NATIONAL MARINE SCIENCE COMMITTEE

National Marine Research Infrastructure: An Enabler for Australia's Sustainable Ocean Future

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Abstract

Australia's vast ocean territory faces rapid climate and coastal changes, impacting national prosperity, security, and well-being. Healthy, resilient and sustainably managed oceans are dependent on future-ready national research infrastructure to support oceanographic, weather, and climate forecasting and understanding of ecosystem changes. Research infrastructure underpins existing and emerging maritime industries, biodiversity conservation, climate adaptation, and coastal development. For example, 2025 National Marine Science Committee white papers reference “infrastructure” over 300 times, highlighting dependencies across science disciplines and topics.

Marine research infrastructure such as research vessels, observing systems, laboratories, collections, aquaria and marine stations and associated data systems are fundamental for research, fostering international collaborations, training marine STEM talent, and more. A national approach is critical to enable Australia’s marine science to scale up, to understand processes at ecosystem, national and regional scales.

Australia’s research infrastructure has been strengthened through deploying cutting-edge technologies and strategic, national-scale investment and coordination, although these have been time bound. Challenges remain, including geographic and thematic gaps, insufficient and disparate funding, inadequate human capacity, and limited cohesive coordination. These gaps undermine Australia’s sovereign capability, maritime security, economic progress and regional and global leadership.

Key research infrastructures need enhancement to meet current and growing needs including:

- integrating Indigenous peoples’ priorities, rights and aspirations into infrastructure planning and use.
- securing and scaling up research vessel (RV) funding to sustain operations for the RV *Investigator* and RSV *Nuyina,* and a modern national RV coastal fleet;
- maintaining and expanding the Integrated Marine Observing System to fill gaps including expansion into coastal regions;
- exploration of sovereign satellite capability for earth and ocean observation;
- deployment of advanced sensors and technologies for the most efficient collection of critical information;
- increased connection, coordination and governance among research stations, and biological and geological collections;
- developing the skilled workforce needed to operate and maintain infrastructure.

By viewing marine research infrastructure as a unified, strategic asset and providing it with steady support, Australia can enable the groundbreaking science and innovation required to achieve its ocean sustainability goals.

Relevance - Societal benefits

Australia is a marine nation, possessing the world's third-largest EEZ, a coastline exceeding 34,000 km, and most of its population living near the coast. The health and sustainable use of our oceans have direct implications for Australian communities, culture, industries, defence, recreation, and climate. The projected future growth of Australia's blue economy underscores the increasing importance and potential of our oceans in the coming decade. This growth, including transitions to offshore renewable energy and exploration for seabed resources, generates new challenges in a more crowded ocean.

Australia's draft SOP emphasises "Knowledge" as a key enabler for a healthy, resilient, and sustainably used ocean by 2040. The need for baseline data, knowledge sharing, and public understanding is highlighted in the SOP and promotes the importance of infrastructure programs. Marine research infrastructure is fundamental to generating the information needed to understand and sustainably manage our marine domain. Australia's vast and varied marine territory requires extensive and diverse infrastructure to support scientific domains from atmospheric and climate sciences to physical and biogeochemical oceanography, geosciences, biology, and ecology.

National-scale research infrastructure enables science to scale up, to understand processes at ecosystem, regional, and national scales. It also facilitates long-term monitoring and assessments that are critical to understanding environmental change in our oceans and atmosphere.

Societal benefits derived from marine research reliant on national research infrastructure are shown in Figure 1 and include:

