

A Volcanic Lost World



Proceedings of the Lord Howe Rise and
South Tasman Sea Research Symposium

May 2025 — Sydney, Australia





Acknowledgement of Country

The symposium organisers acknowledge the Gadigal people of the Eora Nation, Traditional Custodians of the land and waters on which we gathered for this symposium in May 2025. We honour their continued enduring relationship with this Country and pay deep respect to their Elders — past and present — and to emerging leaders who continue to uphold Cultural Knowledge and care for place. We recognise that sovereignty was never ceded.

We extend this acknowledgement and respect to all Traditional Custodians of the lands that symposium participants travelled from.

With gratitude, we also honour the Indigenous Peoples of Oceania, whose deep custodianship extends across the Tasman Sea and into the Pacific. These lands and waters have long been held through cultural practice, navigation, storytelling, and kinship. For tens of thousands of years, Traditional Custodians have maintained sacred relationships with the Sea Kin, the ika who call these waters home, and the seamount ancestors whose ancient contours hold the stories of Earth's memory.

Indigenous cultures hold many ocean creation stories. While varied, they share some common foundations. The ocean is ancestral. Land, sea and sky are fundamentally interconnected. The ocean is a living entity and provider for all people. This report seeks to honour Indigenous Peoples' deep knowledge of ocean science and the cultural importance of ocean systems, developed over millennia.

Many Indigenous people have advised on and contributed to this research symposium and the proceedings report. We are so grateful for your advice and the opportunity to learn through collaboration, which has ensured this report is so much more than a scientific resource. We thank all of you for sharing your time and expertise, and we acknowledge the heavy colonial load, and deep cultural responsibility of your contributions.

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Foreword by the High Seas Alliance and WWF-Australia

The Tasman Sea – connecting Australia and New Zealand, south of New Caledonia – is a wondrous example of how oceans connect cultures, communities, ecosystems, economies and histories. Within the Tasman Sea lie several true biodiversity hotspots, including the South Tasman Sea and associated seamount chains, and the Lord Howe Rise. These areas comprise a volcanic lost world punctuated by towering seamounts, home to a plethora of unique and special species. Nonetheless, no truly comprehensive and contemporary account of these extraordinary places currently exists.

In May 2025, around 70 leaders, scientists, policymakers and advocates came together in Sydney, Australia, to address this gap over two days. This uniquely multidisciplinary initiative explored the ecological, geological, and cultural significance of the Lord Howe Rise and South Tasman Sea, as well as their uses. Collectively, around 30 scientific papers, two discussion panels, a collaborative large-scale mural and many conversations built a rich picture of these areas and took an important step towards identifying knowledge gaps and conservation opportunities.

This proceedings report provides a summary of the papers presented at the symposium and the panel discussions within. In doing so, it brings together ecological data, cultural perspectives, and policy insights from eminent scientists and policy specialists from around 10 countries. We are immensely grateful for their generous contributions of data, analysis and thinking, and pay tribute to those researchers who were unable to contribute directly, but whose work over many decades has made an indelible mark on these proceedings.

In addition to the papers and discussion panels collated in this report, invaluable contributions were made to the symposium by a number of speakers, including Ambassador Peter Thomson, the UN Secretary-General's Special Envoy for the Ocean; Dr Filimon Manoni, the Pacific Ocean Commissioner; Katrina Maguire, Division Head, International Environment, Reef and Ocean, Australian Government; James Bradley, author of *Deep Water*; and Kate Wawatai, deep-sea submersible pilot. Their time, expertise and support are greatly appreciated.

Throughout the symposium, speakers reminded us that the ocean is not only a reservoir of life but also of history, from the geological marvels of seamounts to the devastating legacies of colonialism etched into its depths. Naturally, much of our discussion looked to the future. We heard a clear and resounding call for science and cultural heritage to be primary drivers of conservation

efforts, and for these efforts to be grounded in an understanding of relationships between all parts of the ocean, as well as between the marine species that inhabit and travel through these extraordinary places.

The papers presented in the following pages represent a significant collation of knowledge, but some important gaps remain, including significant issues that are not touched on in this report. The symposium convenors are currently working on a comprehensive review of the scientific literature and a gap analysis, which will provide a companion to this proceedings report.

This symposium foregrounded Indigenous Knowledge systems and science leadership in an effort to elicit a rich, balanced and multifaceted understanding of these special places. We aimed to identify cultural values beyond the tangible, led by eminent Indigenous researchers from across the Pacific region; we hope many others will help inform this evolving conversation.

WWF-Australia and the High Seas Alliance are honoured to support this work and express our deep gratitude to the Deep-Ocean Stewardship Initiative and the Deep Sea Conservation Coalition for their expertise and guidance, and to the Australian Government, the Big Blue Ocean Foundation, Oceans 5 and the Bloomberg Ocean Fund for their collaborative approach and financial support.

This report is both a scientific resource and a narrative of possibility — one that invites collaboration, courage, and care. We hope it will serve as a shared point of reference on which to further build our understanding of this volcanic lost world and, critically, to inform measures to care for it into the future.

Rebecca Hubbard
Director of the High Seas Alliance

Dermot O’Gorman
CEO WWF-Australia



'Waipunarangi' by Te Ara Whakarei Ra Gossage (Ngāti Wai, Ngāti Manuhiri, Ngāti Ruanui); acrylic and whenua on canvas. Waipunarangi means water that pools in the sky. It is also a star name of the Matariki (Pleiades) star constellation, which represents the rain, a connector of sky to land and sea.

Science and Stewardship of A Volcanic Lost World: A DOSI Perspective

The Deep-Ocean Stewardship Initiative (DOSI) is the world's largest network dedicated to deep-ocean science, policy and stewardship. DOSI operates through eight specialist Working Groups and two cross-cutting Task Forces, each addressing key aspects of deep-ocean stewardship, such as biodiversity, climate change and marine resources. DOSI brings together over 1,100 experts and 3,600 newsletter subscribers from more than 115 countries, forming a truly global community. This network of experts integrates scientific and humanistic knowledge to inform deep-ocean governance. DOSI engages with policymakers, cultivates capacity and ocean diplomacy, and creates a collaborative community to advance deep-ocean stewardship.

DOSI's role in the research symposium was to develop and deliver the event's scientific program. The symposium marked an important first step in a broader effort to gather and synthesise knowledge about this unique and largely unexplored region. Regionally focused, multidisciplinary marine science conferences are rare, which made the symposium's format particularly significant. Its integration of diverse marine science disciplines and other knowledge within a regional context proved to be both engaging and effective for scientific participants. The event offered a valuable opportunity to generate multi-disciplinary research in the study area, fostering a deeper understanding across fields.

From DOSI's scientific perspective, this model holds strong potential for advancing understanding of deep-sea regions, features, and ecosystems through integrated, collective study. Bringing together a broad range of stakeholders in this manner encouraged more inclusive and comprehensive engagement, an approach that could meaningfully advance the stewardship of deep-ocean and other marine environments.

The symposium's scientific narrative began with the 'Ocean systems' session, grounding the audience in the physical and geological context of regional marine life. A key takeaway from this session, cited throughout the ensuing science sessions, was the interconnected nature of our ocean. The participants gained an understanding of the region's complex oceanographic patterns, which highlighted the dynamic connectivity of the basin via interacting currents and processes. Through the temporal evolution of the region's geology, the audience also gained an insight into its intricate geomorphology, characterised by an extensive plateau with major seamount chains, and vast deep abyssal plains.

The symposium progressed with two Biodiversity and Ecology sessions – 'Above and below the surface' and 'Life on the seafloor' – shifting focus to biology, from migratory species to deep-sea communities.

The importance of the Lord Howe Rise and nearby seafloor features for species like whales, turtles and seabirds was emphasised. Data from the Migratory Connectivity in the Oceans (MiCO) system identified the region as a global hotspot for migratory connectivity. Vulnerable marine ecosystems have also been identified in the region, including cold-water corals with extreme longevity. Further, leatherback turtles that migrate throughout the region are facing significant extinction risk, largely due to incidental capture as bycatch in fisheries. While technological advances have allowed the science community to make significant progress, knowledge gaps remain, particularly regarding deep-sea fauna, as highlighted in presentations on the region's seafloor biodiversity and deep-water shark populations.

Building on these sessions, the second day of the symposium opened with the 'Human-ocean interactions' session, which examined the cultural importance and impacts of human activity on these ecosystems. The audience learned about the critical gap in understanding and integrating Cultural Ecological Knowledge (CEK) with scientific data and solutions to address this, including collaborative approaches to incorporate Cultural Knowledge into ecological assessments. Preliminary results were also presented from the latest expedition to the Lord Howe Rise in March 2025, revealing damage to seafloor communities from bottom-trawling activities. The symposium concluded with the 'Science-driven conservation' session, highlighting how data, mapping, and evidence-based strategies are being used to address regional challenges, ending the symposium on a forward-looking note. This session underscored the importance of accounting for knowledge gaps, biogeographic patterns, climate change, and ecological connectivity in Area-Based Management Tools (ABMTs), to ensure the effective design of climate-smart marine protected area (MPA) networks in future ocean governance frameworks.



Together, these themes framed a comprehensive scientific foundation for discussing effective, precautionary protections that are responsive to both ecological complexity and existing and emerging threats in the region. The two expert panels built on this foundation to more broadly examine the opportunities and challenges in regional and global ocean governance, with panellists sharing valued insights on knowledge integration, including Cultural Ecological Knowledge, collaborative management, and strengthening ocean stewardship within evolving governance mechanisms.

DOSI recognises these proceedings as a pivotal step in transforming scientific knowledge into actionable policy for the Lord Howe Rise and South Tasman Sea region. They provide a solid foundation for future interdisciplinary collaboration, informed decision-making, and the implementation of precautionary protections. This work is particularly relevant within existing governance frameworks, such as the South Pacific Regional Fisheries Management Organisation (SPRFMO), and emerging protection mechanisms under the Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (BBNJ Agreement). By actively engaging in this process, DOSI helps bridge science and other knowledge with policy, viewing this work as a meaningful step toward real-world stewardship and more effective, inclusive, and ecosystem-based governance of deep-ocean environments in one of the world's most ecologically significant regions.

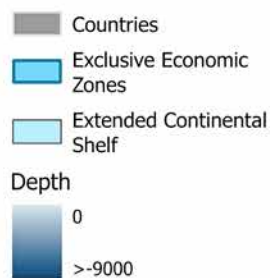
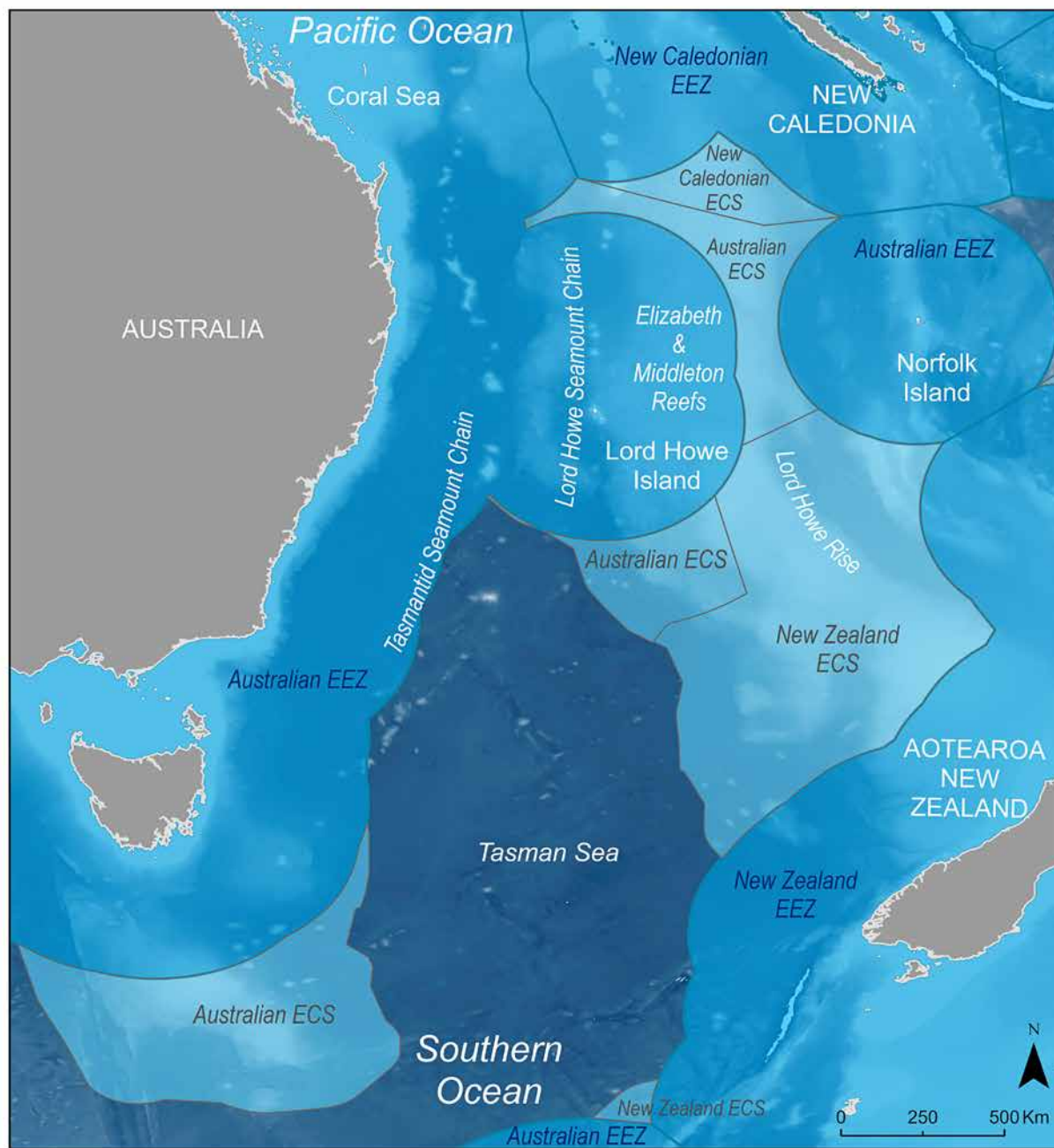
Maria Baker
DOSI Executive Director



Learn more at DOSI-project.org
or contact us at
DOSIcomms@gmail.com.

If you work in marine science or governance and are interested in sharing your expertise to inform and support the conservation and sustainable management of the deep ocean, join DOSI today.

Maritime boundaries and key features within the Tasman Sea

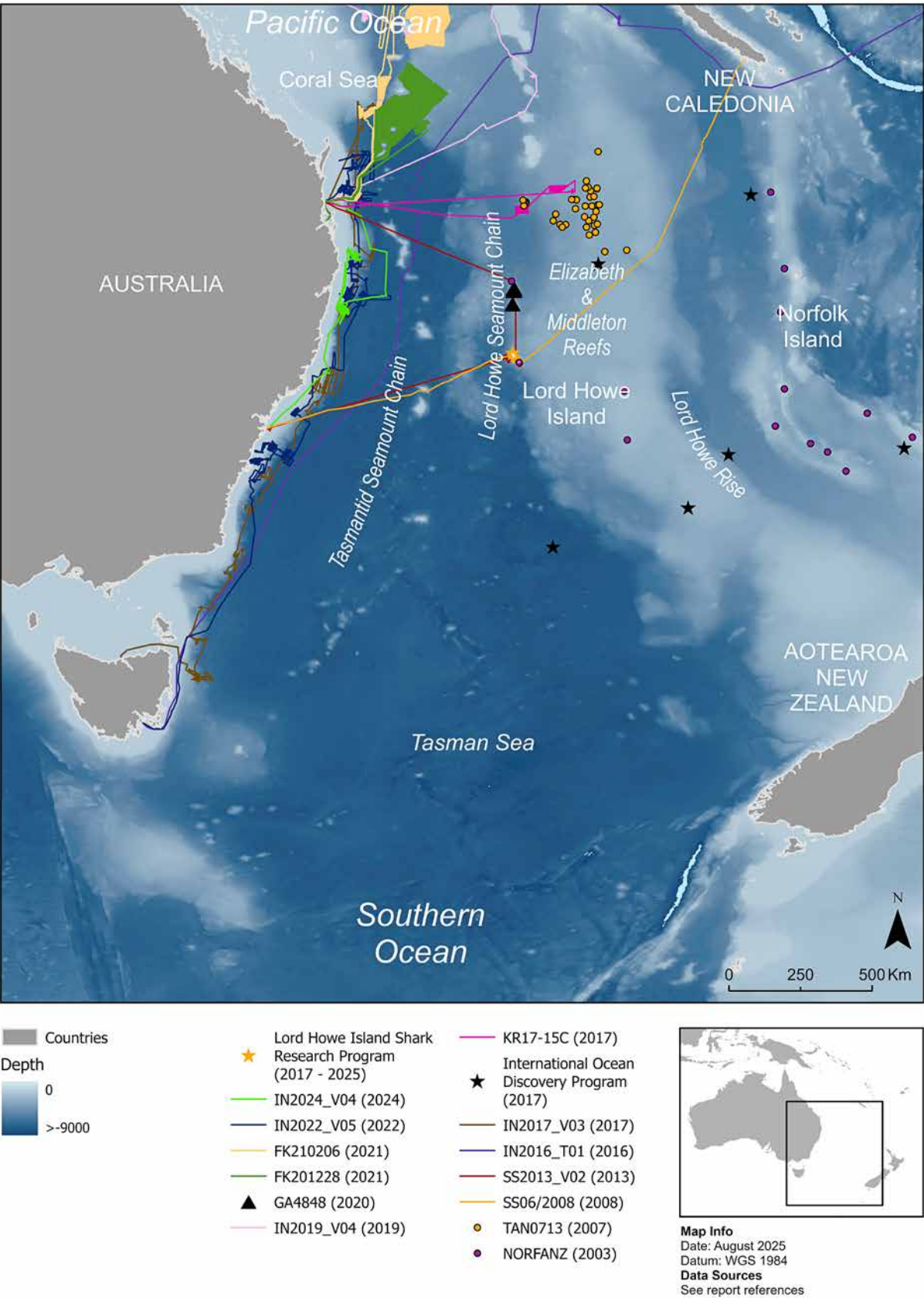


Map Info
 Date: August 2025
 Datum: WGS 1984

Data Sources

Countries: ESRI World Countries <https://hub.arcgis.com/datasets/esri:world-countries/explore?location=-0.413678%2C0.000000%2C1.99>
 Bathymetry: GEBCO <https://www.gebco.net/data-products/gridded-bathymetry-data>
 EEZ / ECS: Marine regions <https://www.marinerregions.org/eez.php>

Indicative map of research effort in the area, 2003-present

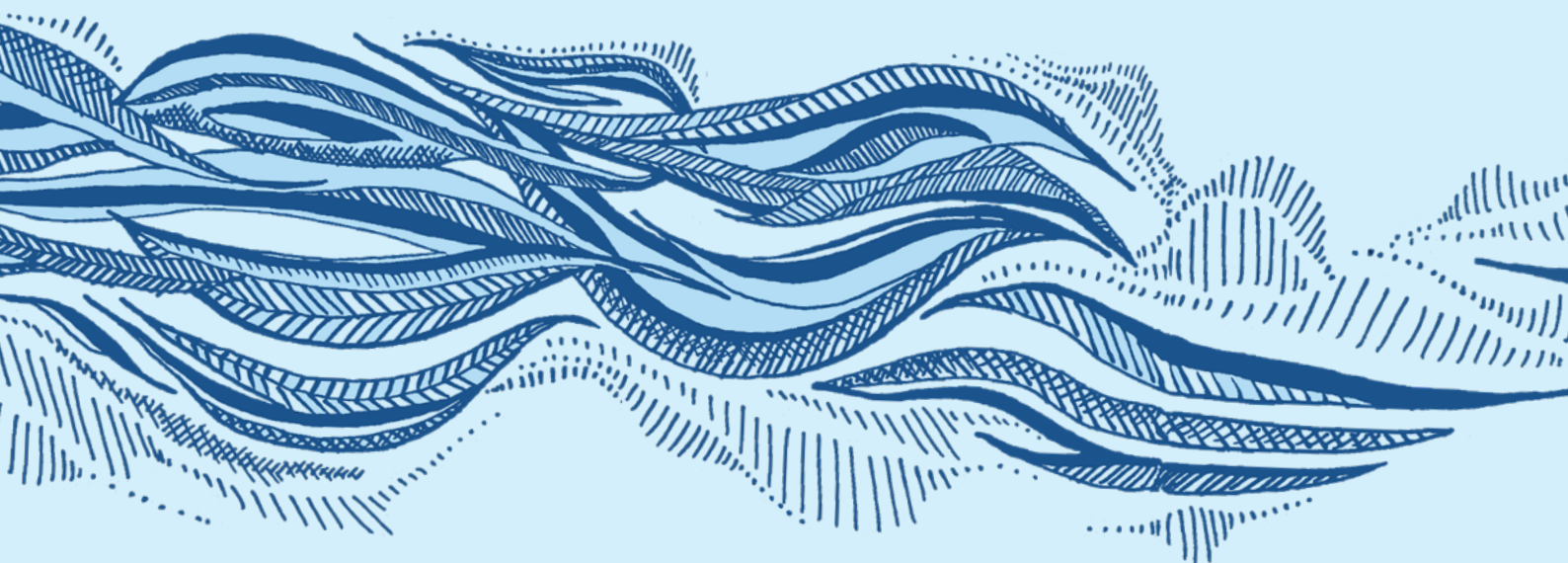


Many thanks to researchers who presented at the symposium and provided details of their research expeditions in the area, which are collated in this map. This map does not incorporate all relevant expeditions; it is an initial attempt to demonstrate research effort over the past two decades, which could serve as the basis of more comprehensive mapping.

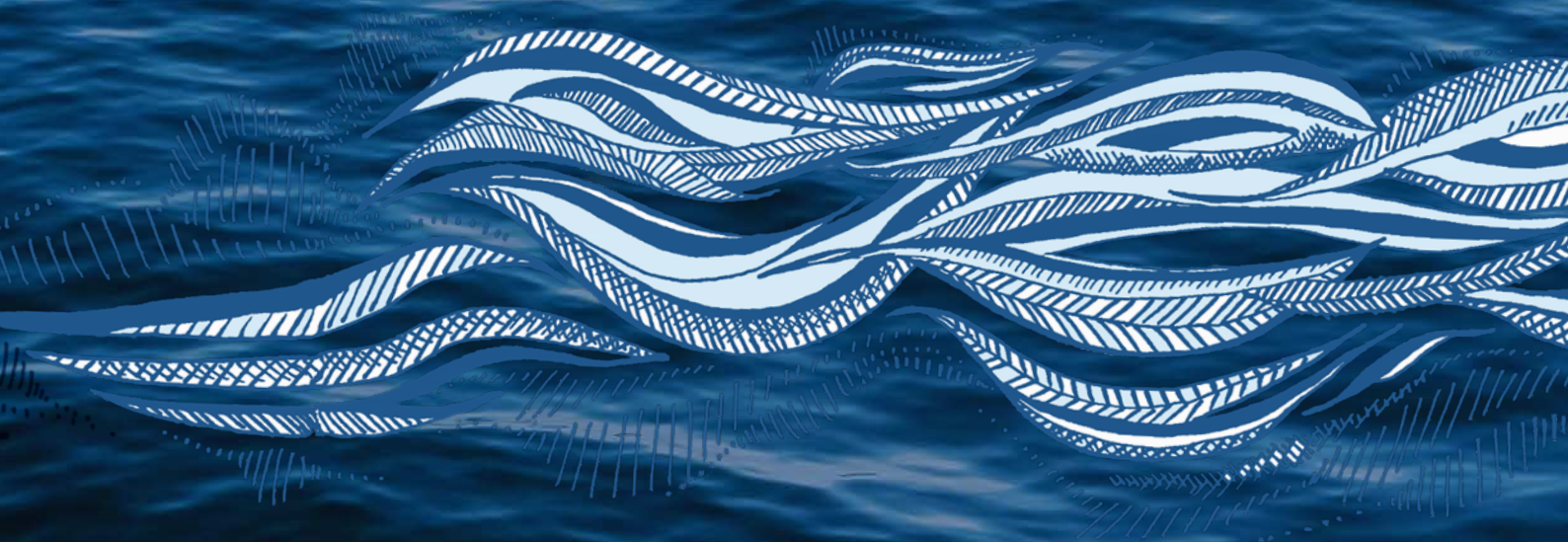
**'Yarluwar/Ocean Currents' by
Nathalia Baechtold, a Ngarrindjeri
Mimini from South Australia living on
Gumbaynggirr Country; ink on paper.**

Artist's statement: 'Yarluwar means the ocean and ocean currents. Yarluwar is what connects us all. My artwork is inspired by Country and follows the lines I see in the natural environment.'

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Ocean systems



Mapping the geological foundations of Northern Zealandia

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The origins of Zealandia and the Lord Howe Rise

The Lord Howe Rise – a largely submerged plateau in the southwest Pacific – is the largest component of Northern Zealandia, part of the now-submerged continent of Zealandia. Evidence from geophysical data suggests Zealandia separated from Australia and Antarctica during the Late Cretaceous Period, but its geological character has historically been poorly understood compared to continents above sea level. Over the past two decades, our understanding of the geological foundations of the Lord Howe Rise and the South Pacific has been significantly advanced through collaborative research by geologists, including those from Australia, New Zealand and New Caledonia. Collectively, this work has allowed us to reconstruct the tectonic and volcanic history of this area to understand its role in the broader evolution of the entire region.

To fully understand the geological origins of the Lord Howe Rise, we need to step back around 500 million years. Around that time, most continents on Earth joined together to form the supercontinent Gondwana (Li and Powell, 2001). Extensive magmatic (volcanic) arcs spanned its eastern margin, undergoing cycles of advance and retreat over hundreds of millions of years. This magmatism formed extensive new domains of crust at the eastern edge of Gondwana, the crust now comprised in eastern Australia, west Antarctica and Zealandia. By the Early Cretaceous Period, Australia and Antarctica had started to separate from the rest of Gondwana and from each other. The volcanic mountain ranges at the eastern margin of Gondwana were similar to the present-day Andes or Aleutian islands before this breakup, lying adjacent to the Pacific Ocean. Through successive volcanic and tectonic processes, the crust within these mountains was thinned to less than half its original thickness. The result of this thinning was the stretched crust of Zealandia, including the structures that now make up the Lord Howe Rise (Mortimer et al, 2023). Subsequently, the stretched Zealandia crust broke away from Australia with the Tasman Sea beginning to open

around 85 million years ago (Gaina et al, 1998). Finally, the once-elevated but now stretched, thinned magmatic arc sank almost completely below sea level.

How does the crust that once comprised a high mountain range on land sink so far beneath the ocean surface? Death Valley in California provides an excellent example of this process. Parts of Death Valley are currently below sea level, but the whole of the Western United States was previously a much higher mountain range that has been gradually stretching and broken apart. The rift basins of East Africa provide another spectacular example of the landscapes that can evolve due to the stretching of Earth's crust. When the Earth starts to stretch apart we see the opposite process of a mountain range forming. The Earth's surface in rift basins subsides as the crust gets thinner and cools, and over time, it can sink far below sea level. Today, the results of the rifting process that produced the Lord Howe Rise are obscured by water and seafloor sediments. However, using remote sensing, we can image the structures produced by rifting of the Lord Howe Rise - and we can delineate the valleys and ridges generated through this stretching and sinking process (Muller et al, 2017), and how they have been filled with marine sediments, resulting in the seafloor morphology we see today.

Mapping and sampling expeditions 2012-2016

We can do a lot with remote sensing, but to really understand the geological heritage of Zealandia – a continent for which little direct evidence existed until 20 or 30 years ago – it is necessary to directly sample the seafloor. This is a major challenge, because so much of Zealandia lies below kilometres of water. A key research expedition in this area was the ECOSAT II voyage in 2016, undertaken on board Australia's Marine National Facility (MNF), the *RV Investigator*. This voyage tracked the location of the Mesozoic magmatic arc, the ancient volcanic arc along the Gondwanan margin, to the Fairway Ridge. The voyage departed from Fiji; traversing the southern margin of New Caledonia; then collected

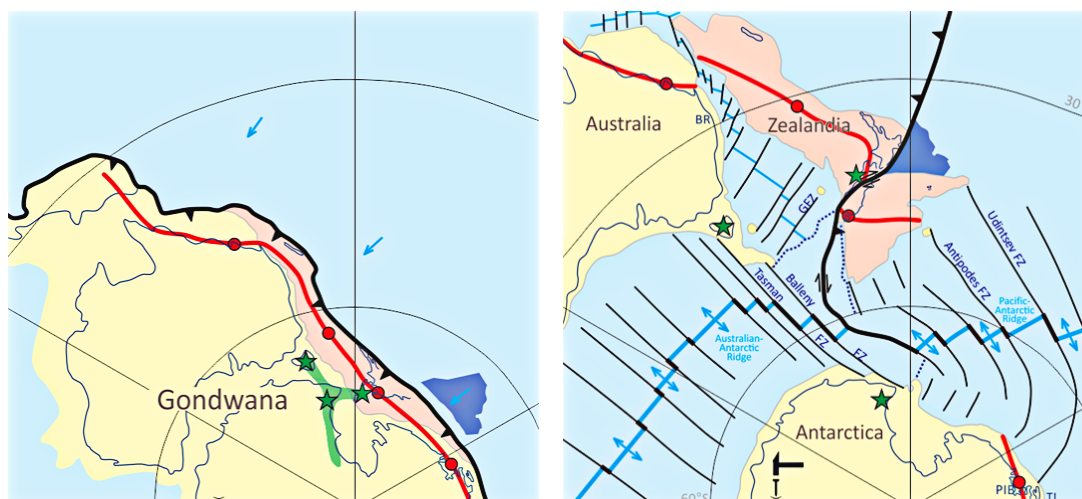


Figure 1: Gondwana 100 million years ago (left) and today (right) (after Mortimer et al, 2017).

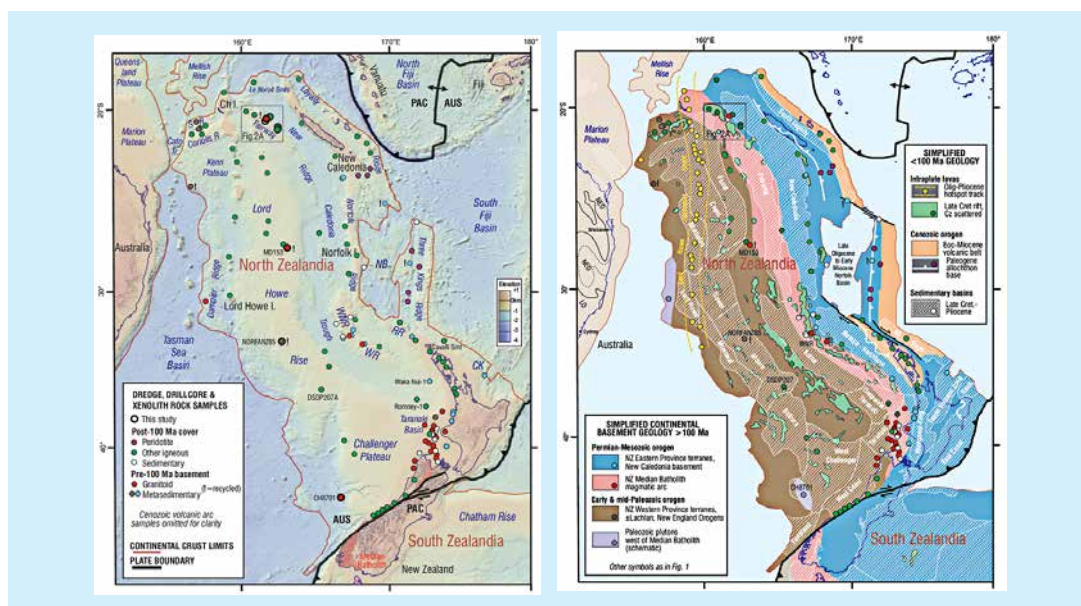


Figure 2: The first geological map of Northern Zealandia. (Source: Mortimer et al, 2023).

samples from the northern part of the Lord Howe Rise before transiting down the eastern coast of Australia to Hobart, Tasmania.

The purpose of the voyage was to target rock samples and data from the Fairway Ridge, a 400-km-long (approximately), fault-controlled basement high that separates the New Caledonia and Fairway sedimentary basins, on the north-eastern part of Lord Howe Rise. Fairway Ridge is one of the two end-member candidates for the location of the Mesozoic magmatic arc linking Queensland to Zealandia and West Antarctica. We identified submarine canyons and other areas not covered in mud and collected samples from those sites on the seafloor.

We collected rocks from seven sites, recovering a mixture of rock types, including sandstone, limestone and also some granite cobbles within a sandstone. These samples originate from both the submerged continental crust and volcanic formations associated with the continent's post-rift magmatic history. While no in-situ basement rocks were recovered, we can infer that the basement samples formed within 10-100 km of the sampling locations.

'Fingerprinting' rocks on the Lord Howe Rise

To test competing hypotheses for the volcanic history and connections of the Lord Howe Rise, we extracted tiny grains from the recovered rocks and subjected

them to laboratory analysis. The results of this analysis reveal that key rock samples we had recovered formed somewhere between 100 and 135 Ma, very similar to specific rock units found in New Zealand. We can look at the geochemical compositions of these rocks as a further way to fingerprint their origin, comparing the specific geochemical composition of the new Lord Howe Rise rock samples with those already catalogued, to uniquely tie those rocks to their 'relatives' in other parts of the region, for example in New Zealand and Queensland. The end result is that we have a much better idea of what the geological map of Zealandia looks like (see Fig. 2). Previously, no such map existed. Now, we're in the process of adding extra data points, to build a much richer and more detailed map.

Creating the first geological map of Zealandia

Zealandia is central to unravelling the evolution of both eastern Australia and the entire south Pacific. To understand the origins of Fiji, Papua New Guinea, Solomon Islands – and the Lord Howe Rise – we need to understand Zealandia. Our work – building on the work of many researchers over the past two decades, has enabled us to reconstruct over 100 million years of geological history that is enabling us to fully appreciate the geological heritage of this region. By integrating seafloor mapping, sampling, geochronology, and geochemical analyses, we have addressed a critical gap in knowledge and offer new perspectives on the tectonic processes that have shaped the southwest Pacific. As a result of this collaborative work, we now have a much better understanding of the Lord Howe Rise and the surrounding region.

Associated paper

Mortimer N, Williams S, Seton M, Calvert A, Waight T, Turnbull R, Nelson D, Palin M, Ramezani J, Sagar MW and Tulloch A (2023) Reconnaissance basement geology and tectonics of North Zealandia. *Tectonics* 42(10) p.e2023TC007961.

Acknowledgements

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Tracing the underwater volcanic ancestry of Lord Howe Island on the Lord Howe Rise

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The volcanic ancestry of Lord Howe Island

Lord Howe Island is a beautiful and incredibly isolated World Heritage site about 600 km off the coast of New South Wales, lauded for its unique volcanic landforms and endemic species. Geologists have known for some time the island is an extinct volcano that last erupted about seven million years ago. We know this because of the radiometric dating of volcanic rocks (basalts) from the island (McDougall et al, 1981). We also know that it erupted through the continental crust that makes up the Lord Howe Rise, part of the submerged continent of Zealandia (Mortimer et al, 2017). After the eruption of the volcano that formed Lord Howe Island, there was collapse of the volcanic centre forming a caldera, followed by gradual subsidence (McDougall et al, 1981). Therefore, the landforms that we see on Lord Howe Island today are principally controlled by its volcanic history.

Although Lord Howe Island has the appearance of being incredibly isolated, it is part of a family of volcanoes with a shared history. The seas of eastern Australia contain two prominent north-south trending chains of seamounts – the Lord Howe Seamount Chain and the Tasmanid Seamount Chain (Fig. 1). The Tasmanid Seamount Chain mainly erupts through the oceanic crust of the Tasman Sea in the south and central part of the trail, and into continental crust to the north. The Lord Howe Seamount Chain mainly erupts through continental crust and includes a number of older seamounts north of Lord Howe Island, which have now subsided below sea level, but previously allowed carbonate reefs to develop on their summits. These include Middleton and Elizabeth reefs, Gifford Seamount, Capel Bank, Kelso Bank, Argo Bank, Nova Bank and the Bellona Plateau. Several smaller and un-named seamounts lie south of Lord Howe Island, with the largest being Flinders Seamount on the Monawai Ridge.

Both chains of seamounts are age-progressive and get progressively older towards the north. Collectively and individually, these seamounts are havens for marine life and are biodiversity hotspots (DSEWPaC, 2012).

What are mantle plumes?

These age-progressive seamount chains are formed by rapid northward motion of the Australian plate over a slowly moving mantle source (Seton et al, 2019). This mantle source is what we call a mantle plume. A mantle plume is a column of hot material that rises from the core-mantle boundary (deep plumes) or from upper mantle instabilities (shallow plumes). As it rises, it interacts with the Earth's lithosphere, where high heat and lower pressure facilitates the melting of rock, erupting a huge volume of volcanic material and forming a Large Igneous Province (LIP). An example of a LIP is the Siberian Traps, which was responsible for the world's worst mass extinction event in which an estimated 90% of marine species died (Erwin, 2006).

As the plate moves away from the mantle source, the conduit of the mantle plume interacts with the surface, which results in a chain of age-progressive volcanoes forming at the surface as the plate continues to move over the stationary hotspot. The most famous example of these types of volcanoes are the ones found along the Hawaiian islands.

While we know these linear chains exist in the vicinity of the Lord Howe Rise, and we know broadly the processes which formed them, our geochronological and geochemical knowledge of these chains is quite limited. This hampers our ability to trace the complete volcanic history of these seamount chains from their inception, which would improve our understanding of this unique volcanic system.

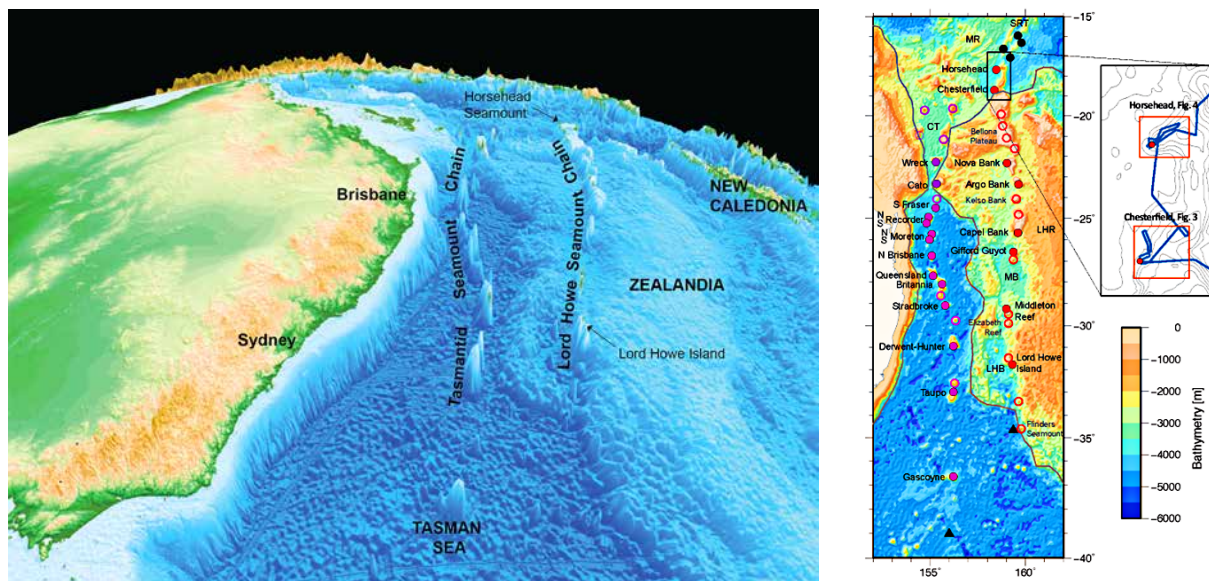


Figure 1: (Left) Perspective view of the bathymetry of the Tasman Sea showcasing the linear trail of seamounts of the Lord Howe and Tasmanid seamount chains. (Right) Individual Tasmanid seamounts (purple) and Lord Howe seamounts (red), with solid filled circles indicating seamounts with published age dates. The black triangles depict the predicted position of a present-day hotspot associated with these trails. The survey data from the Horsehead and Chesterfield sites from the 2012 voyage are also shown. Figure taken from Seton et al, (2019).

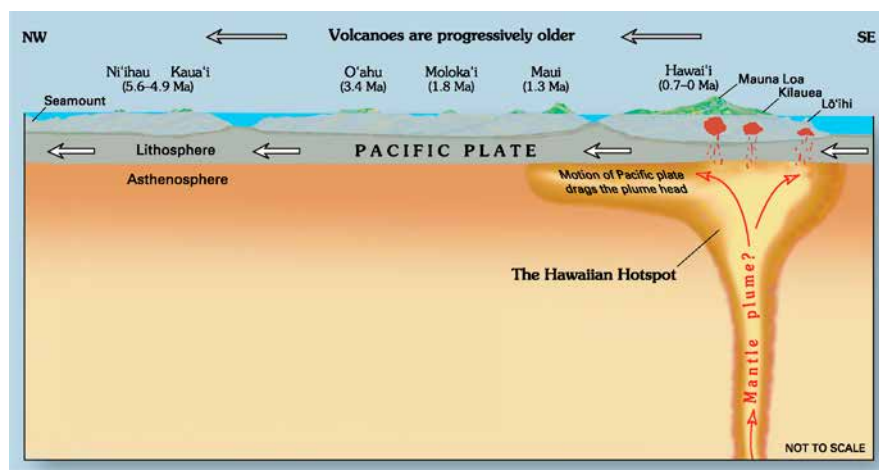


Figure 2: A diagram showing the Hawaiian deeply sourced mantle plume and the series of age-progressive volcanoes that form the Hawaiian Islands. Image source: Joel E. Robinson, USGS., Public domain, via Wikimedia Commons.

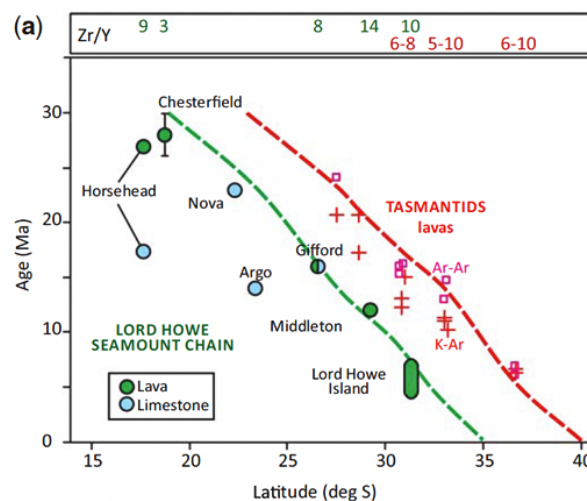


Figure 3: Plot showing the latitude and age of dated Lord Howe Seamount Chain and Tasmanid lavas (modified from Mortimer et al, 2018).

Geophysical mapping and dredging campaigns 2012-2019

Over the past decade, to address this knowledge gap, we conducted swath bathymetry, geophysical mapping and dredging campaigns on the *RV Southern Surveyor* (in 2012) and *RV Investigator* (in 2019) to map the morphology and sample basement from the underwater volcanoes associated with the Lord Howe Seamount Chain. During these expeditions, we collected rock samples from various seamounts along the northern and central portions of this chain using dredging techniques.

