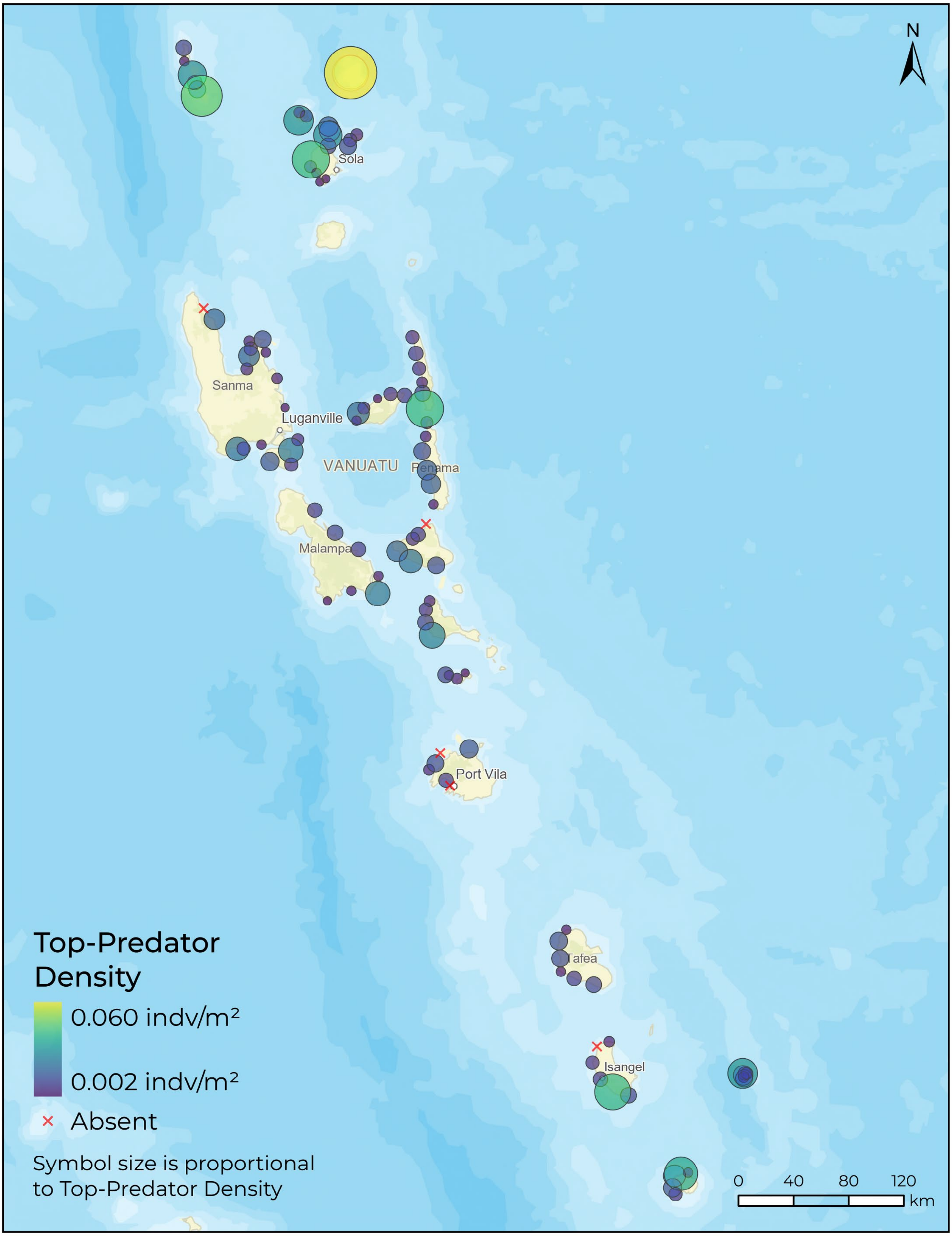
**MAP 1**: *Mean* ***density*** *(number of individuals per square meter) of* ***fish per survey site*** *across Vanuatu.*



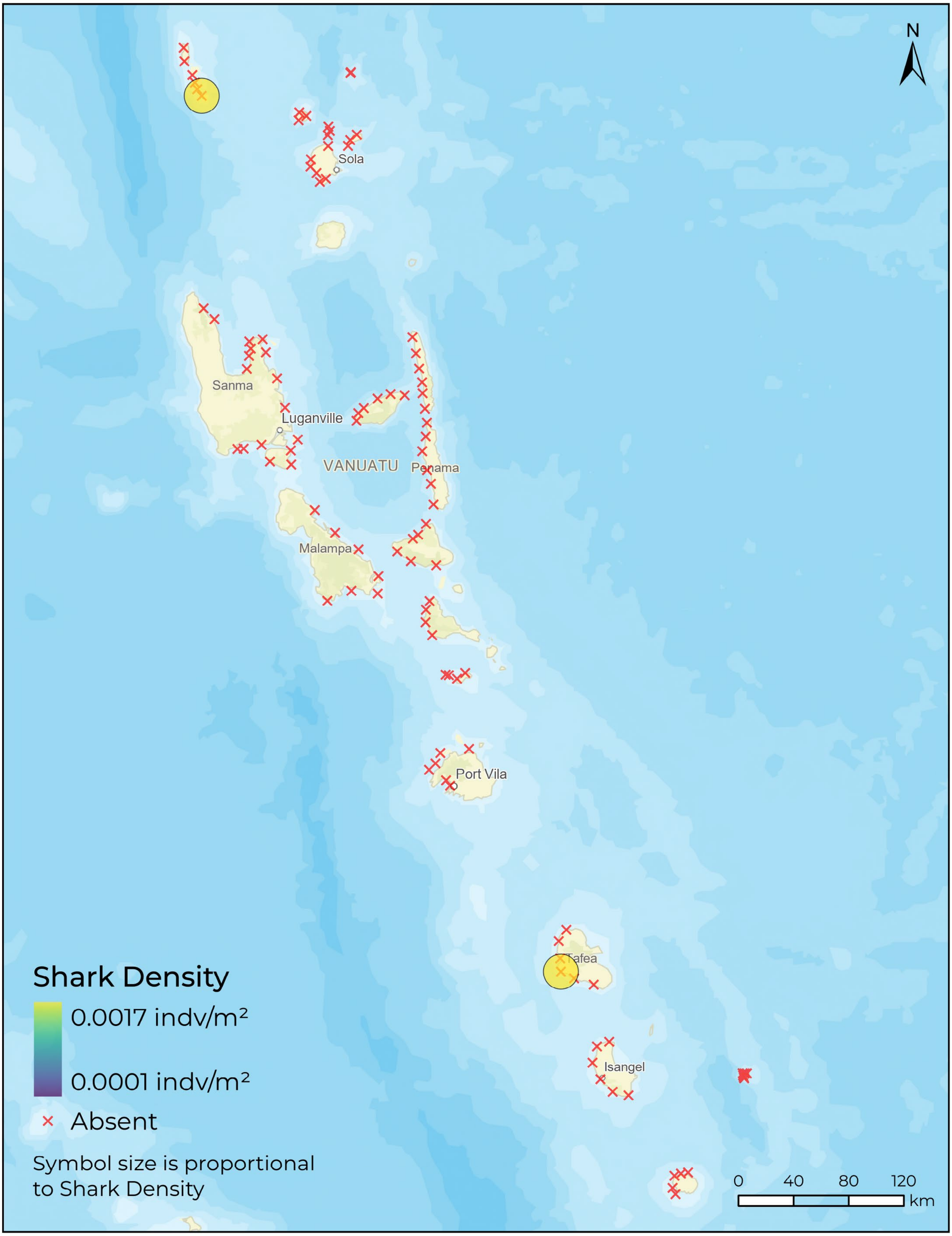
**MAP 2**: *Mean estimated* ***fish biomass*** *(grams per square meter) per survey site across Vanuatu.*



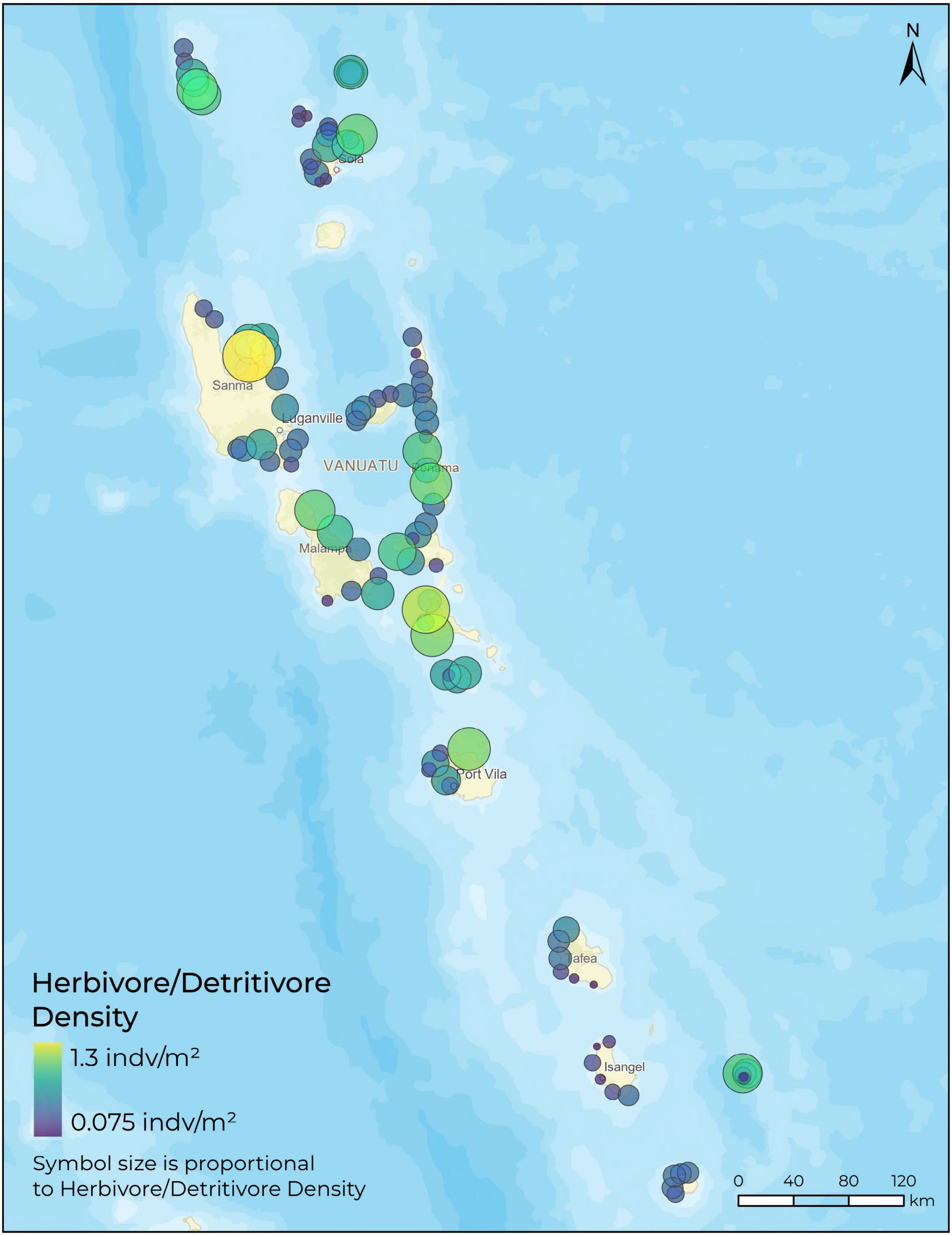
**MAP 3**: *Mean density (number of individuals per square meter) of* ***top-predator fish*** *per survey site across Vanuatu.*



**MAP 4**: *Mean density (number of individuals per square meter) of* ***sharks*** *per survey site across Vanuatu.*



**MAP 5**: *Mean density (number of individuals per square meter) of* ***herbivorous and detritivorous fish*** *per survey site across Vanuatu. Herbivores feed primarily on algae and seaweed, and detritivores consume decaying organic material.*

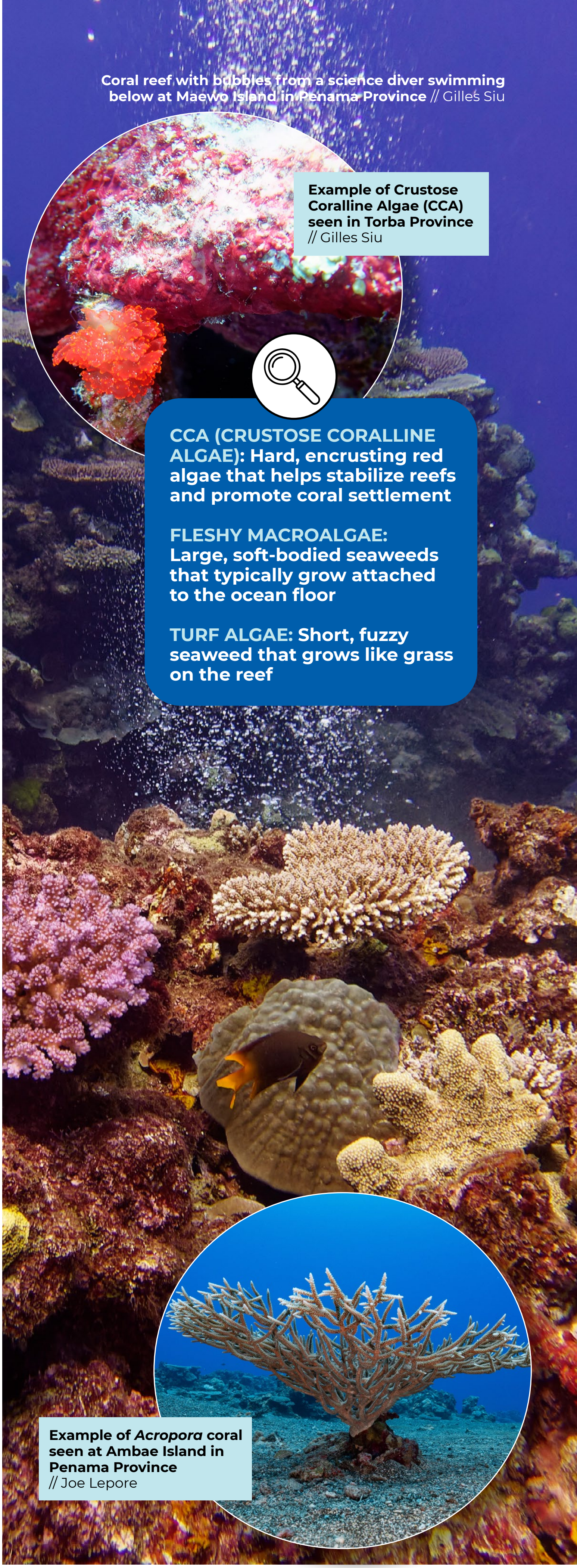


# BENTHIC COVER

**Mean coral cover across Vanuatu was 19.8%** (± 0.8 SE; Map 15). Other major benthic groups were **turf algae** (33.1% ± 1.6 SE; Map 16) and **crustose coralline algae (CCA)**(19.0% ± 1.2 SE; Map 17). **Fleshy macroalgae** cover was low across the country, with a mean of 4.3% (± 0.4 SE; Map 18).

**Tafea and Shefa had lower mean coral cover than the rest of the provinces** (Figure 5). Penama had the highest mean coral cover (26.2% ± 3.0 SE) while Shefa had the lowest (13.8% ± 3.4 SE). **Despite having the two highest mean coral cover values, Penama and Malampa had the lowest mean CCA cover** (11.1% ± 1.4 SE and 12.5% ± 2.6 SE, respectively). Mean CCA cover was highest in Torba at 23.8% (± 3.2 SE). **Turf algae made up the highest proportion of benthic cover in all provinces**, peaking in Shefa at 40.7% (± 4.3 SE). Fleshy macroalgae was low across the country, with a maximum in Torba at 7.1% (± 1.5 SE).

*Porites, Montipora,* and *Acropora* were the most common coral genera across all provinces (Figure 6). *Porites* was particularly abundant in Penama and Malampa, making up 6.6% (± 1.6 SE) and 6.4% (± 2.1 SE) of the total cover in these provinces, respectively. Penama also had the highest cover of *Montipora* (6.5% ± 1.4 SE), while Malampa and Sanma had the highest *Acropora* cover (6.9% ± 2.1 SE and 5.6% ± 1.6 SE). **Geographic distributions of coral genera did not follow any obvious latitudinal patterns**. However, some coral genera were particularly common in certain provinces but rare in others; for example, *Diploastrea* was particularly abundant in Sanma, *Leptastrea* was most abundant in Penama, *Turbinaria* was most common in Shefa, and *Mycedium* was most abundant in Malampa, despite being completely absent in Shefa in photoquadrats. In total, **corals from 48 genera were recorded** in the photoquadrat surveys (Appendix 5). Note, 48 coral genera were recorded in photoquadrats and 42 were recorded in juvenile coral surveys, but due to a lack of complete overlap between the genera in the two surveys, the total number of genera (51) comes out to more than either survey on its own.



**Coral reef with bubbles from a science diver swimming below at Maewo Island in Penama Province** // Gilles Siu

**Example of Crustose Coralline Algae (CCA) seen in Torba Province** // Gilles Siu

**CCA (CRUSTOSE CORALLINE ALGAE): Hard, encrusting red algae that helps stabilize reefs and promote coral settlement**

**FLESHY MACROALGAE: Large, soft-bodied seaweeds that typically grow attached to the ocean floor**

**TURF ALGAE: Short, fuzzy seaweed that grows like grass on the reef**

**Example of *Acropora* coral seen at Ambae Island in Penama Province** // Joe Lepore

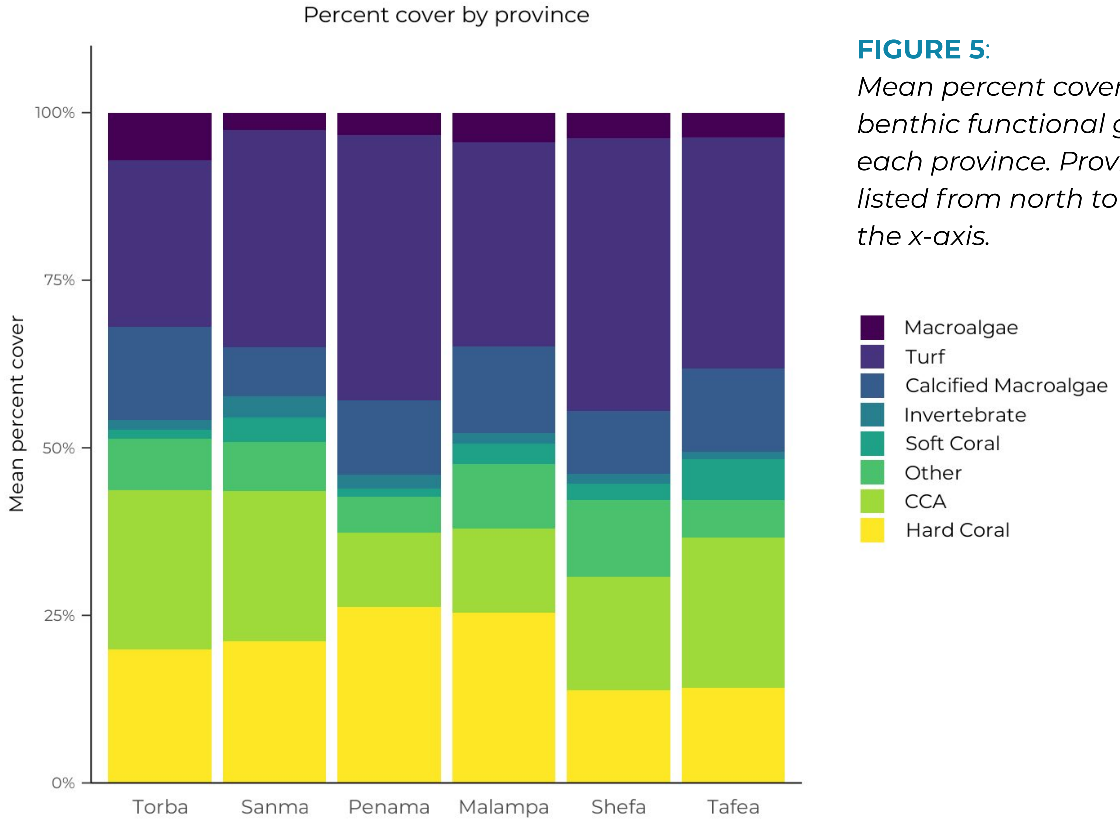



**FIGURE 5**: *Mean percent cover of main benthic functional groups at each province. Provinces are listed from north to south on the x-axis.*

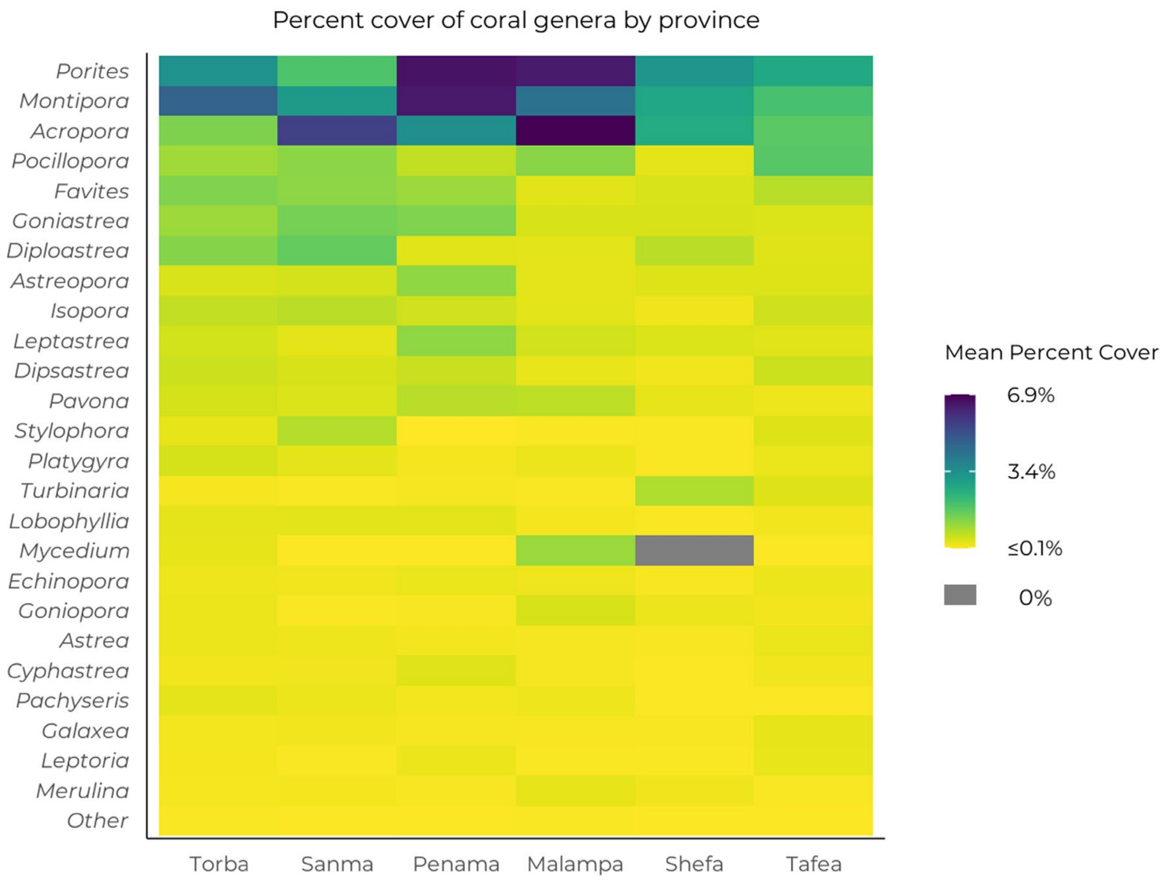
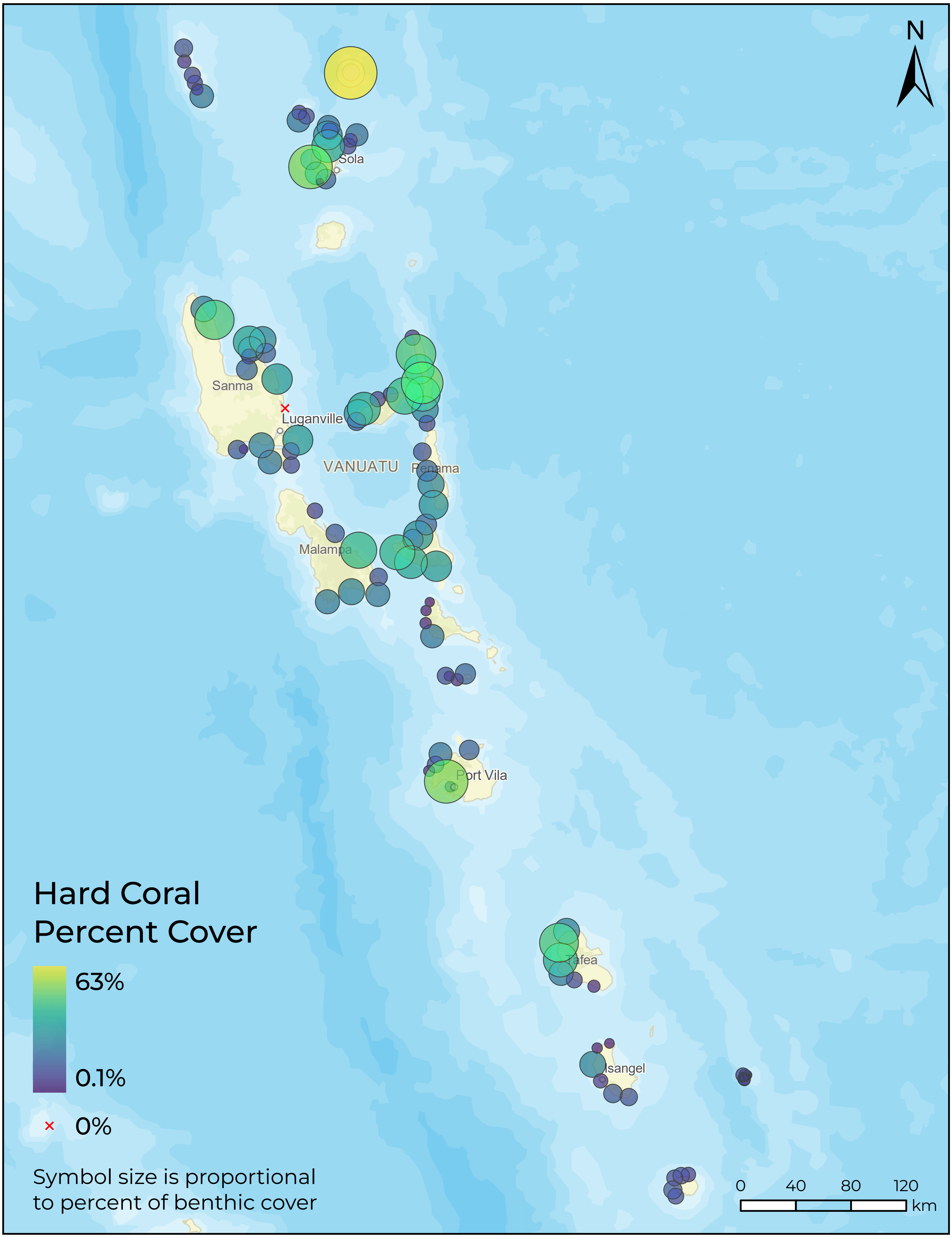
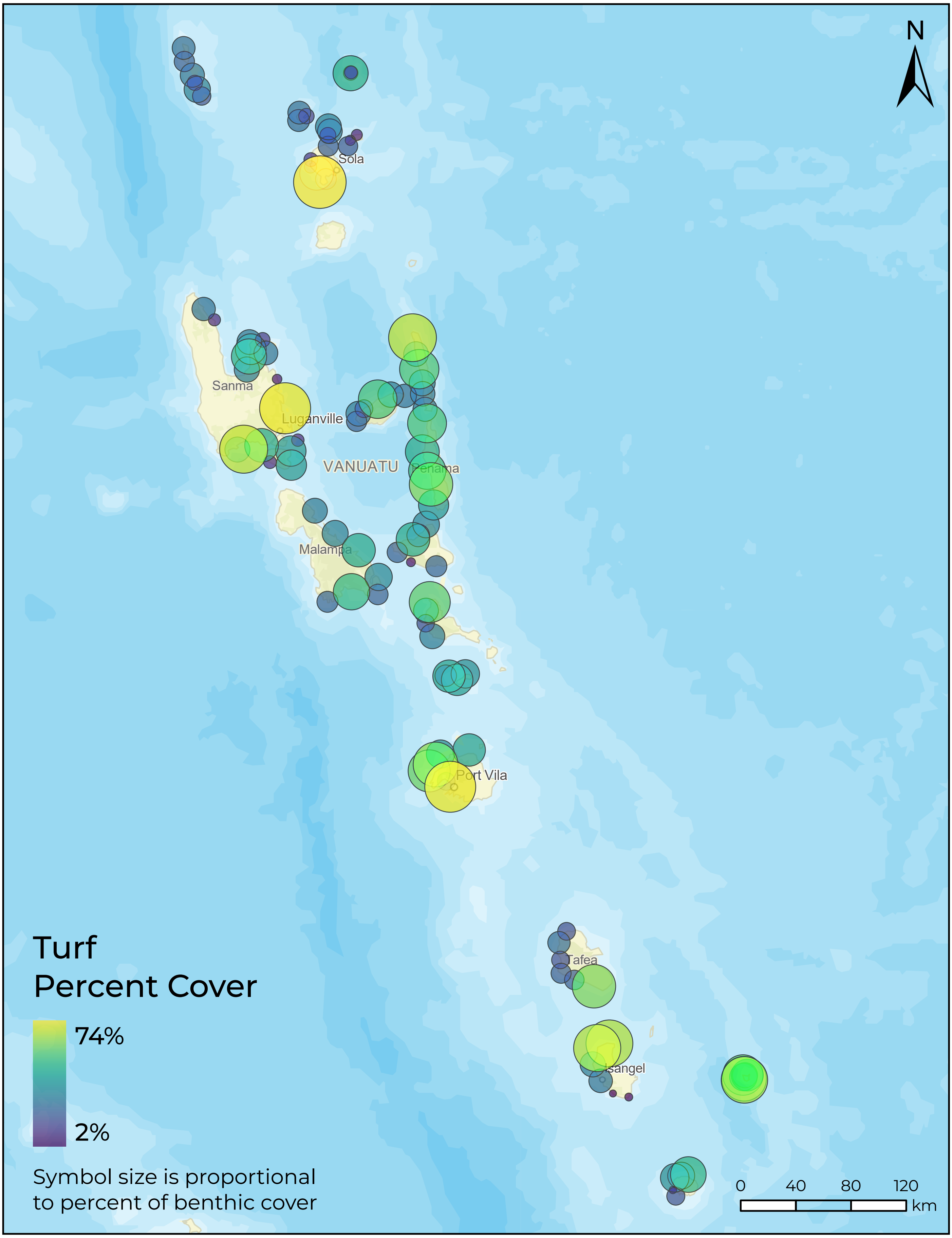



**FIGURE 6**: *Heatmap of the mean percent cover of most abundant coral genera at each province. Coral genera are ranked in order of overall abundance. All coral genera with an overall mean percent cover <0.1% were grouped into "Other". Grey cells indicate that the corresponding genus was not present. Provinces are listed from north to south on the x-axis.*

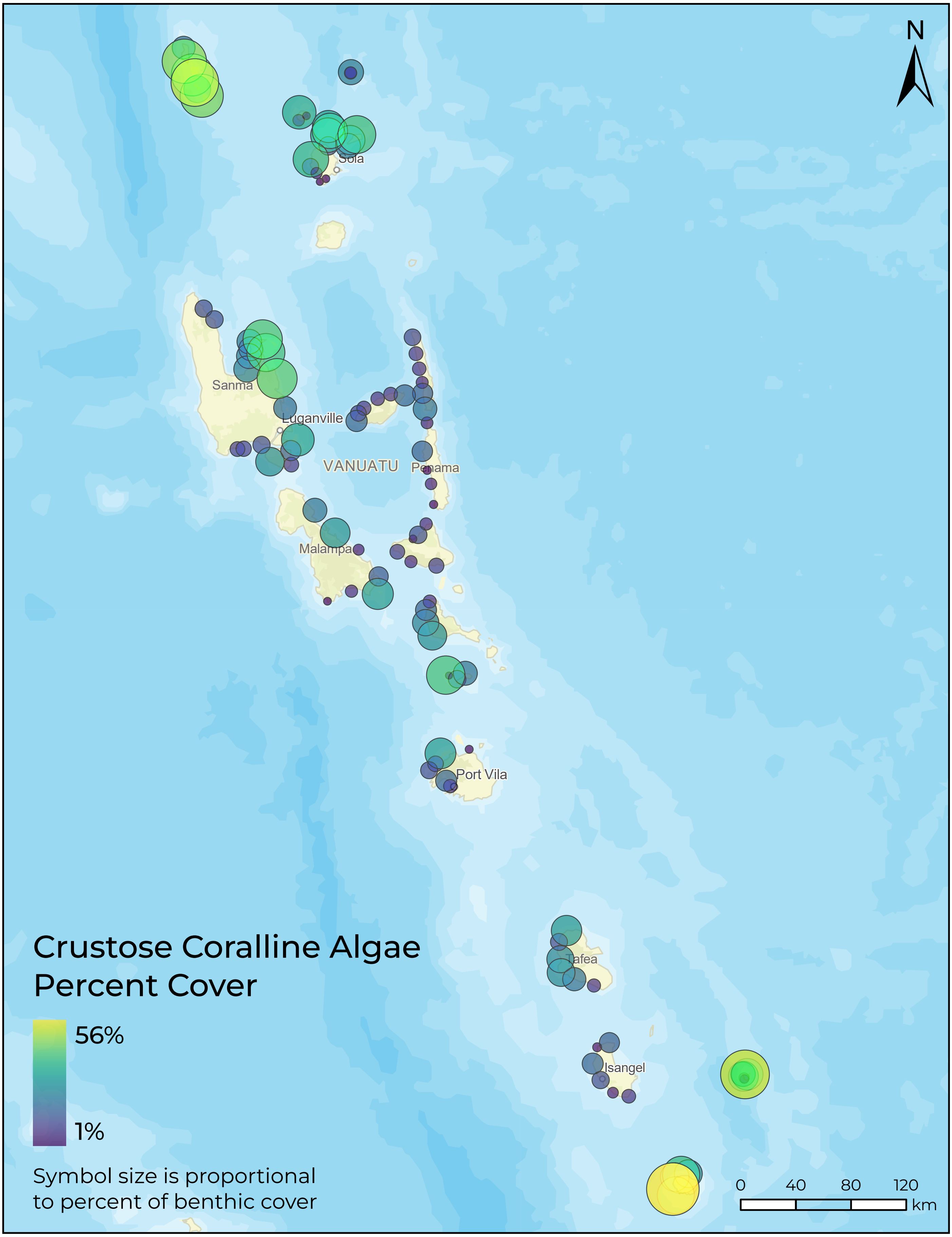
**MAP 15**: *Mean percent of the seafloor covered by* ***living hard corals*** *at survey sites across Vanuatu. Hard corals contribute to reef building and create complex habitats for fish and other organisms.*



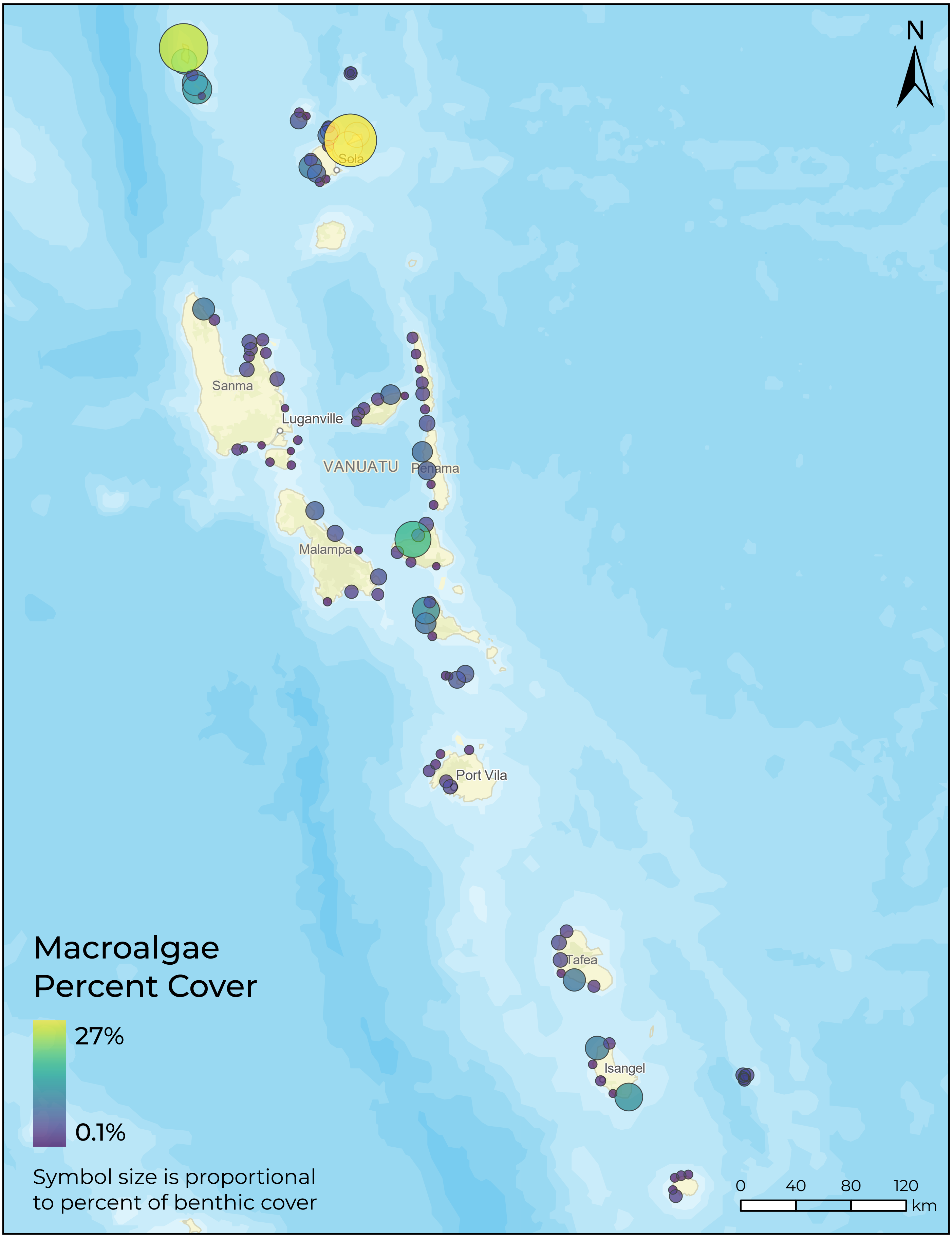
**MAP 16**: *Mean percent of the seafloor covered by **turf algae** at survey sites across Vanuatu. Turf algae is short, filamentous / fuzzy seaweed that grows like grass on the reef.*



**MAP 17**: *Mean percent of the seafloor covered by* ***crustose coralline algae (CCA)*** *at survey sites across Vanuatu. CCA is a hard, encrusting red algae that helps stabilize reefs and promote coral settlement.*



**MAP 18**: *Mean percent of the seafloor covered by **macroalgae** at survey sites across Vanuatu. Macroalgae are soft-bodied seaweeds that typically grow attached to the ocean floor.*



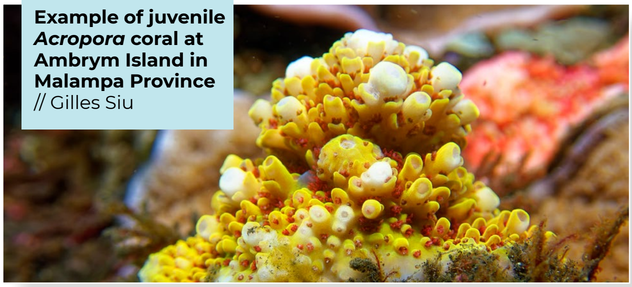
**Coral reef in Torba Province**
// Gilles Siu

**Example of juvenile *Acanthastrea* coral at Ambae Island in Penama Province**
// Gilles Siu

**Example of juvenile *Fungia* coral seen at Vanua Lava Island in Torba Province**
// Gilles Siu

# CORAL RECRUITMENT

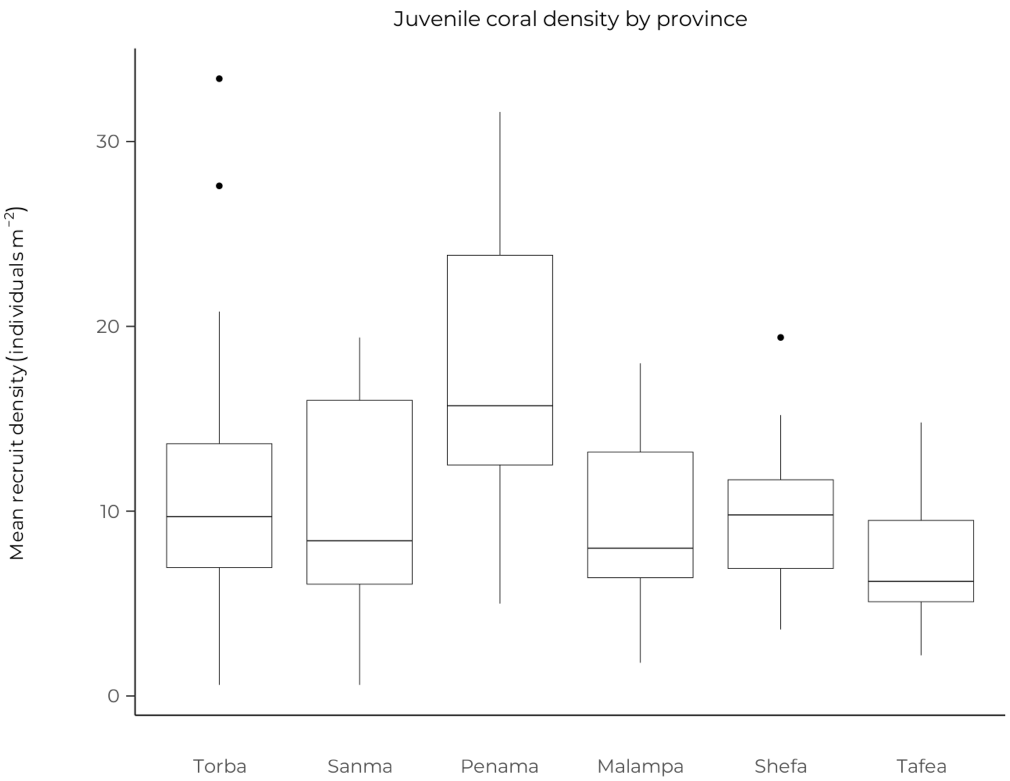
The overall mean density of juvenile corals across all sites surveyed was 10.7 individuals/m² (± 0.7 SE; Map 23). **Mean juvenile coral density was highest in Penama province** (18.0 individuals/m² ± 1.8 SE; Figure 7), driven mostly by Pentecost, which had the highest juvenile coral density of all islands surveyed (24.3 individuals/m² ± 3.2 SE). However, Ambae and Maewo, also in Penama province, had the second- and fourth-highest island-level densities (15.5 individuals/m² ± 2.7 SE and 14.7 individuals/m² 2.0 SE, respectively), indicating high numbers of juvenile corals across the province. Tafea province had the lowest mean juvenile coral density at 7.5 individuals/m² (± 0.8 SE). Mean densities in Malampa, Shefa and Tafea were all lower than densities in the three northern provinces (Torba, Penama and Sanma).



**Example of juvenile *Acropora* coral at Ambrym Island in Malampa Province**
// Gilles Siu

Overall, *Acropora* juveniles were the most common, followed by *Porites* and *Goniastrea* (Figure 8); however, patterns of abundance did not follow this order in all provinces. *Acropora* densities were highest in Sanma (2.5 individuals/m² ± 0.7 SE), where it was the dominant genus among juvenile corals. *Porites* was the most common genus in Tafea province (1.3 individuals/m² ± 0.3 SE), and *Goniastrea* was the most common genus in Penama and Torba (2.7 individuals/m² ± 0.5 SE and 1.5 individuals/m² ± 0.3 SE). While all of the most common genera were found across all provinces (except for *Stylophora* in Malampa), patterns of abundance were different for each province, and did not show any strong geographical patterns. **In total, juvenile corals from 42 genera were recorded** (Appendix 5). Note, 48 coral genera were recorded in photoquadrats and 42 were recorded in juvenile coral surveys, but due to a lack of complete overlap between the genera in the two surveys, the total number of genera (51) comes out to more than either survey on its own.

**FIGURE 7**: *Mean coral recruit density at each province surveyed. Bold horizontal lines represent the median value for each province. Provinces are listed from north to south on the x-axis.*



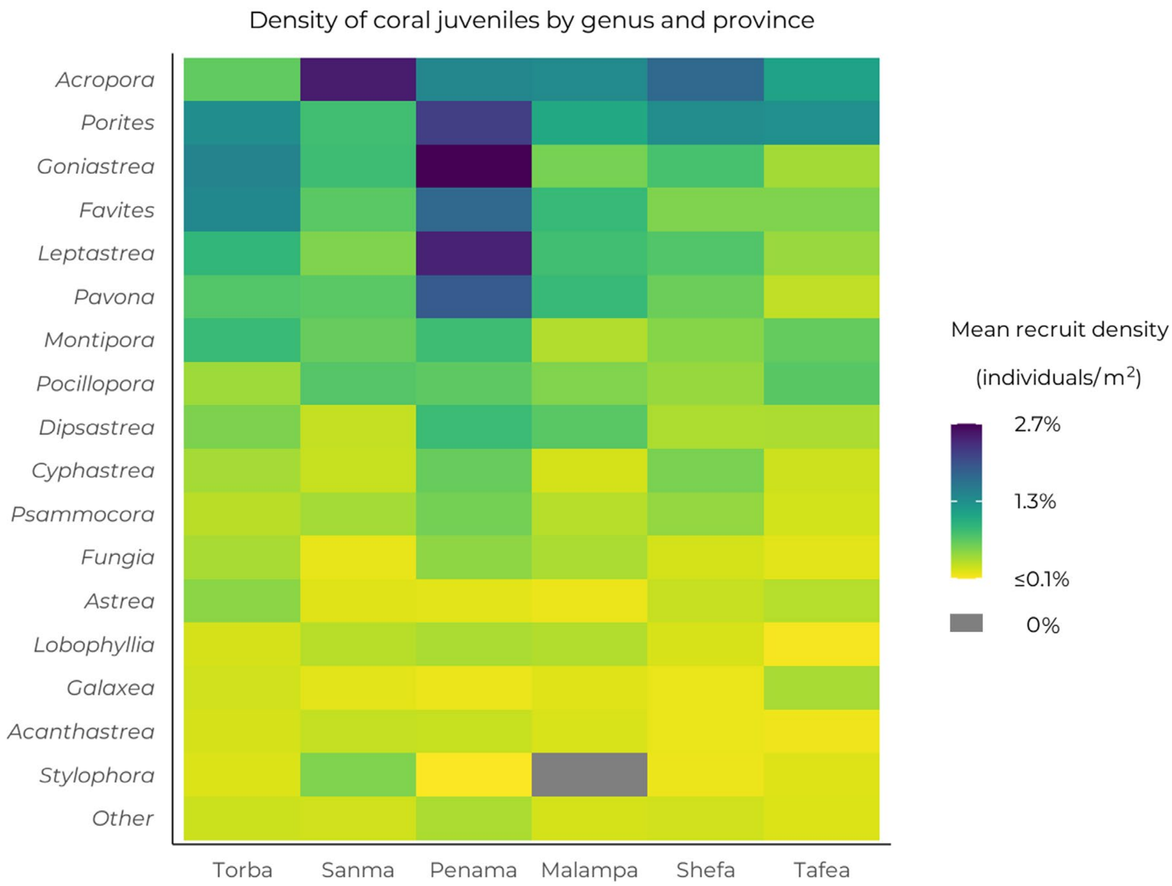
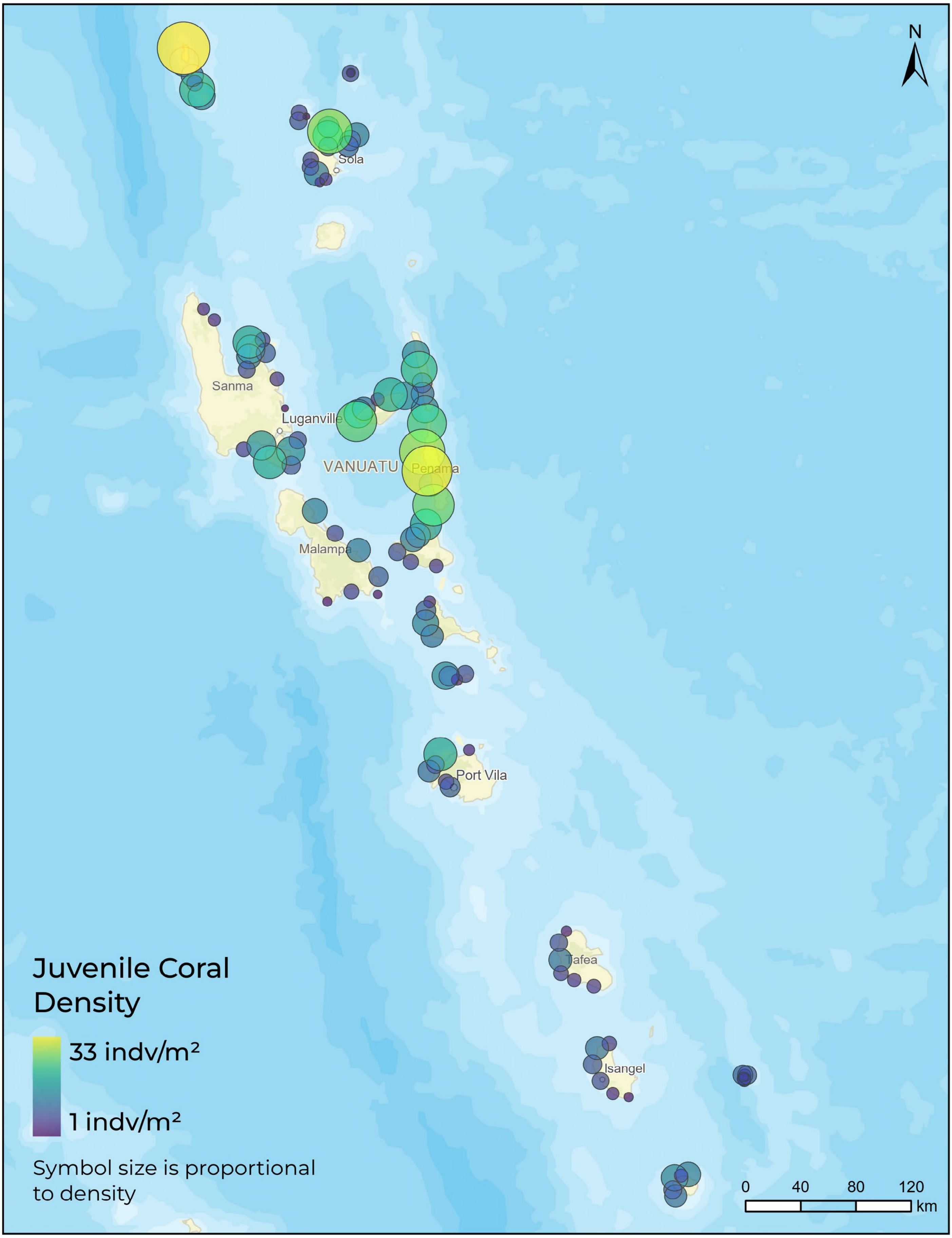




**FIGURE 8**: *Heatmap of the mean recruit density of the most abundant coral genera at each province. Grey cells represent instances where the genus was not present in the corresponding province. Coral genera are ranked in order of overall abundance. All coral genera with an overall mean recruit density <0.1 individuals $m^{-2}$ were grouped into "Other." Provinces are listed from north to south on the x-axis.*

**MAP 23**: *Mean density (number of individuals per square meter) of **baby corals** (typically 1-5 cm in diameter) observed per survey site across Vanuatu.*



# RUGOSITY

Overall mean rugosity across the country was 1.6 (± 0.02 SE). **Rugosity was highest in Malampa province** (1.7 ± 0.07 SE) and **lowest in Tafea province** (1.5 ± 0.04 SE; Figure 9). Of the individual islands surveyed, Mota Lava had the highest rugosity (1.8 ± 0.2 SE) and Tanna had the lowest (1.3 ± 0.07 SE). While rugosity tended to be slightly lower in the southern provinces (Tafea and Shefa), the range of mean values between provinces was small, and no clear latitudinal signal was observed.

**Coral reef at Vanua Lava Island in Torba Province**
// Joe Lepore

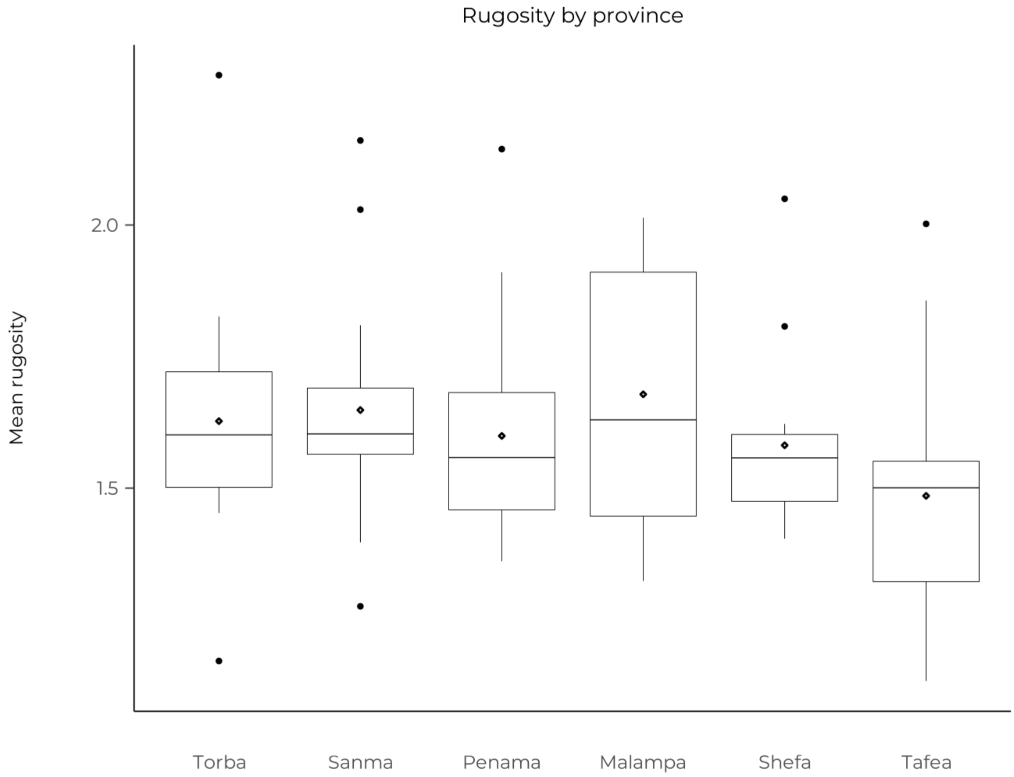
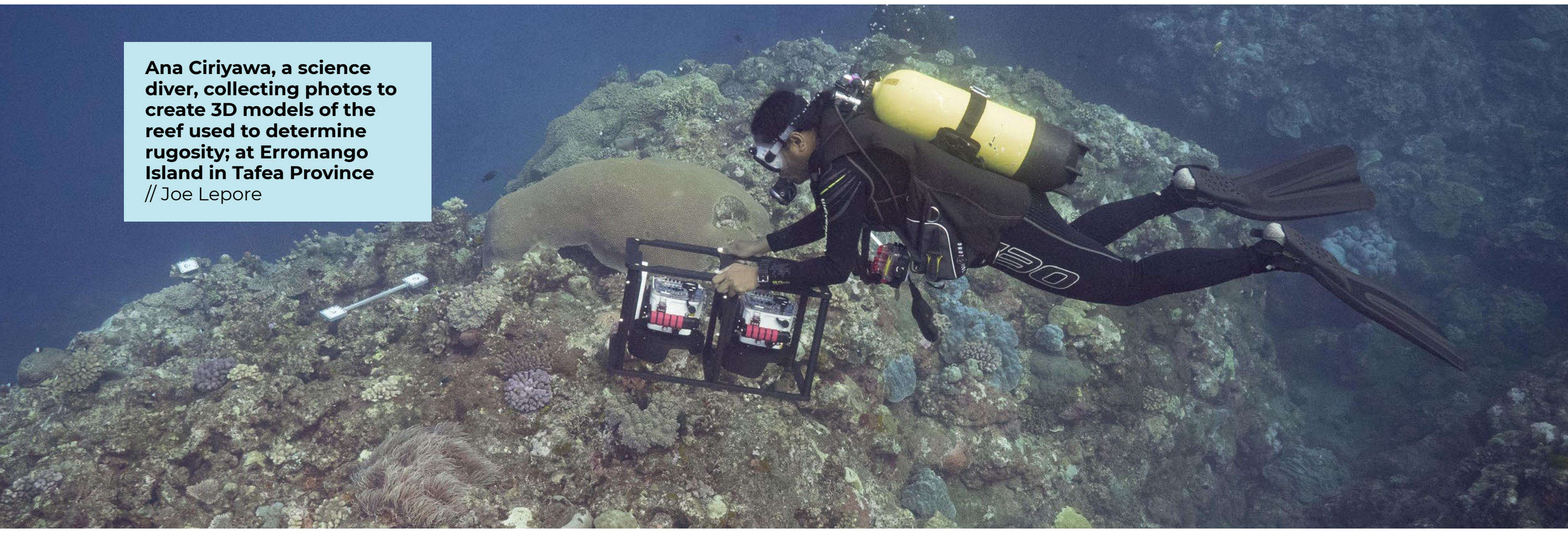



**FIGURE 9**: *Mean rugosity at each province surveyed. Bold horizontal lines represent the median value at each island, and diamonds represent the mean. Provinces are listed from north to south on the x-axis.*

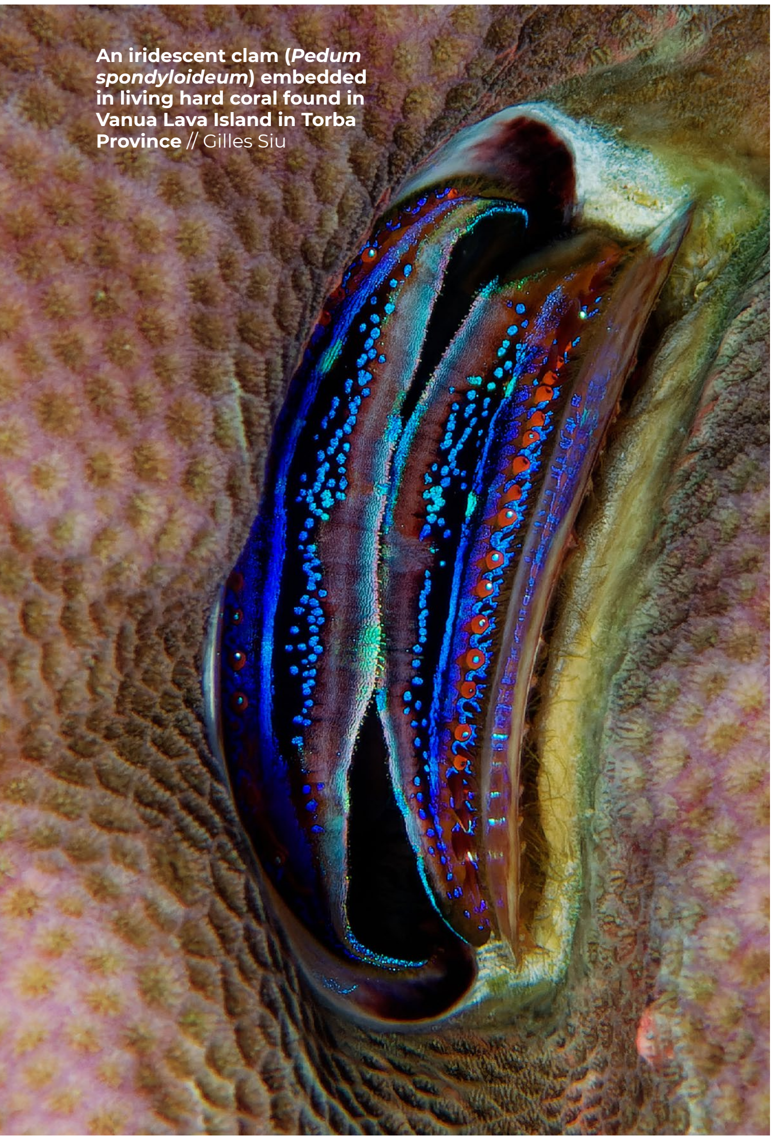


**Ana Ciriyawa, a science diver, collecting photos to create 3D models of the reef used to determine rugosity; at Erromango Island in Tafea Province**
// Joe Lepore

# MACROINVERTEBRATES

**In total, 175 species of macroinvertebrates were counted** during the surveys, including those found in the belt transects and additional species recorded off-transect. In total, one species of **anemone**, 25 species of **bivalve mollusk**, two **cephalopod** species, three **crinoid** species, eight species of **crustacean**, 91 **gastropod** species, one **jellyfish** species, 21 species of **sea cucumber**, eight **sea urchin** species, 12 **sea star** species, and one species of **sponge** were counted (Appendix 6). While the majority of these species were recorded during the belt transect surveys, due to the practicalities of reporting such a diverse dataset, only a subset of the most commercially and ecologically important species recorded in the belt transects are reported here. All densities are reported as the number of individuals per site ($300m^2$) for ease of interpretation (Map 24).