- **Economic Prosperity:** Supporting sustainable growth in industries like fishing, aquaculture, biodiscovery, offshore energy, tourism, transport, and technology development. Supporting sustainable use, management, and security of our marine estate. Marine data and research inform planning, management, and risk mitigation for these sectors.
- **Driving Innovation:** Technology innovations, such as next generation observing systems, autonomous vehicles, and advanced sensor technologies, will rely on research infrastructure for testing and development. As these are adopted, they will enhance our ability to monitor and understand ocean processes and changes.
- **Environmental Stewardship:** Providing critical information to understand and monitor ocean state and health, address climate change impacts (e.g., acidification, heatwaves), conserve biodiversity, protect critical habitats (e.g., blue carbon ecosystems), and manage pollution and biosecurity risks. Infrastructure enables long-term monitoring and assessment of environmental change and the effectiveness of management actions.
- **Coastal Resilience and Security:** Understanding and predicting changes in coastal areas relevant to vessel access to ports, security of defence installations, city planning, safety of infrastructure, and implications for Indigenous communities. Oceanographic modelling and monitoring inform maritime industry and defence operations, and extreme event monitoring and response. Infrastructure provides the data basis for weather and climate forecasting.
- **Social and Cultural Benefits:** Catalysing collaboration between researchers, industry, citizen scientists, decision makers, and communities. Supporting Indigenous inclusion and partnership, recognising their unique connection to Sea Country and interweaving their knowledge with 'conventional' marine science and management. Attracting and training the next generation of marine STEM talent and broadening participation in research. Marine parks management supported by research infrastructure contributes to education, recreation, and human health.

- **Global Leadership and Collaboration:** Connecting Australia's research to global partnerships, supporting international commitments (like the UN Decade of Ocean Science and the High-Level Panel for a Sustainable Ocean Economy), and enabling regional and global scale research, particularly in the Southern Ocean and across climate systems and the Indo-Pacific.

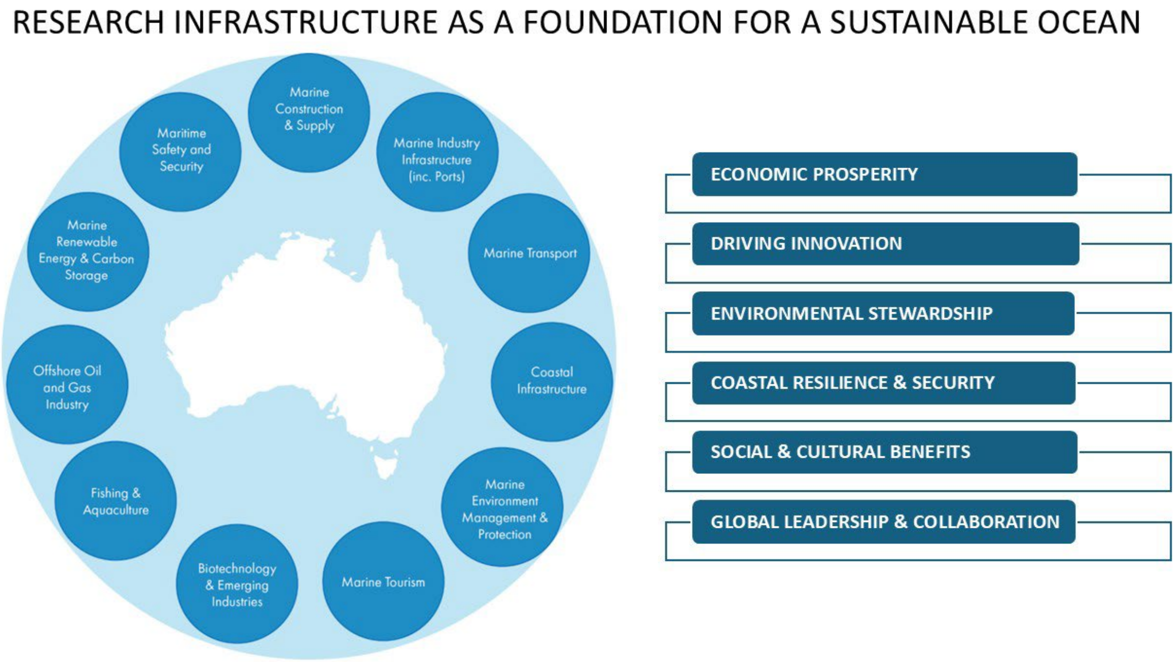

Figure 1. Applications and societal benefits of marine research infrastructure in Australia.

As part of the ocean observation value chain, digital infrastructure, such as e-Research platforms, is increasingly critical to process and analyse vast amounts of marine data. These platforms enable researchers to make sense of complex data sets, facilitating breakthroughs in understanding and stewardship. The role of digital infrastructure in enabling marine science is addressed in the "Data to Information" white paper.