Geochronological analysis of the volcanic rock samples collected during the campaigns revealed some important findings. Based on our analysis, we have been able to revise age dates for numerous seamounts in the area. The oldest intraplate volcano associated with the Lord Howe Seamount Chain is Horsehead Seamount, located approximately 1,600km north of Lord Howe Island, has been dated to around 32 million years. Other seamounts in the northern portion of the chain, such as Argo Bank, produced ages clustering around 21 million years. The ages of the volcanic rocks become progressively younger towards the south, with Lord Howe Island erupting around seven million years ago. These results confirm that the volcanic activity associated with the Lord Howe Seamount Chain exhibits an age-progressive trend, consistent with the northward motion of the Australian plate over a relatively stationary mantle plume or hotspot. The oldest volcanism occurred at Horsehead Seamount, with subsequent volcanic edifices forming as the plate continued to migrate northward.

In addition to volcanic samples, deep and shallow water corals (e.g. *Porites*) from Kelso Seamount and Argo Bank and *halimeda*-dominated rudstones from Kelso Bank were recovered. There were three main types of corals: deep water corals, which were often slightly altered and had iron-manganese crusts around them; *Halimeda*-dominated rudstones; and massive or sub-massive corals heads, usually *Porities*, with algal crusts, worms, bivalves and muds. We also recovered a collection of more detrital samples that included multiple types of coral fragments, algae, basaltic fragments, muds, and impressions of other coral surfaces.

Our work on establishing seamount and coral ages, compositions and morphology will enhance our understanding of biodiversity and resource value of Australia's Temperate East Marine Park Network and New Caledonia's Natural Park of the Coral Sea. Continued exploration and sampling of the Lord Howe Seamount Chain, particularly in the younger, southern portions, will be crucial for fully elucidating the spatio-temporal evolution of this significant volcanic feature within the broader tectonic and oceanographic context of the southwest Pacific.

Conclusion

Our research represents a major step forward in unravelling the volcanic ancestry of Lord Howe Island and the broader Lord Howe Seamount Chain. By combining swath bathymetry, geophysical mapping, and dredging campaigns, we have filled a critical knowledge gap and provided new insights into the volcanic processes that shaped this region. The Lord Howe Seamount Chain is not merely a series of underwater volcanoes — it is a geological archive of ancient volcanism and continental breakup. Continued exploration and integration of geological, geophysical, and oceanographic data will be vital for deepening our understanding of this “lost volcanic world” and its role in Earth's dynamic history.

Associated paper

Seton M, Williams S, Mortimer N, Meffre S, Micklethwaite S, Zahirovic S (2019) 'Magma production along the Lord Howe Seamount Chain, northern Zealandia', *Geological Magazine*, 156(9):1605-1617

Acknowledgments

We acknowledge the use of the CSIRO Marine National Facility (<https://ror.org/01mae9353>) and grant of sea time on *RV Investigator* in undertaking this research and the crew who helped make this research possible. We thank the Australian Research Council for funding part of this research through grant DP200100966.

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The geomorphic evolution of the Tasmantid Seamount Chain

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This paper describes geomorphic features of oceanic volcanoes along the Tasmantid Seamount Chain, and the influence of several processes on their evolution: the northward movement of the Australian Plate, erosion, subsidence, and carbonate accretion. High-resolution bathymetry is used to identify evidence of erosion, carbonate accretion and mass movement on each volcano, and a conceptual model is proposed to explain the evolution of the Tasmantid Seamount Chain since the Oligocene. This paper summarises research undertaken during the lead author's PhD (Johnson, 2024), and recently published in a paper (Johnson et al, 2025).

Formation of oceanic volcanoes

Oceanic volcanoes erupt onto the seafloor as a seamount. The vast majority of volcanoes that erupt through the seafloor cease erupting and remain submerged. However, a small proportion continue to erupt, breach the surface of the ocean and form volcanic islands. As soon as a volcano breaches the surface of the ocean, it is subject to erosion, which starts to reshape the volcano. Over time, wave erosion may develop a marine shelf, and, if given enough time, may effectively remove the top of the volcano and form a guyot. Guyots are characterised by a completely or near-flat summit.

Guyots mark one possible evolutionary pathway for oceanic volcanoes, but not the only one. In warmer waters, reefs and carbonate material tend to form on or around the margin of volcanoes. This is geomorphologically important as reefs attenuate wave energy by up to 90% (Hopley, 1982). Waves carry less energy when they reach the coastline and therefore have less erosive potential. Rather than a guyot forming, a volcanic island may subside and instead develop into an atoll (Fig. 1).

Lord Howe Island illustrates how marine erosion and carbonate correction can modify the geomorphology of an oceanic volcano. It erupted ~6.6 Ma (Gilmore et al, 2020) upon the Australian plate, southwards of the southern limit of reef growth and then predominantly eroded, forming the extensive marine shelf which surrounds it (Woodroffe et al, 2006). The Australian plate has moved northwards at a rate of 7cm^{yr}-1 (70kmMa⁻¹; DeMets et al, 2010) and

moved into warmer waters at the southern limit of reef growth. Reef accretion is apparent through the fossil reef on the marine shelf, and the fringing reef on the western side of the island (Linklater et al, 2015).

Evolution of the Tasmantid Seamount Chain

The Tasmantid Seamount Chain is an age-progressive hot spot chain with the oldest volcanoes in the north and the youngest in the south (Fig. 2). The Tasmantid Seamount Chain from as early as 50 Ma (Richards et al, 2018) through to the Late Miocene (McDougall & Duncan, 1988; Williams et al, 2015; Crossingham et al, 2017; Mortimer et al, 2018).

Like the Lord Howe Chain, the Tasmantid Seamount Chain is located on the northward-moving Australian Plate. Two types of lithospheric crust underlie the chain, oceanic crust and continental crust. The majority of volcanoes are located on the young and elastic oceanic crust. Whereas the northern volcanoes are located on thicker and older continental crust. This contrast in the underlying lithosphere results in differing rates of subsidence along the chain, with those on the oceanic crust subsiding faster than those on the continental crust (Johnson et al, 2025).

Our research explored the geomorphology of the Tasmantid Seamount Chain to deduce their post-eruptive geomorphic evolution. Bathymetric data was collected during two voyages upon the Schmidt Ocean Institute's R/V *Falkor* (FK201228 and FK210206), and supplemented with open-access bathymetry from AusSeabed. Using bathymetry, geomorphic mapping of nineteen volcanoes within the Tasmantid Seamount Chain was undertaken, specifically identifying evidence of erosion, carbonate accretion and mass movement. Dredges and sampling from previous voyages were used to ground truth observations. Based on this mapping, the thickness of carbonate, rate of erosion, and rate of subsidence were calculated. Details on these calculations can be found in Johnson et al, (2025).

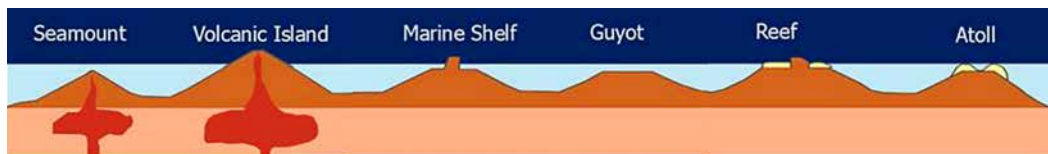


Figure 1: Geomorphic forms of oceanic volcanoes.

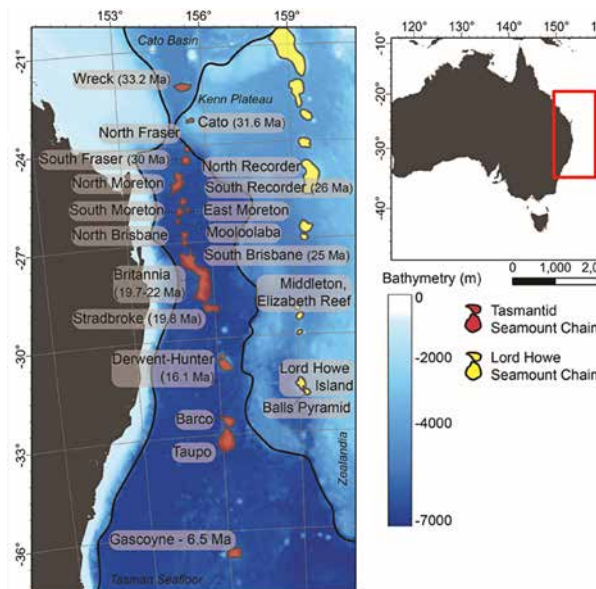


Figure 2: The location of volcanoes within the Tasmanid Seamount Chain and the neighbouring Lord Howe Seamount Chain. Ages from Crossingham et al, (2017). The black line represents the boundary between continental and oceanic seafloor, adapted from EarthByte Global Continent-Ocean Boundaries (Müller et al, 2016). Bathymetry source GEBCO (2024). Sourced from Johnson et al, (2025).

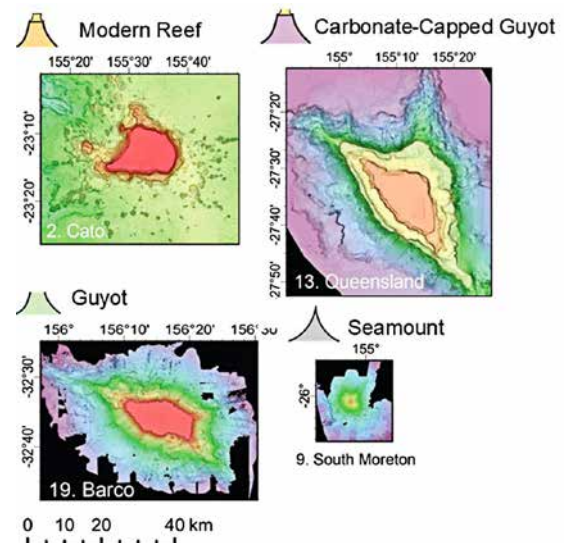


Figure 3: A simplified representation of the four geomorphic forms of oceanic volcano identified in the Tasmanid Seamount Chain.

The geomorphic forms of the Tasmanid Seamount Chain

Four geomorphic forms were identified in the Tasmanid Seamount Chain (Fig. 3).

1. **Modern reefs:** Volcanoes that have an active carbonate reef system growing at modern sea level e.g. Wreck Reef and Cato Reef.
2. **Carbonate-capped guyots:** Submerged volcanoes with a carbonate cap overlying the volcanic substrate, but no longer actively accreting reef material.
3. **Guyots:** Submerged volcanoes that have been completely eroded, leaving a flat summit.
4. **Seamounts:** Volcanoes which never erupted to sea level.

Each volcano was classified into a geomorphic form.

The classification and maps of each volcano can be found in Johnson et al, (2025). Figure 4 illustrates the spatial distribution of these different geomorphic forms and the depth of their upper surface along the length of the Tasmanid Seamount Chain. Several key findings emerged:

- The modern reefs are located in the northernmost portion of the chain, where the volcanoes are situated on thicker, continental crust. This may have allowed for more sustained carbonate accretion over time as the crust will have subsided more slowly.
- The southernmost volcanoes are flat-topped guyots with no evidence of substantial carbonate accretion, transitioning into carbonate-capped guyots north of 32°S. These volcanoes are situated on thinner, faster subsiding, oceanic crust.

We generated a conceptual model of the geomorphic evolution of the Tasmanid Seamount Chain since the Oligocene (Fig. 5). Key points include:

- The Tasmanid Seamount Chain erupted upon a progressive-northwards moving plate, gradually moving the volcanoes into warmer water
- The first dated evidence of carbonate accretion occurred during the Mid-Miocene (Exon et al, 2005) and carbonate appears to have initiated successively on volcanic islands southwards. The timing of carbonate accretion may be linked to the mid-Miocene Climatic Optimum, a period of global warmth.
- The uniform depth of the drowned carbonate platforms (~400 m) suggests a synchronous drowning event, potentially related to the end of the mid-Miocene Climatic Optimum and associated environmental changes.

The geomorphic evolution of the Tasmanid Seamount Chain is strongly influenced by both the northward migration of the volcanoes into warmer waters, as well as the underlying crustal properties that govern the rate of volcanic edifice subsidence. Continued investigation of these seamounts and their carbonate histories will provide valuable insights into the complex interplay between tectonic, oceanographic and environmental processes shaping this region over geological timescales.

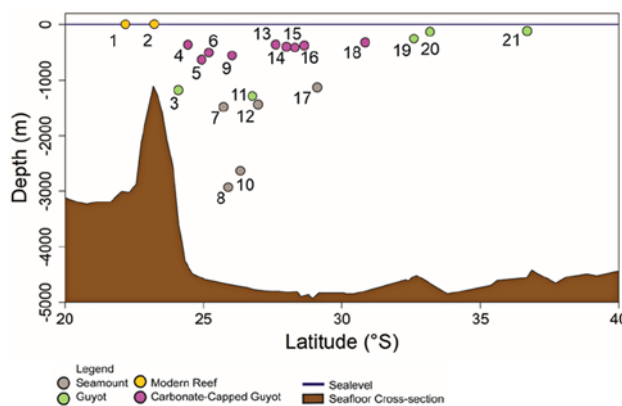


Figure 4: Distribution of volcano morphology viewed along a bathymetric cross-section/ Brown polygon represents seafloor depth parallel to the Tasmanid Seamount Chain from GEMCO (2024). Sourced from Johnson et al, (2025).

Research gaps

The geomorphic evolution of the Tasmanid Seamount Chain is a complex interplay of volcanic activity, marine erosion, carbonate accretion, and tectonic processes. Our research has provided valuable insights into the spatial and temporal patterns of these processes, highlighting the importance of both the northward migration of the Australian plate and the underlying crustal properties in shaping the morphology of an oceanic volcano. While this has helped to build a much more detailed understanding of the Tasmanid Seamount Chain's evolution, several research gaps remain.

Geochronological and geochemical data for many of the seamounts remain limited, particularly those in the southern portion of the chain. Further sampling and analysis could establish a more comprehensive timeline of volcanic activity and carbonate accretion.

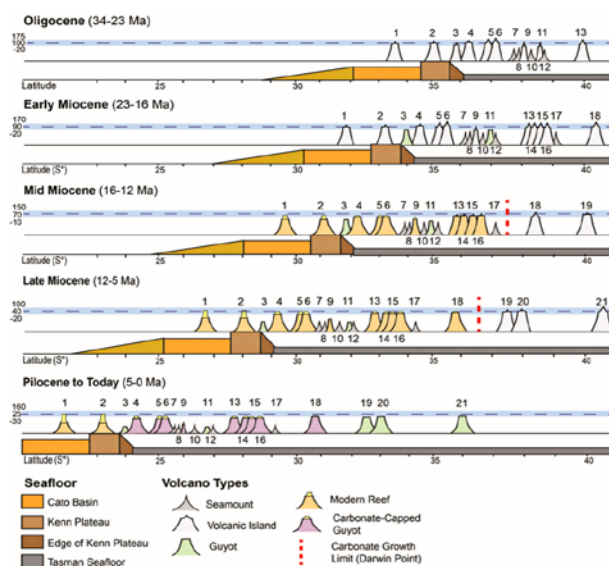


Figure 5: A conceptual model of the evolution of the Tasmanid Seamount Chain, from the Oligocene to the present. 1. Wreck, 2. Cato, 3. North Fraser, 4. South Fraser, 5. North Recorder, 6. South Recorder, 7. North Moreton, 8. East Moreton, 9. South Moreton, 10. Mooloolaba, 11. North Brisbane, 12. South Brisbane, 13. Queensland, 14. North Britannia, 15. Central Britannia, 16. South Britannia, 17. Stradbroke, 18. Derwent-Hunter, 19. Barco, 20. Taupo, 21. Gascoyne. Sourced from Johnson et al, (2025).

Acknowledgements

This research was undertaken under an Australian Government Research Training Program, and a scholarship from the University of Wollongong for a Higher Research Degree. We would like to acknowledge the Schmidt Ocean Institute and the principal scientists and crew aboard voyages FK201228 and FK210206.

Data availability

Multibeam data is available on the AusSeabed data portal - <https://portal.ga.gov.au/persona/marine>

Associated paper

Johnson AM, Dickson ME, Hamylton S and Woodroffe CD (2025) 'The geomorphic evolution of the Tasmanid Seamount Chain', *Marine Geology*, 486:107560.

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Ball's Pyramid, one of the above surface features of the Lord Howe Rise. Source: © Greenpeace / Dillon Hayman.

Mapping the Balleny Seamount Trail across the Tasman

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The name 'Balleny Seamount Trail' reflects a hypothesis – that the seamounts in the Tasman Sea were created by the same plume now located under the Balleny Islands, which are located around 325km north of the Pennell Coast, Antarctica (see Fig. 1). However, some previous studies assert that such a connection is not consistent with plate reconstructions (Merle et al, 2022). This paper presents results from a 2018/19 voyage on the RV Investigator, which undertook the first bathymetric mapping of the oldest section of seamounts, which extends from offshore eastern Tasmania across the Tasman Sea to the Lord Howe Rise. We also present age determinations and geochemical analyses of basaltic rocks dredged from 16 seamounts.

Testing the proposed Balleny Seamount Chain

To explore the geological and tectonic history of the Balleny Seamount Trail, we conducted a dedicated research voyage on CSIRO's RV *Investigator* in 2018/2019 specifically targeting the Tasman Sea region that hosts these seamounts. Through this research, we sought to answer the following questions:

1. Is the Balleny Seamount Trail an age progressive seamount chain?
2. Is it associated with the Balleny Islands and plume?
3. Are any of the seamounts guyots which provide depth constraints?
4. If it is a seamount chain, then how can such a 'small' chain with small seamounts and a large apparent gap in seamounts, persist?

Detailed seafloor bathymetry mapping revealed a diversity of seamount morphologies, including flat-topped features that may represent former islands, as well as smaller seamounts that never reached the sea surface (see Fig. 2). During dredge sampling of the seamounts we collected volcanic rock samples which were subjected to geochemical and geochronological analysis. Geochemical fingerprinting of the volcanic rocks confirmed that they are consistent with an origin from a mantle plume source,

supporting the hypothesis that the Balleny Seamount Trail is related to the same hotspot mechanism as the other regional seamount chains. However, the geochronological data provided some unexpected results.

The seamounts rise from the Tasman Sea abyssal plain (~4000-5500 metres below sea level) and exhibit a mix of conical and flat-topped gross morphologies, with varying heights between 1500-3000m. We have interpreted the seamounts with flat tops as the result of sub-aerial exposure of these edifices early in their existence, which eroded soon after formation. We found that most seamounts sampled formed between 70 and 35 million years ago. The ages of the volcanic rocks generally showed an age-progressive trend from south to north, indicative of northward plate motion over a stationary hotspot. However there were some notable exceptions. Some seamounts in the southern portion of the trail yielded ages that were significantly older than predicted by the hotspot paradigm. This suggests that the tectonic and volcanic history of the Balleny Seamount Trail may be more complex than a straightforward northward migration over a stationary mantle plume. Other factors, such as transient uplift and subsidence of the seafloor, may have played an important role in shaping this volcanic feature over geological time.

The seamounts that do not fit the normal age progressive pattern include one that is the youngest of the Tasmanid Seamount Chain (Gouldi, as shown in Fig. 1, formed ~4 Myr ago), while a group to the east of the South Tasman Rise (Awatea, Funereus, Zeehan and Heemskirk, shown in Fig. 1) likely correlates with continental rifting events between Australia and Antarctica. These complexities in the Balleny Seamount Trail's development may have broader implications for understanding regional oceanographic and climatic changes.

An explanation for why the Tasmanian Gateway took so long to open

In addition to helping us to understand the evolution of the Balleny Seamount Chain, this research has implications for understanding the onset of the Antarctic Circumpolar Current (ACC), which plays a critical role

Figure 1: Seamounts of the Balleny Islands and the Balleny Seamount Chain.

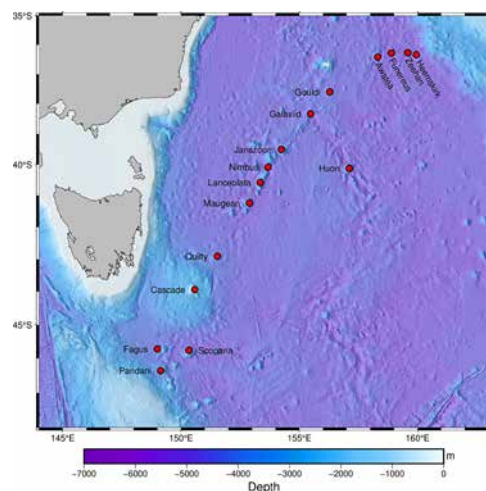


Figure 2: Seamount age estimates along the research area.

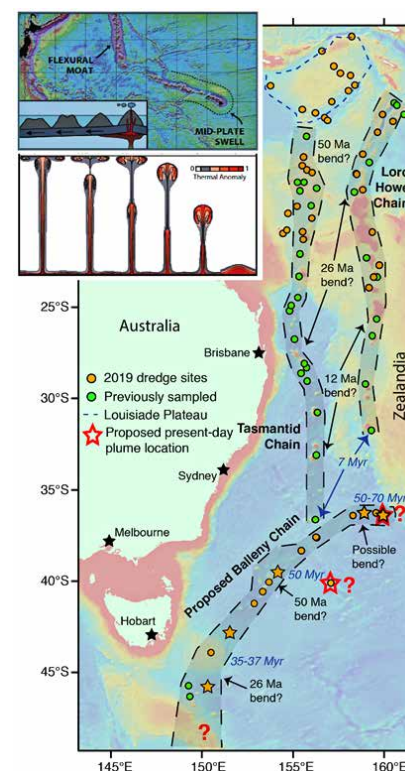
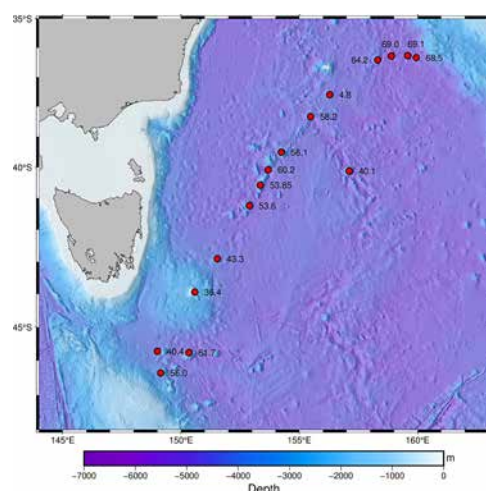


Figure 3: Study area showing age progressive volcanic seamount chains – Tasmanid, Lord Howe, and Balleny, including our 2019 sample sites.

in this oceanic region by keeping Antarctica thermally isolated from warmer lower latitude waters. We have been working with oceanographers also at the Institute of Marine and Antarctic Studies to understand when this change occurred and how it may have played a role in the dramatic transition that occurred around 34 Ma, when glaciers expanded across Antarctica and the continent transitioned from a ‘greenhouse’ world to an ‘icehouse’ world. Previous models have struggled to explain why the Tasmanian Gateway and the ACC did not develop earlier. Our most recent modelling predicts that plume-related uplift of the region around Tasmania could resolve this conundrum (Scher et al, 2015).

Conclusion

The Balleny Seamount Trail is a key volcanic feature in the southwest Pacific, offering valuable insights into the region’s tectonic and volcanic evolution. Data from the 2018 Investigator voyage strongly linked the trail to the Balleny Islands, offshore Antarctica, supporting a mantle plume origin for the entire volcanic chain. The findings of our research not only enhance our understanding of the geological development of the Balleny Seamount Trail but also have broader implications for the initiation

of the Antarctic Circumpolar Current between 30 and 40 million years ago. However, some key questions remain—particularly whether earlier, undiscovered volcanism within the Lord Howe Rise may also be related to the same plume.

Associated paper

Forthcoming

Acknowledgements

Joanne Whittaker, Rebecca Carey, Maria Seton, and Bob Duncan, The Institute for Marine and Antarctic Studies (IMAS) at the University of Tasmania

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Paleogeography of carbonate environments along the Lord Howe Island and Seamount Chain

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We have been investigating the history of reef and carbonate development around Lord Howe Island and the neighboring seamounts over the past two decades. This paper summarises our research on reef growth and associated communities for Lord Howe Island, Ball's Pyramid and Elizabeth and Middleton Reefs, based on bathymetry, underwater imagery, sub-bottom profiles, sediment cores and grabs, much of it gathered during our research cruises on the *RV Southern Surveyor* in 2008 (Brooke et al, 2010) and 2013. We consider what insights can be obtained through examination of stratigraphic data and morphological analyses over past millennia, constrained by paleo-environmental factors but particularly by sea level history.

The evolution of key features within the Lord Howe Seamount Chain

Oceanic volcanoes erupt to form seamounts. If a volcano continues to build above sea level, it will form a volcanic island subject to wave erosion. If marine erosion persists it may result in a guyot, a flat-topped submerged volcano. Alternatively, carbonate may accrete at sea level, resulting in the formation of modern reefs and limiting erosion (Johnson et al, 2025).

The coral reef along the western margin of Lord Howe Island is the southernmost in the Pacific Ocean and an excellent example of this process. The island is part of a chain of volcanic islands and seamounts and lies at the transition from temperate to tropical carbonate production. On the shelf around the island there are fossil reefs more than 20 times larger in area than the modern reef, indicating more prolific coral environments 10,000 years ago. To the south of Lord Howe Island lies Ball's Pyramid – a spectacular monolith rising more than 500 m out of the sea – and to the north lie atoll-like Elizabeth and Middleton Reefs. Our work seeks to understand the processes that have shaped these features and associated reefs (see Fig. 1).

Impact of reefs on volcanic islands

When a coral reef surrounds a volcanic island it reduces wave impact on the shoreline and instead of steep cliffs

that characterise reefless islands, hillslopes are shaped by fluvial incision. The contrast is apparent when comparing Lord Howe Island with Bora Bora in the Society Islands (see Fig. 2). Much of Lord Howe Island is dominated by wave erosion resulting in spectacular cliffs, except where the reef runs along part of its western coast. In contrast, Bora Bora is entirely surrounded by an extensive coral reef, with erosion caused predominantly by fluvial and subaerial processes.

Charles Darwin developed his theory of coral reef development in 1835 during the voyage of the *Beagle* across the Pacific Ocean. When Darwin looked out from the slopes of Tahiti at the barrier reef that surrounds the neighbouring island, Moorea, he hypothesised that the volcanic island might undergo subsidence, but that upward coral growth on the encircling reef could ultimately result in a coral atoll once the central part of the volcano had sunk beneath the sea. Had he seen Bora Bora, further along the Society Chain, it would have provided further support to his thinking.

Shelf and fossil reefs around Lord Howe Island and Ball's Pyramid

Coring and dating have provided important evidence about carbonate sediments, past sea level, and environmental conditions. An extensive submerged fossil reef occurs on the shelf around Lord Howe Island at a depth of 30-50 m, as shown in Fig. 1. When sea level was lower, Lord Howe Island would have looked more like Bora Bora. Ages determined on fossil corals extracted from the upper few metres of the reef's surface have shown that reefs encircling the island flourished between 10,000 and 8,000 years ago (Woodroffe et al, 2010). A similar but smaller reef occurred on Ball's Pyramid.

We have also found evidence of earlier coral reef growth during interglacial periods. A core at the jetty on Lord Howe Island intersected a coral reef that formed during the last interglacial around 120,000 years ago, and this is underlain by an older reef unit considered to have accreted in the previous interglacial. Occurrence of these reef limestones is significant because the location presently marks the southern latitudinal limit to reef

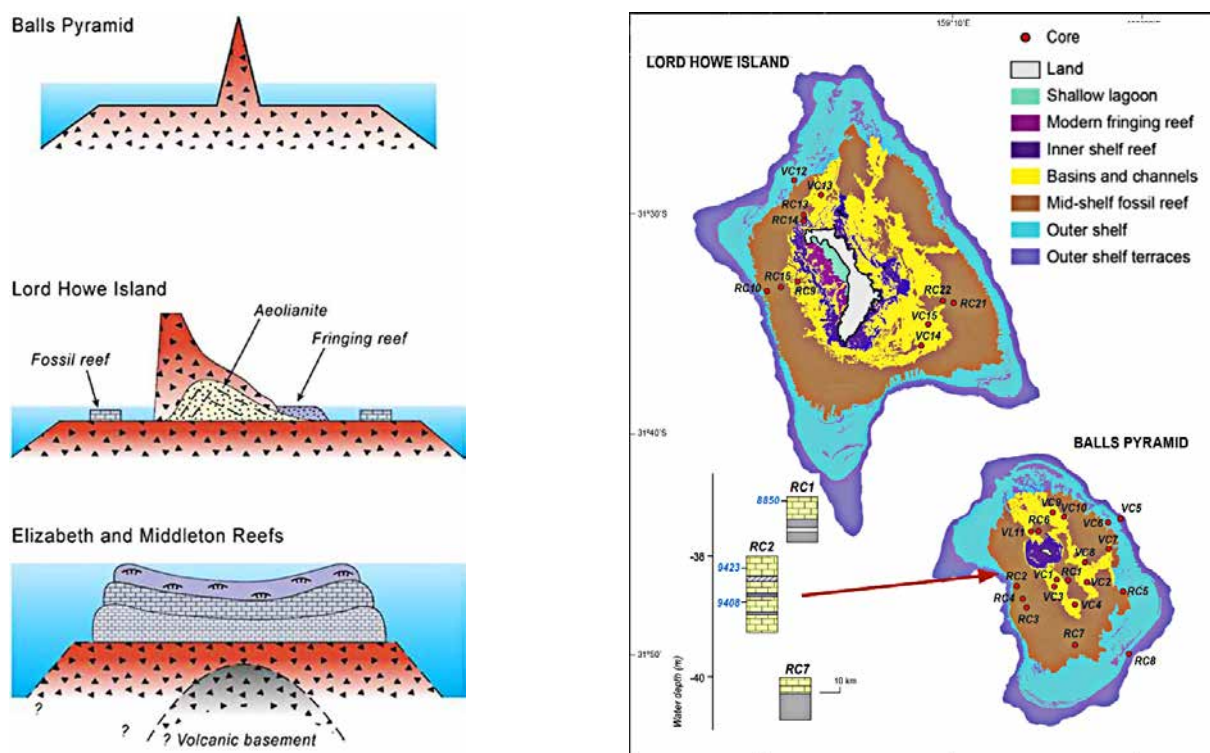


Figure 1: A schematic representation of Ball's Pyramid, a single monolith on a truncated platform, Lord Howe Island, on a similar platform but with a modern reef, submerged fossil reefs and lithified dune sands (aeolianite), and Elizabeth and Middleton Reefs, which may lie on a subsided volcanic peak or a truncated platform. The map on the right shows the geomorphological features on the shelves around Lord Howe Island and Ball's Pyramid. Three typical cores into limestone on the mid-shelf fossil reef are shown with radiometric ages in years (source: Linklater et al, 2018; Woodroffe et al, 2023).

formation in the Pacific Ocean, and the island is gradually moving northwards on the Australian plate, transitioning from reefless to reef-encircled.

Additionally, we have investigated the modern, Holocene-aged fringing reef system that impounds the lagoon. As the sea rose following the melting of polar ice sheets, the fossil reefs on the shelves of Lord Howe and Ball's Pyramid were largely drowned. A short episode of mesophotic coral accretion occurred on the Lord Howe Island shelf 2,500 years ago, while submerged in 30m water depth (Woodroffe et al, 2010). The reef on the western margin of Lord Howe Island backstepped and recommenced growing around 6,000 years ago as sea level stabilised at its present level (Woodroffe et al, 2023). Initially, branching corals flourished in the lagoon, but muds and sands then infilled the lagoon, with relatively little further accretion in the past three millennia (Kennedy and Woodroffe, 2000). This modern reef system is restricted to the western side of the island, in contrast to the more extensive fossil reefs. The submerged shelves of both Lord Howe Island and Ball's Pyramid presently support mesophotic corals in waters up to 60–90 m deep (Linklater et al, 2019), but these veneer the fossil reefs and do not appear to be vertically accreting.

Elizabeth and Middleton Reefs

Our investigations into Elizabeth and Middleton Reefs to the north indicate that these have experienced lagoon infill with carbonate sand. Coring on the southern margin of Middleton Reef encountered Pleistocene-aged limestone that is likely a 120,000-year-old reef, at about eight metres depth. Dating has shown that the modern reef was growing on this foundation by 6,000 years ago, and reached present sea level about 5,000 years ago (Woodroffe et al, 2004). These reefs look very much like coral atolls, but rather than sitting on top of a volcanic peak, as is the case for most atolls in accordance with Darwin's theory of reef development, it seems likely that these two reefs have formed on a truncated platform, similar to a guyot.

Research gaps

Our research has helped to build a more detailed understanding of how these islands and seamounts have undergone considerable changes in the extent of coral reef habitat and associated carbonate environments. They may have looked similar to their modern morphology when the sea was at a level close to its present level

during the last interglacial. However, the sea was about 120 m lower 20,000 years ago, and any reef would have been restricted to a narrow fringing reef on the margins of the volcanic islands of Lord Howe and Ball's Pyramid, and the steep limestone plateaux of Elizabeth and Middleton Reefs. Extensive reefs flourished on the southern islands 10,000 years ago when the sea level was about 30 m lower than now, with the modern reef and lagoon forming in the past 6,000 years as the sea level stopped rising.

However, there are numerous questions we are not yet able to answer. We do not yet know the full extent of fossil reef accretion and the composition of its underlying foundations on Lord Howe Island. Further coring and dating would be required to determine the age and composition of deeper reef units. Additionally, the question of whether Elizabeth and Middleton Reefs are founded on guyots or have formed through subsidence as Darwin proposed remains unresolved. More detailed morphological and stratigraphic analyses are required to answer these questions. Finally, terraces around the margin of Lord Howe Island raise questions about the extent and persistence of corals during lower sea levels. Did fringing reefs exist during these periods, and if so, what was their ecological composition?

Acknowledgements

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Figure 2: Oblique aerial photograph of Lord Howe Island from the north (Image: Ian Hutton), compared with Bora Bora in the Society Islands (Image: Peter Bellingham).

Tasman Sea ocean environmental variability and change

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Determining the variability, change and evolution of the Tasman Sea requires comprehensive understanding of regional and temporal impacts (Fig. 1). The Tasman Sea is a confluence of the sub-tropical Pacific Ocean gyre and Southern Ocean, and is strongly influenced by the East Australian Current (EAC). The Tasman Sea is bi-modal with either the southward EAC-extension or the eastward Tasman Front dominating. Eddy 'trains' are a key feature of the Tasman Sea, supporting mixing of sub-surface nutrient to the euphotic zone, and playing a dominant role in setting ocean environmental properties. This paper explores variability and change in this highly dynamic ocean area, first considering surface waters, then deep ocean properties.

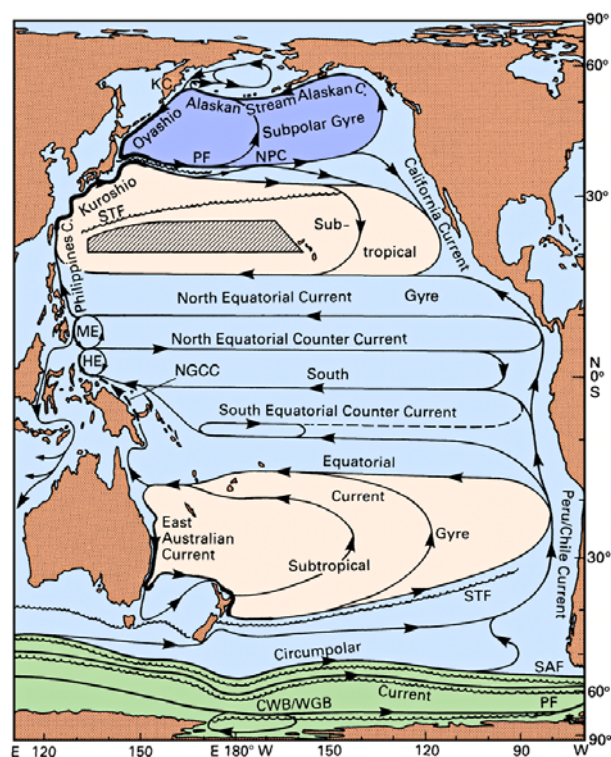


Figure 1: Surface current of the Pacific Ocean (source: Tomczak and Godfrey, 2005).

Upper ocean circulation

The East Australian Current (EAC) is the dominant driver of upper ocean circulation in the Tasman Sea. Originating in the Coral Sea, the EAC flows southward along Australia's eastern coastline, transporting warm, low-salinity, and nutrient-poor tropical waters toward the subtropics. Its strength and path vary across seasonal, interannual, and decadal timescales due to changing ocean dynamics and atmospheric conditions.

At approximately 30°S, the EAC bifurcates into two branches (see Fig. 2): the southward-flowing EAC Extension and the eastward-flowing Tasman Front. The Tasman Front interacts with the Lord Howe Rise before forming the East Auckland Current east of New Zealand. Rather than forming continuous flows, both the EAC Extension and Tasman Front are dominated by energetic eddy fields and mesoscale variability, which play a key role in shaping regional circulation and biological productivity (Oke et al, 2019; Suthers et al, 2023; Fig. 3).

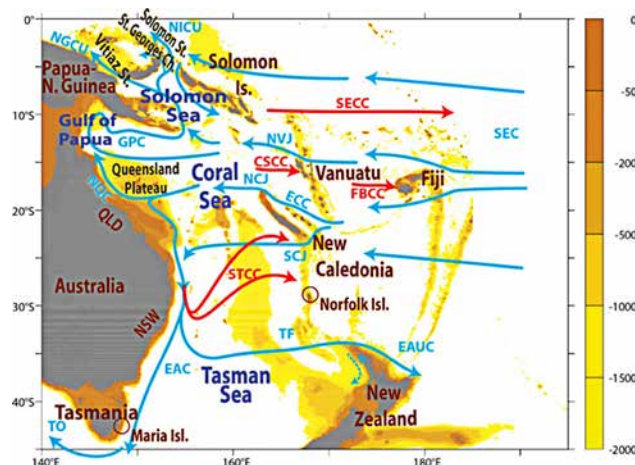


Figure 2: Main currents influencing the Tasman Sea, with main currents depicted in blue and surface-trapped counter currents indicated in red (source: Ganachaud et al, 2014).

Upper ocean variability

The Tasman Sea is a highly dynamic environment, influenced by the interaction of both the South Pacific Ocean and the Southern Ocean. The EAC, which connects to the broader South Equatorial Current, introduces warm tropical waters into the region, while cooler waters from the Southern Ocean contribute to a complex mix of water properties. These interactions drive variability across multiple timescales—from daily to decadal—and influence sea surface temperature (SST) patterns, sub-surface ocean properties, vertical mixing, and nutrient distribution.

The Lord Howe Rise and seamounts in the Tasman Sea significantly influence ocean circulation from the seafloor through to the upper ocean. Lord Howe Rise (and bathymetry to the east) restructures and divides the westward flowing South Equatorial Current (SEC) into a series of jets and influences the circulation of the Tasman Sea. This impacts the circulation of the upper ocean above 2,000 metres and inhibits deep and bottom water exchange between the Tasman Sea and the wider Pacific Ocean (Ganachud, et al, 2014).

Recent advances have improved our understanding, through observational and modelling studies, of the processes that influence the Tasman Sea variability (Oke et al, 2019). Key factors shaping circulation include the EAC's transport along Australia's continental slope, the volume of water transported into the Tasman Sea toward New Zealand and southward with the EAC extension, and the temporal and spatial variability of these ocean pathways (Sloyan and O'Kane, 2015). These dynamics underpin the ecological and climatic variability observed across southeastern Australia and the southwest Pacific.

Deep ocean circulation

Deep ocean circulation in the Tasman Sea remains one of the least understood components of regional oceanography, with circulation and variability remaining largely unexplored. This is due to the logistical and financial challenges of accessing and observing these depths. However, it is increasingly clear that the deep waters of the Tasman Sea are shaped by complex interactions between Southern Ocean inflows and regional geological features, particularly the Lord Howe Rise.

Unlike the waters east of New Zealand, which have more direct access to cold, fresh bottom waters formed in the Ross Sea, the Tasman Sea receives these waters via a more circuitous route—around the southern margin of Antarctica, Kerguelen Plateau and eventually northward into the basin. This detour results in warmer, saltier and more oxygenated deep waters in the Tasman Sea compared with those east of New Zealand (Kawabe and Fujio 2010; Sokolov and Rintoul, 2000; Fig. 4).

Lord Howe Rise provides a northern and eastern

boundary, such that the deep water entering the Tasman Sea along the Tasmania-Australia western boundary is balance by southward return flow along the Lord Howe Rise and New Zealand. Therefore the Tasman Sea is effectively a 'cul-de-sac'. As the deep water circulates in the Tasman Sea, its properties change due to ocean mixing.

Thus Lord Howe Rise acts as a significant geological obstacle, altering the flow of deep currents and contributing to the observed differences in water mass properties across the region. The circulation is not static; even at great depths, the ocean is dynamic, with slow-moving currents that influence temperature, salinity and nutrient distribution. These deep ocean processes, though subtle, play a critical role in shaping the broader marine environment, supporting ecosystems such as deep-sea coral reefs and benthic communities.

Conclusion

The Lord Howe Rise exerts a profound influence on both upper and deep ocean circulation in the Tasman Sea. It shapes the pathways of major currents like the East Australian Current and the Tasman Front, while also acting as a barrier that modifies the flow of deep waters entering from the Southern Ocean. These interactions affect sea surface temperature patterns, nutrient cycling, and the structure of marine ecosystems across the region. Understanding the full extent of these processes is essential for predicting future changes in regional climate, managing marine resources and protecting biodiversity.

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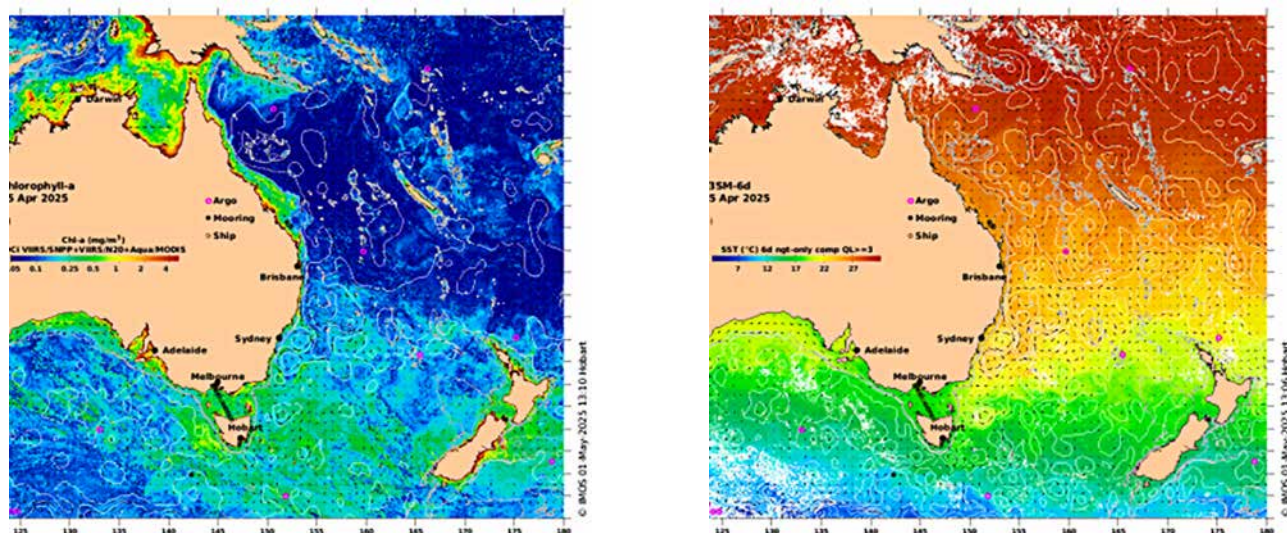


Figure 3: Eddies and nutrient levels in the upper ocean, April 2025; Chlorophyll-a on the left and Sea Surface Temperature (SST) are shown on the right (source: IMOS OceanCurrent 2025).