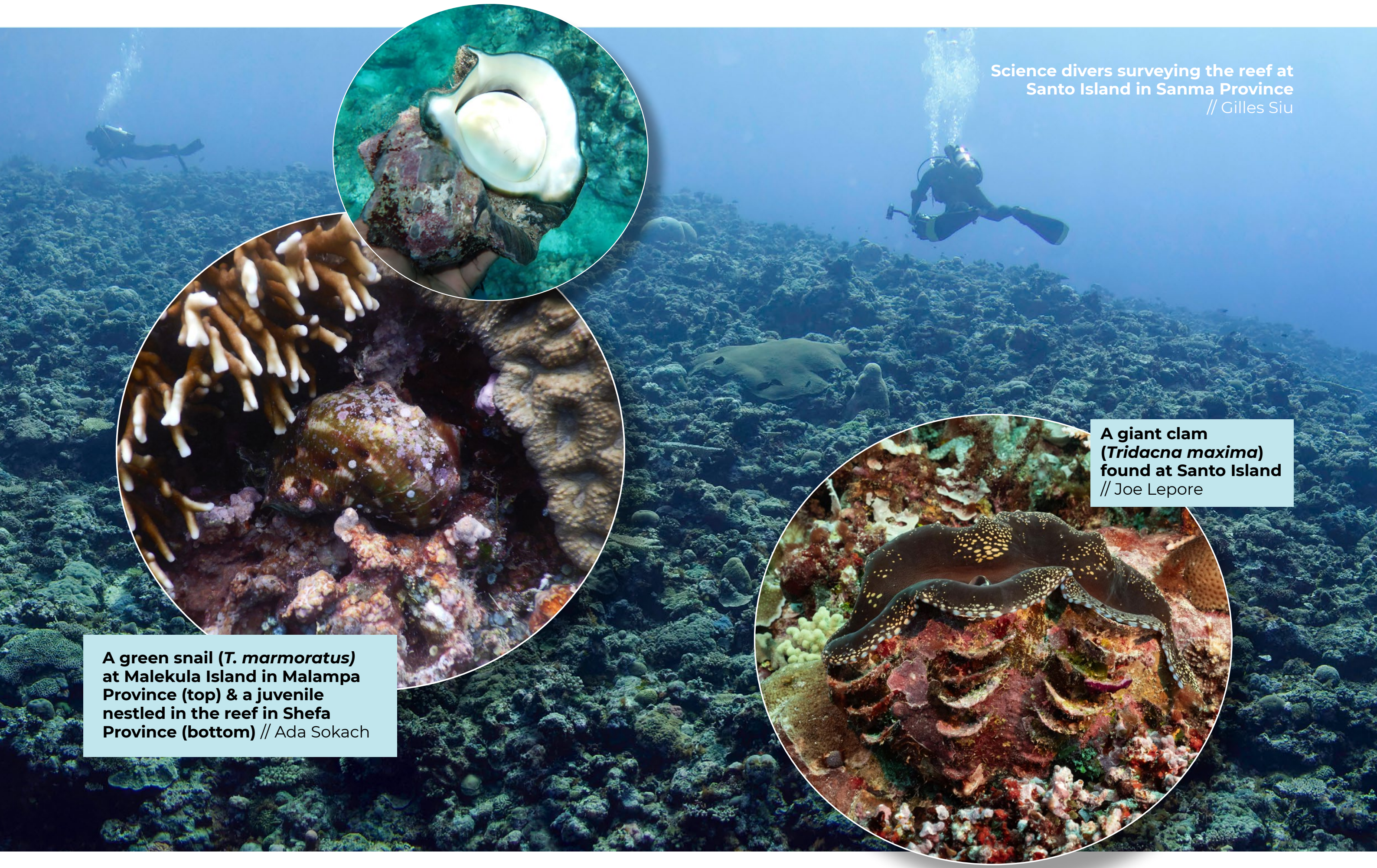
**A pineapple sea cucumber (*Thelenota ananas*) and science diver, Gabe Turner, recording observations at Erromango Island in Tafea Province** // Joe Lepore



**An iridescent clam (*Pedum spondyloideum*) embedded in living hard coral found in Vanua Lava Island in Torba Province** // Gilles Siu

**SEA CUCUMBER** densities and diversity were highest in Shefa and Tafea (Figure 10; Map 25). While 21 species were noted between belt transect surveys and off-transect observations, only 14 were recorded in belt transects and are reported here. **Shefa had the highest overall mean density of sea cucumbers, while Tafea had the highest diversity**, with 10 species found in this province. **Torba had the lowest overall sea cucumber density and diversity of all provinces**, with only three species recorded. ***Thelenota ananas* was the most widely distributed, and the only species found in all 6 provinces**. *Bohadschia argus* and *Holothuria edulis* were the most abundant, particularly in Shefa where they were found in densities of 0.7 individuals/site (± 0.3 SE) and 0.8 individuals/site (± 0.4 SE), respectively. Sea cucumber sizes varied by species, and many species were too rare to show a reliable size frequency distribution (Figure 11). *Actinopyga palauensis* and *T. ananas* had the largest individuals, both at 58 cm in length. Some species, such as *H. edulis* and *Stichopus chloronotus* had sizes skewed towards smaller individuals, while others such as *B. argus* and *T. ananas* had more symmetrical size distributions.

**TROCHUS (*R. nilotica*)** was most abundant in Shefa (2.3 individuals/site ± 1.2 SE) and Tafea (1.6 individuals/site ± 0.7 SE; Figure 12). **While trochus was recorded in all provinces, densities were particularly low in Penama** (0.1 individuals/site ± 0.08 SE) **and Malampa** (0.2 individuals/site ± 0.2 SE; Map 26). Conversely, **these two provinces had the highest densities of green snail** (*T. marmoratus*; Map 27), with a maximum density of 1.1 individuals/site (± 1.1 SE) in Penama. Torba had particularly low green snail densities (0.04 individuals/site ± 0.04 SE). Trochus size (basal diameter) showed that most individuals were within the legal size for harvest (9-13 cm; Figure 13). Some observations in the raw data showed individuals that were larger than previously reported sizes for trochus (e.g., >15 cm; Chambers 2007, Pakoa et al. 2008), but these were removed from the analysis. Most green snail sizes (maximum shell width) were small (<5 cm), but a number of large (>15 cm) individuals were recorded. As with trochus, a small number of anomalously large (>25cm; Batt n.d.) green snail measurements were recorded in the raw data and were omitted from this analysis.



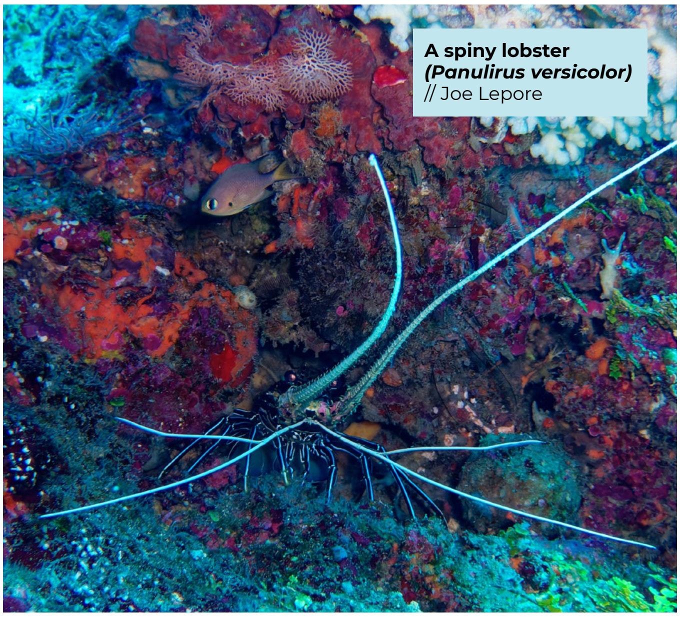
Science divers surveying the reef at Santo Island in Sanma Province // Gilles Siu

A green snail (*T. marmoratus*) at Malekula Island in Malampa Province (top) & a juvenile nestled in the reef in Shefa Province (bottom) // Ada Sokach

A giant clam (*Tridacna maxima*) found at Santo Island // Joe Lepore

**Of the four species of GIANT CLAMS recorded**, two species, *Tridacna crocea* and *Tridacna maxima*, were recorded in all provinces (Figure 14; Map 28). This contrasts with *Hippopus hippopus*, which was limited only to Tafea. **Tafea was the only province where all four species of giant clam were recorded**. While Tafea had the highest diversity, this province had the lowest overall mean density. So while Tafea had the largest number of different species, it had the least number of individual giant clams. **Penama had the highest overall densities of giant clams**, owing largely to a particularly high density of *T. crocea* (5.9 individuals/site ± 1.3 SE). Only *T. crocea* and *T. maxima* had high enough densities to construct meaningful size frequency distributions (Figure 15), and anomalous sizes (greater than the known largest size for each species) were removed from the analysis. Most *T. crocea* were medium to large within the species' range of sizes. *T. maxima*'s size distribution was skewed towards larger individuals, with only a few small individuals recorded.

**The SEA URCHINS** *Echinometra mathaei* and *Echinothrix calamaris* were the most geographically widespread urchin species, occurring in all six provinces (Figure 16; Map 29). *Diadema savignyi* had the highest densities of any urchin species, with particularly high numbers in Malampa (39.2 individuals/site ± 22.7 SE) and Torba (37.2 individuals/site ± 12.7 SE). Particularly high mean densities of *E. mathaei* were found in Penama (39.7 individuals/site ± 8.5 SE). *Echinothrix diadema*, *Phyllacanthus imperialis* and *Heterocentrotus mammillatus* were generally rare, occurring in mean densities of ≤1 individual/site. *E. diadema* was found in Shefa and Tafea, *P. imperialis* in Penama, Malampa and Shefa, and *H. mammillatus* was only found in Tafea.



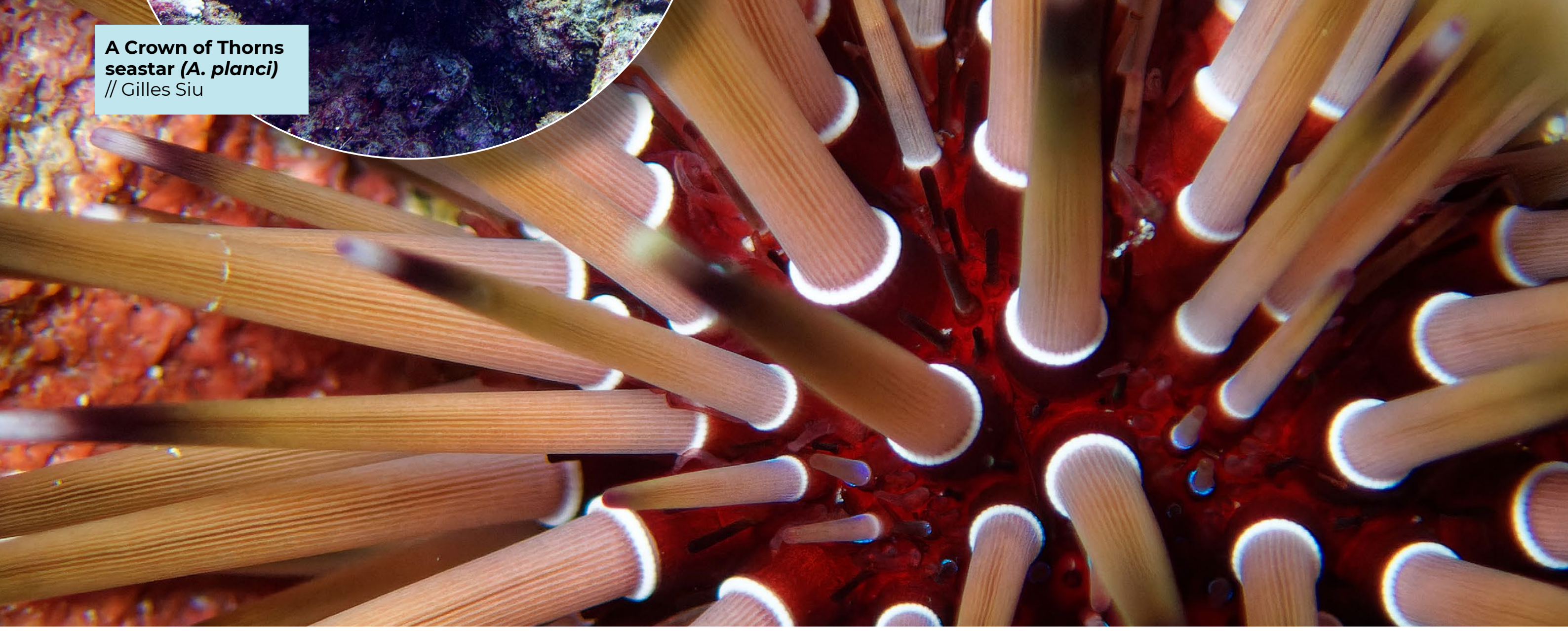
**A spiny lobster *(Panulirus versicolor)*** // Joe Lepore

**The CROWN OF THORNS SEASTAR** (*A. planci*) was uncommon in the surveys, only occurring in Shefa, Tafea and Torba provinces, and at mean densities ≤ 0.1 individuals/site (Figure 17). Conversely, the corallivorous cushion star, *Culcita novaeguineae* was recorded in all provinces, although densities remained low, with a maximum in Sanma at 0.9 individuals/site (± 0.4 SE).

**The LOBSTER** *Panulirus versicolor* was only recorded on belt transects in Tafea and Malampa, and had a maximum mean density in Malampa of 0.08 individuals/site (± 0.08 SE).

**CEPHALOPODS** were uncommon in the belt transect surveys, with only one species of octopus (*Octopus cyanea*) recorded in Shefa with a mean density of 0.7 individuals/site (± 0.7 SE).

**A Crown of Thorns seastar *(A. planci)*** // Gilles Siu



**Sea urchin (*Echinometra mathaei*) in Penama Province** // Gilles Siu

**FIGURE 10**: *Mean density of sea cucumbers in each province. Provinces are listed from north to south on the x-axis.*

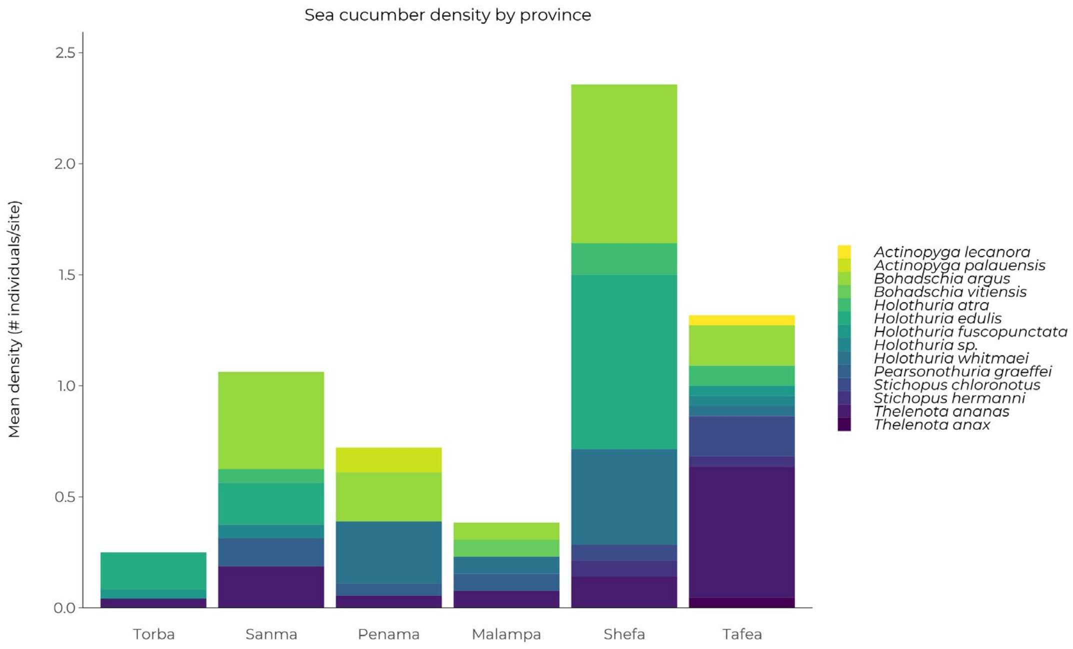



**FIGURE 11**: *Size frequency distributions for sea cucumbers across all sites. Note that only sea cucumbers that were recorded in belt transect surveys were sized, so only these 14 species are represented here. With off-transect observations, a total of 21 species were noted (see Appendix 6 for a full species list).*

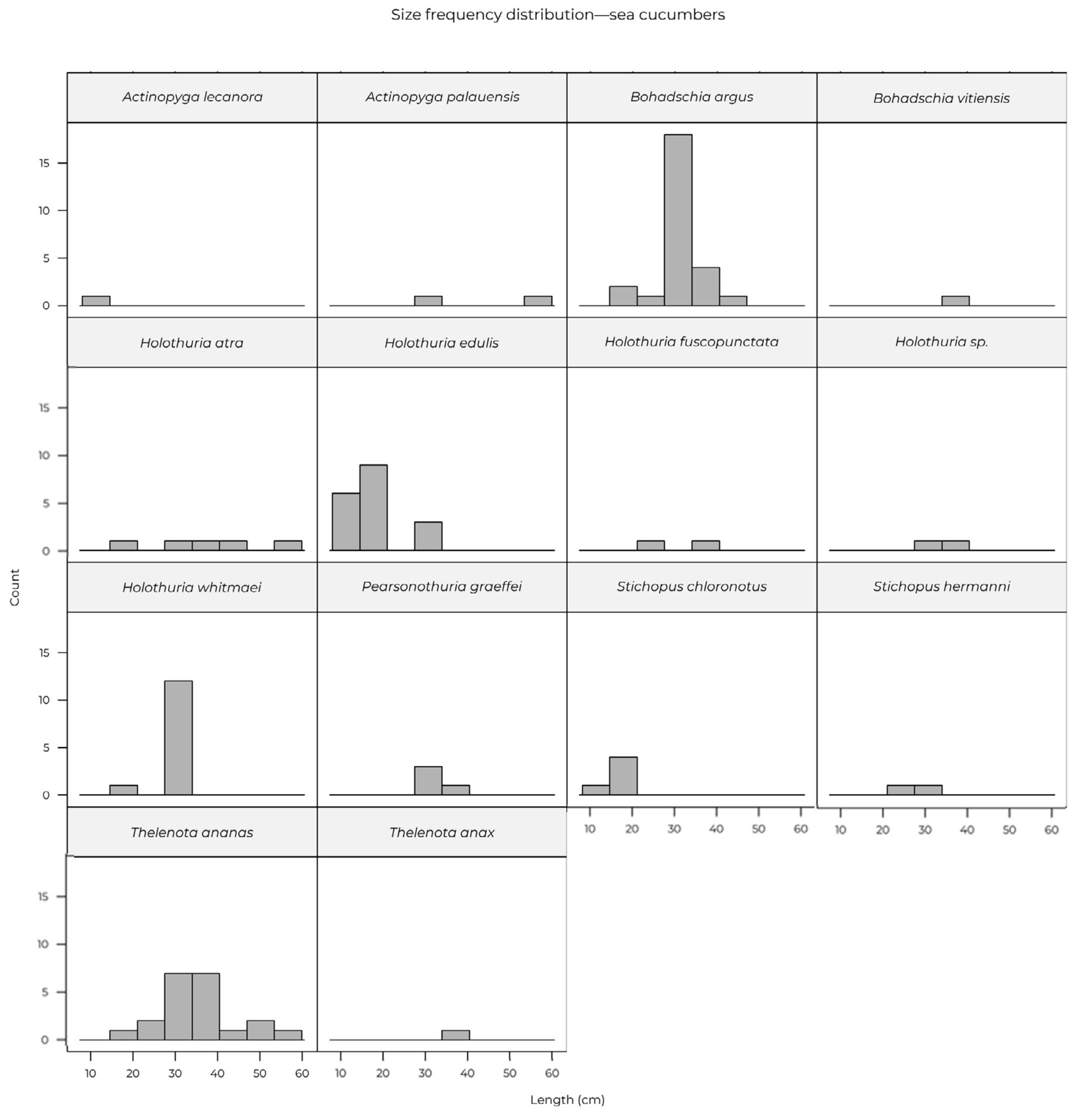


**FIGURE 12**: *Mean density of trochus (*R. nilotica*) and green snail (*T. marmoratus*) in each province. Provinces are listed from north to south on the x-axis.*

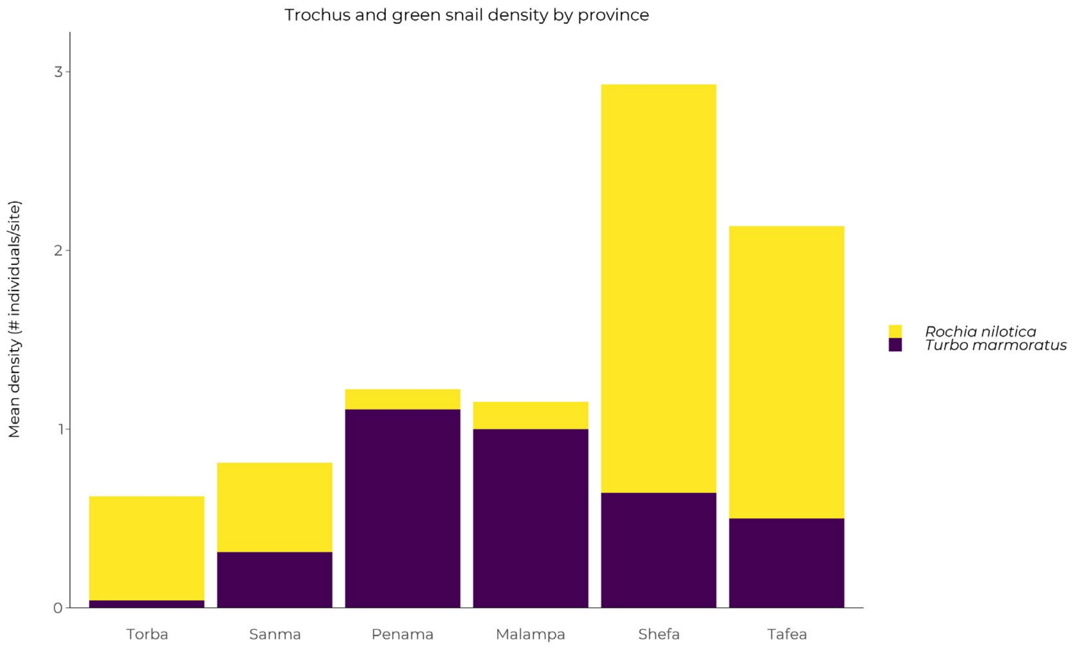
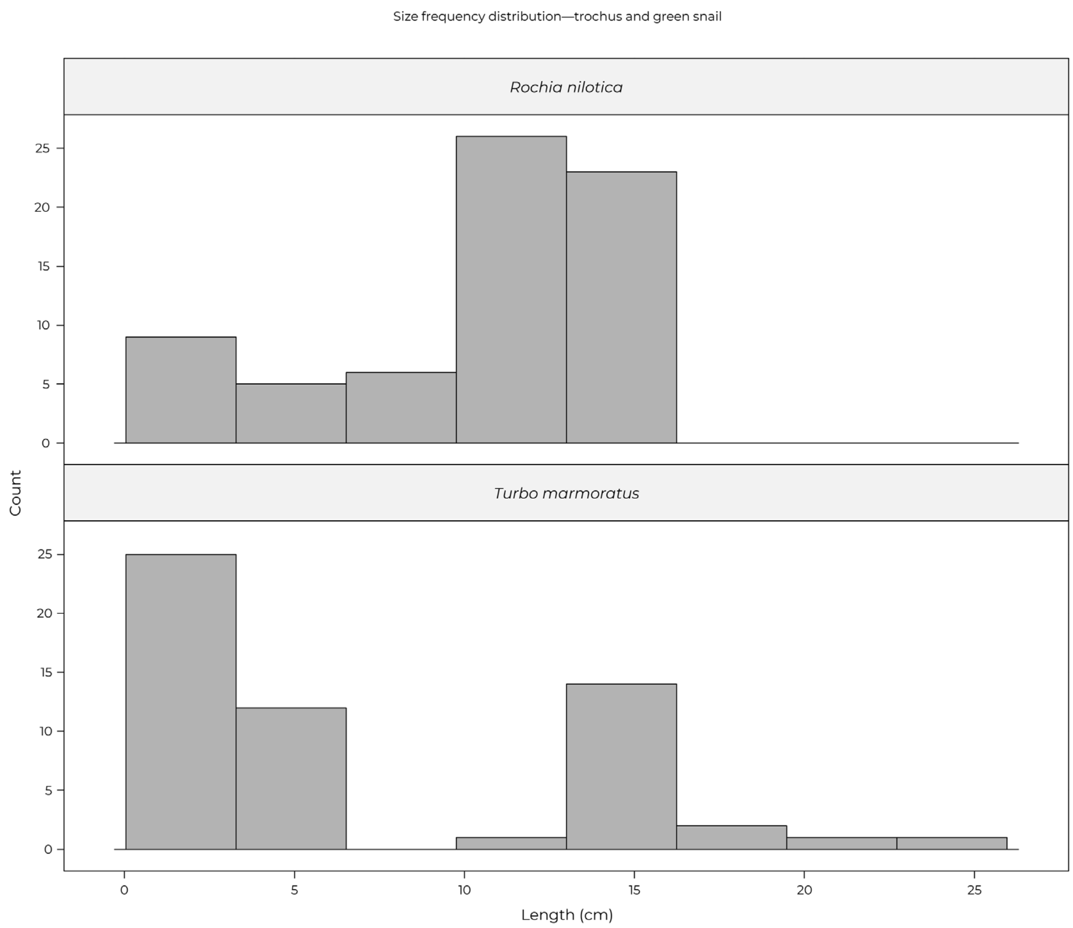



**FIGURE 13**: *Size frequency distributions for trochus (*R. nilotica*) and green snail (*T. marmoratus*) across all sites. Anomalous values greater than the known maximum size for a species have been omitted. Black dotted lines outline the legally harvestable size range for trochus.*



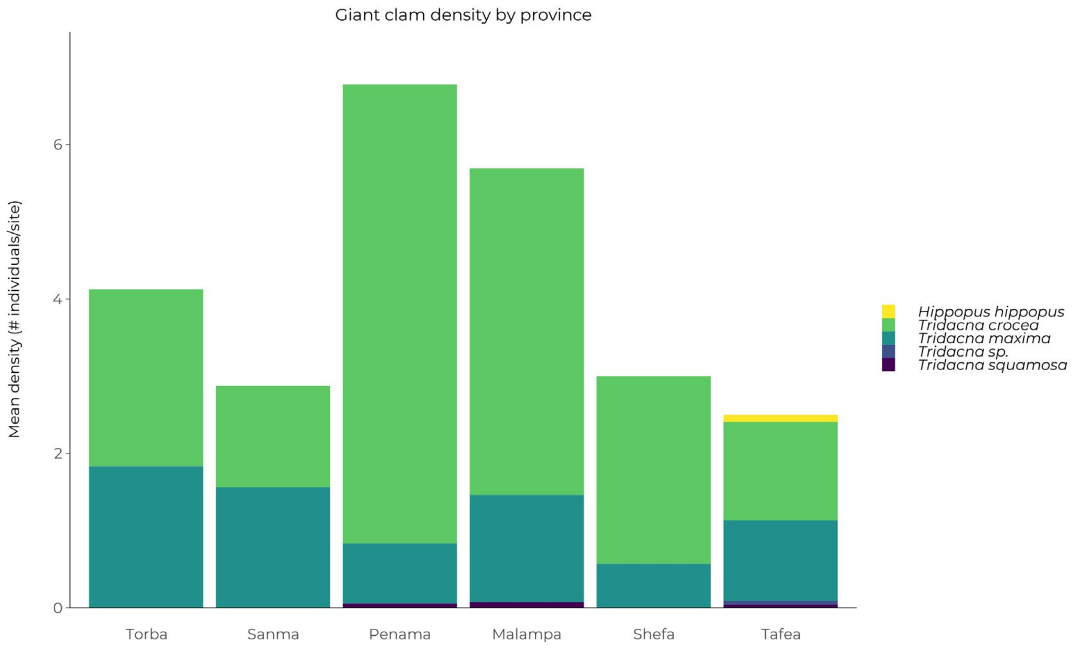



**FIGURE 14**: *Mean density of giant clams in each province. Provinces are listed from north to south on the x-axis.*

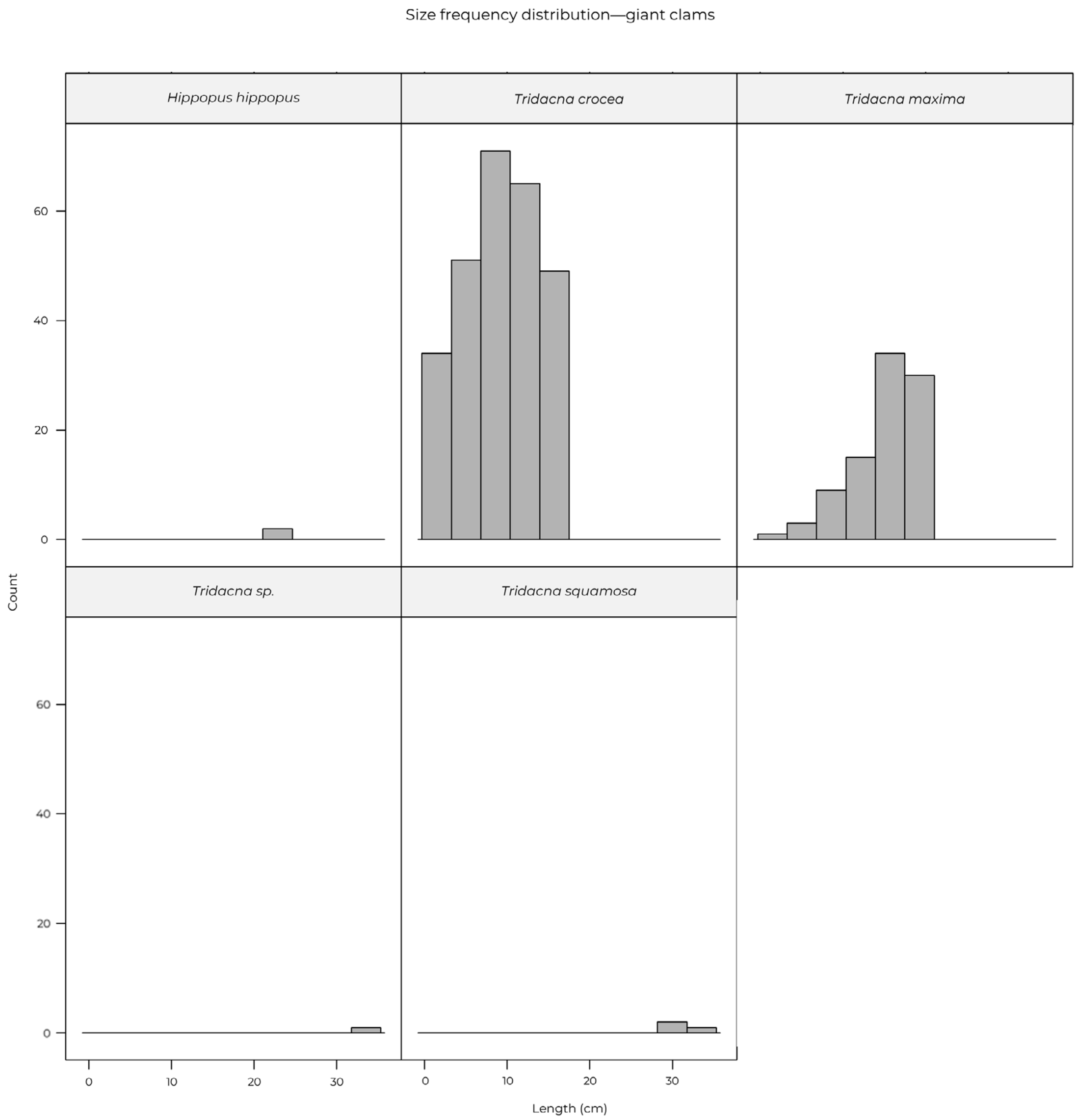



**FIGURE 15**: *Size frequency distributions for giant clams across all sites. Anomalous values greater than the known maximum size for a species have been omitted.*

**FIGURE 16**: *Mean density of sea urchins in each province. Provinces are listed from north to south on the x-axis.*

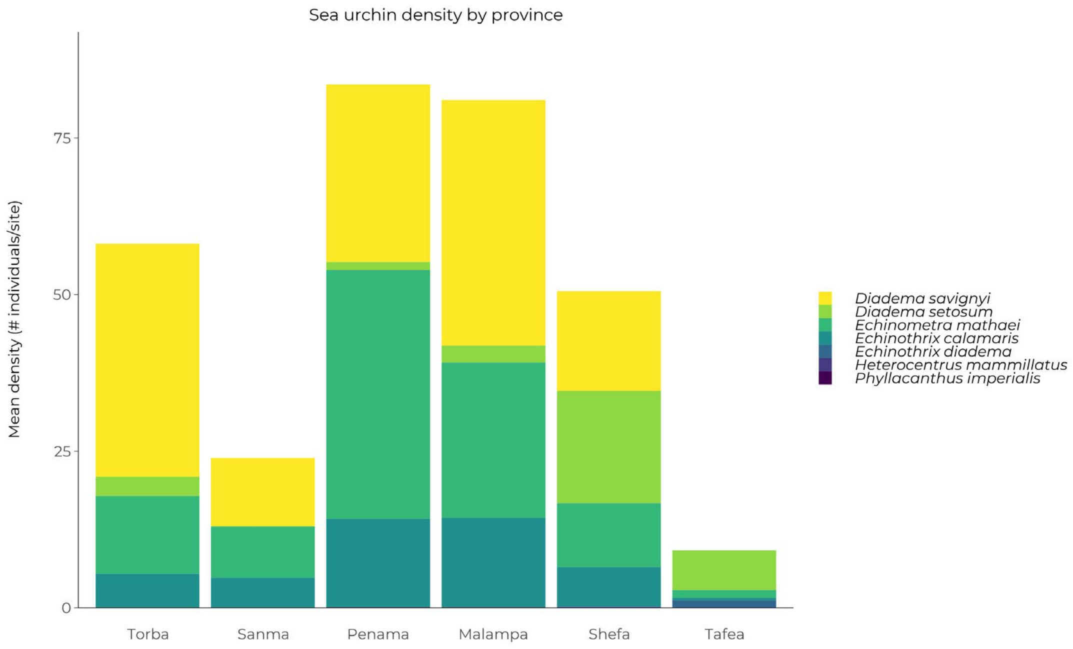
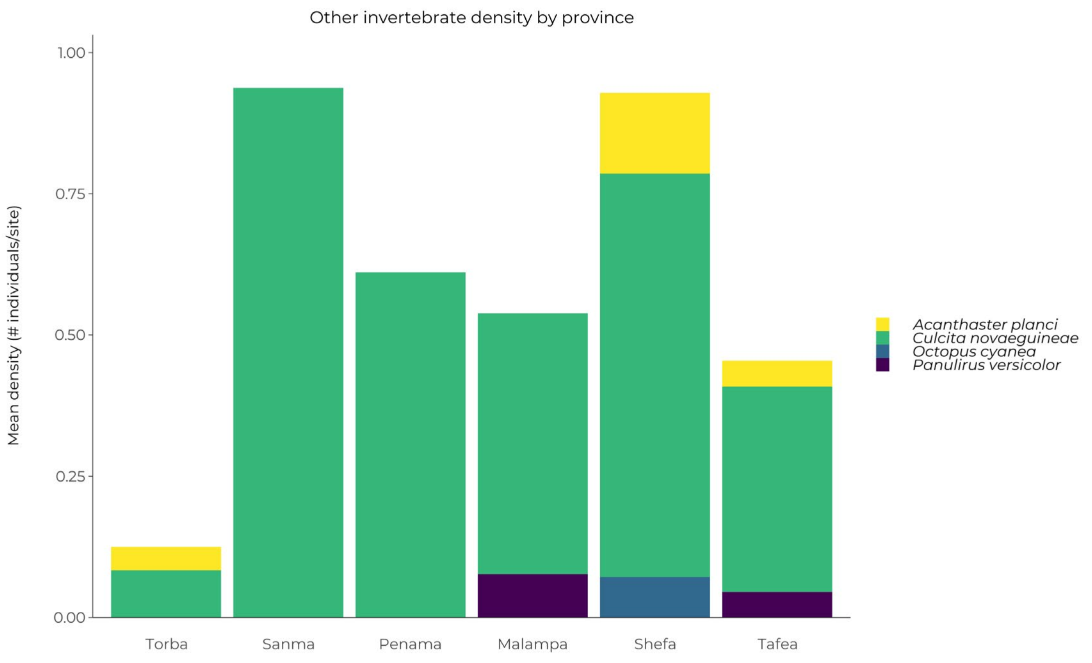
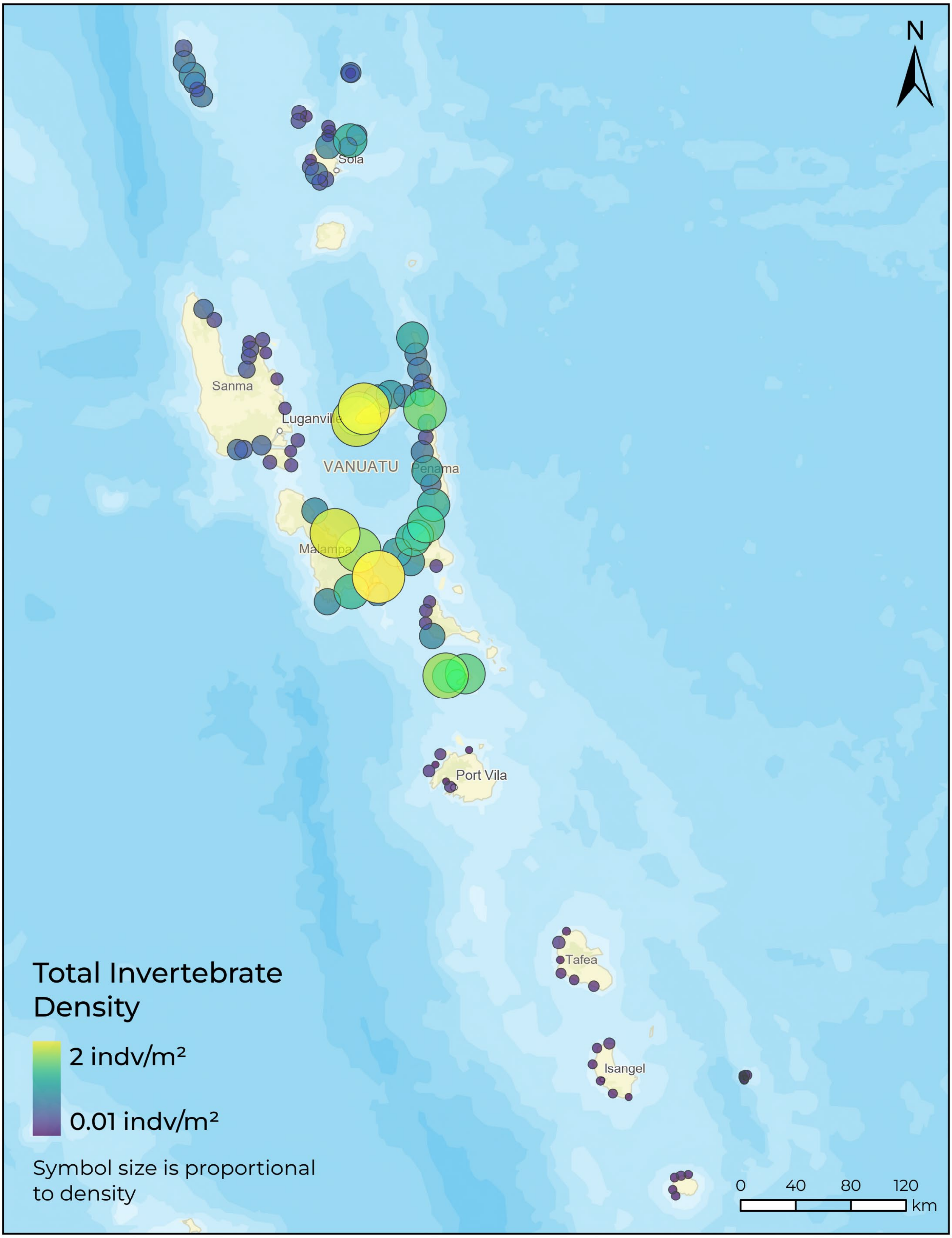


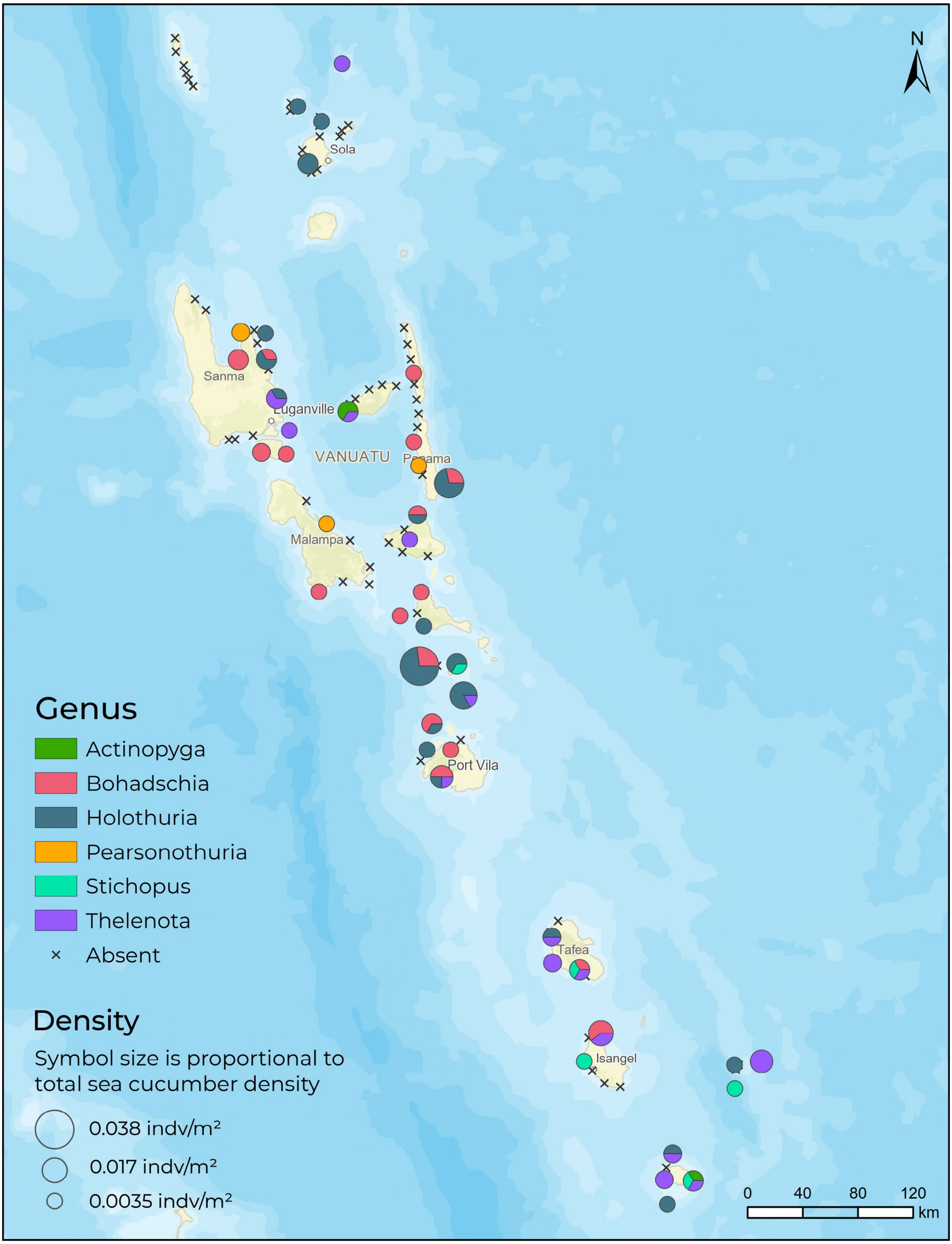

**FIGURE 17**: *Mean density of octopus (*O. cyanea*), corallivorous sea stars (*A. planci *and* C. novaeguineae*), and lobsters (*P. versicolor*) in each province. Provinces are listed from north to south on the x-axis.*



**MAP 24**: *Mean density (number of individuals per square meter) of* ***macroinvertebrates*** *per survey site across Vanuatu. Macroinvertebrates include animals like sea cucumbers, clams, or crabs that do not have a backbone.*



**MAP 25**: *Mean density (number of individuals per square meter) of* ***sea cucumbers by genera*** *observed during belt transects per survey site across Vanuatu.*



# WATER QUALITY

Stable isotope data (δ$^{15}$N) was extracted from dried samples of calcified green algae (*Halimeda spp.* when present, *Tydemania expeditionis* otherwise). See Appendix 3 for sites where algal samples were collected. Low δ$^{15}$N values (0‰ to 4‰) tend to represent natural atmospheric sources of nitrogen, while higher values (7‰ to 38‰) indicate sewage pollution (Dailer et al. 2010). Interpretation of agricultural (fertiliser) inputs of nitrogen are typically context-dependent, as these values overlap with those for atmospheric nitrogen (-4 to 4‰) (Dailer et al. 2010).

Mean δ$^{15}$N was low across all provinces, with a maximum in Shefa at 3.0‰ (± 0.1 SE; Figure 18). Tafea had the lowest mean δ$^{15}$N value, at 2.1 ‰ (± 0.1 SE). There were no obvious latitudinal or other geographic patterns in mean δ$^{15}$N across the country. Interestingly, islands with urban centers did not necessarily have the highest δ$^{15}$N values. Efate had the fourth highest mean value (3.1‰ ± 0.2 SE), while Santo had the fifth lowest value (2.2‰ ± 0.1 SE). The island with the overall highest δ$^{15}$N value was Vot Tande (3.9‰ ± 0.8 SE); however, this value is still within the range of natural atmospheric nitrogen, more likely indicating variability in the isotopic signatures of atmospheric nitrogen across islands, rather than any signal of land-based pollution.

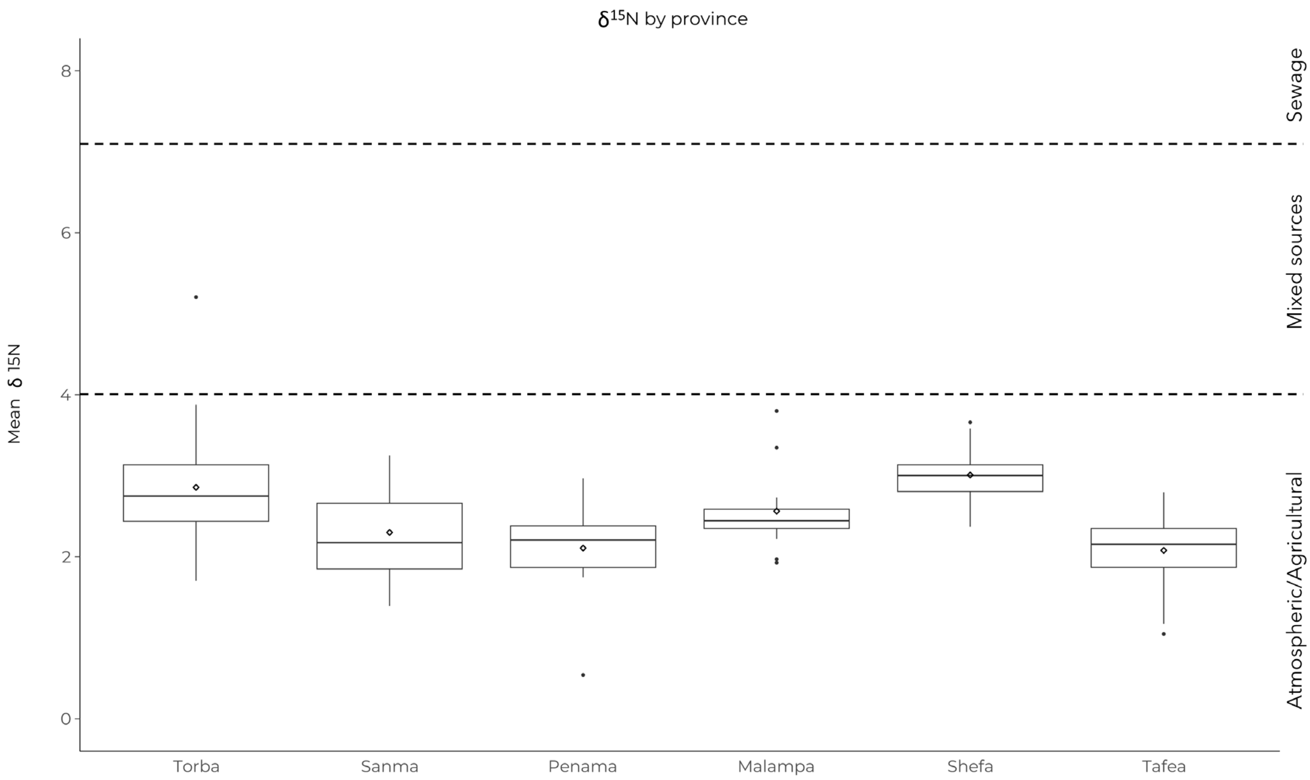
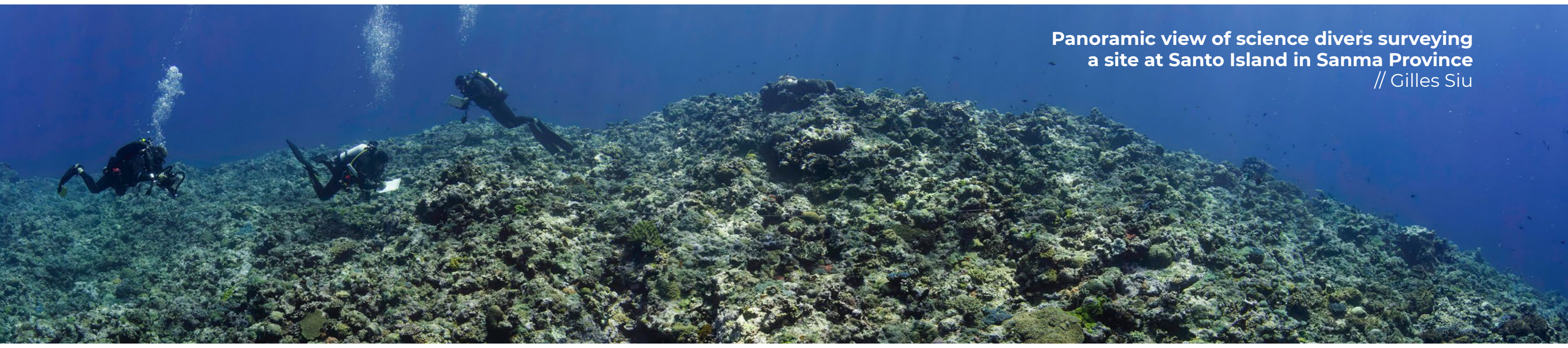



**FIGURE 17**:
*Mean δ$^{15}$N at each province surveyed. Bold horizontal lines represent the median value at each island, and diamonds represent the mean. Dotted lines represent approximate ranges for different sources of nitrogen. Provinces are listed from north to south on the x-axis.*



**Panoramic view of science divers surveying a site at Santo Island in Sanma Province**
// Gilles Siu

# PROVINCIAL SUMMARIES

Province-level means for the main reporting metrics described above are summarized in Table 2.

**TABLE 2**: Province-level means and associated standard errors for major reporting metrics across all surveys.

| | | | TORBA | | SANMA | | PENAMA | | MELAMPA | | SHEFA | | TAFEA | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MEAN | ± SE | MEAN | ± SE | MEAN | ± SE | MEAN | ± SE | MEAN | ± SE | MEAN | ± SE |
| **Fish** | Density (individuals/m²) | Planktivores | 2.5 | 0.6 | 1.9 | 0.4 | 3.1 | 1 | 1.7 | 0.2 | 2.4 | 0.5 | 2.3 | 0.6 |
| | | Herbivores | 0.5 | 0.05 | 0.6 | 0.05 | 0.5 | 0.04 | 0.5 | 0.08 | 0.6 | 0.08 | 0.4 | 0.04 |
| | | Lower-Carnivores | 0.9 | 0.07 | 1.1 | 0.41 | 1 | 0.1 | 0.8 | 0.08 | 1 | 0.2 | 0.6 | 0.04 |
| | | Top-Predators | 0.02 | 0.003 | 0.009 | 0.001 | 0.01 | 0.002 | 0.1 | 0.002 | 0.008 | 0.001 | 0.01 | 0 |
| | | Sharks | 6.9 e-5 | 6.9 e-5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7.2 e-5 | 7.2 e-5 |
| | Biomass (g/m²) | Planktivores | 26 | 5.9 | 31.1 | 10.4 | 44.3 | 11.5 | 52.1 | 21.9 | 44.2 | 15.5 | 23.9 | 4.9 |
| | | Herbivores | 70.1 | 7.7 | 50 | 4.6 | 53.1 | 4.9 | 70.4 | 13.1 | 70.7 | 10.9 | 54.7 | 8.6 |
| | | Lower-Carnivores | 45.6 | 6.2 | 38.4 | 6 | 45.4 | 6.1 | 67.1 | 17.4 | 51.8 | 11.3 | 28.9 | 4 |
| | | Top-Predators | 10.5 | 2.2 | 5.2 | 1.3 | 9.7 | 2.7 | 4 | 1.5 | 7.6 | 2.4 | 4.4 | 1 |
| | | Sharks | 0.75 | 0.75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.9 | 0.9 |
| **Benthic Cover (calcifiers)** | Hard Coral Cover (%) | | 19.9 | 2.8 | 21.2 | 2.8 | 26.2 | 3.01 | 25.4 | 2.6 | 13.8 | 3.4 | 14.2 | 2.2 |
| | Calcified Macroalgae (%) | | 14 | 1.9 | 7.3 | 0.9 | 11.1 | 2.3 | 12.9 | 1.8 | 9.4 | 2.6 | 12.4 | 1.8 |
| | CCA (%) | | 23.8 | 3.2 | 22.4 | 2.5 | 11 | 1.4 | 12.5 | 2.6 | 17 | 2.9 | 22.4 | 3.2 |
| **Benthic Cover (non-calcifiers)** | Invertebrate (%) | | 1.5 | 0.3 | 3.2 | 0.8 | 2.1 | 0.5 | 1.55 | 0.27 | 1.4 | 0.3 | 1.1 | 0.2 |
| | Macroalgae (%) | | 7.1 | 1.5 | 2.6 | 0.5 | 3.3 | 0.6 | 4.43 | 1.2 | 3.9 | 0.9 | 3.7 | 0.6 |
| | Soft Coral (%) | | 1.3 | 0.5 | 3.6 | 1.1 | 1.3 | 0.9 | 3 | 1.2 | 2.5 | 0.8 | 6.1 | 1.4 |
| | Turf (%) | | 24.8 | 3 | 32.4 | 4.6 | 39.6 | 3.4 | 30.5 | 3.2 | 40.7 | 4.3 | 34.6 | 4.2 |
| **Invertebrates** | Macroinvertebrate Density (individuals/300 m²) | Trochus | 0.6 | 0.3 | 0.5 | 0.3 | 0.1 | 0.08 | 0.2 | 0.2 | 2.3 | 1.2 | 1.6 | 0.6 |
| | | Green Snails | 0.04 | 0.04 | 0.3 | 0.3 | 1.1 | 1.1 | 1 | 0.8 | 0.6 | 0.6 | 0.5 | 0.2 |
| | | Giant Clams | 4.1 | 1 | 2.9 | 0.7 | 6.8 | 1.4 | 5.8 | 2.1 | 3 | 1.2 | 2.5 | 0.7 |
| | | Cephalopods | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07 | 0.07 | 0 | 0 |
| | | Crustaceans | 0 | 0 | 0 | 0 | 0 | 0 | 0.08 | 0.08 | 0 | 0 | 0.05 | 0.05 |
| | | Sea Cucumbers | 0.3 | 0.1 | 1 | 0.3 | 0.7 | 0.4 | 0.4 | 0.2 | 2.3 | 0.8 | 1.3 | 0.3 |
| | | Sea Urchins | 58.1 | 11.7 | 23.9 | 2.8 | 83.5 | 15 | 81 | 23.2 | 50.6 | 18.6 | 9.1 | 2.8 |
| | | Seastars | 0.1 | 0.06 | 0.9 | 0.4 | 0.6 | 0.2 | 0.5 | 0.3 | 0.9 | 0.4 | 0.4 | 0.2 |
| **Stable Isotope Ratio** | δ¹⁵N (‰) | | 2.8 | 0.14 | 2.3 | 0.14 | 2.1 | 0.19 | 2.6 | 0.15 | 3 | 0.11 | 2.1 | 0.1 |
| **Rugosity** | Rugosity ratio (no units) | | 1.6 | 0.04 | 1.6 | 0.05 | 1.6 | 0.05 | 1.7 | 0.07 | 1.6 | 0.04 | 1.5 | 0.04 |
| **Juvenile Corals** | Density (individuals/m²) | | 11 | 1.6 | 10.1 | 1.5 | 18 | 1.8 | 9.1 | 1.3 | 9.7 | 1.2 | 7.5 | 0.8 |

Science diver engaging with a community member in Penama Province // Joe Lepore

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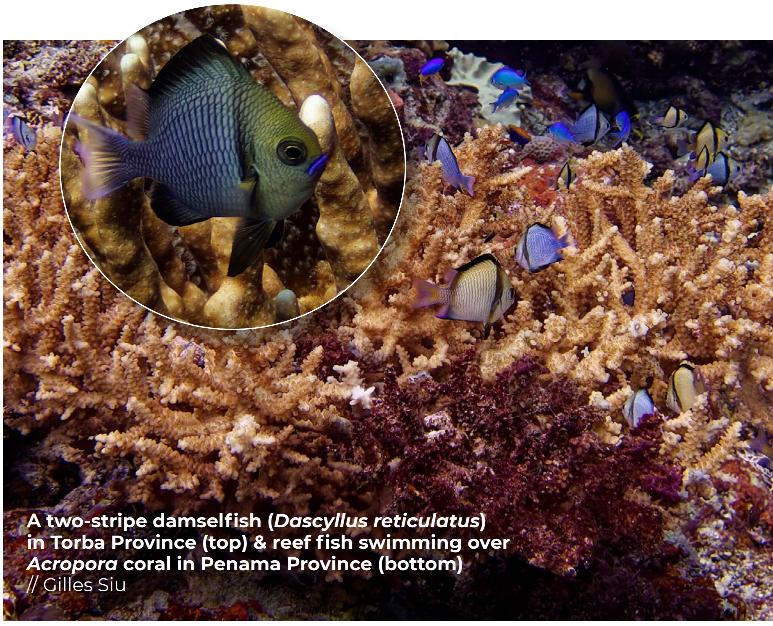
# DISCUSSION

The results presented in this report provide baseline data on coral reef health across the country at the 10 metre depth contour on leeward forereefs. While these surveys do not constitute a stock assessment, they do **provide important information about the abundance, diversity and distribution of commercially and ecologically significant reef resources in Vanuatu**. Understanding the current state of reef health in different locations across the country is the **first step toward effective ocean management**.