Australia occupies a globally significant position in marine science due to its unique ecosystems and strong research capability. Other nations are rapidly upgrading their marine research infrastructure, and without similar strategic investment and uplift, future domestic capability gaps present risks to Australia's scientific leadership and ability to pursue its own research priorities. These gaps undermine Australia's sovereign capability, maritime security, economic progress, regional and global leadership, and more.

Table 1. Types of research infrastructure and their links to areas of national benefit where light blue indicates relevance and dark blue indicates critical dependencies.

	National Security/ Hazards	Energy Security	Food Security	Biodiversity	Climate Change	Urban coasts
Research Vessels						
• RV Investigator						
• RSV Nuyina						
• Nearshore/Shelf/coastal vessels						
Research stations/aquaria						
• National Sea Simulator						
• Other research aquaria						
• Tropical research stations						
• Antarctic stations						
Observing Systems						
• Integrated Marine Obs System						
• Earth Observations						
• Other (e.g. state)						
Biological Collections						
Geological/geophysical Collections						

Current state of marine research infrastructure and its development trajectory

Australia's marine science community is engaged in understanding, monitoring, and predicting the state of its vast and valuable ocean territory. This requires multidisciplinary research, including atmospheric and climate sciences, physical and biogeochemical oceanography, geosciences, biology, and ecology. The infrastructure underpinning this research encompasses physical facilities, research vessels, monitoring and sampling technology, biological and geological reference collections, research stations and marine aquaria facilities (Table 2) as well as intangible assets such as e-research, data collections, and software platforms. Research infrastructure is only made possible by the expertise of the teams that steward these facilities. The national research infrastructure considered here, operates at scales enabling use by multiple institutions and supporting collaborative national and international research.

The current state of Australia's national marine research infrastructure is considered relatively strong due to recent investments in research vessel capability, research stations, aquaria facilities, and major programs like the Integrated Marine Observing System (IMOS). The deployment of cutting-edge technologies (such as autonomous vehicles and advanced sensors) has also strengthened national research infrastructure. However, there are significant gaps and opportunities, particularly in maintaining future-ready national research infrastructure to underpin priority research through the next decade. The status of each is outlined below with more detailed summaries provided in topic area summaries in Appendix 1.

Table 2. Categories and examples of research infrastructure considered in the remainder of the paper.

Infrastructure categories	Sub-categories	Current assets
Vessels	Bluewater, Polar, Shelf scale (tropical, temperate)	RV Investigator RSV Nuyina Coastal Research Vessel Fleet Shelf-scale/nearshore vessels
Experimental facilities	Research aquaria, Research stations, Analytical facilities	Antarctic research stations Great Barrier Reef research stations

		National Sea Simulator (SeaSim)
Observing systems	*In situ*, Earth Observation from Space	Integrated Marine Observing System (IMOS) Earth Observing Systems Operational marine observing (Bureau of Meteorology, Royal Australian Navy, State/Territory, Geoscience Australia, Australian Maritime Safety Authority)
Biological collections	Living and preserved, and the associated metadata	Australian National Algae Culture Collection Australian National Fish Collection National/State/Territory Museum Collections (including DNA libraries) Biosecurity collections
Geological collections	Rock and sediment samples, cores, geophysical datasets (multibeam bathymetry, sub-bottom data, seismic data) and associated metadata	Geoscience Australia Australian Institute of Marine Science (AIMS) University collections State/territory collections

Research vessels

Australia's research vessel (RV) fleet enables research, and supports deployment of observation equipment, collection of underway data, and calibration of remote sensing. Current national RV capacity comprises two oceanic vessels (>80 m length) capable of offshore and deep-ocean science, four regional coastal RVs (20 – 45 m length) and several smaller nearshore RVs operated at the institution level.

The National Marine Science Plan 2015 – 2025 (NMSC Plan) recommended funding national RVs for full use, recognising these were critical to achieving science and impact goals. The current state reflects progress achieved during the life of the NMSC Plan, including:

- *RSV Nuyina* commencing service in 2021, Australia's sole ice-breaker, is a multipurpose resupply and research vessel with advanced modular science capabilities. Its primary logistics role is to support Australia's Antarctic stations with some science activities done underway (~ 60 days/year). It completed its first designated science voyage in early 2025. The Australian Antarctic Strategy and 20 Year Action Plan envision the use of *RSV Nuyina* as an observatory to enhance climate and weather predictions.
- *RV Investigator,* within the Marine National Facility (MNF) was funded to deliver 300 voyage days per year between 2018 to 2028 through National Collaborative Research Infrastructure Strategy (NCRIS) and CSIRO funding. In 2024, the *RV Investigator* celebrated 10 years' service, recognising 112 voyages with over 1,400 participants, from the Equator to the Antarctic ice shelf. Scientific capability upgrades are currently underway, supported by NCRIS funding and informed by a Technical and Innovation Advisory Group.
- The Coastal Research Vessel Fleet (CRVF) was established through partnership between the South Australian Research and Development Institute (SARDI) and Western Australian Department of Primary Industries and Regional Development, with NCRIS funding and support from the MNF. This fleet currently provides researchers with up to 50 fully funded sea days annually shared across *MRV Ngerin* in South Australia or the *RV Naturaliste, RV Djildjit, and RV Linnaeus* in Western Australia.

The overall number of available RVs, total science days at sea, and regional coverage have remained largely unchanged since 2014. The *RV Investigator* and *RSV Nuyina* represent substantially more science and research capability than previous oceanic vessels, however, maintaining access to their capabilities at 300 days and at least 60 days per year respectively, is not secured. Funding for the 300 science days on the *RV Investigator* is uncertain beyond 2027-28. Rising operational costs and fuel prices are key pressures likely to reduce research days at sea. There are also pressures for space on RVs, for example *RSV Nuyina* berths are prioritised for operational and infrastructure projects, which limits scientific capacity. The seasonally dependent nature of some Antarctic activities add to space and logistical challenges.

The CRVF creation was a significant positive step, although the recommendation in the previous NMSC Plan, for up to 50 funded operating days for marine science per region (northern, southern, western and eastern) has not yet been achieved. Access to coastal vessels outside of the CRVF remains dependent on institutional priorities, and institutional or project level funding, leading to limited transparency, potential duplication, logistical inefficiencies, and elevated operational costs. The coastal "fleet" does not yet operate as a coordinated system, with differing access arrangements, governance, processes, and management models across institutions. Underutilised capacity from voyage cancellations or transit legs exists, but due to the lack of coordination, reallocation of time is limited, meaning potential research time is lost. Individual institutions can adjust their RV schedules to respond to time-sensitive or event-based research, which is increasingly important, however it is unclear if this flexibility exists at a 'fleet' level to support wider community access, meaning potential broader scientific impact may lost. While there is an increased focus on coordination across operators, progress towards the establishment of a much-needed national coastal research fleet and associated coordinating committee will remain slow without resources to realise this.

Beyond the two oceanic vessels, Australia's shelf-scale capability is managed by various marine institutions, lacks cohesive national coordination and needs renewal as vessels age (e.g., *MRV Ngerin* – 40 years of age*; RV Cape Ferguson* – 25 years*; RV Solander* – 18 years*, RV Naturaliste* – 14 years, *RV Linnaeus* – 23 years). Planning for replacement vessels or new capabilities remains institutional, with RV replacement funding historically occurring through disparate opportunities. Replacement of aging shelf-scale RV capability is sporadic, with a recent announcement for the replacement of the *MRV Ngerin* welcome, however funding for an *RV Cape Ferguson* replacement is yet to be secured.

The capabilities of RVs vary, with the oceanic RVs having broad sensor suites, underway data collection, and ability to deploy autonomous and remote platforms. The *RV Investigator* is currently upgrading its scientific capabilities, with dedicated NCRIS funding (2025/26 and 2026/27). Only three RVs can conduct sampling operations in waters deeper than 1,000m, despite the vast deep-sea areas within Australia's marine estate. In contrast, many coastal RVs are minimally equipped, requiring extensive setup supported by individual projects or institutions. Equipping a national coastal RV fleet with a core suite of standardised, interoperable instrumentation would provide consistent data quality and improve efficiency of use. Enhancing vessel handling capabilities (A-frames, winches, cranes) for sophisticated equipment and deeper operations will also deliver a broader range of science. This should be complimented with appropriate skills and training for maintenance and use.