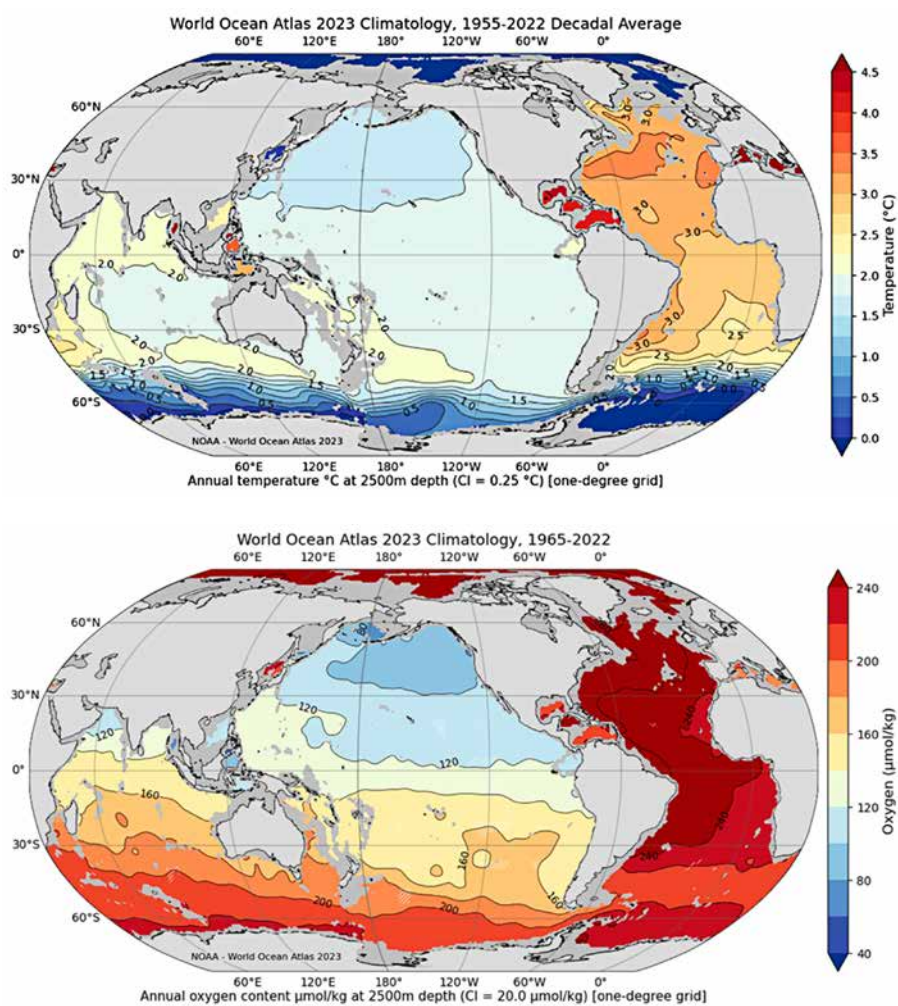
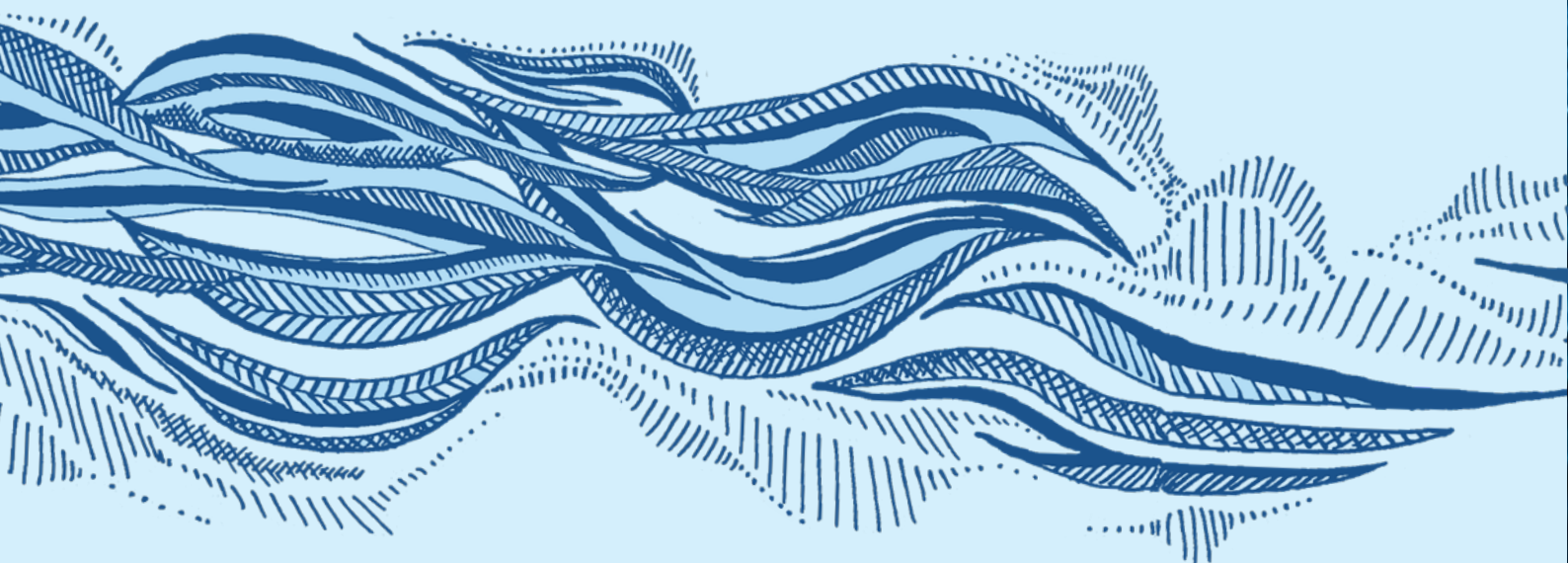
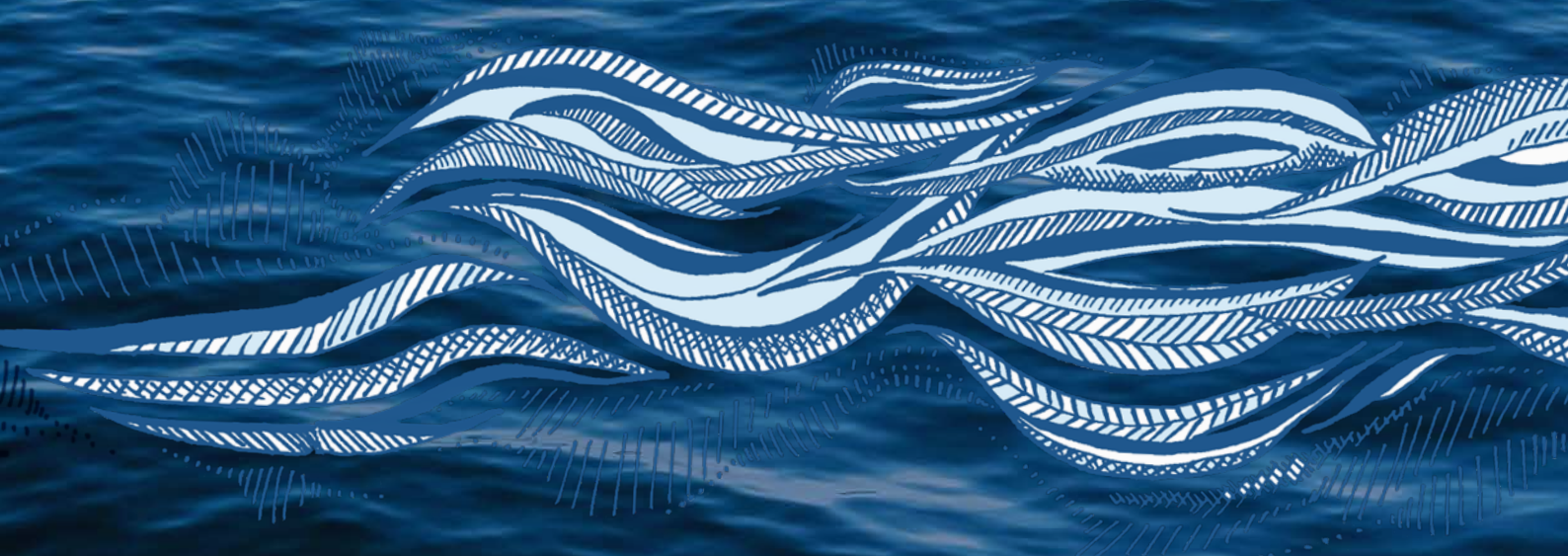


Figure 4: Decadal average water temperature at 2500 m depth (top) and annual oxygen content at 2500 m depth (bottom) (source: World Ocean Atlas 2023).



Biodiversity and ecology: Above and below the surface



Migratory connectivity in the Lord Howe Rise and Tasman Sea: Insights from the MiCO system

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Understanding the movements of migratory marine megafauna is critical for effective ocean governance and biodiversity conservation. Migratory Connectivity in the Ocean (MiCO) is a consortium developing an extensive open-access system with the goal of connecting global processes with actionable knowledge on migratory connectivity to inform worldwide conservation and sustainable use efforts (MiCO 2025). In this presentation, we focus on the application of the MiCO system to the Lord Howe Rise and Tasman Sea, a region of high ecological significance. By leveraging MiCO's interactive tools, we have identified 35 species with important migratory or breeding areas in this region, 27 of which are listed on the IUCN Red List. These findings underscore the region's role as a critical node in global migratory networks and highlight the urgent need for targeted conservation strategies.

Building the MiCO system: A global library for marine megavertebrates

MiCO comprises a growing consortium of more than 50 organisations, led by The Applied Marine Biogeography Lab (AMBL) based at The University of Queensland and The Marine Geospatial Ecology Lab (MGEL) of Duke University. The MiCO system aims to bridge the gap between scientific data and policy application. It synthesises migratory connectivity data into spatially explicit network models, enabling users to visualise and download information on species movements, breeding and feeding sites, and inter-jurisdictional linkages.

The system's foundation lies in a comprehensive literature review spanning 1980 to 2017, capturing 1304 references, aggregating satellite telemetry, acoustic tracking, mark-recapture, and observational data to identify key life-history areas and migratory routes for over 110 marine megavertebrate species. Updates are undertaken on an ongoing basis, most recently incorporating new data on green turtles globally and sharks within the Australian Exclusive Economic Zone (EEZ), using data from as recent as 2023. MiCO's network models are built on

spatial units of 1°, 5° and 10° resolution sites, colour-coded by activity type (e.g., breeding or feeding). The models are downloadable in multiple formats, including PDFs and file geodatabase formats, making them accessible for researchers, conservationists, and policymakers.

Migration across the Lord Howe Rise and Tasman Sea

Looking specifically at the Tasman Sea and Lord Howe Rise, MiCO reveals a complex web of migratory routes connecting this region to distant parts of the Pacific, Indian, and Southern Oceans (Fig. 1). So far, we have identified 35 species with significant life-history stages in this area, including humpback whales (*Megaptera novaeangliae*), leatherback (*Dermochelys coriacea*) and loggerhead turtles (*Caretta caretta*), wandering albatross (*Diomedea exulans*), common thresher sharks (*Alopias vulpinus*), and great white sharks (*Carcharodon carcharias*). Of these species, 27 are listed as Critically Endangered, Endangered, Vulnerable, or Near Threatened under the IUCN Red List. Global network models for each of these species are available at mico.eco/system.

The region serves as both a breeding ground and a migratory corridor, with species movements linking Australia and New Zealand to countries as far afield as Chile, Argentina, South Africa, India, Sri Lanka, Papua New Guinea, and Indonesia. For example:

- Black marlins (*Istiompax indica*) spawn near Lord Howe Island and migrate across the Pacific to Costa Rica.
- Westland petrel (*Procellaria westlandica*) breed in New Zealand and then travel to South America.
- Shy albatrosses (*Thalassarche cauta*) breed in Tasmania and then connect to South Africa.
- Leatherback turtle (*Dermochelys coriacea*) feeding in the Tasman Sea migrate north to Indonesia and Solomon Islands.

These examples illustrate the transboundary nature of marine megafauna movements and the importance

of international cooperation when it comes to conservation planning.

Breeding hotspots and species overlap

We identified 12 breeding species within the Lord Howe Rise and Tasman Sea, 10 of which are IUCN Red Listed (IUCN, 2024; Fig. 2). Notable breeding congregations include:

- Humpback whale (*Megaptera novaeangliae*) breeding between eastern Australia and New Caledonia
- Bull shark (*Carcharhinus leucas*) and great white shark (*Carcharodon carcharias*) nursery sites along the Australian coast
- Loggerhead turtle (*Caretta caretta*) nesting sites along the east coast of Australia, in the southern Pacific
- Seabird breeding colonies around New Zealand and Tasmania

These overlapping breeding sites represent ecological hotspots that warrant prioritisation in marine spatial planning. The presence of multiple threatened species breeding in the same areas amplifies the conservation value of these sites.

Conclusion

The application of MiCO to the Lord Howe Rise and Tasman Sea reveals a region of exceptional ecological importance, serving as a breeding ground, migratory corridor, and connectivity hub for numerous threatened species.

Overall, one-third of all migratory species in the MiCO system use the Lord Howe Rise and Tasman Sea region, and over 75% of these are red-listed. This highlights the global conservation significance of the area and the need for coordinated management strategies that reflect the ecological realities of migratory connectivity.

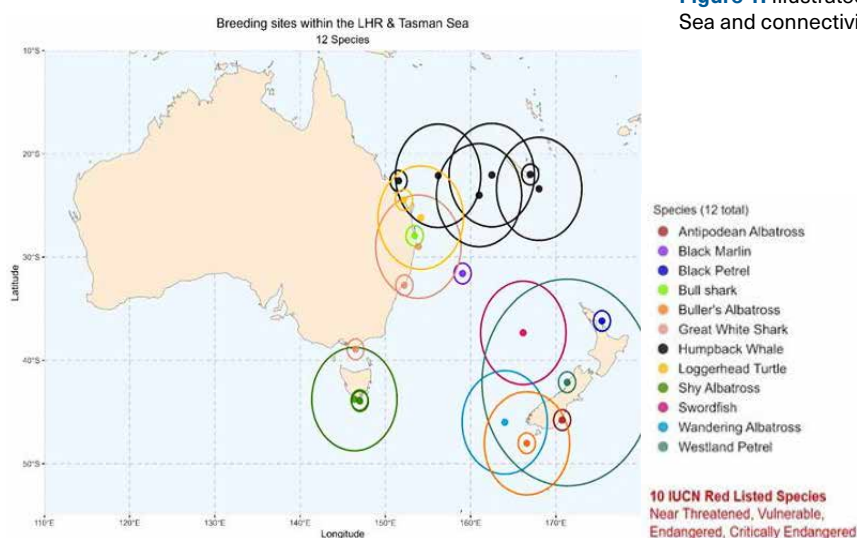


Figure 2: Breeding sites of 12 species in the Tasman Sea and adjacent areas.

Despite the richness of the MiCO database, several knowledge gaps remain, including the underrepresentation of recent data. While updates are underway, the foundational data reflects studies up to 2017. Additionally, although over 110 species are included, many areas and their potentially associated marine megafauna species remain untracked or understudied, particularly for some Pacific Island EEZs and parts of the high seas, limiting the resolution of connectivity models (Sequeira et al, 2025). Addressing these gaps will require expanded tracking efforts, international data sharing, and investment in long-term monitoring programs.

Associated paper

Bentley LK, Nisthar D, Fujioka E, Curtice C, DeLand SE, Donnelly B, Harrison AL, Heywood EI, Kot CY, Ortuño Crespo G and Poulin S (2025) Marine megavertebrate migrations connect the global ocean. *Nature Communications* 16(1) p.4089

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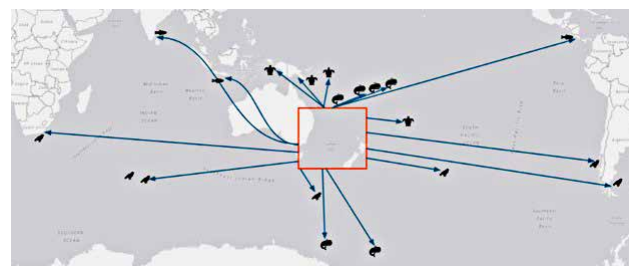


Figure 1: Illustrated map showing species relevant to the Tasman Sea and connectivity to other areas, drawn from MiCO.



Figure 3: A humpback whale (*Megaptera novaeangliae*), which has important breeding grounds in the Lord Howe Rise region. Source: ©Eric J Woehler.

Two decades of research on cetacean seamount habitats in the Southwest Pacific

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9. Association Opération Cétacés, Nouméa, New Caledonia

While seamounts are recognised as critical marine habitats for marine megafauna, relatively few studies have investigated their role in cetacean ecology. In particular, their importance to baleen whales remains under-investigated. Association Opération Cétacés has studied humpback whales (*Megaptera novaeangliae*) in the New Caledonian South Lagoon since 1995, working in partnership with many organisations and researchers in New Caledonia, particularly with the French National Research Institute for Sustainable Development (IRD). This paper provides insights from this research, focusing specifically on humpbacks' use of seamounts not only in New Caledonian waters, but down the east coast of Australia and to the east and west of New Zealand, on their migration routes to Antarctica.

Humpback populations in the region and their migrations

Humpbacks migrate seasonally between tropical breeding grounds and polar feeding grounds, forming distinct breeding subpopulations that were decimated by industrial whaling in the 19th and 20th centuries. While recovery has occurred since the banning of most whaling activities globally, the Oceania population (Fig. 1) is still listed as endangered on the IUCN Red List (IUCN, 2024). Most of the small breeding populations in the South Pacific region remain at extremely low levels, and some are therefore vulnerable to extinction.

Humpback whales are known to occupy coastal habitats during the breeding season. Females, accompanied by a young calf, are thought to seek shallow, warm, and sheltered waters of the South Pacific island lagoons. In 2007, more than 10 years since this research effort commenced, Claire Garrigue and her team deployed

their first satellite tags on whales in the South Lagoon to track their southward migration, and made some very unexpected discoveries.

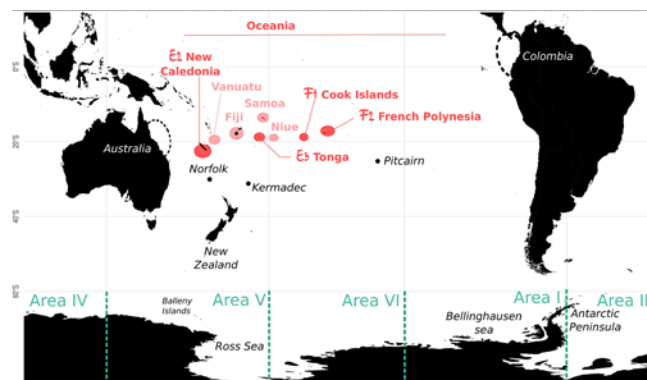


Figure 1: Oceania populations of humpback whales, with subpopulations shown (Derville 2018).

The importance of seamounts: An unexpected discovery

In 2007 and the following years, we saw from our tags that almost all whales seemed to be pausing their southerly migration to spend some time in what appeared to be the middle of nowhere; we subsequently identified their stopping point as Antigonía Seamount, located ~100km south of New Caledonia (see Fig. 2; Garrigue et al, 2010; 2015). This finding represents the starting point of a long research journey. Between 2008 and 2021 we conducted over a dozen surveys, deploying more than 60 satellite tags on humpback whales, including 18 with depth recorders. We also recorded many months of passive acoustic data.

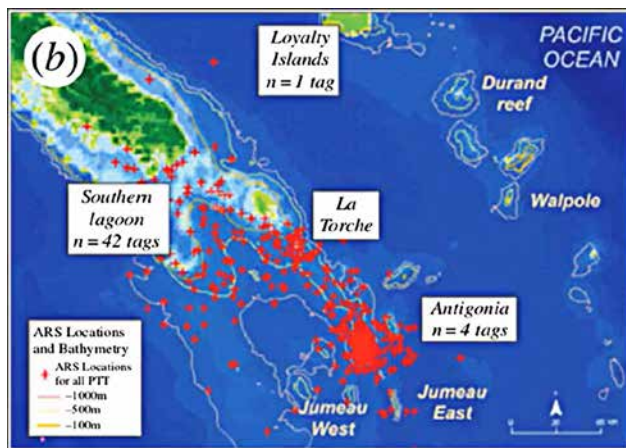


Figure 2: Stopping points of humpback whales south of New Caledonia; red crosses indicate whale positions recorded by satellites. Excerpt from Garrigue et al, 2025 Royal Society Open Science.

Humpbacks regroup in great numbers around seamounts

Through our research collaboration at Oceania scale with the South Pacific Whale Research Consortium, we have observed humpback whales congregating in large numbers around seamounts (Derville et al, 2019). We measured the mean encounter rate of whales during ship-based surveys over many years and found the highest concentrations over the Antigonia seamount and the Orne Bank in New Caledonia. This finding highlights the exceptional aggregations that occur over seamounts and led to predicted habitat modelling at Oceania scale that emphasised seamounts as potential habitats for humpback whales.

Seamounts as breeding and nursery sites

We now know seamounts probably serve multiple and important roles for whales, including as breeding locations – at least, this is the case for those that we have been able to visit on our research vessel. In the vicinity of seamounts, we have observed competitive behaviour between males; numerous females with calves (many more on Antigonia than in the coastal South Lagoon; Derville et al, 2018) and song throughout the breeding season, all day and all night long. All of these behaviours are typical of humpback whales in breeding sites

Seamounts connect populations

Our research suggests seamounts also play a crucial role as 'stepping stones' on humpback migrations, connecting subpopulations together. Fig. 3 compiles satellite tracks from all of the whales we have tagged in New Caledonia over a period of nearly two decades. In addition to their intensive congregation around Antigonia seamount and Orne Bank, whales stop over the Norfolk Ridge (connecting New Caledonia to New Zealand) and over the Lord Howe Seamount Chain (connecting New Caledonia

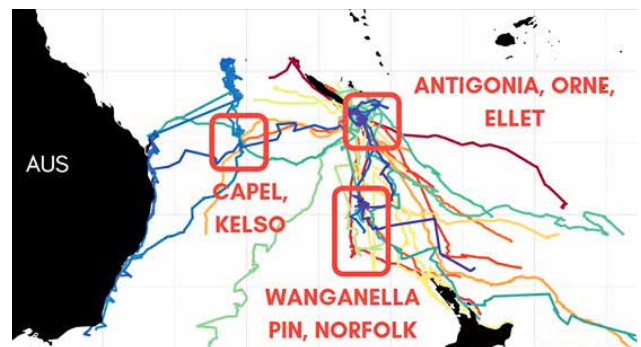


Figure 3: Humpback movements for all individuals tagged in New Caledonia, 2007-2018.

with Australia). We can see from these tracks that some individuals also stopped over quite a few seamounts in the Coral Sea and into the Tasman Sea. This connectivity has implications for population dynamics and conservation strategies.

Unexpected deep diving behaviour

Using the latest animal tracking technology we discovered unexpected deep diving behaviour around seamounts and in offshore waters in general (Derville et al, 2020). Of all the dives we tracked, 11% were deeper than 80 metres. These deep dives occurred more frequently during the day and were in proximity to seamounts shallower than 200 meters. This behaviour suggests high energy expenditure, possibly related to foraging, which challenges our common assumption that humpback whales are thought to avoid feeding during the breeding season and early migration in tropical waters. To test this hypothesis we surveyed three seamounts in 2019 with contrasting topography and oceanographic conditions (Garrigue et al, 2020), observing around 180 diverse cetacean groups across three surveys. Additionally, we found significant micronekton enrichment and dense schools on seamount summits, which could explain the frequent presence of odontocetes detected in acoustic recordings (Receveur, unpublished results).

Humpback/seamount association informing conservation measures

This begs the question: are humpback whales the emblematic umbrella species for seamounts, and can protecting humpback habitats provide benefits to the extraordinary diversity of organisms that depend on seamounts? Uptake of our work suggests that consensus on this matter is settled. Our work has been instrumental in informing the designation of two Important Marine Mammal Areas (IMMA) over seamounts: the Waters of New Caledonia and Loyalty Islands, and Chesterfield-

Biodiversity and ecology: Above and below the surface

Bellona Coral Reef and Seamounts. These IMMAs have informed the design of MPAs within the Parc Naturel de la Mer de Corail in New Caledonian waters (Fig. 5), which cover part of the Norfolk Ridge (with some connectivity into Australia's Exclusive Economic Zone) and part of the Capel Bank, which is on the Lord Howe Seamount Chain.

Forthcoming research

Over the next three years, we will be collecting more passive acoustic data through several current projects, namely MEGAFAUNE, ScinObs and AIPANEMA projects. The MEGAFAUNE project includes plans for new ship-based surveys on the Loyalty Ridge seamounts. We will be undertaking a more formal analysis of cetacean abundance in relation to micronecton and ocean conditions. Finally, our team is currently conducting biochemical ocean modelling around seamounts in New Caledonia through a postdoctoral research project.

Acknowledgements

We thank the Natural Park of the Coral Sea services at the New Caledonian government for their support.

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Bottlenose Dolphins in blue waters of 600 metres depth and located 15 kilometres off Lord Howe Island. Source: Greenpeace

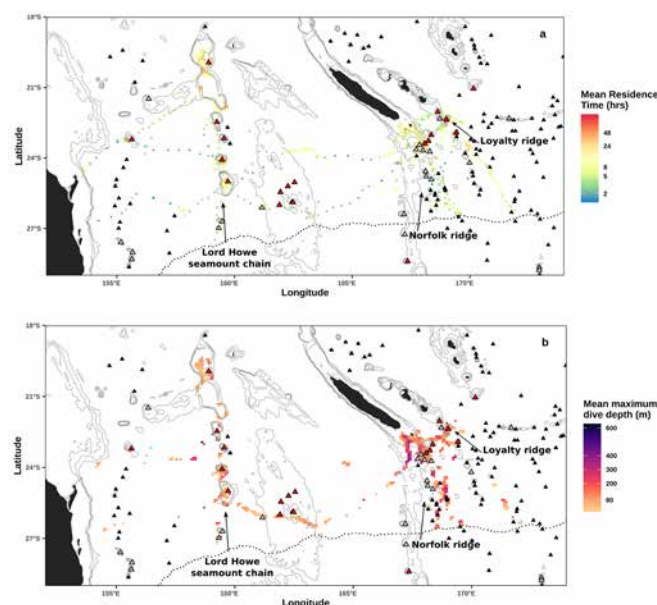


Figure 4: Seamount ridges providing stopover connectivity between Norfolk Ridge and New Zealand (green lines) and the Lord Howe Seamount Chain to Australia (blue lines). Source: Derville et al, 2020.

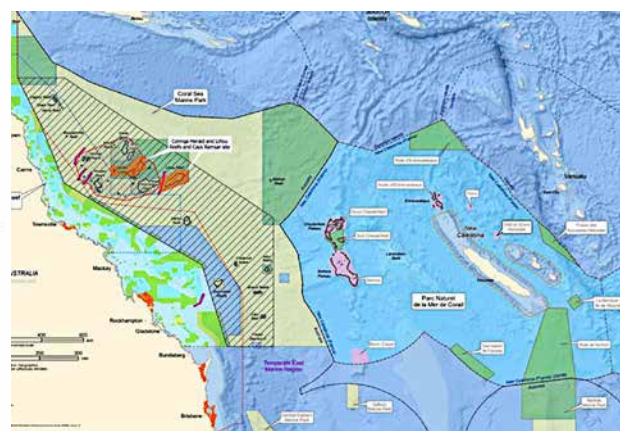


Figure 5: Parc Naturel de la Mer de Corail showing marine protected areas that were informed by IMMAs. Source: Australian Government, 2024.

Deepwater sharks of the South Pacific

Authors: Brittany Finucci^{1,2} (presenter)

1. *Earth Sciences New Zealand, Wellington, New Zealand*
2. *University of Tasmania, Hobart, Australia*

The Australian-New Zealand region is considered a global hotspot for deepwater chondrichthyan (sharks, rays, and chimaeras) diversity (Finucci et al, 2021; Finucci et al, 2024). Despite this, the region remains highly data-deficient, with limited knowledge of the species inhabiting these waters. Deepwater chondrichthyans are still being described regularly in the South Pacific, with some species having restricted and endemic distributions around the Lord Howe Rise and South Tasman Sea. Others are thought to share high levels of connectedness across the South Pacific, extending to New Caledonia. This paper summarises current knowledge and extensive knowledge gaps and discusses recommendations for future areas of research.

Current knowledge of chondrichthyan diversity in the region

Knowledge of chondrichthyans in the Lord Howe Rise and South Tasman is extremely limited, so this paper will expand its focus to consider what we know at regional scale. New Zealand and Australia boast an incredible diversity of chondrichthyans (sharks, rays and chimaeras). New Zealand has 113 species identified to date (with others known to exist but yet to be formally described) and Australia has 331 (Duffy et al, 2016; Simpfendorfer and Rigby 2023). Of these, 365 are unique species, including 197 sharks, 149 rays, and 19 chimaeras. Impressively, this represents approximately 30% of the global diversity of cartilaginous fish (Dulvy et al, 2021), making this region a global hotspot for this taxon (Fig. 1 and 2).

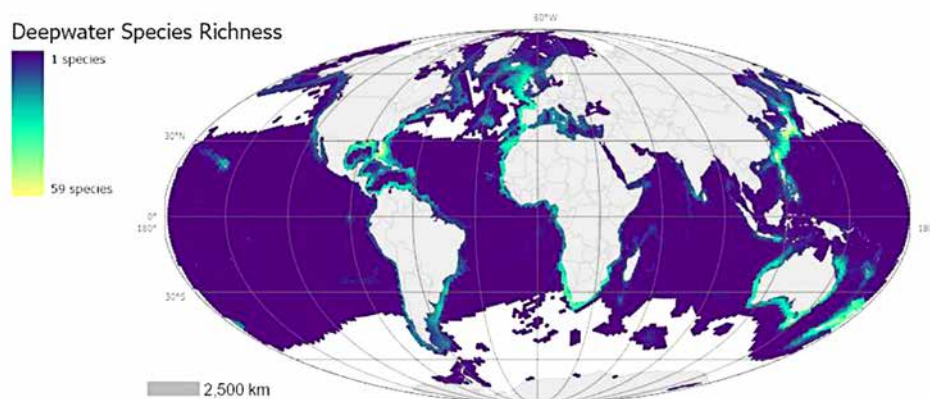


Figure 1: Global indication of deepwater shark and ray richness (Dulvy et al, 2021, *Current Biology*).

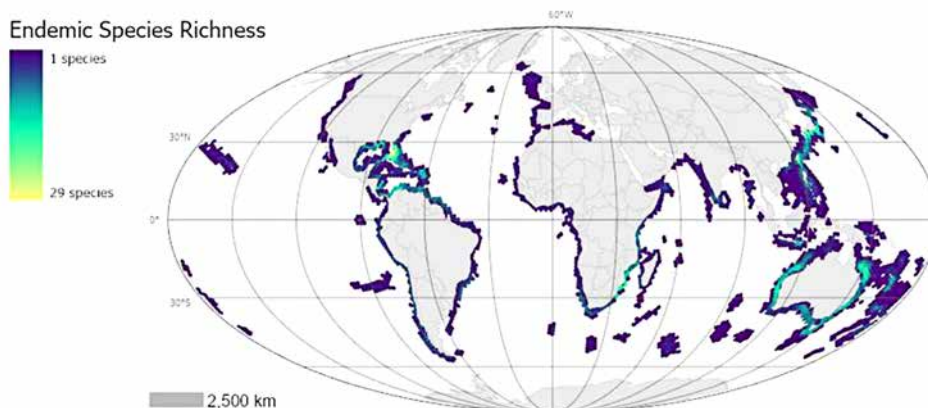


Figure 2: Global indication of endemic deepwater shark richness (Dulvy et al, 2021, *Current Biology*).

Deepwater species

Deepwater chondrichthyans spend most of their life cycles at depths greater than 200 metres and exhibit high levels of endemism – meaning they only exist there. For example, about half of ray species in Australasia are endemic to the region (Last & White 2011). The Tasman Sea acts as a biogeographical barrier, limiting the distribution of many species (Last & Yearsley 2002). Skates, known for their limited movement, further illustrate this point, with tagged individuals often recaptured in the same area as their original tagging location years later.

Chimaeras, or ghost sharks, are particularly noteworthy for their endemism and rarity. Several species, such as the southern chimaera (*Chimera fulva*) and the dark ghost shark (*Hydrolagus novaezealandiae*) are found exclusively in Australasia. The species of this region show a remarkable diversity, including some of the largest species like the giant chimaera (*Chimaera lignaria*). New discoveries have been frequent, with the most recent description being the Australasian long-nosed spookfish (*Harriotta avia*) (Finucci et al, 2024). This species was originally thought to have a global distribution, but we now know the species only occurs in the Australasian region. With further research and support for taxonomic work, we believe there are more species discoveries to come.

Despite the richness of chondrichthyan diversity, significant knowledge gaps remain due to difficulty accessing deep waters. While the 2003 Norfolk Ridge/ Lord Howe Rise Biodiversity Discovery Survey (NORFANZ) expedition took place more than two decades ago,

it remains the best source of information we have on chondrichthyans in this area. That survey recorded an incredible diversity of species, including species new to science. During the NORFANZ expedition scientists sighted several skate species (the pacific blonde skate (*Bathyraja pacifica*), ribbontail skate (*Brochiraja vittacauda*) and eureka skate (*Brochiraja heuresa*)) which I understand have not been observed again since (NORFANZ, 2003; Fig. 3).

Pelagic species

Species such as white sharks (*Carcharodon carcharias*) and school sharks (*Galeorhinus galeus*) use the Tasman Sea as a migratory pathway between New Zealand and Australia (Fig. 4), as demonstrated by tagging data for these species (Hurst et al, 1999; Duffy et al, 2012). While there is less data on other species, we know that satellite-tagged porbeagle (*Lamna nasus*) and mako (*Isurus oxyrinchus*) sharks have travelled in the Tasman Sea (Francis et al, 2015; 2023). However, more research is needed to fully understand the connectivity and population dynamics of these species, especially for those living in deeper habitats.

Human shark conflict is a threat to shark species in the area, with fishing being the primary threat to all sharks, rays, and chimeras (Dulvy et al, 2021). Species are either captured as targeted catch or caught as bycatch. Bottom long line, surface long line and trawl fishing all occur in this area, and these are all gear types that many shark species are susceptible to (Hoyle et al, 2017; Georgeson et al, 2020).



Figure 3: From left to right, several ray species identified on the 2003 NORFANZ expedition: Pacific blonde skate (*Bathyraja pacifica*), ribbontail skate (*Brochiraja vittacauda*) and eureka skate (*Brochiraja heuresa*). Source: Last et al, 2016; Earth Sciences New Zealand.

Conclusion

While the Australian-New Zealand region remains data deficient – and the Lord Howe Rise and South Tasman Sea even more so – the information we do have indicates this area is a global hotspot for deepwater chondrichthyan diversity and a movement corridor for highly migratory species. By addressing persistent knowledge gaps through targeted research and collaboration, we can enhance our understanding of chondrichthyan diversity and inform conservation efforts in this ecologically significant region. I recommend we conduct more comprehensive surveys and tagging studies to track movements and distribution of chondrichthyan, prioritising the study of endemic species and their ecological roles within the region; increase collaboration between researchers in New Zealand, Australia, and South Pacific nations to share data and insights; and expand the use of advanced technologies, such as satellite telemetry and passive acoustics, to monitor species occurring across the Lord Howe Rise and South Tasman Sea.

Associated paper:

Finucci B, Cheok J, Ebert DA, Herman K, Kyne PM and Dulvy NK (2021) Ghosts of the deep–Biodiversity, fisheries, and extinction risk of ghost sharks. *Fish and Fisheries*, 22(2) pp.391-412

Finucci B, Didier D, Ebert DA, Green ME and Kemper JM (2024) *Harriotta avia* sp. nov.–a new rhinochimaerid (Chimaeriformes: Rhinochimaeridae) described from the Southwest Pacific. *Environmental Biology of Fishes*, 107(8) pp.841-865

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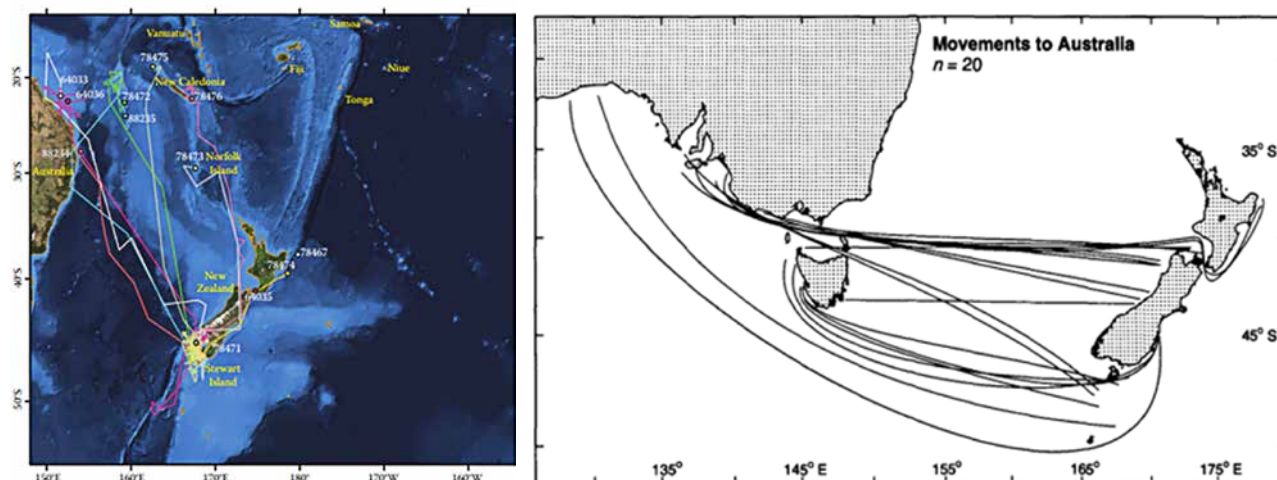


Figure 4: Long distance movements of white sharks (left; Duffy et al, 2012, *MEPS*) and school sharks (right; Hurst et al, 1999, *NZ J. Mar. Fresh. Res.*) between Australia and New Zealand.

Leatherback turtles in the Tasman Sea

Authors: Sean Williamson^{1,2} (presenter)

1. Monash University
2. Queensland Marine Turtle Network

A critically endangered ocean wanderer

The leatherback turtle (*Dermochelys coriacea*) is the largest sea turtle and most wide-ranging of all reptiles. In the Western Pacific, this pelagic species nests primarily in Indonesia, Papua New Guinea, and Solomon Islands, before migrating across vast oceanic distances to forage throughout the Pacific Ocean, including the South Tasman Sea and Lord Howe Rise. Although leatherback turtles possess remarkable resilience and adaptability, including a physiological trait known as gigantothermy, which enables these large-bodied reptiles to regulate their body temperature in cold waters, they are facing a critical decline. Both the East and West Pacific populations have declined by over 90% in the past four decades, prompting their classification as Critically Endangered in the IUCN Red List (Wallace et al, 2013). This paper presents the regional ecology of leatherback turtles and major threats they face, highlighting some modelling of the future viability of the West Pacific population.

Migration, habitat use and emerging threats

Satellite telemetry and observational data have shown us that leatherbacks from the West Pacific population undertake extensive migrations, reaching as far as California, the South China Sea, and the coasts of southeast Australia and New Zealand (Benson et al, 2011). They show seasonal preferences for oceanographic features such as moderate sea surface temperatures (14°C and higher), mesoscale eddies (ocean currents ranging from tens to hundreds of kilometres wide), and frontal systems, all conditions that are commonly found across the Tasman Sea (James et al, 2005).

Bycatch – where species that are not target species for fishers are unintentionally caught or entangled – represents an existential threat to leatherbacks. Bycatch in longline fisheries, crab pot fisheries, and shark meshing nets is becoming increasingly common, particularly along the east coast of Australia. Alarming, bycatch incidents in Shark Nets in New South Wales have risen since 2017, accompanied by an increase in the number of turtles being entangled and killed by about 2 per year. Around 40 more individuals are caught every year as bycatch on longlines from the Australian Eastern Tuna and Billfish Fishery that fishes the South Tasman Sea. The post-release survival of those freed from nets and longlines remains uncertain, and anecdotal evidence suggests

that some have become stranded and die shortly after release, possibly due to high levels of stress from bycatch incidents.

Modelling the future: Population viability and habitat prediction

To better understand the population's trajectory, we have developed a Population Viability Analysis (PVA) using life history data from NOAA's endangered species status review (NOAA Fisheries, 2020). Our model predicts that even without additional bycatch, Solomon Islands nesting population is on track for extinction within this century. For the West Pacific population as a whole, while not as dire as the subpopulation in Solomon Islands, population modelling shows their prospects are still not good with a greatly reduced population size and increased risk of extinction over the coming generations. Various bycatch scenarios we have modelled hasten the rate of extinction. Introducing just two additional mortalities per year significantly accelerates the timeline in our models, underscoring the importance of every individual turtle.

In parallel, an Integrated Species Distribution Model (ISDM) has been developed to predict leatherback presence based on environmental variables such as chlorophyll-a concentration and eddy kinetic energy (Liang et al, 2023). Our models show higher predicted leatherback intensity in the South Tasman Sea during summer months, aligning with observed seasonal patterns. An interactive tool based on this model has been developed for New South Wales threatened species managers to inform decisions about shark net deployment and fishing activity.

Conservation priorities and recommendations

At this point, we can say with high likelihood that we will lose key populations of leatherback turtles in the near future without immediate intervention, and possibly lose the global population in the coming centuries. As a result of this dire situation, we suggest several key priority conservation actions:

1. **Reduce bycatch** through time-area closures, gear modifications (e.g., LED lighting, circle hooks), and increase observer coverage to improve accuracy of bycatch estimates and improve data access from international fisheries operating in the region, where bycatch remains a 'black box'.