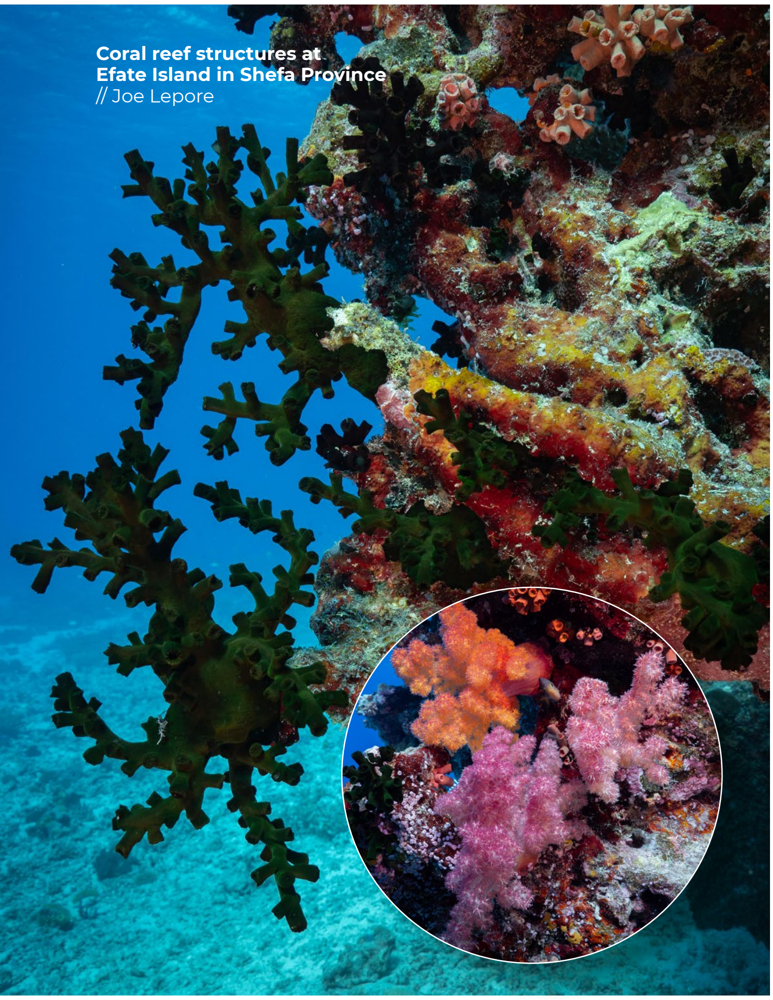
## REEF FISH

**In total, 448 of the 543 known reef fish species found in Vanuatu (Vanuatu Fisheries Department 2009) were recorded in this survey**. This is comparable to a previous survey conducted by Done and Navin in 1990, which recorded 469 species on reefs shallower than 30 m (cited in Naviti & Aston 2000). Vanuatu is located within Melanesia, outside of, but near, the Coral Triangle, where coral reef diversity is highest in the world. As expected based on its geographic position, reef fish diversity in Vanuatu fell between that of Samoa, where comparable surveys found 244 fish species (Government of Samoa 2024) and Papua New Guinea, where extractive surveys found 470 reef fish species (Drew et al. 2015). Mean fish density in Vanuatu was 3.7 individuals/m$^2$, and mean biomass was 151.9 g/m$^2$. A survey of nine Pacific nations, including nearby countries such as Solomon Islands, New Caledonia, and Fiji, found maximum fish densities of 2.8 individuals/m$^2$ in the Tuamotu Archipelago of French Polynesia, suggesting that the estimates found in this study are high compared to other nations in the region (Carlton et al. 2021). In contrast, the biomass estimates found in this study were comparable to or slightly below those for some nearby nations such as New Caledonia (187.9 g/m$^2$) and Fiji (162.5g/m$^2$) (McClanahan et al. 2019).



A two-stripe damselfish (*Dascyllus reticulatus*) in Torba Province (top) & reef fish swimming over *Acropora* coral in Penama Province (bottom) // Gilles Siu

Fish surveys showed that though fish density is relatively similar across provinces, biomass varies more widely, suggesting differences in the size of fish in different parts of the country. For example, Malampa had the lowest fish density but highest mean biomass, indicating that fish are larger on average in this province. This contrasts with Penama, and to a lesser extent Sanma and Tafea, in which biomass was low in comparison to density, suggesting smaller fish sizes on average. Across all provinces, planktivores were most abundant, and top predators and sharks were rare. Herbivore/detritivore densities were remarkably similar across provinces, but biomass varied more widely, indicating larger herbivores on average in Torba, Malampa, and Shefa provinces. Herbivores and lower carnivores made up the majority of the biomass across provinces. The herbivore families with the largest biomass were Acanthuridae (surgeonfishes) and Scarinae (parrotfishes), while the majority of the lower carnivore biomass was found in Labridae (wrasses), Lutjanidae (snappers), Balistidae (triggerfish) and Serranidae (groupers). There was no apparent latitudinal trend for any of the reported metrics.



**Coral reef structures at Efate Island in Shefa Province**
// Joe Lepore

# BENTHIC COVER

## HARD CORALS

**Mean coral cover across Vanuatu was 19.8%. This is lower than some reported averages for the wider South Pacific**, estimated by different groups as 25.6% (Mortiz et al. 2018) and 36% (Carlton et al. 2021). However, it must be noted that all surveys in those studies occurred prior to the 2016 global bleaching event; therefore, current averages may differ. More recent estimates from Tonga showed lower mean coral cover than Vanuatu in 2022 (7.7%) and coral cover in Samoa during the same year was similar to that found in this study (20.9%) (Vava'u Ocean Initiative 2023, Government of Samoa 2024). The current estimate is on par with the few previously published estimates of coral cover from Vanuatu, which typically report between ~13-25% cover (Lovell et al. 2004, Pakoa et al. 2008, Dumas et al. 2017), although some exceptional sites such as Devil's Point in Efate have been previously reported as having up to 70% cover of live coral (Hill 2004).

**There appeared to be a slight trend towards higher coral cover in the northern provinces** (Torba, Sanma, Penema, Malampa) than in the south (Shefa, Tafea). In particular, Tafea and Shefa had lower coral cover than the other four provinces. It should be noted that approximately six months prior to the current survey, twin cyclones Judy and Kevin hit Vanuatu within 48 hours of each other. Both storms passed near or directly over the islands of Tafea and Shefa provinces at their peak intensities (NOAA, 2025). While it is not possible to attribute any causation with the current dataset, it is possible that these disturbances may have led to reduced coral cover in these areas in particular, potentially explaining the lower coral cover in the southern provinces.

Despite moderate mean coral cover, **coral diversity was relatively high, with a total of 51 genera recorded across the benthic photoquadrat and coral recruitment surveys** (note, 48 species were recorded in photoquadrats and 42 were recorded in juvenile coral surveys, but due to a lack of complete overlap between the genera in the two surveys, the total number comes out to more than either survey on its own. See Appendix 5 for a full list).

# BENTHIC COVER (cont.)

## ALGAE

Turf algae made up the highest proportion of cover in all provinces, and fleshy macroalgae was low across the country. Interestingly, CCA cover was lowest in the provinces with the highest coral cover (Malampa and Penama).

# CORAL RECRUITMENT

Coral juvenile density followed a similar pattern to coral cover, with a **slight trend towards higher densities in the north**, with the highest values in Penama province. **Overall mean juvenile coral density was relatively high compared to other Pacific reefs** at 10.7 individuals/m$^2$. Directly comparable surveys in Samoa and Tonga found much lower juvenile coral densities (5.7 and 6.2 individuals/m$^2$, respectively; Vava'u Ocean Initiative 2023, Government of Samoa 2024). On Heron Island in Australia, juvenile coral density was 3.8 individuals/m$^2$ (Doropolus et al. 2015), while reefs in Palau were found to have an average of 6.3 juveniles/m$^2$ at 10 m depth (Gouzeo et al. 2020). However, more remote locations have been found to have much higher rates of recruitment; for example, reefs at Palmyra Atoll had an average of 59.5 juveniles/m$^2$ (Roth & Knowlton 2009). **It is possible that this high level of coral recruitment has allowed Vanuatu's reefs to maintain moderate levels of coral cover, despite recurring disturbances** such as cyclones, earthquakes, volcanic eruptions, bleaching and COTS outbreaks. While patterns of coral diversity did not directly track between benthic photoquadrat and coral recruitment surveys, *Acropora, Porites, Favites* and *Goniastrea* were among the most common genera found in both.

**A small *Acropora* coral seen in Sanma Province**
// Gilles Siu

**Science divers surveying reefs in Torba Province (top) & corals and anemone in Malampa Province (bottom)**
// Gilles Siu

# RUGOSITY

High structural complexity on reefs is often associated with increased habitat for fish and other reef organisms, and reefs with higher rugosity may be capable of supporting populations of larger fish (Nemeth & Appeldoorn 2009; Harborne et al. 2012). As with other benthic metrics, Tafea and, to a lesser extent, Shefa, had the lowest mean rugosity ratios, as expected for the provinces with the lowest coral cover. However, the correlation between coral cover and rugosity was not as clear in the more northern provinces. While Malampa had high coral cover and the highest rugosity, there was little difference in rugosity between Sanma, Penama and Torba, despite differences in coral cover. That being said, however, the range of mean rugosity ratios over the country was small, with a difference of only 0.2 between Tafea and Malampa. Overall, mean rugosity was high when compared to other geographies surveyed using the same methods, where national averages all fell below Vanuatu's average of 1.6 (Maldives atoll-level mean between 1.2-1.4; Samoa island-level mean between 1.2-1.3; Tonga island-level mean between 1.1-1.4) (Vava'u Ocean Initiative 2023, Government of Samoa 2024, Noo Raajje 2025). Therefore, the high mean rugosity seen across Vanuatu may be a contributing factor towards the high fish density and moderate biomass recorded in this study.

# INVERTEBRATES

Commercially important sea cucumbers were present in all provinces, but at low densities. Fourteen species of sea cucumber were recorded in belt transect surveys, and 21 species were recorded when including off-transect observations. While this is lower than other surveys have found (e.g., 36 species, Ducarme et al. 2023), those studies surveyed several habitats preferred by sea cucumbers, while all surveys in this study were conducted at 10 m forereef sites. Of the 21 species recorded, 16 are commercially valuable. *B. argus* was the most commonly recorded species in this study, consistent with findings from Ducarme et al. (2023); however, *H. edulis* had higher relative densities in the current study than found previously. Two species listed as vulnerable by the IUCN (*Actinopyga miliaris* and *Stichopus hermanni*) and four listed as endangered (*Holothuria nobilis, H. whitmaei, T. anax*, and *T. ananas*) were recorded (IUCN 2025). In fact, *T. ananas* was the most widely distributed species and had one of the two largest individuals of all sea cucumbers surveyed. Despite moderately high diversity, however, sea cucumber densities fell far below those found in previous surveys, including those that concluded the need for continued bans on harvesting (Pakoa et al. 2013). However, it should be noted that other surveys specifically focused on assessing sea cucumber abundance have used methods better tailored to assessing densities (e.g., manta tows) and have surveyed more diverse habitats (Pakoa et al. 2013, Ducarme et al. 2023), so lower densities are to be expected with the current methodology.

## TROCHUS & GREEN SNAILS

Trochus and green snails were also found in all provinces at low densities. Densities of trochus in all provinces were well below the fishable stock level of 500 individuals/ha (Pakoa et al. 2008), with the highest mean density in Shefa at only 76.7 individuals/ha. However, trochus is known to prefer shallow reef flats over deeper reef slopes and forereefs (Pakoa et al. 2008, Senior et al. 2020), so the location of the surveys at 10 m forereef sites likely contributed to the low densities seen here. Despite low densities, however, the majority of individuals surveyed fell within the legal collection sizes of 9-13 cm. Patterns were similar for green snails, with densities far below those found in previous surveys, despite a 15-year ban on collection and continued management of the resource (Pakoa et al. 2014, Terashima et al. 2020). However, these results should be viewed with the same caveats on survey methodology and habitat type as applied for trochus. While the majority of individuals were very small (<5 cm), a number of larger (>15cm) individuals were recorded. Further surveys of optimal habitats and depths for both trochus and green snail would be useful in determining true densities and size frequency distributions for these commercially important species.

**Science divers surveying the site using the photoquadrat method in Torba Province**
// Gilles Siu

**A green snail at Efate Island in Shefa Province**
// Ada Sokach

## GIANT CLAMS

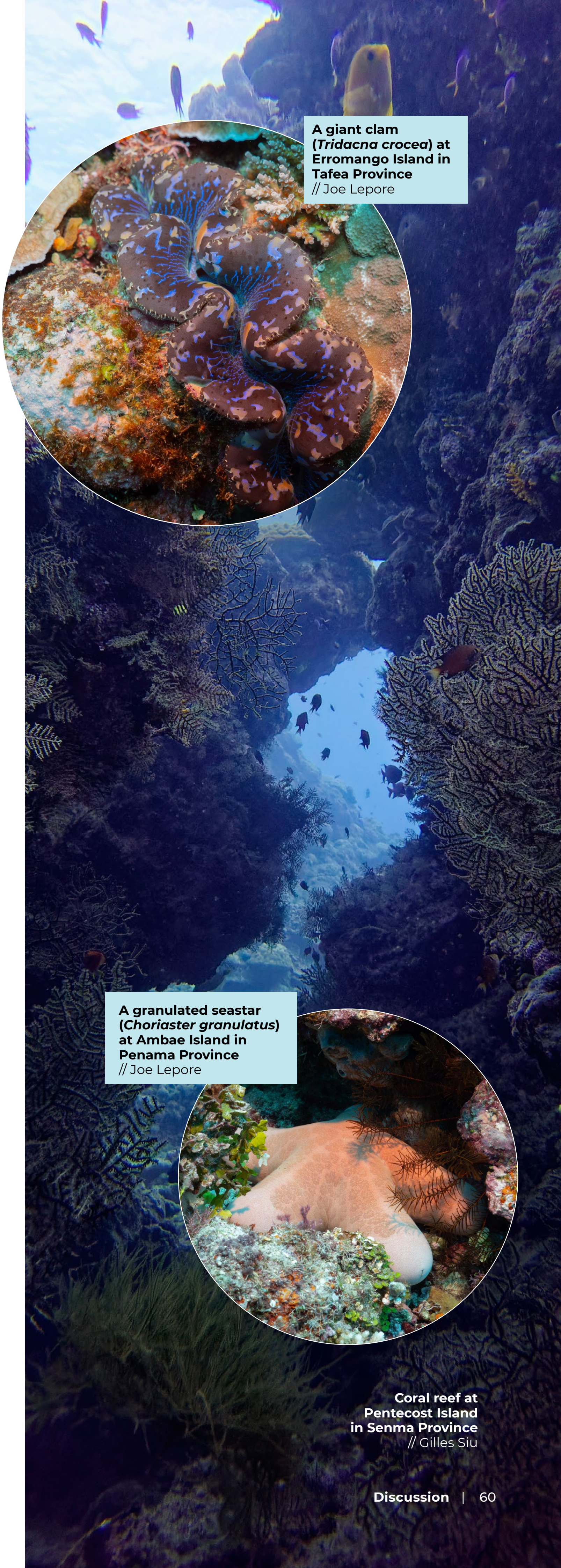
**Four species of giant clam were present in the surveys**, but *T. crocea* and *T. maxima* made up the majority of sightings and were the only species found in all provinces. *T. crocea* densities were previously extremely low in Vanuatu (Pakoa et al. 2008) and harvest of this species was banned nationally (Sulu et al. 2002, Lovell et al. 2004), so the high numbers found in this survey are encouraging. *H. hippopus* was the rarest species, found only in Tafea, while *Tridacna squamosa* appeared in low densities in half of the provinces. As with other invertebrate groups, **additional surveys in different habitats would help create a more holistic understanding** of giant clam populations across Vanuatu.

## LOBSTERS & OCTOPUS

Lobsters and octopus, other species commonly targeted for fisheries, were **rare** in the belt transect surveys.

## SEASTARS & SEA URCHINS

**COTS (*A. planci*), which has periodically experienced outbreaks in Vanuatu, was found in very low numbers** in this survey, and was only recorded in three of the six provinces. Therefore, there is currently **no evidence of strong COTS predation on corals in any forereef location in the country**, despite this being identified as a strong threat to reefs in the past. It should be noted that the Vanuatu Fisheries Department conducted coordinated cleanups of COTS in Pango and Ifira on Efate in 2022 in response to large aggregations noted in the area, so despite the findings here, **recent outbreaks have occurred near some of the areas surveyed in this study** (Vanuatu Fisheries Department 2022). The corallivorous cushion star, *C. novaeguineae*, was more abundant and widely distributed than *A. planci*, but densities were still low. Conversely, **sea urchin densities were relatively high**, except in Tafea and Sanma. Sea urchins are important reef herbivores, and high densities **help maintain reef health** by keeping algal growth in check.



**A giant clam (*Tridacna crocea*) at Erromango Island in Tafea Province**
// Joe Lepore

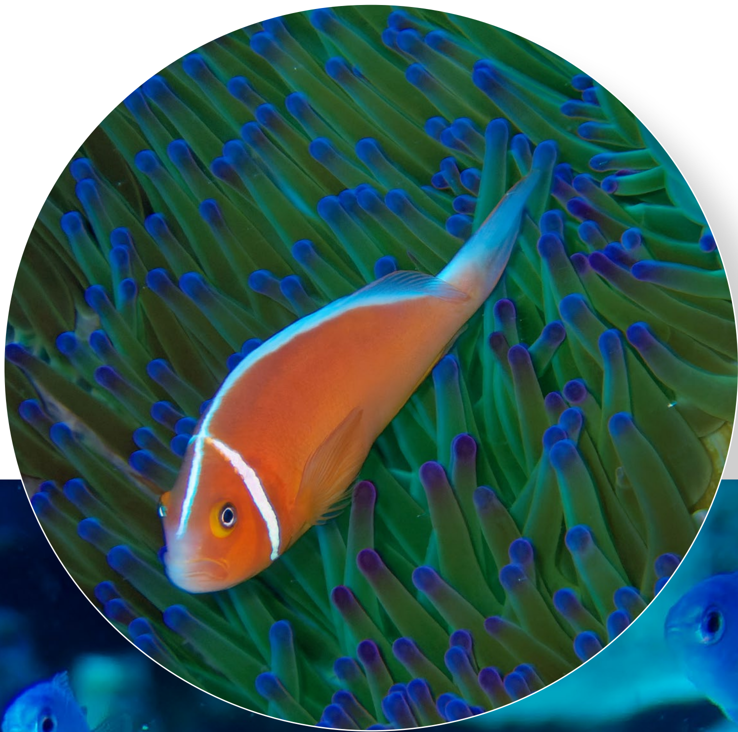
**A granulated seastar (*Choriaster granulatus*) at Ambae Island in Penama Province**
// Joe Lepore

**Coral reef at Pentecost Island in Senma Province**
// Gilles Siu

# WATER QUALITY

**There is no evidence of sewage pollution on 10 m forereefs across any of the provinces.** Even highly populated islands, such as Efate, had $\delta^{15}$N values below 4, despite previous reports of high amounts of sewage pollution. While in rural areas, the signals found in this study are likely representative of the true runoff from land, in urban areas, it is likely that **any land-based pollution may have been diluted by the time it reached 10 m on the forereef**; further testing closer to shore and within lagoons would be needed to get a more accurate picture of true sewage runoff in these areas. However, regardless of potential sewage pollution in shallower, lagoonal sites, **it does not appear that sewage pollution has an influence on forereefs in any location in Vanuatu**.

Mean $\delta^{15}$N in this study ranged from 2.1‰ in Tafea to 3.0‰ in Shefa. The stable isotope ratio of nitrogen ($^{15}$N:$^{14}$N, expressed as $\delta^{15}$N), can be used to trace the source of nutrients on a reef (Dailer et al. 2010; Dailer et al. 2012). Typically, natural (atmospheric/oceanic) sources of nitrogen, as well as nitrogen from synthetic fertilisers, have low $\delta^{15}$N values ranging from 0‰ to 4‰ and -4‰ to 4‰, respectively, while sewage tends to have values greater than 7‰ (Dailer et al. 2010; Dailer et al. 2012).



**A pink anemonefish (*Amphiprion perideraion*) at Ambrym Island in Malampa Province (top) & a school of blue-green chromis (*Chromis viridis*) at Maewo Island in Penama Province (bottom)**
// Gilles Siu

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Coastline of Malekula Island in Malampa Province
// Andy Estep

# CONCLUSIONS

**This baseline survey provides a holistic snapshot of the current status of Vanuatu's reefs from which future management efforts can be developed**. This survey can also serve as a benchmark against which future assessments of fishing pressure or reef health can be compared.

Overall, reefs in Vanuatu are characterised by low to moderate coral cover, relatively high rugosity and fish density, and moderate fish biomass. Fish and coral communities displayed high levels of diversity. High levels of coral recruitment throughout the country may be partially responsible for maintaining coral cover despite ongoing disturbances, such as cyclones, earthquakes, volcanic eruptions, bleaching and COTS outbreaks. Densities of commercial invertebrates were low; however, given the habitats surveyed and the methodology used, it is difficult to determine to what extent this is due to the effects of overharvesting rather than being an artefact of the survey design. It is likely that both factors influenced the observed patterns. COTS densities were very low, and no COTS outbreaks were observed on 10 m forereefs. Sea urchin densities were moderately high, likely partially contributing to the low levels of macroalgae seen in this study. Land-based sewage pollution, though possibly present in the lagoons in some parts of the country, does not appear to affect forereefs at any location.

**These findings establish a critical foundation for ongoing reef monitoring, and future surveys will be essential to track changes over time and support sustainable ocean management in Vanuatu.**

**A bubble coral shrimp inside a bubble coral (*Plerogyra sinuosa*) at Pentecost Island**
// Gilles Siu

# RECOMMENDATIONS FOR FUTURE SURVEYS

### Expand the range of this survey to include unsurveyed islands and coasts, and plan to resurvey existing sites over time.

While efforts were made to ensure that data generated in this study covered the full extent of the country, not all islands were able to be included, and surveys were constrained to leeward coasts to ensure safe diving conditions. Conducting additional surveys in the areas not included in this study would help create a more holistic understanding of the state of Vanuatu's reefs, and would provide useful information to the communities located in these unsurveyed areas. In addition, all sites surveyed in this study were marked with a GPS point and a permanent marker, making resurvey of the exact same reef area possible. While the data presented in this study represent a snapshot of reef condition at a given point in time, resurveying sites allows for an understanding of trends and changes over time. These data are useful in understanding the effects of human pressures, climate change, and management actions on reefs, and can help inform future management initiatives. If possible, future surveys should follow the methodology outlined in this study in order to produce directly comparable results between time points and locations.

### Expand the range of this survey to include additional depth strata and habitat types.

In an effort to standardise data across locations and increase the geographic footprint of this survey, only forereef sites at 10 m depth were surveyed. However, coral reef communities vary widely between different depth strata, and reefs at different depths are affected differently by anthropogenic and physical forces such as fishing and temperature fluctuations. Similarly, reef communities vary widely between different habitats, with forereefs serving different ecological functions and comprising different species assemblages than lagoons, back reefs, and other reef habitats. Different habitats are also utilised differently by coastal communities, and thus may see different pressures despite being in close geographic proximity. Expanding this survey effort to include additional depth strata and habitat types will help create a more comprehensive understanding of coral reef health and function across the country, and may help identify locations for additional management (e.g., areas exposed to high fishing pressure, areas of particular ecological significance, etc.).

### Improve bleaching awareness and assessment readiness.

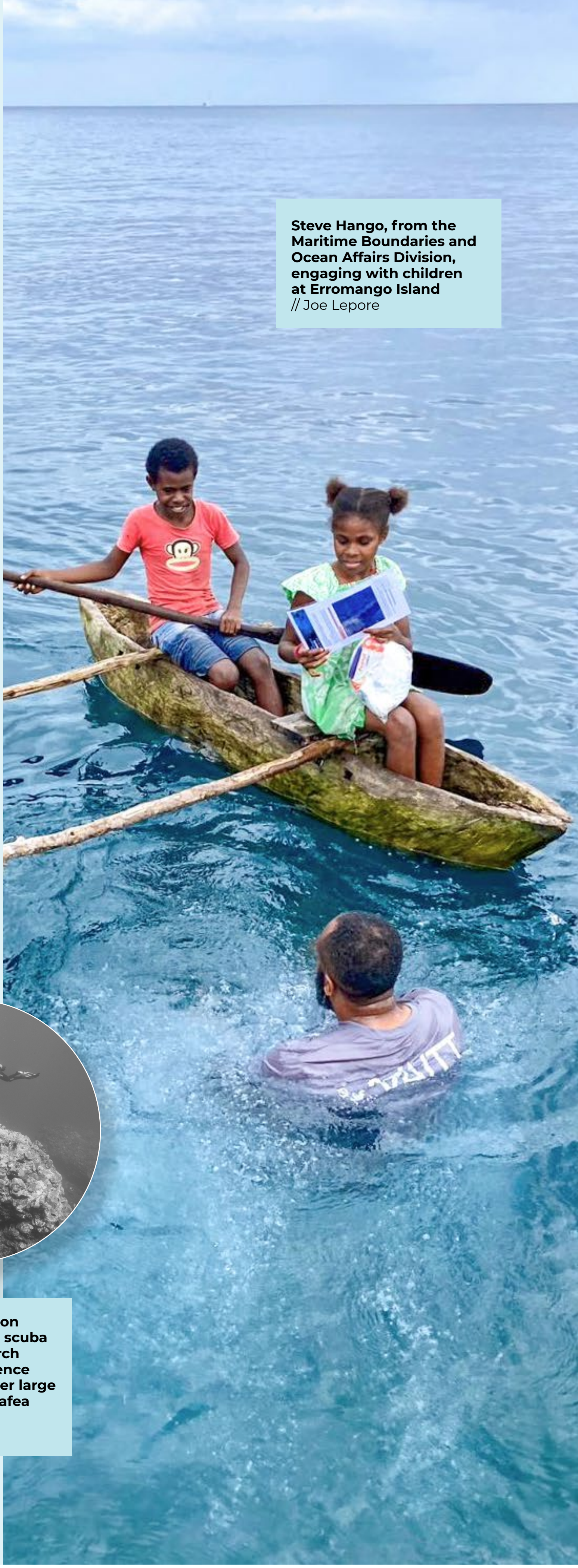
While coral bleaching was not assessed in this study, thermal stress is a known threat to coral reef health in Vanuatu. As climate change progresses, bleaching events are predicted to increase in frequency and intensity, so preparedness for bleaching assessments and management measures is key to understanding how these events will affect reefs and coastal communities. Therefore, it is recommended that capacity be built within Vanuatu to mount appropriate rapid response assessments when bleaching events are predicted or detected, and that resources be allocated to support these efforts.

**A science diver, Fabrice Billandon, from Big Blue Vanuatu, swimming over *Acropora* coral at Rowa Island in Torba Province** // Joe Lepore

### Collect temperature loggers to help understand nearshore temperature dynamics over time.

Temperature loggers were deployed at a subset of sites across the country, and set to collect measurements at 45 minute intervals. At this rate of data collection, the loggers have sufficient battery life to collect data for several years (>5 years). Once collected, the data from these loggers can help shed light on temperature dynamics over various temporal (days, months, years) and geographic (site, island, province) scales. In concert with survey data, these temperature data can be used to shed light on reef dynamics, such as coral bleaching, algal cover, fish recruitment, etc.

# RECOMMENDATIONS (CONTINUED)



Steve Hango, from the Maritime Boundaries and Ocean Affairs Division, engaging with children at Erromango Island
// Joe Lepore

## Collect and integrate data on ocean use and socioeconomic realities.

Blue Prosperity Vanuatu intends to provide advice on how to best design MPA networks and resource management strategies to maintain and/or improve coastal ecosystem health. Understanding patterns of use and socioeconomic parameters across space will provide a holistic view on the relationships between use, ecosystem condition, and socioeconomic realities.

## Focus on prioritised and strategic capacity building to equip Vanuatu with the skills, tools and financial resources necessary to complete this work independently.

In order for future monitoring initiatives to be sustainable, it is important that Vanuatu have the capacity to complete the work independently. Therefore, working to establish the necessary technical expertise, infrastructure, and funding resources needed to support this type of work in the future is key. To ensure the appropriate investments in capacity building, clear goals and priorities should be outlined, which support the needs of the country of Vanuatu.

Science diver Hudson Feremaito carrying scuba tanks on the research vessel (left) & a science diver swimming over large reef structures in Tafea Province (right)
// Joe Lepore

# 07

Science diver, Fabrice Billandon, taking photos of the reef at Rowa Islands in Torba Province
// Joe Lepore

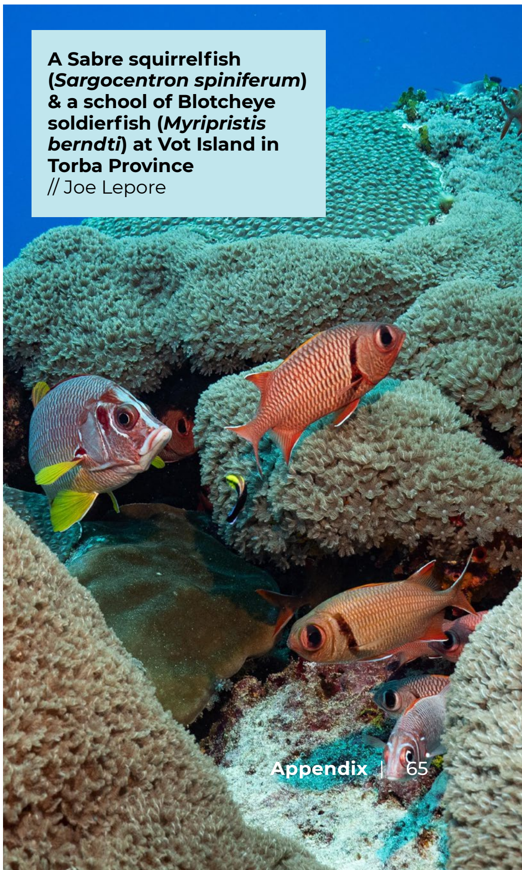
# APPENDIX

## Appendix 1

# METHODOLOGY

## SITE SELECTION

Sites were selected with the goal of maximising coverage across Vanuatu, while including priority sites identified by the Ministry of Foreign Affairs, Vanuatu Fisheries Department, and the Department of Environmental Protection and Conservation. Sites were selected to include various locations within each province, and leeward (West, Northwest) sites were selected in order to maintain safe diving conditions and to minimise variability. All sites were located on the forereef at 10 m depth; no surveys were undertaken in the lagoon, and river outfalls and estuaries were avoided. Efforts were made to select larger islands to ensure that sites were at least 2 km apart from each other to avoid pseudoreplication. On larger islands, a minimum sample size of six sites was targeted, and on smaller islands, at least three sites were surveyed when possible. Communities were consulted prior to surveys being conducted within traditional tenure areas.



**A Sabre squirrelfish (*Sargocentron spiniferum*) & a school of Blotcheye soldierfish (*Myripristis berndti*) at Vot Island in Torba Province**
// Joe Lepore

# FISH

**Underwater visual census approaches in the form of belt transect methods were used to enumerate the density, size structure, biomass and species composition of the reef fish assemblage at each reef.** At each site, divers laid out three 25 m transect lines along the reef, identifying and estimating the length of all fishes to the nearest 5 cm size class along each transect. Fish abundance estimates were made by means of two passes for each 25 m transect: on the outward swim, the divers surveyed an 8 m width (200 $m^2$ area) for individuals >20 cm total length (TL), and on the return swim, a 4 m width (100 $m^2$ area) was surveyed for species ≤20 cm TL. All fish were identified to the species level where possible.

Trophic groupings for each fish species surveyed were assigned using the best available information from FishBase and the published literature. Biomass was estimated using the length-weight equation W = a Lb, where W is the weight of the fish in grams, L is the total length of the fish in cm, a is the species-specific scaling coefficient, and b is a species-specific shape parameter related to body shape. a and b values were selected using Akiona et al. (in press).

# BENTHIC COVER

**Benthic cover was estimated using photoquadrats taken of the benthos at each site.** Following the completion of each fish belt transect survey, divers collected photoquadrat images along the same transect line, **taking photos every 1.5 m**, for a total of 13-15 photos per transect. A monopod was attached to each camera to ensure that photos were taken from a fixed distance and covered the same area of the benthos (approximately 0.72 $m^2$ per photo).

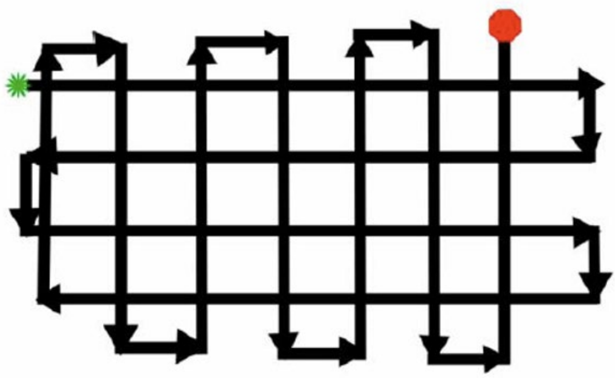
Photoquadrat images from the expedition were analysed using the image analysis software ReefCloud (AIMS 2024), which projects 25 random points onto each image. The taxon under each randomly generated point was identified to the lowest taxonomic level possible in order to determine percent cover of each taxon. Photoquadrat analysis was undertaken by a group of analysts based out Vanuatu and contracted through the University of the South Pacific Institute for Applied Sciences in Suva, Fiji.

Following initial annotation by the analysts, quality control procedures were conducted by the Sandin Lab at the Scripps Institution of Oceanography to ensure data accuracy. Three random images from each transect (n=9 images per site) were checked for accuracy. If the accuracy of these images was found to be ≥ 90%, no further quality control measures were undertaken. If the accuracy of these images was <90%, then all images from the site were checked and corrected.

# CORAL RECRUITMENT

Coral juveniles were identified using large-area imagery techniques. At each site, a 10 m x 10 m plot was selected to be surveyed using this method. To capture the imagery, a diver swam a specialised camera rig containing two Nikon D780 SLR cameras set to different focal lengths (24 mm and 60 mm) in a double lawnmower pattern (Figure 19) approximately 1.5 m above the reef at each site. As the diver slowly swam the plot, the cameras took photographs of the benthos each second. This created a set of approximately 3000 photos of each plot, all with high overlap between adjacent images, which can be stitched together to form a 3D model. Each plot was marked with two stainless steel stakes for potential future resurveys.

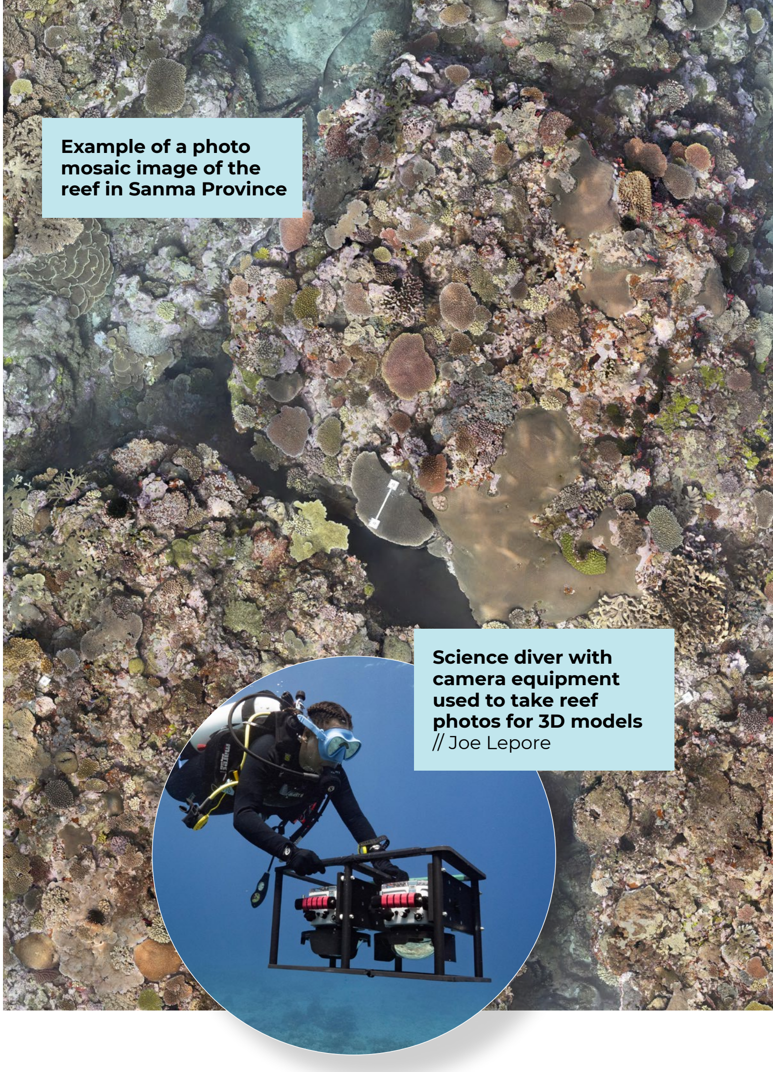
**FIGURE 19**:
*Schematic of diver survey pattern to collect images of mosaic plot.*



3D models of each plot are reconstructed using the commercially available Structure from Motion (SfM) based software Agisoft Metashape, which fuses raw imagery from the 24mm camera to create 3D point clouds. These point clouds can then be analysed using a specially developed software program, Viscore, allowing data to be extracted from the models. Viscore allows for the visualisation of the 3D model and raw imagery, as well as the ability to measure reef features to mm-scale resolution (Figure 20).

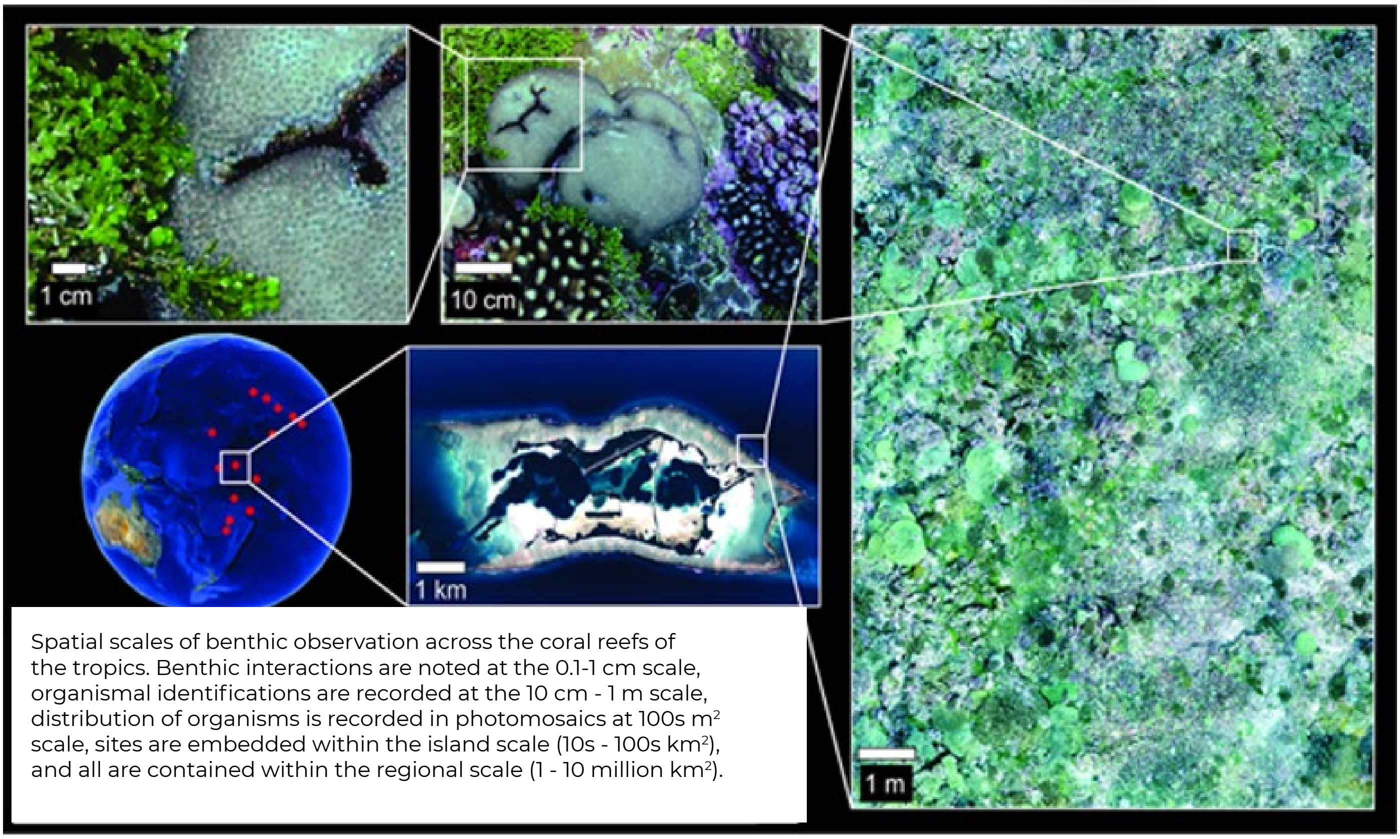
For the juvenile coral analysis, a 10 m x 10 m area was defined on each photomosaic, and 1 m x 1 m quadrats were drawn inside this area. Five randomly selected quadrats were analysed per model. Within each quadrat, the raw imagery used to build the mosaic was searched, and all coral juveniles less than 5 cm in maximum diameter were identified to the lowest taxonomic level possible.

Due to computational difficulties, site MAE_085 was not included in juvenile coral analyses.



**Example of a photo mosaic image of the reef in Sanma Province**

**Science diver with camera equipment used to take reef photos for 3D models** // Joe Lepore




Spatial scales of benthic observation across the coral reefs of the tropics. Benthic interactions are noted at the 0.1-1 cm scale, organismal identifications are recorded at the 10 cm - 1 m scale, distribution of organisms is recorded in photomosaics at 100s $m^2$ scale, sites are embedded within the island scale (10s - 100s $km^2$), and all are contained within the regional scale (1 - 10 million $km^2$).

**FIGURE 20**:
*Schematic showing the different scales of resolution afforded by the large-area imagery methodology.*

# RUGOSITY

Rugosity data were collected from the 3D models described above using a simulated point gauge approach (McCormick 1994). In Viscore, a 10 m x 10 m area was defined on each mosaic. Point clouds that had noticeable noise (i.e., errant points floating above the reef surface) were cleaned up using Viscore's point confidence function prior to collecting rugosity measurements. Within this area, 100 parallel transects spaced 10 cm apart were sampled in an alongshore direction across the model. Along each transect, depths were sampled every 1 cm following the contours of the reef from a top-down perspective. The length of each transect following the depth contours was divided by the linear length of the transect (in this case, 10 m) to calculate the rugosity ratio for each transect. The rugosity ratios for all 100 transects were then averaged to produce a mean rugosity value for each site. A ratio of 1 indicates a completely flat reef, with increasing values indicating more complex reefs.

# MACROINVERTEBRATES

Estimates of key macro-invertebrate species were made using modified belt transect methodologies as outlined by the Global Coral Reef Monitoring Network (GCRMN; Hill & Wilkinson 2004). To summarise, at each site a diver estimated the number of macroinvertebrates found along the three 25 m transects used for fish and photoquadrat surveys. For each survey, a 4 m wide swath was inspected for invertebrates, yielding a 100 $m^2$ survey area for each transect. Certain commercially or ecologically important species found within the transects were also measured (maximum length for sea cucumbers, maximum basal width for trochus, maximum shell width for green snails) to the nearest mm. Results from macroinvertebrate surveys are reported in individuals per site (300 $m^2$) rather than individuals per $m^2$ due to the low densities of most invertebrate species at each site.

# WATER QUALITY

Stable isotope ($\delta^{13}C$–$\delta^{15}N$) approaches were used to assess water quality across Vanuatu. These water quality assessments were made by collecting five samples of the calcified macroalga Halimeda spp. along the three transects at each site. In some cases, where algal cover was low or if Halimeda was not present at a site, samples of Tydemania expeditionis were collected instead, as previous studies have shown similar values for these two taxa (e.g., Noo Raajje 2025). If less than five samples of either taxa were present at a site, fewer samples were collected. For each site, three replicate samples (where available) were randomly selected for stable isotope analysis. See Appendix 3 for a list of sites where algae were collected.

Samples were first rinsed with fresh water, dried in a salad spinner to remove excess water, and dried overnight in a food dehydrator for storage and transport in aluminum foil packets. Once in the lab, samples were rinsed with deionised water and decalcified for 24 hours in a 5% HCl solution. Samples were then rinsed with deionised water and placed in a food dehydrator to dry for 48 hours. Dried samples were then ground into a fine powder using a Wig-L-Bug amalgamator, and 2.5 mg (± 0.5 mg) of each sample was packed into foil for analysis. Samples were analysed using mass spectrometry at the UC Davis Stable Isotope Facility for $\delta^{15}N$, total N, $\delta^{13}C$ and total C.

# TEMPERATURE LOGGERS

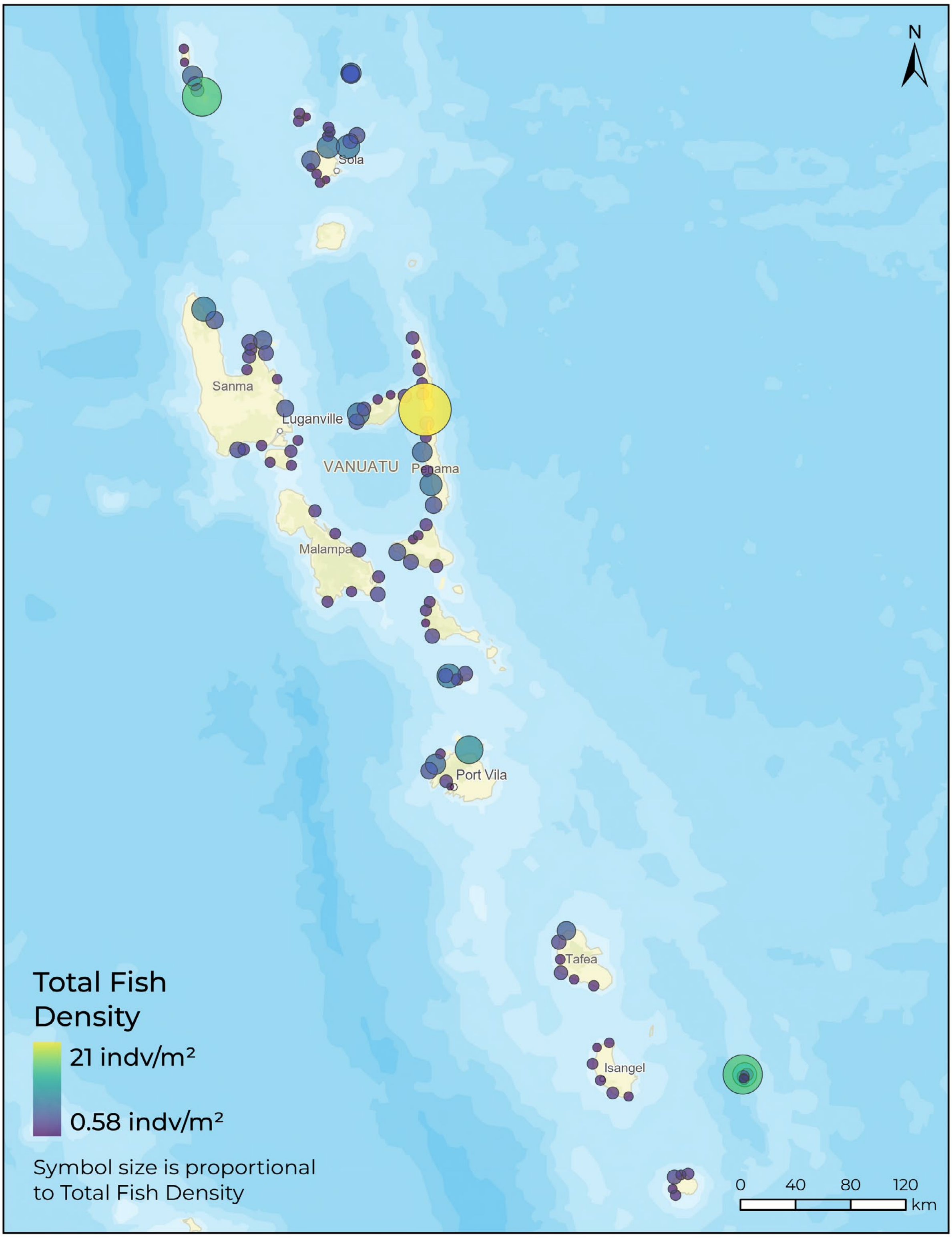
At a subset of sites (Appendix 3), a temperature logger (Onset HOBO TidbiT MX) was deployed at 10 m depth, on one of the stainless-steel stakes used to mark the large area imagery plots. Loggers were wrapped in electrical tape to prevent fouling and were set to record measurements every 45 minutes. Loggers will be collected for analysis at a later date.

**Close-up view of *Pachyseris* hard coral**
// Gilles Siu

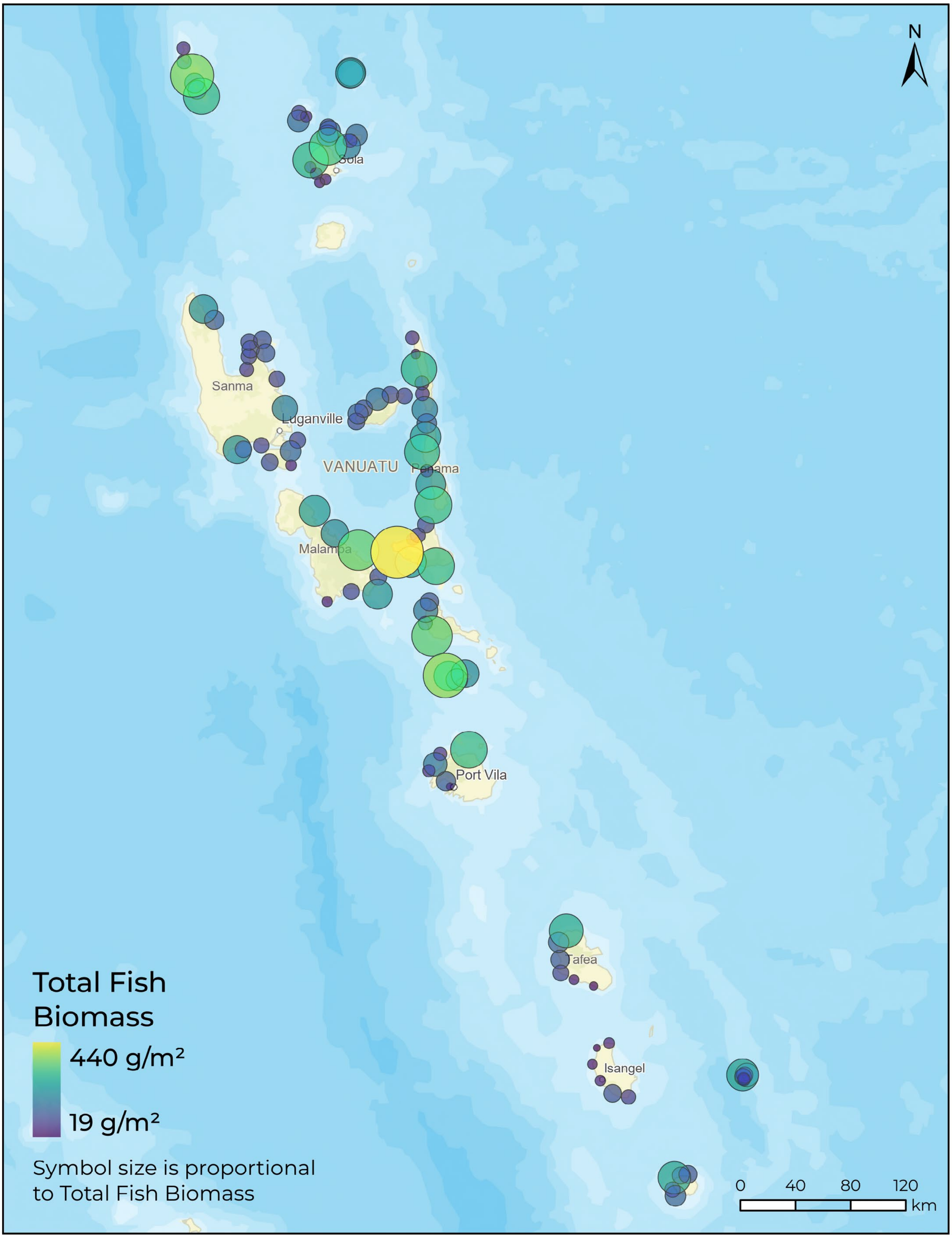
## Appendix 2

# MAP BOOK

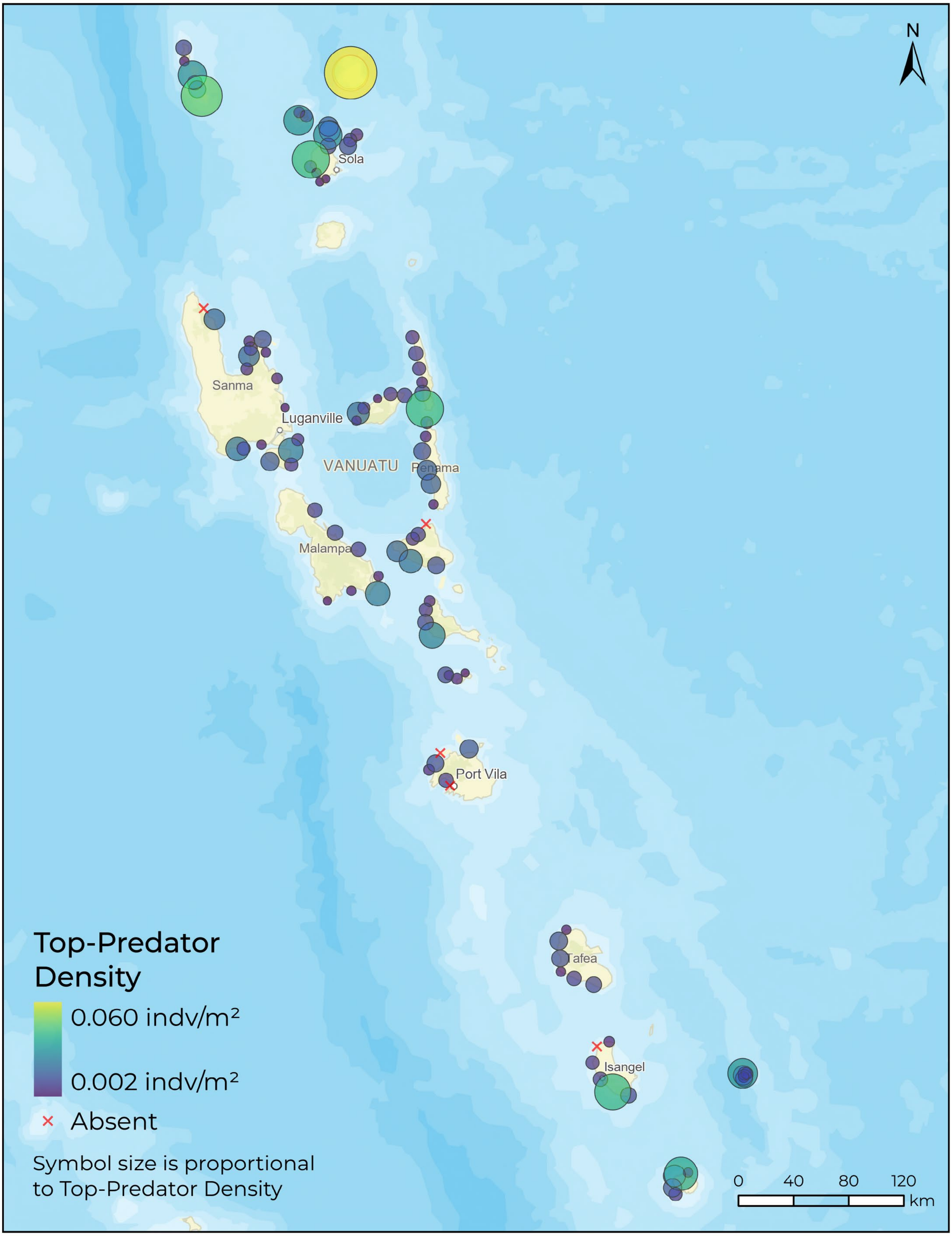
**MAP 1**: *Mean **density** (number of individuals per square meter) of fish per survey site across Vanuatu.*



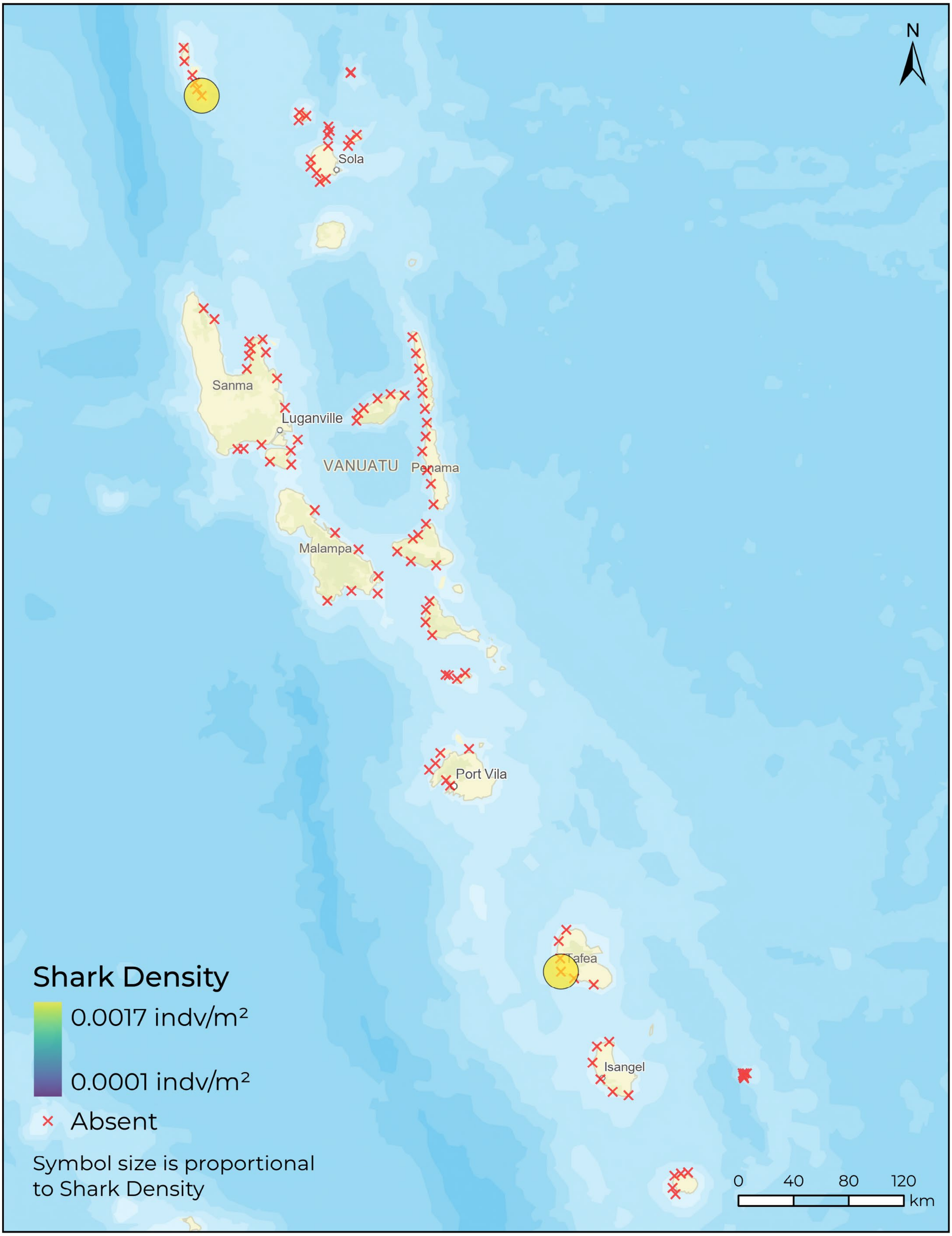
**MAP 2**: *Mean estimated **fish biomass** (grams per square meter) per survey site across Vanuatu.*



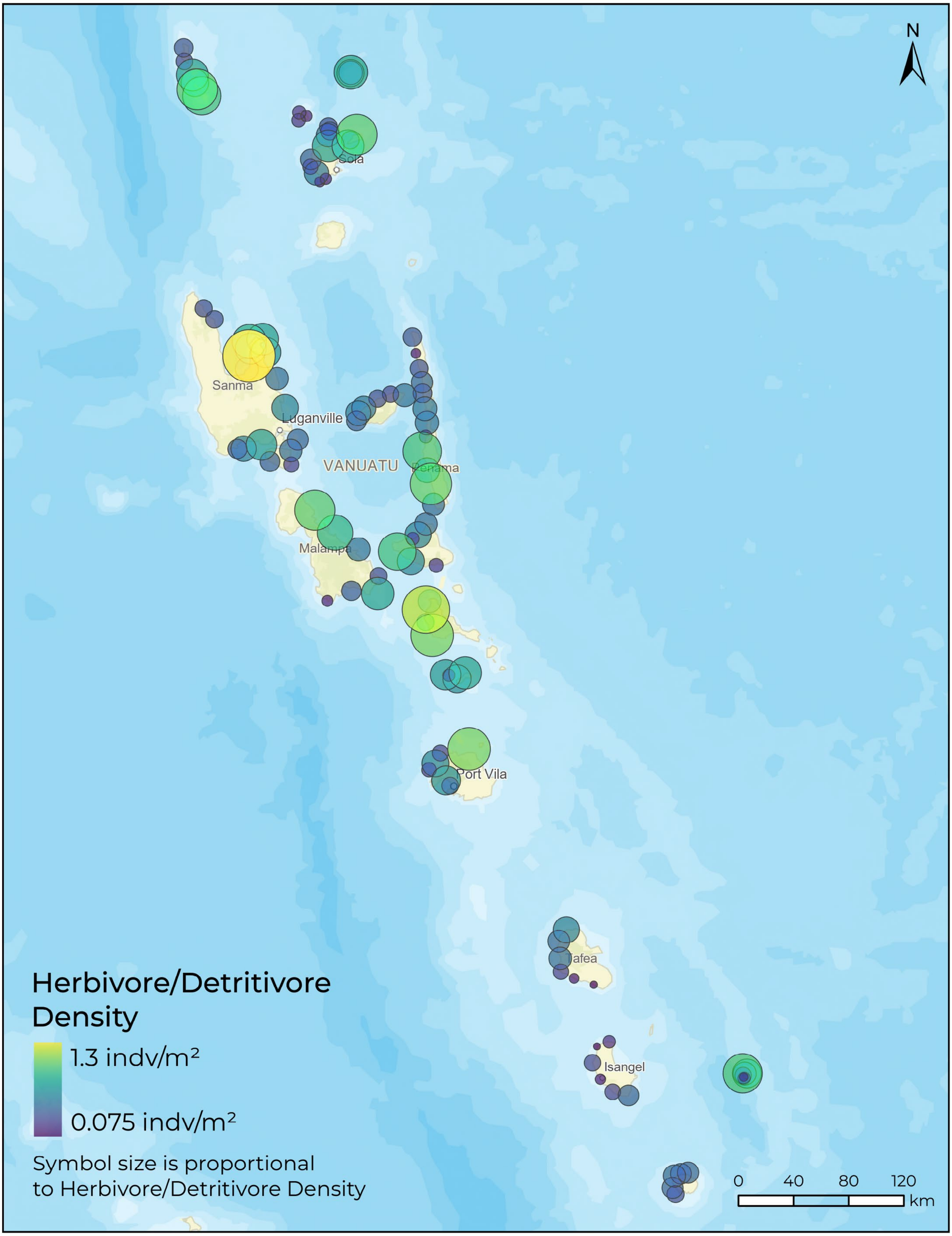
**MAP 3**: *Mean density (number of individuals per square meter) of **top-predator fish** per survey site across Vanuatu.*