National observing systems

The national observing systems integrated through IMOS, and Earth Observation from Space (EOS), form another foundational infrastructure pillar. IMOS serves as a cornerstone, providing openly available, state-of-the-art, ocean measurements critical for Australian science, management, policy, and industry. IMOS delivers data for a significant number of Global Ocean Observing System Essential Ocean Variables (EOVs) and Global Climate Observing System Essential Climate Variables (ECVs). Since the 2014 NMSC assessment, IMOS has received additional support through NCRIS step-change funding and worked to expand observing capability. This includes expansion of existing operations to a national scale (e.g., expanded glider operations) as well as introduction of new capabilities (e.g., deep Argo, microplastics sampling). However, there is still a significant gap in coastal marine infrastructure which prompted IMOS to coordinate establishment of a national coastal research infrastructure (CoastRI) initiative request to NCRIS in 2025. If funded, this would be a significant advance in research infrastructure for the land-sea interface and address impending issues including coastal erosion and inundation.

Despite its essential role, IMOS has spatial and thematic gaps, limiting the ability to meet current and future priorities. Identified data gaps align with EOVs and ECVs, including subsurface data on carbon, nitrous oxide, and dissolved oxygen. Gaps also exist in data for ocean acidification, plastics and pollution, biodiversity, biogeochemical processes, and the emerging priority of ocean sound. Spatially, gaps noted in 2014 persist, particularly across northern Australia, the Great Australian Bight, around Tasmania, and in the Southern Ocean. Infrastructure and data are also lacking in coastal and deep ocean ecosystems. There is strong demand to broaden IMOS' spatial and thematic scope, including integrating coastal observations in nearshore environments where most users operate. In addition, continued support for innovation and integrating emerging technologies is necessary to future-proof IMOS. Expanded domestic sensor development and calibration capacity is needed to reduce dependency on international providers.

The development trajectory for IMOS focuses on addressing known gaps, ensuring sustainment of existing operations, and translating data into information to support and expand use of available data streams via IMOS' Australian Ocean Data Network (AODN). However, current funds allocated to IMOS are not keeping pace with increasing costs of infrastructure operation, and new capabilities can only be invested in if other capabilities are ceased. Long-term, sustained funding beyond the current NCRIS cycle (secured until 2027-28) with adequate consumer price index increases (CPI) is a key priority to enable strategic planning and infrastructure stability.

Earth Observation from Space (EOS) is globally mature, providing valuable data like sea surface temperature and topography with long time series. These observations require validation which is facilitated through *in situ* measurements from IMOS and RVs. Australia lacks an independent national satellite capability and is dependent on other nations for access to this infrastructure and associated data streams. Reliance on foreign satellite systems means Australia cannot directly control user relevance of EOS data. The development trajectory includes implementing the National Earth Observations from Space Infrastructure Plan (NEOS-IP) concerning ground networks, calibration/validation facilities, and storage/processing through facilities like the National Computational Infrastructure (NCI). There is also a need to invest in research to fully harness EOS potential, including data interpretation to increase use.

Research stations and aquarium facilities

Experimental facilities, including research stations and marine aquaria, are vital platforms, providing access to remote field sites, enabling long-term *in situ* research, and allowing controlled experiments. Many aquarium facilities are managed, resourced, and accessed at the institutional scale. Research stations are generally open for broader access, depending on how they are managed. Given the range of research stations and aquaria and their user base, the adequacy of the existing capacity and equipment is variable, with the outlook for the future suggesting more access and equipment are required. Key equipment is reportedly missing at some research stations.

Antarctic stations and the subantarctic station at Macquarie Island face constraints on their fundamental observational capacity and in hosting scientists. Most of the infrastructure on Australia's three Antarctic research stations dates from the 1980s and 1990s. The Australian Antarctic Division (AAD) is working on an Antarctic Infrastructure Renewal Program (AIRP) aimed to deliver the infrastructure, assets and technology needed to ensure operability, support the work of expeditioners and scientists, and work toward the government's Net Zero 2030 target. For Macquarie Island, the federal government committed $371m in 2024 over nine years to construct a new research station to continue to support year-round research and monitoring programs.

The AAD has been operating a krill aquarium at its headquarters in Kingston since 2002. The AAD in collaboration with the University of Tasmania have engaged in the construction of a new state of the art Southern Ocean research aquarium at Taroona with an investment of $36.7 m by the Department of

Climate Change, Energy, the Environment and Water (DCCEEW). This facility is expected to be completed by early 2028 and will interface with the containerised aquaria and research laboratories of the *RSV Nuyina*.