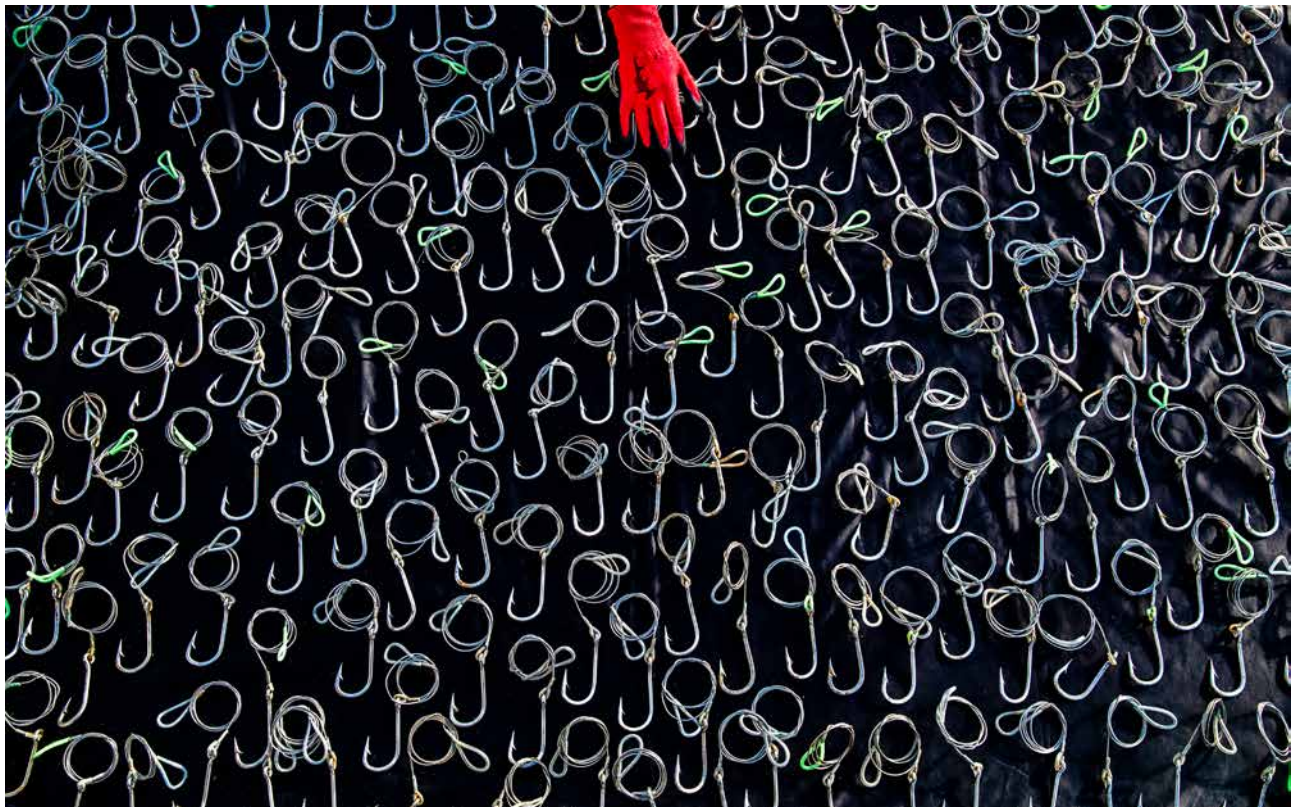


Figure 1: A collection of hooks used for longline fishing. Source: ©Paul Hilton / Greenpeace.

2. **Enhance nesting beach protection**, particularly in impoverished communities where turtle harvest persists.
3. **Expand monitoring using satellite tagging**, aerial surveys, and drone technology to better understand habitat use.
4. **Engage stakeholders** as conservation partners, through renewed workshops with fishers and managers to raise awareness and co-develop solutions.

While the idea of establishing migratory corridors has been discussed, researchers suggest that time-based closures—similar to those used in California—may be more effective, given the scattered nature of leatherback movements post-nesting.

Conclusion

The Tasman Sea and surrounding waters are ecologically vital for the survival of the West Pacific leatherback turtle. Without immediate and coordinated conservation action, this population faces a high risk of extinction within decades. By integrating robust data, predictive modelling, and stakeholder engagement, we can chart a more hopeful path forward for one of the ocean's most iconic and imperiled species.

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Seabirds of the Tasman Sea

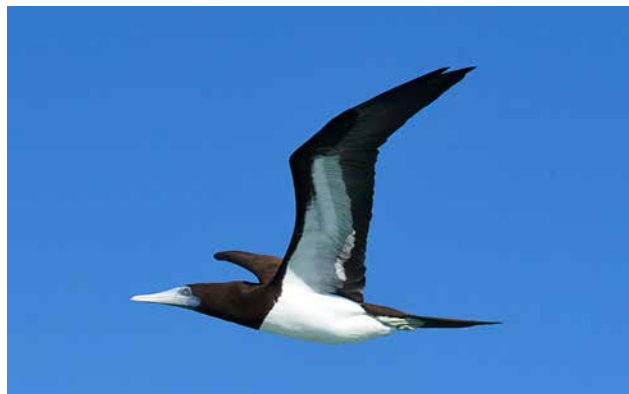
Author: Eric J Woehler¹ (presenter)

1. Australasian Seabird Group

Introduction and context

As top predators in marine ecosystems, seabirds are widely used as indicators of overall health of marine ecosystems. Their long lifespans, far-ranging dispersive and migratory movements and their sensitivity to environmental conditions make them well suited to integrate signals from the marine environment across broad spatial and temporal scales.

Our long-term standardised seabird at-sea survey program has compiled over 65,000 records within the Coral and Tasman Seas since the 1980s. This presentation provides our initial synthesis of seabird survey data collected in the Tasman Sea area and some conclusions from analysis of the data, which can provide insight into the state of this globally significant marine environment.



Brown booby (*Sula leucogaster*) of the Tasman Sea region.
Source: ©Eric J Woehler.

Results

Relatively high densities of seabird sightings have been recorded in the southern Tasman Sea, particularly along the southeast Australian coast and around Tasmania, with many one-degree grid cells containing over 100 records. However, some areas have been surveyed less frequently, such as the northern Tasman Sea and Coral Sea, where many grid cells contain fewer than 100 records. The distribution of seabird observations reflects the challenges of undertaking surveys throughout Australia's large Exclusive Economic Zone (EEZ), particularly remoter areas.

The areas of highest seabird species diversities (calculated by the Shannon-Weaver diversity index) supported seven or more seabird species and corresponded with known oceanographic features likely

to enhance productivity, including coastal upwelling zones, shelf breaks and eddy systems (Fig. 1). This suggests that seabird communities are closely tracking the spatial and temporal variability in marine food web dynamics within the Tasman Sea. Our recent study of seabird communities within the East Australia Current established the baseline understanding of the relationships between oceanography and seabird assemblages that are predicted to respond to changes associated with climate change.

Endangered birds of the region

Importantly, the seabird survey data allowed for the identification of critical habitat areas for seabird species listed as Endangered and Vulnerable under Australia's Environment Protection and Biodiversity Conservation (EPBC) Act 1999 (Fig. 2). By overlaying the locations of sightings of EPBC Act-listed threatened seabirds, including several albatross and petrel species, it is possible to identify seasonal and/or year-round hotspots where these sensitive species have been observed. These observations provide significant value for informing marine spatial planning and conservation efforts targeting the protection of the region's most threatened avian species.

Identified knowledge gaps

Unfortunately, substantial gaps in the seabird survey coverage exist, particularly in the northern Tasman Sea and Coral Sea regions. These gaps underline the logistical challenges of undertaking surveys in remote areas of Australia's EEZ. However, these data gaps do not preclude preliminary generalisations about seabird distributions and community patterns from being generated. The gaps represent foci for future research investment and opportunities for the expansion of survey efforts.

Seabirds: An indicator taxon

As long-lived, highly mobile predators, seabirds possess an unparalleled capacity to integrate environmental signals over a range of spatial and temporal scales. Their sensitivity to changes in prey availability, oceanographic conditions, and anthropogenic threats make them excellent sentinels for tracking the overall status of marine systems. Data on seabirds in the Coral and Tasman Seas have shown that spatial patterns in seabirds' distributions are consistent with global patterns, with warmer waters supporting fewer species of seabirds due to lower oceanic productivity. Observations since the 1980s have



A Buller's Albatross (*Thalassarche bulleri*), which forage between Tasmania and New Zealand in the Tasman Sea.
Source: ©Eric J Woehler.

documented approximately 150 species of resident, migratory and dispersive seabirds over the Coral and Tasman Seas (Daudt et al, 2024). Our seabird data clearly show the global significance of the area to seabirds.

Conclusion

The Tasman Sea region supports an exceptionally diverse seabird community, with half of the world's seabird species recorded in this area (Woehler, 2021; BirdLife, 2023). The identification of hotspots for Endangered species, and the broader patterns of biodiversity, underscores the global significance of this marine environment for seabirds – and the need for a holistic management framework for the conservation of the region. However, the existence of data gaps, particularly in the northern extents of the study area, represents an important limitation that must be addressed to obtain a comprehensive overview and understanding of the area.

It is critical that the importance of seabirds as vital indicators of ocean health is recognised and incorporated into all discussions and considerations. The available data clearly show the critical role that seabirds should play in monitoring and managing the health of the Tasman Sea ecosystem. By expanding and integrating seabird survey efforts with other marine megafauna data, researchers and policymakers will be better equipped to detect emerging trends, identify priority conservation areas, and implement effective management strategies. Investing in this critical research frontier will be essential for safeguarding the long-term ecological integrity of this globally significant marine region.

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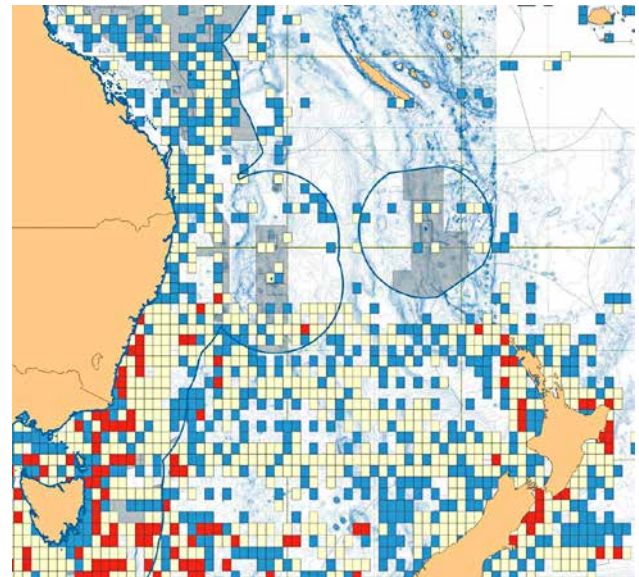


Figure 1: Map showing the Coral and Tasman Seas. Seabird observations have been collated into 1° latitude x 1° longitude cells for analysis. Cells with high seabird diversities (Shannon Weaver Diversity Index H') are shown in red, with lower diversities in yellow, then blue. Unmapped cells represent nil survey effort. Bathymetry is shown, as are the 5° latitude and longitude graticules.

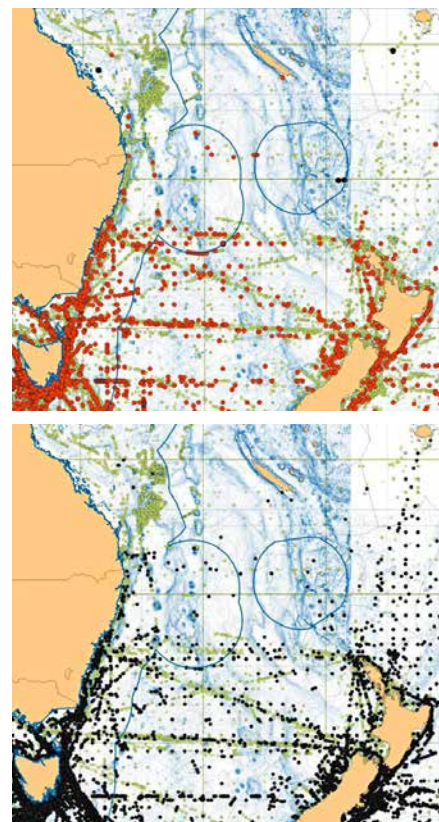


Figure 2: Maps showing observations of seabirds listed as EPBC Endangered ($n = 7$; 5 albatrosses and 2 petrels, left image in red), and the Critically Endangered herald petrel (left image in black), and the right map shows observations of seabirds listed as EPBC Vulnerable ($n = 21$; 11 albatrosses, 3 terns and 7 petrels). Bathymetry is shown, as are the 5° latitude and longitude graticules.



First Nations Knowledge panel

Reflections from the symposium organisers

The first panel of the symposium brought together leading thinkers, researchers and practitioners from the Gumbaynggirr and Yuin Nations (Australia); Aotearoa and Hawaii to discuss First Nations leadership in ocean conservation and approaches to integrating Cultural and Traditional Knowledge with other scientific methods to inform ocean conservation.

The panel comprised Dr Jodi Edwards (a Yuin woman with Dharawal kinship connection and VC Senior Indigenous Research Fellow at the Australian National Centre for Ocean Resources and Security (ANCORS) at the University of Wollongong), Dr Chels Marshall (Gumbaynggirr woman, Senior Researcher at ANCORS and Honorary Fellow, Faculty of Arts & Education NIKERI at Deakin University) and Pelika Andrade (a native Hawaiian born and raised on the island of Kaua'i; Founder and Executive Director of Nā Maka Onaona and member of the Papahānaumokuākea Advisory Council). Dr Dan Hikuroa (Ngāti Maniapoto, Waikato-Tainui, Ngaati Whanaunga, Pākehā and Associate Professor of Maori Studies at the University of Auckland) moderated the session.

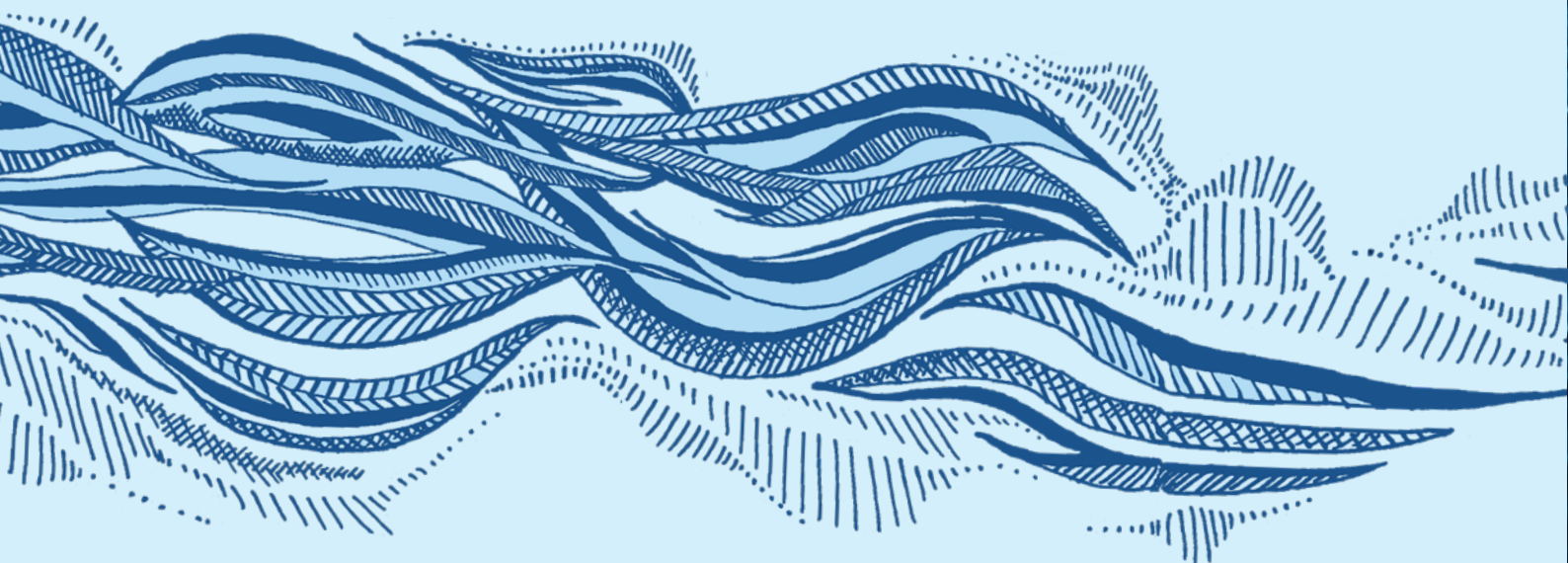
Throughout the discussion three key themes emerged: relationships, reciprocity and responsibility. People's relationship with the ocean was at the core of this discussion. For many cultures, the ocean is a living entity with its own life and agency. It is not a vast resource to be exploited for human gain, or an expanse requiring areas to be delineated for protection and management, but rather a living relative to be respected and cared for. This worldview shapes the work of many First Nations ecologists and researchers, whose work focuses on connections between land, sea, and sky, and the seasonal cycles that govern the behaviour of marine species.

Strong and enduring cultural connections with Sea Kin/ika were discussed extensively. While many scientists focus on the differences between species, panellists discussed the importance of recognising our common heritage and what that means for our relationships with marine life. While conceptualising whales as human relations may seem peculiar to some, all life began in the ocean and all species share common ancestors. When this lens is applied to interspecies relations, it becomes clear how marine species can be regarded as human relations. This has significant implications for reciprocity and responsibility when it comes to caring for the ocean.

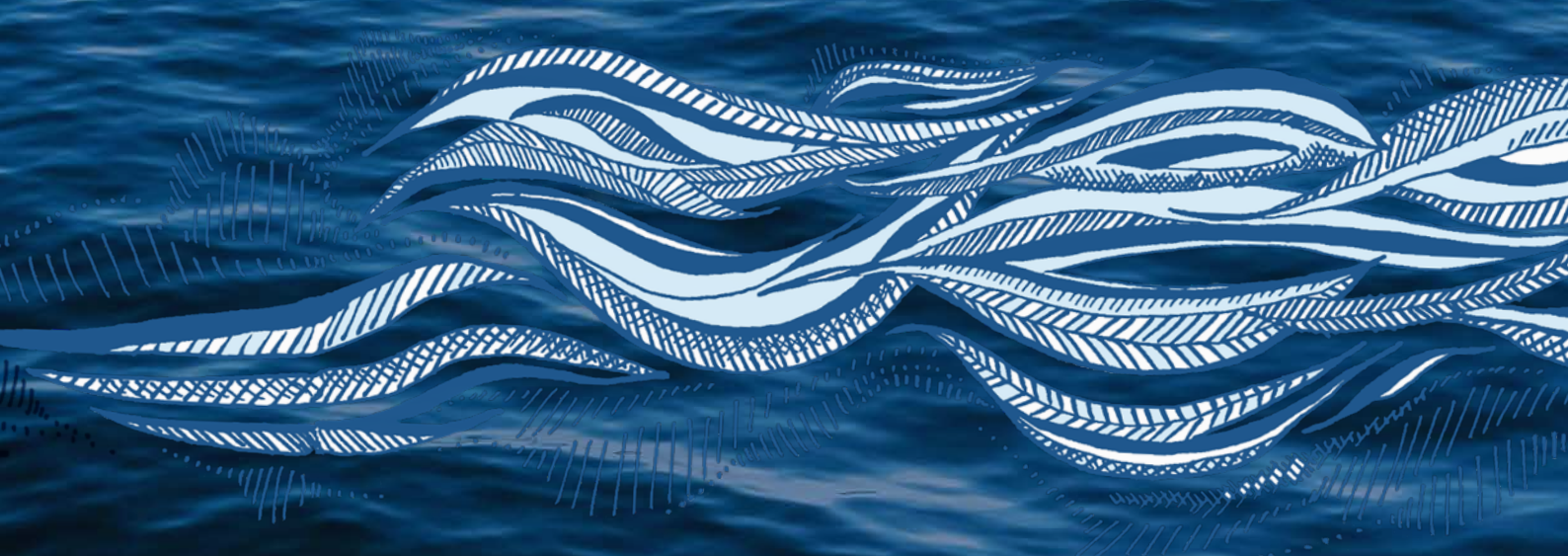
Reciprocity – mutual dependence between people, the ocean and marine life, and the concept of collaborating towards mutual benefit – was a second key theme of this panel discussion. The panel explored what being a 'good ancestor' means, drawing on the knowledge and wisdom of the past to take decisions and actions that will benefit countless generations to come. The centrality of storytelling to Indigenous cultures was emphasised as an important source of knowledge about reciprocal relationships, as well as being an important way of nurturing them. The term 'unbroken whispers' – the ripples connecting people with Sea Kin – was discussed briefly as a means of understanding reciprocal relationships between species over many generations.

Respect (and responsibility) comprised a final unifying theme of this discussion. There were several dimensions to this strand of discussion. Among these was the need to reconsider what we are collectively responsible for when it comes to ocean conservation. Panellists were united behind the need to reframe our responsibility as collectively caring for all ocean ecosystems, as opposed to delineating and protecting small parts of the ocean. A second important strand explored how well (or not) Cultural Ecological Knowledge has shaped ocean conservation at regional and global scale, and the urgent need for improvement in this area. The Lord Howe Rise and seamounts in the area were identified as an opportunity to collectively develop an inclusive approach to ocean conservation on the high seas.

While the themes of relationships, reciprocity and respect were a focus of this panel, they resonated beyond and throughout the symposium. These were accompanied by a clear call to action: Sustainability must be considered and implemented differently, driven by cultural responsibility. This must involve a shift from economically-driven decision-making to an approach grounded in the themes explored in this panel. All participants were challenged to ensure these themes are taken forward in Lord Howe Rise and South Tasman Sea conservation planning, through substantive consultation and co-design, underpinned by rigorous research that incorporates and elevates cultural values and knowledge.



Biodiversity and ecology: Life on the seafloor



A review of seafloor biodiversity research conducted, and data held, by Earth Sciences New Zealand for the Tasman Sea, with a focus on Lord Howe Rise

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Earth Sciences New Zealand (formerly NIWA) carries out extensive research to enhance the economic value and sustainable management of New Zealand's aquatic resources and environments. Earth Sciences New Zealand has been collecting and analysing biodiversity data in the Tasman Sea area for many decades, some of which have been produced to help inform conservation and management efforts in the high seas of this region. In this presentation, we present a review of these data and examples of research conducted to describe biodiversity patterns that include the South Tasman Sea and Lord Howe Rise.

The Earth Sciences New Zealand invertebrate collection and biodiversity patterns

Our research places emphasis on benthic invertebrates, supported by the Earth Sciences New Zealand Invertebrate Collection, which houses over 175,000 registered sample lots—including nearly 5,000 type specimens, with majority of the data originating from the New Zealand Exclusive Economic Zone (EEZ). This extensive resource underpins species identification and biodiversity research, with approximately 80% and 60% of records identified to genus and species level (respectively), making it highly valuable for conservation planning.

While much of this biodiversity data is from within New Zealand's EEZ, collaborations with Australian researchers have extended our scope into the high seas between the two countries. These efforts have led to the discovery of new species and deeper insights into benthic community structure, including the description of assemblages found at seamounts.

One of our collaborative studies focused on brittle stars, which are a good indicator of broader benthic diversity patterns, and demonstrated the existence of transitional ecoclines, rather than distinct biogeographic boundaries in the bathyal fauna (Fig. 1; O'Hara et al, 2011). Around the Lord Howe Rise, this transition aligns with

the Tasman Front and such transitional areas are often associated with elevated biodiversity. As such, these areas may be especially important for conservation efforts aimed at protecting both species and the habitats that support them.

Genetic connectivity studies have also informed our understanding of regional biodiversity patterns. For example, research on squat lobsters suggested a potential genetic barrier in the Tasman Sea between populations in Australian and New Zealand waters (Fig. 2; Yan et al, 2020). Although this study lacked data from the central Tasman region, it highlighted the need to consider trans-national gene flow when managing anthropogenic impacts on Vulnerable Marine Ecosystems.

Contributing to the above-mentioned records of benthic invertebrates across the Tasman Sea region, the NORFANZ survey in 2003 recorded thousands of

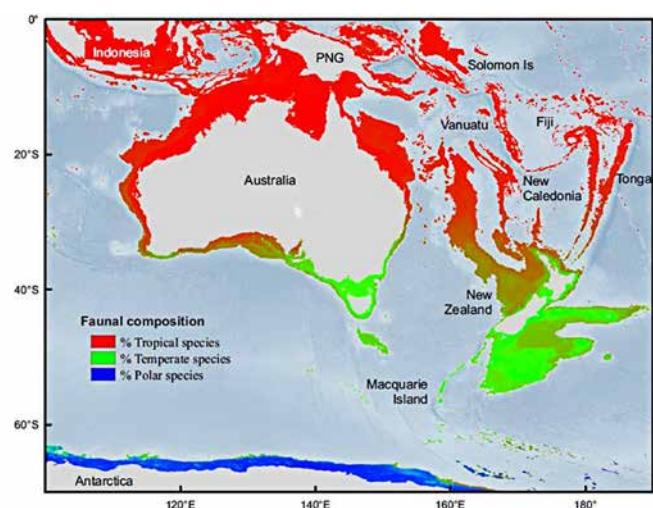


Figure 1: A visualization of spatial patterns of predicted species distribution, formed by assigning the proportion of tropical, temperate, and polar species from MaxEnt modelling to the red, green and blue bands of an RGB colour image (source: O'Hare et al, 2011).

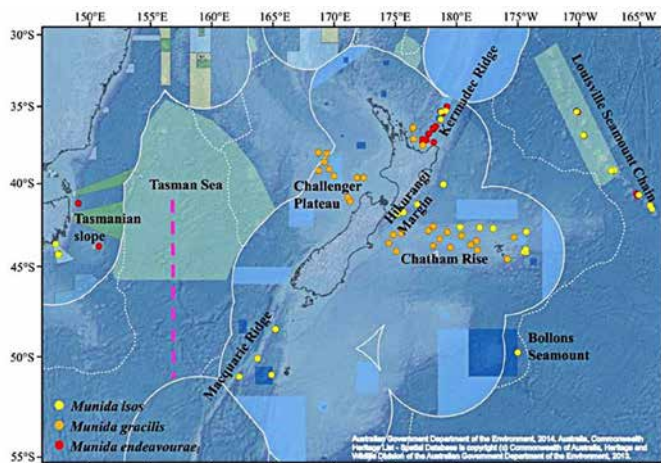


Figure 2: Map showing the distribution of marine protected areas (shaded), major geomorphic features and locations of the samples in the southwest Pacific Ocean region. White solid lines indicate the boundary of economic exclusive zone. White dashed lines represent the boundary of Extended Continental Shelf. Pink dashed line is marked as the potential genetic barrier (source: Yan et al, 2020).

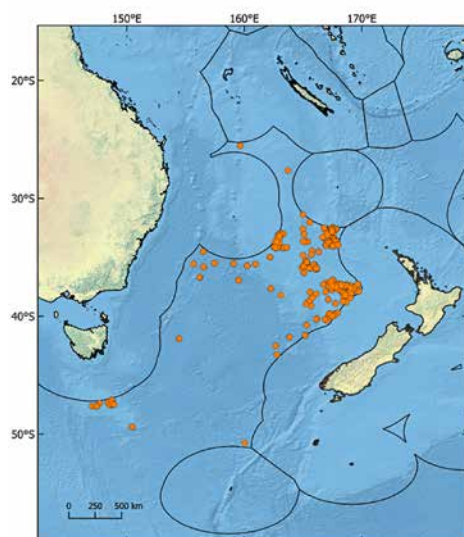


Figure 3: Location of specimen records in Earth Sciences New Zealand's Invertebrate Collection database for the high seas between the EEZs of Australia, New Zealand and France (New Caledonia). Note the absence of records for the deeper areas of the South Tasman Sea (source: Earth Sciences New Zealand).

megafauna taxa, including many previously undescribed species on the Norfolk Ridge and Lord Howe Rise. The survey revealed significant spatial heterogeneity in species distribution patterns, shaped by hydrographic patterns and seabed topography, and to a lesser extent by substrate type (Williams et al, 2011). The survey demonstrated the high conservation value of the study area; however, the future survey and research needs highlighted in Williams et al, (2011) for the benefit of national and international conservation planning initiatives have not yet been addressed.

Although not originally intended to support biodiversity research, Earth Sciences New Zealand's involvement in the deployment and maintenance of ocean buoys as part of the Deep-ocean Assessment and Reporting of Tsunamis (DART) network has provided valuable opportunities for further Tasman Sea exploration. Regular monitoring voyages have enabled sampling of pelagic assemblages, offering insights into larval transport, invertebrate settlement, and genetic connectivity. Seafloor mapping beneath buoy locations has also proven useful for understanding habitat structure and topography in the region, including the Lord Howe Rise.

Data gaps and future directions

Despite the apparent wealth of data that has been used to describe biodiversity patterns in the Tasman Sea to date, significant gaps remain. Most benthic faunal samples and seafloor imagery come from relatively shallower depths, leaving a substantial spatial and depth range gap, particularly in the South Tasman Sea (Fig. 3). Any attempts under the High Seas Treaty to design and implement Area-based Management Tools in this area would require compilation of existing information, addressing major data gaps, and be driven by significant cooperation between governments, as well as relevant institutes and organisations.

A joint biodiversity survey between New Zealand and Australia in the Tasman Sea could play a crucial role in addressing existing knowledge gaps. For example, the resubmission of a previously unsuccessful trans-Tasman initiative to use the RV *Investigator* to explore ecological gradients across the Subtropical Front in the South Tasman Sea. Building on the spatial scope and approach of the NORFANZ survey would also be particularly valuable for filling the remaining data gaps. Revisiting these initiatives and fostering collaboration among regional institutions could significantly enhance our understanding of biodiversity patterns and support more informed transboundary conservation efforts in the deep areas of the Tasman Sea.

Acknowledgements

Thanks to all those who have contributed one way or another to the research and data collection described in this presentation – including the funders of the work.

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Zealandia as a deep-sea biodiversity hotspot: A perspective from crustacean ostracods

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Introduction

Present-day deep-sea ecosystems are characterised as highly biodiverse, but the reasons behind this biodiversity are unclear. Fossil records and geological history may provide insights; however, most deep-sea benthos do not have good fossil preservation or records. Fortunately, benthic crustacean ostracods are an exception, with excellent fossil records in deep-sea sediments. Building on Robin Whatley's hypothesis several decades ago, which suggests the area between Australia and New Zealand as a key evolutionary hotspot of many modern deep-sea species due to tectonic subsidence (sinking) during the Paleogene — we suggest that further investigation in this region is merited, given the implications for understanding how present-day deep-sea fauna evolved. This paper explores this proposal in detail and summarises the high biodiversity and cosmopolitanism of deep-sea ostracods in this region, especially on the Lord Howe Rise.

Geological history and ostracod fossil records

The Lord Howe Rise and other key areas within Zealandia have been the focus of deep-sea drilling projects, providing long sediment cores that cover tens of millions of years of seafloor deposition history. These cores offer valuable insights into deep-sea evolution over time, particularly through the study of ostracods—tiny crustaceans with calcium carbonate shells that are well-preserved as fossils in deep-sea sediments (see Fig. 1). Ostracods serve as proxies for broader animal biodiversity, allowing us to study paleoecology and macroscale evolution in deep time.

Many sediment cores have been drilled in this region including those from a recent International Ocean Discovery Program (IODP) expedition (Expedition 371) (Fig. 2) (Sutherland et al, 2019). The cores reveal significant subsidence – the deepening of the seafloor – in the region during the Cenozoic era (66 million years

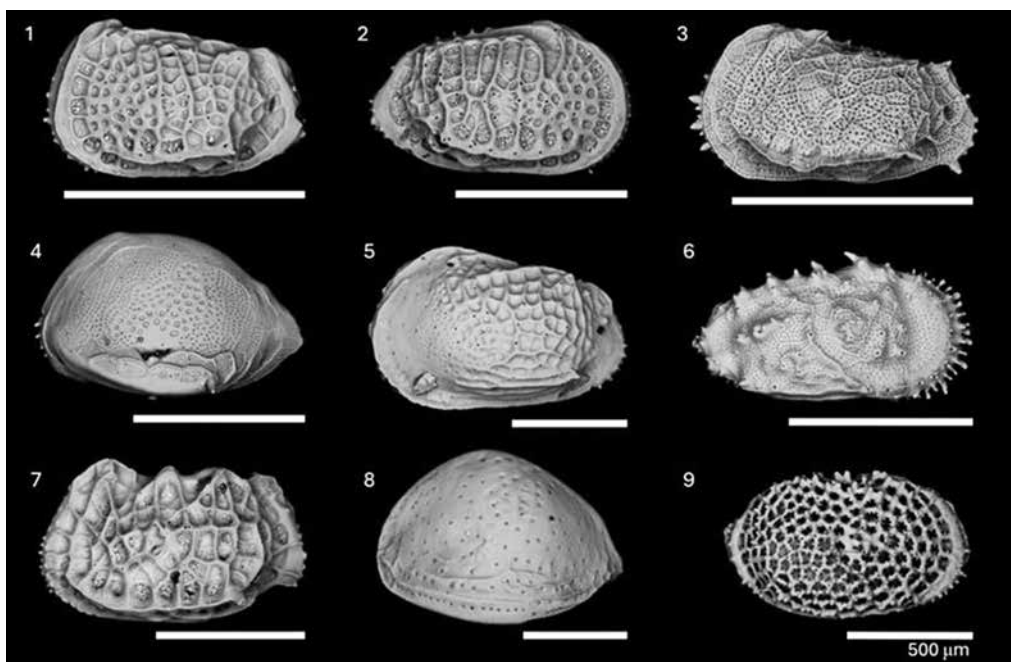


Figure 1: Scanning electronic images of various adult and juvenile specimens of deep-sea genera: (1-2) *Poseidonamicus*, (3) *Bradleya*, (4) *Cytheropteron*, (5) *Philoneptunus*, (6) *Cythereis*, (7) *Bradleya*, (8) *Pelecocythere*, (9) *Anebocythereis*. Source: Huai-Hsuan May Huang.

ago to present day), transitioning from the shallow marine environments to eventually the modern water depths of over 1000 metres (Sutherland et al, 2020). This subsidence may have led to deep-sea evolution for various taxonomic groups, including ostracods.

Evolutionary insights from ostracod genera

Ostracod fossil records provide valuable insights into deep-sea evolution, as several deep-sea ostracod genera found in multiple ocean basins today have probably originated from their shallow marine ancestors in the southwestern Pacific region. For example, the genus *Poseidonamicus* was hypothesised to have experienced evolutionary radiation during the tectonic subsidence in the southwestern Pacific and subsequently dispersed into global deep-sea environments during the Neogene. Deep-sea ostracod genera endemic to the southwestern Pacific and adjacent regions are also known.

These exemplify how geological subsidence and environmental changes have driven deep-sea evolution and high endemism on the Lord Howe Rise and throughout Zealandia (Whatley et al, 1983). The transition from shallow- to deep-water environments could have initiated the evolution of certain deep-sea organisms, resulting in high deep-sea biodiversity. While ostracods provide a clear paleontological record, other groups such as isopods and brittle stars may also exhibit similar patterns of evolution.

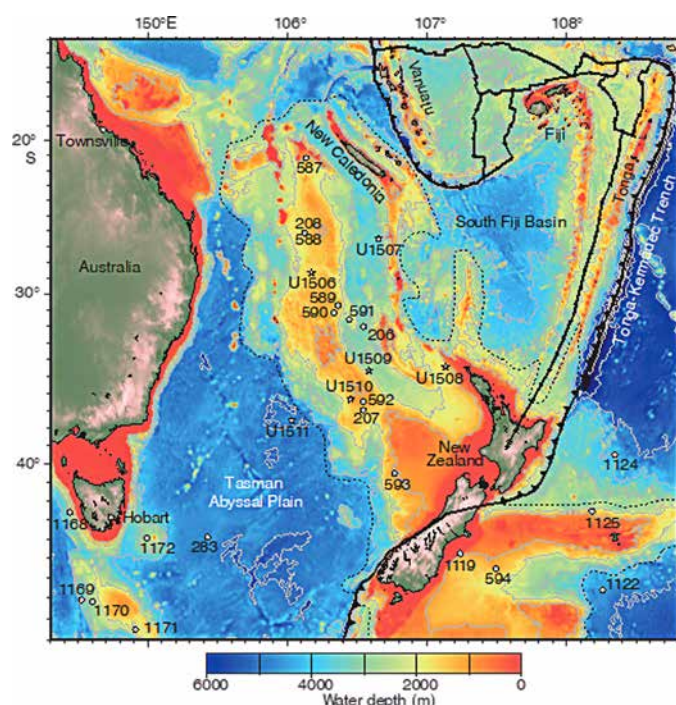


Figure 2: IODP Expedition 371 Sites U1506–U1511 and other DSDP (Deep Sea Drilling Project) and ODP (Ocean Drilling Program) coring sites in the region (from Sutherland et al, 2019).

Despite the valuable insights gained from ostracod fossil records, significant research gaps remain, particularly in the availability of sediment core samples from key regions within Zealandia, including the Lord Howe Rise. The current understanding of deep-sea evolutionary history in this region is limited by the scarcity of well-preserved, stratigraphically continuous cores that span critical geological transitions. Additional surface sediment samples, such as box cores and multiple cores, are needed to understand spatial distribution of recent ostracods in this region which is not well understood. By better understanding ostracod evolutionary history from their fossil records and Recent distribution, we can test whether similar evolutionary patterns are evident in other deep-sea taxa by comparing ostracod results with, for example, molecular phylogeny of other taxa that have scarce fossil record. These collaborative efforts will be important to fully explore the hypothesis of Zealandia as a global centre of deep-sea biodiversity.

Conclusion

Our research highlights Zealandia – particularly the Lord Howe Rise – as a significant centre for deep-sea biodiversity and evolution. Geological subsidence during the Paleogene era accompanied the origination of certain deep-sea forms, corresponding to high endemism and biodiversity in ostracods and potentially other taxa in the region. By leveraging fossil records and modern paleontological techniques, we can gain deeper insights into the origins and drivers of deep-sea biodiversity. Continued collaboration and access to sediment samples will be essential for furthering this research and understanding the evolutionary significance of the southwestern Pacific region.

Acknowledgements

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Mesophotic habitats of Lord Howe Island and Ball's Pyramid

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Introduction

In the South Pacific Ocean, modern coral reef growth occurs at its southernmost extremity in the shallow waters of Lord Howe Island. Here, a coral reef fringes the island's western lagoon, built upon Holocene coral reef accretions that developed as sea level rose to its present level (Kennedy and Woodroffe, 2000). The region's marine benthos is characterised as possessing both temperate species, due to its subtropical location, and tropical species, due to the influx of warm waters from the southward-flowing East Australian Current which eddies east to Lord Howe Island. It is globally recognised through World Heritage status and is protected by a network of Commonwealth and state marine parks and reserves.

In the mesophotic waters surrounding Lord Howe Island and Ball's Pyramid, extensive drowned fossil reefs have been discovered in 30 to 50m depth on the broad, submerged shelves surrounding the islands (Fig. 1). These reefs have been revealed to have formed, in part, during the Holocene transgression, accreting several metres of coral growth during 10 to 2 ka (Woodroffe et al, 2010, Woodroffe et al, 2023). Between the fossil reef outcrops are sedimentary basins, interpreted as paleolagoons, which contain up to 25 m of soft sediment (Brooke et al, 2010).

Given the evidence of substantial fossil coral accretion and the importance of the region at the latitudinal limits of coral reef growth, we sought to understand to what extent live corals were colonising the drowned fossil reefs. This research aimed to characterise the composition of mesophotic benthic communities and their relationship to the fossil reefs, with a particular focus on the presence and distribution of stony corals.

Methods

Towed underwater video and still imagery were captured around Lord Howe Island and Ball's Pyramid aboard a survey on the R.V. *Southern Surveyor* in February 2013 and a subsequent survey aboard Marine Parks Vessel *Tursiops* in November 2013. These surveys captured imagery in 3 to 115 m water depth, capturing 1,287 stills

from 24 transects for the Lord Howe Island shelf and 1,381 stills from 15 transects for the Ball's Pyramid shelf.

Still images were extracted for classification at 10 m intervals, totalling 2,668 stills. Images were classified by organism and substrate type and organism morphology using the Collaborative and Annotation Tools for Analysis of Marine Imagery and Video (CATAMI) classification scheme with a 25-point grid overlay. General trends in organism cover were explored for the full classified transect data. Classified data were sub-sampled into 20-stills per site for statistical analyses, resulting in 33 sites, totalling 660 stills (selected shallow tows were removed from analyses). Classified, sub-sampled data were related to bathymetry data (5 m cell size) and geomorphic features compiled by Linklater et al, (2018), which identified inner, mid and outer shelf reefs, basins, outer shelf pavement and outer shelf terrace features. Statistical analyses were performed to determine whether the benthos varied between shelves and geomorphic features.

Results

We observed diverse mesophotic habitats across both shelves, with biotic communities comprising a mix of algae, stony corals, black and octocorals, sponges and coralline algae. Substrates ranged from consolidated rock, pebbles, biogenic substrates (including rhodoliths and bivalve beds) and carbonate sands. The mid-shelf reefs exhibited higher cover of mixed benthic communities, including the highest occurrences of stony corals, with lower relative cover observed on inner-shelf reefs (excluding modern fringing reefs and lagoon), outer shelf reefs and pavements. The mesophotic habitats exhibit the distinctive quality of the region whereby stony corals co-occur in close proximity to algae due to its tropical and subtropical influences.