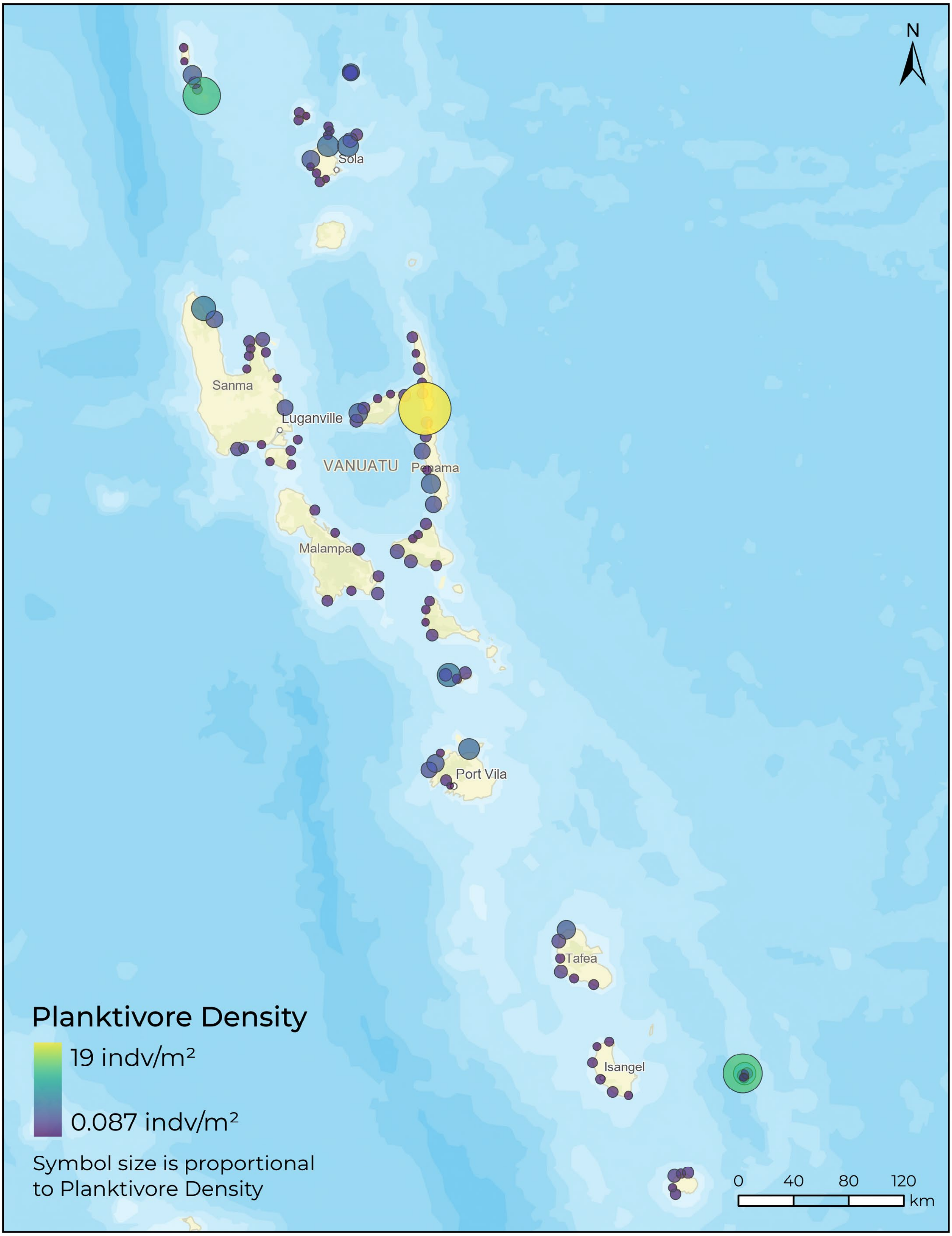
**MAP 4**: *Mean density (number of individuals per square meter) of **sharks** per survey site across Vanuatu.*



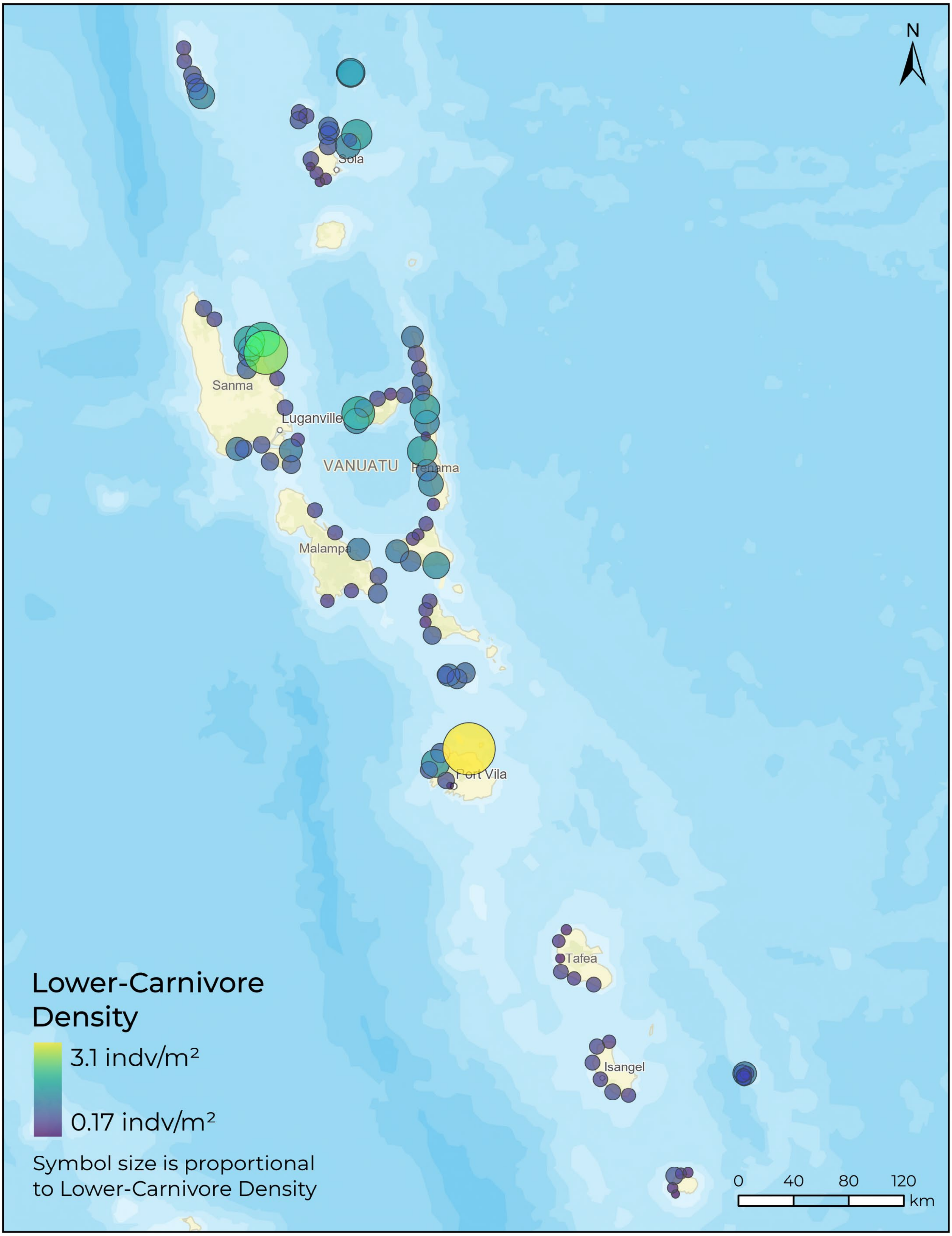
**MAP 5**: *Mean density (number of individuals per square meter) of **herbivorous and detritivorous fish** per survey site across Vanuatu. Herbivores feed primarily on algae and seaweed, and detritivores consume decaying organic material.*



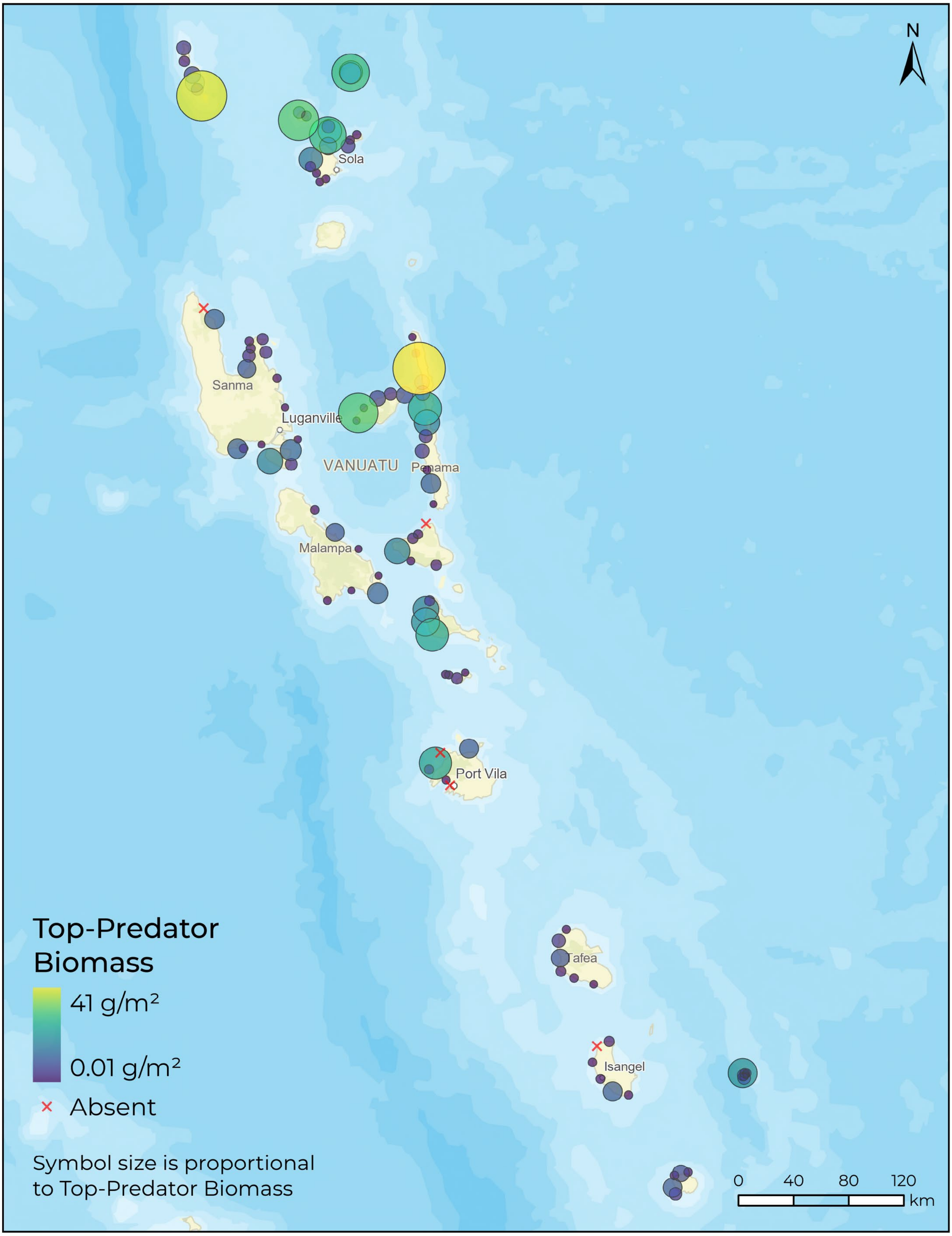
**MAP 6**: *Mean density (number of individuals per square meter) of* ***planktivore fish*** *per survey site across Vanuatu. Planktivores feed on plankton and tiny organisms floating in the water.*



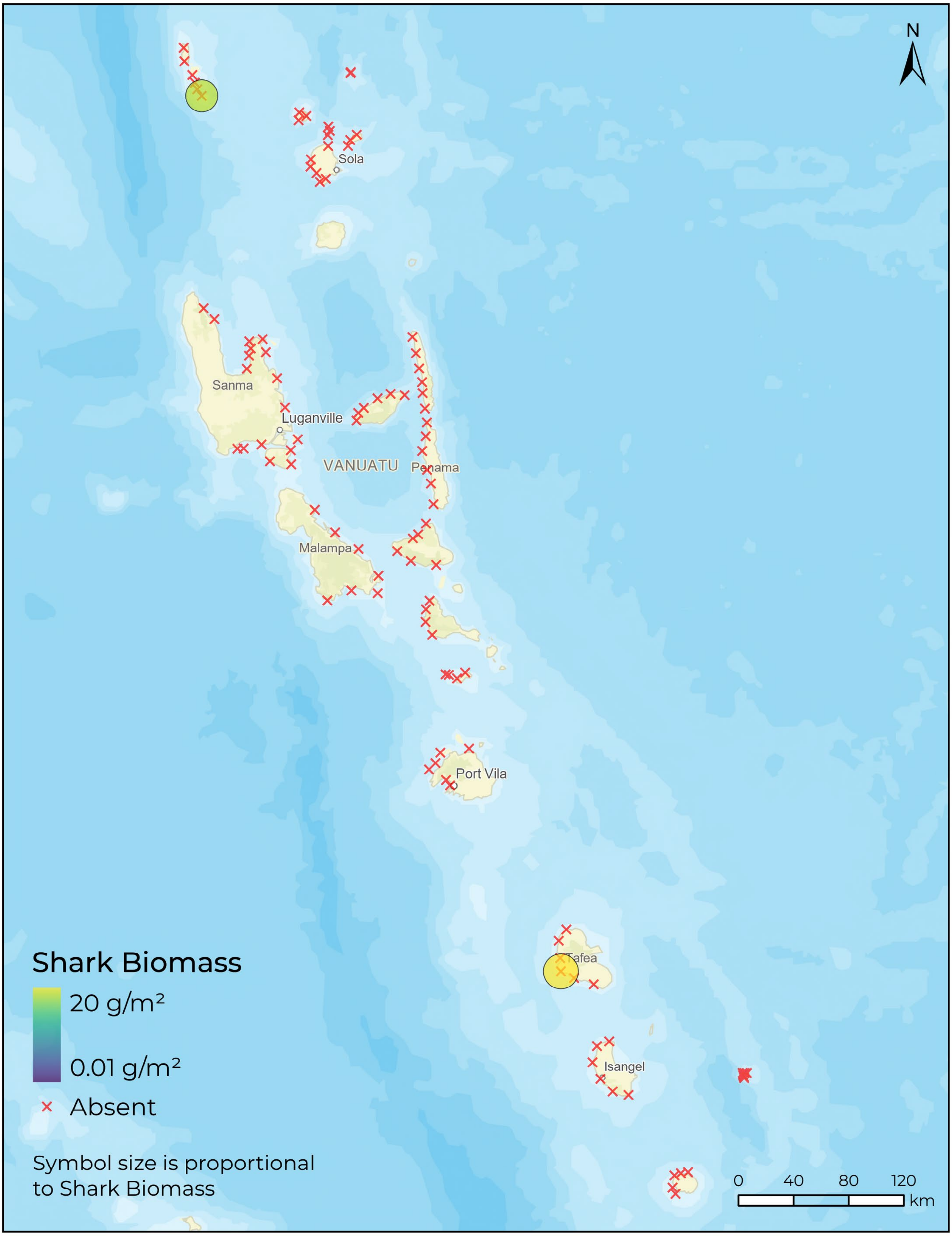
**MAP 7**: *Mean density (number of individuals per square meter) of **lower-carnivore fish** per survey site across Vanuatu. Lower carnivore fish include smaller piscivores (fish that eat other fish) and invertivores (fish that primarily consume invertebrates) such as wrasses, triggerfish, etc.*



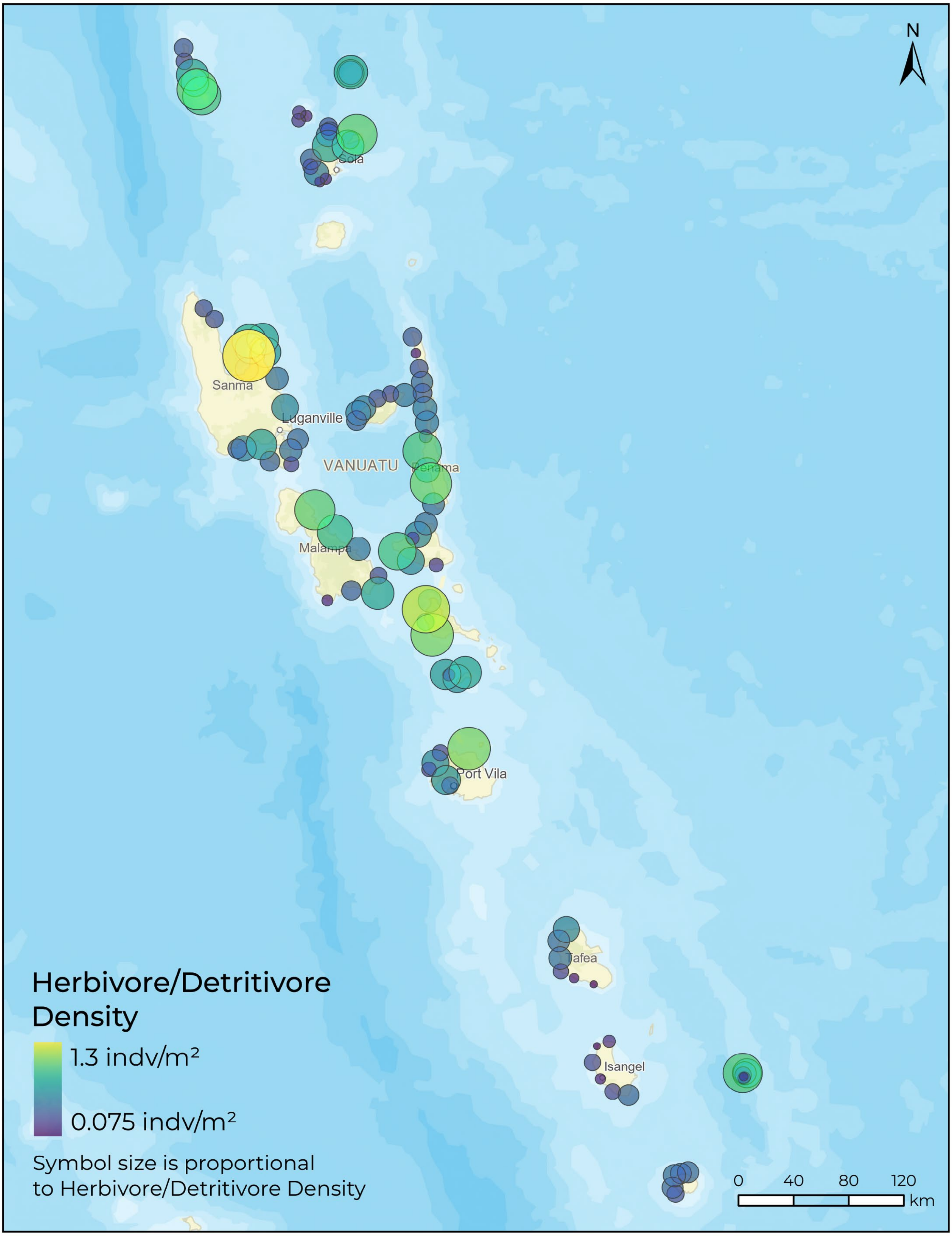
**MAP 8**: *Mean biomass of **top-predator fish** per survey site across Vanuatu.*



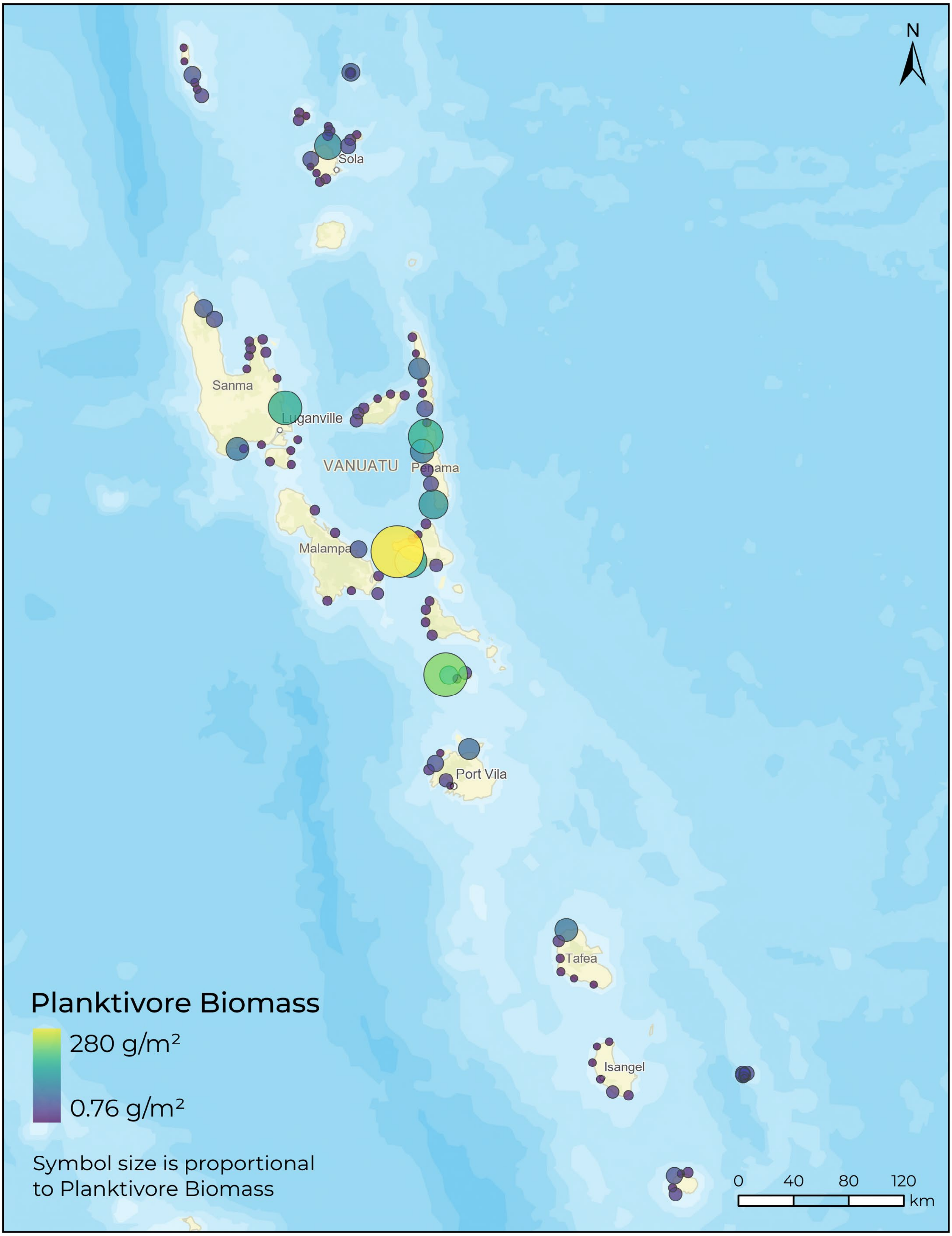
**MAP 9**: *Mean biomass of **sharks** per survey site across Vanuatu.*



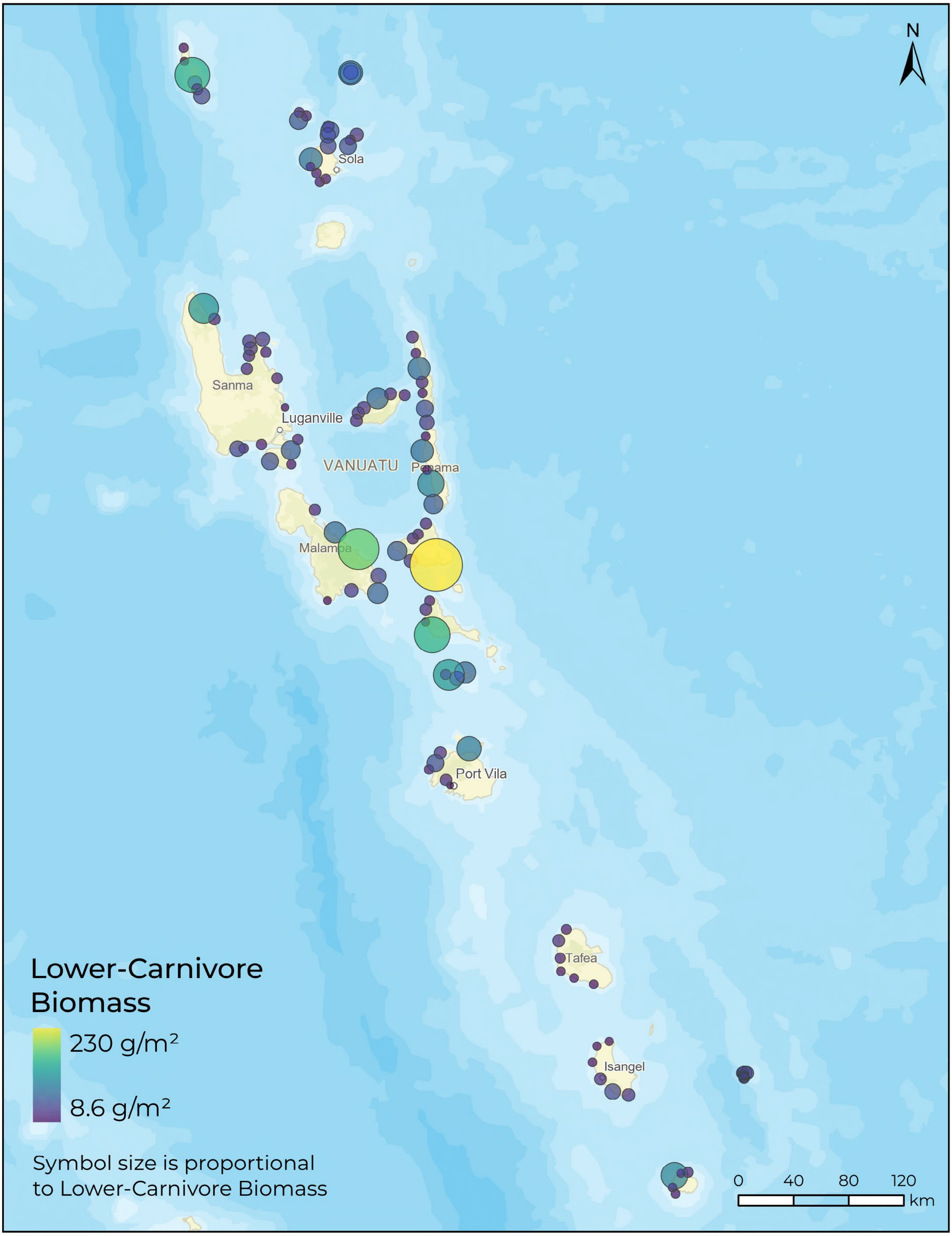
**MAP 10**: *Mean biomass of **herbivorous and detritivorous fish** per survey site across Vanuatu.*



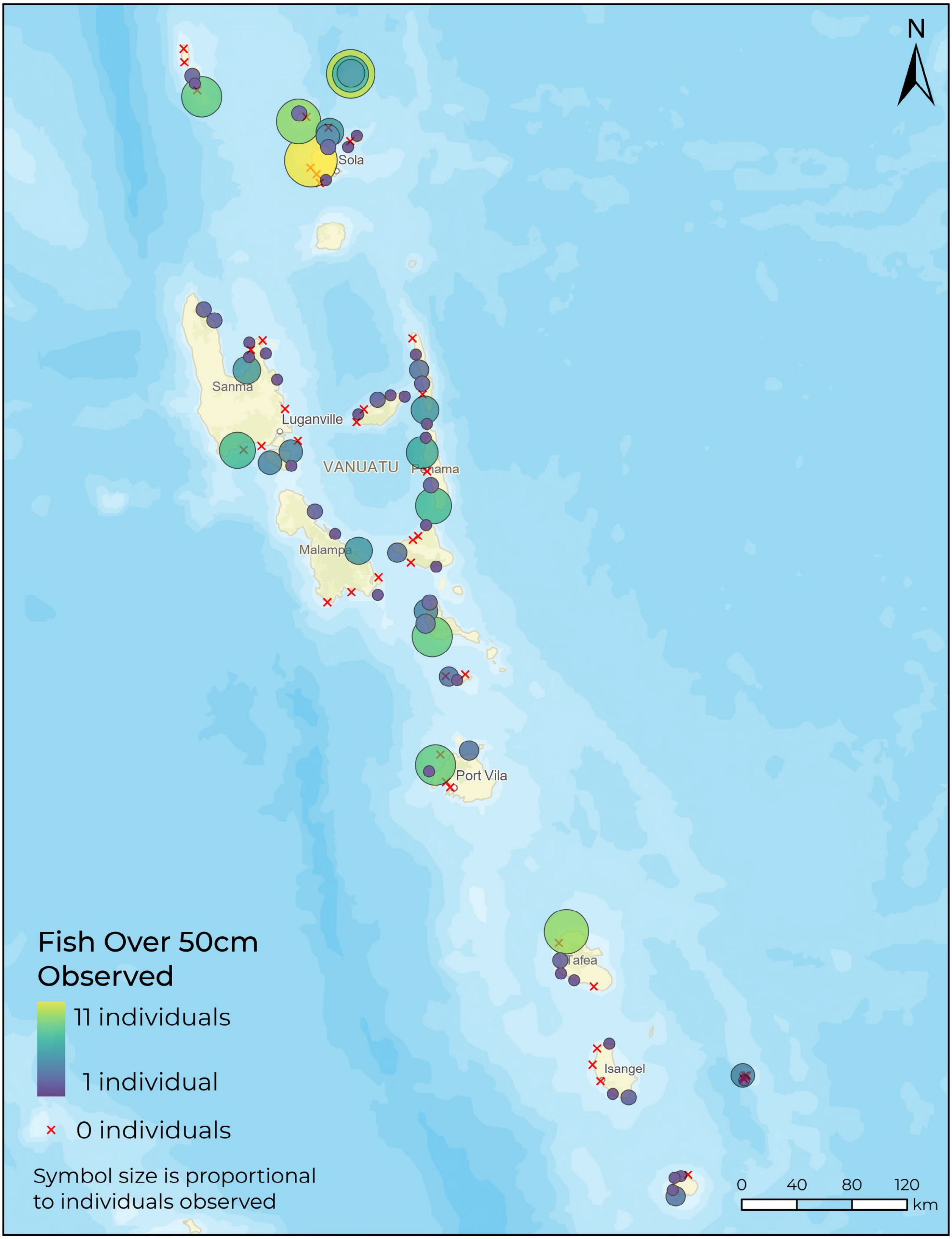
**MAP 11:** *Mean biomass of **planktivore fish** per survey site across Vanuatu.*



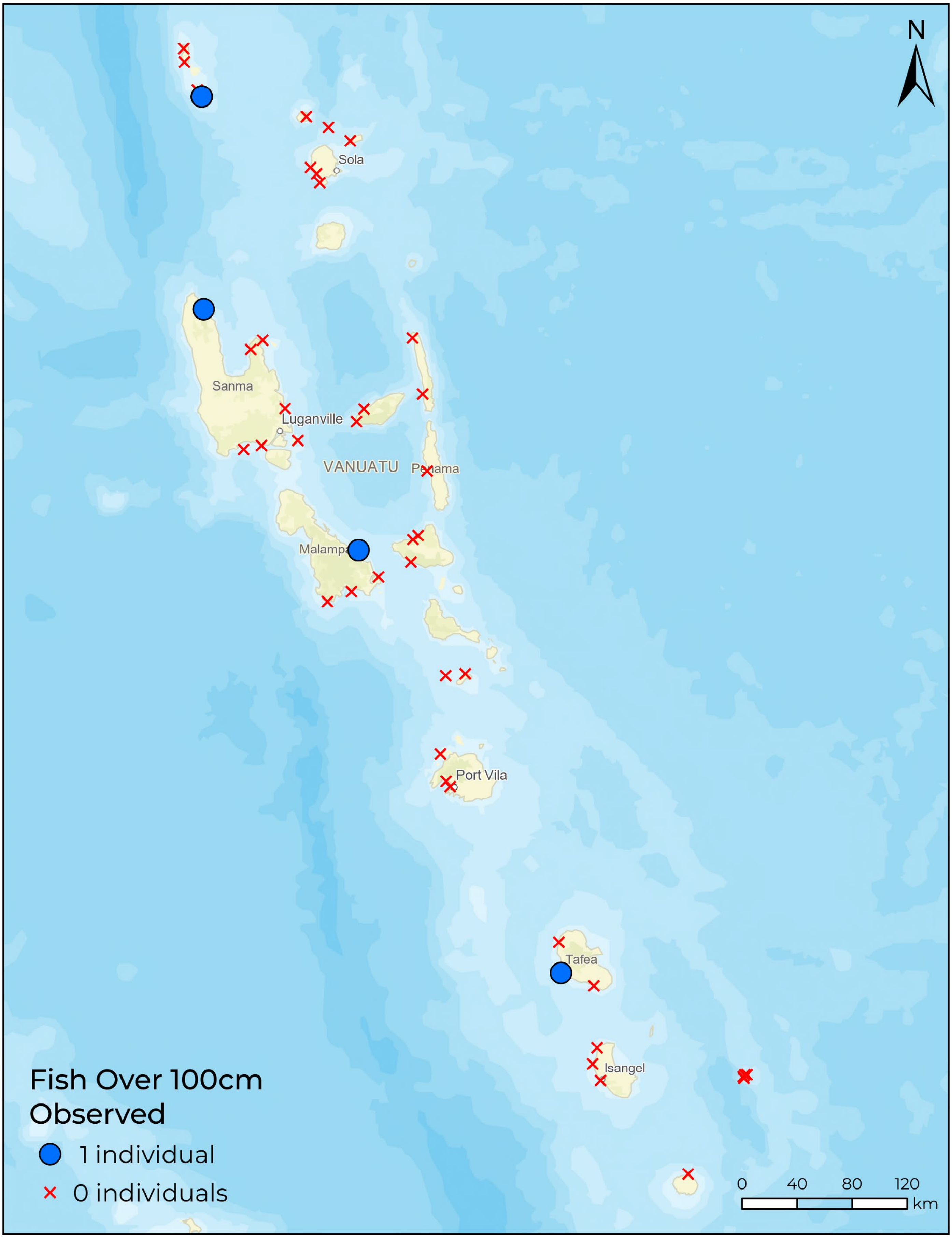
**MAP 12**: *Mean biomass of **lower-carnivore fish** per survey site across Vanuatu.*



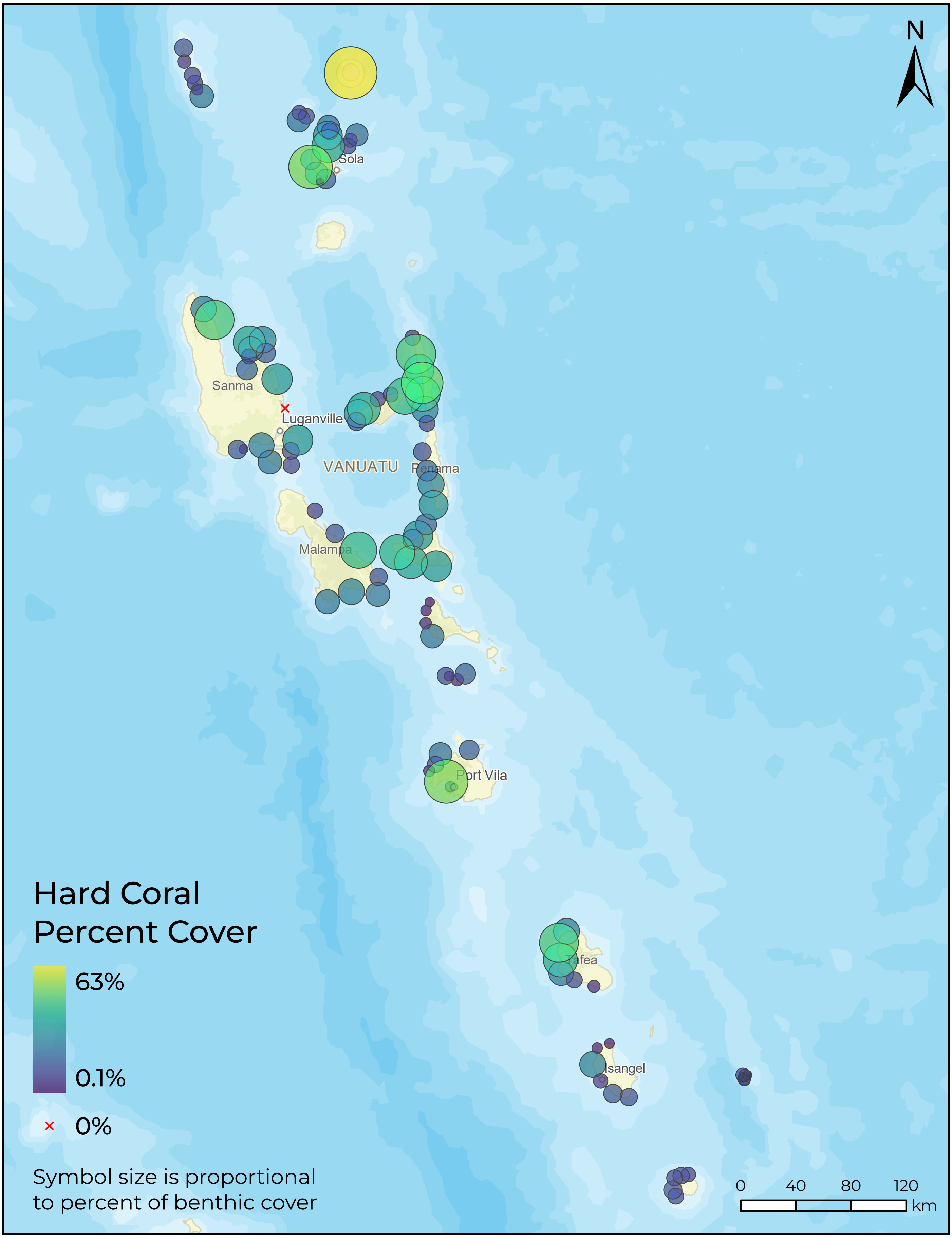
**MAP 13**: *Observations of* ***fish over 50cm*** *per survey site across Vanuatu.*



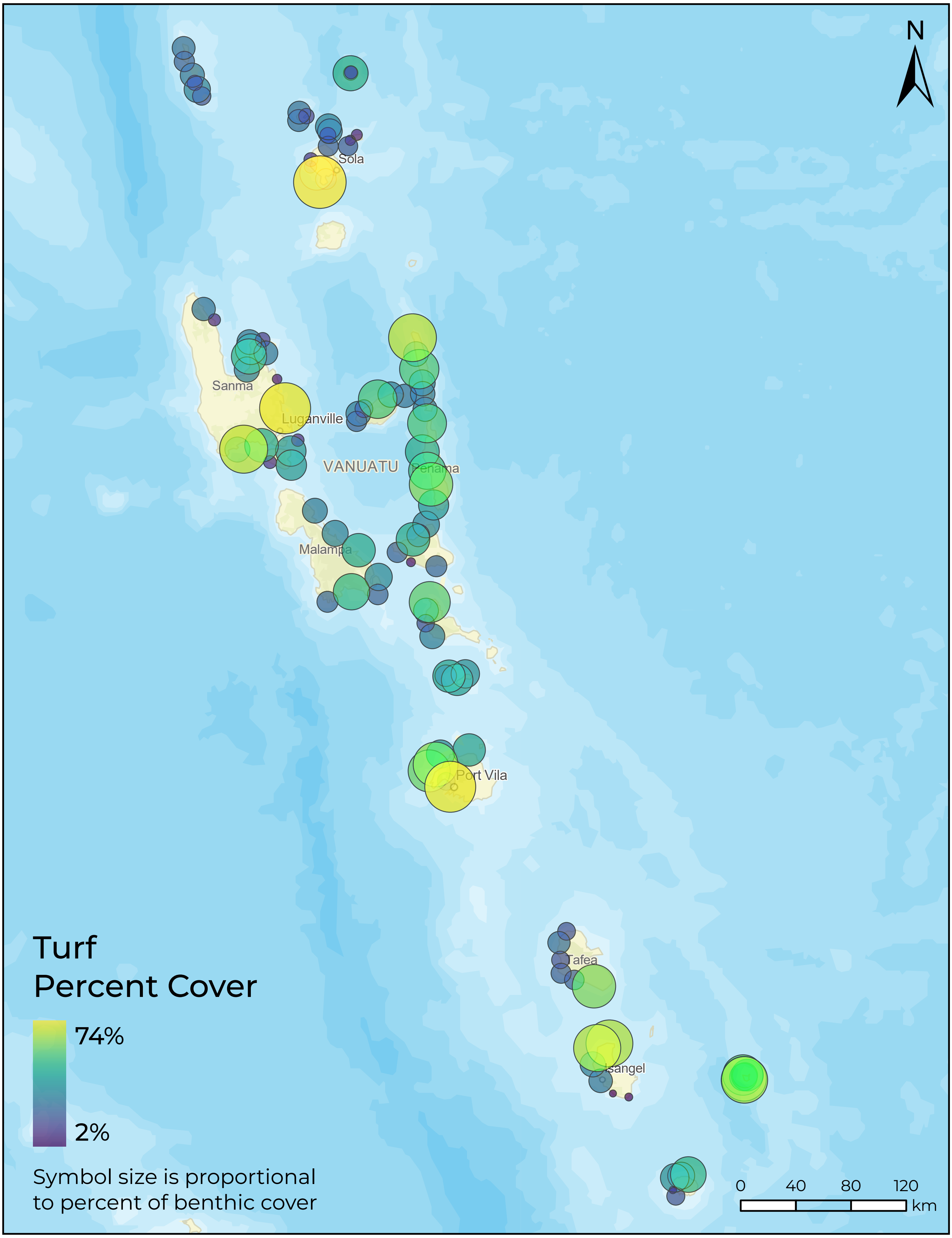
**MAP 14**: *Observations of* ***fish over 100cm*** *per survey site across Vanuatu.*



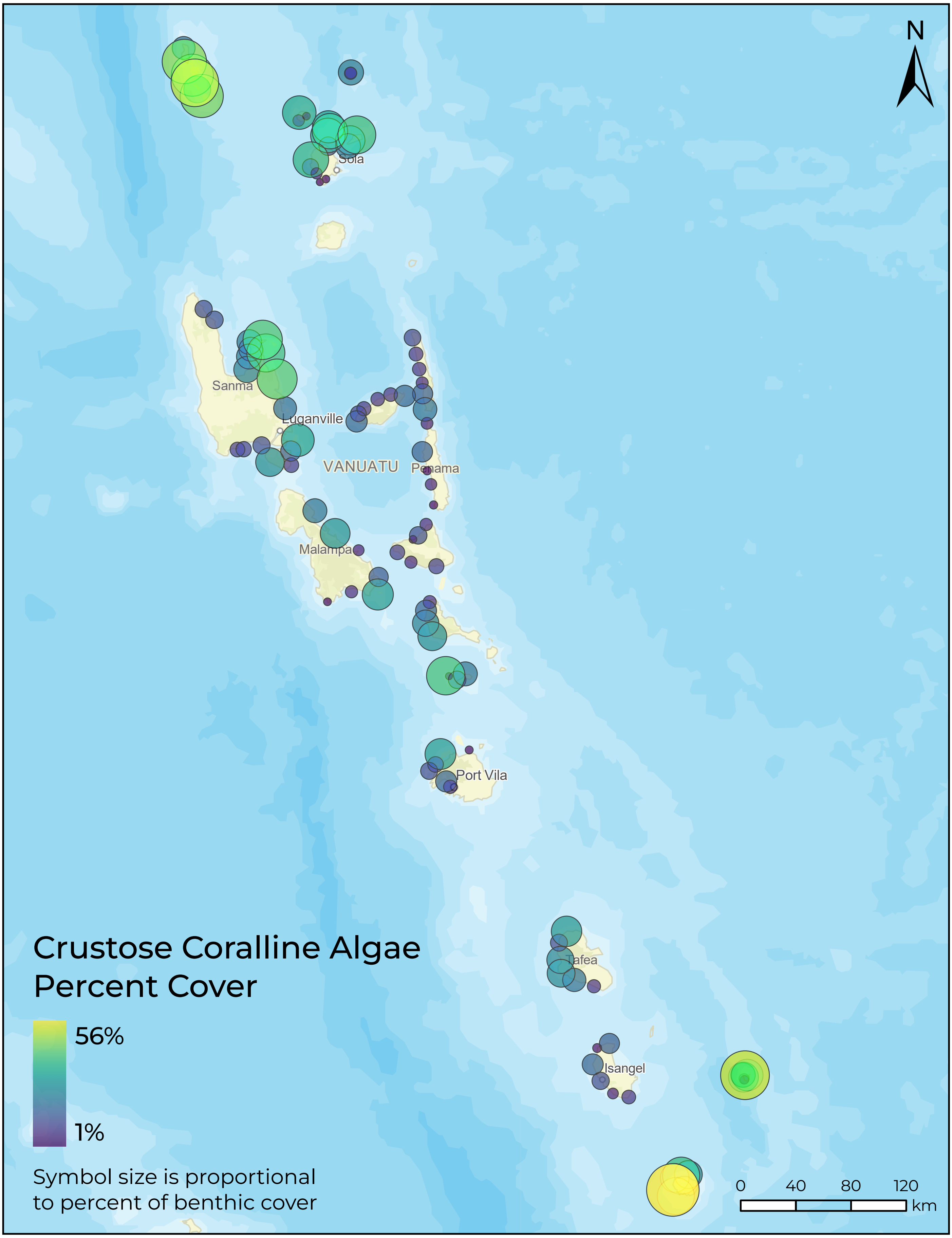
**MAP 15**: *Mean percent of the seafloor covered by* ***living hard corals*** *at survey sites across Vanuatu. Hard corals contribute to reef building and create complex habitats for fish and other organisms.*



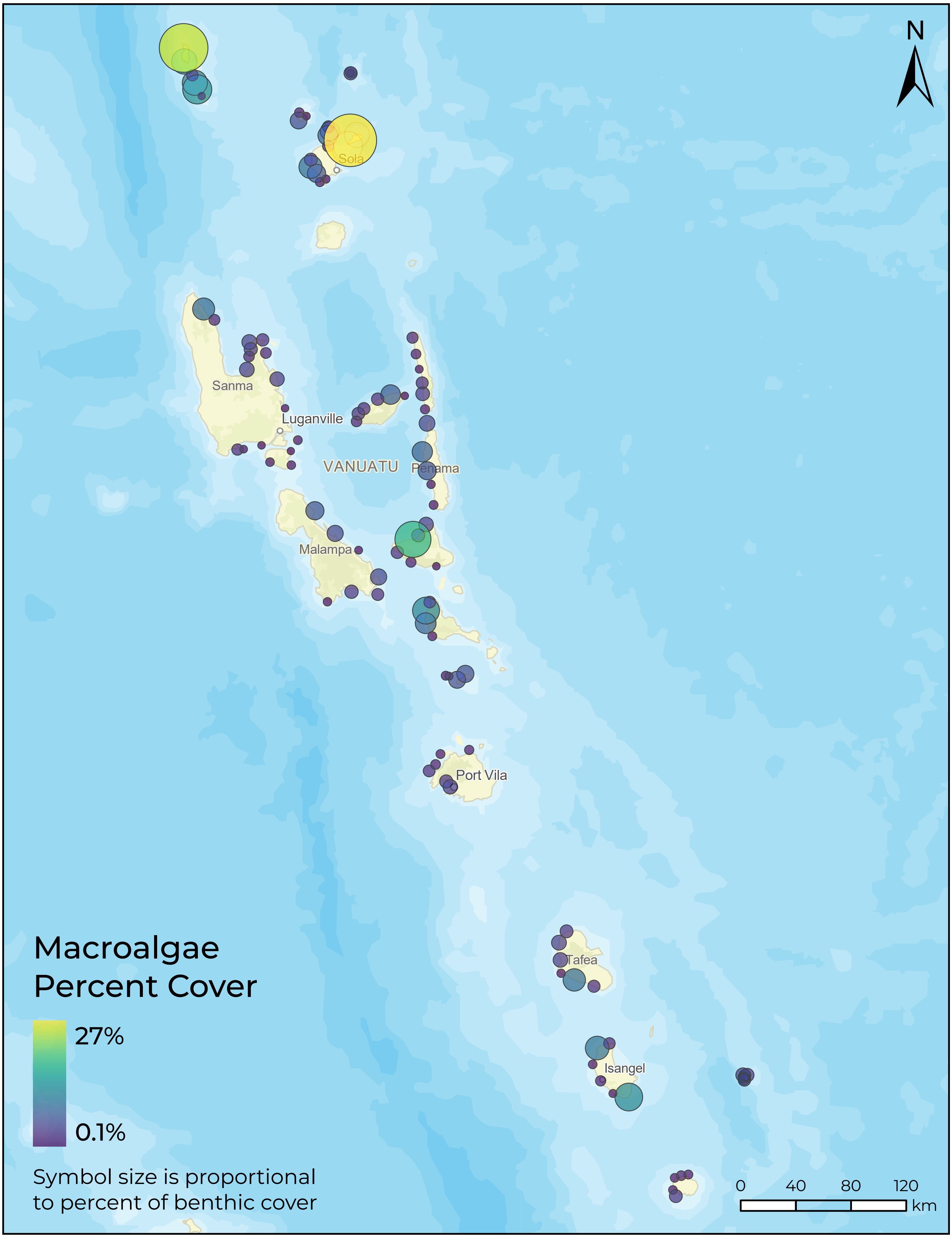
**MAP 16**: *Mean percent of the seafloor covered by* ***turf algae*** *at survey sites across Vanuatu. Turf algae is short, filamentous / fuzzy seaweed that grows like grass on the reef.*



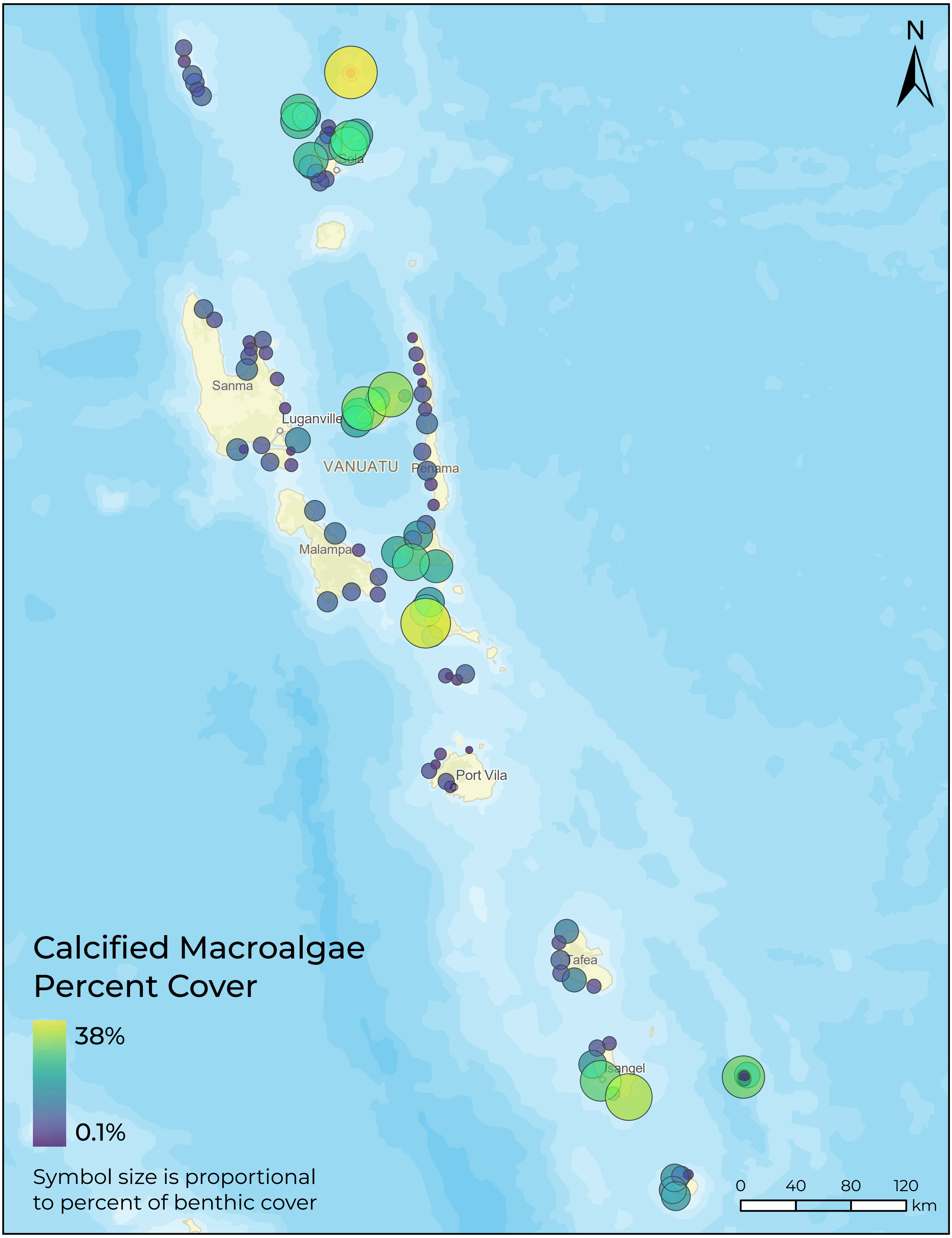
**MAP 17**: *Mean percent of the seafloor covered by **crustose coralline algae (CCA)** at survey sites across Vanuatu. CCA is a hard, encrusting red algae that helps stabilize reefs and promote coral settlement.*



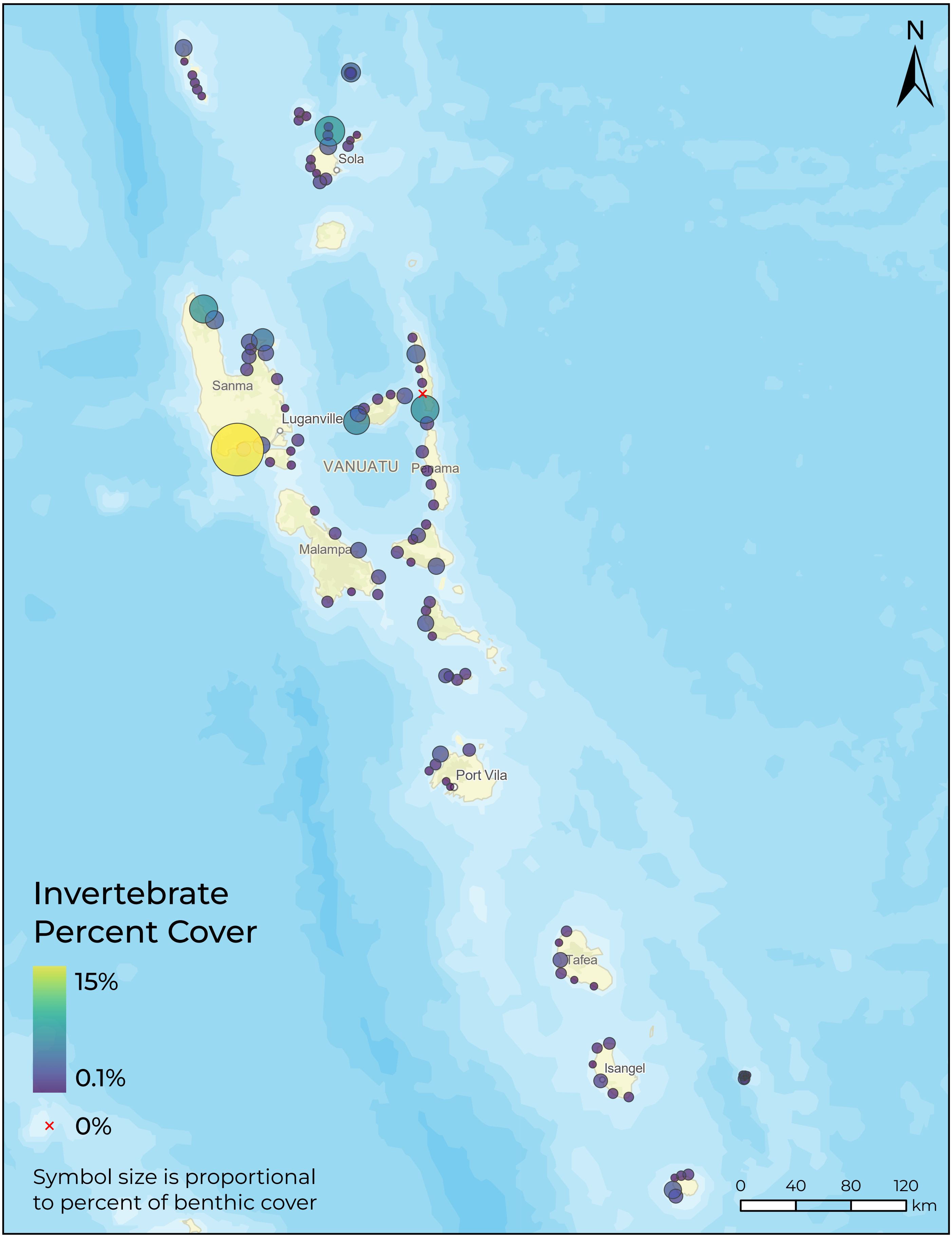
**MAP 18**: *Mean percent of the seafloor covered by* ***macroalgae*** *at survey sites across Vanuatu. Macroalgae are soft-bodied seaweeds that typically grow attached to the ocean floor.*



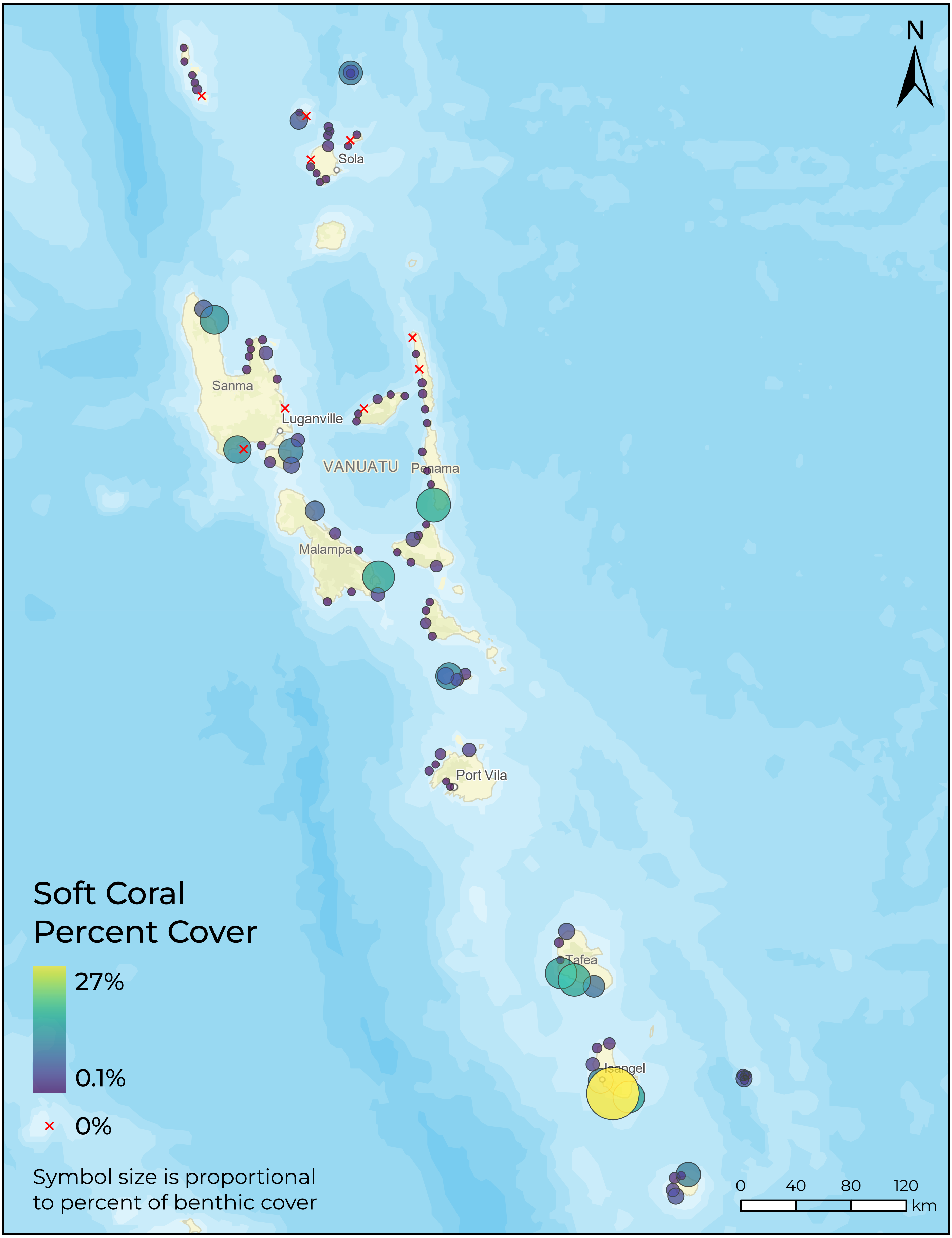
**MAP 19**: *Mean percent of the seafloor covered by **calcified macroalgae** at survey sites across Vanuatu.*