Other aquarium and research station facilities are predominantly in tropical areas and major population centres resulting in a lack of suitable stations in temperate and mid-latitude regions on both the east and west coast. This limits access and use and may bias our knowledge and understanding of ecosystems. There are significant opportunities for enhanced continuity and collaboration between stations to enable research to address large scale questions.

The National Sea Simulator (SeaSim), at the Australian Institute of Marine Science (AIMS), is a world-class facility that enables researchers to simulate, quantify and predict the effect of multiple pressures on marine and coastal ecosystems. SeaSim celebrated 10 years of operations in 2023, supporting over 1,320 researchers across more than 300 experiments involving over 70 collaborating and funding partners. In 2021, a significant expansion of the research aquarium's capacity was supported through NCRIS, including support for merit-based access as a 'National Facility'. In early 2025, this major expansion was opened, nearly doubling the amount of experimental space.

There is currently no centralised database across research stations and aquaria that would facilitate greater coordination, transparency, and resource utilisation. Differences in funding models, support, and management approaches across facilities present a challenge to knowledge sharing and collaboration. An integrated approach, using large-scale and long-term experiments across different locations with standardised protocols, could build a national view on key science questions, rather than local knowledge. This network of nationally co-ordinated aquarium facilities should be supported by consistent and coordinated processes for access, prioritisation, and resource allocation to ensure effective alignment of proposed research with experimental capabilities, and match user demand with facility capacity.

The current development trajectory for these facilities appears to be driven by individual institutions and opportunistic funding, except perhaps for the Antarctic and subantarctic research stations and SeaSim. Current improvements to coordination and collaboration rely on individual institutions and could benefit from greater integration.

Biological and geological reference collections

Biological reference collections underpin Australia's understanding of marine species and systems. They provide certainty in identification of species, which underpins biodiversity assessments. They also provide a record of species changes through time and space. Currently, key biological collections for marine species are maintained by state and territory museums and the CSIRO, the Australian National Fish Collection, and the Australian Algal Culture Collection (a living collection). The backbone of collections remains the physical specimens, envisioned to expand to include DNA reference material. Increasing use of new technologies, including -omics, digitisation,and AI/ML is generating new information from physical specimens, although these initiatives have largely been supported by short-term funding.

In terms of secure, national reference collections there are taxonomic gaps for plankton, micro-benthic taxa and viruses – important parts of marine biodiversity and abundance. There are spatial gaps, with limited representation from the outer shelf and deep ocean. In comparison to collections of terrestrial organisms there is less sampling through time, limiting temporal comparisons.

Reductions in resourcing have resulted in reduced investment in physical infrastructure, staffing, and ability for digitisation and application of new technologies. Although there have been some exceptions, such as recent refurbishment of the Australian National Fish Collection. Critically there is a backlog of unprocessed specimens requiring funding for accession and taxonomic research. Resourcing is needed to incentivise private organisations or small collections to share/accession specimens, which would reduce the need to establish project or institutional level collections.

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The current trajectory for resourcing and reliance on short-term funding is not sufficient to establish new collections, expand use of new technologies, or address the backlog. The Australian collections community have articulated key transformations to realise a nationally distributed collection, involving sectoral leadership, collection digitisation storage and management, digital infrastructure, data access and integration, emerging technologies, and workforce development. This initiative should be supported to expand the contribution of marine biological collections to future science.

Geological collections play a crucial role in advancing Australia's understanding of marine systems providing essential information on the character, composition, and geological history of the seabed and sub-seabed. These collections underpin research into marine resources, the history and evolution of continents, past climates, boundary determination, and broader environmental and economic applications.

Currently, key geological collections for marine data and samples—including rocks, cores, sediments, and seismic sections—are maintained by Geoscience Australia, some state/territory surveys, the AIMS, and some universities. These collections serve as valuable repositories of both existing and newly acquired geological information about Australia's oceans. Emerging technologies and advanced analytical techniques offer much potential to extract new insights from these legacy collections, at a fraction of the cost of collecting new samples.