Relationship of benthos to geomorphology

Mesophotic communities were shown to be statistically different between the inner, mid and outer shelf reefs for the two shelves. The greatest difference was observed between the Ball's Pyramid mid shelf reefs and the Lord

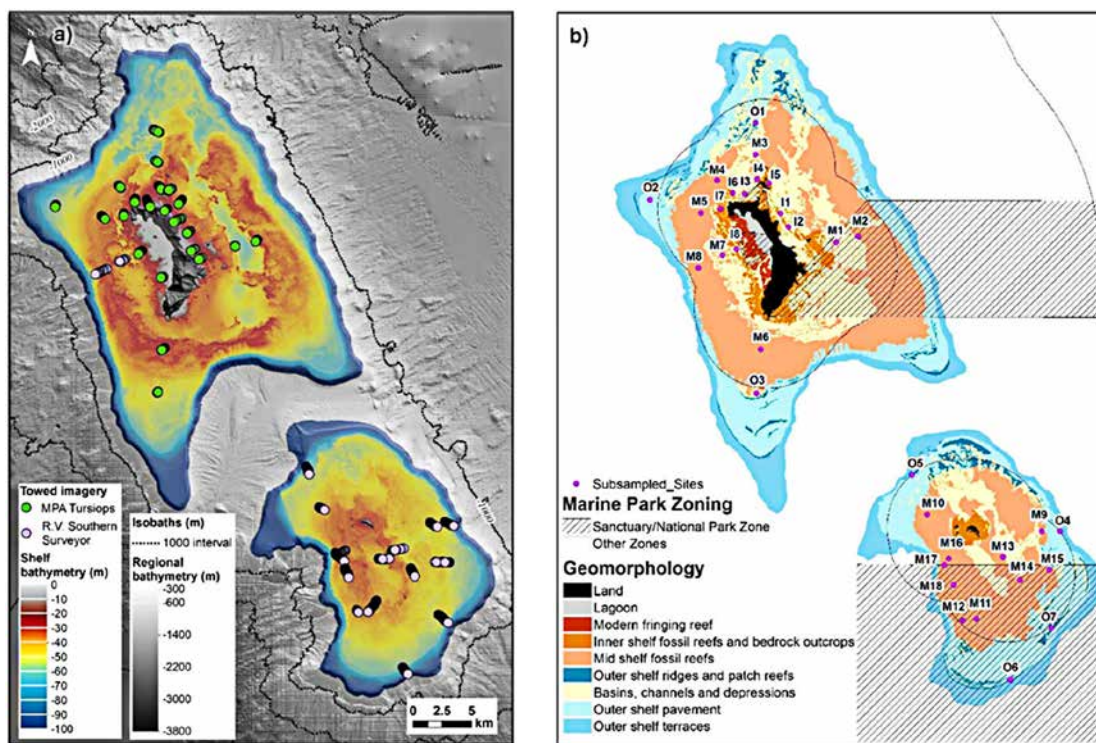
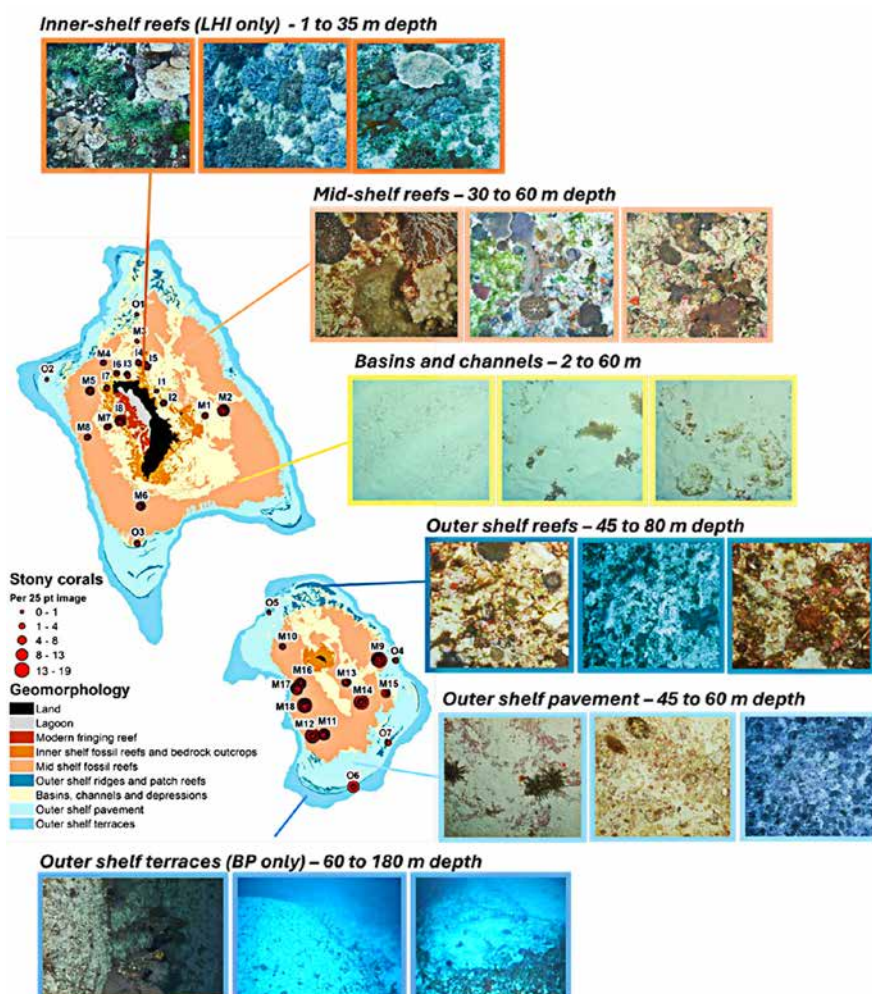


Figure 1: a) Towed underwater imagery collected from R.V. *Southern Surveyor* (light purple dots) and *Tursiops* (green dots) surveys in 2013, overlain on 5m bathymetry grid coloured to 100m depth; b) Sub-sampled sites (20-image subsets) overlain on classification of geomorphic features. Bathymetry and classified geomorphology sourced from Linklater et al, (2018). State and Commonwealth 'no-take' areas shown as hatched areas.

Figure 2: Stony coral counts are shown as a bubble map (red) for sub-sampled site data, using the count of stony corals per image (25-point image analysis). Representative images are shown for key geomorphic features. The depth ranges provided for the geomorphic features are generally indicative of where the features are predominantly distributed.



Howe Island inner shelf reefs, and the weakest difference was between the outer shelf reefs across the two shelves.

General patterns in the distribution of benthos on geomorphic features were observed and described (Fig. 2, Fig. 3). Inner-shelf reefs (excluding modern fringing reef and lagoon) were characterised by octocorals and fleshy algae. Massive digitate and ridge octocorals, branching fleshy octocorals (e.g. *Dendronephthya* spp.), stony corals, and filamentous and encrusting algae (e.g. *Chlorodesmis* spp., *Caulerpa* spp.) were commonly observed. Mid-shelf reefs were typically colonised by encrusting and submassive stony corals, sponges, coralline algae, and encrusting algae, with octocorals also common. The level of cover varied between sites though remained typically mixed benthos, with some areas algal-dominated (e.g. *Peyssonnelia* spp.). The outer-shelf reefs were associated with higher occurrences of pebbles and rhodoliths, with whips and branching octocorals. Anemones were observed most often in deeper waters around the outer-shelf.

Prolific carbonate sands accumulated in the sediment basin features, with cobbles and algae also occurring in basin areas. On the outer-shelf pavement, sand veneers were overlain on flat limestone foundations, with rhodoliths increasingly common from the mid to outer-shelf regions. On the outer-shelf terraces, raised reefs and drop-offs were associated with black corals (e.g. fans), with whip gardens and sand veneers common

in flatter areas. Sea urchins were often observed, typically *Prionocidaris* spp., occasionally present in large abundances.

Stony coral distribution

Live stony corals were widespread across the mesophotic habitats of the Ball's Pyramid and Lord Howe Island shelves, found in greatest abundance on the Ball's Pyramid mid-shelf (Fig. 3, Fig. 4). Maximum coral cover for an individual still was recorded at 84% in 30 m depth on the Ball's Pyramid mid shelf. For sub-sampled data, average stony coral cover was generally less than 10%. Stony coral cover was overall higher across most sites on the Ball's Pyramid mid shelf relative to the Lord Howe Island mid and inner shelves. On the Lord Howe Island mid-shelf, stony coral cover was greatest on the southeastern shelf. Lowest stony coral cover occurred on the Ball's Pyramid northwestern mid-shelf and northern shelf of Lord Howe Island. On the outer shelf reefs, average stony coral abundance was highest on the southern shelves of Ball's Pyramid and Lord Howe Island.

The deepest stony coral recorded from the still imagery occurred at 94 m depth on the southern outer shelf of Ball's Pyramid, which is an impressive depth given the region's high latitude location at the limit of reef development. Stony coral growth at this location demonstrates high water clarity which enables photosynthetic coral growth to extend to such depths.

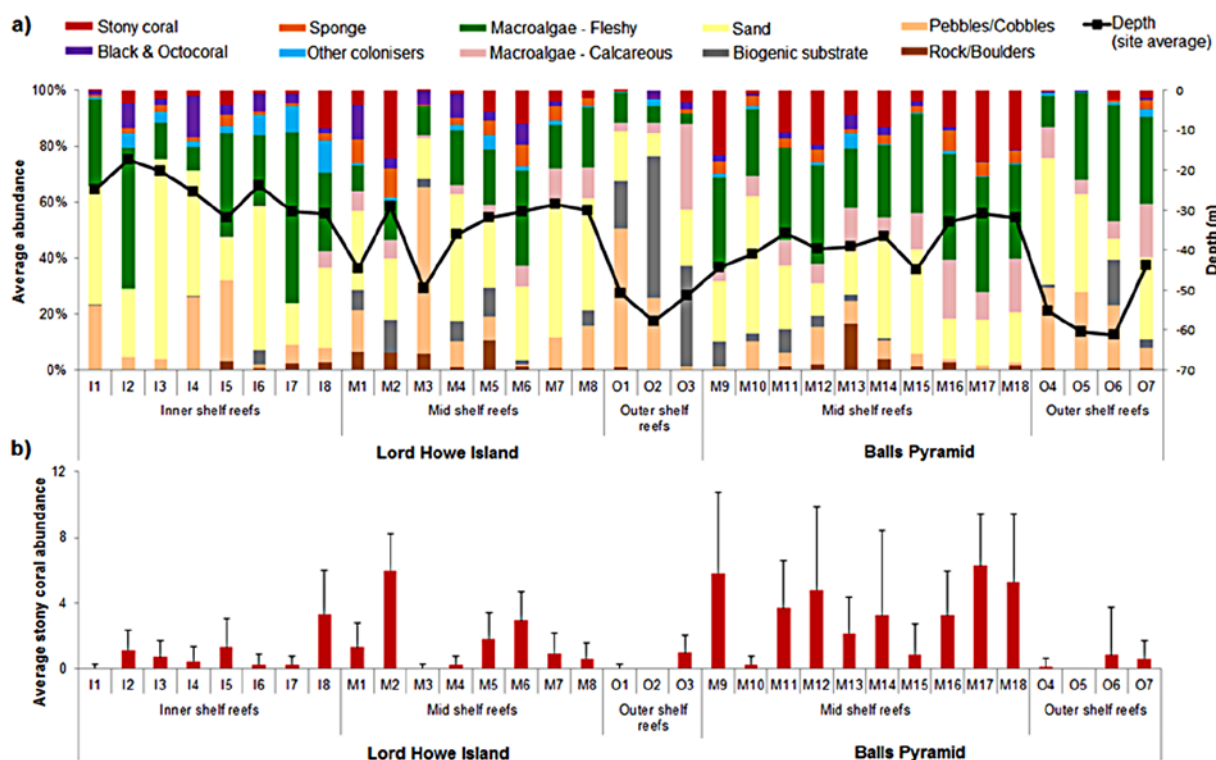


Figure 3: a) Average abundance of organisms and substrates for the sub-sampled site data. Depth shown as secondary axis; b) Average stony coral abundance for each sub-sampled site, with standard deviation shown as positive error bar. Figure reproduced from Linklater et al, (2019).

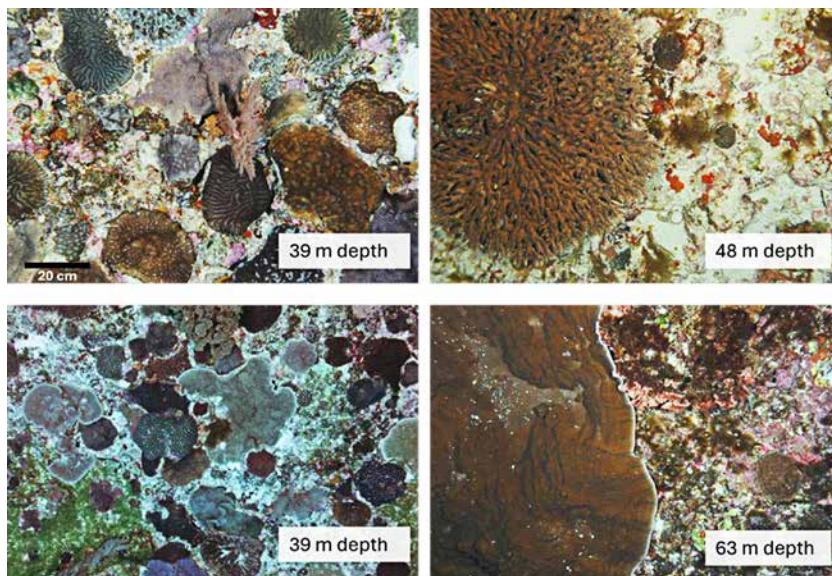


Figure 4: Example still images demonstrating high coral cover observed on Ball's Pyramid shelf reefs.

Conclusion

Higher than anticipated stony coral cover was observed on the surface of the drowned fossil reefs, with the mid-shelf reefs supporting the highest levels of coral cover. Live stony corals co-occurred with algae, black and octocorals, sponges, and other organisms including urchins and anemones. High carbonate production is demonstrated by the common occurrence of calcifying organisms, and the expansive carbonate sand basins and sand veneers.

The deep occurrence of live stony corals, reaching depths of over 90 m, is remarkable for this high latitude setting, and highlights the high water clarity of the region. The presence of stony corals and broad distribution across the two shelves raises the question of whether these mesophotic habitats may act as potential refuge areas for corals under ongoing climate change. Our research provides important baseline data for ongoing monitoring of these high value ecosystems, occurring at a critical threshold of global coral reef development.

Associated papers

Linklater M, Carroll AG, Hamylton SM, Jordan AR, Brooke BP, Nichol SL and Woodroffe CD (2016) 'High coral cover on a mesophotic, subtropical island platform at the limits of coral reef growth' *Continental Shelf Research*, 130:34-46.

Linklater M, Jordan AR, Carroll AG, Neilson J, Gudge S, Brooke BP, Nichol SL, Hamylton SM and Woodroffe CD (2018) 'Mesophotic corals on the subtropical shelves of Lord Howe Island and Ball's Pyramid, south-western Pacific Ocean' *Marine and Freshwater Research*, 70(1):43-61.

Data availability

Bathymetry data, geomorphic classifications, tow video summaries and classified benthic data are available via Seamap Australia <https://seamapaustustralia.org/>. Still and video imagery for the R.V. *Southern Surveyor* cruise are available via CSIRO National Computer Infrastructure facility.

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The mesophotic corals of Lord Howe Island Marine Park

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Introduction and context

The discovery of occasional patches of high coral cover in the mesophotic depths (midwater depths of approximately 30 – 150m) surrounding Ball's Pyramid during surveys by Geoscience Australia came as something of a surprise given the high latitude of this site with respect to hermatypic coral distributions (Linklater et al, 2019). Interest in mesophotic corals has been stimulated in part by more ready access to specimens due to advances in diving technology and remote imaging platforms, but also due to the possibility that the mesophotic might serve as a refuge from warming seas' surface waters (Baird et al, 2018) and a reservoir of novel biodiversity (Bridge et al, 2013).

Video transects were provided by Geoscience Australia from which screen shots of individual corals were extracted (Fig. 1). In addition, approximately 60 specimens were collected from between 20 and 80m depths in the waters of the Lord Howe Island Marine Park. Field images were identified at as high a resolution as possible based on the consensus expert opinion. Specimens were identified using a combination of morphological and molecular approaches and comparison to the type material.

Mesophotic diversity

A total of 46 morpho-species were identified on the video transects provided by Geoscience Australia. A total of 32 species were collected between 22m and 69m.



A shallow reef system of Lord Howe Island.
Source: © Bridget Ferguson / Greenpeace.

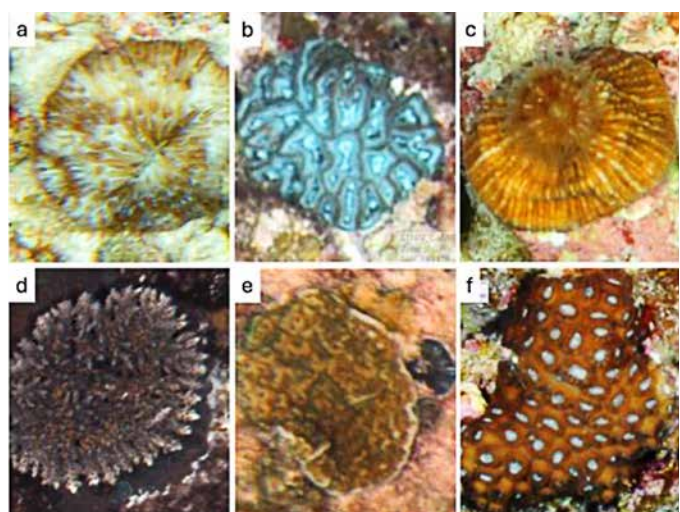


Figure 1: Representative mesophotic corals from the Geoscience Australia video transects (a) *Cyclosers aff tenuis*, (b) *Homophyllia hillae*, (c) *Cycloseris aff costulata*, (d) *Acropora solitaryensis* (e) *Leptoseris aff mycetoceriodes* (f) *Astrea cf curta*.

Genus	on	species	voucher	image	shallow	described
<i>Acanthastrea</i>	cf	<i>echinata</i>	no	yes	yes	yes
<i>Acropora</i>		<i>arborescent sp_1</i>	no	yes	yes	no
<i>Acropora</i>		<i>arborescent sp_2</i>	no	yes	yes	no
<i>Acropora</i>	cf	<i>cytherea</i>	yes	no	yes	yes
<i>Acropora</i>	aff	<i>solitaryensis</i>	yes	no	no	no
<i>Acropora</i>		<i>solitaryensis</i>	yes	yes	yes	yes
<i>Acropora</i>		<i>tabular sp-1</i>	no	yes	?	no
<i>Alveopora</i>	aff	<i>gigas</i>	yes	no	yes	no
<i>Alveopora</i>		<i>gigas</i>	yes	no	yes	yes
<i>Astrea</i>	cf	<i>curta</i>	yes	yes	yes	yes
<i>Astreopora</i>	cf	<i>moretonensis</i>	yes	no	no	yes
<i>Coscinaraea</i>	cf	<i>columna</i>	yes	yes	yes	yes
<i>Cycloseris</i>	cf	<i>curvata</i>	yes	yes	no	no
<i>Cycloseris</i>	cf	<i>doederleni</i>	yes	yes	no	yes
<i>Cycloseris</i>	cf	<i>mortoni</i>	no	yes	no	yes
<i>Cycloseris</i>	cf	<i>vaughani</i>	yes	yes	no	yes
<i>Cycloseris</i>	cf	<i>wellsi</i>	yes	yes	no	yes
<i>Cyphastrea</i>		<i>salae</i>	yes	yes	yes	yes
<i>Dipsastraea</i>	aff	<i>matthai</i>	no	yes	yes	no
<i>Dipsastraea</i>	cf	<i>uva</i>	yes	yes	yes	yes
<i>Duncanopsammia</i>	cf	<i>peltata</i>	no	yes	yes	yes
<i>Echinophyllia</i>	aff	<i>aspera</i>	yes	yes	yes	no
<i>Goniopora</i>	cf	<i>norfolkensis</i>	yes	yes	yes	yes
<i>Homophyllia</i>	aff	<i>australis</i>	no	yes	yes	no
<i>Homophyllia</i>	cf	<i>bowerbanki</i>	yes	yes	yes	yes
<i>Homophyllia</i>		<i>hillae</i>	yes	yes	yes	yes
<i>Hydnophora</i>		<i>pilosa</i>	yes	yes	yes	yes
<i>Leptoseris</i>	aff	<i>hawaiiensis</i>	yes	yes	no	no
<i>Leptoseris</i>		<i>incrustans</i>	yes	no	no	yes
<i>Leptoseris</i>	aff	<i>mycetoseroides</i>	no	yes	no	no
<i>Leptoseris</i>		<i>striatus</i>	yes	no	no	yes
<i>Micromussa</i>		<i>lordhowensis</i>	no	yes	yes	yes
<i>Micromussa</i>	cf	<i>pacifica</i>	no	yes	yes	yes
<i>Montipora</i>		<i>capricornis</i>	yes	yes	yes	yes
<i>Montipora</i>		<i>encrusting sp_1</i>	no	yes	?	?
<i>Montipora</i>		<i>encrusting sp_2</i>	no	yes	?	?
<i>Montipora</i>		<i>encrusting sp_3</i>	no	yes	?	?
<i>Montipora</i>	cf	<i>turgescens</i>	no	yes	yes	yes
<i>Paragoniastrea</i>	cf	<i>benhami</i>	yes	yes	yes	yes
<i>Paragoniastrea</i>	aff	<i>russelli</i>	yes	yes	yes	no
<i>Pavona</i>	cf	<i>explanulata</i>	no	yes	yes	yes
<i>Platygyra</i>	cf	<i>edwardsi</i>	yes	no	yes	yes
<i>Plesiastrea</i>	cf	<i>peroni</i>	yes	yes	yes	yes
<i>Pocillopora</i>	aff	<i>damicornis</i>	no	yes	yes	no
<i>Porites</i>	cf	<i>heronensis</i>	yes	yes	yes	yes
<i>Porites</i>	cf	<i>lutea</i>	yes	yes	yes	yes
<i>Psammocora</i>	cf	<i>contigua</i>	no	yes	yes	yes
<i>Psammocora</i>	aff	<i>profundacella</i>	yes	yes	yes	no
<i>Seriatopora</i>	cf	<i>hystrix</i>	yes	no	yes	yes
<i>Stylocoeniella</i>	aff	<i>guentheri</i>	yes	no	no	no
<i>Stylophora</i>	aff	<i>pistillata</i>	no	yes	yes	no
<i>Turbinaria</i>	cf	<i>frondens</i>	no	yes	yes	yes
<i>Turbinaria</i>	cf	<i>mesenterina</i>	no	yes	yes	yes
<i>Turbinaria</i>	cf	<i>patula</i>	no	yes	yes	yes
<i>Turbinaria</i>		<i>radicalis</i>	no	yes	yes	yes

Table 1: A list of mesophotic corals from Lord Howe Island and Ball's Pyramid. on = open nomenclature to convey taxonomic uncertainty (see Cowman et al, 2020); voucher = whether or not a specimen was collected; image = presence or absence on video transects; shallow = present between 0-10 m on Lord Howe Island; described = whether or not the species has been described.

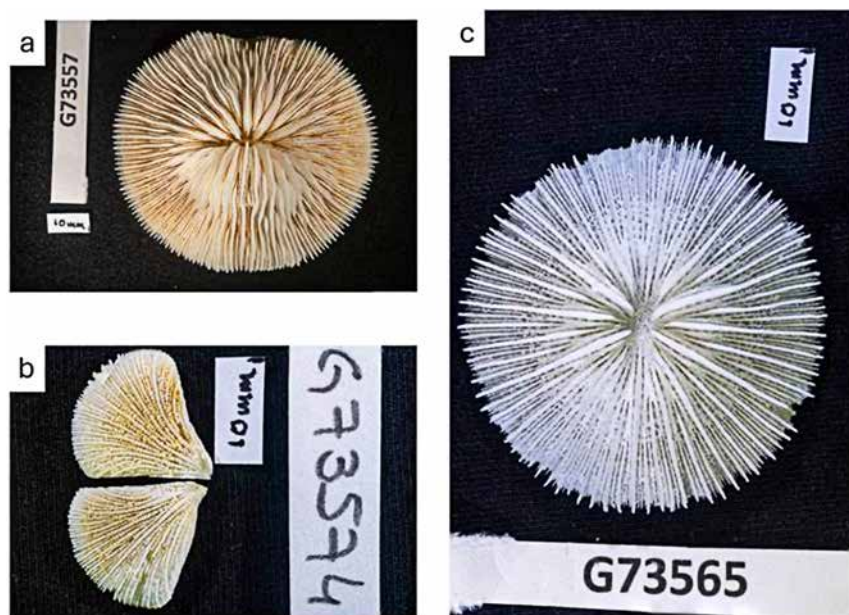


Figure 2: Mesophotic *Cycloseris* of the Lord Howe Island Marine Park (a) *Cyclosers cf doederleni*, (b) *Cyclosers mortoni*, (c) *Cyclosers cf vaughani*.

When these list were combined a total 56 morpho-species were observed at mesophotic depth in the Lord Howe Island Marine Park (Table 1). This makes the mesophotic fauna typically species rich with respect to a regional fauna of approximately 100 spp (unpublished data). Typically, the mesophotic assemblage is a much smaller subset of the regional fauna.

Thirty-nine (70%) of these 56 species also occurred in the shallow water surrounding Lord Howe Island (1-10m, unpublished data). Again, this proportional overlap between the mesophotic and the shallow water fauna is atypical and indicates that depth can provide a refuge from disturbance for most of the shallow water species of the Lord Howe Island Marine Park.

Thirteen species (27%) were found exclusively in the mesophotic. These 13 included five species of *Cycloseris* (Fig. 2), four species of *Leptoseris*, *Acropora aff solitaryensis*, *Astreopora cf mortenensis* and *Stylocoeniella aff guentheri*. Another notable feature of the mesophotic fauna was the lack of *Acropora* spp with only six species recorded below 22m. Below 40m, only *Cycloseris* and *Leptoseris* were observed.

At least 22 (37%) of these species are likely to be undescribed and many are likely to be endemic to the Lord Howe Island Rise. The coral fauna of the Lord Howe Island Marine Park is not a depauperate tropical assemblage as previous suggested, rather a distinct fauna comprised of many small range regional endemics

Future work

Species identifications are preliminary and further molecular and morphological research is required for accurate assessments of taxonomic identities.

- Many of these species are small range endemics, however, their abundance within the Lord Howe

Island Marine Park is unquantified. Further surveys are required to assess species abundance to allow an accurate assessment of extinction vulnerability.

Conclusions

The coral fauna of the Lord Howe Island Marine Park is not a depauperate tropical assemblage as previous suggested, rather a distinct fauna comprised of many small range regional endemics. A high proportion of small range endemics of potentially low abundance in a climate change hot spot makes the coral of the LHIMP some of the most vulnerable corals species on earth. A high proportion of undescribed species indicates that urgent work is required to prevent silent extinctions.

Acknowledgments

Field: Erika Woolsey, Sally Keith, Tane Sinclair-Taylor, Steve Lindfield, Morgan Pratchett, Andy Hoey. Logistics: Brian Busteed, Howea Divers; Aaron and the crew from ProDive; Sallyann Gudge, Justin Gilligan and Caitlin Woods, Department of Primary Industries; the Lord Howe Island Board. Funding: ARC Centre of Excellence for Coral Reef Studies.

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SeaSearchin' for urchins: Utilising museum collections and citizen science to assess species on the move in the genus *Tripneustes*

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As species ranges continue to shift with the advancement of global warming and associated marine heat waves, accurately quantifying species distributions is critical to understanding the ongoing effects on biodiversity (Parmesan and Yohe, 2003; Pecl et al, 2017). The genus *Tripneustes* comprises globally important sea urchin taxa that have the potential to transform ecosystems due to their seagrass and macroalgae grazing abilities. In eastern Australia, there are two *Tripneustes* species, the tropical *T. g. gratilla* and the subtropical-temperate *T. australiae*. The temperate distribution of *T. australiae* was considered to be a climate-driven range extension of *T. g. gratilla* until recent taxonomic clarification distinguished the two as separate species (McLaren et al, 2023; Fig. 1).

Museum and Reef Life Survey data

The distribution of *Tripneustes* species was examined, combining data from several museums, including the Australian Museum, the Natural History Museum London and the Reef Life Survey, which comprises citizen science divers that regularly undertake broad-scale benthic abundance research at places like Lord Howe Island. We also undertook some molecular work, which incredibly, included several specimens believed to be around 100 years old.

We used this rich dataset to do some habitat suitability modelling, which enabled us to use remotely-sensed environmental data – for example temperature, depth, seawater velocity – combined with distribution data and climate modelling by the Intergovernmental Panel on Climate Change, to determine potential future distributions.

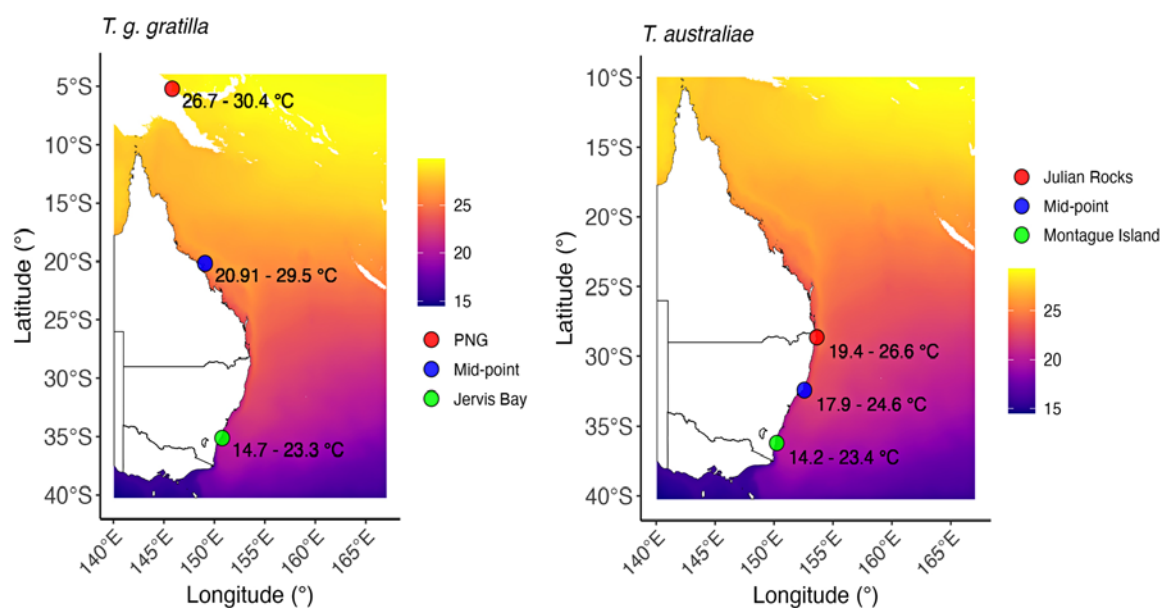


Figure 1: The east Australian distributions of *T. g. gratilla* (orange dash) and *T. australiae* (green dash).

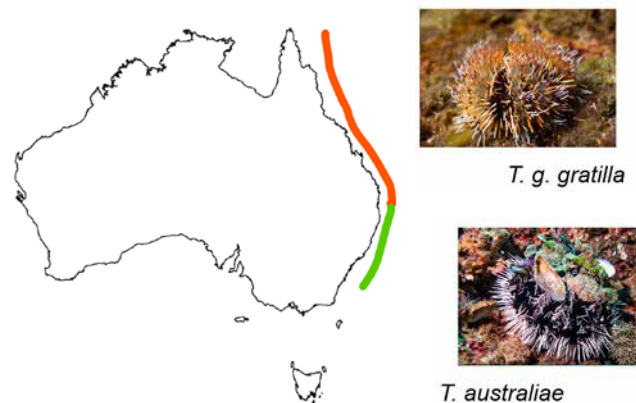


Figure 2: Habitat suitability modelling for *T. g. gratilla* (left) and *T. australiae* (right).

Two distinct distributions within a genus

Our analysis revealed distinct distributions and thermal niches for the two *Tripneustes* species. *T. g. gratilla* has a wide tropical-temperate distribution in the region from Papua New Guinea to Jervis Bay and a broad realised thermal niche of 16.3°C–29.97°C (Fig. 2). In contrast, *T. australiae* has a subtropical-temperate distribution - Byron Bay to Narooma - and a narrower thermal niche of 15.3°C–26°C (Fig. 2). *Tripneustes* densities were highest in the subtropical ecoregions. The two taxa co-occur on Lord Howe Island and Norfolk Island.

Habitat suitability modelling indicated that *T. australiae* is more specialised in its preferred temperature. While populations are currently abundant in the Lord Howe and Norfolk Island ecoregion, our work suggests it will undergo a range shift by the year 2100. In contrast, *T. g. gratilla* is a generalist that appears capable of occupying a broader range of conditions, and we expect that these populations may continue to persist across the Lord Howe and Norfolk Islands, potentially filling the ecological niche for both species in this region.

Despite their similar ecological roles, both *Tripneustes* species in eastern Australia and the Tasman region have contrasting distributions and thermal niches, with distinct implications for their future distributions as the ocean warms. The trans-Tasman distribution of *T. australiae* and other echinoderms with similar thermal profiles may change in the near future.

Future research priorities

Although we have utilised a rich dataset for our analysis, several knowledge gaps remain. Spatial coverage was limited to specific transects, and while the surveys captured a broad range of depths and geomorphic features, there are likely additional habitats that remain unexplored. Taxonomic resolution was also constrained by the use of morphology-based classification, which, while efficient, may overlook cryptic species or subtle community differences (Pecl et al, 2017). Accurate taxonomy underpins this work, as adequate conservation is extremely difficult; we don't know what species we are dealing with.

We suggest future research should aim to:

- Use genetic and molecular tools to refine species-level identification;
- Regularly monitor for changes in community composition to detect climate-driven shifts.

Conclusion

This study provides a foundational dataset for monitoring *Tripneustes* sea urchins in eastern Australia and the Tasman region. The discovery of distinct thermal niches and potential future range shifts for *T. australiae* and *T. g. gratilla* offers new perspectives on the ecological potential of these taxa. As climate change continues to alter ocean temperatures and light regimes, understanding the distribution and habitat suitability of these sea urchins will be critical for conservation efforts (Sunday, Bates and Dulvy, 2012).

Associated paper

McLaren E, Sommer B, Pine C, Miskelly A and Byrne M (2025) Searchin'for Urchins: Utilising Museum Collections and Citizen Science to Assess Species on the Move in the Genus *Tripneustes*. *Journal of Biogeography*, 52(5):e15092.

<https://onlinelibrary.wiley.com/doi/pdf/10.1111/jbi.15092>

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Return of the lamingtons – boom-and-bust populations of the sea urchin *Tripneustes australiae* on Lord Howe Island reefs

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Introduction

Sea urchins in the genus *Tripneustes* have fast growth and boom-and-bust population dynamics (Lawrence and Agatsuma, 2020). *Tripneustes australiae* is endemic to the east coast of Australia and New Zealand (Bronstein et al, 2019; McLaren et al, 2023). This sea urchin is currently undergoing a population 'boom' in the Lord Howe Island Marine Park (LHIMP); *Tripneustes australiae* occurs in subtidal reefs where its grazing pressure in population outbreaks can create barrens-type habitats, void of seaweeds and in coral reef habitats reduces algal overgrowth of coral (Valentine and Edgar, 2010; McLaren et al, 2024).

Our work aims to understand the population dynamics of *Tripneustes australiae* in the LHIMP, focusing on the factors driving its boom-and-bust cycles. We used data from the Reef Life Survey, which spans from 2006 to 2024 and included observations from 38 sites around Lord Howe Island and four sites around Ball's Pyramid, to track the density and distribution of *T. australiae* (Reef Life Survey, 2024). The survey data were analysed to identify trends and potential recruitment hotspots. Additionally,

we examined the size and depth distribution of individuals to determine the age, structure and habitat preferences of the population.

Key findings

Our analysis revealed two distinct population outbreaks of *T. australiae* on reefs surrounding Lord Howe Island: one in 2008 and another starting in 2024. A smaller population outbreak also occurred in 2022 on reefs surrounding Ball's Pyramid (Fig. 1). Densities of urchins varied on the reefs surrounding Lord Howe Island between the two outbreak years. During the 2008 outbreak, high densities of sea urchins were observed around the Admiralty Islands, Keyhole North, and Rupert's Reefs. In 2024, the population density increased again, and a staggering 4,600 individual urchins were surveyed.

Apart from a recurrence at the Admiralty Islands in 2024, there was no spatial overlap with the 2008 booms on reef surrounding Lord Howe Island, with notable concentrations occurring at Little Slope, Rupert's Reefs, and Sugarloaf West in 2024. Their size distribution data indicated that most individuals recorded in 2024 were juveniles, with sizes ranging from 2.5 to 5cm.

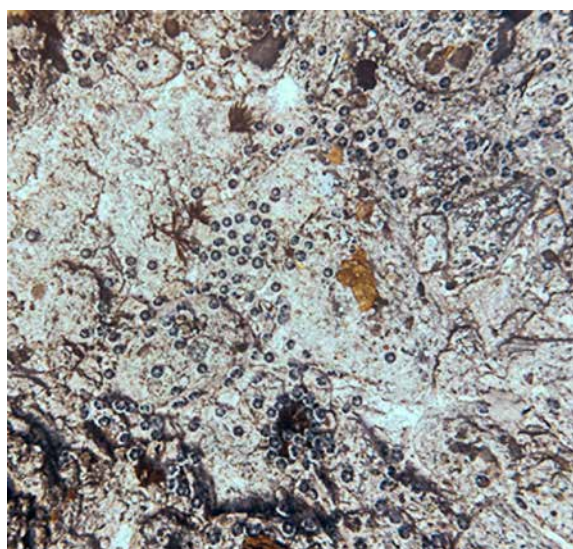


Figure 1: Outbreak of *Tripneustes australiae* 'barrens' in Lord Howe Island Marine Park at Ball's Pyramid in 2022. (Source: Caitlin Woods, Lord Howe Island Marine Park).

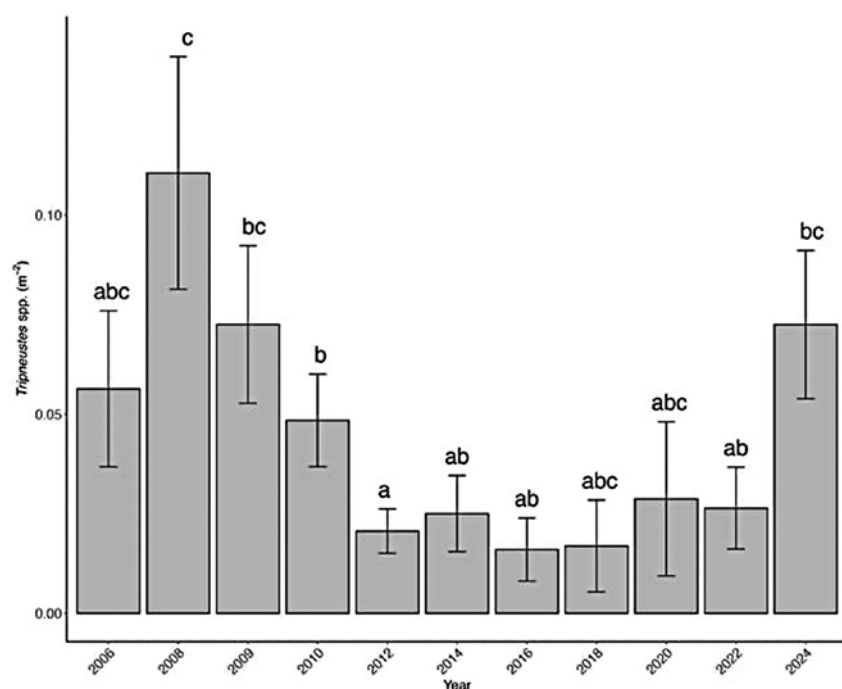
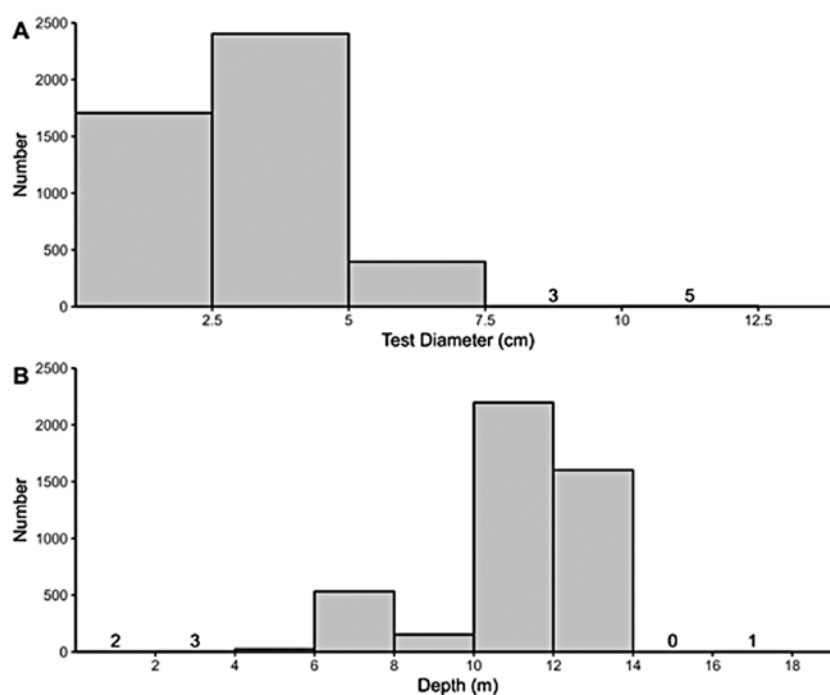


Figure 2: Boom and bust population dynamics of *Tripneustes australiae* on Lord Howe Island reefs 2008 – 2024.

Figure 3: Size and depth of all *T. australiae* encountered in the Reef Life Surveys in 2024, n = 4626.



These juveniles were predominantly found at depths between 10 and 14 metres. The presence of juveniles suggests a recent recruitment event, and we expect that these individuals will grow to their full size of up to 12cm by 2026.

The Admiralty Islands consistently appeared as a recruitment hotspot for *T. australiae*, suggesting a strong influence of ocean currents and connectivity with eastern Australia. Interestingly, our results suggest there is no difference in urchin abundance during outbreaks in habitat protection zones and sanctuary zones of the Lord Howe Island Marine Park.

Ecological implications

The boom-and-bust population dynamics of *T. australiae* have significant ecological implications for the Lord Howe Island ecosystem. During population outbreaks, the grazing pressure exerted by sea urchins can lead to the formation of barrens-type habitats, where algae are heavily grazed, resulting in reduced habitat complexity, as has been seen in temperate, kelp-dominated ecosystems (Byrne et al, 2024). There is also concern about the vulnerability of endemic algae species to grazing impacts in the LHIMP (Stuart-Smith et al, 2025). For coral reefs in the LHIMP, there was no discernible impact of the *T.*

australiae outbreak on other species in the system (corals, invertebrates, fishes) (Valentine and Edgar, 2010).

Interestingly, the relationship between sea urchins and corals appears to be mutually beneficial. Sea urchins help prevent algae overgrowth on corals, which can enhance coral health and resilience. However, the long-term consequences of repeated boom-and-bust cycles on the ecosystem remain uncertain, particularly in the context of ongoing climate change.

Knowledge gaps

Despite the extensive data collected, several knowledge gaps remain. The drivers of the boom-and-bust population dynamics of *T. australiae* are not fully understood. Factors such as climate anomalies, ocean currents, and larval recruitment patterns likely play a role, but further research is needed to understand these mechanisms. Additionally, the impact of habitat protection zones and sanctuary zones on sea urchin populations requires further investigation. We found no significant differences in population densities were observed between these zones, yet understanding the role of marine protected areas in regulating sea urchin populations (or not) is crucial for effective management.

Conclusion

The study of *Tripneustes australiae* in the LHIMP provides valuable insights into the population dynamics of this regionally endemic sea urchin species. The observed boom-and-bust cycles highlight the importance of long-term monitoring and the need to understand the underlying drivers of these fluctuations. As climate change continues to impact marine ecosystems, understanding the responses of key species like *T. australiae* is essential for effective conservation and management, especially as more species begin to move and re-establish their geographical niches as marine heatwave events occur. We suggest future research should focus on identifying the factors driving recruitment events and population declines, as well as the broader ecological impacts of sea urchin grazing.

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Reflections on day one of the symposium

by Dr Jodi Edwards

Unbroken Whispers: Kinship in the Currents

Out there...

Beyond where the coastline forgets its name,
Beyond where the maps go mute,
The ocean holds a memory.
Not a still memory —
But a living one.
An unbroken whisper.
A Seamount Chain —
A procession of underwater volcanoes,
Rising, falling,
Breathing beneath the waves.
And they remember.

They remember being sung into being.
It was sung.
It was mapped—
Not with satellites,
But with songlines.
Not with charts,
But with footsteps.
With ceremony.
With kin moving through Country.

This is how the sea remembers.
And through her —
Move the Sea Kin.

The Humpback Whale —
Their voices are not just a song.
They are transmissions.
A memory encoded in rhythms.
Each note is a landmark.
Each breach — a ceremony of joy.
The White Sharks —
Not terrors, but a teachers.
She follows the Earth's own electromagnetic
breath —
Moving not with sight, but with sense.
With listening.

And the Dolphins —
The ones who laugh with the sea.
They write patterns through the currents.
Dancing leaving tail prints.
Not for play —
But for connection.

Beneath them sleeps the Lord Howe Rise.
And beneath that —
The Elders.
The volcanoes.
Still Heavy with knowing.
Alive with stories not yet spoken.
Coral grows on lava —
Not as colonisers,
But as carers.
That's not geology.
That's ceremony.

And here's the first lesson
That Cultural Knowledge offers us:

Life is relational.

You don't just study the fish.
You speak to it.
You thank it.
You honour its part in the pattern.
mainstream science have words for this:

Trophic webs.

Keystone species.

Biodiversity hotspots.

But Culture teaches us...
With responsibility.

We've forgotten how to walk with the sea.

We manage it.

We mine it.