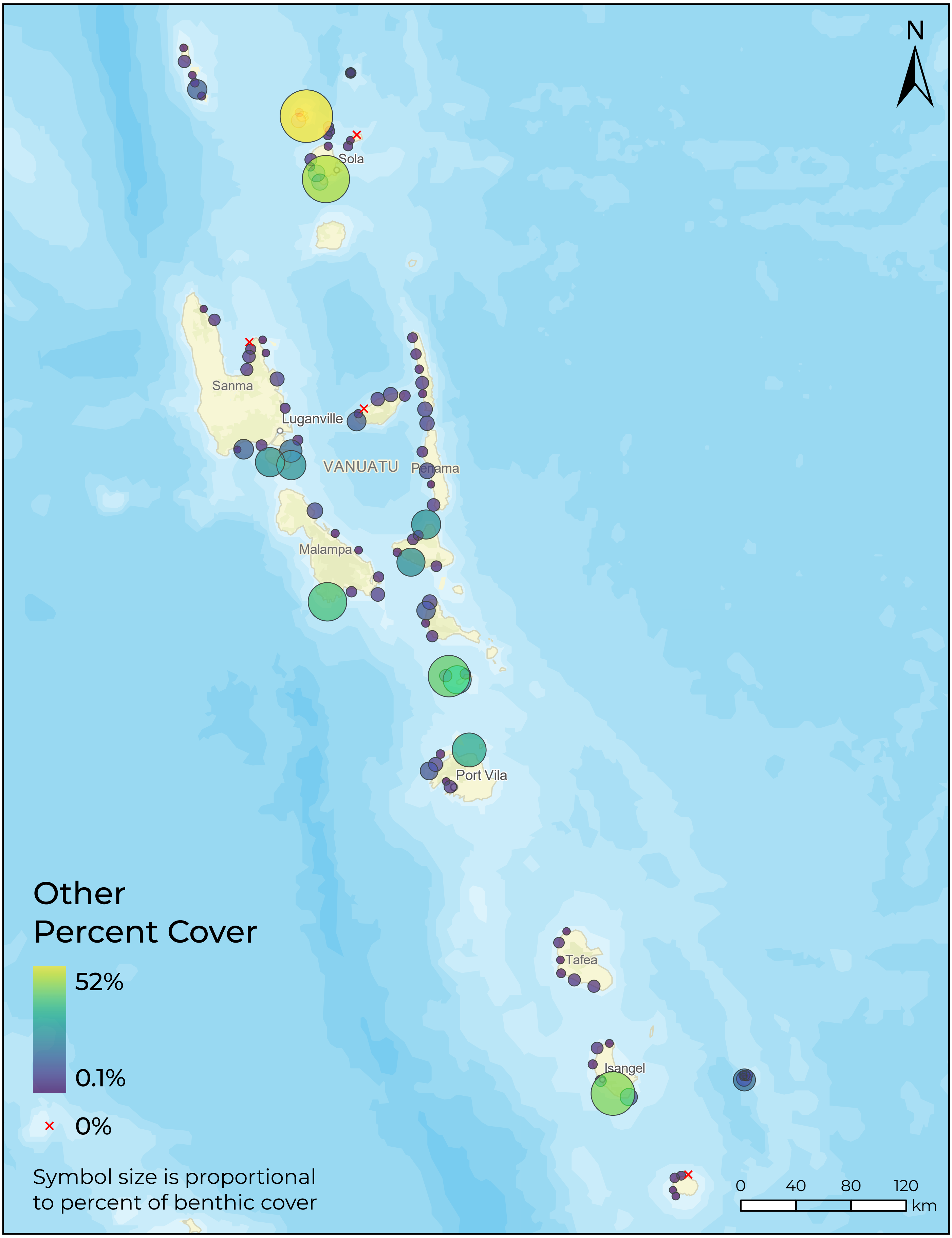
**MAP 20**: *Mean percent of the seafloor covered by* ***invertebrates*** *at survey sites across Vanuatu.*



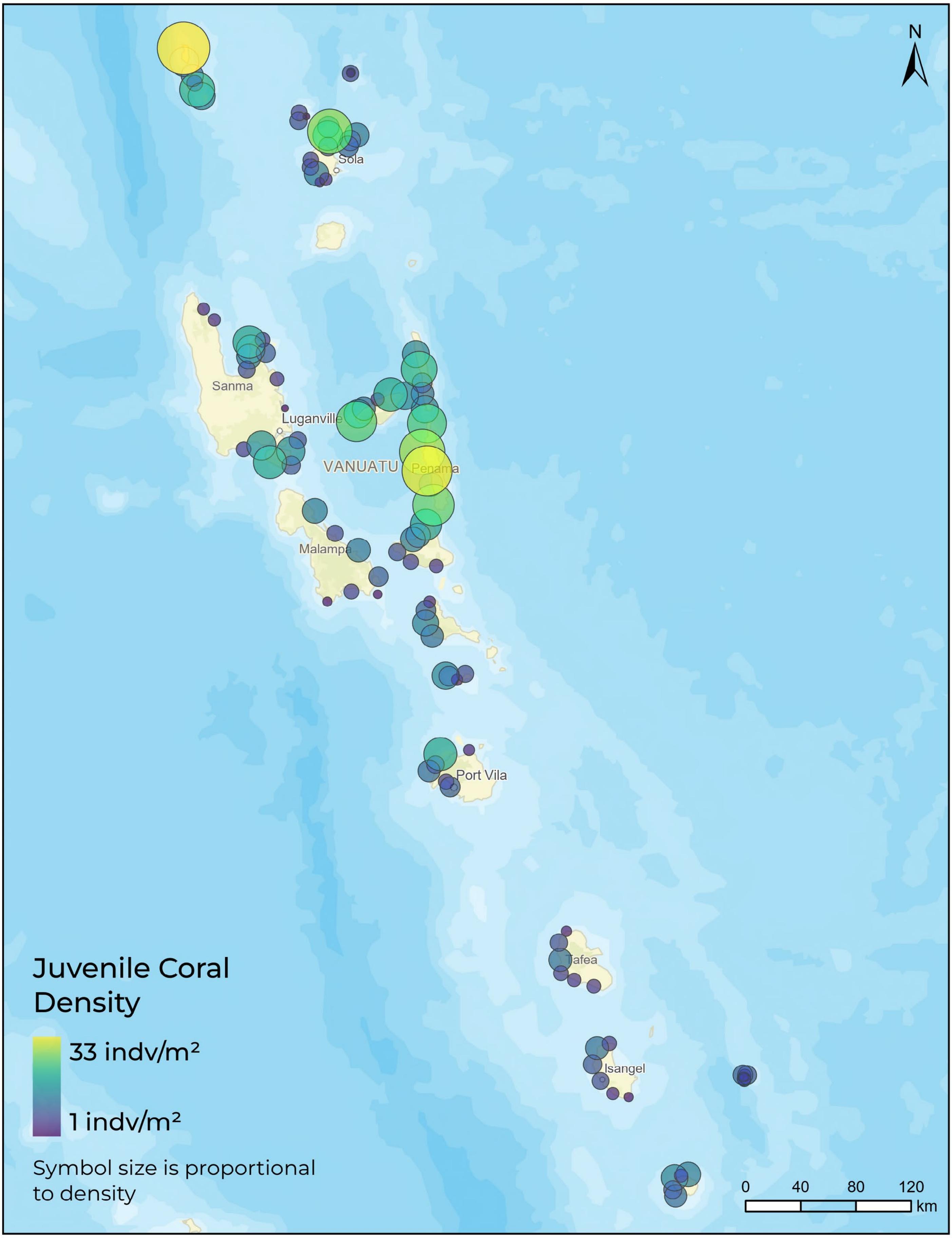
**MAP 21**: *Mean percent of the seafloor covered by **soft corals** at survey sites across Vanuatu.*



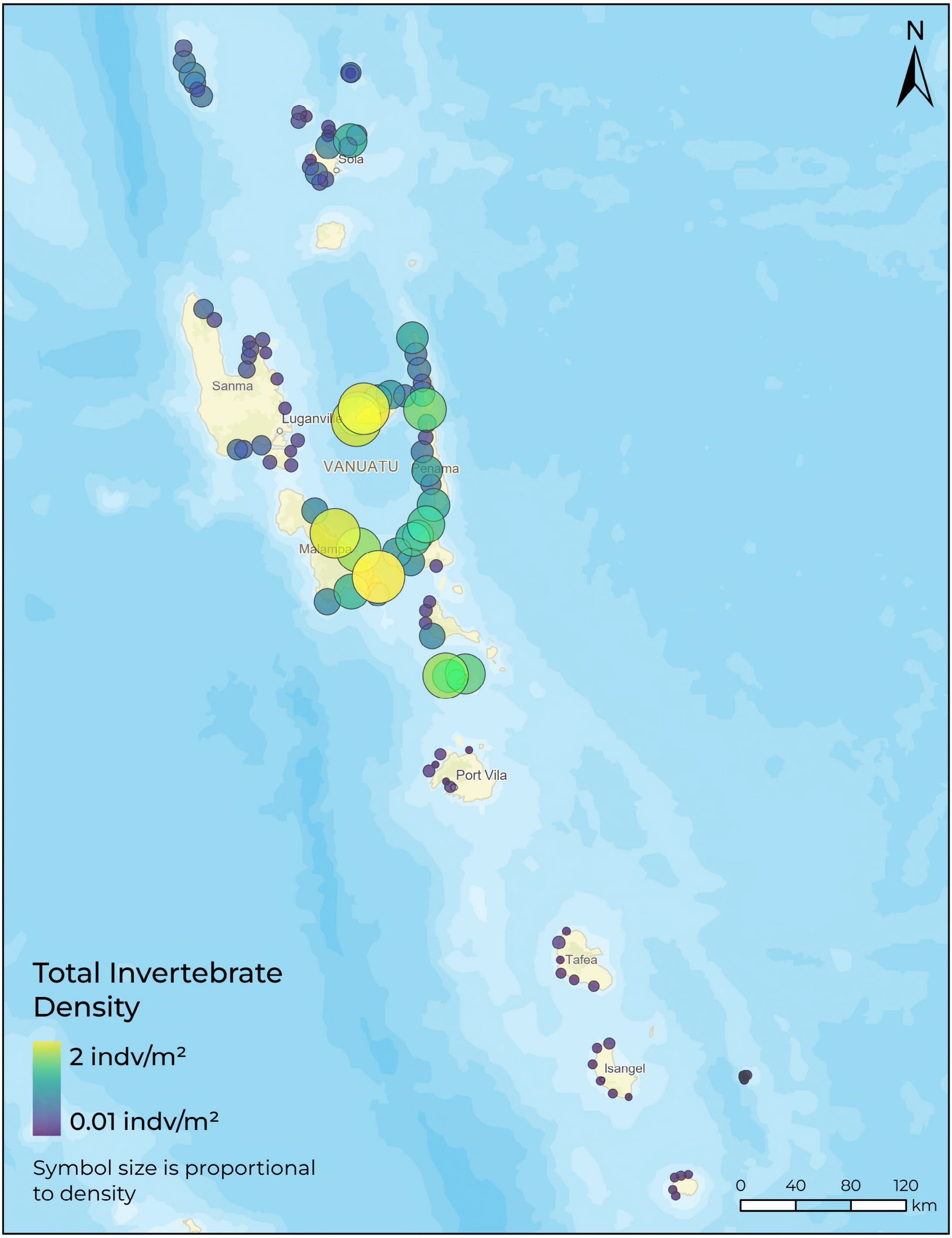
**MAP 22**: *Mean percent of the seafloor covered by **other substrates** at survey sites across Vanuatu.*



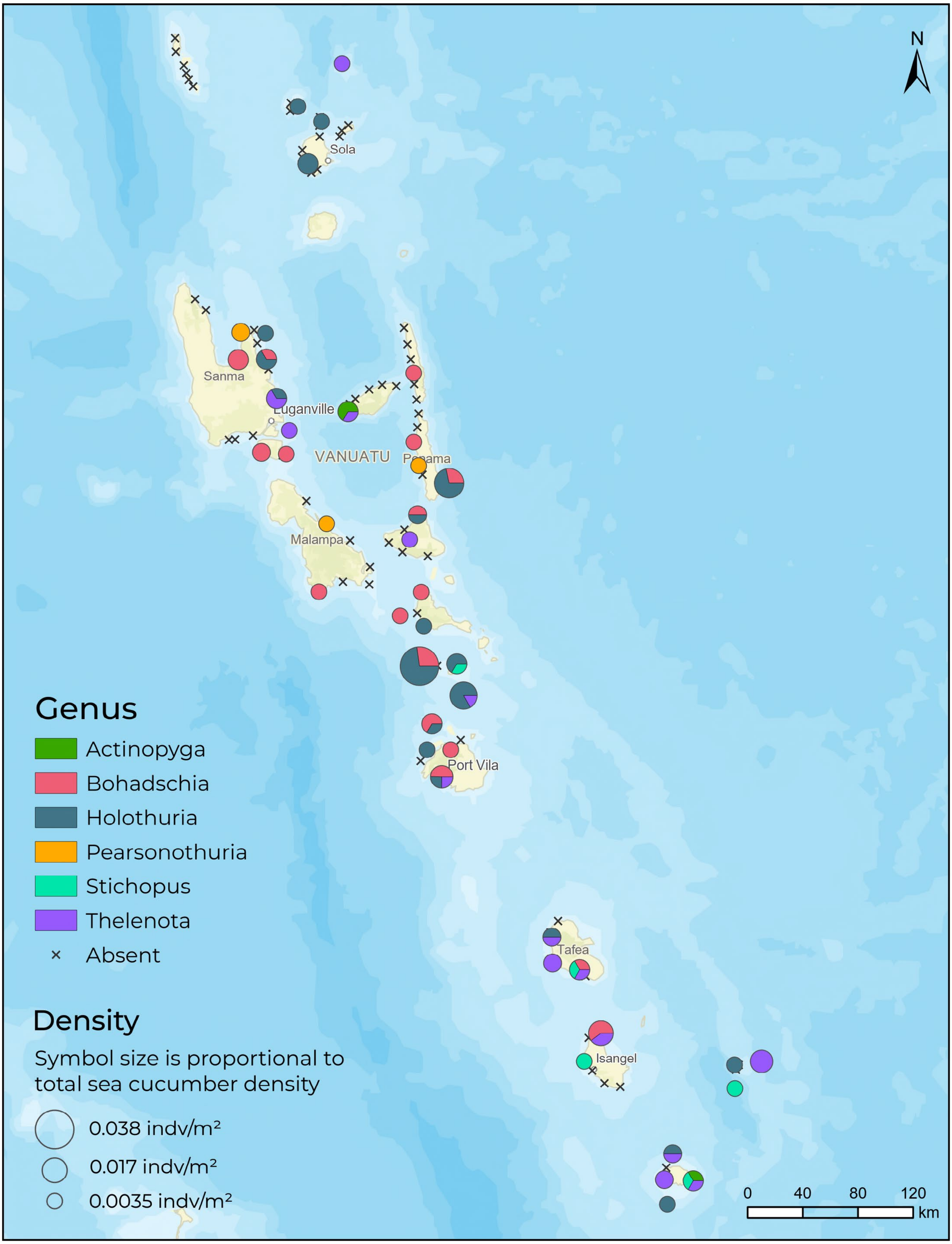
**MAP 23**: *Mean density (number of individuals per square meter) of **baby corals** (typically 1-5 cm in diameter) observed per survey site across Vanuatu.*



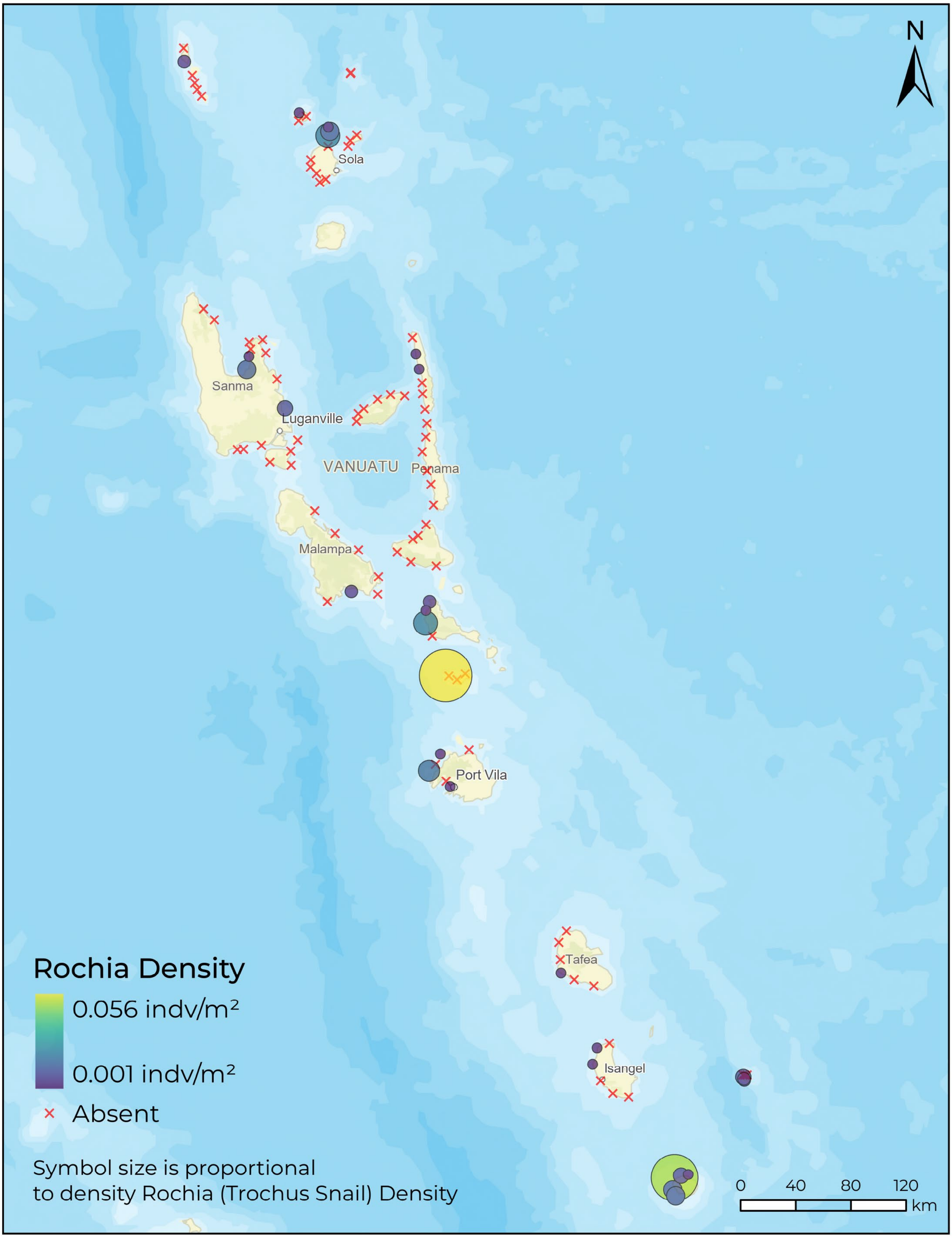
**MAP 24**: *Mean density (number of individuals per square meter) of* ***macroinvertebrates*** *per survey site across Vanuatu. Macroinvertebrates include animals like sea cucumbers, clams, or crabs that do not have a backbone.*



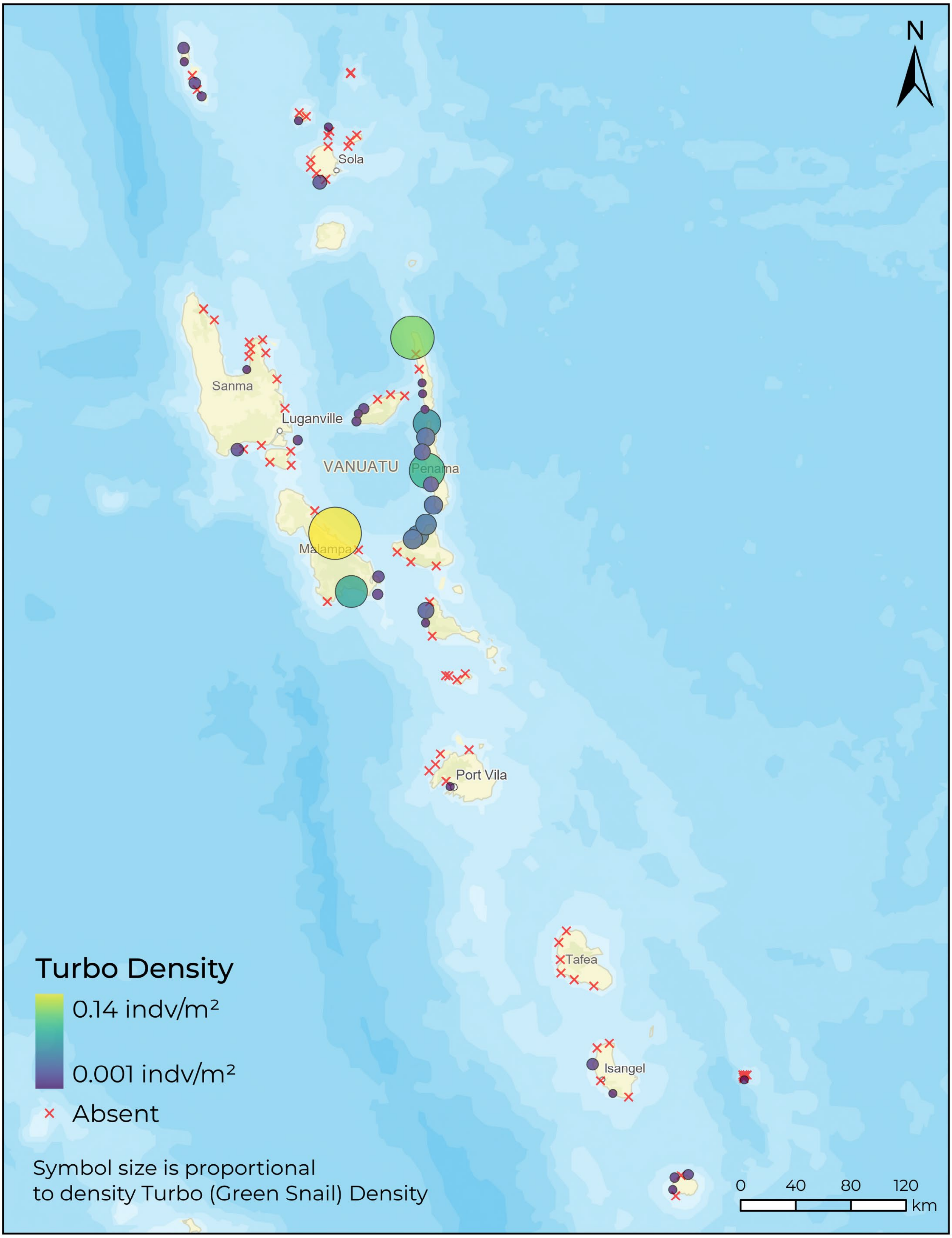
**MAP 25**: *Mean density (number of individuals per square meter) of* ***sea cucumbers by genera*** *observed during belt transects per survey site across Vanuatu.*



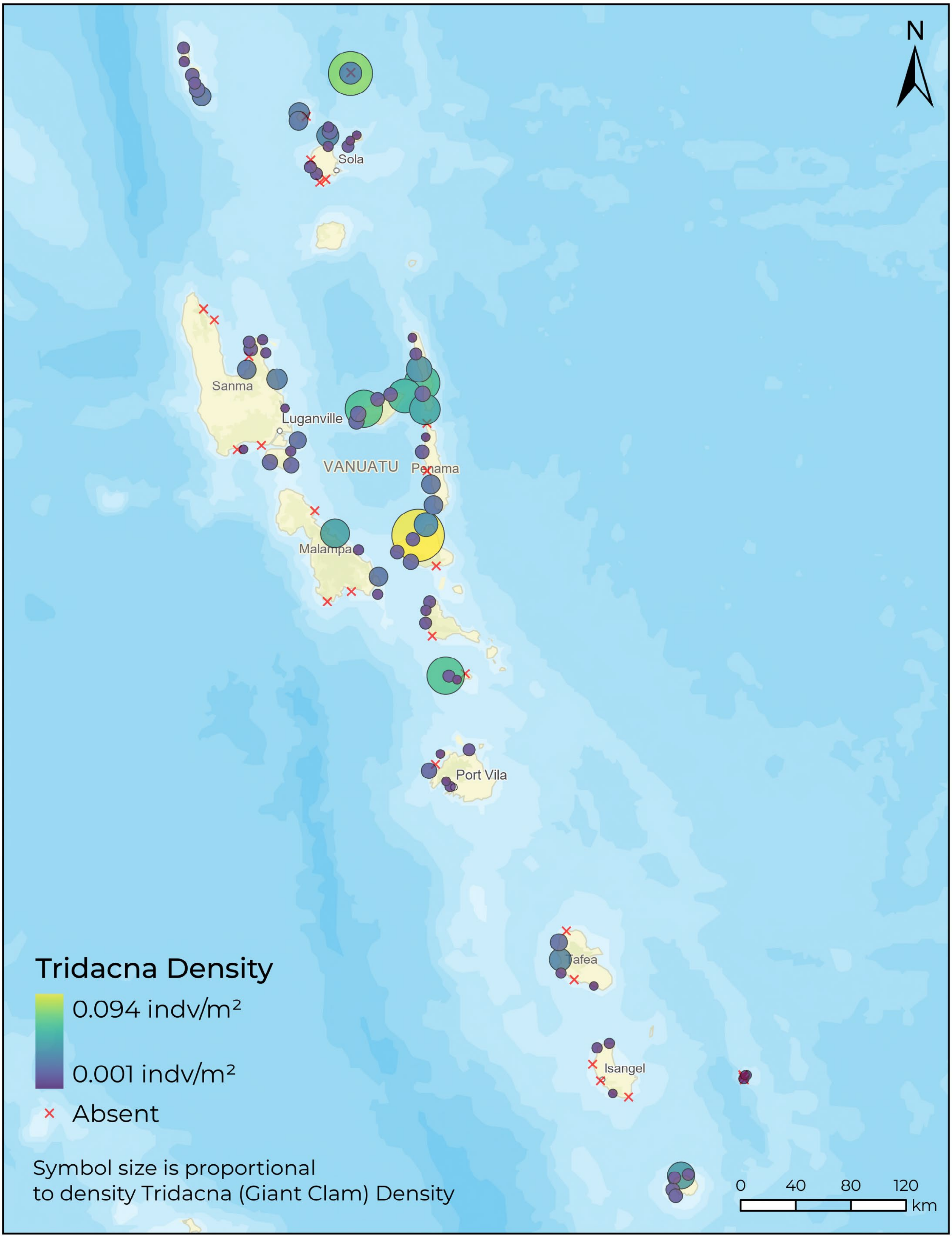
**MAP 26**: *Mean density (number of individuals per square meter) of* ***trochus snails*** (Rochia nilotica) *observed at survey sites across Vanuatu.*



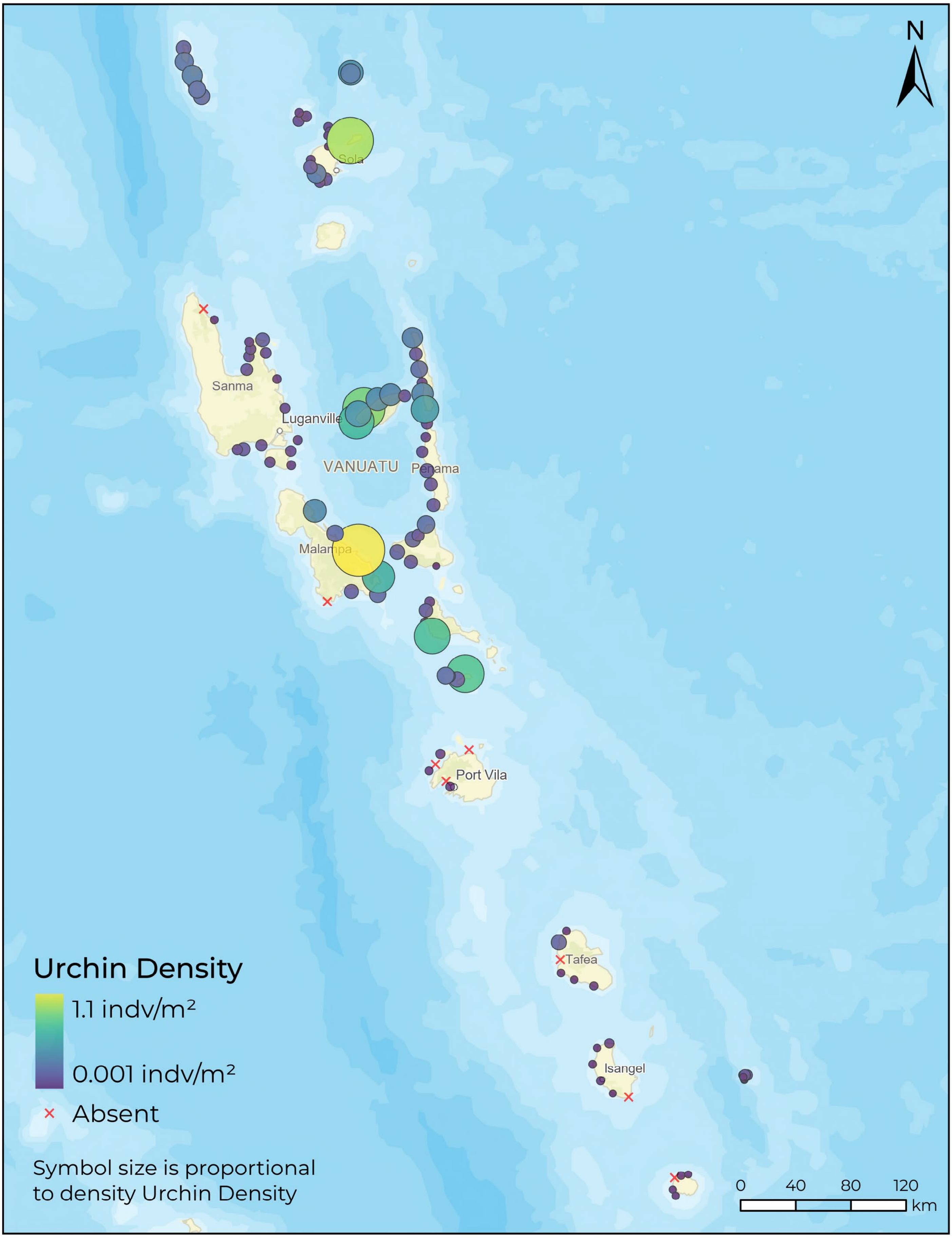
**MAP 27**: *Mean density (number of individuals per square meter) of* ***green snails*** (Turbo marmoratus) *observed at survey sites across Vanuatu.*



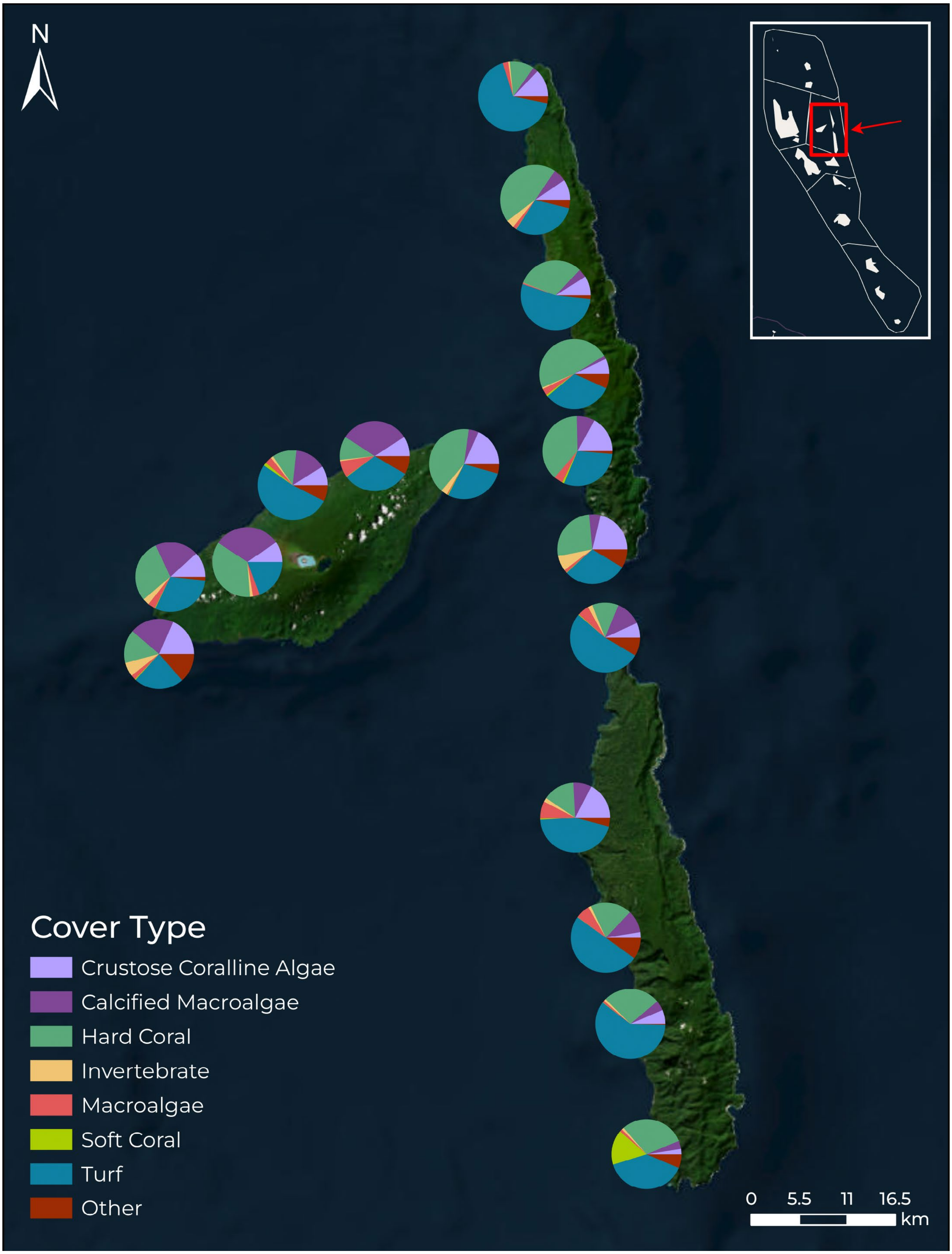
**MAP 28**: *Mean density (number of individuals per square meter) of **giant clams** in the genus Tridacna observed at survey sites across Vanuatu.*



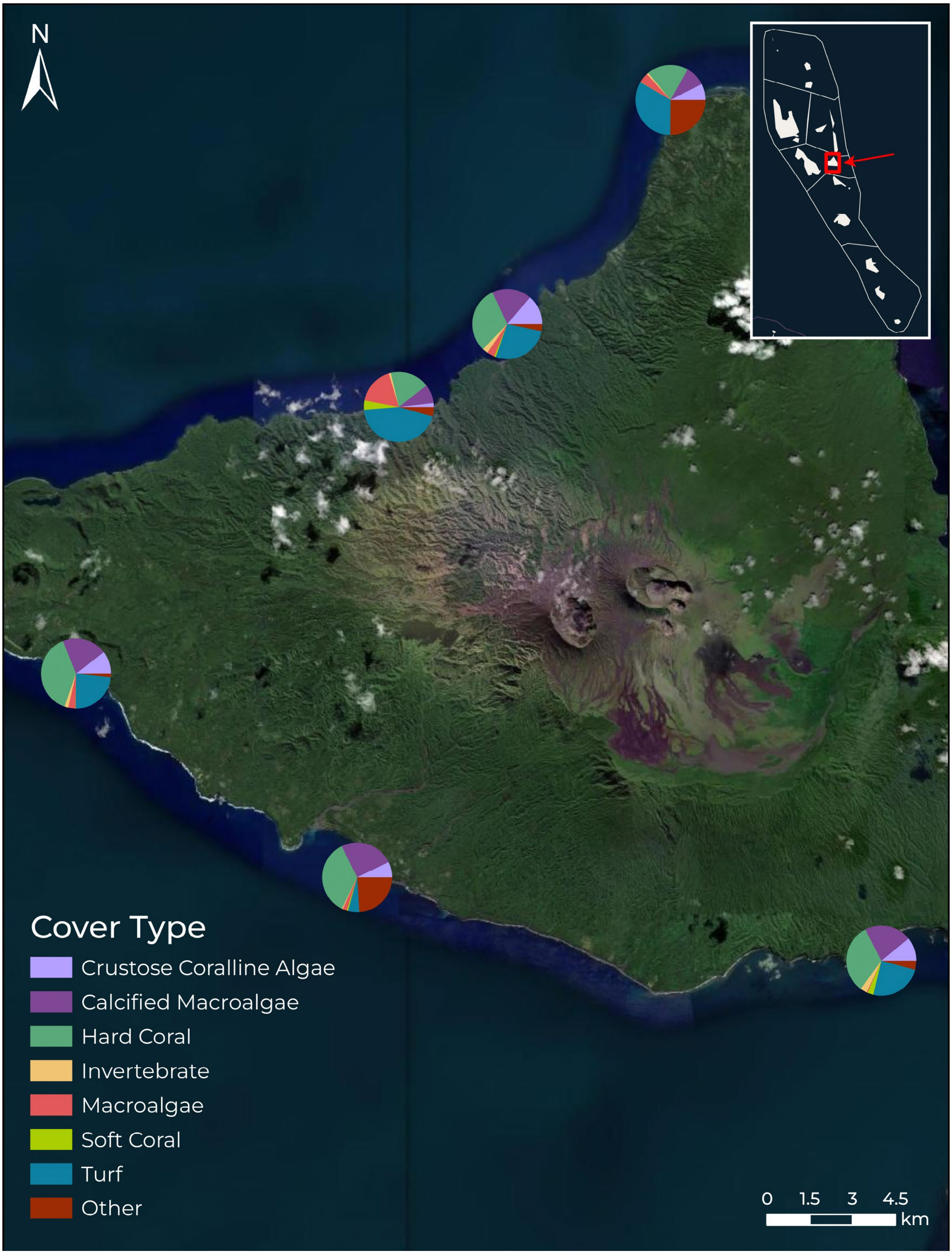
**MAP 29**: *Mean density (number of individuals per square meter) of **sea urchins** observed at survey sites across Vanuatu.*



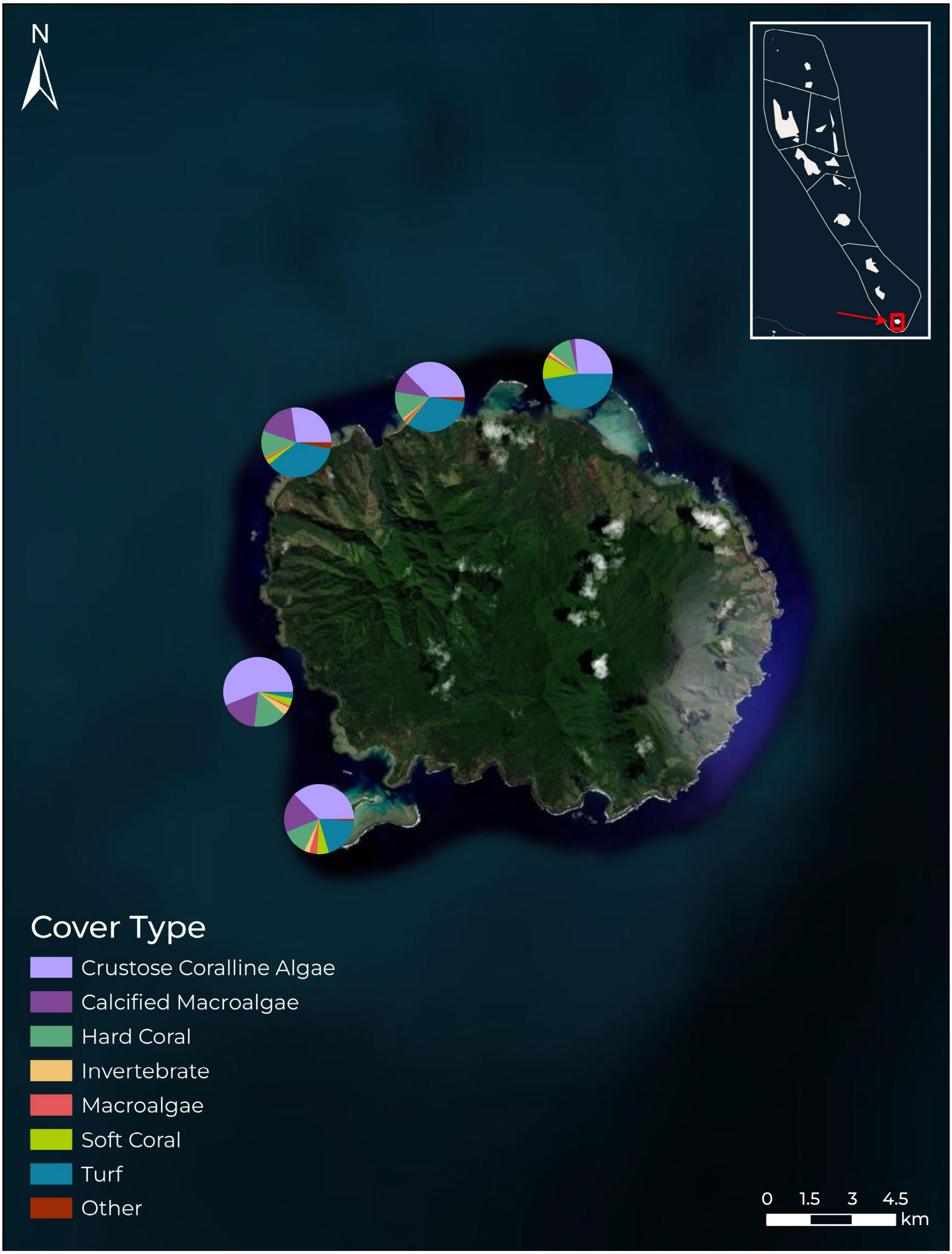
**MAP 30**: *Percent benthic cover types for Ambae, Maewo, and Pentecost Islands*



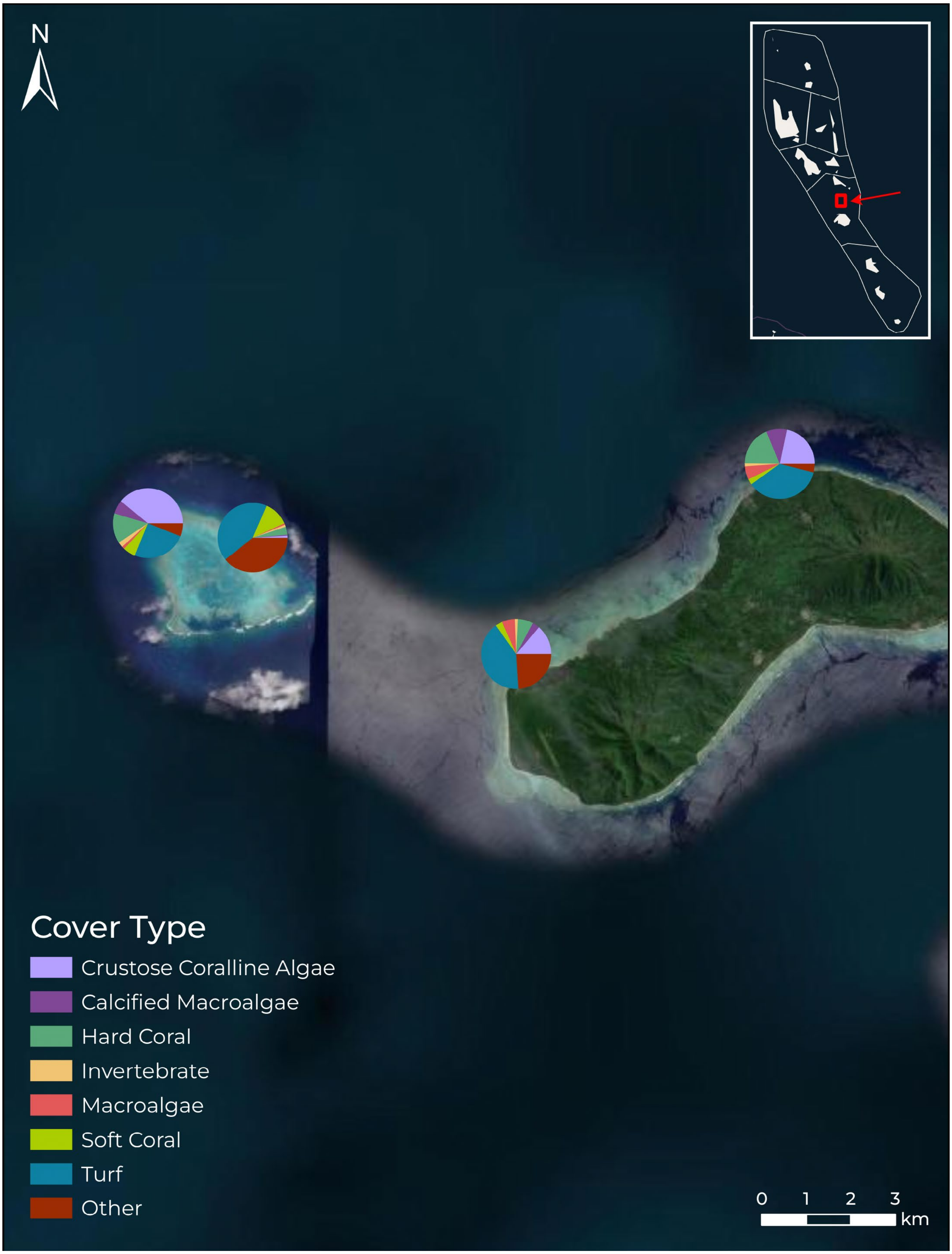
**MAP 31**: *Percent benthic cover types for Ambrym Island.*



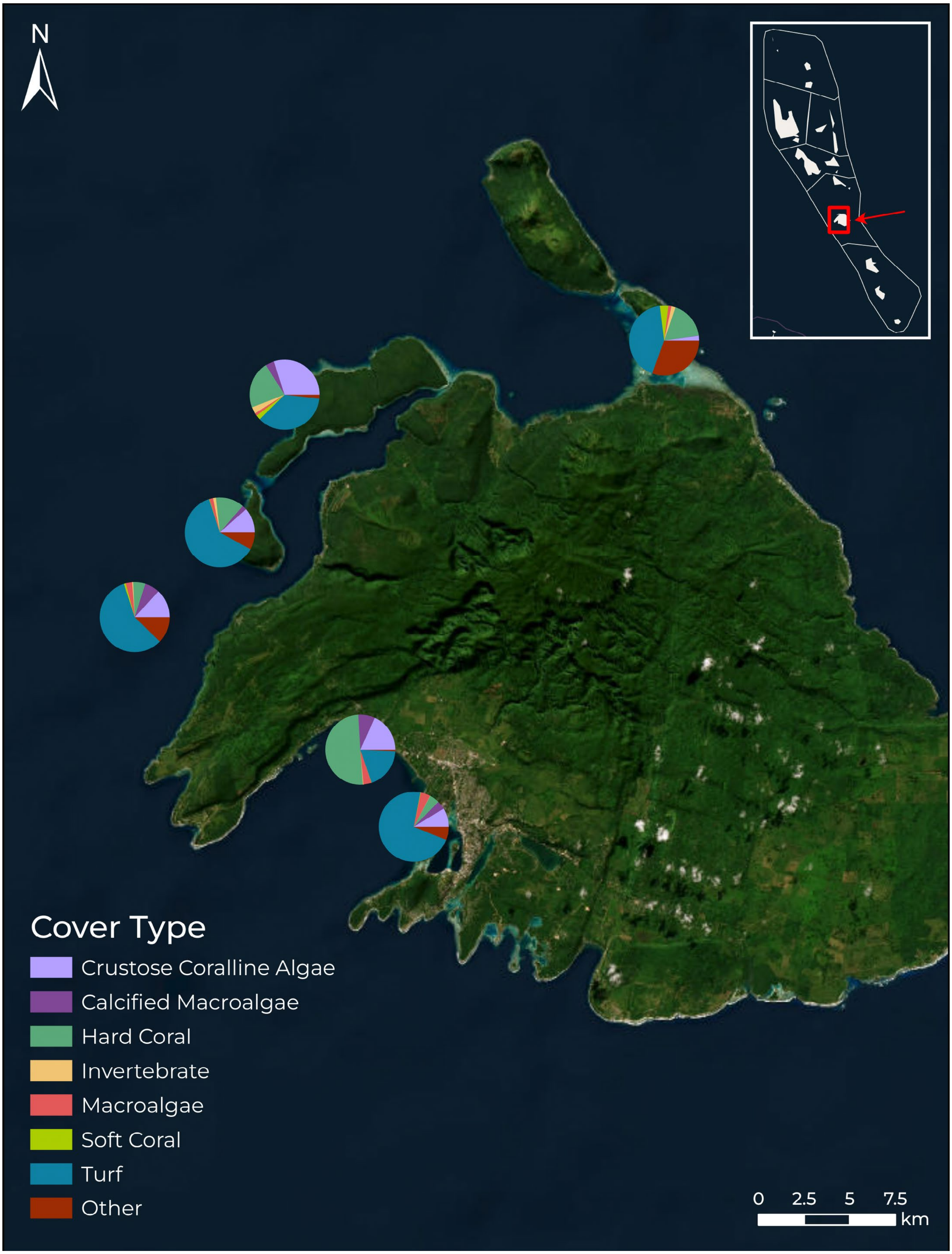
**MAP 32**: *Percent benthic cover types for Aneityum Island.*



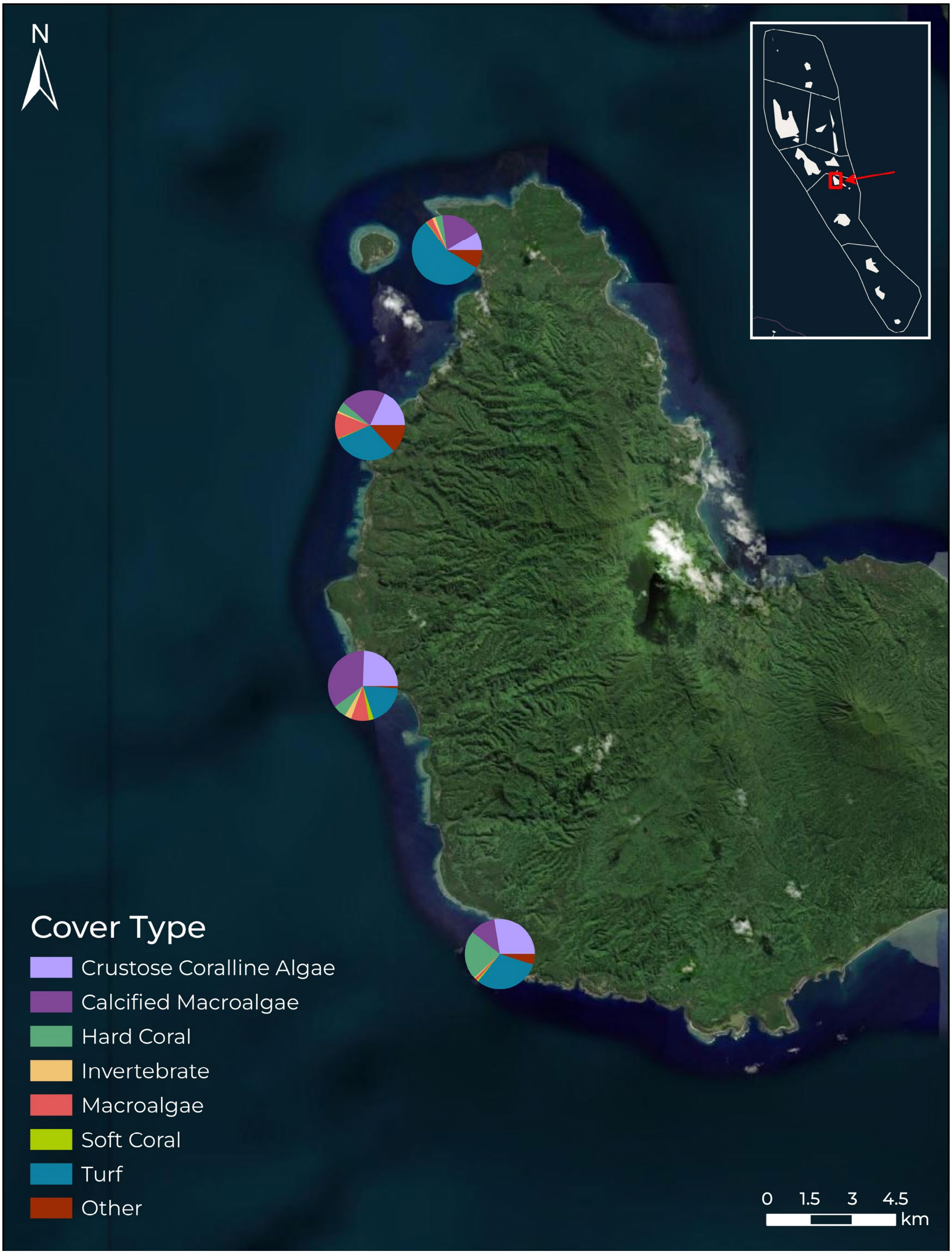
**MAP 33**: *Percent benthic cover types for Cook's Reef & Emae Island.*



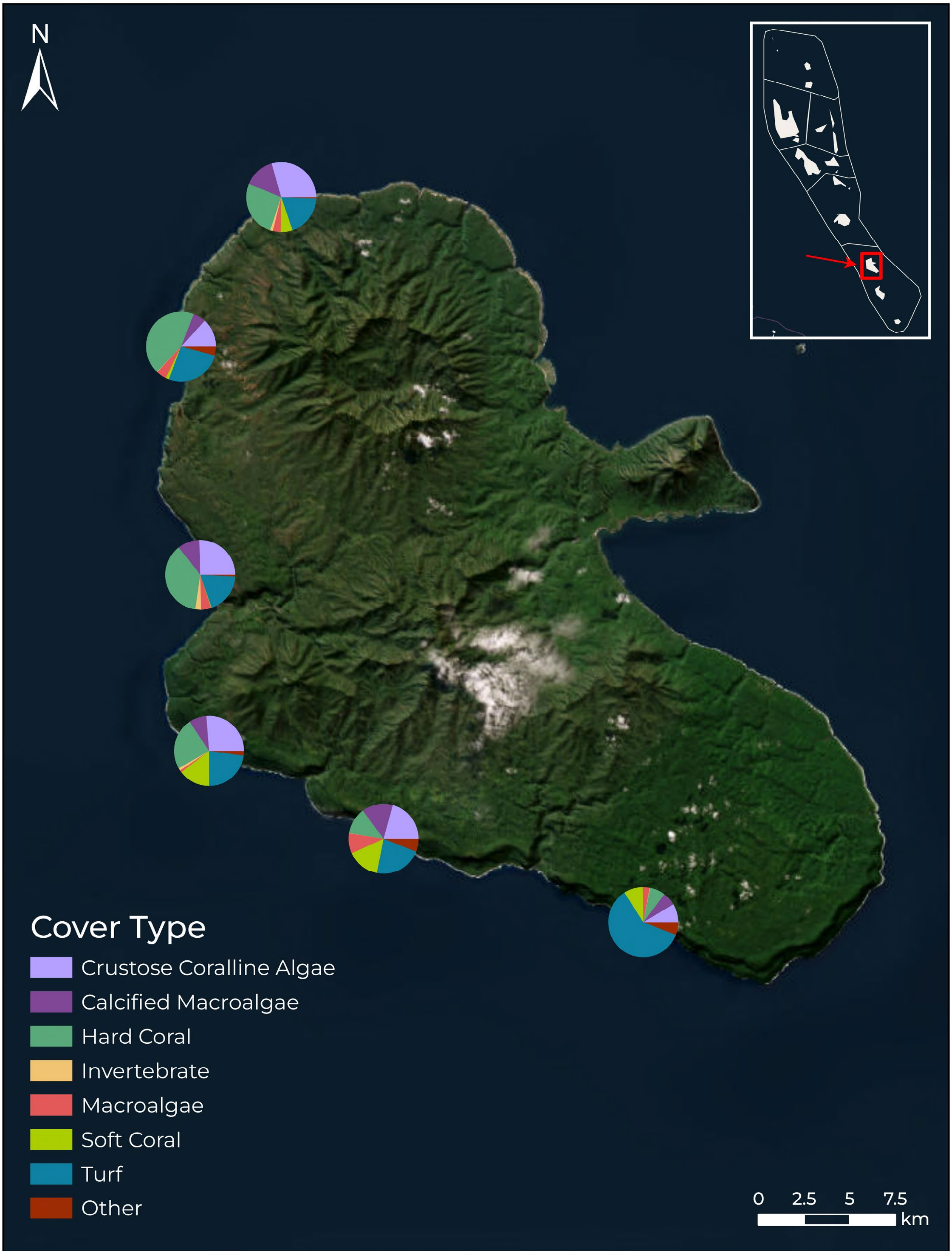
**MAP 34**: *Percent benthic cover types for Efate Island.*



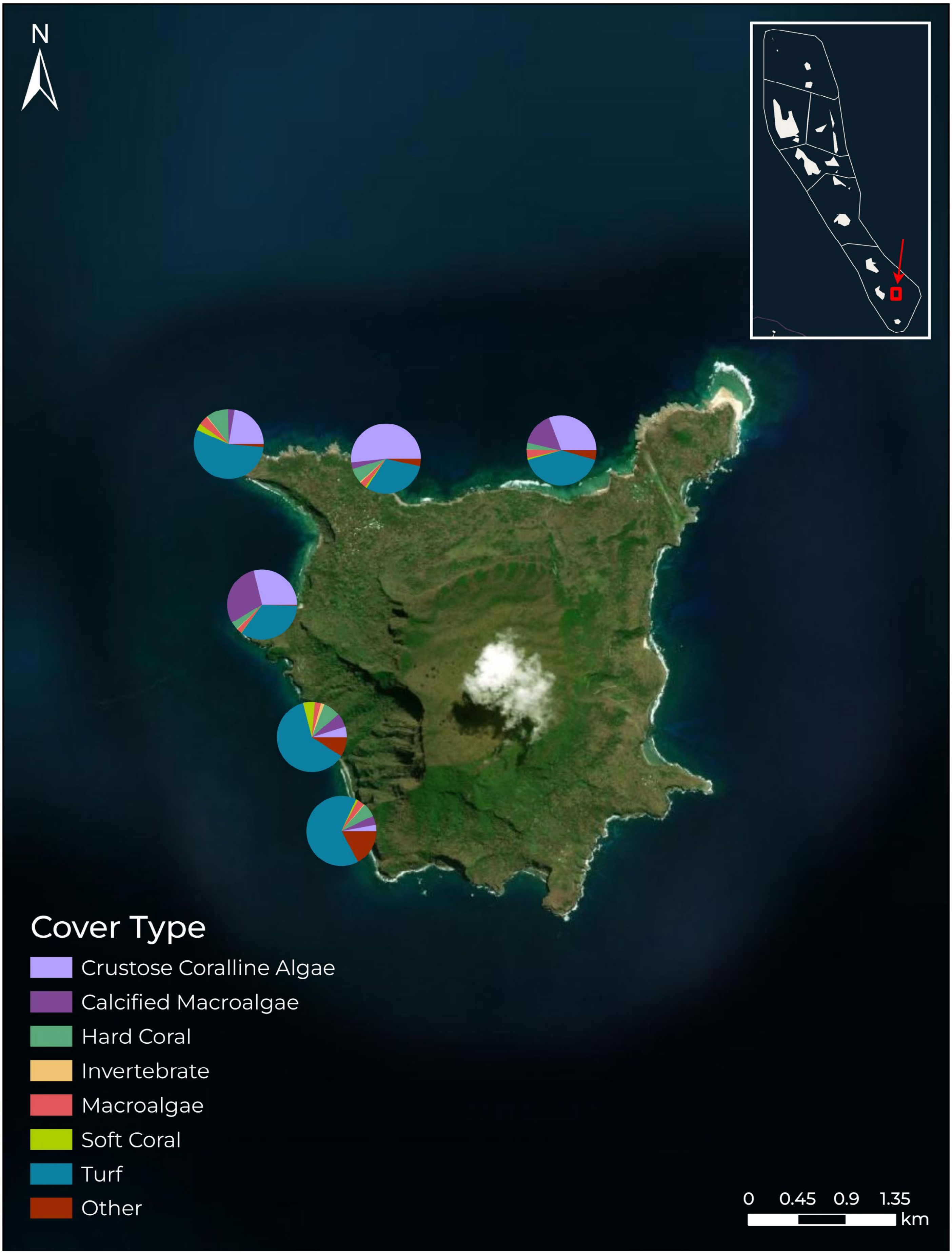
**MAP 35**: *Percent benthic cover types for Epi Island.*