Geoscience Australia's Repository is the custodian of nationally significant collections of data and physical samples, which are vital for industry, government, academic, and community stakeholders. This includes geological samples, data, and seabed imagery acquired through decades of marine surveys funded through programs such as the National Environmental Science Program and its predecessors. Data and samples from significant government supported research programs are required to be retained as national archives.

Cross-cutting issues

Several cross-cutting issues apply to all types of research infrastructure, including funding limitations. There is a common recognition that benefits could be derived from greater coordination and integration to share resources, streamline access, and encourage collaboration. The delivery of science-ready research infrastructure also relies on a skilled workforce. Workforce development has not kept pace with technological transformation. Postgraduate training often lacks cross-disciplinary training and technical skills development. The Collaborative Australian Postgraduate Sea-Training Alliance Network (CAPSTAN) model, which provides development opportunities for undergraduates on the *RV Investigator*, could contribute to structured pathways for infrastructure operational and technical roles. Rising operational costs outpacing research income could lead to the loss of highly skilled staff, further reducing capability.

Indigenous community priorities

Respect for Indigenous rights, and interweaving knowledge, capabilities, and aspirations into conventional marine science is increasingly recognised as essential. Australia's National Science and Research Priorities include elevating Aboriginal and Torres Strait Islander knowledge systems and the process to develop the draft SOP explicitly included Indigenous perspectives and leadership. There is an increasing need to include Indigenous perspectives - central to this will be ensuring Indigenous peoples and communities are authentically involved in decision making, are resourced to engage and have their priorities addressed. The future direction of two-way knowledge sharing and interweaving of knowledge systems is articulated in the Indigenous Science blak paper.

National marine research infrastructure needs to evolve to include priorities and participation of Indigenous peoples. Examples of how research expectations are being established can be seen in the AIMS Indigenous Partnerships Plan and the NESP Marine and Coastal Hub's Indigenous Partnerships Strategy. The MNF offers Indigenous Time at Sea Scholarships that provide opportunities for Indigenous STEM undergraduates to participate in voyages and has committed to develop a science on Sea Country framework. The IMOS Sea Country Initiative is working to establish linkages, collaborate, and co-design with Indigenous communities to deliver ocean and coastal observations on Sea Country.

Infrastructure and capability needs

Research vessels

Australia's RV capability could be described as constrained when considering the scale of Australia's scientific, environmental, and sovereign tasks. There is a lack of blue-water RVs (45-80m length) and the coastline is served by sparse distribution of aging medium-sized coastal RVs. This distribution may result in research being focused where coastal RVs are available rather than where needs are greatest. The limited number of research days available restricts the ability to conduct the sustained, long-term and broad-scale data collection needed for national priorities like seabed mapping, baselines for industries such as offshore renewable energy, climate monitoring, and ecosystem assessment.

There are a range of needs related to RVs spanning replacement, enhanced capability, additional vessels and alternative solutions to data collection. These include:

- Planning for the phased replacement of ageing RVs, expected to reach end-of-life within the next decade. Securing funding for replacement is a critical priority.
- Ensuring funding for full year operations for the *RV Investigator* to meet scientific demand
- A comprehensive assessment of national demand for additional coastal and medium-range RVs, as well as considering alternative platforms like autonomous or remotely operated vehicles (AUVs, USVs, ROVs) or partnerships with commercial/industry vessels to meet user demand.
- Expanding RV access through a national scheme supporting dedicated, contestable sea days across all regions (e.g., 50 days per year in each of the four marine regions).
- Enhancing Australia's polar research capability, possibly through increased international collaboration and taking advantage of the UN Ocean Decade endorsed programme Antarctica InSync, extending *RSV Nuyina*'s operational science days, or acquiring a second polar RV if justified by demand and strategic value, especially ahead of the International Polar Year 2032–2033.
- Establishing a National RV Strategy and Planning Committee to guide fleet design and expansion, aligning with emerging science priorities and technological capabilities. Ideally this group would establish and maintain a publicly accessible National Fleet registry/information portal to enhance transparency, collaboration, and allow reallocation of unused capacity. Streamlining administrative processes and implementing a transparent, merit-based sea-time allocation system are also part of the trajectory to improve access and coordination.