We market it.

But the ocean?
She is not a commodity, a resource.
She is a **relative**.

And the Tasmanian volcanoes?
They are not just underwater rocks.
They are Elders —
Resting, dressed in reef,
Listening for the return of our remembering.

I once saw a whale breach at sunrise.
The light caught her mid-air,
And I swear...
She was flying toward the sun.

And in that moment,
I realised:
She wasn't just moving through the ocean.
She was moving with it.
She was singing the path.

So what if...
What if a migrating whale is not just a mammal?
But a moving memory?
What if a reef isn't a fragile structure,
But a child's gift — like sea-weed cloak
Laid gently over the bones of an Elder?
What if every shark, every coral polyp, every
seabird,
Is not a data point —
But kin?

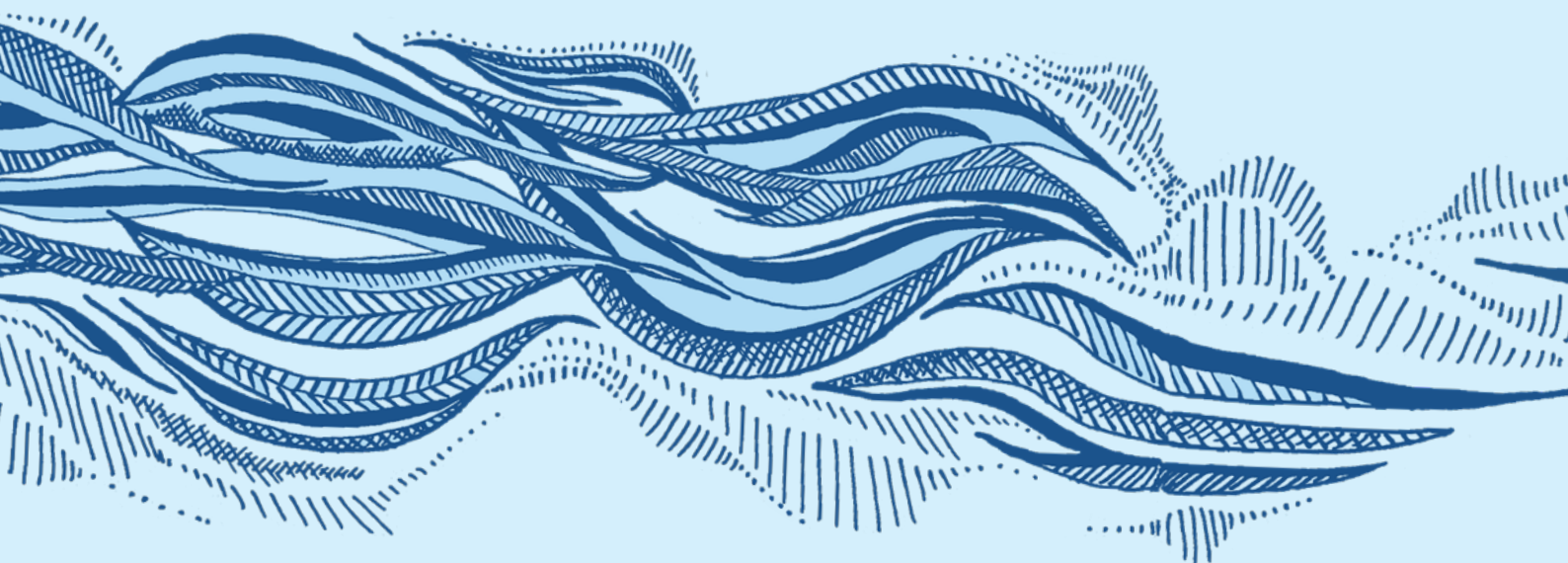
This is not mythology.
This is relational law.
This is truth older than science.
This is our responsibility.

Because the whispers?
They are still singing.
The question is...
Are we ready to remember how to listen?

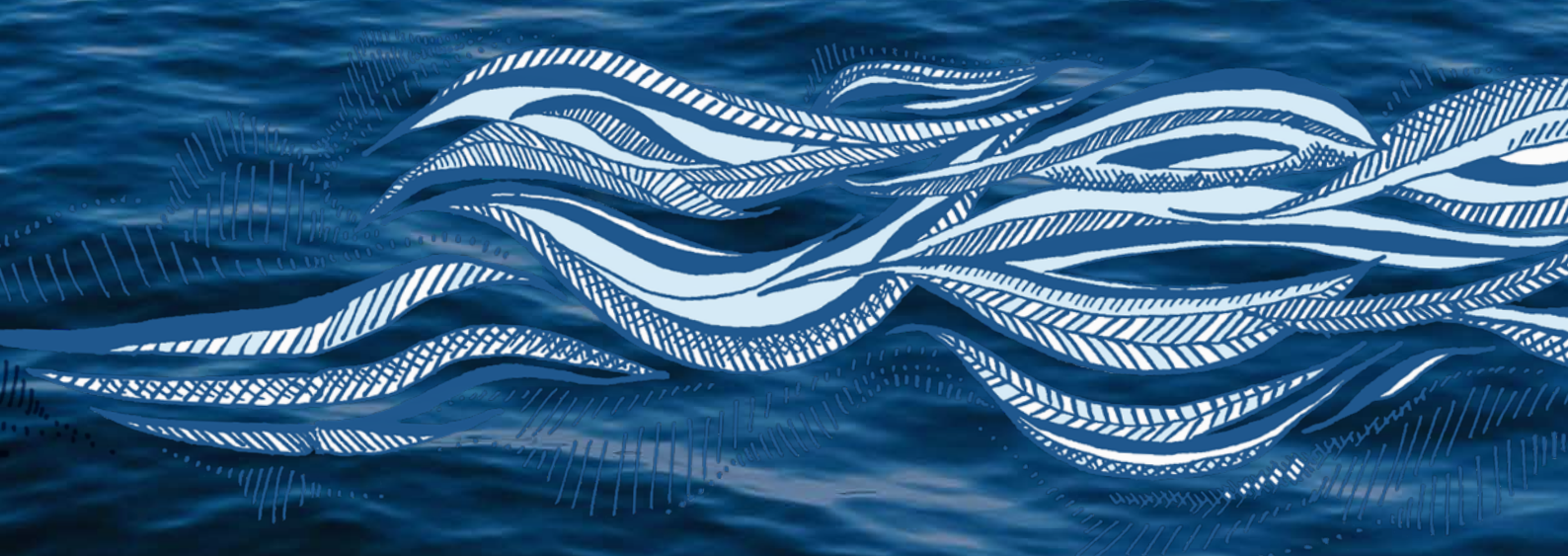
Because when we remember the sea as family —
We don't just protect her.
We walk with her.



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Human-ocean interactions



Understanding conservation needs and opportunities in the Lord Howe Rise area: A collaborative approach to mapping Culturally Important Areas

Authors: Dr Chels Marshall¹ (presenter) and Dr Jodi Edwards¹

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In this paper, we explore the profound relationship between Indigenous peoples and the ocean, emphasising the cultural, ecological, and spiritual dimensions of Sea Country. Drawing from oral histories, kinship systems, and intergenerational knowledge, we highlight the urgent need to embed Indigenous science into contemporary marine policy and management to achieve positive outcomes for the ocean, together. We identify challenges in current ways of working and propose culturally grounded pathways for sustainable ocean stewardship, including the concepts of Cultural Keystone Species and Culturally Important Areas.

Storylines and Sea Kin

Indigenous knowledge systems are encoded in storylines and songlines – oral repositories of ecological, spiritual, and social lore. These narratives, passed through generations, are embedded in the land, sea, and sky, providing guidance for our relationship with and stewardship of Country. For the Gumbaynggirr and Yuin peoples (our people) and other Saltwater nations, the ocean is a living and sacred being, holding our lore, our ancestors and our future within it. These knowledge systems are strong and enduring, and less prone to the sudden shifts we see in many Western societies. They reflect a fundamentally different worldview where humans are part of the web of life, not separate from it.

First Nations kinship extends beyond human relationships to include animals, plants, celestial bodies, and natural phenomena. Through totemic affiliations, individuals are connected to specific species and ecosystems. For example, the Gaagal (ocean) is the totem of the Gumbaynggirr Nation, which instantly connects me to every living entity in the ocean. I am connected to the corals, every stream and every flow of water that moves into the ocean, every season around the sun, the star constellations that reflect into the ocean and story, and the moon cycles and phases that dictate that flow of the ocean.

Women and Sea Country

Our culture has always foregrounded nature and embraced the complexity of natural systems and flows. Over tens of thousands of years, we formed social constructs that worked with nature, and nature dictated our practices and our way of living; this is still the case for many of us. The Industrial Revolution and the all-encompassing nature of capitalism and materialism fundamentally shifted this balance for many cultures globally, and its impact on our culture has been profound. We now live in egocentric times, where people – often men – regard themselves as being the centre of everything, often positioning humans as a species above and separate from all other species.

In Indigenous ideology and lore, a lot of Sea Country is women's business, with women holding significant custodial knowledge and authority. There are two points worth making in relation to matriarchal stewardship of Sea Country. The first is the importance of those matriarchal structures and practices when engaging in research and science. The second is to note the stark contrast on the one hand between modern patriarchal and egocentric approaches to ocean governance, and matriarchal, ecocentric ways of doing business on the other. We have allowed the former option to dominate, and a course correction towards the latter is desperately needed.

Cetaceans as Cultural Keystone Species

Our project 'Unbroken whispers: the ripples connecting Sea Kin' aims to develop a richer, shared understanding of threatened and migratory whales and dolphins, through incorporation of Indigenous ecological knowledge. Our starting point is unique. To us, whales are not simply a species to study. They are our Sea Kin and our ancestors, our aunties, uncles, parents and siblings. In other words, they are family. Whales are embedded in our culture, stories, songs, dances and other art forms. With this kinship comes a strong and binding sense of cultural responsibility. We have developed a term to describe the cultural significance of certain species to Indigenous Australians: Cultural Keystone Species (CKS). If you have not heard this term, we urge you to get acquainted with it.



Southern whale. Source: © Eric J Woelher.

We know Aboriginal people communicate with other species, and that this communication is grounded in respect, reciprocity and trust between species. We have eroded, and in some cases broken, some incredibly important bonds between us and these Cultural Keystone Species over the past few hundred years. Dolphins are being groped by tourists and fed food that makes them sick. Sharks have been demonised and hunted down. Orcas' reciprocal relationships with Saltwater communities were exploited by whalers. And industrial whaling operations pushed great whale species to the edge of extinction.

As we address the complex challenges outlined above, to regain balance and correct our course towards an ecocentric approach to conservation and ecosystem management, there are a few simple things we can do to start making amends with some of our Cultural Keystone Species. We can stop calling orcas 'killer' whales. We can remove the word 'right' from the species name southern right whale, so-called by whalers because it was the 'right' whale to hunt. These actions won't change the world, but they will accord these species and our culture the respect and reciprocity that must underpin our efforts towards ecocentric approaches, and away from egocentric ones.

Introducing Culturally Important Areas

CKS are a central element of Culturally Important Areas (CIA), a concept and term we have developed that describes places of importance to culture and species, and the relational complexities to them. We see a role for CIAs in complementing other tools such as Biologically Important Areas (BIAs); collectively, they could help to comprehensively inform threatened species recovery plans and other relevant processes and conservation measures. CIAs are very similar to how the BIAs are structured, but they have an additional component and numerous categories relating to cultural systems.

We are working with a number of partners, including the University of Tasmania to develop the CIA framework. For example, we are mapping the movement and connectivity of culturally significant species, including the eel and southern whale, with a focus on not only their migration

pathways, but also the connectivity between species and places. This work involves development and testing of a model for collecting, collating and analysing data and stories, and considering how that knowledge is owned and shared by communities with other stakeholders.

All of this work aims to support and progress the integration of Indigenous knowledge systems into marine science and policy both in Australia and around the world. Integration of Indigenous knowledge systems is not optional—it is essential, both a right and a responsibility. This approach offers a path forward that honors the past, heals the present, and safeguards the future for all beings who call the ocean home. Our work on CKS and CIAs proposes a way forward that integrates considerations that have for too long been underserved, and we invite all policymakers and researchers to engage with this process and way of working.

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Lord Howe Island Shark Research Program: Towards a Conceptual Framework to Manage Human-shark Interactions

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The Galapagos shark (*Carcharhinus galapagensis*) is the most common shark species found in the marine park waters surrounding Lord Howe Island and it is an important indicator species for marine park management (Edgar et al, 2010; Harasti et al, 2022). We know that the species has a global distribution, yet mostly occurs around seamounts and remote islands. Lord Howe Island, Elizabeth and Middleton Reefs and Norfolk Islands are the only locations where the species is known to occur within Australian waters. We also know that the species has a limited rebound potential, with a slow reproductive cycle (they give birth every two–three years) and relatively late maturity (between six and nine years old at a total length of 1.7–2.5 m, for males and females, respectively) (Last and Stevens 2009). Yet, we know very little about their global and local population trends.



Figure 1: A Galapagos shark about to be depredated a hooked yellowtail kingfish. Source: Shark Ethology Australia (SEA) | Consulting.

Most sharks encountered at Lord Howe are juveniles (<2m in total length) and neonates (newborns, still displaying their visible umbilical scar) are seasonally caught by local fishers. This suggests this location may serve as an important nursery area for the species. Due to their limited rebound potential and the isolation of certain parts of their stock, the species remain vulnerable to fishing pressure and any population decline.

In recent years, the level of fisher-shark interactions, in the form of shark bycatch (where they take the bait and become hooked) and depredation (where sharks remove fish off the hooks) has reportedly increased causing threats to a range of social, economic and ecological values for the marine park management. Because of these frequent interactions, fishers are now calling for a cull, or the re-establishment of a targeted local shark fishery, to reduce the depredation issue.

With no baseline data on the population status nor regional population trends, implementing any management measure would not be properly informed. Also, since 2022, two local tourism operators have been running tours where visitor can swim with Galapagos sharks, creating a positive value for this species. The impact of any management measures needs to consider the whole range of ways in which the community and tourism activities interact with Galapagos sharks at Lord Howe Island may lead to negative outcomes for the species and the marine ecosystem it inhabits. Our research, therefore, aims to increase understanding of Galapagos shark movement ecology at Lord Howe Island and the factors influencing human-shark interactions, to help inform evidence-based solutions and improved management of this conflict.

This paper summarises our investigation to date, which involves a long-term, multidisciplinary research program focused on interactions between fishers and sharks since 2018 (LHI Shark Research Program). Our work encompasses ecological and fisheries monitoring, social sciences, and community engagement to develop sustainable, locally-supported management strategies.

A holistic, co-designed research framework

Working closely with marine park staff and the local community, including fishers and tourism operators, we have co-designed a research program, which encompasses seven main objectives:

1. Quantify shark bycatch and depredation using fisheries data
2. Map spatio-temporal interactions between sharks and fishers using acoustic telemetry and vessel monitoring system (VMS) data
3. Test and develop a set of mitigation tools to reduce the human-wildlife conflict
4. Clarify the shark population status and its significance for local management using population genetics
5. Gain the community perspectives using socio-economic surveys
6. Describe basic biology opportunistically with museum staff and academic collaborators
7. Engage with residents and visitors through a citizen science project, a talk series at the Lord Howe Island Museum, and other communication channels (e.g. marine park newsletters, local newspaper)

The overarching goal is to integrate the different ecological, social and economic aspects into a conceptual framework that can be used as a practical tool for management.

Shark movement ecology and fisheries interactions

Thirty juvenile Galapagos sharks were tagged in 2018 (with internal acoustic tags), and the detections from 29 individuals were recorded all year round over the first five years, suggesting a population that is mostly resident. Shark presence was highest in areas with greater fishing activity, benthic habitat complexity, and during warmer months. Interestingly, eight individuals are still being detected today, after seven years of tracking them. Most are now adults, so we hope to learn more about whether adult shark movement patterns and home range differ from those of the juveniles.

Our heatmaps revealed persistent overlap between tagged sharks and fishing vessel activity at shelf edges, particularly in the northeast and southeast, near Ball's Pyramid, and at the southern entry to the lagoon – a former fish waste disposal site (Fig. 2). This particular insight informed a change in management whereby the island waste management facility created a bio-composting system to handle fish waste thus minimising the amount entering the ocean and reinforcing a change in shark behaviours (where they tend to associate boats with the presence of easy foods).

Galapagos sharks accounted for 25% of the total annual catch despite not being a targeted species (Figueira and Haranto 2022). Although most shark bycaught are reported to be released, this highlights the scale of the bycatch issue. The vast majority of sharks caught were juveniles, with only 10% exceeding 2m in total length. Depredation rates averaged around 50%, which is higher than mainland Australia (Mitchell et al, 2018; 2023) but lower than other remote sites, such as Cocos (Keeling) Islands (Mitchell et al, 2025b).

The acoustic tracking array at Lord Howe Island is also important to detect the presence of other transient megafauna species across the northern Tasman Sea,

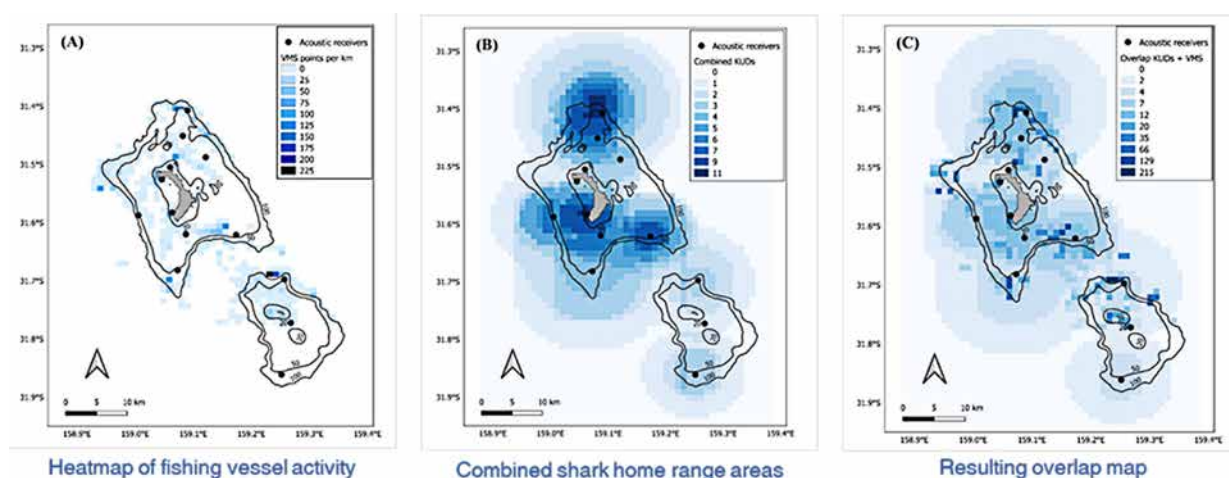


Figure 2: Heat maps of a) fishing vessel activity; b) combined shark home range areas and c) a combination of maps a) and b), to identify key hotspots of overlap.

Human-ocean interactions

as evidenced by our detecting 19 other tagged animals since 2018 (including white sharks from the mainland, tiger sharks from the mainland and Norfolk Is., and kingfish tagged locally).

Shark population status

To better understand the size of the Galapagos shark population at Lord Howe Island and the broader Southwest Pacific region and its potential vulnerability to overexploitation, global genetic structure analysis, have been conducted in collaboration with Macquarie University (Adam Stow's Lab: Krause, Petrolo, Stow et al, unpl.). This work, which has used Single Nucleotide Polymorphisms, has estimated a contemporary population of ~6,000 sharks ($\pm 2,000$) across the Southwest Pacific region. The results also show that mixing does occur between Lord Howe Island and other locations in the Southwest Pacific region, albeit over long timescales.

This has important implications for management because it indicates that the Southwest Pacific Galapagos shark population should be managed at a larger regional level, not just at the scale of Lord Howe Island alone. Our results also suggest the presence of three main global genetic stocks—Atlantic, alongside the previously confirmed East Pacific, and West Pacific—with Lord Howe belonging to the latter (Fig. 3). However, we found contrasting patterns of genetic diversity and population divergence, which do not support a hypothesised East Pacific origin with westward expansion, leaving the species' phylogeography inconclusive.

Community engagement and citizen science

We established a citizen science project with local dive operators who have been running shark encounter tours since 2022. This program involves taking photos of the left flank of Galapagos sharks (often bearing distinctive pigments and/or markings) to build a database of images that helps to identify individuals. So far, this photo-ID

project has identified 98 individual sharks, 20 of which have been re-sighted (some multiple times) across 15 dive sites. This initiative enhances visitors and community involvement, complementing acoustic tracking, especially in shallower areas, by providing information about shark residency and movement patterns.

Shark interactions are occurring frequently: how can they be managed?

Our research has developed a more detailed understanding of the human-shark conflict occurring at Lord Howe Island. To build on this, we are now trialling ways to reduce interactions with Galapagos sharks. This has included creating an educational leaflet with best-practice guidelines to inform fishers about the most effective methods for avoiding shark interactions, which includes practical tips for using different fishing gear and techniques, as well as maps of shark interaction hotspots to avoid. We are also trialling three electromagnetic shark deterrents to assess their potential to provide a practical solution to the issue. These devices have been trialled under controlled experimental conditions and during real fishing scenarios to assess their effectiveness at reducing the frequency of sharks biting the bait or depredating hooked fish. Initial results from 200 trials of controlled testing show that the deterrent devices can reduce bites on the bait bag by up to 55% (Mitchell et al, 2025a). In real fishing scenarios, bycatch and depredation dropped by 83% (Mitchell et al, 2025a). Further testing of new prototypes is also planned for late 2025 to continue building on these promising results and equipping fishers with devices that are both effective at reducing shark interactions and easy to use during everyday fishing activities.

Emerging challenges

Through working closely with the fishing community at Lord Howe Island, we have recently received increasing anecdotal reports of deepwater shark bycatch involving

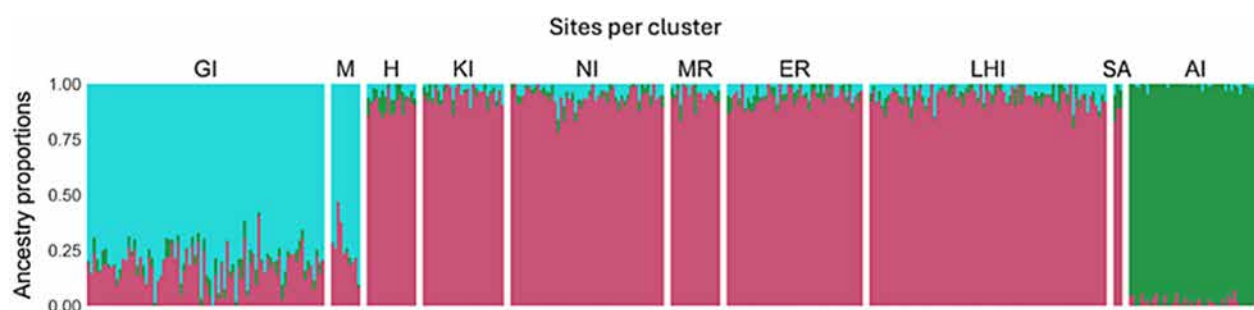


Figure 3: A genetic cluster bar graph for the global Galapagos shark population: East Pacific (blue), West Pacific (pink), and Atlantic (green). GI, Galapagos Islands (Ecuador); M, Malpelo Island (Columbia); H, Hawaii (USA); KI, Kermadec Islands (NZ); NI, Norfolk Island (Australia); MR, Middleton Reef (Australia); ER, Elizabeth Reef (Australia); LHI, Lord Howe Island (Australia); SA, South Africa; AI, Ascension Island (UK). Globally, this population structure and diversity plot shows all the individual shark sampled (represented by a vertical bar) and the site and region they are from; this further highlights the separation between the three stocks, yet show evidence of mixing occurring, so larger movement and gene flow must occur.



Galapagos shark.
Source: ©Justin Gilligan

some unidentified dogfish (*Squalus*) species. Detailed analysis of two specimens and pups sent to the Australian Museum suggest that these individuals could be a newly documented hybrid species or even a new species altogether, but further genetic research is needed to confirm this. This highlights a broader issue: without species-level identification, a common issue when identifying bycatch, it is difficult for fisheries to inform effective management. This is particularly important at Lord Howe Island due to its isolation and the fact that it is home to numerous endemic species, making them highly vulnerable to population declines.

Conclusion and future directions

The next goal of the LHI shark research program is to integrate the diverse datasets into a unified decision-making model that would inform and facilitate marine park and fisheries management. This conceptual model will leverage data from the different aspects of the project, such as shark population size, fishing effort and mitigation methods used, to simulate management scenarios, identifying future outcomes. This will be valuable for managers and the local community, to evaluate trade-offs and identify optimal strategies. Our findings underscore the importance of holistic, community-driven approaches to managing fisher-shark interactions, as part of the human-shark conflict in general, an issue experienced in a growing number of coastal communities in Australia and worldwide. The integrated approach applied at Lord Howe Island can be used as a case study and is therefore valuable for developing research and management approaches in other island communities.

Our next steps include continuing long-term acoustic tracking to monitor the movements of Galapagos sharks into adulthood and document other transient megafauna in the region; expanding deterrent testing and improving the useability of the devices; investigating unidentified deepwater shark species catch rates and biology; and finalising the conceptual framework that can be used as an additional management tool to facilitate data-driven decision-making processes. By combining ecological and fisheries science, social research, and local knowledge, we aim to promote the sustainable coexistence between fishers and sharks—benefiting the community and the unique marine ecosystem—of Lord Howe Island.

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Link to associated paper

Mitchell JD, Camilieri-Asch V, Gudge S, Jaine FR, Peddemors VM and Langlois TJ (2024) Applying acoustic telemetry, vessel tracking and fisher knowledge to investigate and manage fisher-shark conflict at Lord Howe Island, Australia. *Marine Biology*, 171(12):230.

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A review of seafloor biodiversity information available through the South Pacific Regional Fisheries Management Organisation (SPRFMO)

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The South Pacific Regional Fisheries Management Organisation (SPRFMO) has jurisdiction over a vast expanse of ocean, encompassing approximately one quarter of areas beyond national jurisdiction (ABNJ, or the high seas). SPRFMO primarily manages fisheries targeting jack mackerel (*Scomber scombrus*), jumbo flying squid (*Dosidicus gigas*), and orange roughy (*Hoplostethus atlanticus*). Bottom fishing (bottom and mid-water trawling, bottom long-lining) is concentrated in specific areas within the SPRFMO Convention Area, mainly between Australia and New Zealand (Fig. 1) and the Louisville Ridge.

The main objective of the SPRFMO Convention [JT1] is, through the application of the precautionary approach and an ecosystem approach to fisheries management, to ensure the long-term conservation and sustainable use of fishery resources and, in so doing, to safeguard the marine ecosystems in which these resources occur, including *inter alia* the prevention of significant adverse impacts on vulnerable marine ecosystems. To support this, extensive research and predictive modelling have been undertaken over the years to aid in the identification and management of Vulnerable Marine Ecosystems (VMEs) within the SPRFMO Convention Area. This paper provides an overview of this research, focusing specifically on the Lord Howe Rise in the Tasman Sea (Fig. 1).

Vulnerable marine ecosystems (VMEs)

In 2009, the Food and Agriculture Organization of the United Nations (FAO) published the *International Guidelines for the Management of Deep Sea Fisheries in the High Seas*, developed in response to UNGA Resolutions 59/25 (2004) and 61/105 (2006). These Guidelines assist States and regional fisheries

management organisations (RFMOs) in applying precautionary, ecosystem-based approaches to deep-sea fisheries and in preventing significant adverse impacts (SAIs) on VMEs (FAO 2009). The FAO Deep Sea Guidelines provide a conceptual description of VME, and criteria to help identify VMEs, and examples of what a VME may be. This publication also provides criteria for identifying VME indicator taxa, whose occurrence may indicate the presence of a VME. The FAO Deep Sea Guidelines has been a transformational document that has guided much of the work deep-sea RFMOs have undertaken since their publication.

Developing lists of VME indicator taxa

Identification of VME indicator taxa was one of the first tasks that was undertaken to inform SPRFMO bottom fisheries but remains an ongoing process as new and improved data becomes available. Iterative analysis of occurrence records from across the South Pacific included comparing these records against the FAO criteria to define a list of candidate VME indicator taxa. Around 100,000 individual records were assessed, 5,300 of which were from within the Evaluated Area (see Fig. 2). Taxonomists and para-taxonomists assessed the likely morphological, ecological and life history characteristics of the species and genera within each VME indicator taxon group against the FAO guidelines. Experts identified 281 genera and 231 species that, in the opinion of the expert reviewers, met FAO VME criteria and therefore could be considered VME indicator taxa. The current list contains 13 VME indicator taxa as per Annex 5 of the Conservation and Management Measure for the Management of Bottom Fishing in the SPRFMO Convention Area [JT2] (SPRFMO 2025).

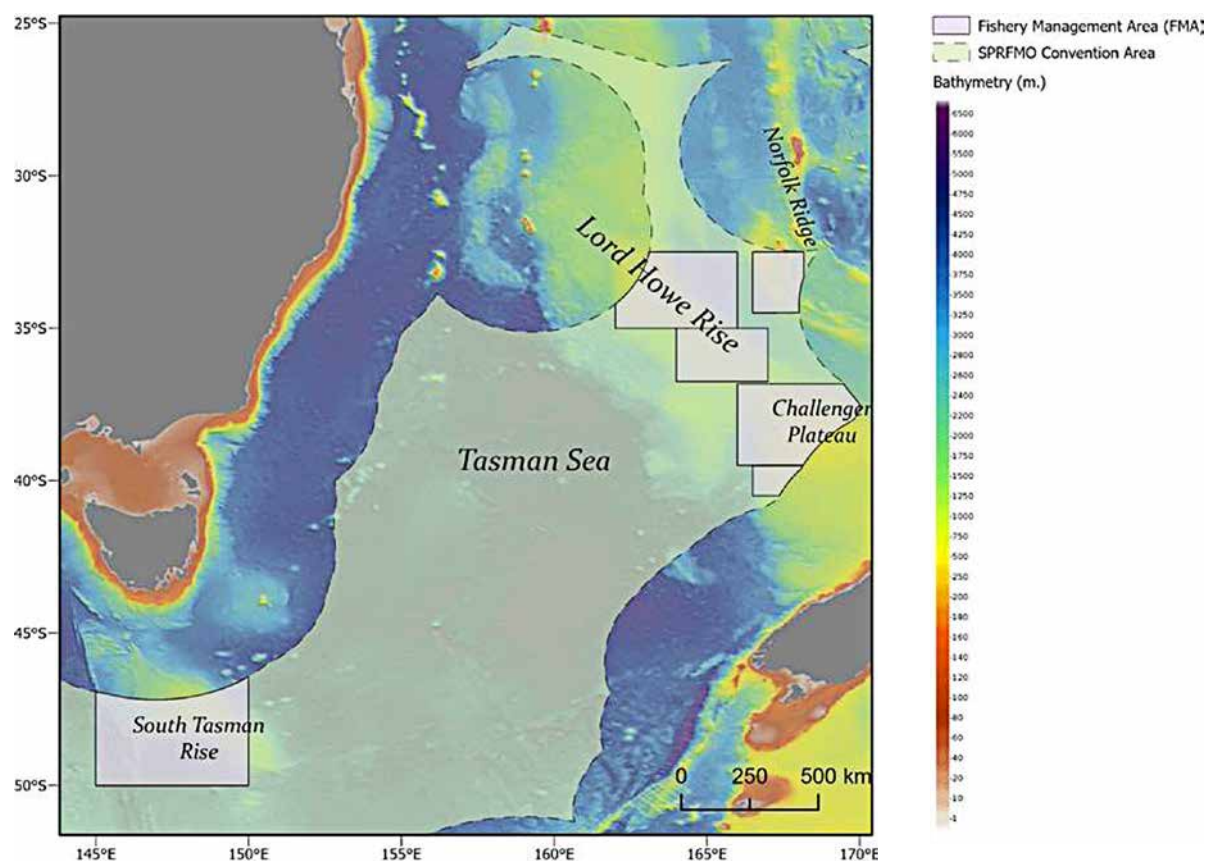


Figure 1: SPRFMO Fishery Management Areas in the Tasman Sea (source: Jordi Tablada and AusSeabed Marine Data Portal (bathymetric layer)).

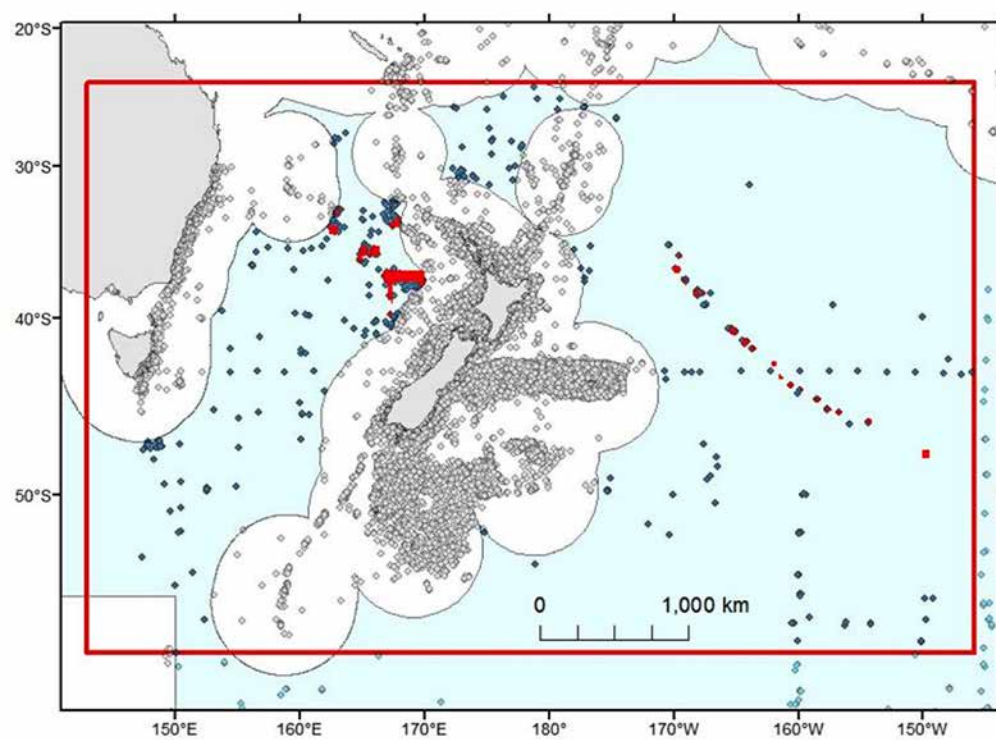


Figure 2: The Evaluated Area (red box) showing the location of VME indicator taxa observations (blue polygons) and the locations of areas open to bottom trawling (red polygons) (source: Geange et al, 2021).

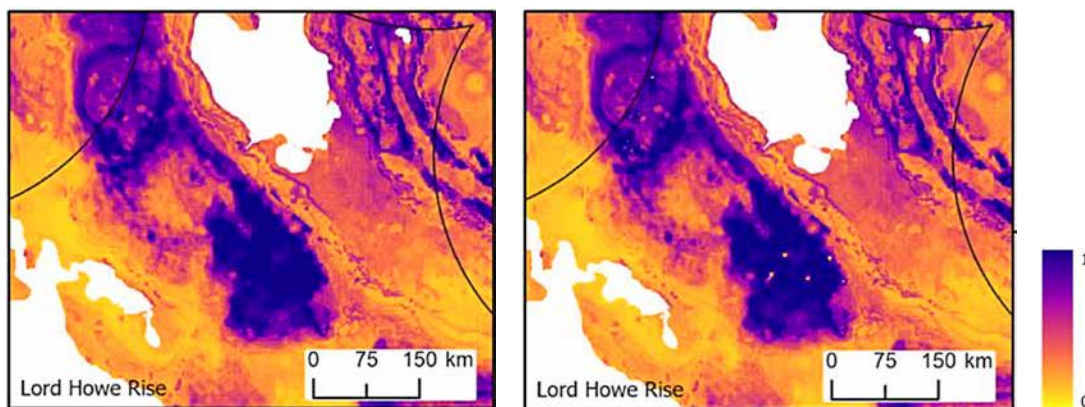


Figure 3: HSI model for *Antipatharia* (black coral) before (left) and after (right) accounting for deep sea fishing impacts (source: Jordi Tablada).

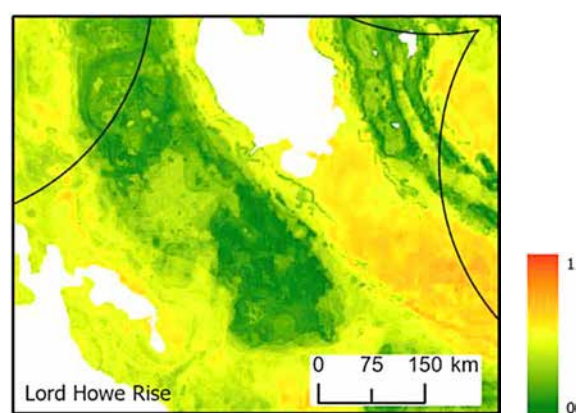


Figure 4: Spatially-explicit measure of uncertainty for *Antipatharia* (black coral) (source: Jordi Tablada).

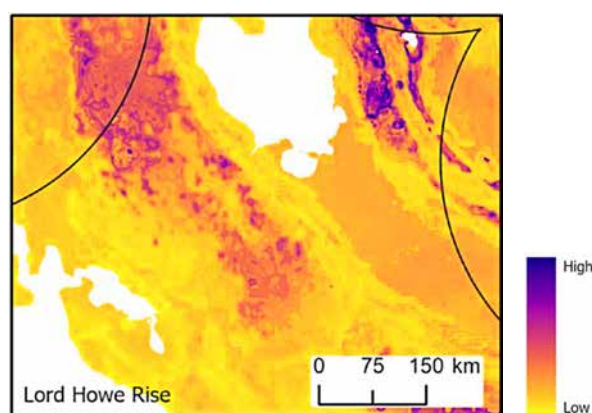


Figure 5: Abundance model for black coral in the Lord Howe Rise area (source: Jordi Tablada).

Developing habitat suitability index (HSI) models for VME indicator taxa

Habitat suitability index (HSI) models for various VME indicator taxa, such as sea anemones, soft corals, black corals and sponges have been developed and refined over the years. These numerical models combine occurrence data, including from trawl surveys and bycatch records, with environmental data to predict suitable habitats. For example, the HSI model for black corals identifies parts of the Lord Howe Rise as being highly suitable for this taxon (Fig. 3) (Georgian et al, 2019; Stephenson et al, 2021). HSI models that account for historical fishing impacts have also been developed, allowing comparisons between impacted and unimpacted predictions of suitable habitat. According to the model predictions, areas in the Lord Howe Rise with evidence of historically high fishing intensity display lower values of suitable habitat than other undisturbed sites (Fig. 3). While HSI models are projected to a large part of the SPRFMO Convention Area, they are informed by a limited number of records, with most of them within Australia and New Zealand EEZs.

Spatially-explicit measures of uncertainty are also available for these models, which tells us how certain or uncertain the model predictions are. In some of the areas that suggest high habitat suitability, there may be low uncertainty, therefore we can be confident of the model, whereas in other areas, more uncertainty is highlighted in the model, so if they are used, caution is required. For example, in the Lord Howe Rise, areas with predictions of highly suitable habitat for black corals are considered of low uncertainty by the model (Fig. 4).

The Deep Towed Imagery System developed by Earth Sciences New Zealand in 2006 has enabled the collection of not only occurrence data but also abundance data (e.g., number of individuals of a particular species per square kilometre) (Earth Sciences New Zealand, 2006). This has led to the development of abundance models for VME indicator taxa (Tablada et al, 2023a,b; Bennion et al, 2024). Predictions of abundance for black coral in the Lord Howe Rise, suggest relatively high abundances in discrete areas (Fig. 5) but not as spatially widespread as what the HSI model suggested (Fig. 3). This suggests that there isn't a linear relationship between predicted habitat suitability and abundance.

To complement and simplify the use of abundance models for management purposes, a VME-index proof of concept has also been developed (Gros et al, 2024; Bennion et al, 2024). In SPRFMO, the VME-index layer is the result of combining existing HSI and abundance models (including their estimates of uncertainty) for 17 VME indicator taxa, which can be used, for example, to identify areas with high abundance, high richness and high certainty (as a potential proxy for VMEs),

VME indicator taxa bioregionalisation

A bioregionalisation using VME indicator taxa occurrence data and environmental data has also been recently developed (Bennion et al, 2024). The VME indicator taxa bioregionalisation predicts compositional turnover using biotic and environmental data and identifies seven distinct groups within the western part of the SPRFMO Convention Area.

Key gaps and future directions

Our integrated modelling approach provides a foundational framework for identifying and managing VMEs in the Lord Howe Rise and broader Tasman Sea. By combining habitat suitability models, abundance models, and a bioregionalisation for VME indicator taxa, managers are equipped with powerful spatially-explicit tools to help inform fisheries and conservation decisions. However, the persistent lack of ground-truth data remains a critical limitation. Collection of seafloor data in areas of interest across the high seas of the Tasman Sea is needed to allow for the improvement and validation of such models.

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Expedition footage documenting Vulnerable Marine Ecosystems and the impacts of bottom trawling in the Lord Howe Rise and South Tasman Sea

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2. *Greenpeace Aotearoa, Auckland, New Zealand*

Introduction

We recently conducted a Greenpeace-funded expedition to survey Vulnerable Marine Ecosystems (VMEs) in the Tasman Sea to gather high-resolution video and still imagery of bottom trawling impacts and VME indicator taxa. We conducted transect surveys focused on seamounts and non-seamount areas within the South Pacific Regional Fisheries Management Organisation Convention Area and New Zealand's Exclusive Economic Zone. This brief expedition report presents and contextualises some preliminary findings from the South Tasman Sea, noting that the expedition was very recent and our analysis is ongoing.

Objectives and methodology

The primary objectives of the expedition were to collect high-resolution imagery of bottom trawling impacts and VME indicator taxa; to reduce existing uncertainties relating to VME modelling; and to improve our knowledge on the diversity and abundance of deep-sea ecosystems in the Tasman and increase the accuracy to predict where VMEs are. We planned to use an H800 ROV rated to 1,000 metres, a modified drop/TOW camera setup rated to 1,500 metres, but only the TOW camera system was operational. While we had initially intended to collect opportunistic specimens, we were constrained by permitting requirements and personnel and dropped this objective. Our expedition comprised a no-contact video survey, which resulted in some hugely useful findings that we are currently analysing.

The sites surveyed on the High Seas included four sites on the Challenger Plateau inside and outside the Northwest Challenger Bottom Trawl Management Area (BTMA) and one site within the Central Lord Howe BTMA (Fig. 1). Our expedition and research plans were informed by extensive biodiversity data and VME habitat suitability modelling, and the best available bottom trawl fisheries data we had access to. We worked alongside a number of eminent experts from New Zealand's Department of Conservation, Ministry for Primary Industries, Earth Sciences New Zealand, and some international scientists to design

the survey; their input was invaluable. We focused on sites with varying probabilities of containing VME indicator taxa, encompassing seamount sites and non-featured sites.

The Central Lord Howe site was surveyed because of a recent (2024) VME encounter by a New Zealand bottom trawl vessel, where the trawler brought up 37kg of deep-sea corals (far exceeding the 15kg threshold), triggering a temporary closure of this area. This was a priority site to ensure the best available information is reviewed by officials to assess if this temporarily closed area contains VMEs.