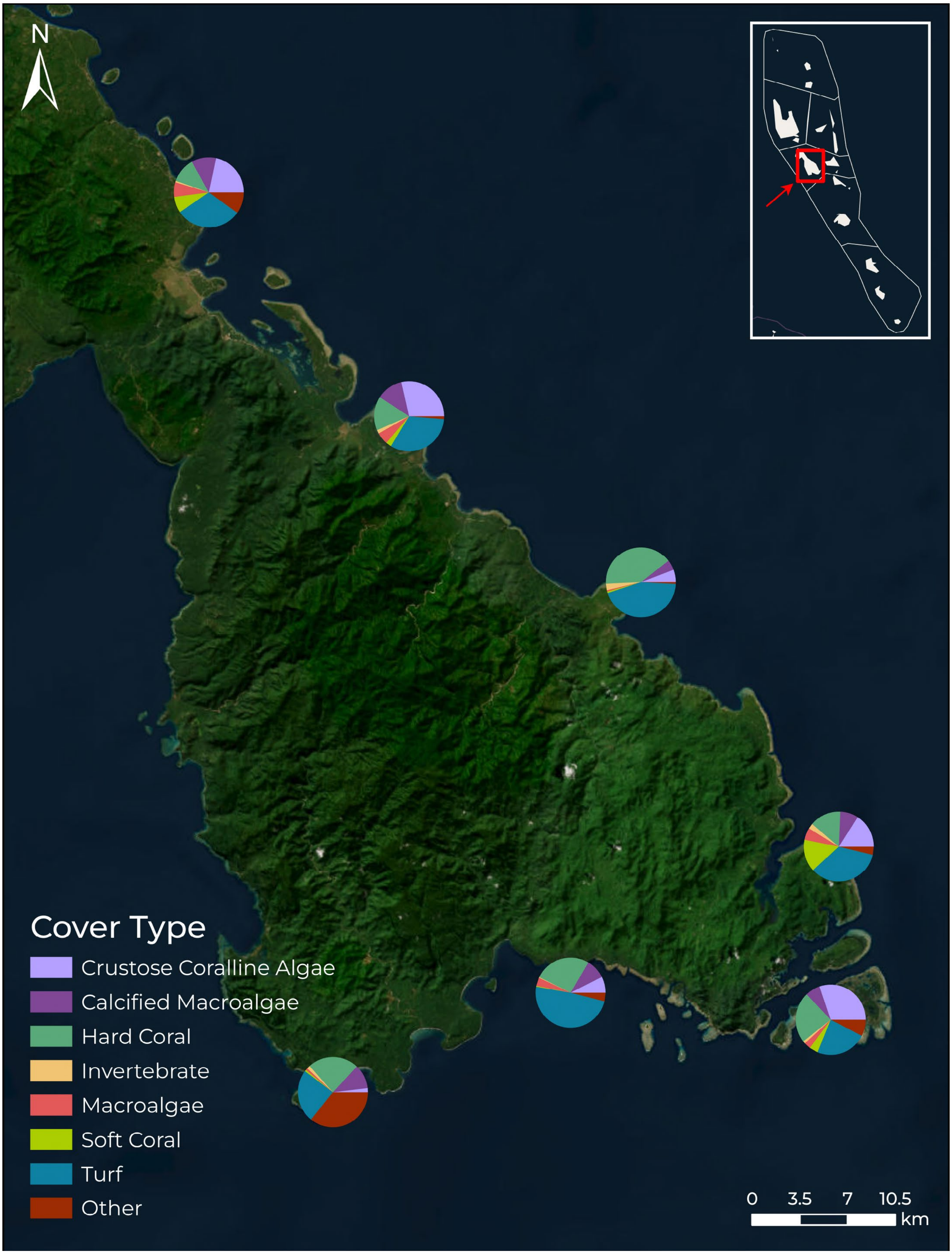
**MAP 36**: *Percent benthic cover types for Erromango Island.*



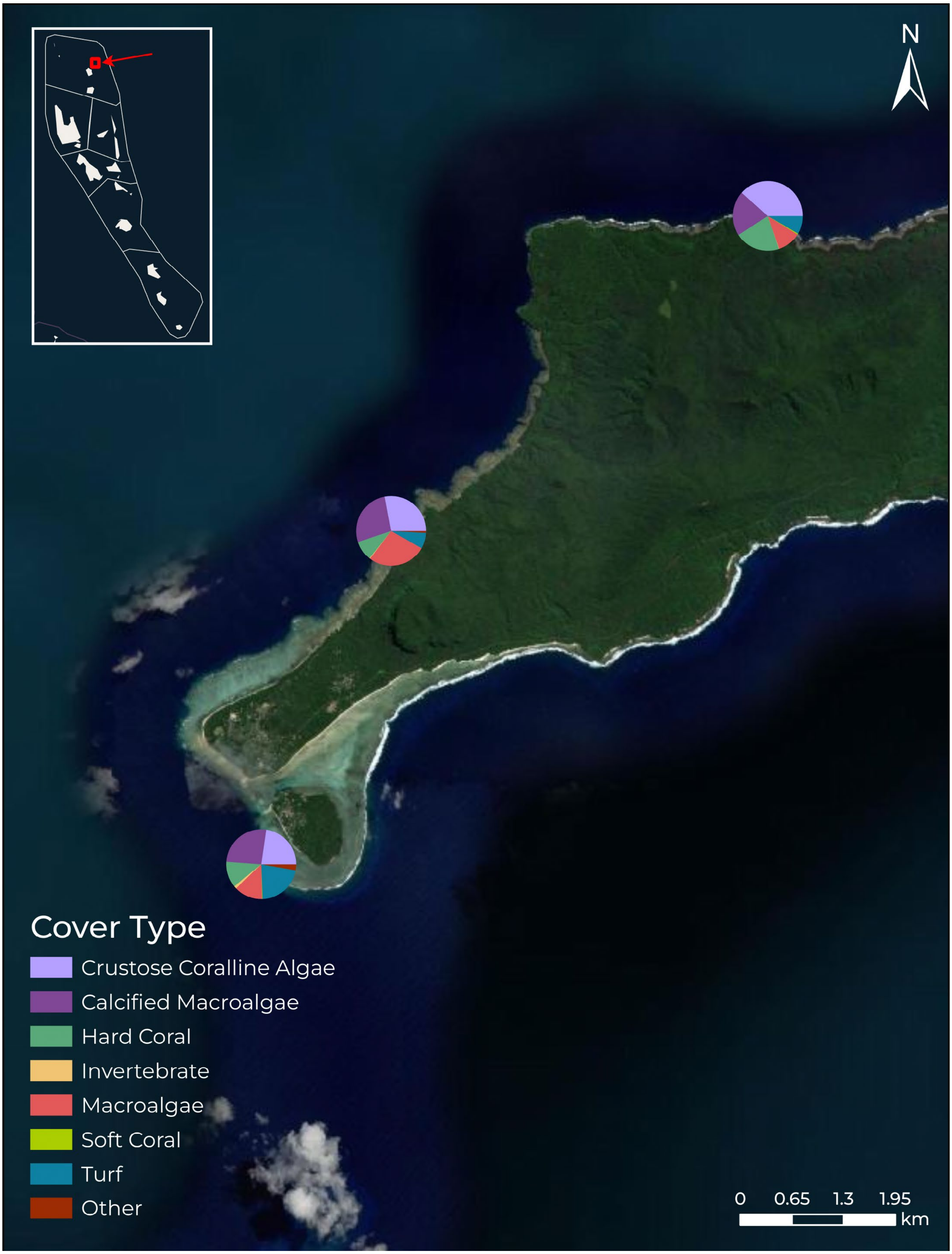
**MAP 37**: *Percent benthic cover types for Futuna Island.*



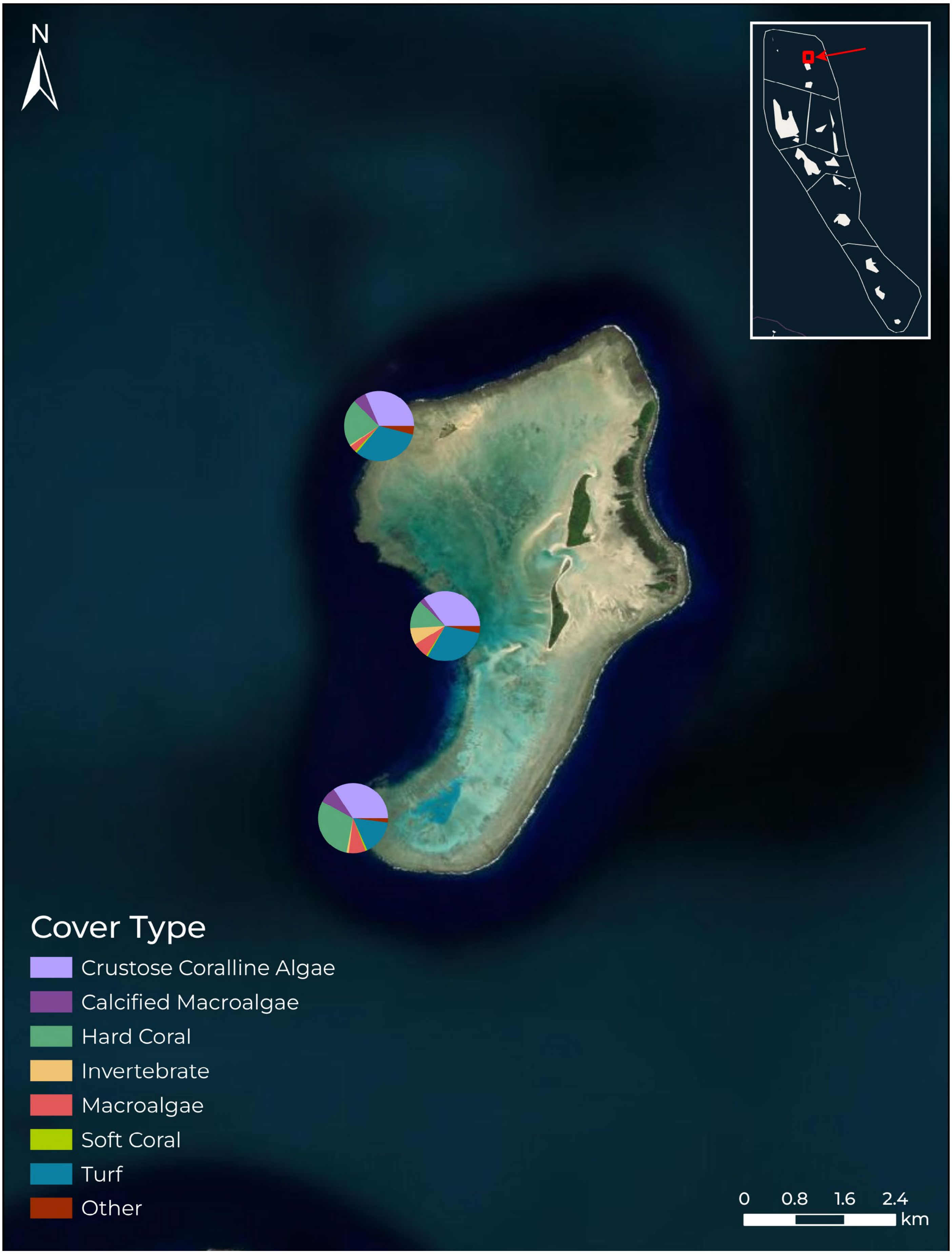
**MAP 38**: *Percent benthic cover types for Malekula Island.*



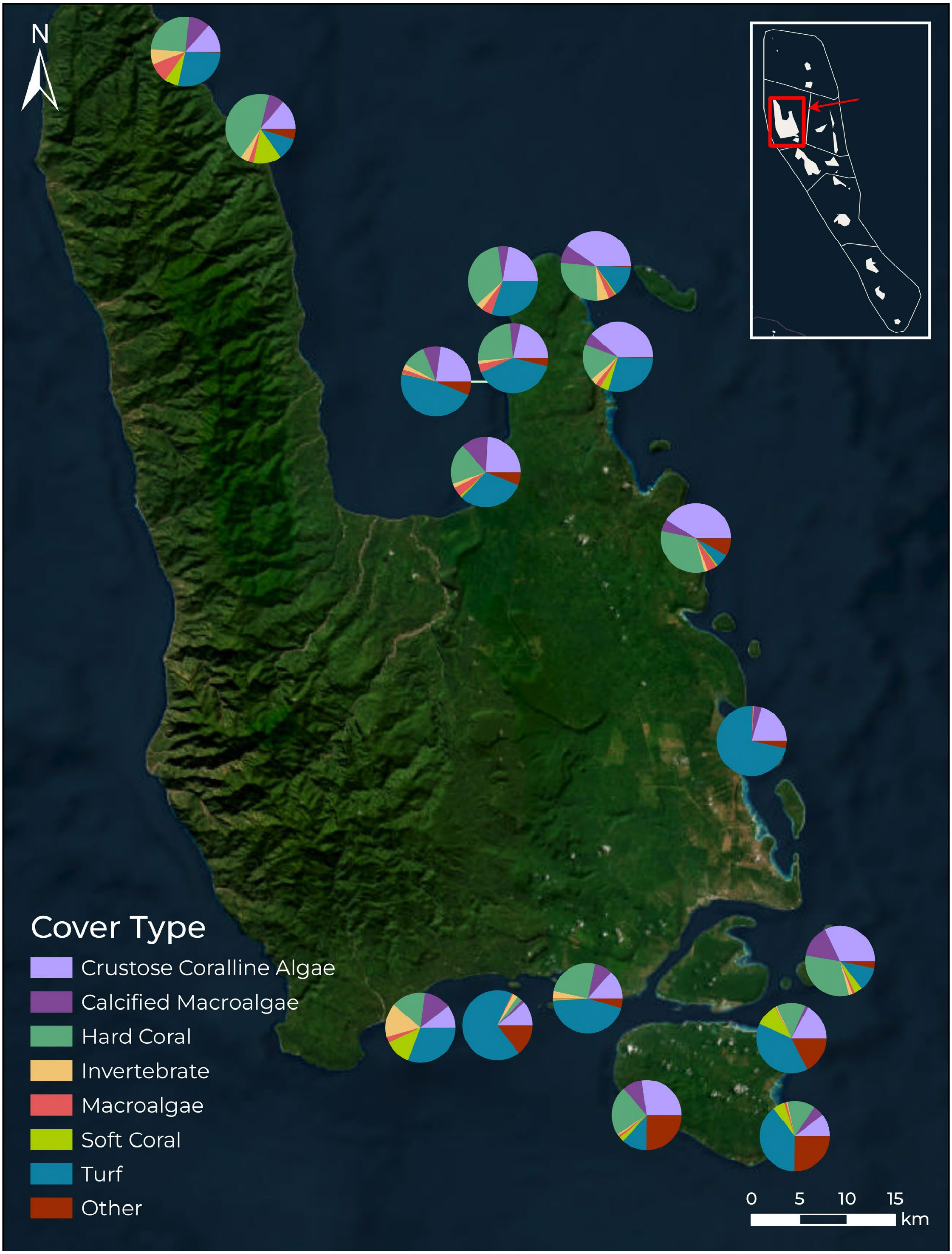
**MAP 39**: *Percent benthic cover types for Mota Lava Island.*



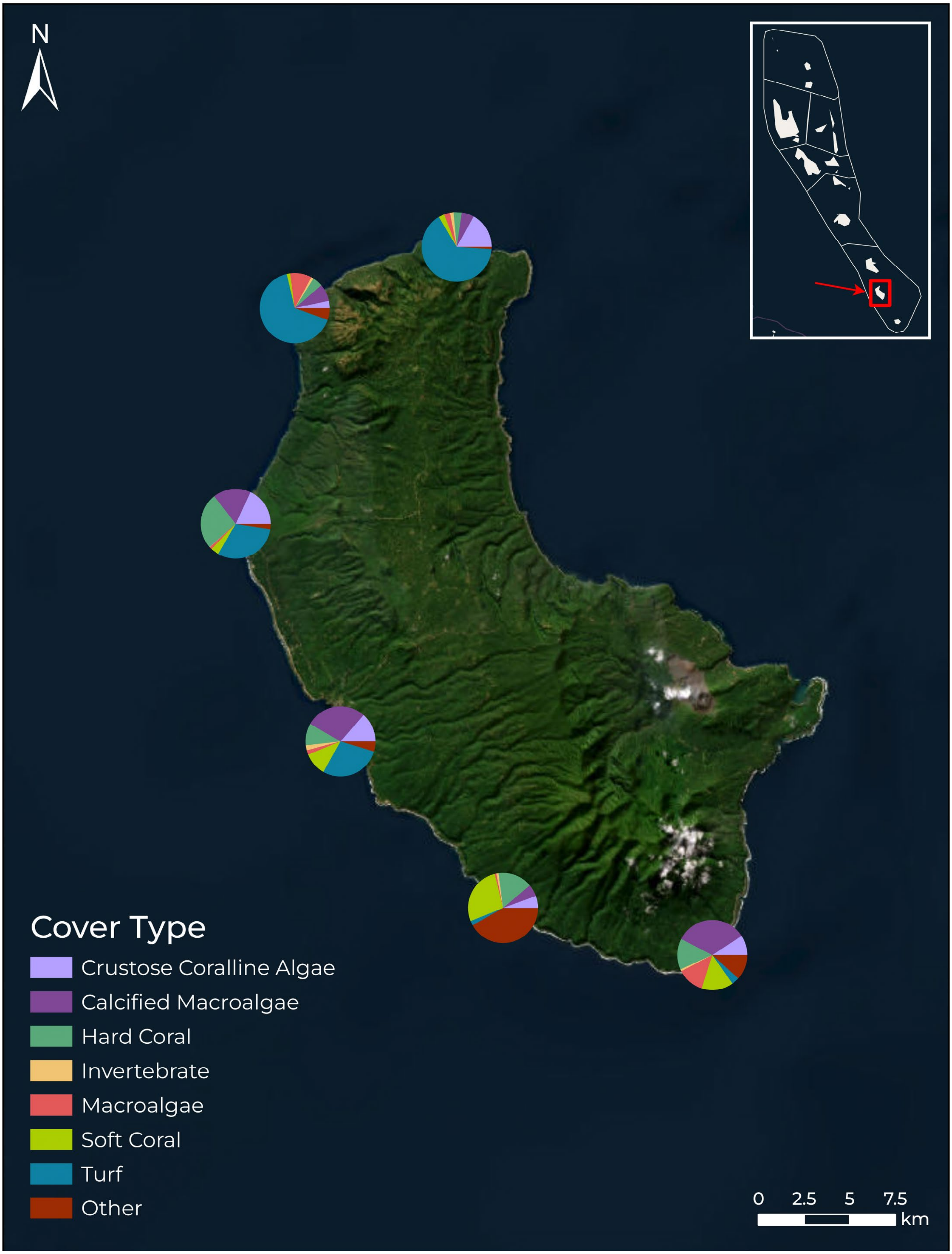
**MAP 40**: *Percent benthic cover types for Rowa Islands.*



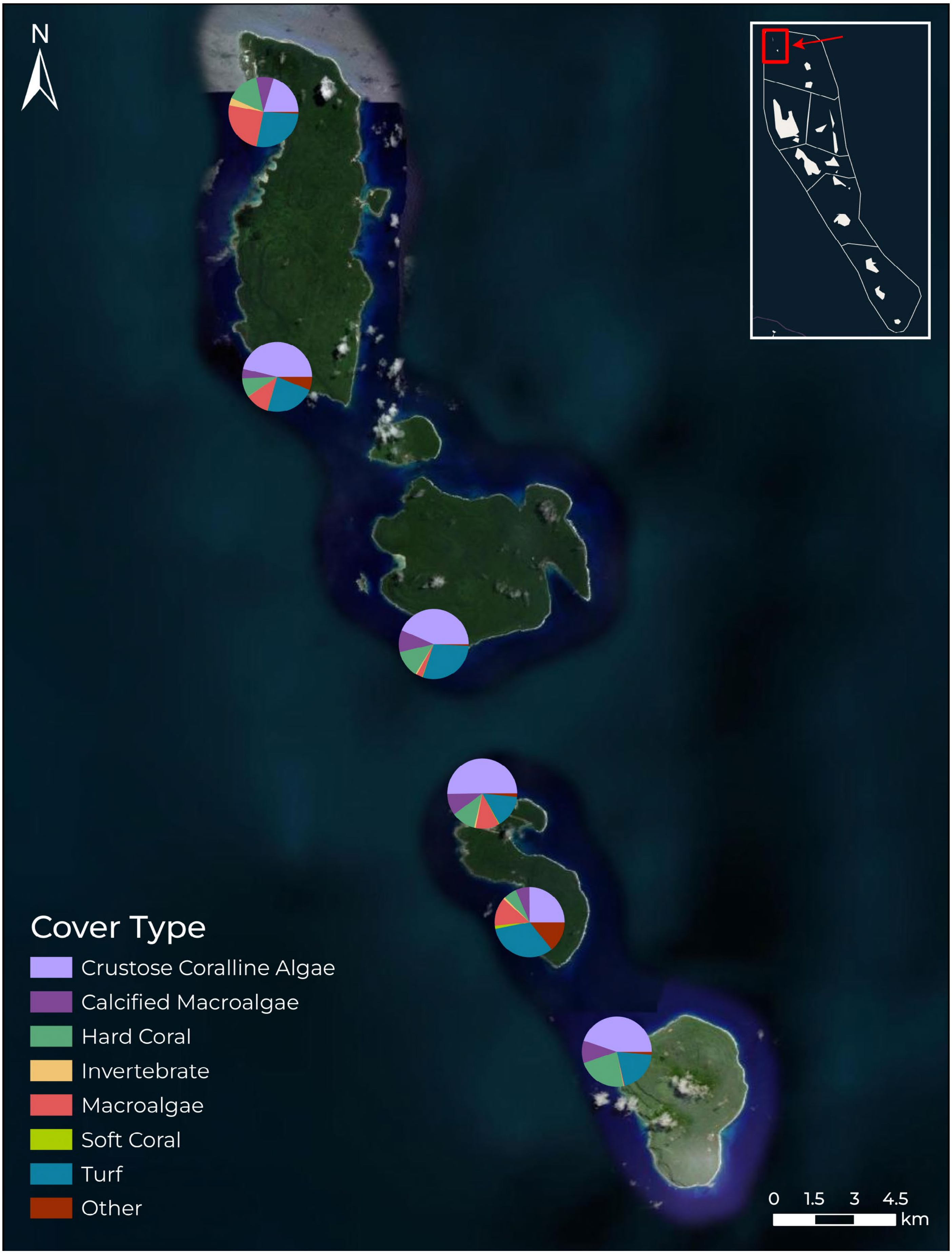
**MAP 41**: *Percent benthic cover types for Santo & Malo Islands.*



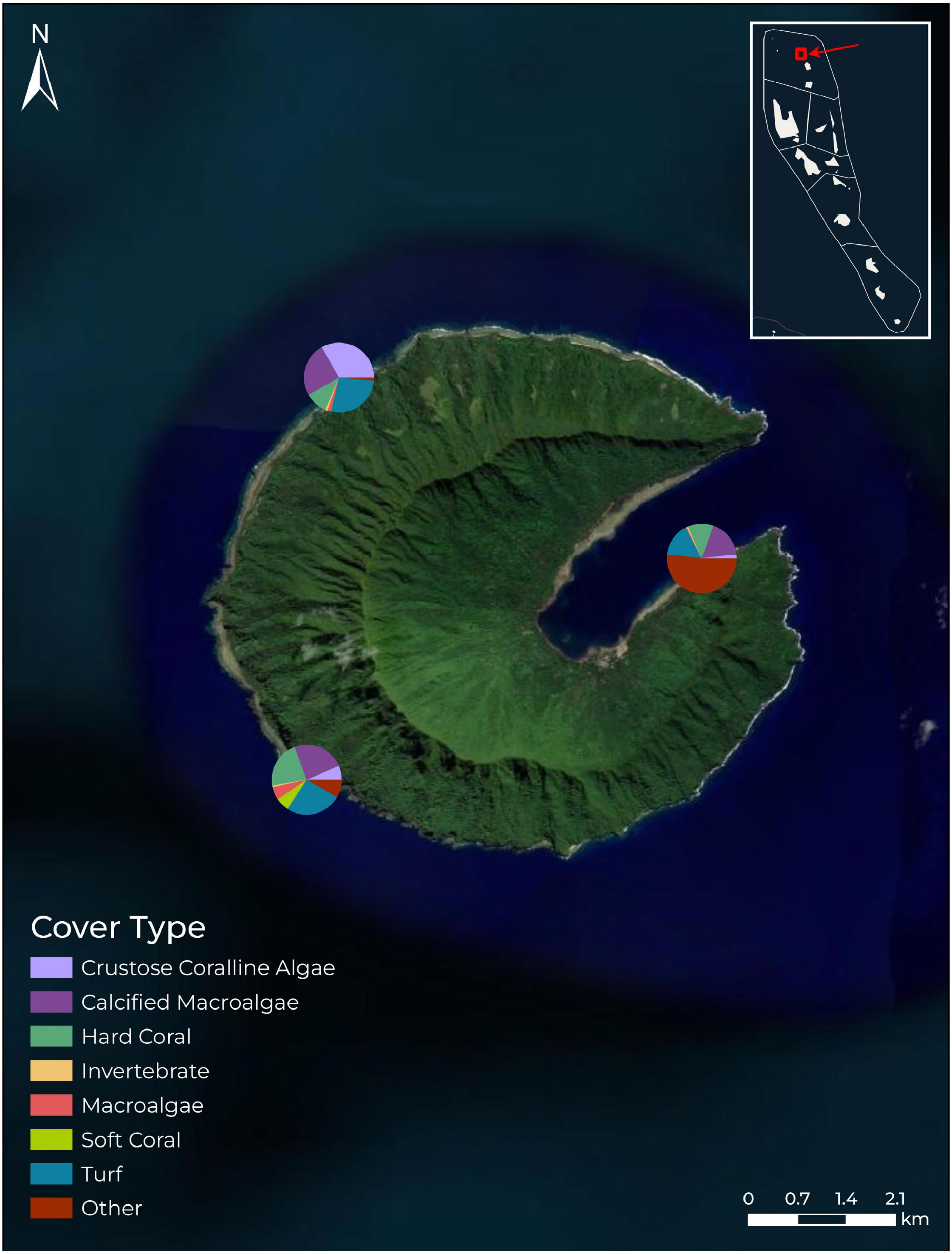
**MAP 42**: *Percent benthic cover types for Tanna Island.*



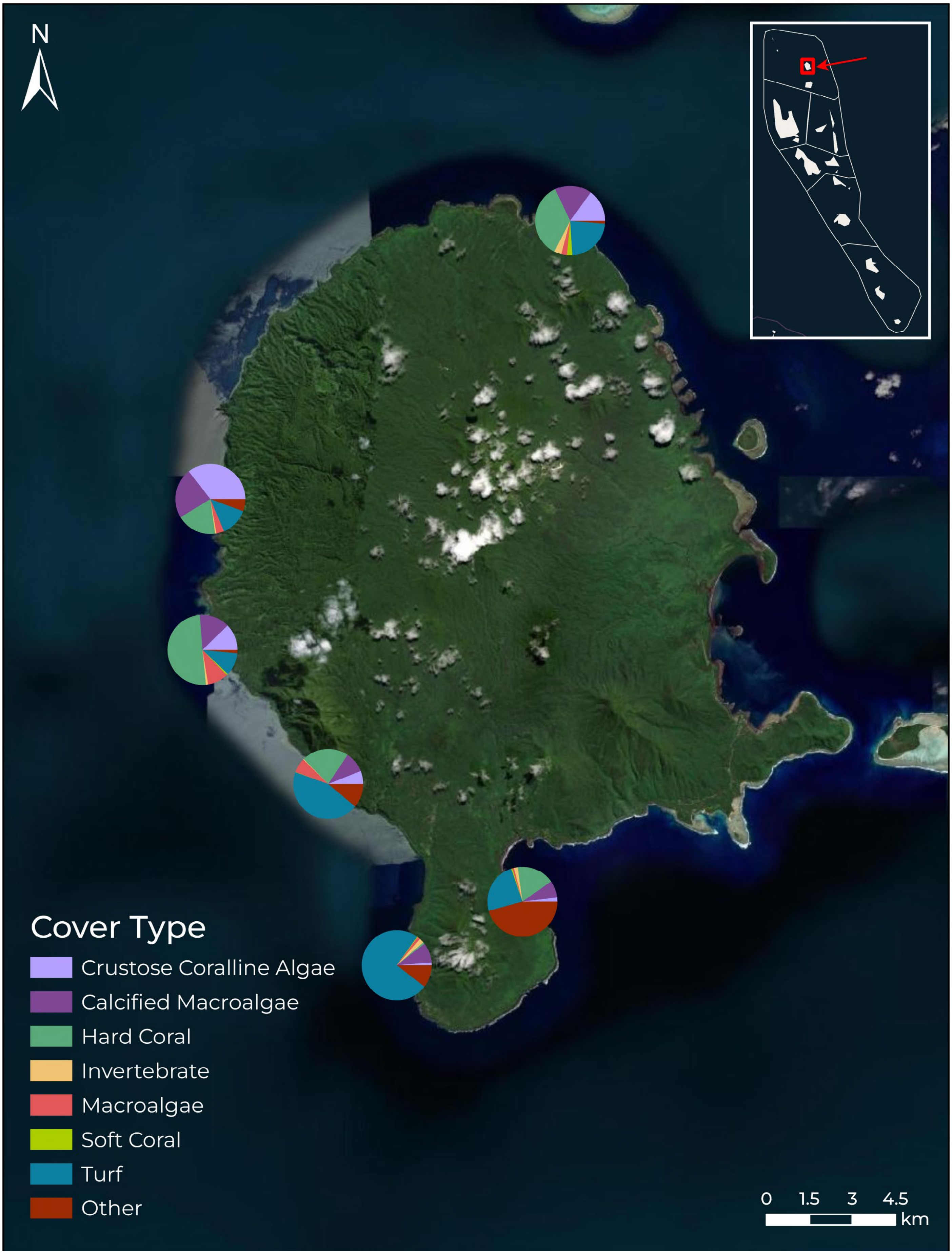
**MAP 43**: *Percent benthic cover types for Torres Islands.*



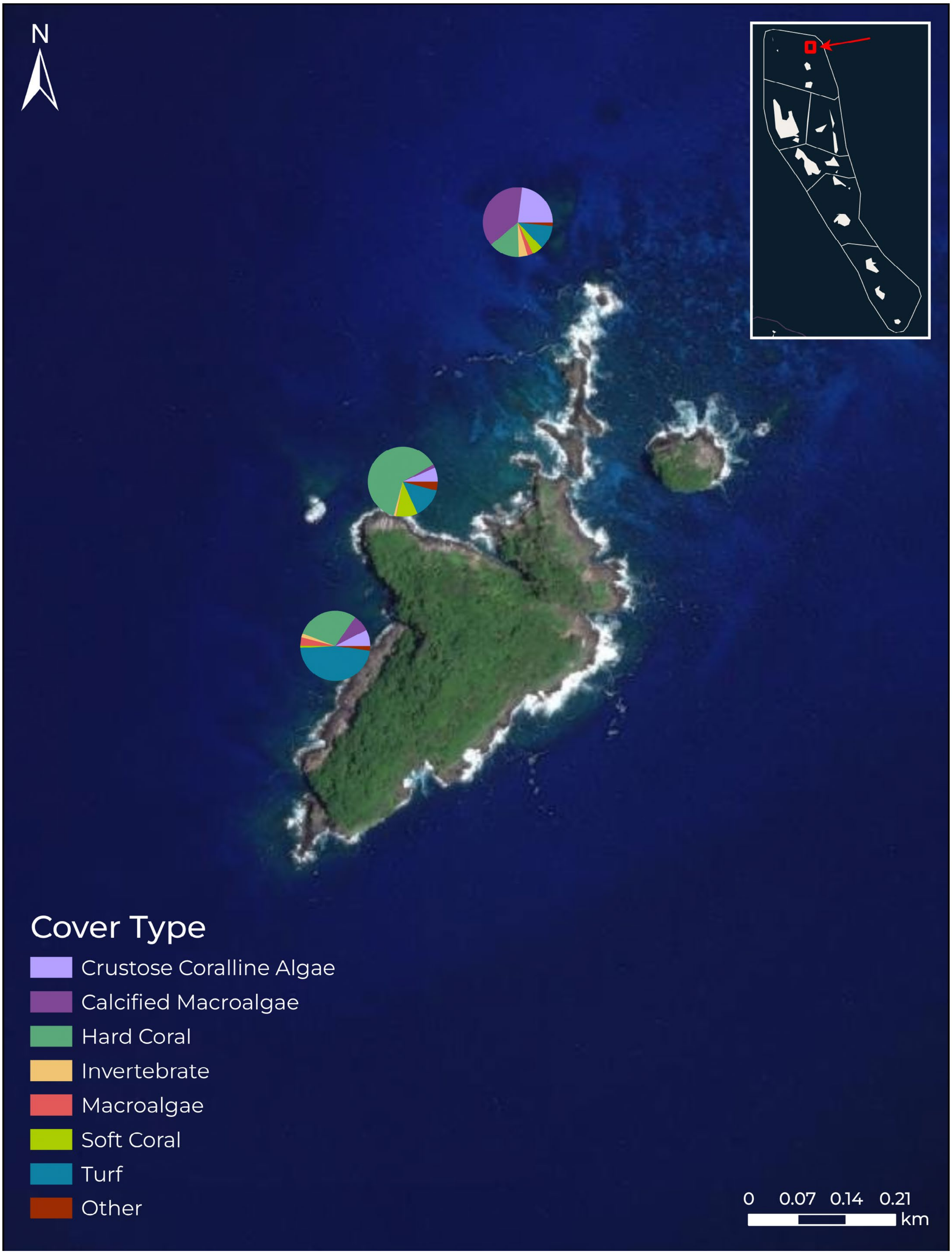
**MAP 44**: *Percent benthic cover types for Ureparapara Island.*



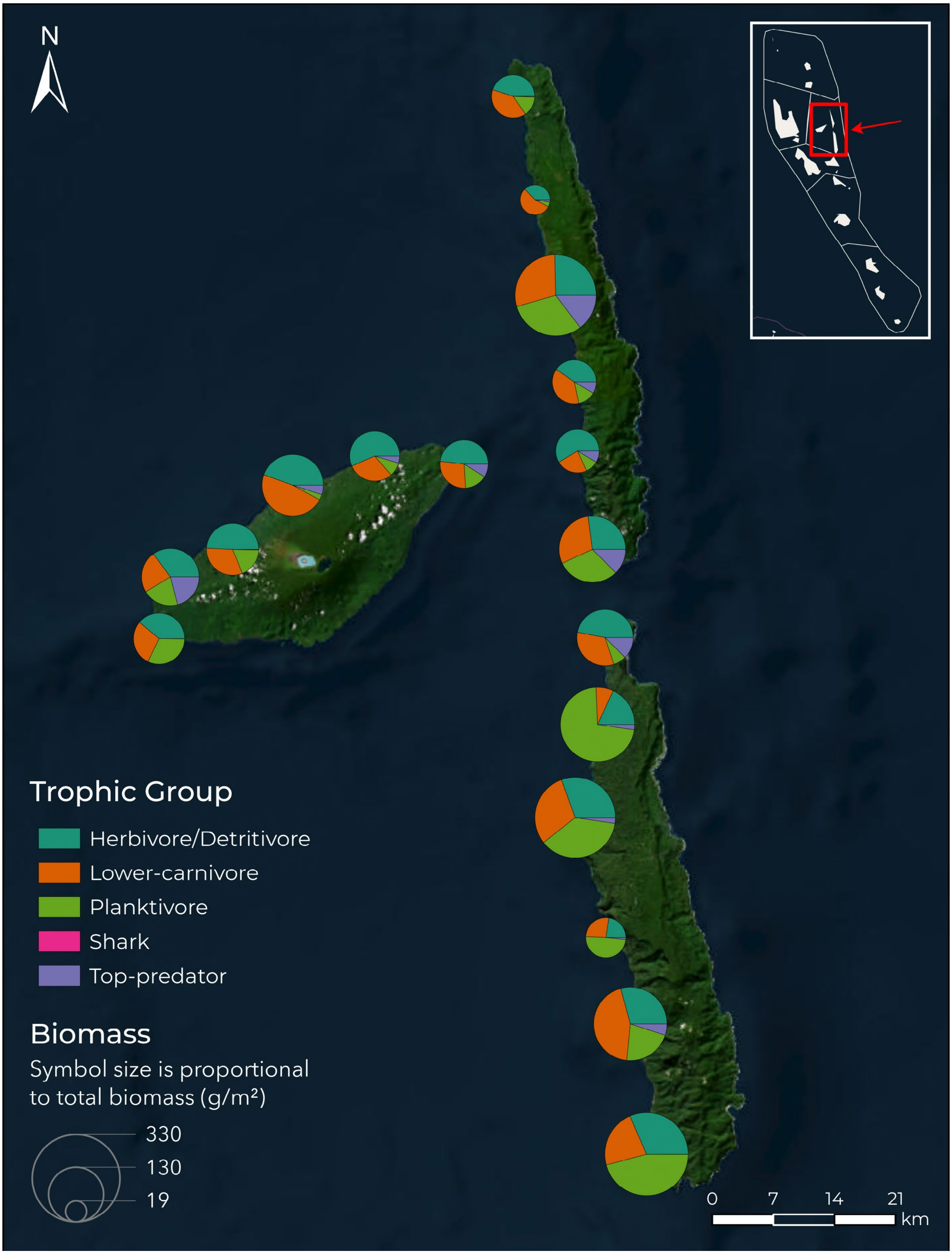
**MAP 45**: *Percent benthic cover types for Vanua Lava Island.*



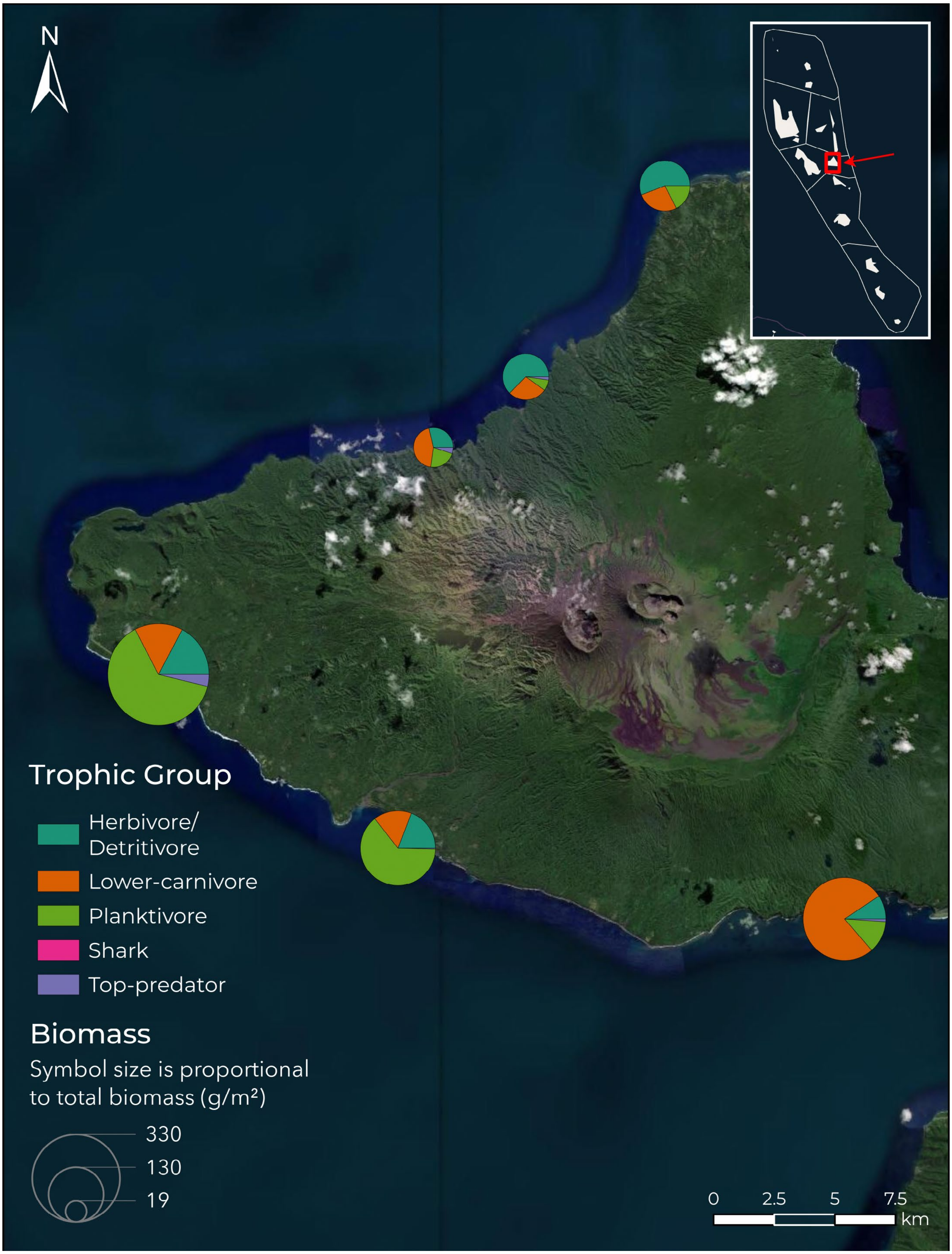
**MAP 46**: *Percent benthic cover types for Vot Tande Island.*



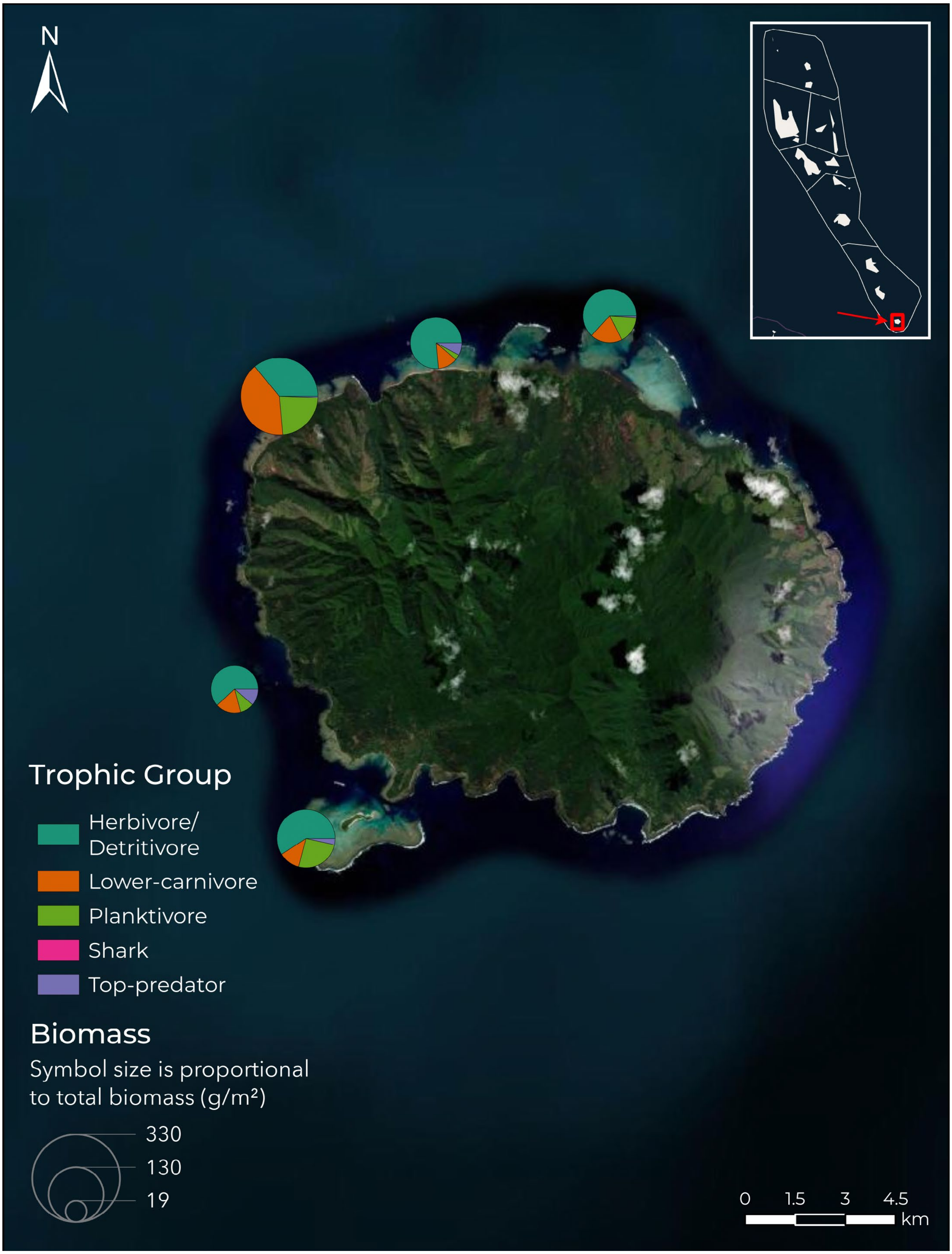
**MAP 47**: *Total fish biomass by trophic group for Ambae, Maewo, and Pentecost Islands.*



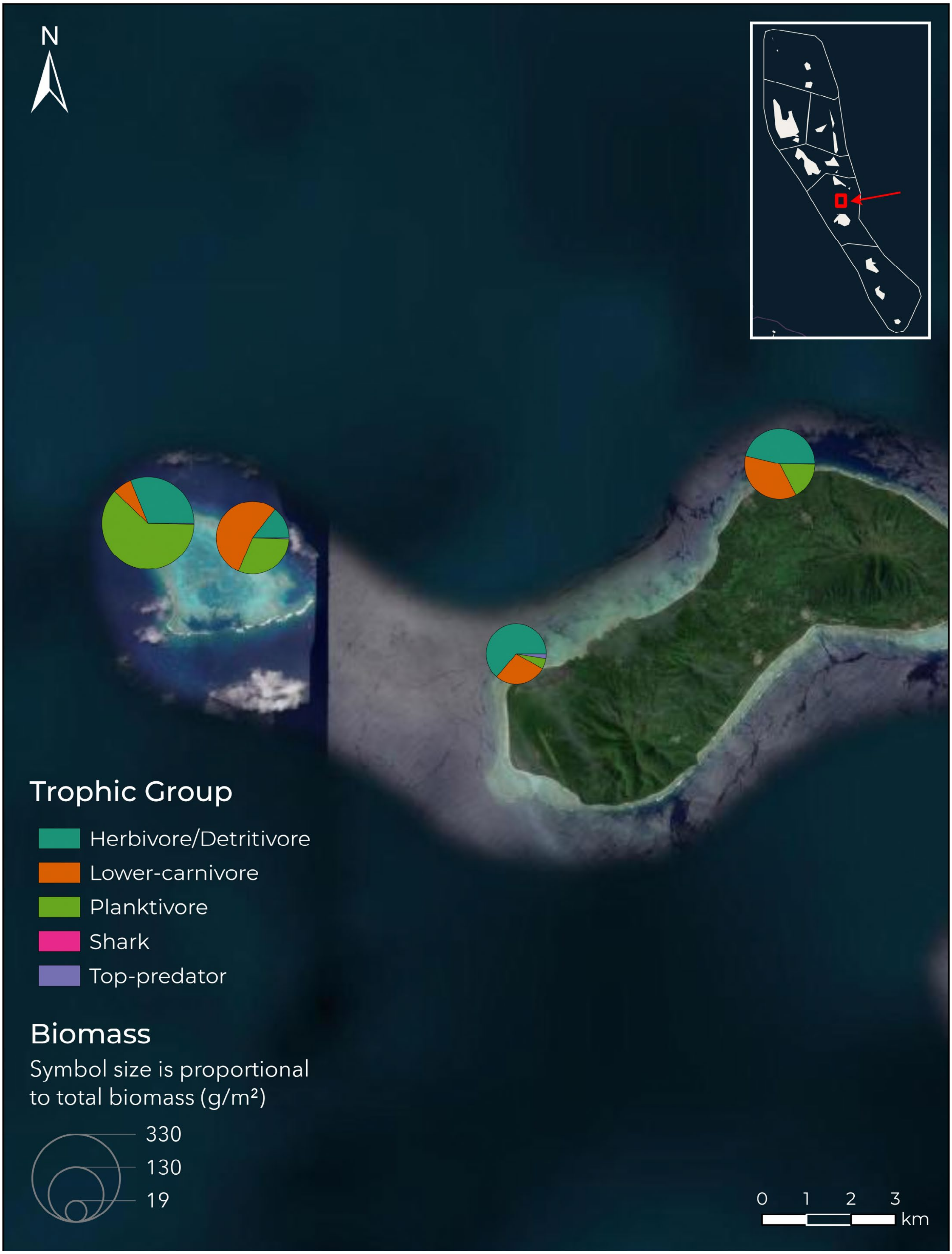
**MAP 48**: *Total fish biomass by trophic group for Ambrym Island.*



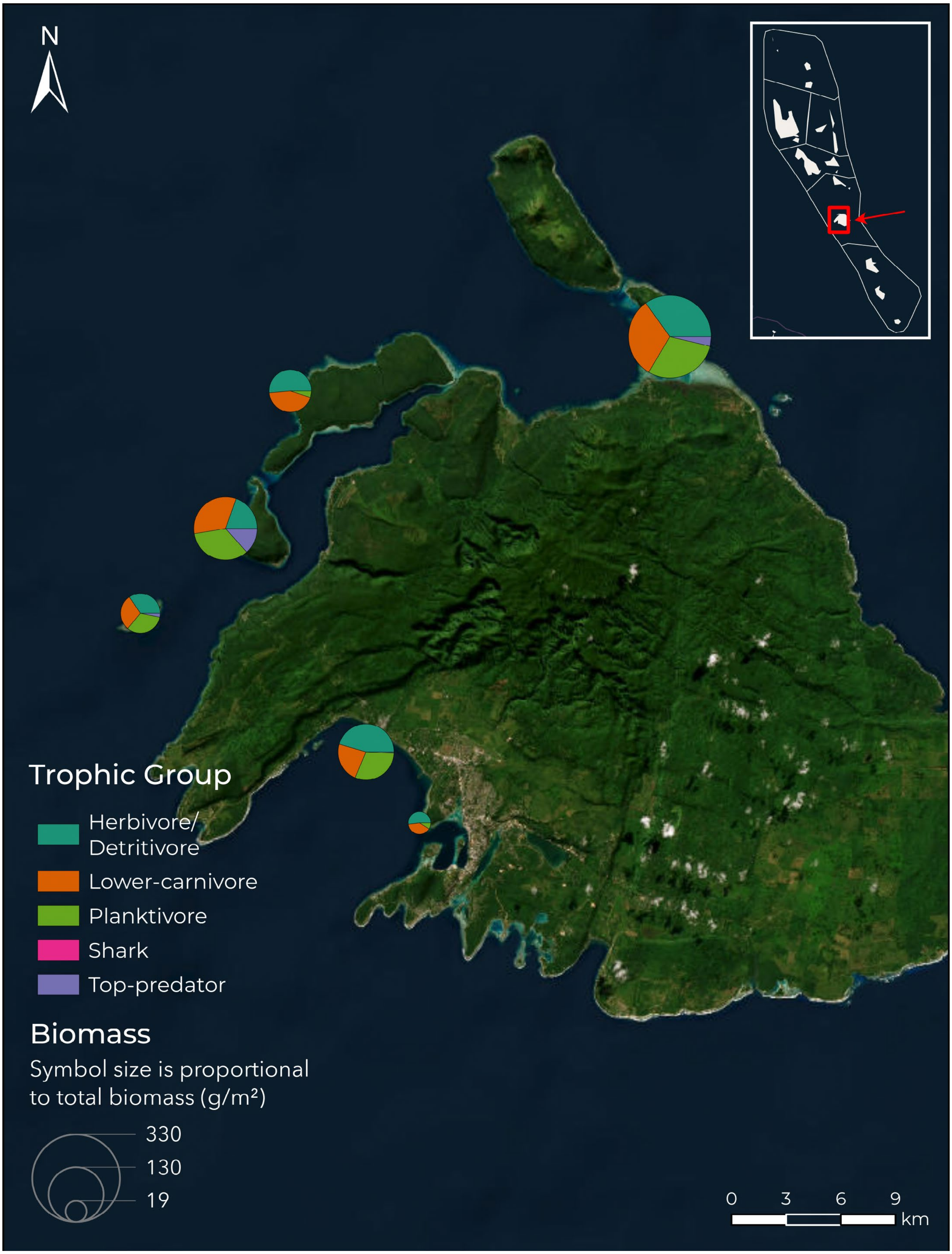
**MAP 49**: *Total fish biomass by trophic group for Aneityum Island.*



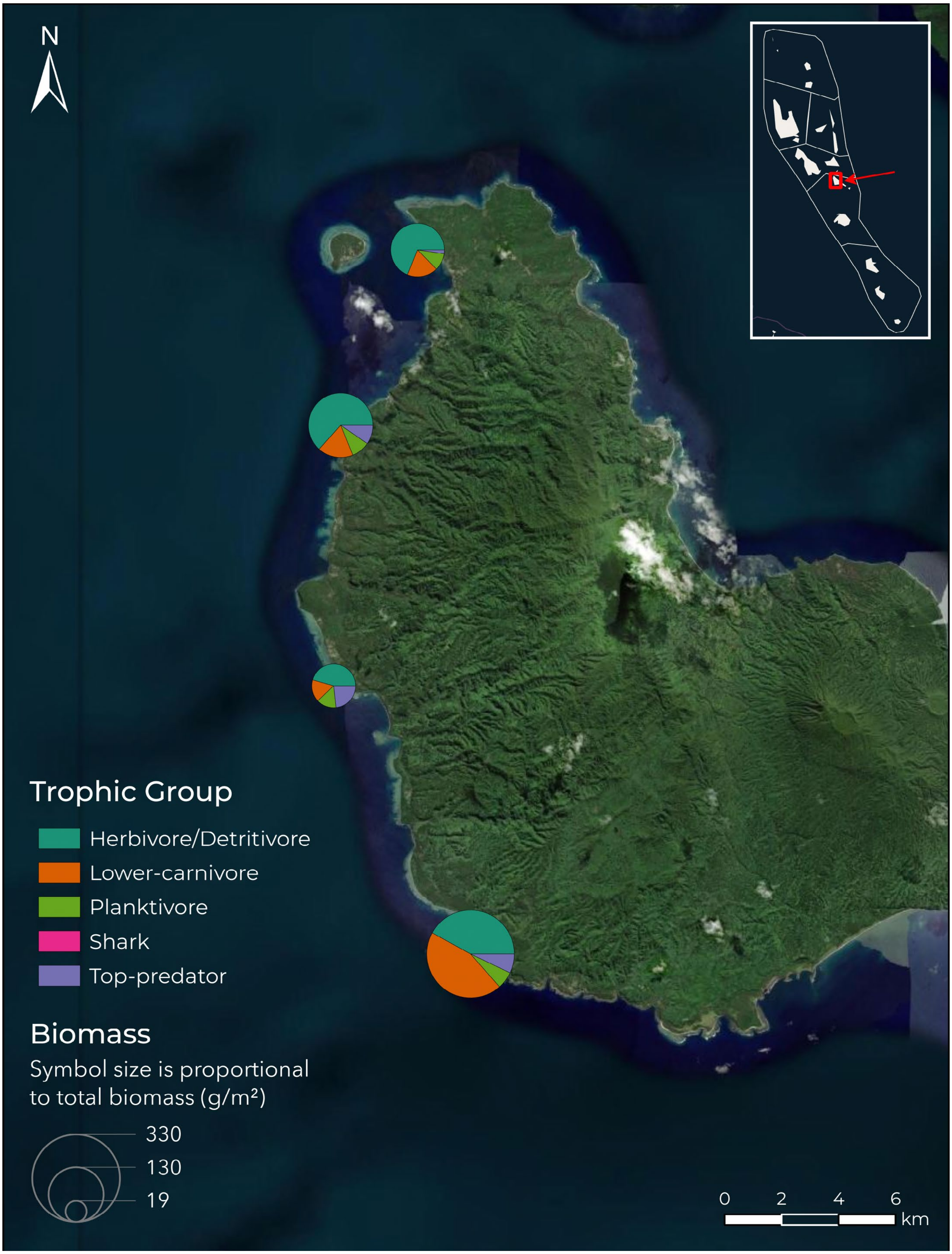
**MAP 50**: *Total fish biomass by trophic group for Cook's Reef & Emae Island.*



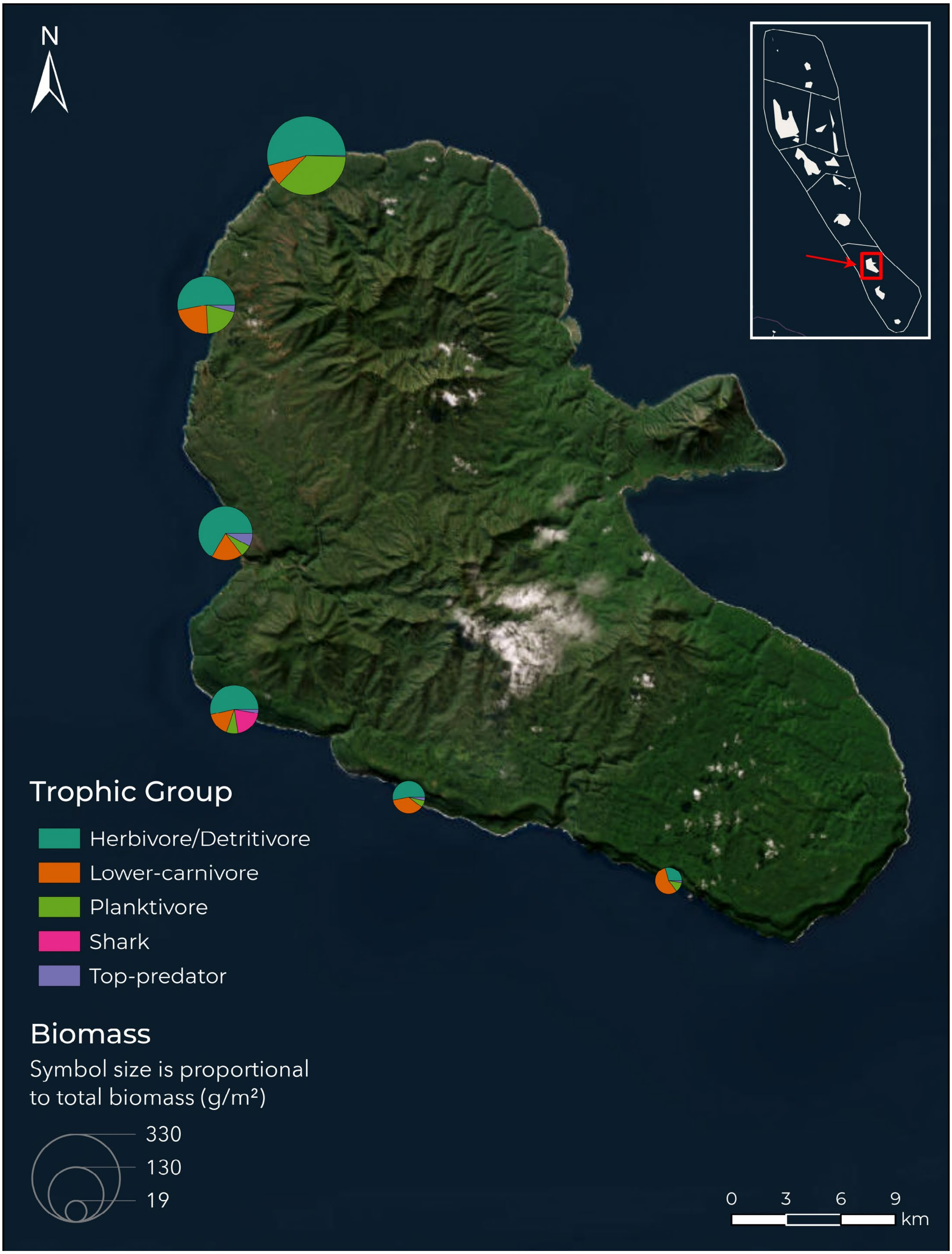
**MAP 51**: *Total fish biomass by trophic group for Efate Island.*



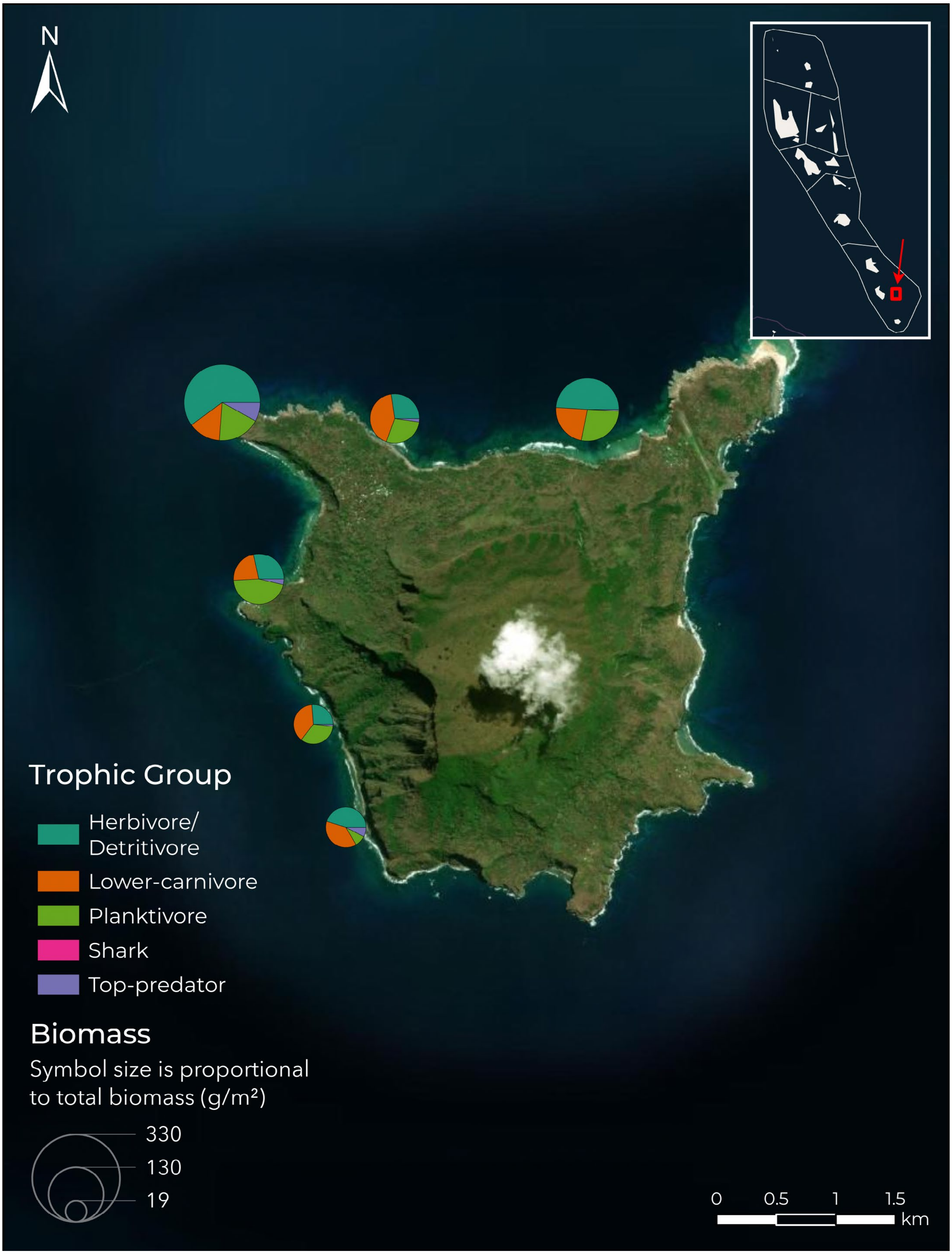
**MAP 52**: *Total fish biomass by trophic group for Epi Island.*



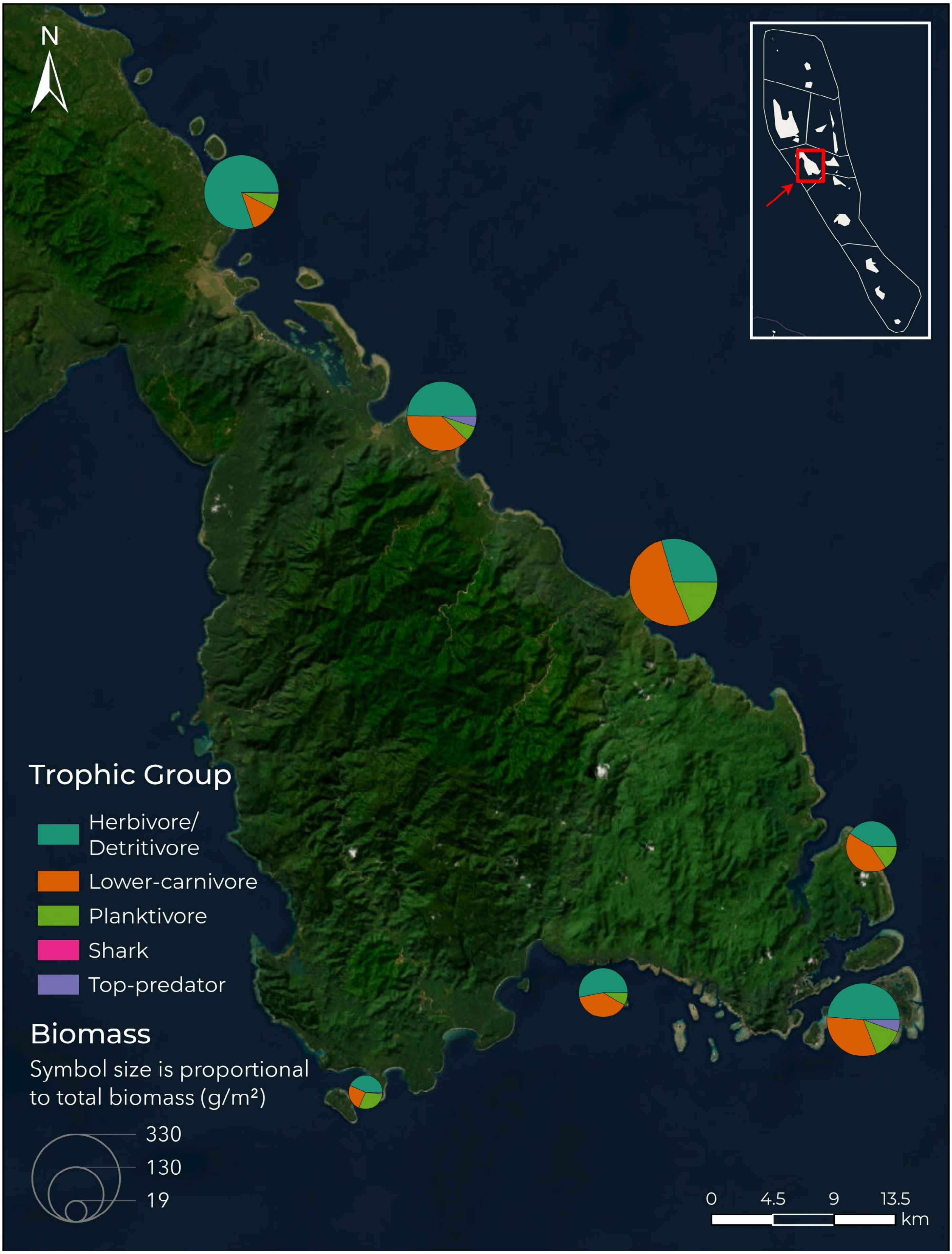
**MAP 53**: *Total fish biomass by trophic group for Erromango Island.*



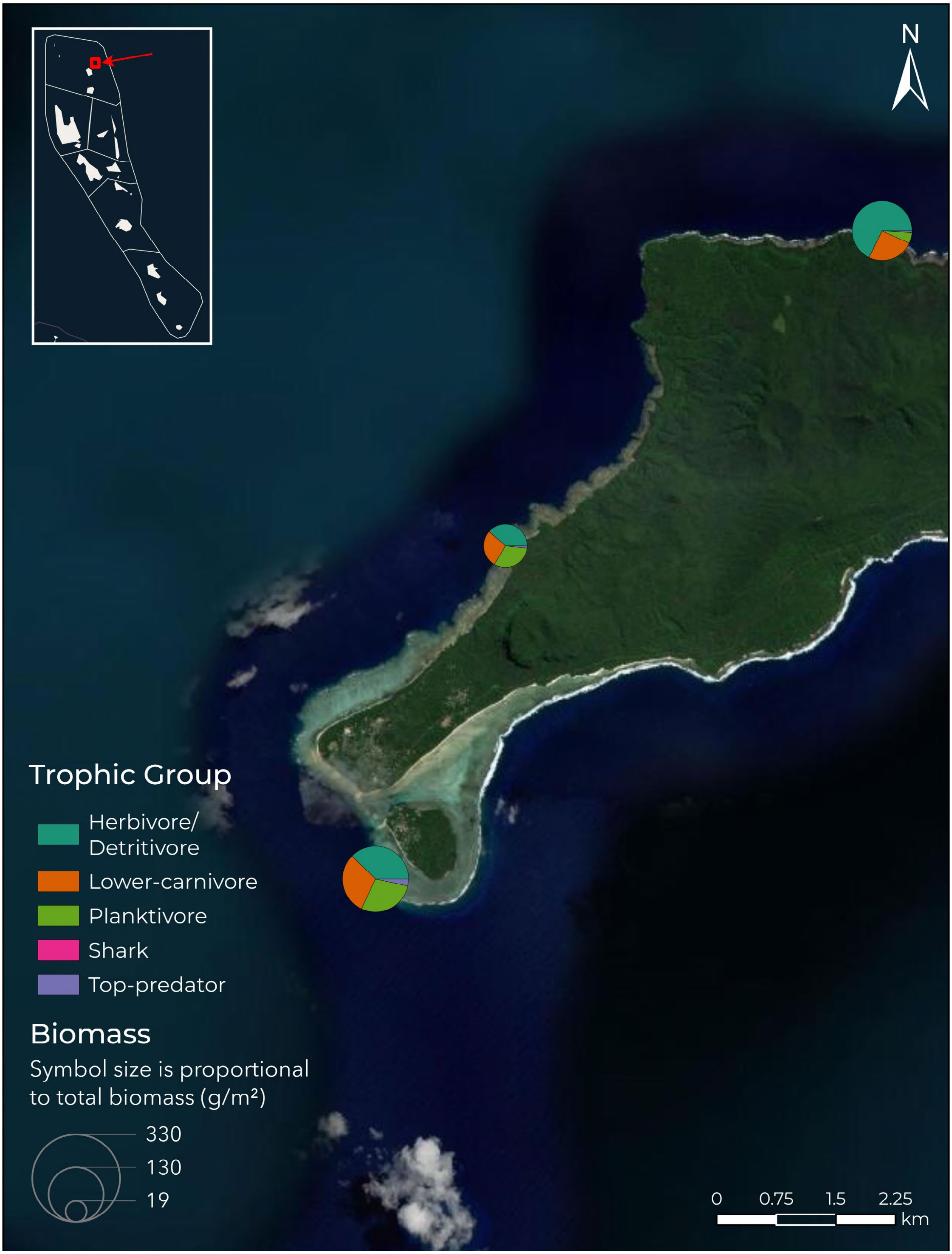
**MAP 54**: *Total fish biomass by trophic group for Futuna Island.*



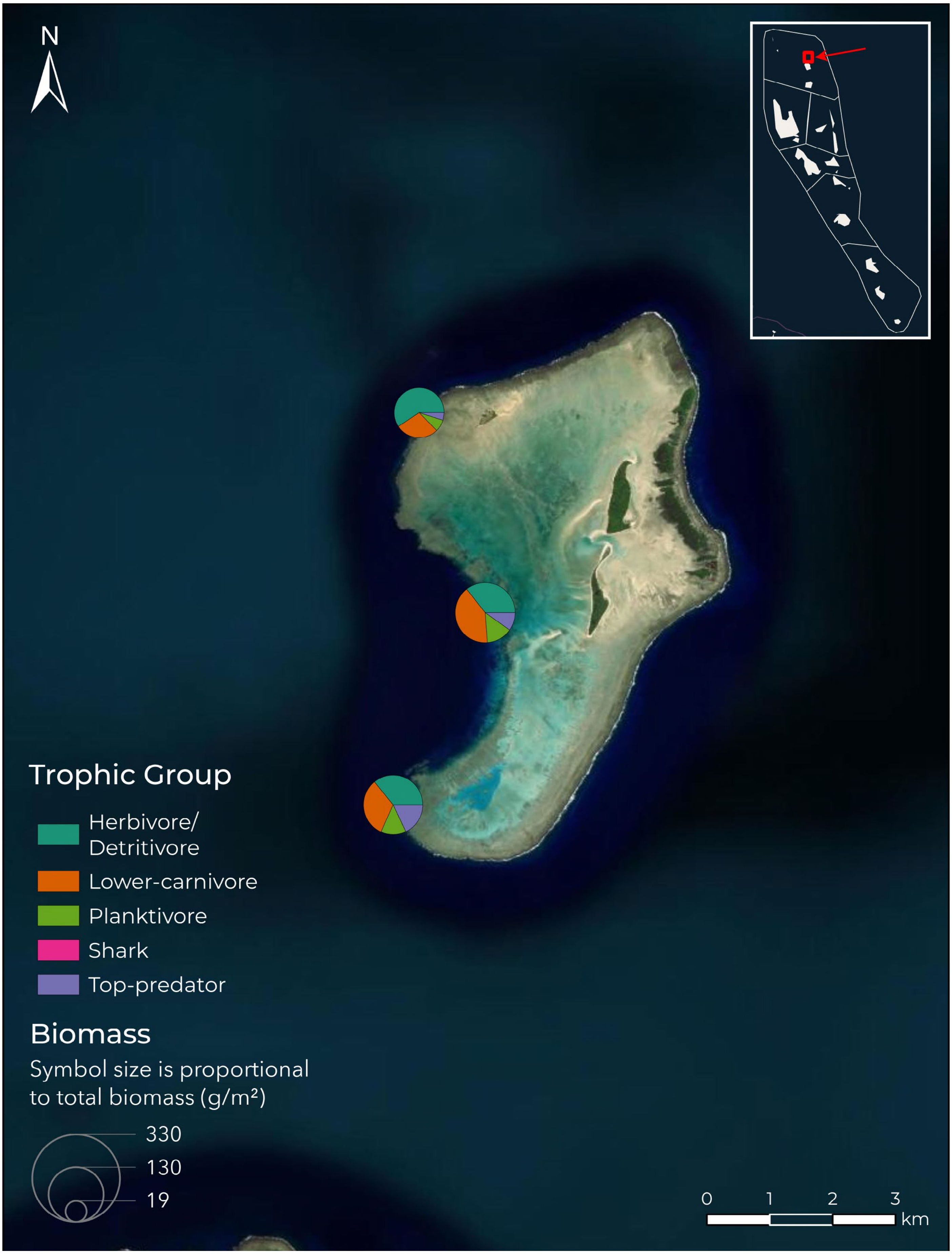
**MAP 55**: *Total fish biomass by trophic group for Malekula Island.*



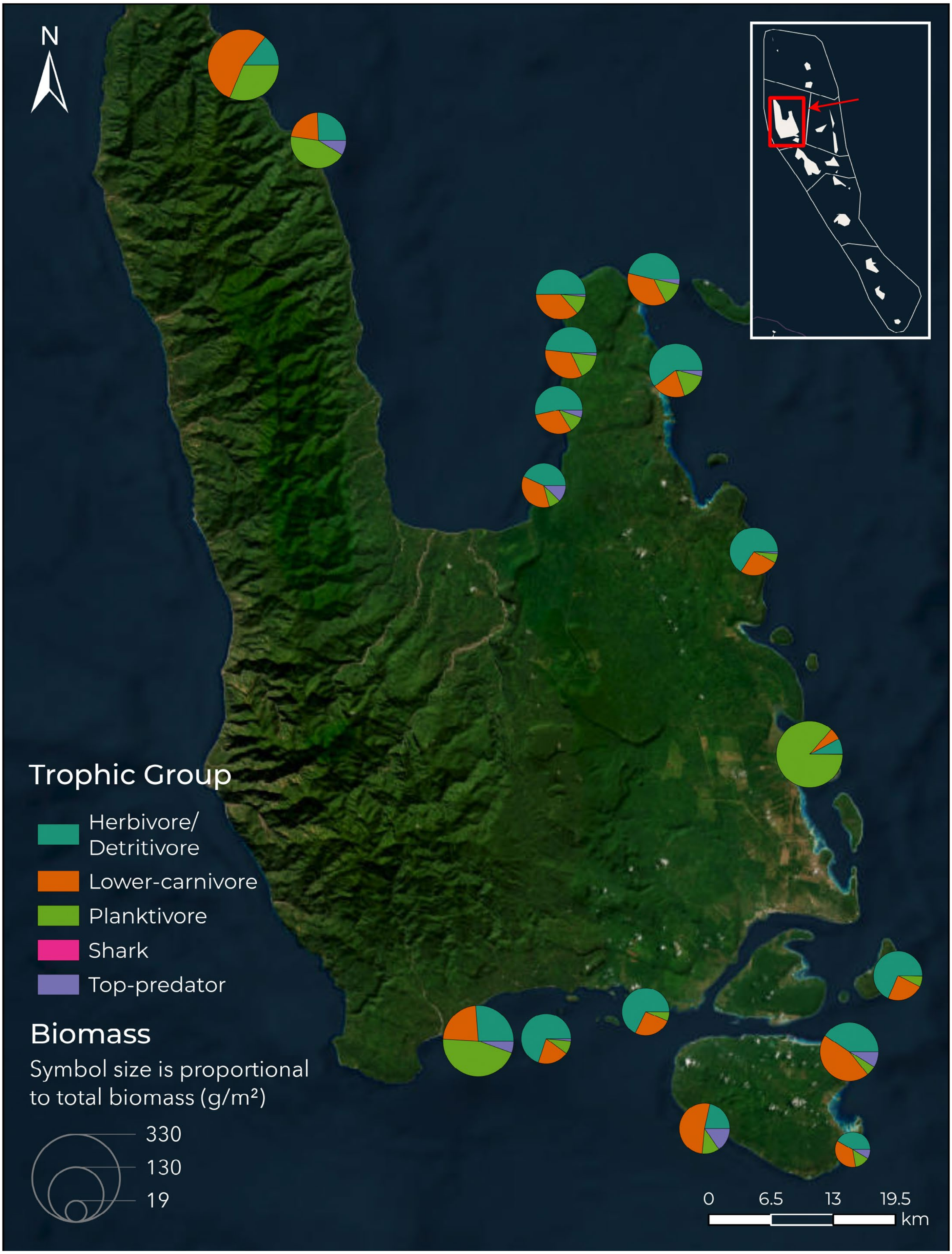
**MAP 56**: *Total fish biomass by trophic group for Mota Lava Island.*



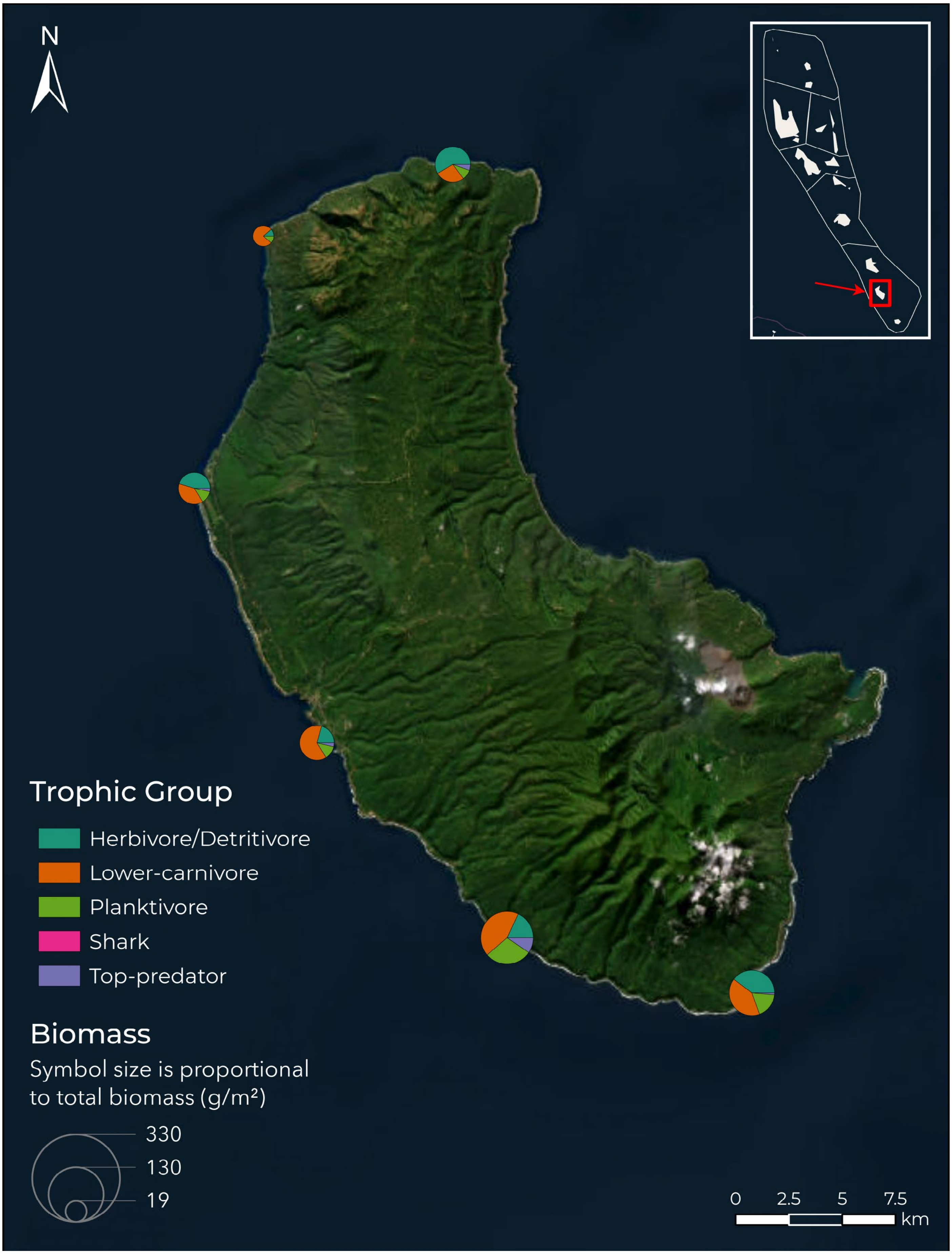
**MAP 57**: *Total fish biomass by trophic group for Rowa Islands.*



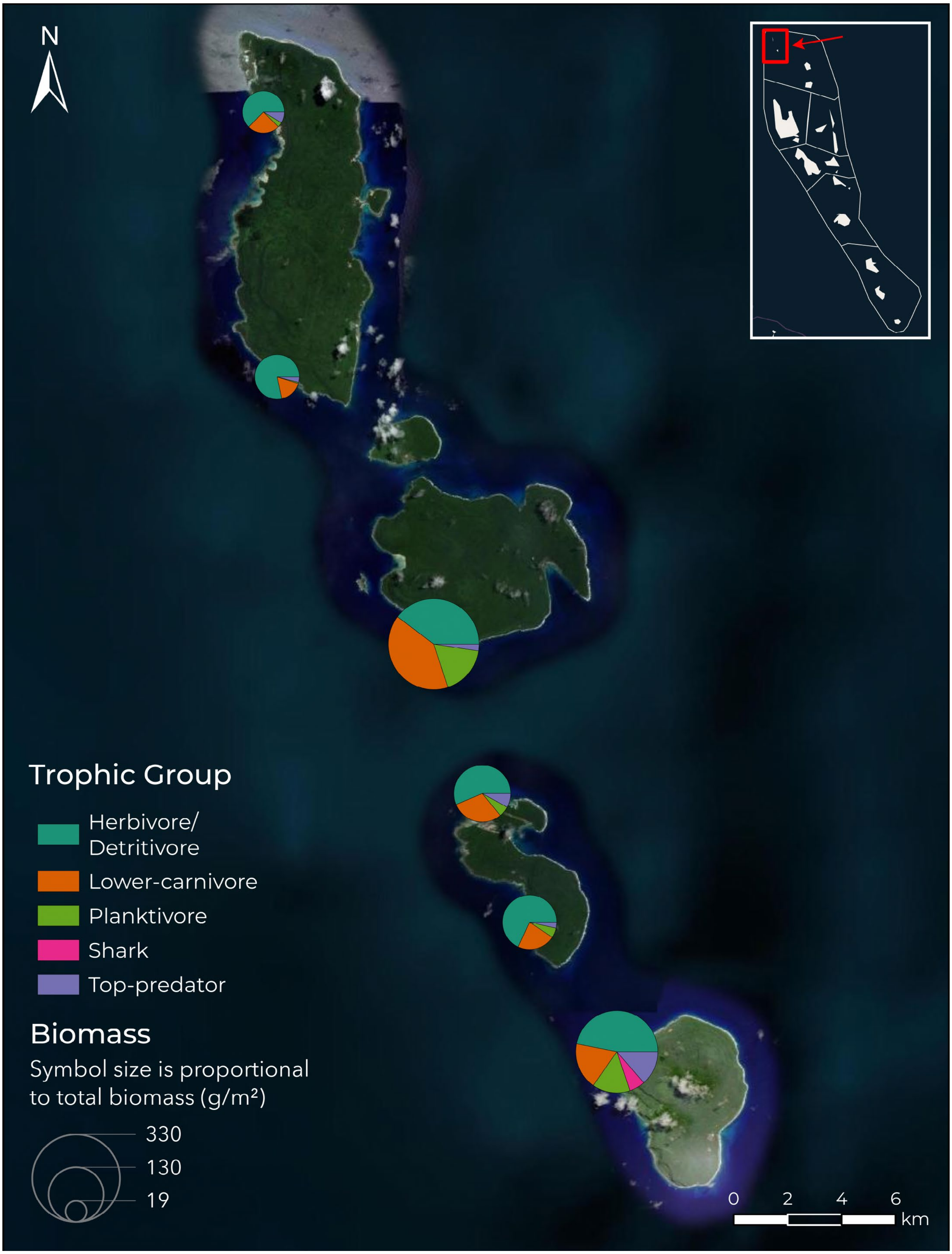
**MAP 58**: *Total fish biomass by trophic group for Santo & Malo Islands.*



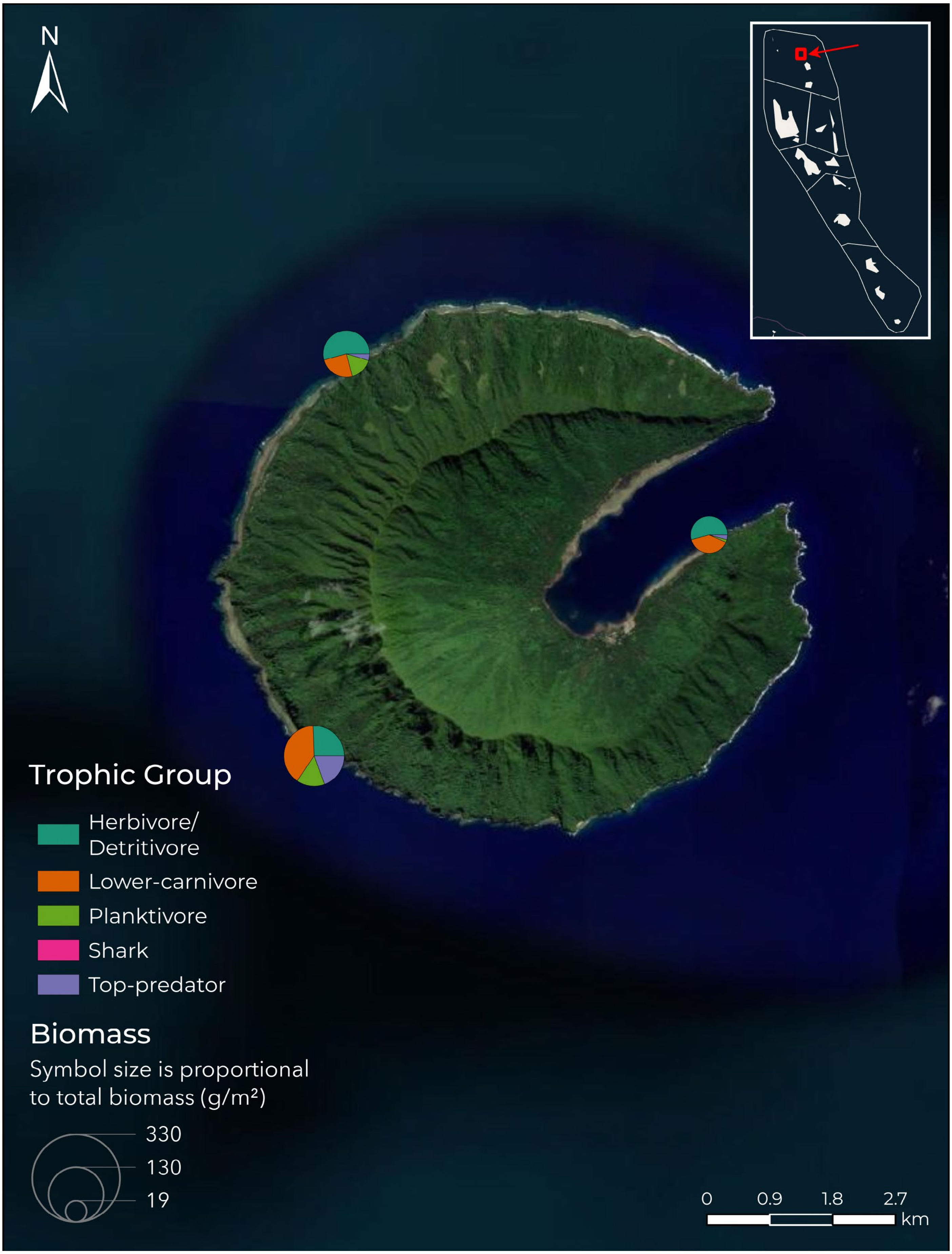
**MAP 59**: *Total fish biomass by trophic group for Tanna Island.*



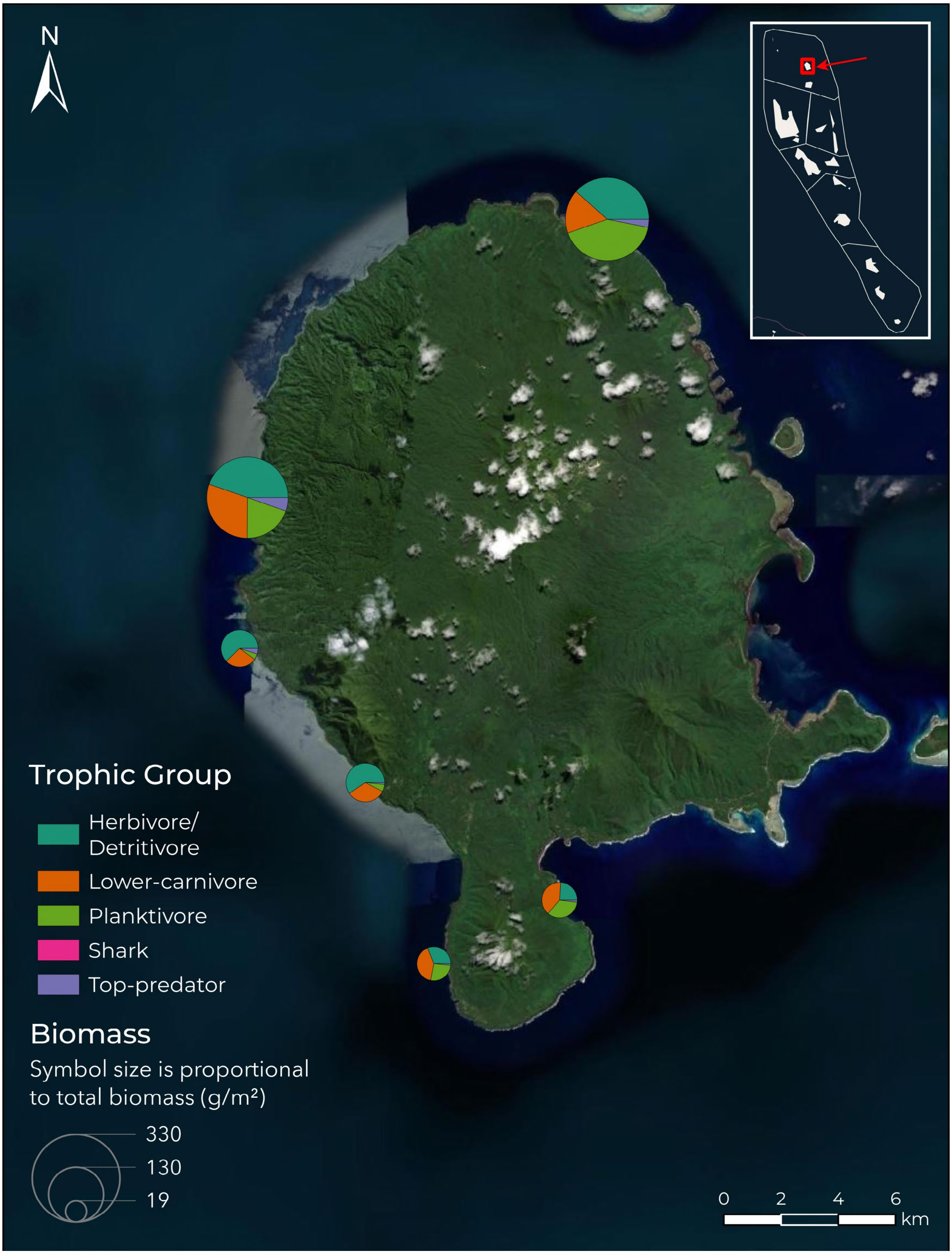
**MAP 60**: *Total fish biomass by trophic group for Torres Islands.*



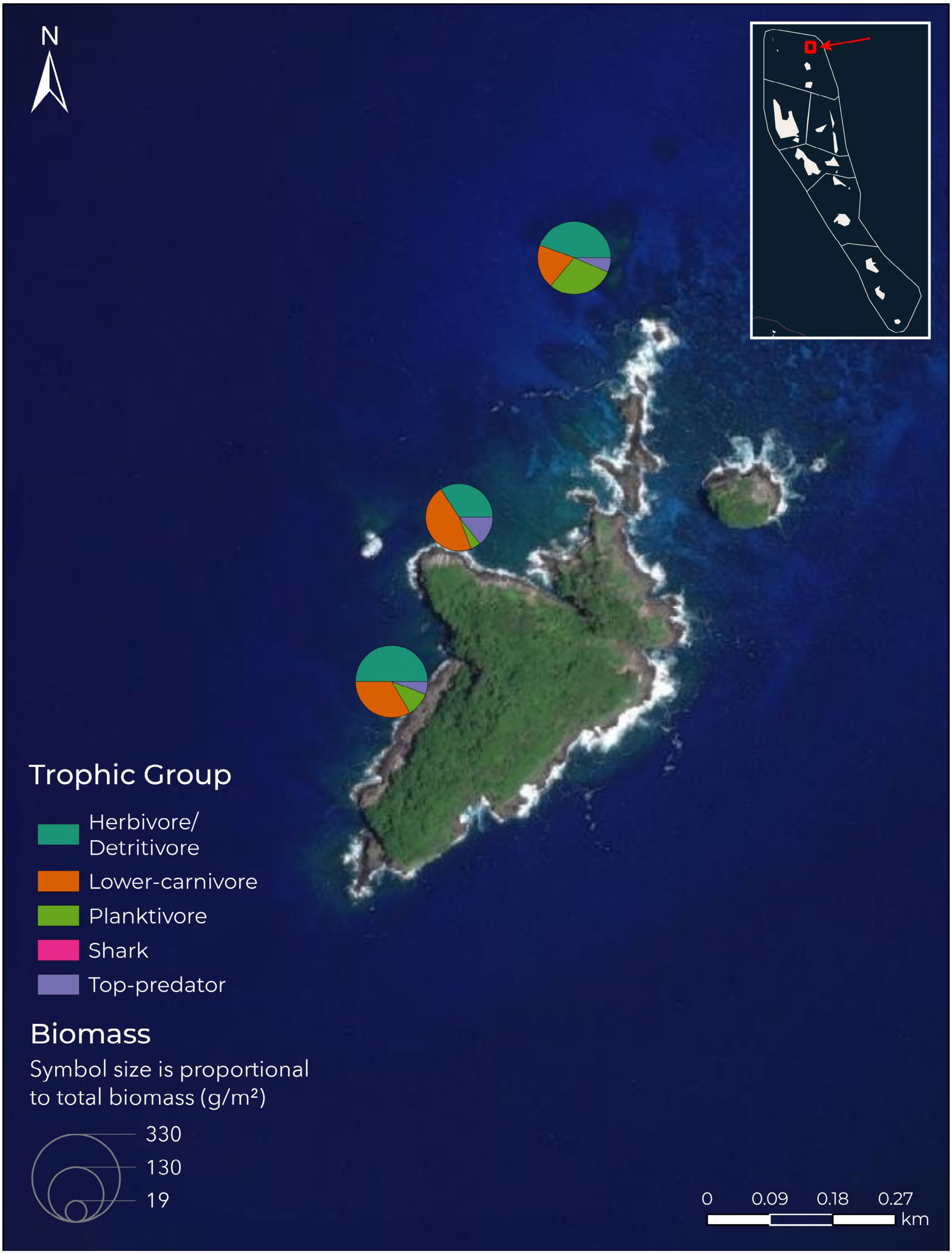
**MAP 61**: *Total fish biomass by trophic group for Ureparapara Island.*



**MAP 62**: *Total fish biomass by trophic group for Vanua Lava Island.*



**MAP 63**: *Total fish biomass by trophic group for Vot Tande Island.*



## Appendix 3

# SITE METADATA

**TABLE 3**:
*Site metadata for all sites surveyed. Codes for "Data Collected" are as follows: B=benthic photoquadrats, F=fish, M=mosaic, I=invertebrates, A=algae collected, T=temperature logger installed.*

| ISLAND | STATION ID | LATITUDE (DD) | LONGITUDE (DD) | DATA COLLECTED |
|---|---|---|---|---|
| Ambae | AMB_079 | -15.31552 | 167.81712 | B, F, M, I, T |
| Ambae | AMB_080 | -15.45503 | 167.67961 | B, F, M, I, A |
| Ambae | AMB_081 | -15.28663 | 167.90154 | B, F, M, I, A |
| Ambae | AMB_082 | -15.40681 | 167.69121 | B, F, M, I, A |
| Ambae | AMB_083 | -15.29455 | 167.99356 | B, F, M, I |
| Ambae | AMB_084 | -15.37522 | 167.72751 | B, F, M, I, A |
| Ambrym | AMR_097 | -16.10082 | 168.13263 | B, F, M, I, A |
| Ambrym | AMR_098 | -16.36162 | 168.19914 | B, F, M, I, A |
| Ambrym | AMR_099 | -16.16879 | 168.08115 | B, F, M, I, A, T |
| Ambrym | AMR_100 | -16.33640 | 168.03381 | B, F, M, I, A, T |
| Ambrym | AMR_101 | -16.19392 | 168.04695 | B, F, M, I, A |
| Ambrym | AMR_102 | -16.27468 | 167.94514 | B, F, M, I, A |
| Aneityum | ANE_001 | -20.25389 | 169.75871 | B, F, M, I, A |
| Aneityum | ANE_003 | -20.21625 | 169.73950 | B, F, M, I, A |
| Aneityum | ANE_004 | -20.14233 | 169.75154 | B, F, M, I, A |
| Aneityum | ANE_005 | -20.12889 | 169.79366 | B, F, M, I, T |
| Aneityum | ANE_006 | -20.12205 | 169.84030 | B, F, M, I, A |
| Cook's Reef | COO_111 | -17.04436 | 168.26042 | B, F, M, I, A |
| Cook's Reef | COO_113 | -17.04716 | 168.28154 | B, F, M, I, A |
| Efate | EFA_031 | -17.53131 | 168.22607 | B, F, M, I, A, T |
| Efate | EFA_032 | -17.50585 | 168.41312 | B, F, M, I, A |
| Efate | EFA_033 | -17.63590 | 168.15221 | B, F, M, I |
| Efate | EFA_034 | -17.59597 | 168.19414 | B, F, M, I, A |
| Efate | EFA_035 | -17.73426 | 168.28973 | B, F, M, I, A, T |
| Efate | EFA_036 | -17.70098 | 168.26338 | B, F, M, I, A |
| Emae | EMA_112 | -17.06962 | 168.33475 | B, F, M, I, A |
| Emae | EMA_114 | -17.03290 | 168.38795 | B, F, M, I, A |
| Epi | EPI_025 | -16.79830 | 168.17284 | B, F, M, I, A, T |
| Epi | EPI_026 | -16.63851 | 168.13188 | B, F, M, I, A |
| Epi | EPI_027 | -16.71730 | 168.12967 | B, F, M, I, A |
| Epi | EPI_029 | -16.58554 | 168.15613 | B, F, M, I, T |
| Erromango | ERR_019 | -18.88696 | 169.01158 | B, F, M, I, A |
| Erromango | ERR_020 | -18.80485 | 169.00723 | B, F, M, I, A |
| Erromango | ERR_021 | -18.92794 | 169.09758 | B, F, M, I, A |
| Erromango | ERR_022 | -18.69827 | 168.99777 | B, F, M, I, A, T |
| Erromango | ERR_023 | -18.96689 | 169.22556 | B, F, M, I, A, T |
| Erromango | ERR_024 | -18.62841 | 169.04713 | B, F, M, I, A |
| Futuna | FUT_007 | -19.52501 | 170.19905 | B, F, M, I, A |

| ISLAND | STATION ID | LATITUDE (DD) | LONGITUDE (DD) | DATA COLLECTED |
|---|---|---|---|---|
| Futuna | FUT_008 | -19.51247 | 170.19629 | B, F, M, I, A |
| Futuna | FUT_009 | -19.53532 | 170.20316 | B, F, M, I, A, T |
| Futuna | FUT_010 | -19.51361 | 170.20929 | B, F, M, I, A, T |
| Futuna | FUT_011 | -19.54263 | 170.20561 | B, F, M, I |
| Futuna | FUT_012 | -19.51297 | 170.22380 | B, F, M, I, A |
| Maewo | MAE_085 | -14.92912 | 168.04401 | B, F, M, I, A |
| Maewo | MAE_086 | -15.37919 | 168.12552 | B, F, M, I |
| Maewo | MAE_087 | -15.03190 | 168.06668 | B, F, M, I, A, T |
| Maewo | MAE_088 | -15.28160 | 168.11023 | B, F, M, I, A, T |
| Maewo | MAE_089 | -15.12705 | 168.08778 | B, F, M, I, A |
| Maewo | MAE_090 | -15.21306 | 168.10695 | B, F, M, I |
| Malo | MAO_037 | -15.71024 | 167.11588 | B, F, M, I, A |
| Malo | MAO_039 | -15.72918 | 167.25470 | B, F, M, I, A |
| Malo | MAO_041 | -15.64100 | 167.25153 | B, F, M, I, A |
| Malekula | MLK_103 | -16.15649 | 167.54021 | B, F, M, I, A, T |
| Malekula | MLK_104 | -16.01468 | 167.40826 | B, F, M, I, A |
| Malekula | MLK_105 | -16.42865 | 167.82321 | B, F, M, I |
| Malekula | MLK_106 | -16.26159 | 167.69284 | B, F, M, I, A |
| Malekula | MLK_108 | -16.53801 | 167.81790 | B, F, M, I, A, T |
| Malekula | MLK_109 | -16.58368 | 167.49002 | B, F, M, I, A |
| Malekula | MLK_110 | -16.52096 | 167.64655 | B, F, M, I, A |
| Mota Lava | MOT_056 | -13.64950 | 167.68158 | B, F, M, I, A, T |
| Mota Lava | MOT_058 | -13.68410 | 167.63902 | B, F, M, I, A |
| Mota Lava | MOT_060 | -13.72071 | 167.62434 | B, F, M, I, A |
| Pentecost | PEN_091 | -15.55314 | 168.13087 | F, I |
| Pentecost | PEN_092 | -15.46698 | 168.13860 | B, F, M, I, A |
| Pentecost | PEN_093 | -15.76452 | 168.13939 | B, F, M, I, A, T |
| Pentecost | PEN_094 | -15.64536 | 168.10783 | B, F, M, I, A, T |
| Pentecost | PEN_095 | -15.97858 | 168.18127 | B, F, M, I |
| Pentecost | PEN_096 | -15.84973 | 168.16463 | B, F, M, I |
| Rowa Islands | ROW_055 | -13.59856 | 167.49652 | B, F, M, I, A |
| Rowa Islands | ROW_057 | -13.62636 | 167.50595 | B, F, M, I, A, T |
| Rowa Islands | ROW_059 | -13.65302 | 167.49280 | B, F, M, I, A |
| Santo | SAN_038 | -15.63145 | 166.90389 | B, F, I, A |
| Santo | SAN_040 | -15.62933 | 166.94418 | B, F, M, I, A, T |
| Santo | SAN_042 | -15.60505 | 167.06068 | B, F, M, I, A |
| Santo | SAN_043 | -15.57259 | 167.29716 | B, F, M, I, A |
| Santo | SAN_044 | -14.95652 | 166.98112 | B, F, M, I, A |
| Santo | SAN_045 | -15.37247 | 167.21428 | B, F, M, I, A |
| Santo | SAN_046 | -14.94266 | 167.06821 | B, F, M, I, A |
| Santo | SAN_047 | -15.18915 | 167.16205 | B, F, M, I, A, T |
| Santo | SAN_048 | -15.02510 | 167.08905 | B, F, M, I, A |
| Santo | SAN_073 | -15.00138 | 166.99065 | B, F, M, I, A |
| Santo | SAN_074 | -14.74850 | 166.68370 | B, F, M, I, A, T |
| Santo | SAN_075 | -15.12935 | 166.96513 | B, F, M, I, A |
| Santo | SAN_076 | -14.81676 | 166.75403 | B, F, M, I, A |
| Santo | SAN_077 | -15.04732 | 166.97920 | B, F, M, I, A, T |
| Tanna | TAN_013 | -19.31838 | 169.32642 | B, F, M, I, A, T |
| Tanna | TAN_014 | -19.64753 | 169.45239 | B, F, M, I, A |
| Tanna | TAN_015 | -19.34689 | 169.24661 | B, F, M, I, A |
| Tanna | TAN_016 | -19.62572 | 169.34926 | B, F, M, I, A, T |
| Tanna | TAN_017 | -19.44714 | 169.21753 | B, F, M, I, A |
| Tanna | TAN_018 | -19.54828 | 169.26918 | B, F, M, I, A |

| ISLAND | STATION ID | LATITUDE (DD) | LONGITUDE (DD) | DATA COLLECTED |
|---|---|---|---|---|
| Torres Islands | TOR_067 | -13.09904 | 166.55348 | B, F, M, I, A |
| Torres Islands | TOR_068 | -13.40370 | 166.67114 | B, F, M, I, A |
| Torres Islands | TOR_069 | -13.18499 | 166.55803 | B, F, M, I, A |
| Torres Islands | TOR_070 | -13.36181 | 166.64211 | B, F, M, I, A |
| Torres Islands | TOR_071 | -13.27167 | 166.61018 | B, F, M, I, A, T |
| Torres Islands | TOR_072 | -13.32005 | 166.62634 | B, F, M, I, A |
| Ureparapara | URE_049 | -13.50856 | 167.30650 | B, F, M, I, A |
| Ureparapara | URE_051 | -13.55883 | 167.30235 | B, F, M, I, A, T |
| Ureparapara | URE_053 | -13.53117 | 167.35313 | B, F, M, I, A |
| Vanua Lava | VAN_061 | -13.92879 | 167.48003 | B, F, M, I, A |
| Vanua Lava | VAN_062 | -13.72112 | 167.49500 | B, F, M, I, A, T |
| Vanua Lava | VAN_063 | -13.85206 | 167.37961 | B, F, M, I, A |
| Vanua Lava | VAN_064 | -13.80601 | 167.38208 | B, F, M, I, A |
| Vanua Lava | VAN_065 | -13.94814 | 167.44057 | B, F, M, I, A, T |
| Vanua Lava | VAN_066 | -13.89290 | 167.41907 | B, F, M, I, A |
| Vot Tande | VOT_050 | -13.25745 | 167.64160 | B, F, M, I, A, T |
| Vot Tande | VOT_052 | -13.25420 | 167.64308 | B, F, M, I, A |
| Vot Tande | VOT_054 | -13.25951 | 167.64073 | B, F, M, I, A |

Appendix 4

# BELT TRANSECT SUMMARY DATA

**TABLE 4:**
*Full list of species surveyed during the belt transect surveys. DACOR (Dominant, Abundant, Common, Occasional, Rare) classifications are as follows:*

*D = observed at ≥ 75% of sites*
*A = observed at 50-74% of sites*
*C = observed at 25-49% of sites*
*O = observed at 10-24% of sites*
*R = observed at <10% of sites*

| Family | Species | Mean density (individuals m^-2) | Mean biomass (g m^-2) | Number of sites | DACOR |
|---|---|---|---|---|---|
| Acanthuridae | *Acanthurus albipectoralis* | 0.0006422018349 | 0.1415101641 | 3 | R |
| | *Acanthurus blochii* | 0.002706422018 | 1.639545016 | 41 | C |
| | *Acanthurus dussumieri* | 0.0004587155963 | 0.2704301322 | 9 | R |
| | *Acanthurus guttatus* | 0.00003058103976 | 0.01315913665 | 1 | R |
| | *Acanthurus leucopareius* | 0.00003058103976 | 0.03990532998 | 1 | R |
| | *Acanthurus lineatus* | 0.01256225426 | 3.004653366 | 47 | C |
| | *Acanthurus maculiceps* | 0.0001681957187 | 0.06047908404 | 3 | R |
| | *Acanthurus mata* | 0.00003058103976 | 0.0145141938 | 1 | R |
| | *Acanthurus nigricauda* | 0.002691131498 | 0.8672083306 | 44 | C |
| | *Acanthurus nigrofuscus* | 0.09340541721 | 3.500335153 | 107 | D |
| | *Acanthurus nigricans* | 0.004150283967 | 0.4036828589 | 22 | O |
| | *Acanthurus olivaceus* | 0.004801223242 | 1.067066533 | 15 | O |
| | *Acanthurus pyroferus* | 0.01016819572 | 1.280053221 | 73 | A |
| | *Acanthurus thompsoni* | 0.001432940149 | 0.1018842635 | 9 | R |
| | *Acanthurus triostegus* | 0.00003058103976 | 0.002750369078 | 1 | R |
| | *Acanthurus xanthopterus* | 0.00004368719965 | 0.01696686144 | 2 | R |
| | *Ctenochaetus binotatus* | 0.04417868065 | 2.498270951 | 92 | D |
| | *Ctenochaetus cyanocheilus* | 0.01346876365 | 1.036316346 | 66 | A |
| | *Ctenochaetus striatus* | 0.06049584972 | 8.222407021 | 97 | D |
| | *Ctenochaetus tominiensis* | 0.0004587155963 | 0.0421955057 | 4 | R |
| | *Naso annulatus* | 0.00007645259939 | 0.02542326421 | 3 | R |
| | *Naso brachycentron* | 0.00006116207951 | 0.08221823205 | 3 | R |
| | *Naso brevirostris* | *0.0006422018349* | *0.2150457416* | *11* | *O* |

| Family | Species | Mean density (individuals m^-2) | Mean biomass (g m^-2) | Number of sites | DACOR |
|---|---|---|---|---|---|
| **Acanthuridae (continued)** | *Naso caesius* | 0.000122324159 | 0.131924301 | 3 | R |
| | *Naso hexacanthus* | 0.006605504587 | 2.644486231 | 16 | O |
| | *Naso lituratus* | 0.01482743556 | 4.799155121 | 89 | D |
| | *Naso tonganus* | 0.0003058103976 | 0.4897484999 | 12 | O |
| | *Naso unicornis* | 0.0006858890345 | 0.5777826524 | 22 | O |
| | *Naso vlamingii* | 0.0006880733945 | 0.3353487317 | 15 | O |
| | *Paracanthurus hepatus* | 0.0008256880734 | 0.08773081498 | 2 | R |
| | *Zebrasoma scopas* | 0.02083224115 | 1.636573637 | 59 | A |
| | *Zebrasoma velifer* | 0.002199650502 | 0.6807446142 | 42 | C |
| **Aetobatidae** | *Aetobatus narinari* | 0.00001529051988 | 0.2126442809 | 1 | R |
| **Anthiadidae** | *Serranocirrhitus latus* | 0.002415902141 | 0.01082542068 | 8 | R |
| **Apogonidae** | *Cheilodipterus artus* | *0.000122324159* | *0.01293501321* | *3* | *R* |
| | *Cheilodipterus isostigmus* | *0.0003975535168* | *0.0009350840236* | *2* | *R* |
| | *Cheilodipterus macrodon* | *0.0004740061162* | *0.05547184512* | *11* | *O* |
| | *Ostorhinchus angustatus* | *0.00003058103976* | *0.0007378767776* | *1* | *R* |
| | *Ostorhinchus nigrofasciatus* | *0.0002140672783* | *0.002227126502* | *4* | *R* |
| | *Pristiapogon kallopterus* | *0.0001834862385* | *0.004264682402* | *4* | *R* |
| **Aulostomidae** | *Aulostomus chinensis* | 0.0001834862385 | 0.01132918322 | 8 | R |
| **Balistidae** | *Balistoides conspicillum* | 0.0003363914373 | 0.2318381552 | 12 | O |
| | *Balistapus undulatus* | 0.009824159021 | 0.9914163795 | 87 | D |
| | *Balistoides viridescens* | 0.0005810397554 | 0.8491852473 | 26 | O |
| | *Melichthys niger* | 0.00001529051988 | 0.00550958384 | 1 | R |
| | *Melichthys vidua* | 0.004159021407 | 1.381973226 | 54 | C |
| | *Odonus niger* | 0.004113149847 | 0.2112576369 | 6 | R |
| | *Pseudobalistes flavimarginatus* | 0.00004587155963 | 0.05064913047 | 3 | R |
| | *Rhinecanthus aculeatus* | 0.00003058103976 | 0.00168155639 | 1 | R |
| | *Sufflamen bursa* | 0.003639143731 | 0.4064787717 | 49 | C |
| | *Sufflamen chrysopterum* | 0.0024617737 | 0.3036388208 | 28 | C |
| | *Xanthichthys auromarginatus* | 0.00009174311927 | 0.01443477062 | 1 | R |
| **Blenniidae** | *Cirripectes imitator* | 0.0008868501529 | 0.01275480821 | 9 | R |
| | *Cirripectes polyzona* | 0.000244648318 | 0.004168629754 | 2 | R |
| | *Cirripectes stigmaticus* | 0.004189602446 | 0.05428477419 | 37 | C |
| | *Crossosalarias macrospilus* | 0.0003363914373 | 0.005731865912 | 8 | R |
| | *Ecsenius bicolor* | 0.0007339449541 | 0.00268678698 | 16 | O |
| | *Ecsenius fourmanoiri* | 0.00009174311927 | 0.0001513847185 | 2 | R |
| | *Meiacanthus atrodorsalis* | 0.009517256444 | 0.02916638325 | 80 | A |
| | *Meiacanthus oualanensis* | 0.00006116207951 | 0.000032563638 | 1 | R |
| | *Plagiotremus laudandus* | 0.001009174312 | 0.002345835647 | 21 | O |
| | *Plagiotremus rhinorhynchos* | 0.0006116207951 | 0.002840889522 | 10 | R |
| | *Plagiotremus tapeinosoma* | 0.002140672783 | 0.004627149673 | 18 | O |

| Family | Species | Mean density (individuals m^-2) | Mean biomass (g m^-2) | Number of sites | DACOR |
|---|---|---|---|---|---|
| **Caesionidae** | *Caesio caerulaurea* | 0.02990825688 | 4.982093306 | 25 | O |
| | *Caesio cuning* | 0.0005963302752 | 0.2236153402 | 3 | R |
| | *Caesio lunaris* | 0.005764525994 | 1.736378308 | 8 | R |
| | *Caesio teres* | 0.02377675841 | 2.421192022 | 20 | O |
| | *Caesio xanthonota* | 0.0009480122324 | 0.0108663603 | 1 | R |
| | *Pterocaesio digramma* | 0.0004892966361 | 0.09975892363 | 2 | R |
| | *Pterocaesio marri* | 0.01616207951 | 1.146748002 | 10 | R |
| | *Pterocaesio pisang* | 0.003577981651 | 0.2495657424 | 4 | R |
| | *Pterocaesio tile* | 0.006788990826 | 1.265690423 | 11 | O |
| | *Pterocaesio trilineata* | 0.02003058104 | 1.150449967 | 11 | O |
| **Carangidae** | *Caranx melampygus* | 0.0001791175186 | 0.1499101781 | 9 | R |
| | *Carangoides oblongus* | 0.00001529051988 | 0.006421726844 | 1 | R |
| | *Craterognathus plagiotaenia* | 0.0001529051988 | 0.04616161033 | 5 | R |
| | *Caranx sexfasciatus* | 0.00002621231979 | 0.02780483752 | 1 | R |
| | *Decapterus macarellus* | 0.00006116207951 | 0.01006238762 | 1 | R |
| | *Elagatis bipinnulata* | 0.0004128440367 | 0.1729980242 | 4 | R |
| | *Scomberoides lysan* | 0.00001529051988 | 0.004397396316 | 1 | R |
| | *Trachinotus blochii* | 0.00001529051988 | 0.01775837495 | 1 | R |
| **Carcharhinidae** | *Triaenodon obesus* | 0.00003058103976 | 0.3485499181 | 2 | R |
| **Chaetodontidae** | *Chaetodon auriga* | 0.0002140672783 | 0.01792384049 | 4 | R |
| | *Chaetodon baronessa* | 0.003822629969 | 0.1134905373 | 27 | O |
| | *Chaetodon citrinellus* | 0.005229357798 | 0.1190092813 | 48 | C |
| | *Chaetodon ephippium* | 0.0002905198777 | 0.04927821651 | 7 | R |
| | *Chaetodon kleinii* | 0.002782874618 | 0.05726529047 | 22 | O |
| | *Chaetodon lineolatus* | 0.00009174311927 | 0.03243004531 | 3 | R |
| | *Chaetodon lunula* | 0.00009174311927 | 0.008301714803 | 2 | R |
| | *Chaetodon lunulatus* | 0.005220620358 | 0.2233436624 | 44 | C |
| | *Chaetodon melannotus* | 0.00003058103976 | 0.003146775481 | 1 | R |
| | *Chaetodon mertensii* | 0.001131498471 | 0.03826418758 | 12 | O |
| | *Chaetodon ornatissimus* | 0.00122324159 | 0.08193447332 | 21 | O |
| | *Chaetodon pelewensis* | 0.0144429882 | 0.3961798683 | 79 | A |
| | *Chaetodon plebeius* | 0.0003058103976 | 0.03233420126 | 2 | R |
| | *Chaetodon punctatofasciatus* | 0.0001834862385 | 0.004419551542 | 2 | R |
| | *Chaetodon rafflesii* | 0.0003582350371 | 0.02057546092 | 9 | R |
| | *Chaetodon reticulatus* | 0.001804281346 | 0.06916932989 | 13 | O |
| | *Chaetodon semeion* | 0.00003058103976 | 0.005921714568 | 1 | R |
| | *Chaetodon speculum* | 0.0003888160769 | 0.03350282563 | 6 | R |
| | *Chaetodon trifascialis* | 0.001559633028 | 0.05740595947 | 18 | O |
| | *Chaetodon ulietensis* | 0.0007339449541 | 0.02806993575 | 9 | R |
| | *Chaetodon unimaculatus* | *0.0003669724771* | *0.02192244795* | *7* | *R* |

| Family | Species | Mean density (individuals m^-2) | Mean biomass (g m^-2) | Number of sites | DACOR |
|---|---|---|---|---|---|
| **Chaetodontidae (continued)** | *Chaetodon vagabundus* | 0.003058103976 | 0.1870194573 | 40 | C |
| | *Forcipiger flavissimus* | 0.003239405854 | 0.1238370409 | 37 | C |
| | *Forcipiger longirostris* | 0.0001529051988 | 0.01579807701 | 3 | R |
| | *Heniochus acuminatus* | 0.00006116207951 | 0.01660268632 | 1 | R |
| | *Heniochus chrysostomus* | 0.0009785932722 | 0.2237415299 | 12 | O |
| | *Heniochus monoceros* | 0.00003058103976 | 0.01602088624 | 1 | R |
| | *Heniochus singularius* | 0.000377894277 | 0.179314901 | 9 | R |
| | *Heniochus varius* | 0.002262996942 | 0.4040949753 | 30 | C |
| **Cirrhitidae** | *Cirrhitichthys falco* | 0.008241590214 | 0.09032528092 | 55 | A |
| | *Cirrhitichthys oxycephalus* | 0.0001834862385 | 0.002337360388 | 4 | R |
| | *Paracirrhites arcatus* | 0.02607252075 | 0.2641749808 | 85 | D |
| | *Paracirrhites forsteri* | 0.003569244211 | 0.146464058 | 48 | C |
| | *Paracirrhites hemistictus* | 0.00001529051988 | 0.008106586035 | 1 | R |
| **Dasyatidae** | *Taeniura lessoni* | *0.00001529051988* | *0.8711822051* | *1* | *R* |
| | *Taeniura lymma* | *0.00003058103976* | *0.08534204077* | *2* | *R* |
| **Diodontidae** | *Diodon hystrix* | 0.00001529051988 | 0.03610938198 | 1 | R |
| **Ephippidae** | *Platax orbicularis* | 0.0001529051988 | 0.3205757589 | 7 | R |
| **Fistularidae** | *Fistularia commersonii* | 0.0001529051988 | 0.09543148282 | 5 | R |
| **Gobiidae** | *Amblyeleotris fasciata* | 0.00003058103976 | 0.000329400878 | 1 | R |
| | *Amblyeleotris guttata* | 0.0003669724771 | 0.005318521453 | 7 | R |
| | *Amblyeleotris steinitzi* | 0.000122324159 | 0.001317603512 | 1 | R |
| | *Amblyeleotris wheeleri* | 0.00003058103976 | 0.00004805786294 | 1 | R |
| | *Ctenogobiops feroculus* | 0.00003058103976 | 0.00004669707406 | 1 | R |
| | *Exyrias puntang* | 0.00006116207951 | 0.002623023823 | 1 | R |
| | *Koumansetta rainfordi* | 0.00006116207951 | 0.0000985071796 | 2 | R |
| | *Valenciennea strigata* | 0.003501529052 | 0.02794129191 | 18 | O |
| **Haemulidae** | *Plectorhinchus gibbosus* | 0.0001070336391 | 0.2730861381 | 3 | R |
| | *Plectorhinchus lessonii* | 0.00001529051988 | 0.010143381 | 1 | R |
| | *Plectorhinchus vittatus* | 0.0001681957187 | 0.06126550902 | 4 | R |
| **Holocentridae** | *Myripristis adusta* | 0.0002140672783 | 0.08520525167 | 5 | R |
| | *Myripristis amaena* | 0.00003058103976 | 0.004191313966 | 1 | R |
| | *Myripristis berndti* | 0.001758409786 | 0.3273914446 | 24 | O |
| | *Myripristis kuntee* | 0.01067278287 | 1.21322961 | 47 | C |
| | *Myripristis violacea* | 0.001039755352 | 0.1629947706 | 11 | O |
| | *Neoniphon sammara* | 0.001804281346 | 0.2434994439 | 18 | O |
| | *Sargocentron caudimaculatum* | 0.007380952381 | 0.6558960549 | 59 | A |
| | *Sargocentron diadema* | 0.0001987767584 | 0.01520192204 | 6 | R |
| | *Sargocentron ittodai* | 0.00006116207951 | 0.01469472945 | 3 | R |
| | *Sargocentron microstoma* | 0.0002752293578 | 0.02532210767 | 3 | R |
| | *Sargocentron punctatissimum* | *0.00003058103976* | *0.0004387321092* | *1* | *R* |