Key findings

A few short videos were played at the symposium to highlight examples of video footage from multiple sites, which at the time of the presentation were being further analysed.

In summary, on the Challenger Plateau, outside of the Northwest Challenger BTMA, we surveyed a relatively shallow seamount which, according to the historical trawl data, had experienced minimal bottom trawl effort and VME taxa modelling suggested low abundance and probabilities. This site showed no sign of trawl scarring, but we did observe large numbers of fish, and varying corals, sponges, a few deepwater sharks and other invertebrates.

Inside the Northwest Challenger BTMA, deeper sites, including seamounts and non-seamounts with varying levels of historic and recent trawl effort, and varying VME prediction probabilities were surveyed more thoroughly. At a number of these sites, trawl scarring was observed, alongside fields of coral rubble. When transect lines didn't focus on historic trawl tracks but on rougher grounds or ledges on or around seamounts, then larger individual corals (>1m in height) and small coral clusters were observed alongside sponges and other invertebrates. Occasionally, deepwater fish, including sharks, were observed. One site with relatively low VME predictions had a large deep-sea anemone garden which spanned hundreds of metres in length in a gully between two peaks and included corals, deep-sea fish and other invertebrates.

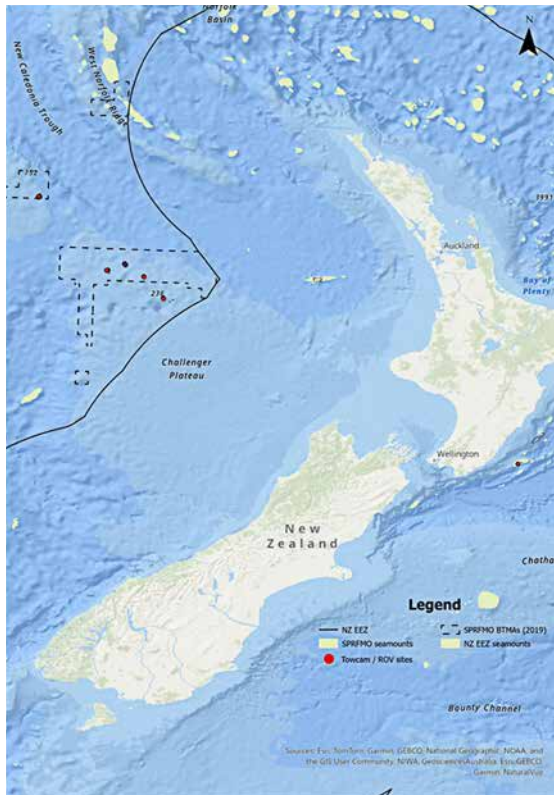


Figure 1: The five survey sites shown with red and blue circles, from the Central Lord Howe and Northwest Challenger Bottom Trawl Management Areas shown with hashed lines located in the high seas.

Our aim was for our data to be comparable to data obtained through advanced digital imaging techniques, enabling us to help validate existing and future modelling. Towards the end of our transects along the Challenger Plateau, we found on several occasions that as we approached sloped gradients, larger and more diverse coral types were apparent.

At the Central Lord Howe priority site, we conducted four dives. The New Zealand Government would not release the location of the bottom trawl track, or even closed area boundary where the encounter occurred, so we obtained the closed area from Australia and designed these transects to focus on key areas within the closed area that could have been part of the trawl and areas that may also contain VME indicator taxa given what we knew based on historic trawl tracks and biodiversity modelling. Surveying this site, which at times was deeper than 1,200m, was incredibly challenging, and often there were significant deep-sea currents and no high-resolution bathymetry data available.

We observed coral clusters, larger and older individual corals near ledges, or in gullies, coral rubble and trawl scarring along known trawled areas and occasionally saw a lone orange roughy and some deepwater sharks. There were a number of sponges and other invertebrates observed too.

This footage collected is being analysed to inform the review of whether the area should remain closed or reopened. Greenpeace is externally getting this analysis completed to a) confirm the presence of VME indicator taxa and b) assess the video and still imagery obtained based on published criteria (Baco et al, 2023) as to whether or not VMEs exist within this closed area. Based on the limited video footage and still imagery shown in the presentation, our preliminary results show this area is likely to contain multiple VME indicator taxa and VMEs.

Challenges

We faced several challenges on this expedition, including equipment limitations and failures, adverse weather conditions and an operational failure of the ROV. High-resolution bathymetry data were scarce, requiring manual adjustments during some surveys. Despite these obstacles, we successfully gathered valuable data on VMEs and bottom trawling impacts, which are being further analysed and will be used to improve confidence in the VME modelling and to inform the forthcoming SPRFMO review of the area that is currently closed following the above-mentioned bycatch incident.

Conclusion

Our expedition to survey VMEs in the Tasman Sea has provided critical insights into the distribution of VME indicator taxa and the impacts of bottom trawling on these ecosystems. The collected data will help us identify more species ranges across our transect lines and validate existing models. Our intent is for this data to inform management decisions in the Tasman Sea and be used by SPRFMO's Scientific Committee to ensure decisions are based on the best available science and uphold the Organisation's conservation mandate, particularly in relation to protecting VMEs.

Acknowledgements

Greenpeace International for funding this expedition, and NorthTec Te Pukenga for their support. New Zealand Seaworks and the crew aboard the Seaworker vessel, alongside all the experts within New Zealand and overseas who inputted into this survey.

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Civil society perspectives on the threats to the Lord Howe Rise and South Tasman Sea and challenges hindering their protection

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While coastal waters are more familiar to most people, the high seas, starting 200 nautical miles from shore, are vitally important to life itself. They cover 43% of our planet and provide more than 90% of the habitable space on Earth. Within the UN Convention on the Law of the Sea, these are known as 'areas beyond national jurisdiction' (ABNJ), which are designated as the common heritage of humankind and have associated conservation obligations. The Tasman Sea is one such area, exhibiting immense biodiversity and importance to species and ecosystems within and beyond this Sea. This paper will examine key threats to the seamounts in the Tasman Sea and the obstacles to protecting these areas through the lens of civil society organisations that have built knowledge of and connection to the Tasman Sea over several decades of efforts to protect it.

Key threats to vulnerable marine ecosystems in the Tasman Sea

Numerous threats exist to species and ecosystems within the Tasman Sea. Among these, bottom trawling – a highly destructive fishing method – has been identified as one of the major threats, particularly to vulnerable marine ecosystems (VMEs), including seamounts. Bottom trawl fishing gear is highly destructive, involving dragging huge, weighted nets over the seabed. Trawl doors at the front of the net can weigh half a tonne each, and their movement across the seabed essentially acts like a bulldozer.

A single trawl can do significant damage to deep-sea corals, and as few as 10 trawls can reduce coral habitat to rubble (Fosså et al, 2002). The damage caused by bottom trawling will not be healed in our lifetimes. In the South



Figure 1: A deep-sea coral of approximately 500 years of age dragged up in the net of a bottom trawler (source: Greenpeace/Malcolm Pullman).



Figure 2: A bottom trawl haul of Orange Roughy, a slow-lived species susceptible to overfishing (source: Greenpeace).

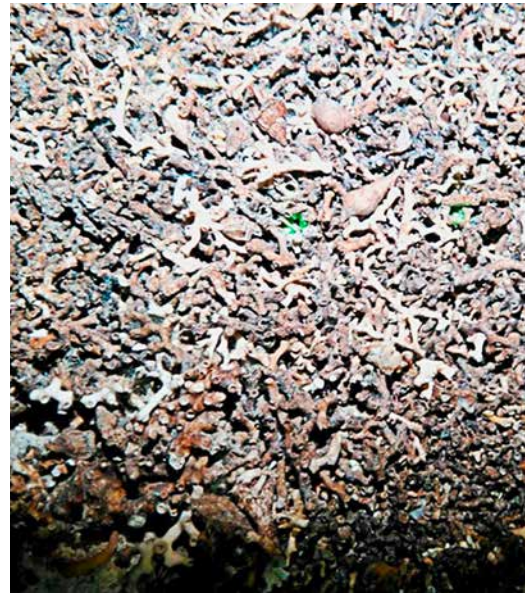


Figure 3: A seamount near New Zealand which has been intensively bottom trawled for several decades (source: Greenpeace).

Pacific, tonnes of ancient corals have come up in single bottom trawl (Tablada, et al, 2023, Althaus et al, 2009, Anderson and Clark 2003). Bottom trawling over corals like this is essentially like ripping out the pages of our history book. These impacts are devastating, cumulative and long-lasting, but they do not represent the entirety of harms caused by bottom fishing VMEs; significant impacts have also been recorded in relation to the target species of the fisheries themselves.

Orange roughy: A treasure of the Lord Howe Rise

Orange roughy (*Hoplostethus atlanticus*) are slow-breeding, deepwater demersal fish that can live to over 200 years (Horn and Maolagáin 2019). They are found in the cold, deep waters of the Pacific, Atlantic and Indian Oceans, including the Lord Howe Rise and South Tasman Sea. The species is slow to reach reproductive maturity and this combined with its long lifecycle and its formation of spawning aggregations over seamounts, makes orange roughy particularly vulnerable to overfishing. Over the past five decades, we have seen the impacts of overfishing on this species result in the collapse of some stocks and the loss of spawning aggregations from heavily trawled seamounts.

As well as providing vital habitat for corals and other benthic life, feeding grounds and waypoints for migratory species, seamounts are also important spawning areas for orange roughy. In recent years, in New Zealand waters, spawning aggregations of orange roughy have been significantly reduced or disappeared altogether from heavily trawled seamounts – this is a major concern (Dunn et al, 2022). In some cases, the only spawning

grounds in certain fishing areas are on the seamounts that have been closed to bottom trawling (Fisheries New Zealand 2025).

Ancient corals as collateral damage

Bottom trawling has been identified as a particularly significant threat to corals and is responsible for 99% of coral bycatch in this region (Althaus et al, 2009). Comparisons between fished and unfished seamounts in the Tasman Sea have shown that repeated trawling can leave seamounts ‘almost without any live intact reef’ (Tracey et al, 2023). Significant coral bycatch has been taken by vessels operating in the Lord Howe Rise region, including a 2020 incident in which the *Tasman Viking* took an unquantified amount of bamboo coral, some of which was dragged overboard before observers could weigh it (Milardi et al, 2021). In 2024, the same vessel brought up 37kg of coral from three different taxa while fishing in the LHR area, triggering an automatic but temporary suspension of fishing in the area (Morrah 2025).

The extent and impact of coral bycatch that we know about are likely dwarfed by the actual damage that has been sustained by vulnerable marine ecosystems in the Tasman Sea. Recorded incidences and impacts likely represent the tip of the iceberg, because only a fraction of coral impacted are brought up in a net (Meyer, 2023). The vast majority of corals damaged or destroyed remain on the seafloor. This has implications not only for our obligations to urgently and effectively preserve and protect these ecosystems and species, but it also has implications for accountability. Where bycatch is not brought to the surface and recorded, no entity can be held accountable for this widespread destruction.

Should countries implement a ban on bottom trawling in the South Pacific high seas?

Aotearoa New Zealand
Horizon Research 2024

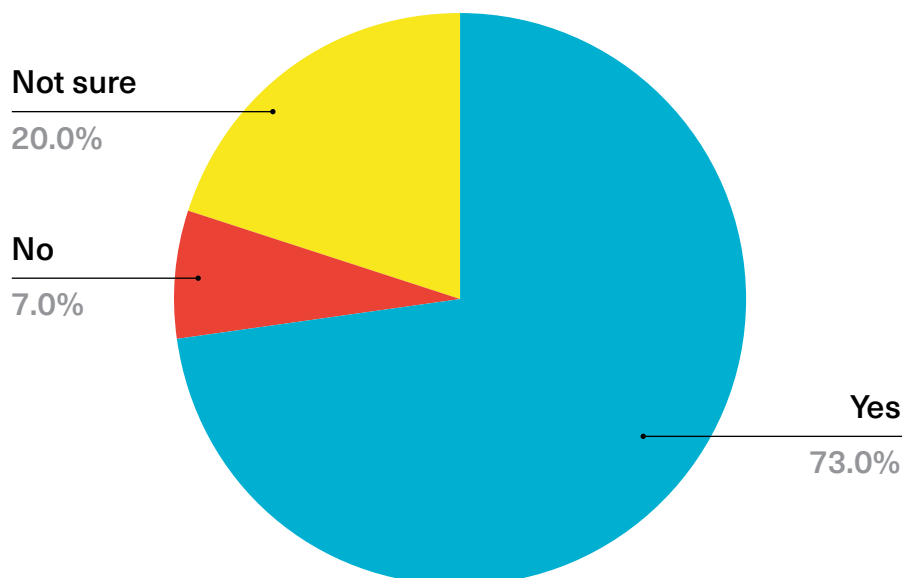


Figure 4: Public polling in New Zealand on bottom trawling perceptions.

Barriers to effective VME protection

The known impacts of bottom trawling on the Lord Howe Rise give rise to a glaring question: why are these vulnerable marine ecosystems still being bottom trawled? The answer, as is so often the case, has both political and economic dimensions. Fishing in the Lord Howe Rise area was unregulated until the South Pacific Regional Fisheries Management Organisation (SPRFMO) applied catch limits in 2007. Australian vessels no longer trawl on the Lord Howe Rise, New Zealand is now the only country still bottom trawling in the South Pacific (SPRFMO SC member country Annual Reports, 2024).

While the SPRFMO Convention requires Parties to make decisions based on the best available information and stipulates application of the precautionary and ecosystems approaches, SPRFMO largely operates by consensus, meaning any country can effectively block any decision. Recent meetings have seen the New Zealand Government block management measures that have significant support, including measures proposed by Australia. This has included proposals to close VMEs to bottom trawling (Government of Australia 2024, Morrah, 2025). While SPRFMO has a register of VMEs in the South Pacific, no sites are listed, despite extensive evidence that many meet the widely accepted criteria to be classified as VMEs.

The role of civil society in advancing conservation

Civil society groups play a crucial role in documenting threats, collaborating with scientists, raising the public and political profile of environmental destruction, and ultimately achieving changes to policies and practices. Greenpeace, for example, has obtained images of human-induced destruction that have been brought both to the public and to government negotiators and decision-makers. Without civil society organisations, as well as scientists, much of this information would remain undocumented and unknown.

Civil society is also playing a significant role in advocating rapid entry into force of the BBNJ Agreement under United Nations Convention on the Law of the Sea, and those efforts are speeding the process of governments' ratification and entry into force of the Treaty. This Agreement does not just deal with extractive activities, but includes important obligations to identify and reduce environmental risk and establish conservation measures. While civil society organisations will continue to advocate, there is a clear role for existing bodies to join the challenge and push the BBNJ Agreement entry into force.

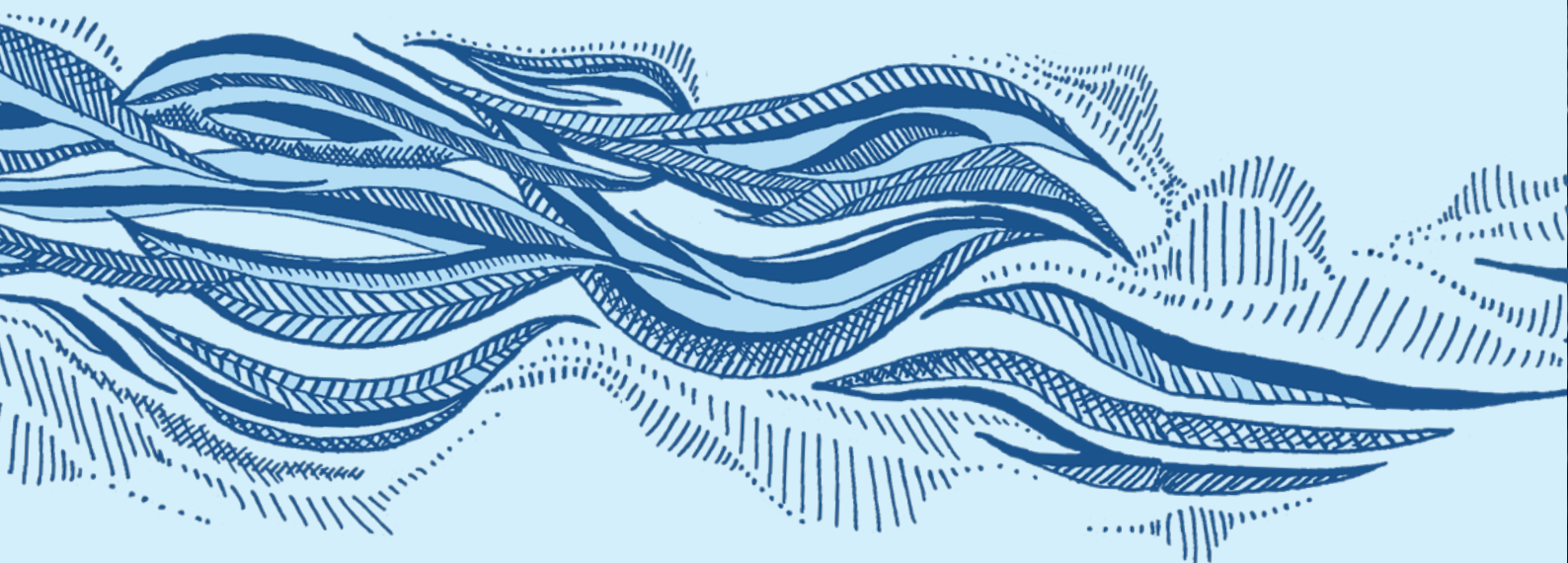
Civil society organisations also work extensively with members of the public, playing an important role in building awareness and measuring public opinion on a range of issues. Through our work, we know there is strong public support for strengthening marine protection at regional scale, with 73% of people polled in New Zealand in 2024 supporting a bottom trawling ban in the South Pacific high seas (Horizon Research Oceans Survey, 2024). This polling has been consistent year after

year. While the BBNJ Agreement presents significant opportunities, SPRFMO already has the mandate to protect seamount habitats, and now is the time to rise to the challenge and close these VMEs to bottom trawling.

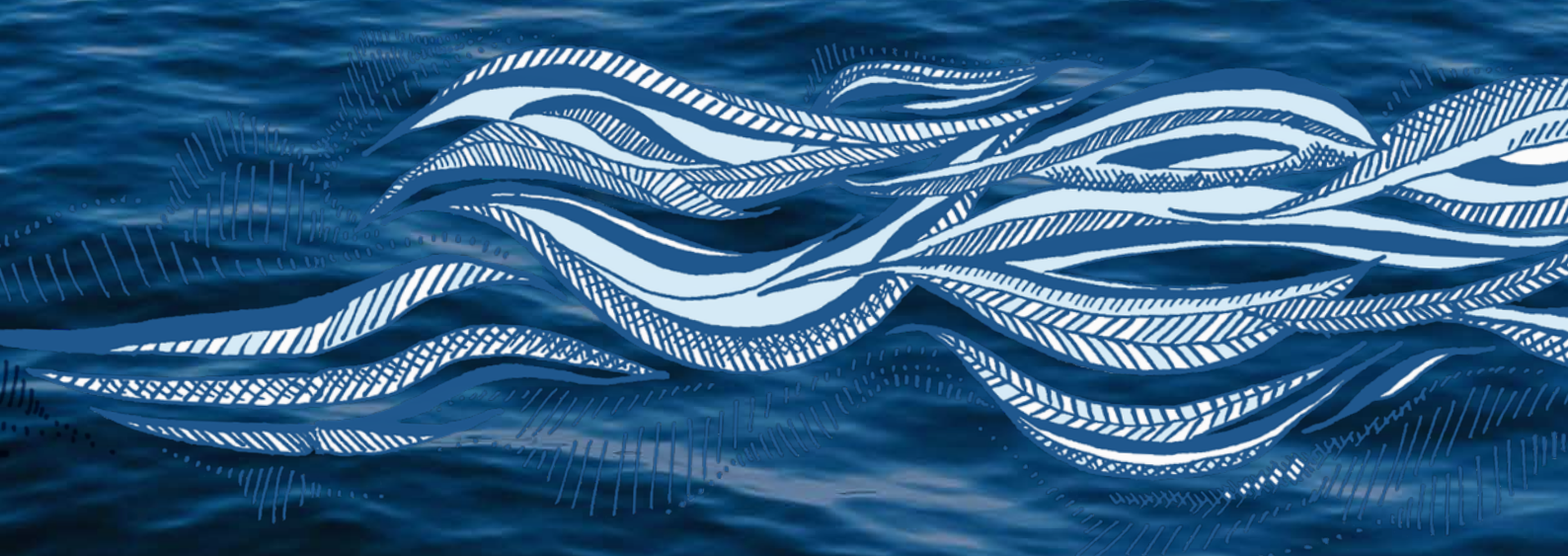
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Science-driven conservation



Biogeography of the Lord Howe Rise region

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In 2011, our paper titled 'Biogeography of the Lord Howe Rise Region, Tasman Sea' was published in a special edition of *Deep Sea Research*, which included numerous foundational papers on the Lord Howe Rise area. At that time, Lord Howe Rise was a significantly under-studied area. The purpose of our study was to draw on survey collections of benthic invertebrates (mostly large benthic epifauna) to describe the biogeography of the Lord Howe Rise area at regional and sub-regional scales.

Biogeography is the study of the geographic distribution of organisms. It incorporates habitat information from geological, oceanographic, and biological sources that exist at multiple spatial scales. It is an inherently interdisciplinary field, and the knowledge gaps we have identified for the Lord Howe Rise region encourage a multifaceted research approach. This paper revisits the findings of our 2011 publication and provides updates on recent research. It also identifies persistent evidence gaps that have not yet been addressed and proposes some next steps for consideration.

Early findings on the region

Our 2011 paper incorporated a literature review and drew on data from two major surveys: The Norfolk Ridge/Lord Howe Rise Biodiversity Discovery Survey (NORFANZ) survey in 2003 was a joint initiative by CSIRO (Australia), Australian museums and Earth Sciences New Zealand (New Zealand). The TAN0713 survey in 2007 was undertaken by Geoscience Australia to sample and characterise deep-sea environments on the east Australian margin and to map the Capel and Faust basins. The approximate locations of these surveys are shown in Fig. 1. Many scientists were involved in these seminal surveys, which were critical in building some of our baseline knowledge of the region.

Our paper defined an area spanning 1.94 million km² as the 'Lord Howe Rise region', including Lord Howe Rise

itself and numerous adjacent features. We found the area to be influenced significantly by a range of complex processes, including the East Australian Current (EAC) and the Tasman Front. We established that raised bathymetric features in the area support richer and more abundant epifaunal assemblages than subdued features (see Fig. 2); however, this trend varies among features based on area of exposed substrata, depth, elevation, and latitude. Gifford Guyot, for example, lacks fauna diversity compared to other guyots, which are far more biologically rich.

Overall, the Lord Howe Rise region supports a mixture of regionally endemic species together with species associated with the Australian and New Zealand continental margins (Smith et al, 2011). Some of these species are shown in Fig. 3.

Our 2011 paper identified the following knowledge gaps relating to the Lord Howe Rise region: limited biological data, including on endemism and species distribution;

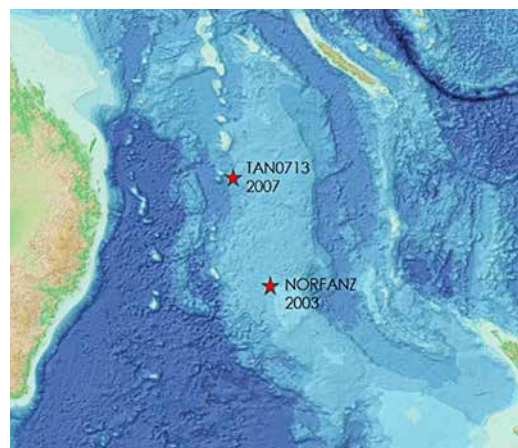


Figure 1: Surveys that informed 'Biogeography of the Lord Howe Rise region' (Przeslawski 2011).

Figure 2: Species accumulation curves (source: NORFANZ survey).

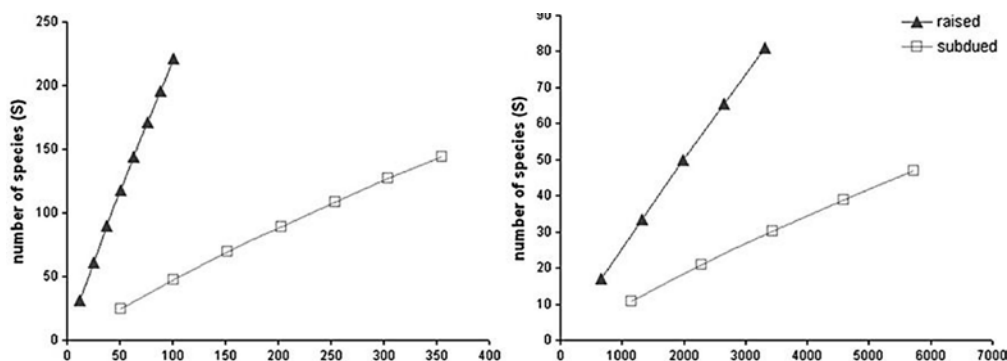




Figure 3: Deep-sea fauna from the LHR region (left to right): Glass sponge (*Hexactinellida*); 'Spider trace'; Jellynose fish (*Ateleopus*) and Acorn worm (*Enteropneusta*).

environmental and oceanographic influences; historical and paleo-environmental processes; fine-scale habitat complexity; and temporal changes and long-term monitoring.

Recent updates and persistent knowledge gaps

Since 2011, numerous surveys have been conducted in the Lord Howe Rise region. Many of these have helped to address the gaps we identified, and some have informed other papers in this proceedings report. These surveys have supported research and important findings across numerous disciplines, including geological and ecological research. Collectively, they represent a significant step forward in an interdisciplinary appreciation of the Lord Howe Rise region. Relatively recent findings of particular note include mapping and geological modelling underpinning our contemporary understanding of Zealandia, the seventh lost continent (Mortimer et al, 2023).

Persistent gaps remain, however, including the need for more comprehensive data on benthic and demersal ecology, the impacts of climate change, and the potential effects of deep-sea mining (if indeed this area is being considered by this emerging industry, which is not yet clear). Additionally, there is a lack of integration of Indigenous knowledge into scientific research, which is crucial for a holistic understanding of the region's biogeography (McLean et al, 2023). Existing data is fragmented across various disciplines and portals, making it challenging to synthesise and apply to management and conservation efforts.

Proposed next steps

To address these knowledge gaps, the following steps are proposed. These are not intended as sequential steps, but areas of work that may overlap, integrate and in some cases, be undertaken iteratively:

1. **Habitat mapping:** Develop regional-scale habitat maps that incorporate both geomorphic and biological data to help us identify key environmental values and areas of high biodiversity, as well as to identify areas of limited knowledge to guide future surveys.

2. **Risk assessment:** Identify the risks to the region's environmental values, including climate change, trawling, and deep-sea mining and assess the value of deep-sea protection and inform management actions to mitigate these risks.
3. **Data collation:** Conduct a data collation exercise, such as a comprehensive desktop review to integrate information from various disciplines, including Indigenous knowledge to develop a unified dataset that can be used for planning further research and importantly, to inform management actions.
4. **Management actions:** Based on existing information and assessments, identify management actions to conserve and sustain the environmental and cultural values of the area. While information gaps remain, these may be addressed iteratively, concurrent with the application of conservation measures based on what we already know.
5. **Collaborative efforts:** Lastly, we need to continually encourage collaboration among scientists, policymakers, and Indigenous communities to ensure that research and conservation efforts are inclusive and effective. The symposium reported on in this publication is an excellent example of this mode of working and its potential benefits.

Associated paper

Przeslawski R, Williams A, Nichol S, Hughes M, Anderson T, and Althaus F (2011) 'Biogeography of the Lord Howe Rise region, Tasman Sea' *Deep Sea Research Part II: Topical Studies in Oceanography* 58(7-8):959.

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Accounting for ecological connectivity in the design of marine protected areas

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Ecological connectivity describes the ecological linkages between locations and habitats, including individual organisms and the resources they require. It is a critical concept in marine conservation, particularly in the design of marine protected area (MPA) networks. This paper explores different types of connectivity and their importance, and practical approaches to incorporating connectivity into MPA network design. Understanding connectivity in the context of the Tasman Sea and beyond will be an essential input into future marine spatial planning to inform conservation in this area, and there is much to learn from connectivity conservation approaches that have been implemented elsewhere.

Types of connectivity

Connectivity can be understood at various levels, including population connectivity, genetic connectivity, and ecosystem connectivity. Population connectivity involves the movement of adult organisms, such as fish, whales, and birds, between feeding and breeding areas. Larval dispersal is another form of population connectivity, where planktonic larvae are transported by currents between locations. Genetic connectivity refers to gene flow between populations. In contrast, ecosystem connectivity encompasses the movement of multiple species or entire groups of animals, and the resulting transfer of energy and nutrients between habitats.

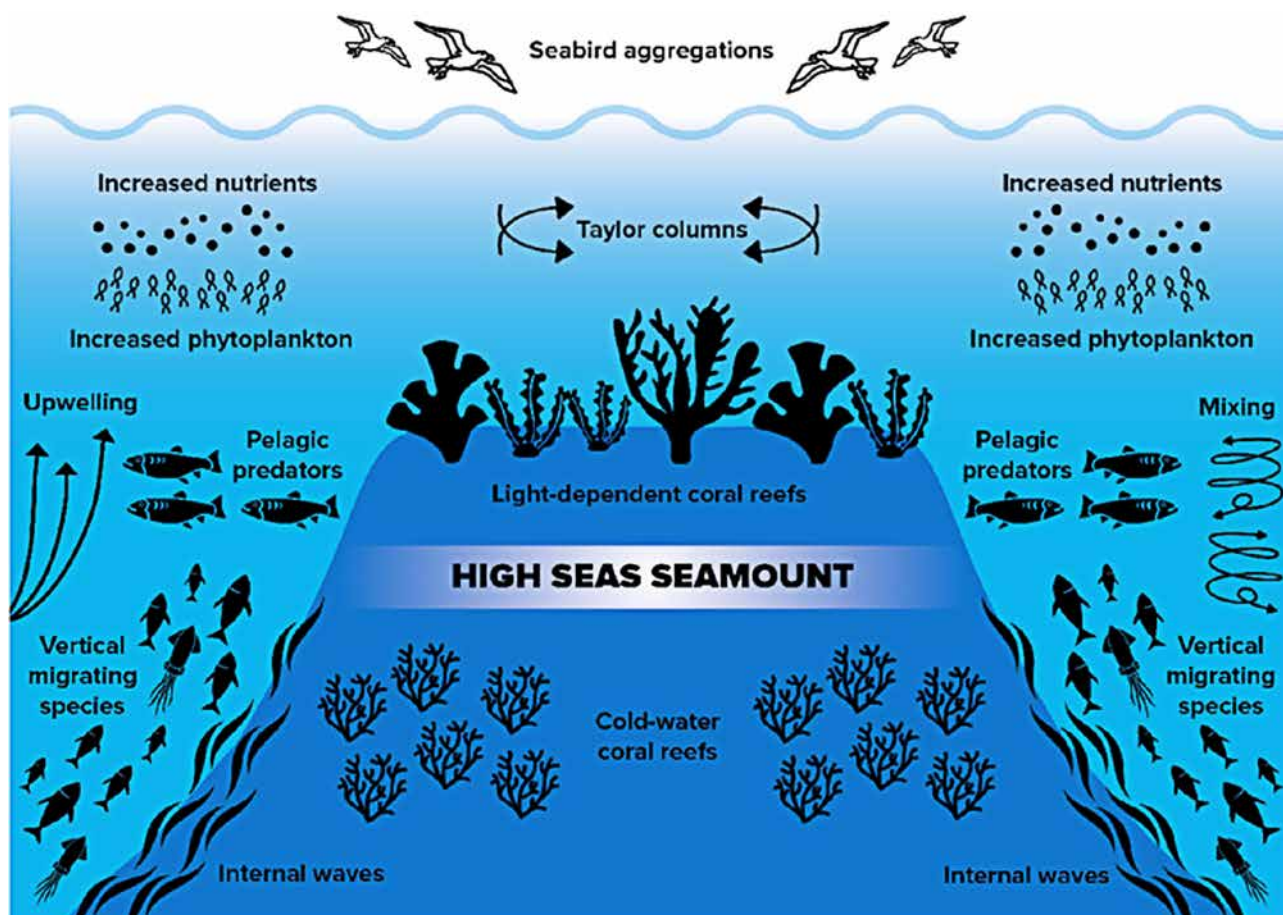


Figure 1: Diagram showing the functional importance of high seas coral reefs, which are associated with seamounts (source: Wagner et al, 2020).

Importance of connectivity

Connectivity ensures the replenishment of populations, maintains genetic diversity, links different habitats to support various life-history stages, and maintains trophic linkages. Figure 1 shows how vertical connectivity relates to seamounts, which we know provide refugia to a range of species in the Tasman Sea. Importantly, connectivity promotes resilience to disturbances, such as climate change, deep-sea mining, and trawling. Without connectivity, populations impacted by disturbances may struggle to recover, highlighting the need to protect and maintain ecological corridors (areas that genetic information, or individuals of a population move along).

Connectivity breakdown can have catastrophic ecological impacts. Certain locations, habitats or populations can play a critical role within a network, and if they are adversely affected, we see consequential impacts throughout an entire network or ecosystem. Airline systems provide a useful analogy to understand. One network node shutting down may provide a minor inconvenience that can be managed. If a major hub or a minor route that links into another critical route cannot function, the entire system will be affected, and full recovery to normal operations can take a long time.

Integrating connectivity considerations into marine conservation

Designing MPA networks requires understanding the type of connectivity occurring and identifying priority areas of movement between habitats. To date, connectivity has not been directly considered in many networks of marine protected areas, with perceptions about the complexity

of connectivity modelling and science acting as a barrier. Complex methods, such as dispersal modelling using high-resolution hydrodynamic circulation models, can provide detailed insights into larval trajectories and probability density distributions. However, simpler approaches, such as using current meter data to estimate dispersal distances, can also be effective in some cases and as a minimum estimate. Network analysis can identify critical nodes and connections within the ecosystem, helping prioritise areas for protection.

A useful example of how connectivity science can guide conservation comes from research on the deepwater coral *Desmophyllum pertusum*, found in the Gulf of Mexico and along the east coast of North America. Researchers used computer models to track how coral larvae move between different areas, identifying the direction and strength of connections between coral populations (Fig. 2). This helped them understand which locations are most important for keeping coral populations connected. They found that some sites act like 'stepping stones', helping larvae travel between otherwise isolated populations. Others are so central that losing them could break the entire network, putting the coral ecosystem at risk. This analysis helps identify which areas should be prioritised for protection to maintain healthy, resilient marine ecosystems (Guy et al, 2025).

Advancing connectivity in marine spatial planning

Establishing clear, science-based targets for ecological connectivity remains one of the most challenging – but important – aspects of marine spatial planning (Balbar et al, 2024). While global conservation frameworks

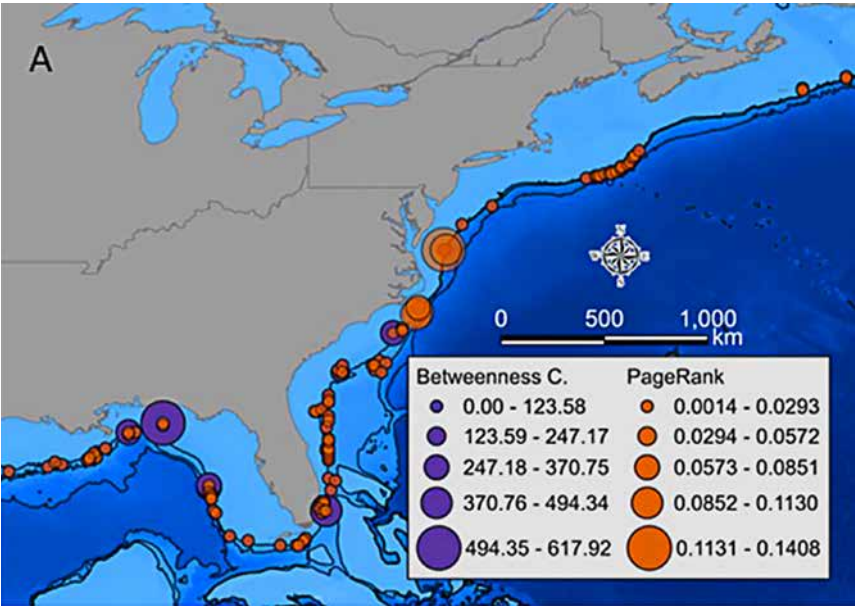


Figure 2: Ratings of importance of the steppingstones (labelled 'Betweenness C') and the connectivity 'nodes' of the populations (labelled 'PageRank') for deepwater coral species *Desmophyllum pertusum*. Larger circles indicate more important steppingstones and nodes.

increasingly emphasise the need for well-connected networks of MPAs—seen as a critical component of Targets 2 and 3 of the Kunming-Montreal Global Biodiversity Framework—the operational definition of what constitutes ‘well-connected’ is often vague or inconsistently applied. To address this, a recent paper proposed a framework to translate high-level conservation goals (e.g., persistence, recovery, resilience) into measurable, well-defined objectives and actions. This framework can assist in guiding the process of identifying relevant ecological data, modelling connectivity pathways, and integrating these insights into decision-making tools for MPA design (Gaines et al, 2010; Magris et al, 2018).

Importantly, we note that while sophisticated modeling approaches can offer detailed insights, they are not always necessary to inform effective management. In many cases, simpler, data-informed methods—such as current meter analysis or larval duration estimates—can provide the guidance needed to identify key ecological linkages and prioritize areas for protection. This pragmatic approach ensures that connectivity considerations are not sidelined due to resource constraints and data limitations.

Ensuring connectivity is properly incorporated into marine conservation strategies is not just a technical exercise; it is absolutely necessary for ensuring the long-term viability of marine ecosystems. If we can identify and protect critical nodes, maintain dispersal pathways, and encourage collaboration across disciplines and jurisdictions, then we can build networks that support biodiversity, ecosystem services, and climate adaptation. As we move toward ambitious conservation targets, the integration of ecological connectivity into spatial planning must be prioritised—as a practical pathway to sustaining ocean health.

Acknowledgements

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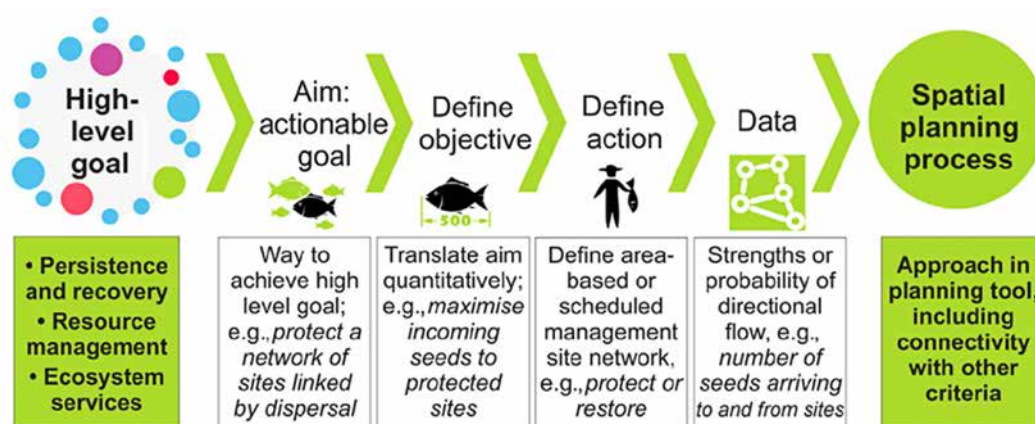


Figure 3: Tool to assist with integration of connectivity into spatial conservation planning (source Beger et al, 2022).

Current approaches and future opportunities in designing climate-smart protected areas

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Climate change and biodiversity loss are intertwined global problems, where failure to address one often exacerbates the effects of the other (Pörtner et al, 2023). Protected areas—among other area-based management tools—are designed to separate biodiversity from threats, but they have done little to ameliorate climate-change impacts. Even worse, climate change also reduces the effectiveness of existing protected areas.

Despite advances in climate-change ecology, conservation science has been slow to translate these insights into action. As we move towards protecting 30% of land, waters, and seas by 2030—also known as the ‘30x30’ initiative, we have a once-in-a-lifetime opportunity to design new protected areas that consider climate change from their outset. This opportunity is especially important in the high seas. While the high sea covers more than 60% of our oceans, only <2% of it is protected. With the soon-to-be ratified Biodiversity Beyond National Jurisdiction (BBNJ) Agreement, there will be a formal mechanism to conserve and sustainably use the high seas in a climate-smart way.

Conservation planning refers to the structured process of identifying, assigning and monitoring areas for conservation or management (Margules and Pressey, 2000). Spatial prioritisation—the process of identifying priority areas where specific conservation and/or management measures can be implemented—is one crucial step in conservation planning, where new protected areas that could be established are identified. While several reviews have synthesised how climate change has been incorporated in different steps of the broad conservation planning process, approaches that explicitly incorporate climate change in climate-smart spatial prioritisation has not been synthesised since (Jones et al, 2016).

In this review, we scoured through more than a hundred peer-reviewed literature that used climate projections to inform their spatial prioritisations. We synthesised four key approaches that explicitly incorporate climate change in spatial prioritisation: protecting species’ future habitats, protecting climate refugia (areas projected to buffer biodiversity from climate change), protecting areas that facilitate climate connectivity (shifts and changes in

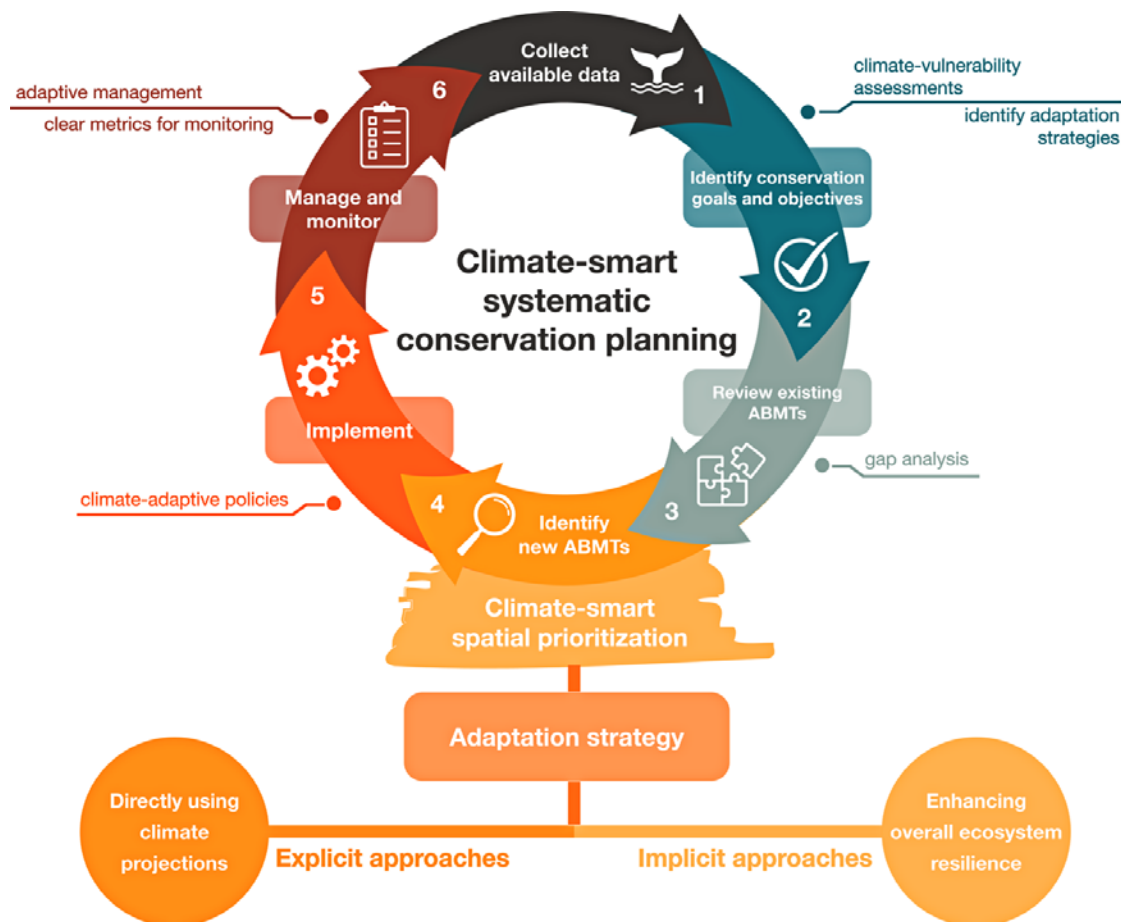


Figure 1: A broad view of how climate change can be incorporated in the different steps of systematic conservation planning (source: Buenafe 2025).

species' climate niches), and protecting areas that foster natural adaptation to climate change. We also provide actionable guidance for applying these 'climate-smart' approaches in spatial prioritization, resulting in protected areas that are more resilient to the changing climate.