| Family | Species | Mean density (individuals m^-2) | Mean biomass (g m^-2) | Number of sites | DACOR |
|---|---|---|---|---|---|
| **Holocentridae (continued)** | *Sargocentron spiniferum* | 0.0005482743556 | 0.2293332591 | 18 | O |
| | *Sargocentron tiere* | 0.000122324159 | 0.01848418164 | 3 | R |
| **Kyphosidae** | *Kyphosus cinerascens* | 0.00006116207951 | 0.06049098769 | 1 | R |
| | *Kyphosus vaigiensis* | 0.0001834862385 | 0.271630397 | 2 | R |
| **Labridae** | *Anampses caeruleopunctatus* | 0.0001376146789 | 0.01419212963 | 4 | R |
| | *Anampses melanurus* | 0.0002271734382 | 0.00372295495 | 4 | R |
| | *Anampses meleagrides* | 0.00006116207951 | 0.001393543301 | 2 | R |
| | *Anampses neoguinaicus* | 0.0005198776758 | 0.01944199745 | 9 | R |
| | *Anampses twistii* | 0.002625600699 | 0.05972386208 | 36 | C |
| | *Bodianus axillaris* | 0.00249890782 | 0.1951452981 | 46 | C |
| | *Bodianus loxozonus* | 0.0004565312363 | 0.0780807573 | 14 | O |
| | *Bodianus mesothorax* | 0.0006422018349 | 0.054260619 | 13 | O |
| | *Bodianus perditio* | 0.00005897771953 | 0.04753547832 | 4 | R |
| | *Cheilinus chlorourus* | 0.00119266055 | 0.04538418411 | 18 | O |
| | *Cheilinus fasciatus* | 0.0002599388379 | 0.05075251113 | 9 | R |
| | *Choerodon fasciatus* | 0.00001529051988 | 0.008501062484 | 1 | R |
| | *Cheilinus oxycephalus* | 0.002079510703 | 0.04370894956 | 32 | C |
| | *Cheilinus trilobatus* | 0.0003975535168 | 0.09487732907 | 12 | O |
| | *Cheilinus undulatus* | 0.0002905198777 | 0.6462625001 | 7 | R |
| | *Cirrhilabrus exquisitus* | 0.006162079511 | 0.01901141861 | 27 | O |
| | *Cirrhilabrus punctatus* | 0.01094801223 | 0.07410976285 | 22 | O |
| | *Cirrhilabrus rubrimarginatus* | 0.0007339449541 | 0.005551744704 | 2 | R |
| | *Cirrhilabrus scottorum* | 0.001590214067 | 0.00874925509 | 6 | R |
| | *Coris aygula* | 0.0001681957187 | 0.1026688283 | 8 | R |
| | *Coris batuensis* | 0.0004587155963 | 0.01461938801 | 9 | R |
| | *Coris dorsomacula* | 0.0008562691131 | 0.02025953723 | 10 | R |
| | *Coris gaimard* | 0.001636085627 | 0.2487423153 | 37 | C |
| | *Epibulus brevis* | 0.0003975535168 | 0.05524299086 | 11 | O |
| | *Epibulus insidiator* | 0.0005198776758 | 0.1534085035 | 21 | O |
| | *Gomphosus varius* | 0.01302533858 | 0.2289474094 | 92 | D |
| | *Halichoeres argus* | 0.00009174311927 | 0.003700024051 | 3 | R |
| | *Halichoeres biocellatus* | 0.0145412844 | 0.2360112016 | 70 | A |
| | *Halichoeres chrysus* | 0.00006116207951 | 0.003188502901 | 1 | R |
| | *Halichoeres claudia* | 0.003237221494 | 0.05845071355 | 30 | C |
| | *Halichoeres hartzfeldii* | 0.00003058103976 | 0.001090339378 | 1 | R |
| | *Halichoeres hortulanus* | 0.01425513325 | 0.801401526 | 89 | D |

| Family | Species | Mean density (individuals m^-2) | Mean biomass (g m^-2) | Number of sites | DACOR |
|---|---|---|---|---|---|
| Labridae (continued) | *Halichoeres marginatus* | 0.0009480122324 | 0.02411123248 | 16 | O |
| | *Halichoeres margaritaceus* | 0.001834862385 | 0.01467244362 | 10 | R |
| | *Halichoeres melasmapomus* | 0.00001529051988 | 0.003665971128 | 1 | R |
| | *Halichoeres melanurus* | 0.0001529051988 | 0.00689401771 | 2 | R |
| | *Halichoeres nebulosus* | 0.00006116207951 | 0.0001197913967 | 1 | R |
| | *Halichoeres ornatissimus* | 0.0007033639144 | 0.0342245354 | 8 | R |
| | *Halichoeres prosopeion* | 0.005458715596 | 0.2128007996 | 41 | C |
| | *Halichoeres richmondi* | 0.00006116207951 | 0.0008409266434 | 1 | R |
| | *Halichoeres trimaculatus* | 0.00006116207951 | 0.00184649418 | 2 | R |
| | *Hemigymnus fasciatus* | 0.001588029707 | 0.2328180088 | 37 | C |
| | *Hemigymnus melapterus* | 0.0007033639144 | 0.2577423248 | 21 | O |
| | *Hologymnosus annulatus* | 0.00004587155963 | 0.02324578537 | 3 | R |
| | *Hologymnosus doliatus* | 0.0003211009174 | 0.0704602607 | 8 | R |
| | *Labropsis australis* | 0.0002752293578 | 0.002245846975 | 8 | R |
| | *Labroides bicolor* | 0.002136304063 | 0.01910375095 | 36 | C |
| | *Labroides dimidiatus* | 0.01474006116 | 0.07741876107 | 88 | D |
| | *Labroides pectoralis* | 0.0009480122324 | 0.002365817532 | 17 | O |
| | *Labrichthys unilineatus* | 0.0009174311927 | 0.02049494347 | 18 | O |
| | *Labropsis xanthonota* | 0.006681957187 | 0.04048459747 | 63 | A |
| | *Macropharyngodon meleagris* | 0.005504587156 | 0.07200355002 | 54 | C |
| | *Macropharyngodon negrosensis* | 0.0006422018349 | 0.01478105866 | 11 | O |
| | *Novaculichthys taeniourus* | 0.0001070336391 | 0.01111873966 | 3 | R |
| | *Oxycheilinus digramma* | 0.00629750983 | 0.3124307624 | 61 | A |
| | *Oxycheilinus orientalis* | 0.001559633028 | 0.05235621683 | 23 | O |
| | *Oxycheilinus unifasciatus* | 0.0008868501529 | 0.1100568024 | 19 | O |
| | *Pseudojuloides atavai* | 0.00003058103976 | 0.00005980305181 | 1 | R |
| | *Pseudocheilinus evanidus* | 0.003868501529 | 0.02586265616 | 40 | C |
| | *Pseudocheilinus hexataenia* | 0.02352118829 | 0.08585528044 | 92 | D |
| | *Pseudodax moluccanus* | 0.0003211009174 | 0.04992674014 | 14 | O |
| | *Pseudocheilinus octotaenia* | 0.0025600699 | 0.04451771929 | 35 | C |
| | *Pseudocoris yamashiroi* | 0.00009174311927 | 0.003125980065 | 2 | R |
| | *Pteragogus cryptus* | 0.00006116207951 | 0.0009664268054 | 1 | R |
| | *Stethojulis bandanensis* | 0.00128440367 | 0.02276137119 | 25 | O |
| | *Stethojulis strigiventer* | 0.0003669724771 | 0.02222392853 | 2 | R |

| Family | Species | Mean density (individuals m^-2) | Mean biomass (g m^-2) | Number of sites | DACOR |
|---|---|---|---|---|---|
| **Labridae (continued)** | *Stethojulis trilineata* | 0.0004892966361 | 0.01610931696 | 11 | O |
| | *Thalassoma amblycephalum* | 0.01667540411 | 0.2010753428 | 28 | C |
| | *Thalassoma hardwicke* | 0.005703363914 | 0.1074058882 | 47 | C |
| | *Thalassoma jansenii* | 0.002324159021 | 0.1659849151 | 8 | R |
| | *Thalassoma lunare* | 0.003241590214 | 0.09670753971 | 27 | O |
| | *Thalassoma lutescens* | 0.0148580166 | 0.4636628238 | 52 | C |
| | *Thalassoma nigrofasciatum* | 0.007599388379 | 0.1908649128 | 33 | C |
| | *Thalassoma purpureum* | 0.00001529051988 | 0.004659279131 | 1 | R |
| | *Thalassoma quinquevittatum* | 0.004877675841 | 0.06174475231 | 13 | O |
| **Labridae (Scarinae)** | *Bolbometopon muricatum* | 0.00004587155963 | 0.7401239183 | 2 | R |
| | *Calotomus carolinus* | 0.0003211009174 | 0.0832982095 | 10 | R |
| | *Cetoscarus bicolor* | 0.006009174312 | 0.08622755027 | 22 | O |
| | *Cetoscarus ocellatus* | 0.001417649629 | 1.070547044 | 35 | C |
| | *Chlorurus bleekeri* | 0.002171253823 | 1.008377129 | 28 | C |
| | *Chlorurus frontalis* | 0.000122324159 | 0.05071449116 | 2 | R |
| | *Chlorurus japanensis* | 0.005290519878 | 1.794982792 | 61 | A |
| | *Chlorurus microrhinos* | 0.003027522936 | 2.403690486 | 41 | C |
| | *Chlorurus sordidus* | 0.007565530799 | 1.975399964 | 59 | A |
| | *Chlorurus spilurus* | 0.009210353866 | 3.269116476 | 72 | A |
| | *Hipposcarus longiceps* | 0.0001529051988 | 0.1050151692 | 5 | R |
| | *Scarus altipinnis* | 0.001177370031 | 1.156569112 | 26 | O |
| | *Scarus chameleon* | 0.0008868501529 | 0.2387571641 | 27 | O |
| | *Scarus dimidiatus* | 0.0006422018349 | 0.2233733755 | 8 | R |
| | *Scarus festivus* | 0.00001529051988 | 0.003563583149 | 1 | R |
| | *Scarus forsteni* | 0.004622105723 | 1.848389397 | 58 | A |
| | *Scarus frenatus* | 0.0003363914373 | 0.1511141962 | 12 | O |
| | *Scarus ghobban* | 0.00007645259939 | 0.02934503061 | 4 | R |
| | *Scarus globiceps* | 0.001146788991 | 0.4055773019 | 21 | O |
| | *Scarus hypselopterus* | 0.00001529051988 | 0.007805552949 | 1 | R |
| | *Scarus longipinnis* | 0.00009174311927 | 0.05920410189 | 3 | R |
| | *Scarus niger* | 0.0127621232 | 4.016033488 | 81 | A |
| | *Scarus oviceps* | 0.001891655745 | 1.050676966 | 40 | C |
| | *Scarus psittacus* | 0.001009174312 | 0.2258409485 | 26 | O |
| | *Scarus quoyi* | 0.000244648318 | 0.1022930128 | 7 | R |
| | *Scarus rivulatus* | 0.0001070336391 | 0.06106032243 | 5 | R |
| | *Scarus rubroviolaceus* | 0.00374399301 | 3.22627438 | 59 | A |
| | *Scarus schlegeli* | 0.002354740061 | 0.9718412506 | 36 | C |
| | *Scarus spinus* | 0.00129969419 | 0.4493379492 | 31 | C |

| Family | Species | Mean density (individuals m^-2) | Mean biomass (g m^-2) | Number of sites | DACOR |
|---|---|---|---|---|---|
| **Lethrinidae** | *Gnathodentex aureolineatus* | 0.004364351245 | 0.7131307931 | 14 | O |
| | *Lethrinus atkinsoni* | 0.00001529051988 | 0.007612739238 | 1 | R |
| | *Lethrinus erythracanthus* | 0.0001987767584 | 0.165981271 | 10 | R |
| | *Lethrinus obsoletus* | 0.00006116207951 | 0.03372797064 | 4 | R |
| | *Lethrinus olivaceus* | 0.0001070336391 | 0.1210807619 | 4 | R |
| | *Lethrinus xanthochilus* | 0.0002140672783 | 0.2332588712 | 9 | R |
| | *Monotaxis grandoculis* | 0.004412407165 | 2.446924672 | 53 | C |
| | *Monotaxis heterodon* | 0.0009545653124 | 0.4121618293 | 23 | O |
| **Lutjanidae** | *Aphareus furca* | 0.001804281346 | 0.4787981434 | 42 | C |
| | *Aprion virescens* | 0.00006880733945 | 0.1373507634 | 4 | R |
| | *Lutjanus argentimaculatus* | 0.00007645259939 | 0.09263221012 | 1 | R |
| | *Lutjanus biguttatus* | 0.00001529051988 | 0.003536255046 | 1 | R |
| | *Lutjanus bohar* | 0.003081039755 | 2.846365918 | 54 | C |
| | *Lutjanus fulviflamma* | 0.000122324159 | 0.05081666766 | 3 | R |
| | *Lutjanus fulvus* | 0.006035386632 | 1.910184317 | 21 | O |
| | *Lutjanus gibbus* | 0.004831804281 | 1.845107963 | 32 | C |
| | *Lutjanus kasmira* | 0.0003211009174 | 0.07998159196 | 3 | R |
| | *Lutjanus madras* | 0.003501529052 | 0.7824458798 | 1 | R |
| | *Lutjanus monostigma* | 0.000871559633 | 0.3964653622 | 13 | O |
| | *Lutjanus rivulatus* | 0.0003058103976 | 0.7537394422 | 17 | O |
| | *Lutjanus semicinctus* | 0.00121559633 | 0.4917477937 | 43 | C |
| | *Lutjanus vitta* | 0.0001987767584 | 0.02437916421 | 2 | R |
| | *Macolor macularis* | 0.001957186544 | 1.295155103 | 40 | C |
| | *Macolor niger* | 0.002721712538 | 2.417940764 | 28 | C |
| | *Lutjanus mizenkoi* | 0.00001529051988 | 0.004527486273 | 1 | R |
| **Malacanthidae** | *Malacanthus brevirostris* | 0.00004587155963 | 0.002581507113 | 2 | R |
| | *Malacanthus latovittatus* | 0.0003822629969 | 0.04870683193 | 8 | R |
| **Microdesmidae** | *Nemateleotris magnifica* | 0.0121559633 | 0.02805905355 | 46 | C |
| | *Ptereleotris evides* | 0.005718654434 | 0.06130987286 | 43 | C |
| | *Ptereleotris heteroptera* | 0.0004587155963 | 0.006067730054 | 5 | R |
| | *Ptereleotris zebra* | 0.0006727828746 | 0.003414459964 | 1 | R |
| | *Amanses scopas* | 0.00006116207951 | 0.007250168789 | 2 | R |
| | *Cantherhines dumerilii* | 0.0002293577982 | 0.06938449233 | 9 | R |
| | *Cantherhines pardalis* | 0.0003058103976 | 0.02270662715 | 6 | R |
| | *Oxymonacanthus longirostris* | 0.0003975535168 | 0.007980785131 | 6 | R |
| | *Pervagor janthinosoma* | 0.000244648318 | 0.004813573619 | 6 | R |
| | *Pervagor melanocephalus* | 0.00003058103976 | 0.0006751375385 | 1 | R |
| **Mullidae** | *Mulloidichthys vanicolensis* | 0.001039755352 | 0.2190323852 | 7 | R |
| | *Parupeneus barberinus* | 0.000749235474 | 0.1344998675 | 22 | O |
| | *Parupeneus crassilabris* | 0.004563128003 | 1.250086182 | 56 | A |

| Family | Species | Mean density (individuals m^-2) | Mean biomass (g m^-2) | Number of sites | DACOR |
|---|---|---|---|---|---|
| **Mullidae (continued)** | *Parupeneus cyclostomus* | 0.003165137615 | 0.3885332928 | 58 | A |
| | *Parupeneus multifasciatus* | 0.01790519878 | 0.969997824 | 98 | D |
| | *Parupeneus pleurostigma* | 0.000244648318 | 0.0151559633 | 6 | R |
| **Muraenidae** | *Gymnothorax javanicus* | 0.00006116207951 | 0.04418505248 | 3 | R |
| **Nemipteridae** | *Scolopsis bilineata* | 0.001720183486 | 0.2226613713 | 24 | O |
| | *Scolopsis lineata* | 0.0002599388379 | 0.06215091555 | 1 | R |
| | *Scolopsis trilineata* | 0.00006116207951 | 0.003475848989 | 2 | R |
| **Ostraciidae** | *Ostracion cubicum* | 0.00001529051988 | 0.006542579319 | 1 | R |
| | *Ostracion meleagris* | 0.000122324159 | 0.006018904569 | 4 | R |
| **Pempheridae** | *Pempheris oualensis* | 0.007048929664 | 0.4795702858 | 18 | O |
| | *Pempheris vanicolensis* | 0.0009785932722 | 0.06067063719 | 4 | R |
| **Pinguipedidae** | *Parapercis clathrata* | 0.001788990826 | 0.1558565584 | 28 | C |
| | *Parapercis millepunctata* | 0.0003975535168 | 0.006397780821 | 6 | R |
| | *Parapercis xanthogramma* | 0.0001834862385 | 0.008473368823 | 3 | R |
| **Pomacanthidae** | *Apolemichthys trimaculatus* | 0.0001529051988 | 0.01422753783 | 3 | R |
| | *Centropyge bicolor* | 0.004648318043 | 0.181001211 | 15 | O |
| | *Centropyge bispinosa* | 0.03387942333 | 0.7138679958 | 93 | D |
| | *Centropyge fisheri* | 0.000244648318 | 0.003024843886 | 1 | R |
| | *Centropyge flavissima* | 0.01203363914 | 0.4057516356 | 84 | D |
| | *Centropyge heraldi* | 0.0009785932722 | 0.04151032214 | 11 | O |
| | *Centropyge loriculus* | 0.0006422018349 | 0.01024988021 | 9 | R |
| | *Centropyge nox* | 0.00003058103976 | 0.000807681387 | 1 | R |
| | *Centropyge vrolikii* | 0.00880733945 | 0.1984821057 | 69 | A |
| | *Genicanthus melanospilos* | 0.00003058103976 | 0.001829903405 | 1 | R |
| | *Paracentropyge multifasciata* | 0.00003058103976 | 0.0009256595136 | 1 | R |
| | *Pomacanthus imperator* | 0.0001681957187 | 0.06629899527 | 6 | R |
| | *Pomacanthus semicirculatus* | 0.00001529051988 | 0.01656363522 | 1 | R |
| | *Pomacanthus xanthometopon* | 0.00003058103976 | 0.02737083178 | 2 | R |
| | *Pygoplites diacanthus* | 0.00630624727 | 0.7831596119 | 60 | A |
| **Pomacentridae** | *Abudefduf sexfasciatus* | 0.001039755352 | 0.07379819773 | 3 | R |
| | *Abudefduf vaigiensis* | 0.001865443425 | 0.1468802798 | 9 | R |
| | *Acanthochromis polyacanthus* | 0.06321100917 | 0.8499370535 | 45 | C |
| | *Amphiprion akindynos* | 0.00009174311927 | 0.00246751945 | 1 | R |
| | *Amblyglyphidodon aureus* | 0.0003058103976 | 0.01027367337 | 3 | R |
| | *Amphiprion chrysopterus* | 0.002599388379 | 0.08387084925 | 26 | O |
| | *Amphiprion clarkii* | 0.0009785932722 | 0.02884188971 | 8 | R |
| | *Amblyglyphidodon curacao* | 0.0006422018349 | 0.02758138489 | 4 | R |
| | *Amblyglyphidodon leucogaster* | 0.002752293578 | 0.07241289541 | 10 | R |
| | *Amphiprion melanopus* | 0.00003058103976 | 0.00009259592865 | 1 | R |
| | *Amblyglyphidodon orbicularis* | 0.0003975535168 | 0.02855105733 | 2 | R |

| Family | Species | Mean density (individuals m^-2) | Mean biomass (g m^-2) | Number of sites | DACOR |
|---|---|---|---|---|---|
| Pomacentridae (continued) | *Amphiprion perideraion* | 0.0005504587156 | 0.01158765829 | 5 | R |
| | *Amphiprion rubrocinctus* | 0.001009174312 | 0.03046740683 | 12 | O |
| | *Pycnochromis acares* | 0.02836173001 | 0.1557699121 | 18 | O |
| | *Pycnochromis agilis* | 0.008422892093 | 0.08523384219 | 16 | O |
| | *Chromis alpha* | 0.001865443425 | 0.03987445147 | 11 | O |
| | *Pycnochromis amboinensis* | 0.05928134557 | 0.5433051766 | 40 | C |
| | *Chromis atripectoralis* | 0.005076452599 | 0.01581761366 | 5 | R |
| | *Pycnochromis atripes* | 0.1523722149 | 0.462223544 | 81 | A |
| | *Chrysiptera caesifrons* | 0.0005504587156 | 0.0011698116 | 3 | R |
| | *Chromis chrysura* | 0.002913936217 | 0.1546947986 | 7 | R |
| | *Chrysiptera chrysocephala* | 0.001673219747 | 0.01333623764 | 4 | R |
| | *Pycnochromis delta* | 0.00003058103976 | 0.0005257985149 | 1 | R |
| | *Chromis flavomaculata* | 0.0007339449541 | 0.009661182629 | 4 | R |
| | *Pycnochromis iomelas* | 0.1799082569 | 0.5559134508 | 86 | D |
| | *Chromis kennensis* | 0.000122324159 | 0.00210319406 | 1 | R |
| | *Azurina lepidolepis* | 0.0154259502 | 0.08823883564 | 46 | C |
| | *Pycnochromis lineatus* | 0.007125382263 | 0.01635149771 | 4 | R |
| | *Pycnochromis margaritifer* | 0.4073263434 | 1.153422936 | 94 | D |
| | *Chromis opercularis* | 0.0007645259939 | 0.01983101267 | 4 | R |
| | *Pycnochromis retrofasciatus* | 0.01793359546 | 0.1038138755 | 29 | C |
| | *Chrysiptera rex* | 0.0003975535168 | 0.003324667979 | 6 | R |
| | *Chrysiptera rollandi* | 0.009266055046 | 0.02340319211 | 27 | O |
| | *Chrysiptera talboti* | 0.04493883792 | 0.138916351 | 59 | A |
| | *Chrysiptera taupou* | 0.000122324159 | 0.000297153974 | 2 | R |
| | *Chromis ternatensis* | 0.03126256007 | 0.7701740028 | 40 | C |
| | *Pycnochromis vanderbilti* | 0.1642726081 | 0.3369973916 | 24 | O |
| | *Chromis viridis* | 0.001314984709 | 0.002627915916 | 4 | R |
| | *Chromis weberi* | 0.09373088685 | 0.8841124734 | 57 | A |
| | *Chromis xanthura* | 0.07073394495 | 1.227888759 | 75 | A |
| | *Dascyllus reticulatus* | 0.1362232416 | 1.035967417 | 53 | C |
| | *Dascyllus trimaculatus* | 0.01180428135 | 0.2894572723 | 43 | C |
| | *Dischistodus perspicillatus* | 0.00009174311927 | 0.007157079607 | 2 | R |
| | *Hemiglyphidodon plagiometopon* | 0.00009174311927 | 0.002460345979 | 1 | R |
| | *Lepidozygus tapeinosoma* | 0.1716863259 | 0.6205195773 | 12 | O |
| | *Neopomacentrus azysron* | 0.02 | 0.1607449066 | 6 | R |
| | *Neoglyphidodon carlsoni* | 0.0003058103976 | 0.00890811926 | 2 | R |
| | *Neoglyphidodon melas* | 0.0001529051988 | 0.01118823384 | 2 | R |
| | *Neoglyphidodon nigroris* | 0.005198776758 | 0.1231015439 | 16 | O |
| | *Neopomacentrus violascens* | 0.01614678899 | 0.03294101291 | 6 | R |
| | *Plectroglyphidodon dickii* | 0.008580166011 | 0.06707309728 | 30 | C |

| Family | Species | Mean density (individuals m^-2) | Mean biomass (g m^-2) | Number of sites | DACOR |
|---|---|---|---|---|---|
| **Pomacentridae (continued)** | *Plectroglyphidodon johnstonianus* | 0.002429008301 | 0.01932353663 | 21 | O |
| | *Stegastes lacrymatus* | 0.05874836173 | 1.020235621 | 94 | D |
| | *Pomacentrus adelus* | 0.001437308869 | 0.0164820101 | 14 | O |
| | *Pomacentrus alexanderae* | 0.00003058103976 | 0.0001010822916 | 1 | R |
| | *Pomacentrus amboinensis* | 0.02816513761 | 0.5538040878 | 29 | C |
| | *Pomacentrus bankanensis* | 0.154102228 | 1.003292007 | 105 | D |
| | *Pomacentrus brachialis* | 0.003975535168 | 0.03783726778 | 11 | O |
| | *Pomacentrus coelestis* | 0.1006574924 | 0.4747824225 | 52 | C |
| | *Pomacentrus lepidogenys* | 0.1253604194 | 1.036489151 | 80 | A |
| | *Pomacentrus moluccensis* | 0.01620795107 | 0.04168556132 | 25 | O |
| | *Pomacentrus nagasakiensis* | 0.003669724771 | 0.03536086241 | 10 | R |
| | *Pomacentrus nigromanus* | 0.0006116207951 | 0.01179470986 | 3 | R |
| | *Pomacentrus nigriradiatus* | 0.123003495 | 2.257420466 | 75 | A |
| | *Pomacentrus nigromarginatus* | 0.0005810397554 | 0.01431406397 | 4 | R |
| | *Pomacentrus pavo* | 0.00003058103976 | 0.0004410849946 | 1 | R |
| | *Pomacentrus reidi* | 0.01392966361 | 0.5810409603 | 32 | C |
| | *Pomachromis richardsoni* | 0.009847094801 | 0.01274695211 | 10 | R |
| | *Pomacentrus spilotoceps* | 0.0008868501529 | 0.00436579564 | 4 | R |
| | *Pomacentrus vaiuli* | 0.160958934 | 1.593161372 | 102 | D |
| | *Plectroglyphidodon fasciolatus* | 0.01094364351 | 0.3178823412 | 24 | O |
| | *Stegastes nigricans* | 0.00003058103976 | 0.0008201153265 | 1 | R |
| **Priacanthidae** | *Priacanthus hamrur* | 0.00004587155963 | 0.009220999598 | 1 | R |
| **Pseudochromidae** | *Cypho purpurascens* | 0.004434250765 | 0.02718667991 | 51 | C |
| | *Cypho zaps* | 0.00006116207951 | 0.0001024117616 | 2 | R |
| **Scombridae** | *Gymnosarda unicolor* | 0.00004587155963 | 0.0403531303 | 3 | R |
| | *Rastrelliger kanagurta* | 0.001834862385 | 0.7006132153 | 3 | R |
| **Scorpaenidae** | *Caracanthus unipinna* | 0.00009174311927 | 0.0003337252819 | 2 | R |
| | *Pterois antennata* | 0.00006116207951 | 0.003252994997 | 1 | R |
| | *Pterois volitans* | 0.00007645259939 | 0.002636267387 | 1 | R |
| | *Scorpaenopsis possi* | 0.00001529051988 | 0.007250632871 | 1 | R |
| **Serranidae** | *Aethaloperca rogaa* | 0.0001681957187 | 0.08517209819 | 7 | R |
| | *Belonoperca chabanaudi* | 0.0003363914373 | 0.01229301367 | 9 | R |
| | *Cephalopholis argus* | 0.0006553079948 | 0.3323808032 | 31 | C |
| | *Cephalopholis leopardus* | 0.0007951070336 | 0.05123046758 | 15 | O |
| | *Cephalopholis miniata* | 0.00004587155963 | 0.006935147375 | 2 | R |
| | *Cephalopholis sonnerati* | 0.00003058103976 | 0.003702298906 | 1 | R |
| | *Cephalopholis urodeta* | 0.0196505024 | 1.87565534 | 87 | D |
| | *Diploprion bifasciatum* | 0.00003058103976 | 0.001950156214 | 1 | R |
| | *Epinephelus coeruleopunctatus* | 0.00003058103976 | 0.02025830508 | 1 | R |
| | *Epinephelus fasciatus* | 0.00006116207951 | 0.01134167761 | 2 | R |

| Family | Species | Mean density (individuals m^-2) | Mean biomass (g m^-2) | Number of sites | DACOR |
|---|---|---|---|---|---|
| **Serranidae (continued)** | *Epinephelus hexagonatus* | 0.00001529051988 | 0.005748569836 | 1 | R |
| | *Epinephelus howlandi* | 0.00001529051988 | 0.01739534913 | 1 | R |
| | *Epinephelus merra* | 0.0003822629969 | 0.0464024354 | 14 | O |
| | *Epinephelus polyphekadion* | 0.00001529051988 | 0.01498381066 | 1 | R |
| | *Epinephelus tauvina* | 0.00004587155963 | 0.04596285583 | 3 | R |
| | *Gracila albomarginata* | 0.0002293577982 | 0.05699261208 | 2 | R |
| | *Grammistes sexlineatus* | 0.00003058103976 | 0.0003714025939 | 1 | R |
| | *Plectropomus areolatus* | 0.000244648318 | 0.1993088508 | 11 | O |
| | *Plectropomus laevis* | 0.0003975535168 | 1.136433055 | 19 | O |
| | *Pogonoperca punctata* | 0.00006116207951 | 0.007404597811 | 1 | R |
| | *Pseudanthias dispar* | 0.0947706422 | 0.2123241179 | 11 | O |
| | *Pseudanthias pascalus* | 0.0008562691131 | 0.006605079716 | 3 | R |
| | *Pseudanthias squamipinnis* | 0.01110091743 | 0.06104374165 | 18 | O |
| | *Pseudanthias tuka* | 0.01834862385 | 0.12039399 | 8 | R |
| | *Variola albimarginata* | 0.000122324159 | 0.06120720419 | 7 | R |
| | *Variola louti* | 0.0007186544343 | 0.4443977874 | 20 | O |
| **Siganidae** | *Siganus argenteus* | 0.0003822629969 | 0.08385844696 | 5 | R |
| | *Siganus corallinus* | 0.0003516819572 | 0.1509656264 | 9 | R |
| | *Siganus doliatus* | 0.00007645259939 | 0.04185220031 | 3 | R |
| | *Siganus javus* | 0.00003058103976 | 0.01597968126 | 1 | R |
| | *Siganus puellus* | 0.00006116207951 | 0.01333342135 | 2 | R |
| | *Siganus punctatus* | 0.001314984709 | 0.1847105148 | 4 | R |
| | *Siganus punctatissimus* | 0.00009174311927 | 0.04652763715 | 3 | R |
| | *Siganus spinus* | 0.00003058103976 | 0.000494787831 | 1 | R |
| | *Siganus vulpinus* | 0.0002905198777 | 0.1023567196 | 8 | R |
| **Synodontidae** | *Saurida gracilis* | 0.00004587155963 | 0.00419225692 | 2 | R |
| | *Synodus binotatus* | 0.0005155089559 | 0.01738220786 | 14 | O |
| | *Synodus jaculum* | 0.0001529051988 | 0.004357156317 | 5 | R |
| **Tetraodontidae** | *Arothron meleagris* | 0.00001529051988 | 0.0114145209 | 1 | R |
| | *Arothron nigropunctatus* | 0.0006422018349 | 0.3041209013 | 30 | C |
| | *Arothron stellatus* | 0.00004587155963 | 0.1520547618 | 3 | R |
| | *Canthigaster amboinensis* | 0.0001747487986 | 0.004675155025 | 3 | R |
| | *Canthigaster bennetti* | 0.0002402795981 | 0.003034692779 | 4 | R |
| | *Canthigaster compressa* | 0.00003058103976 | 0.0007049432129 | 1 | R |
| | *Canthigaster solandri* | 0.00009174311927 | 0.003261018026 | 2 | R |
| | *Canthigaster valentini* | 0.0005198776758 | 0.01752405001 | 8 | R |
| **Zanclidae** | *Zanclus cornutus* | 0.002086063783 | 0.290986932 | 28 | C |

## Appendix 5

# CORAL DIVERSITY

**TABLE 5**:
*Full list of coral genera recorded in the photoquadrat and juvenile coral surveys.*

| GENUS | PHOTOQUADRATS | JUVENILES |
|---|---|---|
| *Acanthastrea* | x | x |
| *Acropora* | x | x |
| *Alveopora* | x | |
| *Anacropora* | x | |
| *Astrea* | x | x |
| *Astreopora* | x | x |
| *Cantharellus* | | x |
| *Caulastrea* | x | x |
| *Coeloseris* | x | |
| *Ctenactis* | x | |
| *Cycloseris* | x | x |
| *Cynaria* | | x |
| *Cyphastrea* | x | x |
| *Diploastrea* | x | x |
| *Dipsastrea* | x | x |
| *Echinomorpha* | x | x |
| *Echinophyllia* | x | x |
| *Echinopora* | x | x |
| *Euphyllia* | x | x |
| *Favites* | x | x |
| *Fungia* | x | x |
| *Galaxea* | x | x |
| *Gardineroseris* | x | x |
| *Goniastrea* | x | x |
| *Goniopora* | x | |
| *Heliofungia* | x | |
| *Herpolithia* | x | |
| *Hydnophora* | x | x |
| *Isopora* | x | x |
| *Leptastrea* | x | x |

| GENUS | PHOTOQUADRATS | JUVENILES |
|---|---|---|
| *Leptoria* | x | x |
| *Leptoseris* | x | x |
| *Lithophyllon* | | x |
| *Lobophyllia* | x | x |
| *Merulina* | x | x |
| *Montipora* | x | x |
| *Mycedium* | x | x |
| *Pachyseris* | x | x |
| *Pavona* | x | x |
| *Pectinia* | x | x |
| *Physogyra* | x | x |
| *Platygyra* | x | x |
| *Pocillopora* | x | x |
| *Podobacia* | x | |
| *Porites* | x | x |
| *Psammocora* | x | x |
| *Sandalolitha* | x | x |
| *Seriatopora* | x | x |
| *Stylophora* | x | x |
| *Trachyphyllia* | x | |
| *Turbinaria* | x | x |

## Appendix 6

# INVERTEBRATE DIVERSITY

**TABLE 6**:
*Full list of invertebrate species recorded in belt transect surveys.*

| SCIENTIFIC NAME | ORGANISM TYPE |
|---|---|
| *Stichodactyla gigantea* | Anemone |
| *Anadara antiquata* | Bivalve |
| *Asaphis violascens* | Bivalve |
| *Atrina vexillum* | Bivalve |
| *Chama croceata* | Bivalve |
| *Codakia interrupta* | Bivalve |
| *Fragum unedo* | Bivalve |
| *Gafrarium pectinatum* | Bivalve |
| *Gafrarium tumidum* | Bivalve |
| *Hippopus hippopus* | Bivalve |
| *Modiolus ariculatus* | Bivalve |
| *Pedum spondyloideum* | Bivalve |
| *Periglypta purpera* | Bivalve |
| *Pinctada margaritifera* | Bivalve |
| *Pinna muricata* | Bivalve |
| *Pitar prora* | Bivalve |
| *Spondylus squamosus* | Bivalve |
| *Tapes literatus* | Bivalve |
| *Tellina palatum* | Bivalve |
| *Tellina scobinata* | Bivalve |
| *Timoclea marica* | Bivalve |
| *Tridacna crocea* | Bivalve |
| *Tridacna gigas* | Bivalve |
| *Tridacna maxima* | Bivalve |
| *Tridacna squamosa* | Bivalve |
| *Vasticardium elongatum* | Bivalve |
| *Octopus cyanea* | Cephalopod |
| *Sepia officinalis* | Cephalopod |
| *Comaster nobilis* | Crinoid |
| *Comaster schlegelii* | Crinoid |

| SCIENTIFIC NAME | ORGANISM TYPE |
|---|---|
| *Tropiometra afra* | Crinoid |
| *Calappa hepatica* | Crustacean |
| *Calcinus laevimanus* | Crustacean |
| *Coenobita perlatus* | Crustacean |
| *Dardanus spp* | Crustacean |
| *Eriphia sebana* | Crustacean |
| *Etisus splendidus* | Crustacean |
| *Palinurus ornatus* | Crustacean |
| *Panulirus versicolor* | Crustacean |
| *Acanthopleura gemmata* | Gastropod |
| *Alanbeuella corrugata* | Gastropod |
| *Astralium rhodostomum* | Gastropod |
| *Cassis cornuta* | Gastropod |
| *Cerithium nodulosum* | Gastropod |
| *Cerithium vulgatum* | Gastropod |
| *Charonia tritonis* | Gastropod |
| *Chicoreus ramosus* | Gastropod |
| *Chromodoris annae* | Gastropod |
| *Chromodoris elizabethenia* | Gastropod |
| *Chromodoris inormata* | Gastropod |
| *Chromodoris lochi* | Gastropod |
| *Chromodoris willani* | Gastropod |
| *Conus flavidus* | Gastropod |
| *Conus geographicus* | Gastropod |
| *Conus leopardus* | Gastropod |
| *Conus litteratus* | Gastropod |
| *Conus marmoreus* | Gastropod |
| *Conus miles* | Gastropod |
| *Conus textile* | Gastropod |
| *Conus vexillum* | Gastropod |
| *Coralliophila violacea* | Gastropod |
| *Corallophila neritoidea* | Gastropod |
| *Cyprea annulus* | Gastropod |
| *Cyprea capusterpensis* | Gastropod |
| *Cyprea maurititana* | Gastropod |
| *Cyprea moneta* | Gastropod |
| *Cyprea tigris* | Gastropod |
| *Dendropoma maximum* | Gastropod |
| *Dolabella auricularia* | Gastropod |
| *Drupa morum* | Gastropod |

| SCIENTIFIC NAME | ORGANISM TYPE |
|---|---|
| *Drupella cornus* | Gastropod |
| *Drupella spp* | Gastropod |
| *Fryeria picta* | Gastropod |
| *Flabellina exoptata* | Gastropod |
| *Hypselodoris tryoni* | Gastropod |
| *Hesperisternia multangulus* | Gastropod |
| *Lambis crocata* | Gastropod |
| *Lambis lambis* | Gastropod |
| *Lambis scorpius* | Gastropod |
| *Lambis truncata* | Gastropod |
| *Lambis millepedia* | Gastropod |
| *Latirolagena smaragdula* | Gastropod |
| *Mammilla melanostoma* | Gastropod |
| *Malea pomum* | Gastropod |
| *Monoplex pilearis* | Gastropod |
| *Muricopsis zeteki* | Gastropod |
| *Nassa francolina* | Gastropod |
| *Nassa serta* | Gastropod |
| *Nembrotha cristata* | Gastropod |
| *Nerita undata* | Gastropod |
| *Oliva caerulia* | Gastropod |
| *Peristernia reincarnata* | Gastropod |
| *Phyllidiopsis striata* | Gastropod |
| *Phyllidia coelestis* | Gastropod |
| *Phyllidia elegans* | Gastropod |
| *Phyllidia ocellata* | Gastropod |
| *Phyllidia pustulosa* | Gastropod |
| *Phyllidia varicosa* | Gastropod |
| *Phyllidia sp.* | Gastropod |
| *Pleuroploca filamentosa* | Gastropod |
| *Polygona spp* | Gastropod |
| *Pseudobiceros bedfordi* | Gastropod |
| *Pteraeolidia ianthina* | Gastropod |
| *Reishia armegira* | Gastropod |
| *Rhinoclavis aspera* | Gastropod |
| *Gibberulus gibberulus* | Gastropod |
| *Canarium labiatus* | Gastropod |
| *Lentigos lentiginosus* | Gastropod |
| *Conomurex luhuanus* | Gastropod |
| *Talparia talpa* | Gastropod |

| SCIENTIFIC NAME | ORGANISM TYPE |
|---|---|
| *Tectus pyramis* | Gastropod |
| *Oxymeris maculata* | Gastropod |
| *Terebralia palustris* | Gastropod |
| *Thalessa aculeata* | Gastropod |
| *Menathais intermedia* | Gastropod |
| *Reishia bitubercularis* | Gastropod |
| *Menathais tuberosa* | Gastropod |
| *Trochus maculata* | Gastropod |
| *Rochia niloticus* | Gastropod |
| *Turbo argyrostomus* | Gastropod |
| *Turbo chrystostomus* | Gastropod |
| *Turbo marmoratus* | Gastropod |
| *Turbo petholatus* | Gastropod |
| *Turbo setosum* | Gastropod |
| *Turbo spp* | Gastropod |
| *Tutufa bubo* | Gastropod |
| *Vasum ceramicum* | Gastropod |
| *Vasum turbinellum* | Gastropod |
| *Vexillum discolorium* | Gastropod |
| *Vexillum unifascialis* | Gastropod |
| *Cassiopea andromeda* | Jellyfish |
| *Actinopyga lecanora* | Sea Cucumber |
| *Actinopyga mauritiana* | Sea Cucumber |
| *Actinopyga miliaris* | Sea Cucumber |
| *Actinopyga palauensis* | Sea Cucumber |
| *Bohadschia argus* | Sea Cucumber |
| *Bohadschia similis* | Sea Cucumber |
| *Bohadschia vitiensis* | Sea Cucumber |
| *Holothuria atra* | Sea Cucumber |
| *Holothuria coluber* | Sea Cucumber |
| *Holothuria edulis* | Sea Cucumber |
| *Holothuria flavomaculata* | Sea Cucumber |
| *Holothuria fuscopunctata* | Sea Cucumber |
| *Holothuria hila* | Sea Cucumber |
| *Holothuria nobilis* | Sea Cucumber |
| *Holothuria whitmaei* | Sea Cucumber |
| *Pearsonothuria graeffei* | Sea Cucumber |
| *Stichopus chloronotus* | Sea Cucumber |
| *Stichopus hermanni* | Sea Cucumber |
| *Stichopus horrens* | Sea Cucumber |

| SCIENTIFIC NAME | ORGANISM TYPE |
|---|---|
| *Thelenota ananas* | Sea Cucumber |
| *Thelenota anax* | Sea Cucumber |
| *Diadema savignyi* | Sea Urchin |
| *Diadema setosum* | Sea Urchin |
| *Echinometra mathaei* | Sea Urchin |
| *Echinothrix calamaris* | Sea Urchin |
| *Echinothrix diadema* | Sea Urchin |
| *Heterocentrus mammillatus* | Sea Urchin |
| *Phyllacanthus imperialis* | Sea Urchin |
| *Tripneustes gratilla* | Sea Urchin |
| *Acanthaster planci* | Sea Star |
| *Amphiura triscacantha* | Sea Star |
| *Archaster typicus* | Sea Star |
| *Choriaster granulatus* | Sea Star |
| *Culcita novaeguineae* | Sea Star |
| *Fromia monilis* | Sea Star |
| *Gomophia gomophia* | Sea Star |
| *Linckia laevigata* | Sea Star |
| *Linckia multifora* | Sea Star |
| *Nardoa novaecaledoniae* | Sea Star |
| *Ophiothrix spp* | Sea Star |
| *Valvaster striatus* | Sea Star |
| *Leucetta chagosensis* | Sponge |

# LITERATURE CITED

Akiona, A.K., Zgliczynski, B.J., Agarwal, M.A., French, B.J., Hanna Holloway, N., Lubarsky, K.A., Shirley, M.E., Sullivan, C.J., and Sandin, S.A. (in press). A database of life history parameters for Pacific coral reef fish.

Amos, M. J. (2007). Vanuatu fishery resource profiles. Apia, Samoa: Secretariat of the Pacific Regional Environment Programme.

Andrew, N., Campbell, B., Delisle, A., Li, O., Neihapi, P., Nikiari, B., ... & Uriam, T. (2020). Developing participatory monitoring of community fisheries in Kiribati and Vanuatu. Fisheries Newsletter, 162, 32-38.

Australian Institute of Marine Science (AIMS). (2024) ReefCloud. https://doi.org/10.25845/g5gk-ty57

Babcock, R. C., Dambacher, J. M., Morello, E. B., Plagányi, É. E., Hayes, K. R., Sweatman, H. P., & Pratchett, M. S. (2016). Assessing different causes of crown-of-thorns starfish outbreaks and appropriate responses for management on the Great Barrier Reef. PloS one, 11(12), e0169048.

Bartlett, C. Y., Manua, C., Cinner, J., Sutton, S., Jimmy, R., South, R., ... & Raina, J. (2009). Comparison of outcomes of permanently closed and periodically harvested coral reef reserves. Conservation Biology, 23(6), 1475-1484.

Bhardwaj, J., & Kuleshov, Y. (2024). Monitoring and predicting marine heatwaves in Vanuatu. Environmental Research Communications, 6(12), 125005.

Buckwell, A., Ware, D., Fleming, C., Smart, J. C., Mackey, B., Nalau, J., & Dan, A. (2020). Social benefit cost analysis of ecosystem-based climate change adaptations: a community-level case study in Tanna Island, Vanuatu. Climate and Development, 12(6), 495-510.

Carlton, R., Dempsey, A., Thompson, L., Heemsoth, A., Lubarsky, K., Faisal, M., & Purkis, S. (2021). Global Reef Expedition Final Report. Khaled bin Sultan Living Oceans Foundation, Annapolis, MD. Vol 15.

Carter, R. (1990). Hydraulic and water quality studies, Erakor lagoons and Port Vila Harbour, Vanuatu. South Pacific Applied Geoscience Commission.

Chin, A., Lison de Loma, T., Reytar, K., Planes, S., Gerhardt, K., Clua, E., ... & Wilkinson, C. (2011). Status of coral reefs of the Pacific and outlook: 2011. Global coral reef monitoring network.

CITES. (2023). Appendices I, II and III. Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Dailer, M. L., Knox, R. S., Smith, J. E., Napier, M., & Smith, C. M. (2010). Using $\delta^{15}N$ values in algal tissue to map locations and potential sources of anthropogenic nutrient inputs on the island of Maui, Hawai 'i, USA. Marine pollution bulletin, 60(5), 655-671.

Dailer, M. L., Ramey, H. L., Saephan, S., & Smith, C. M. (2012). Algal $\delta^{15}N$ values detect a wastewater effluent plume in nearshore and offshore surface waters and three-dimensionally model the plume across a coral reef on Maui, Hawai 'i, USA. Marine pollution bulletin, 64(2), 207-213.

David, G. (1994). Traditional village fishing in fisheries development planning in Vanuatu. Science of Pacific Island peoples, Morrison J., Geraghty P. and Crowl L.(eds.). Institute of Pacific studies, The University of the South Pacific, Suva, Fiji, 1, 11-40.

David, G., & Cillaurren, E. (1992). National fisheries development policy for coastal waters, small scale village fishing and food self reliance in Vanuatu. Man and Culture in Oceania, 8, 35-58.

Department of Strategic Policy, Planning and Aid Coordination (DSPPAC). (2023). Post disaster needs assessment: Vanuatu tropical cyclones Judy and Kevin. Port Vila, Vanuatu.

Devlin, M., Smith, A., Graves, C. A., Petus, C., Tracey, D., Maniel, M., ... & Lyons, B. P. (2020). Baseline assessment of coastal water quality, in Vanuatu, South Pacific: Insights gained from in-situ sampling. Marine Pollution Bulletin, 160, 111651.

Doropoulos, C., Ward, S., Roff, G., González-Rivero, M., & Mumby, P. J. (2015). Linking demographic processes of juvenile corals to benthic recovery trajectories in two common reef habitats. PLoS One, 10(5), e0128535.

Drew, J. A., Amatangelo, K. L., & Hufbauer, R. A. (2015). Quantifying the human impacts on Papua New Guinea reef fish communities across space and time. PLoS One, 10(10), e0140682.

Ducarme, F., Dumas, P. P., & Kaku, R. (2023). Field inventory and population assessment of sea cucumbers from Vanuatu. SPC Bêche-de-mer Information Bulletin, (43), 4-10.

Dumas, P., Jimenez, H., Léopold, M., Petro, G., & Jimmy, R. (2010). Effectiveness of village-based marine reserves on reef invertebrates in Emau, Vanuatu. Environmental Conservation, 37(3), 364-372

Dumas, P., Gereva, S., Moutardier, M., Ham, J., & Kaku, R. (2015). Collective action and lime juice fight crown-of-thorns starfish outbreaks in Vanuatu. SPC Fisheries newsletter, 146, 47-52

Dumas, P., Ham, J., Kaku, R., William, A., Kaltavara, J., Gereva, S., & Léopold, M. (2017). Tectus (Trochus) nilotica search for suitable habitats can cause equivocal benefits of protection in village-based marine reserves. Plos one, 12(5), e0176922.

Eriksson, H., Albert, J., Albert, S., Warren, R., Pakoa, K., & Andrew, N. (2017). The role of fish and fisheries in recovering from natural hazards: Lessons learned from Vanuatu. Environmental Science & Policy, 76, 50-58.

Faivre, G., Sami, E., Mackey, B., Tomlinson, R., Zhang, H., Kotra, K. K., ... & Rand, E. (2021). Water circulation and impact on water quality in the southwest of Efate Island, Vanuatu. Marine Pollution Bulletin, 173, 112938.

Gillett, R. D. (2020). Aquarium products in the Pacific Islands: a review of the fisheries, management and trade. Pacific Community.

GEF Pacific. (2008) Ridge to Reef Programme Vanuatu National R2R Programme Document.

Gouezo, M., Olsudong, D., Fabricius, K., Harrison, P., Golbuu, Y., & Doropoulos, C. (2020). Relative roles of biological and physical processes influencing coral recruitment during the lag phase of reef community recovery. Scientific reports, 10(1), 2471.

Government of Samoa, Ministry of Natural Resources and Environment. (2024). Final Science Report: 2022 Samoa Ocean Expedition in support of the Samoa Ocean Strategy. Government of Samoa.

Hafezi, M., Sahin, O., Stewart, R. A., Connolly, R. M., Mackey, B., & Ware, D. (2020). Adaptation strategies for coral reef ecosystems in Small Island Developing States: integrated modelling of local pressures and long-term climate changes. Journal of Cleaner Production, 253, 119864.

Hafezi, M., Stewart, R. A., Sahin, O., Giffin, A. L., & Mackey, B. (2021). Evaluating coral reef ecosystem services outcomes from climate change adaptation strategies using integrative system dynamics. Journal of environmental management, 285, 112082.

Harborne, A. R., Mumby, P. J., & Ferrari, R. (2012). The effectiveness of different meso-scale rugosity metrics for predicting intra-habitat variation in coral-reef fish assemblages. Environmental Biology of Fishes, 94, 431-442

Hickey, F. R. (2006). Traditional marine resource management in Vanuatu: Acknowledging, supporting and strengthening indigenous management systems. SPC Traditional Marine Resource Management and Knowledge Information Bulletin. 20.

Hickey, F. R. (2008). Nearshore fisheries and human development in Vanuatu and other parts of Melanesia. SPC Traditional Marine Resource Management and Knowledge Information Bulletin, 24(1), 9-18.

Hickey, F. R., & Johannes, R. E. (2002). Recent evolution of village-based marine resource management in Vanuatu. SPC traditional marine resource management and knowledge information bulletin, 14, 8-21.

Hill, J. (2004). Reef Check Vanuatu Report July-August 2004.

Hill, J., and Wilkinson, C. (2004) Methods for Ecological Monitoring of Coral Reefs. Australian Institute of Marine Science.

IUCN. 2025. The IUCN Red List of Threatened Species. Version 2025-1. https://www.iucnredlist.org. Accessed on 21 May 2025.

Houk, P., & Raubani, J. (2010). Acanthaster planci outbreaks in Vanuatu coincide with ocean productivity, furthering trends throughout the Pacific Ocean. Journal of Oceanography, 66(3), 435-438.

Johannes, R. E. (1998). Government-supported, village-based management of marine resources in Vanuatu. Ocean & coastal management, 40(2-3), 165-186.

Klint, L. M., Jiang, M., Law, A., DeLacy, T., Filep, S., Calgaro, E., ... & Harrison, D. (2012). Dive tourism in Luganville, Vanuatu: Shocks, stressors, and vulnerability to climate change. Tourism in Marine Environments, 8(1-2), 91-109.

Komugabe-Dixson, A. F., de Ville, N. S., Trundle, A., & McEvoy, D. (2019). Environmental change, urbanisation, and socio-ecological resilience in the Pacific: Community narratives from Port Vila, Vanuatu. Ecosystem Services, 39, 100973.

Léopold, M., Beckensteiner, J., Kaltavara, J., Raubani, J., & Caillon, S. (2013). Community-based management of near-shore fisheries in Vanuatu: What works?. Marine Policy, 42, 167-176.

Léopold, M., David, G., Raubani, J., Kaltavara, J., Hood, L., & Zeller, D. (2017). An Improved Reconstruction of Total Marine Fisheries Catches for the New Hebrides and the Republic of Vanuatu, 1950–2014. Frontiers in Marine Science, 4, 306.

Lincoln, S., Vannoni, M., Benson, L., Engelhard, G. H., Tracey, D., Shaw, C., & Molisa, V. (2021). Assessing intertidal seagrass beds relative to water quality in Vanuatu, South Pacific. Marine Pollution Bulletin, 163, 111936.

Lovell, E., Sykes, H., Deiye, M. A. R. G. O., Wantiez, L., Garrigue, C., Virly, S., ... & Sulu, R. E. U. B. E. N. (2004). Status of Coral Reefs in the South West Pacific: Fiji, Nauru, New Caledonia, Samoa, Solomon Islands, Tuvalu and Vanuatu. Status of coral reefs of the world, 2, 337-362.

Maynard, J. A., & Done, T. J. (2008). Further bouts of bleaching and errant shore divers worsen recovery rates at Million Dollar Point and the SS President Coolidge, Vanuatu. Coral Reefs, 27, 975-975.

McClanahan, T. R., Schroeder, R. E., Friedlander, A. M., Vigliola, L., Wantiez, L., Caselle, J. E., ... & Cinner, J. E. (2019). Global baselines and benchmarks for fish biomass: comparing remote reefs and fisheries closures. Marine Ecology Progress Series, 612, 167-192.

McCormick, M. I. (1994). Comparison of field methods for measuring surface topography and their associations with a tropical reef fish assemblage. Marine ecology progress series. Oldendorf, 112(1), 87-96.

Mies, M., Dor, P., Güth, A. Z., & Sumida, P. Y. G. (2017). Production in giant clam aquaculture: trends and challenges. Reviews in Fisheries Science & Aquaculture, 25(4), 286-296.

National Oceanic and Atmospheric Administration. (NOAA)(2025). Historical hurricane tracks. NOAA Office for Coastal Management. https://coast.noaa.gov/hurricanes/ . Accessed June 3, 2025.

Naviti, W., & Aston, J. (2000). Status of coral reef and reef fish resources of Vanuatu. In Regional Symposium on Coral Reefs in the Pacific: Status and Monitoring (pp. 22-24).

Nemeth, M., & Appeldoorn, R. (2009). The distribution of herbivorous coral reef fishes within fore-reef habitats: the role of depth, light and rugosity. Caribbean Journal of Science, 45(2–3), 247-253.

Nimoho, G., Seko, A., Iinuma, M., Nishikawa, K., & Wakisaka, T. (2013). A baseline survey of coastal villages in Vanuatu. SPC Traditional Marine Resource Management and Knowledge Information Bulletin, 32, 2-84.

Noo Raajje. (2025). Maldives Coral Reef Assessment 2021. La Jolla, California, USA.

Pakoa, K., Friedman, K., Tardy, E., & Lasi, F. (2008). Epi Island trochus and sea cucumber resource status and recommendations for management. Secretariat of the Pacific Community.

Pakoa, K., Raubani, J., Siaosi, F., Amos, G., & Ham, J. (2013). The status of sea cucumbers fisheries and resources in Vanuatu. Secretariat of the Pacific Community, Noumea, New Caledonia.

Pakoa, K., William, A., Neihapi, P., & Kikutani, K. (2014). The status of green snail (Turbo marmoratus) resource in Vanuatu and recommendations for its management. Secretariat of the Pacific Community, Noumea, New Caledonia.

Purcell, S. W., Amos, M. J., & Pakoa, K. (2004). Releases of cultured sub-adult Trochus nilotica generate broodstock for fishery replenishment in Vanuatu. Fisheries Research, 67(3), 329-333.

Raubani, J. J. J., & Arnason, R. (2006). Community fisheries management (CFM): Future considerations for Vanuatu. Port Vila: Vanuatu Fisheries Department.

Raubani, J., Eriksson, H., Neihapi, P. T., Baereleo, R. T., Amos, M., Pakoa, K., ... & Andrew, N. (2017). Past experiences and the refinement of Vanuatu’s model for supporting community-based fisheries management. SPC Traditional Marine Resource Management and Knowledge Information Bulletin, 38(June 2017), 3-13.

Senior, K. M., Smith, S. D., Logan, M., & Purcell, S. W. (2020). Biophysical habitat features explain colonization and size distribution of introduced trochus (Gastropoda). Frontiers in Marine Science, 7, 223.

Steenbergen, D. J., Raubani, J., Gereva, S., Naviti, W., Arthur, C., Arudere, A., ... & Andrew, N. L. (2022). Tracing innovation pathways behind fisheries co-management in Vanuatu. Ambio, 51(12), 2359-2375.

Sulu, R., Cumming, R., Wantiez, L., Kumar, L., Mulipola, A., Lober, M., ... & Pakoa, K. (2002). Status of coral reefs in the southwest Pacific to 2002: Fiji, Nauru, New Caledonia, Samoa, Solomon Islands, Tuvalu and Vanuatu. Status of coral reefs of the world, 181-201.

Sustainable Fisheries Group, University of California Santa Barbara (2019). Vanuatu Summary Report. Santa Barbara, California, USA.

Tavue, R. B., Neihapi, P., Cohen, P. J., Raubani, J., & Bertram, I. (2016). What influences the form that community-based fisheries management takes in Vanuatu? SPC Traditional Marine Resource Management and Knowledge Information Bulletin, 37(2016), 22-34.

Terashima, H., Ham, J., Kaku, R., William, A., Malisa, M., Gereva, S. R., & Kakuma, S. (2018). A field survey of the green snail (Turbo marmoratus) in Vanuatu: Density, effects of transplantation, and villagers' motives for participation in transplantation and conservation activities. SPC Traditional Marine Resource Management and Knowledge Information Bulletin, 39.

United Nations Development Programme (UNDP). (2012). Amal-Crab Bay Community Resource Management Initiative, Vanuatu. Equator Initiative Case Study Series. New York, NY.

Valentin, F., Herrscher, E., Zinger, W., Ponchelet, J., André, G., Bray, F., ... & Willie, E. (2024). Changing subsistence practices in pre-European populations of South Vanuatu. Journal of Archaeological Science: Reports, 59, 104756.

Vanuatu Fisheries Department. (2009). Vanuatu National Marine Aquarium Trade Management Plan. Noumea, New Caledonia: Pacific Community.

Vanuatu Fisheries Department. (2014) Community Based Coastal Resource Management (CBCRM) plan for Malakula. Port Vila, Vanuatu.

Vanuatu Fisheries Department. (2019a). Vanuatu National Roadmap for Coastal Fisheries: 2019-2030. Noumea, New Caledonia: Pacific Community. 24p.

Vanuatu Fisheries Department. (2019b). Vanuatu National Sea Cucumber Fishery Management Plan 2019-2024: a national policy for the management and development of Vanuatu's sea cucumber fishery. Noumea, New Caledonia: Pacific Community. 24p.

Vanuatu Fisheries Department. (2022). 2022 Crown-of-Thorns outbreak clean up report. Efate, Vanuatu. 10p.

Vanuatu National Statistics Office. (2020a). Vanuatu 2020 national population and housing census: basic tables report. Volume 1, version 2. Vanuatu National Statistics Office

Vanuatu National Statistics Office. (2022b). Vanuatu National Agriculture Census 2022 Report. Port Vila, Vanuatu: Vanuatu National Statistics Office.

Vava'u Ocean Initiative (2023). 2022 Tonga Expedition Report. La Jolla, California, USA.

Wilkinson, C., Brodie, J. (2011). Catchment Management and Coral Reef Conservation: a practical guide for coastal resource managers to reduce damage from catchment areas based on best practice case studies. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre. Townsville, Australia.

**A science diver at Vot Tande Island in Torba Province**
// Joe Lepore

LONG GOD YUMI STANAP

BLUE PROSPERITY VANUATU

WAITT INSTITUTE

SCRIPPS INSTITUTION OF OCEANOGRAPHY