However, integrating climate change into conservation planning is not without its challenges, limiting the uptake of these climate-smart approaches in on-the-ground conservation planning. Appropriately capturing uncertainty in climate projections and species' responses remains a hurdle in climate-smart conservation planning. There are noticeable data gaps that limit the number of climate-smart approaches that can be applied in data-poor regions, such as the high seas and the Global South. Finally, navigating the seemingly limitless complexities and trade-offs of the different climate-smart approaches presents a considerable challenge. However, these challenges can be overcome. We call attention to the ways these challenges can be circumvented, such as properly accounting for uncertainty by considering

multiple emission scenarios and using an ensemble of climate models, taking advantage of approaches that use measures of climate exposure from climate projections as proxies whenever species-specific biodiversity data is not available, and applying 'bet-hedging' strategies in conservation planning where multiple (potentially contrasting) climate-smart approaches could be included in the same protected-area design.

We end this review by highlighting promising ways to integrate advances in climate-change ecology into conservation planning:

1. Developing climate-smart strategies applicable to data-poor regions;
2. Embedding climate connectivity into protected-area designs;
3. Enhancing reproducibility of conservation-planning frameworks; and
4. Promoting transboundary collaboration in conservation planning.



A short-beaked common dolphin, found across the Tasman Sea. Source: ©Eric J Woehler.

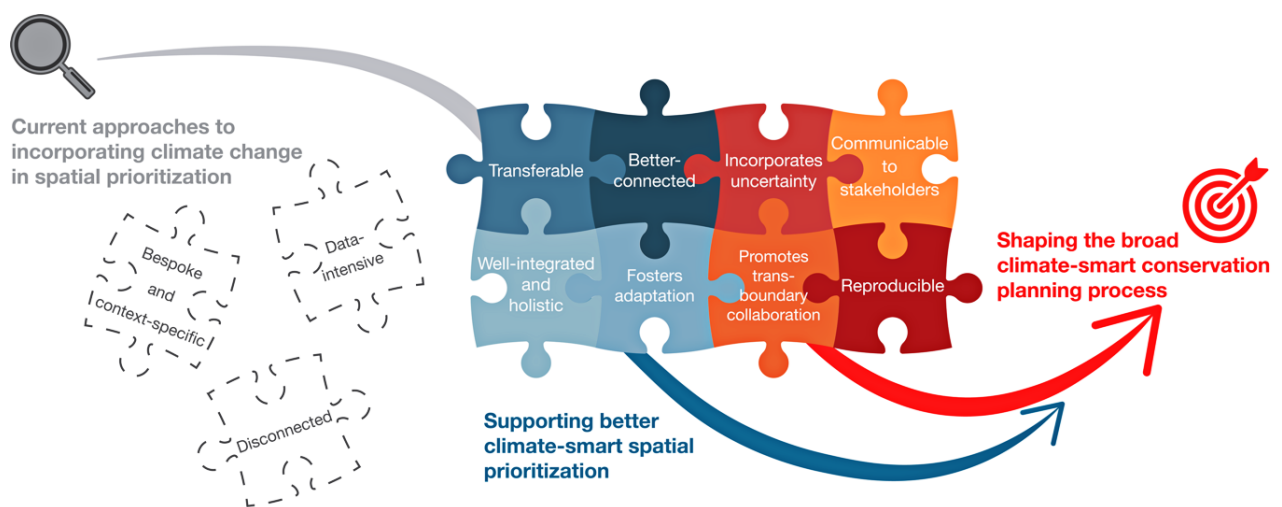


Figure 2: A roadmap to shaping the broad climate-smart conservation planning process (source: Buenafe 2025).

Associated paper

Buenafe KCV, Dunn DC, Metaxas A, Schoeman DS, Everett JD, Pidd A, Hanson JO, Bentley LK, Kim SW, Neubert S, Scales KL, Dabalà A, Brito-Morales I and Richardson AJ (2025) Current approaches and future opportunities for climate-smart protected areas', *Nature Reviews Biodiversity*, 1:284–297.

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Providing lessons and enhancing understanding of potential synergies between the BBNJ Treaty and the South Pacific Regional Fisheries Management Organisation (SPRFMO)

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The South Pacific Regional Fisheries Management Organisation (SPRFMO) is an intergovernmental body dedicated to the long-term conservation and sustainable use of fisheries resources in the South Pacific Ocean (SPRFMO 2022) (Fig. 2). SPRFMO includes members from various regions, including Asia, Europe, the Americas and Oceania. It manages jack mackerel and jumbo flying squid in the southeast Pacific near South America, and deep-sea species in the southwest Pacific (primarily bottom trawling for orange roughy), including in the Tasman Sea and the Lord Howe Rise (Fig. 1).

This paper reflects lessons learnt from the SPRFMO experience in establishing Area Based Management Tools (ABMTs) for bottom fisheries in the South Pacific



Figure 1: Orange roughy swimming over a deepwater coral reef. Source: Earth Sciences New Zealand; Voyage TAN1402.

and has two main objectives. First, we share lessons learned from integrating science into policymaking during the development of ABMTs within SPRFMO. Second, we propose practical recommendations for how a future Biodiversity Beyond National Jurisdiction (BBNJ) body could collaborate with regional and sectoral marine governance organisations in establishing ABMTs in the Tasman Sea.

SPRFMO has implemented a bottom fishing conservation management measure (CMM) to help ensure the long-term conservation and sustainable use of deep-sea fishery resources, including safeguarding the marine ecosystems in which these resources occur and preventing significant adverse impacts (SAIs) on vulnerable marine ecosystems (VMEs) (SPRFMO, 2025). Management measures included in the CMM to prevent SAIs on VMEs include the establishment of spatial management measures (i.e. bottom fishing management areas), which were designed to 'protect large portions of the predicted distribution of VME indicator taxa while permitting access for fisheries' (SC8- DW07_rev1); and an encounter protocol, which provides a mechanism for the immediate temporary closure and assessment of bottom fishing in an area where the bycatch of VME indicator taxa is above a threshold level.

The Scientific Committee of SPRFMO reviews all encounters with potential VMEs and provides advice on management measures to prevent SAIs on VMEs. The CMM also requires fishing vessels to carry government observers and for fishers to report VME bycatch, including providing photographs and, occasionally, physical samples. Reports are submitted to government

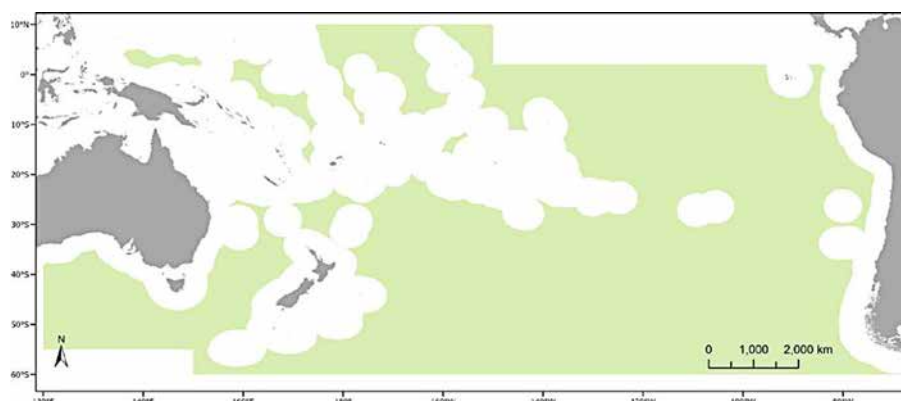


Figure 2: The SPRFMO Convention Area (light green area).

officials, and samples are added to the Earth Sciences New Zealand invertebrate collection. These reports and associated information help with the development of species distribution models that inform management decisions. The current demersal fisheries within the Evaluated Area of SPRFMO are also supported by a cumulative Bottom Fishing Impact Assessment (BFIA), prepared in conformity with the CMM, and consistent with the actions called for in the United Nations General Assembly sustainable fisheries resolutions.

The design of the bottom fishing management tools, including the ABMTs, encounter protocols and standards for preparing the BFIA took over 10 years to develop. The SPRFMO bottom fishing management measures have been developed with the intention of giving effect to the UN General Assembly resolutions concerning deep-sea fisheries.

Management design

The design of ABMTs for bottom trawling in SPRFMO included objective setting, followed by compiling and verifying data to feed into decision-support tools which informed the development of recommendations and decision-making (Fig. 2). All stages of the process happened within a broader engagement process involving working groups, the SPRFMO Scientific Committee and the SPRFMO Commission. Stakeholder input and interaction were important throughout the process, particularly during objective setting and the use of decision-support tools. Verification and the iterative development of area-based management approaches (represented by Feedback loops 1-3 in Fig. 2), and review of the ongoing effectiveness of area-based management (represented by Feedback loop 4 in Fig. 2) were crucial to ensuring the design of area-based management was effective in achieving management objectives. All ABMT proposals were reviewed by the SPRFMO Scientific Committee, which provides scientific advice and recommendations to the SPRFMO Commission, the organisation's ultimate decision-making body.

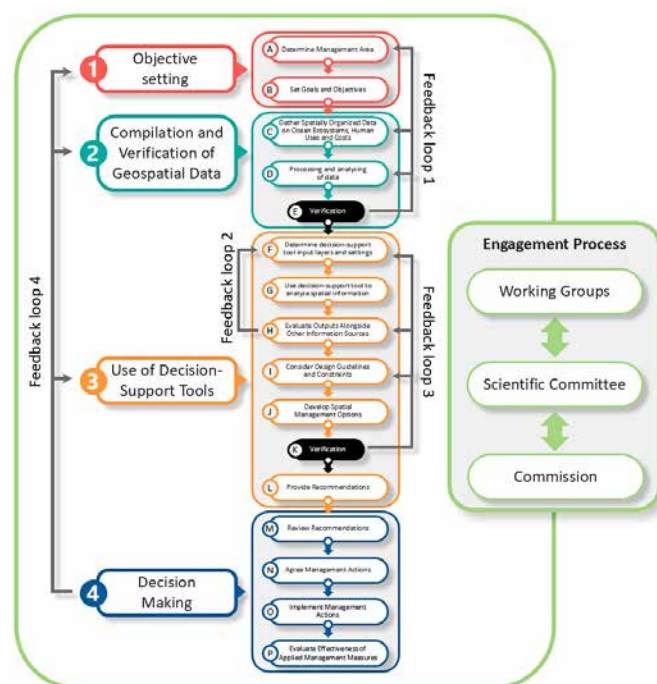


Figure 3: An overview of the approach to designing ABMTs.

Lessons learnt while developing and implementing Area Based Management

This paper outlines six key lessons learned from SPRFMO processes, which we believe can inform the design of effective ABMTs for the Tasman Sea.

1. Considering the relationship between protection and sustainable use at the outset of a planning process is critical. Stakeholders often have diverse, and sometimes opposing, perspectives on the importance of protection versus sustainable use. Explicitly considering the relationship between these at the outset of a planning process is essential to reduce misunderstandings about their relative importance. It also helps ensure they are appropriately considered during decision-making processes, which can lead to greater long-term acceptance of management measures. In the SPRFMO case, the effectiveness of the current management measures continue to be

debated – potentially because the relative importance of these key themes wasn't well resolved during initial planning, potentially affecting the acceptance of the CMM. Article 1 of the BBNJ Agreement refers to ABMTs being managed to achieve conservation and sustainable use as objectives (United Nations, 2023). In practice, achieving this aim will require careful consideration of the relationship between protection and sustainable use when developing objectives that are to be applied to an area.

2. Clearly defined objectives are important for keeping people on task. SPRFMO is an intergovernmental organisation, and collaboration among scientists from various institutions was key to achieving a shared goal. Effective collaboration was supported by clearly defined objectives, which (i) provide a roadmap and timeline for what needs to be done; (ii) enable the prioritising of tasks leading to better location of time and resources; (iii) reduce ambiguity and align effort towards common targets; and (iv) foster collaboration for team work. Article 19 of the BBNJ Agreement requires proposals to describe specific objectives for any area to be implemented under the agreement, whether conservation or sustainable use in nature (United Nations, 2023). In practical terms, addressing this article will necessitate the development of clearly defined and measurable objectives against which the success of the planning process can be measured.
3. Reaching agreements on how to apply fundamental concepts in practice is crucial. During the SPRFMO process, disagreements on how to interpret and use fundamental concepts—like 'significant adverse impacts' (SAIs) and identifying 'vulnerable marine ecosystems' (VMEs)—created challenges. While the FAO Guidelines (Food and Agriculture Organization, 2009) defined these terms, they offer limited guidance on their practical implementation, especially when designing ABMTs. Issues like determining the correct spatial scale at which to assess SAIs on VMEs were particularly difficult. Article 19.3 of the BBNJ Agreement outlines some fundamental concepts, including the precautionary and ecosystem approaches, both of which must be operationalised effectively to guide the development of ABMTs (United Nations, 2023).
4. Including diverse working groups is beneficial to the process. SPRFMO working groups included industry, NGOs, scientists, and key SPRFMO member states. These groups set goals and objectives, compiled and verified geospatial data sets, and assisted in parameterising and using the decision-support tools. They also verified decision-support tool outputs and identified any caveats associated with the outputs so they could be considered during the decision-making process. Diversity of thought within the working groups led to innovation and creative problem solving and helped identify pitfalls and potential opportunities that a more homogeneous working group may not have identified. Article 19.2 in the BBNJ Agreement requires parties to collaborate and consult with relevant stakeholders, including States and global, regional, subregional and sectoral bodies, as well as civil society, the scientific community, the private sector, Indigenous Peoples and local communities in the development of proposals (United Nations, 2023). In practical terms, the main learning for any BBNJ process in the Tasman Sea is that it will be crucial to understand who the stakeholders are in the region to allow collaboration through good BBNJ cooperative procedures.
5. Iterative development of proposals has clear benefits. In the SPRFMO case, iterative development allowed time for participants to understand the scientific underpinnings of a process. It also facilitated regular feedback, ensuring stakeholder concerns and insights were considered during the decision-making process. Iterative development also allowed for small incremental changes to the design of such measures as ABMTs, which reduced the potential for the accumulation of errors. It allowed for adjustment to changing information, which helped ensure measures remain relevant and effective, while keeping the process transparent – an essential component for people to trust the process. The BBNJ Agreement inherently builds in an iterative process for developing ABMT proposals through the requirement to consult on their development (Article 19), to make proposals available for review (Article 20), and consultation on proposals, including the requirement for proponents to consider contributions received and revise the proposal as appropriate (Article 21) (United Nations, 2023). As such, we recommend that iterative co-development of any proposals for the Tasman Sea is explicitly built into collaboration and consultation processes with relevant stakeholders, including States and global, regional, subregional and sectoral bodies, as well as civil society, the scientific community, the private sector, Indigenous Peoples and local communities prior to public consultation.
6. Ongoing evaluation is essential to ensure that objectives continue to be met. In the SPRFMO case, regular reviews were important in triggering processes to refine spatial boundaries of ABMTs and encounter thresholds. Review processes considered changing perceptions of the uncertainty of information underpinning the design of ABMTs (e.g. outputs of species distribution models), the availability of new scientific information (particularly that which addresses existing uncertainties and caveats) and improved approaches for designing and evaluating the effectiveness of ABMTs. Ultimately, review processes resulted in lowering the thresholds that trigger move-on rules. This review process highlights the importance

of reassessing the scientific basis and uncertainty underlying ABMTs, and incorporating new scientific information as it becomes available. Article 26.4 of the BBNJ agreement supports this sort of approach carried out by SPRFMO by including a formal monitoring and review process to assess the effectiveness of ABMTs in achieving their objectives.

We believe the lessons learned from SPRFMO's experience in creating ABMTs could be valuable for any future BBNJ body working on similar tools in the Tasman Sea, including the development of protected areas.

How can the SPRFMO and BBNJ bodies work together in future?

Key principles of the BBNJ Agreement include to 'not undermine' the existing legal instruments or mandates of regional and sectoral marine governance organisations and to promote coherence and coordination, as set out in Articles 5(2) and 22 of the BBNJ Agreement. The phrase 'not undermine' will ultimately shape the relationship between the BBNJ Agreement and RFMOs. This 'not undermine' principle in Article 5(2) highlights the influence of RFMOs, that while protected by the principle, will be able to influence the BBNJ Agreement's ability to advance attention to biodiversity issues in fisheries management. However, significant ambiguities remain to the scope and implications of the obligations to 'not undermine' and 'respect the competencies of'. Ultimately it will depend on the practice of the Conference of the Parties and RFMOs to give meaning to these terms, though there are lots of emerging legal interpretations on how that could be done.

One mechanism for facilitating cooperation between a BBNJ body and other regional and sectoral marine governance organisations, such as RFMOs, could be through non-binding Memorandums of Understanding (MOU). SPRFMO for example, has previously used MOUs to facilitate cooperation with various international organisations, and a list of these is publicly available on its website.

An MOU between a BBNJ body and SPRFMO could:

- Define the nature of their interaction,
- Outline areas for future collaboration, such as data and scientific information sharing,
- Help implement Article 2 of the BBNJ agreement (the 'not undermine' clause), and likely the coherence article as well.

In practice, any BBNJ body will need to work closely with other relevant legal instruments—such as SPRFMO and the International Seabed Authority—when developing proposals for ABMTs in the Tasman Sea.

Acknowledgements

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Building on EBSAs: Using seabird tracking data and new insights to guide management of the South Tasman Sea

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BirdLife International is a network of 123 organisations working collaboratively to address the biodiversity crisis – with an emphasis on bird species and areas of biological importance – which overlaps significantly with the climate crises. In 2011, BirdLife contributed extensive seabird data to the description of the South Tasman Sea and Lord Howe Ridge Ecologically and Biologically Significant Marine Areas (EBSAs). In this presentation we review the developments since the EBSA descriptions with a focus on the South Tasman Sea, emphasising the wealth of new data available and the value that seabird tracking contributes to marine spatial planning globally.

New data to inform area-based management

Since the initial EBSA description, there has been a significant increase in published data on seabirds. Landon et al, (2022) reviewed the scientific literature relevant to the South Tasman Sea EBSA, narrowing more than 7,000 results to analyse 101 papers. Seabird and fish

studies both comprised around one-third of these studies, with marine mammals and planktonic/microbial studies comprised around 10% each. More than half of these were biological studies, with a smaller proportion (less than one third) were physical or socioeconomic studies.

Three-quarters of the studies referred to the biological diversity and productivity of 75 species across all of the literature. Nearly 70% addressed cumulative and transboundary impacts; 60% referred to vulnerability to a range of threats; and nearly half examined ecological connectivity (Landon, 2022). Of the studies considering ecological connectivity, 25 seabird species were examined, five marine mammal species, two sea turtle species and 11 invertebrate species. This analysis provides an excellent source of information that can assist in informing both current and potential future conservation measures in the South Tasman Sea.

This significant increase in published studies, and data availability, has been made possible by major advancements in tracking technology. Satellite tags are now much smaller and lighter, allowing for more extensive tracking studies across a broader range of species and colonies. BirdLife hosts a tracking database with nearly 70 million data points from 170 seabird species, thanks to contributions from over 250 data owners (Fig 2). Contributors retain ownership of their data, but submission to BirdLife's database enables open access to support higher quality research and conservation management. This database has facilitated the identification of Key Biodiversity Areas (KBAs) and supported various conservation initiatives (Carneiro et al, 2021).

Case study: North Atlantic Current and Evlanov Seamount Marine Protected Area (NACES MPA)

A successful example of applying seabird tracking to marine spatial planning is the NACES MPA in the North Atlantic. Several countries of the OSPAR Convention, which collectively manage the area of the high seas in the North Atlantic, requested tracking data from BirdLife to support identification of a high seas MPA within the Convention area. We compiled tracking data from

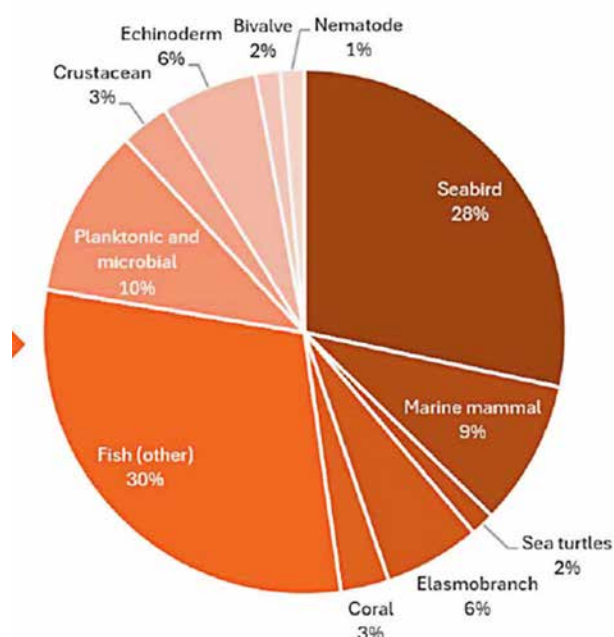


Figure 1: Primary focus of scientific literature on the South Tasman Sea EBSA, published since 2011 (source: Landon 2011).

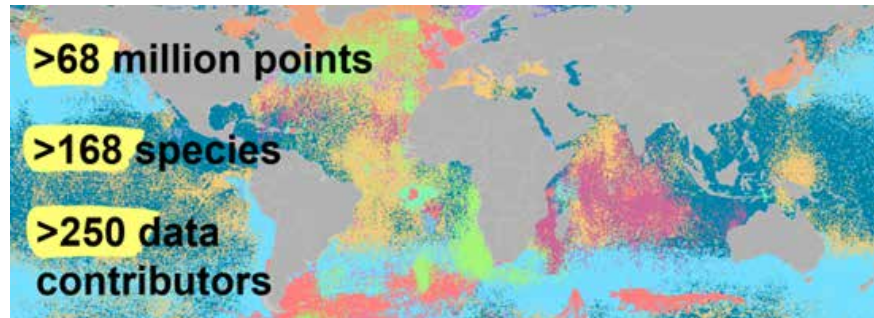
1989 - number of colonies tracked: 1



2019 - number of colonies tracked: 360



Figure 2: The accumulation of data on bird colonies between 1989 and 2019 (above) and a compilation of all BirdLife data points (right).



21 different species, representing approximately 5 million birds covering a 12-month period (see Fig. 3). In total, the analysis brought together over 2,000 bird tracks from over 100 different colonies, thanks to the data contribution of almost 80 scientists (Davis et al, 2020).

It focused on seabird tracking to identify the most important area utilised by those 100 colonies. Many lessons have been learned throughout this process, including some that may be appropriate for us to consider for the Tasman Sea. We identified several key strengths of this data-driven approach. Firstly, seabirds are excellent indicators of biodiversity and a focal taxon, with many countries having existing seabird action plans. Secondly, the approach emphasises national linkages to areas via species, which is a powerful driver of governments' support for MPAs outside of their national waters. Thirdly, this approach builds on governments' familiarity with the Key Biodiversity Area process. Finally, the approach supports collaborative science, from data-holders through to government scientists and policy advisers.

Application to the Tasman Sea

The Tasman Sea shares many ecological characteristics with the North Atlantic, including high biodiversity and dense seabird populations (one of the species common to both areas is shown in Fig. 3). Tracking data show that seabirds in the Tasman Sea originate from multiple countries, reinforcing the need for international cooperation in conservation planning.

BirdLife has initiated a collaboration with New Zealand's Department of Conservation to apply a similar analytical

approach to the Tasman Sea. The project will begin with the formation of an advisory group, followed by workshops to assess available data and identify gaps. While funding is limited, the initiative aims to leverage existing tracking data to inform the development of high seas MPAs in the region (Landon et al, 2022).

This effort aligns with the objectives of the Biodiversity Beyond National Jurisdiction (BBNJ) Agreement, which emphasises the use of best available science. The Tasman Sea project will help determine how much relevant data already exists, what remains inaccessible, and what new data may be needed.

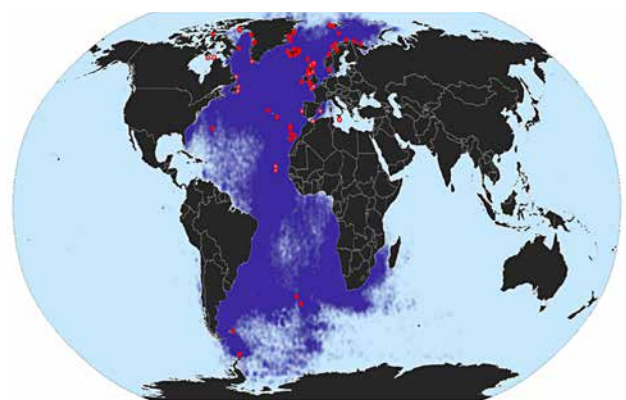


Figure 3: The collection of raw bird tracking data (in purple) and colonies (in red) collected throughout the course of a year to inform the NACES MPA (source: Carneiro et al, 2021).

Conclusion

Seabird tracking is a powerful tool for marine spatial planning, offering insights into biodiversity, connectivity, and conservation priorities. While seabird tracking data is certainly not the only data consideration, it can provide an informative and powerful start for delineation and advocacy. With regard to process, the success of the NACES MPA provides a model for the Tasman Sea, where similar methods can support the designation of domestic and high seas protected areas, and conservation measures implemented by other competent bodies.

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The Antipodean albatross (*Diomedea antipodensis*), a migratory species which resides across the region of interest.
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Applying the conservation ladder to identify conservation knowledge gaps of threatened species on Norfolk Island

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This paper applied the conservation ladder (Watson et al, unpublished 2025) to threatened species on Norfolk Island, a knowledge framework that enables the conservation community to quickly diagnose and communicate the specific knowledge, management and monitoring gaps that must be addressed to safeguard and/or recover species. Here, we presented the rationale, framework and application of the conservation ladder to a spatial location on Norfolk Island, and how this can be adapted to marine species within the Lord Howe Rise and South Tasman Sea.

Introducing the conservation ladder

Ladders are a handy tool to get to places out of reach. A functional ladder requires strong consecutive rungs, and if a rung(s) is missing or unstable the uncertainty to arrive at the top rung greatly increases, with these rungs being hierarchical in nature, where lower rungs need to be in place before higher rungs are considered useful. In this presentation, we argued that the road to reaching successful conservation outcomes can be usefully conceived as a theoretical ladder, and through contextual consideration, different types of conservation knowledge that are critical to achieving conservation success can be set as the ‘rungs’ on a ladder. The conservation ladder allows a shift from the sole focus on extinction

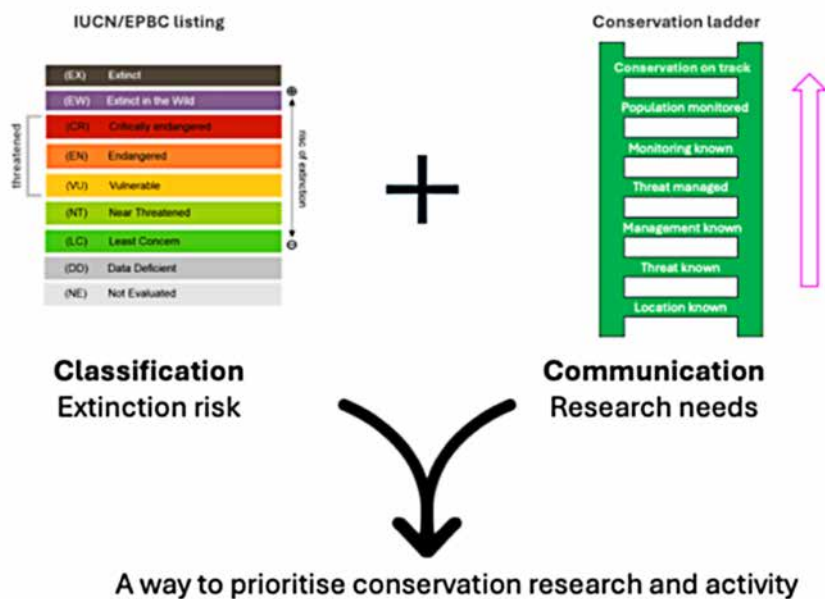


Figure 1: A traditional classification of extinction risk combined with the conservation ladder to prioritise conservation research and activity (source: The IUCN categorisation image of extinction risk was adapted from *The IUCN Red List of Threatened Species*. IUCN. 2025. Version 2025; and Chuanji Yong).

Science-driven conservation

risk classification to a more actionable, knowledge-based prioritisation and communication of knowledge management needs.

James Watson, in collaboration with the Research and Recovery of Endangered Species (RES) Group, initially developed the conservation ladder to assess Australian threatened birds nationwide, providing the first comprehensive assessment on the actual state of species' conservation needs for Australia's most threatened bird taxa.

Rationale for a new framework

Traditional conservation assessments, such as those by the IUCN (Red List) or under Australia's EPBC Act, are focused on assessing the risk of extinction for a species. However, we believe these classifications don't adequately emphasise which specific knowledge gaps are most influential on conservation management feasibility. Watson proposed an additional focus—different forms of knowledge gaps and working through different research activities needed (see Fig. 1). The conservation ladder facilitates by offering a structured, stepwise approach to evaluating the readiness of species for effective conservation intervention.

The conservation ladder: Structure and purpose

The conservation ladder has to be tailored to the context, and this was done in consultation with Parks Australia and Norfolk Island National Park managers. We built the Norfolk Island conservation ladder with six rungs to arrive at the top rung that indicates on-track conservation status, with each representing a critical prerequisite for successful species recovery. Progress up the ladder is contingent on satisfying the lower ladder 'rungs'. For example, a species cannot be considered effectively monitored if its location or threats remain unknown. This hierarchical structure ensures that conservation actions are grounded in foundational knowledge. The rungs are as follows:

Location: Do we know where the species is?

Major threats: Do we know what the major threats are?

Management capability: Do we know (in theory) how to abate the major threats? Are they technically, socially and financially feasible?

Management implementation: Has management been applied effectively and consistently at scale?

Monitoring capability: Do we have the tools and methods to monitor the species?

Monitoring implementation: Is the species/threat actively and effectively monitored?

Conservation on track: Taxon has met all the prerequisites needed for successful conservation.

Case Study: Norfolk Island

Norfolk Island, located on the Norfolk Ridge, presents a unique conservation context. The island hosts 58 threatened species, with varying degrees of data availability and management feasibility. Our team collaborated with local park managers to apply the conservation ladder to each species, generating a comprehensive assessment of conservation needs. We found that while many species are on a positive trajectory—particularly those who that more knowledge covering most of the 'rungs'—several remain in critical need of foundational research. For instance, two critically endangered snail species have not been observed in years, and these two species fall on the "1 – Location of species" rung, highlighting the urgent need for basic location data before any other conservation needs are addressed.

Key findings and knowledge gaps

Our application of the conservation ladder revealed several critical insights:

- Knowledge gaps are widespread: Many species lack basic data on location and threats, particularly invertebrates and lesser-known taxa.
- Monitoring is often weak: Even when management is in place, monitoring systems often lack the sensitivity to detect population changes.
- Threat abatement is inconsistent: While some threats are well understood, their management is not always feasible or implemented at scale.

These findings align with broader critiques of conservation science, which emphasise the need for evidence-based prioritization and management plans which can be adaptable (Sutherland et al, 2009; Possingham et al, 2001).

Implications for broader application

The conservation ladder is adaptable across ecosystems and taxa. The initial application was taxon-based applied to all threatened birds in Australia, while our pilot focused on a spatially defined area (Norfolk Island National Park) and the threatened species that it encompasses. This implies that the framework can be applied to entire taxonomic groups (e.g. marine birds, cetaceans) or broader spatial scales (e.g. Lord Howe Rise), with the rungs on the ladder determined in consultation with the end-users. Its flexibility makes it a valuable tool for national and regional conservation planning. We are currently exploring its application across other federally managed parks and integrating it with National Seed Bank assessments to evaluate how ready we are to conduct effective conservation in the wild.

Conclusion

Our research demonstrates that the conservation ladder is a powerful tool for identifying research priorities, guiding management decisions, and allocating conservation resources effectively. By focusing on knowledge gaps and feasibility, the ladder complements traditional risk assessments and enhances good conservation outcomes. We recommend its broader adoption across conservation programs, particularly in data-deficient or resource-limited contexts. Future work should focus on refining the ladder's criteria, integrating it with decision-support systems, and validating its predictive power by testing it across diverse ecological settings. Ultimately, the conservation ladder provides a structured approach to overcoming the challenges of species recovery, ensuring that conservation efforts are both strategic and impactful.

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A data deficient Dusky dolphin (*Lagenorhynchus obscurus*), Tasman Sea. Source: ©Eric J Woehler.

Ocean governance panel

Reflections from the symposium organisers

The ocean governance panel, convened as part of the Lord Howe Rise and South Tasman Sea Research symposium, was an opportunity for experts and symposium participants to explore the dynamics of ocean governance beyond the boundaries of the Lord Howe Rise and South Tasman region. The current evolution in governance policy and frameworks, coupled with a heightened understanding of the importance of rights and interests, provided the panel with an opportunity to discuss the levers that will shape ocean stewardship for generations to come.

The panel brought together eminent leaders and thinkers working across a range of organisations and issues. Dr Filimon Manoni, the Pacific Ocean Commissioner, joined Pepe Clark, Head of WWF's global Oceans Practice; Dr Aline Jaeckel, Associate Professor at the Australian National Centre for Ocean Resources and Security (ANCORS); and Salā Dr George Carter, Senior Fellow and Deputy Head of the Department of Pacific Affairs at the Australian National University on the panel, which was moderated by Bronwen Golder, Seamounts Campaign lead at the Deep Sea Conservation Coalition.

This wide-ranging discussion traversed the range of expectations and ambition for ocean governance, from the perspectives of selected experts in the law of the sea, environmental advocacy, the management of Pacific Ocean resources, climate security and Indigenous and Traditional Knowledge. Their diverse but intersecting expertise and perspectives ensured that the symposium audience came away with a sense of the increasing complexity and opportunity that ocean science, conservation and sustainable use discussions are going to have to grapple with.

While panel observations were broad and at times contested, a number of key themes and considerations emerged from the session:

- Governance, particularly in a region like the Pacific, is about more than 'lines in the ocean'. Traditional Knowledge, Indigenous rights and customary approaches to stewardship must be central to all ocean governance debates and resolutions, including implementation of the BBNJ Agreement.
- Our collective learning from regulatory models that have evolved out of UNCLOS – RFMOs, the IMO, the ISA – can (must) inform, reform or evolve the future shape of ocean governance. While imperfect, those frameworks will provide critical points of reference for future action under ocean governance agreements.

- Pacific advocacy and action on climate change, ocean protection and management provide lessons and guidance for the future shape of ocean stewardship, one that recognises the rights and interests of Pacific States and peoples in the negotiation and implementation of international policy.
- In the past, ocean governance has too often focused on regulating use and extraction– a 'commoditisation' of resources rather than guardianship of them. Looking ahead, the rights and interests of Indigenous and Traditional Knowledge holders, ocean (Pacific) States, and civil society need to be recognised and fully integrated into ocean governance and management.

In responding to the panelists perspectives the symposium audience expressed, simultaneously, a sense of exasperation with the implementation of past frameworks, a concern for the integrity of current promises, and an ambition for a future pathway that more consistently embraces the 'preserve and protect' commitment that sits at the heart of UNCLOS with a respect for the rights and interests of Traditional Knowledge holders alongside the unique perspective and experience of island (Pacific) peoples.

While the ocean governance panel session did not speak directly to the future governance of the Lord Howe Rise and South Tasman, the layers of knowledge, experience and perspective that the panelists (and audience responses) brought to the discussion helped illuminate the dynamic cultural, legal and political context in which future ocean governance negotiations will need to take place. From different but interacting perspectives, the panellists urged the symposium audience to pursue ocean governance collectively and with ambition.

Exploring science through art



Participants collaborated over the two days on a large-scale mural of the Lord Howe Rise, coordinated by the Deep Sea Conservation Coalition (DSCC). The mural's progression is shown in the image above, and the final piece is shown below. The mural incorporates culturally important symbols and markings from First Nations Australian and Hawaiian cultures, and depicts a range of iconic, unique and ecologically and culturally important species that live in, travel through and depend on the Lord Howe Rise for their survival.

This mural was built on a global collection of works supported by DSCC, with creative direction from the Chilean artist Payo and Bla! Bringing together deep-sea knowledge, art and public engagement, these 'deep dive' murals showcase the natural wonders of seamounts across the world. The complete collection, painted in several countries over more than a year, travelled to the UN Ocean Conference in France in June 2025, representing seamounts of the Pacific and the Mediterranean in vibrant colour.

The symposium transitioned seamlessly into the Australian premiere of Sir David Attenborough's 2025 documentary 'Ocean', the day after its global premiere in London. Many symposium participants attended the premiere and had the privilege of seeing their life's work writ large by Sir David Attenborough. As with the symposium, the film effectively wove scientific research with stories, imagery and Cultural Knowledge to highlight the importance of all ocean ecosystems, including those rarely seen in the deep ocean.

The film's strong focus on the importance of seamounts and the impacts of destructive fishing and harmful exploitation brought to life many of the findings and discussions shared over the previous two days. Not only did the event provide a fitting closure to the symposium, but it also provided a compelling example of the power of breathtaking cinematography and scientific research to demonstrate the importance of ocean conservation and regeneration.



Reflections on day two of the symposium by Dr Jodi Edwards

The Living Memory Beneath the Waves

Beneath the surface,
where the light fades
and the depths deepen,
lies a world not just teeming with life —
but holding deep memory.

The Lord Howe Marine Park,
its waters flowing between state and
Commonwealth boundaries,
is not just a sanctuary.
It is a kin-system.
A breathing entity.
A place where the world's most
southerly coral reefs
offer their colours like a gift.

These reefs —
along with Elizabeth and Middleton —
are not scattered features.
They are ceremonial peaks.
Perched upon the Lord Howe Seamount Chain —
those ancient underwater mountains that rise
from the ocean floor
like Elders returning to speak.

Each one — bursting with life,
yes —
but more than that:
bursting with story.

Here, marine life is not simply abundant.
It is relational.
It is sovereign.
It is unique because it belongs to this place,
and this place belongs to it.

The Galapagos Shark,
a familiar presence in these waters,
does not come to dominate.
He comes as a teacher.
A law-carrier.
Guiding the rhythms of the ocean's ancient dance
— a choreography older than human time.

Yet this delicate web,
woven over eons,
is fraying.

The lines we cast are not just fishing lines —
they are entanglements.
Interactions with fishing vessels have led
to shark bycatch and depredation.
This is not merely an economic problem.
It is a wound in the kinship fabric.
A cycle of loss and retaliation —
hurting fishers,
hurting sharks,
hurting relationship.

But Country always leaves a door open.

An ongoing program, born in 2018,
did not begin with control —
but with listening.
With respect.
It asked not just *what's happening?*
But *how can we heal this?*

Through acoustic telemetry,
vessel tracking,
social surveys —
we are gathering story, not just data.
We are learning to observe with humility,
to combine ways of knowing.

This isn't just research.
It is relational repair.
A ceremony of re-weaving.
Bridging human movement
with marine rhythm.
Bringing back the dance.

The Deep Sea: A Realm of Elders

Deeper still —
beyond where light gives up its name —
rests the Lord Howe Rise.

A vast Elder.
Spanning over 1.5 million square kilometres.
This is not a barren place.
This is an old place.
A storied place.

And though we may not yet know all her contours,
she knows us.



She remembers.

The Rise is home to
vulnerable marine ecosystems —
VMEs they are called —
but names cannot contain their meaning.

Cold-water corals.
Sponges.
Sea pens.
Each a living document.
A braided library of Earth's long memory.

They are not merely habitats.
They are places of law.
Places of ceremony.
They teach us that fragility
and strength
can coexist.

These ecosystems respond to harm.
They hold grief.
But when offered protection,
they regenerate.
Like stories told again
when the fire is right.

And now,
efforts are being made —
to map, to know,
to protect.

But beneath those words —
to honour.
To walk with these Elders in a good way.
To stop pretending we are above them.
To remember we are downstream of their wisdom.

Ecological Connectivity: Threads of Life

The ocean does not deal in separation.
It does not draw straight lines.
It weaves.

It is not a series of isolated pockets of life.
It is a breathing network.
A vast kin-system,
interlaced like bark and root,
current and wind.

Ecological connectivity
is not just a concept.
It is an echo of what Indigenous Knowledge
has always held true:
Everything is in relation.
Everything affects everything.

This connectivity
links not only locations and habitats —
but beings, movements, migrations,
ceremonies of spawning,
cycles of bloom and rest.

It is what sustains persistence,
what strengthens resilience,
what allows for recovery
when disturbance comes —
as it always does.

And finally,
this truth is being named
in international spaces —
in the Global Biodiversity Framework,
the BBNJ Agreement.

But naming is not enough.
We must walk it.
Not just as scientists,
but as relatives.
As people accountable
to the life around us.

Because in the ocean,
as on land —
knowledge is not a possession.
It is a relationship.
And relationships
must be nourished.

**The ocean is not beyond us —
it is within our kinship web.
We must govern with humility, not dominion.
Let law rise from relationship, not extraction.
BBNJ must mean: Beyond borders, we belong.**

Acknowledgements

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Thanks to the Australian National Maritime Museum for hosting the symposium and to all Museum staff and affiliates who supported the event. Thanks also to the DSCC team – Bronwen Golder, Victoria Riglen and Karli Thomas – for instigating the Lord Howe Rise mural and encouraging all of us to take a moment away from our screens and data to collaboratively create an iconic representation of this special place.

We are deeply grateful to Greenpeace for sharing imagery from their 2024 expedition to the Lord Howe Rise area, and to the talented photographers aboard that expedition who captured the wonder and beauty of this region, as featured in many of the photographs in this report.

To the team at Minderoo Pictures with whom we worked closely to link the symposium with the Australian premiere of 'Ocean with David Attenborough': many thanks for your collegiate approach and flexibility.

Finally, we thank all speakers, panellists, and attendees for their engagement and insights, which enriched the discussions and helped foster meaningful connections across disciplines. These efforts made the symposium a resounding success and a vital first step in the long-term preservation of this remarkable high seas region.