Future RVs should be designed with modular, flexible systems for rapid mobilisation and multidisciplinary science. Equipping national RVs with a core suite of standardised, interoperable capabilities and instrumentation for consistent data quality and utility would be a major improvement. Expanding the capability to deploy advanced autonomous and remote platforms across the fleet would increase flexibility and efficiency. For example, there is a need for RVs to be equipped with full-ocean-depth capabilities, including ROVs. Seafloor mapping tools need upgrades to match international benchmarks. Underway data collection capabilities on RVs need strengthening to avoid missed opportunities and support satellite calibration. Fully equipping RVs is critical because many coastal RVs are minimally equipped, requiring extensive setup to meet user needs.

In terms of sustainable RV operations, the International Research Ship Operators (IRSO) are moving towards greener fuel options to cut carbon emissions, aligning with the International Maritime Organisation's (IMO) net-zero target by 2050. Australia can lead in adopting sustainable RV operations influenced by international trends. While zero-emission RVs are not yet feasible for long-range voyages and remote operations, national planning could speed up the creation of next-generation, low-emission replacements inspired by greener-fuel RVs emerging from the UK and US.

Observing systems

Despite areas of strength, significant gaps remain in our fundamental understanding of marine ecosystems and processes and there is a critical need to better understand cumulative impacts. These needs must be underpinned by observing infrastructure which can identify the state and trends of our ecosystems to help inform decision-making for sustainable use, conservation or intervention. The vast size of the Australian marine estate provides an additional challenge since scaling-up of applied research on ocean ecosystems and ecosystem services is needed to fill key knowledge gaps and advance innovation for the ocean economy.

While IMOS operates at a national scale and from the open ocean to the coast, it is not adequately resourced to cover all observing needs. There are ongoing gaps in both key variables that should be measured and geographic regions or habitats which remain under-observed. There is a lack of adequate baseline and current-state data on key ocean issues and systems. A range of variables lack adequate measurement including subsurface data on carbon, nitrous oxide, and dissolved oxygen; parameters critical for understanding ocean acidification and informing marine carbon dioxide removal approaches. Biogeochemical parameters, particularly subsurface nutrient and chemical observations, remain sparse, limiting the ability to understand nutrient cycling, understand harmful algal blooms, and improve models. Ocean sound is an emerging priority and cross-disciplinary variable that is understudied and lacking infrastructure for systematic monitoring, which is increasingly recognised as essential for assessing ecosystem health and understanding anthropogenic impacts. Enhanced biological data on species distribution, abundance, and condition are also needed for ecosystem assessments.

Data gaps are compounded by significant spatial and ecosystem-based gaps in infrastructure, many of which were identified in 2014 and have not been filled due to resource limitations. Regions that are particularly under-observed include northern Australia, the Great Australian Bight, around Tasmania, and the Southern Ocean. Under-observation in northern Australia hinders Sea Country management and the improvement of ocean and climate models. Expanded monitoring in southern Australia is needed to establish ecological baselines for emerging offshore renewable energy industries. Given the Southern Ocean's importance in understanding climate change, additional infrastructure there is increasingly important. Beyond specific regions, infrastructure and data are lacking in both coastal and deep ocean ecosystems. The national coastal research infrastructure (CoastRI) initiative would help fill this gap, but funding has not been secured. Observing infrastructure planning and resourcing needs to be sustained, expanded and delivered at scales relevant to decision-making and aligned with the pace of CPI and costs.

There are also gaps in specific technologies and capabilities required for modern marine science. Autonomous vehicles are largely bespoke and unaffordable for broad-scale use. There is a critical need to better explore the deep marine estate, requiring investment in more autonomous technologies and tools, including Autonomous Underwater Vehicles, Unmanned Surface Vehicles, and Remotely Operated Vehicles. Currently, only a few RVs can operate beyond 1,000m, despite deep-sea areas accounting for over 70% of Australia's Exclusive Economic Zone (EEZ). Seafloor mapping tools need upgrading to match international benchmarks on some RVs. Only approximately 38% of Australia's seafloor is mapped in sufficient detail for sustainable resource management. Standardised, cost-effective estuarine and marine habitat mapping using remote sensing is needed to support decision-making. Investing in technologies to enhance RVs' underway data collection capabilities would fill data gaps and better support calibration and validation of satellite observations. In short, additional infrastructure is needed to improve understanding of ocean ecosystems, the seabed, and underwater cultural heritage.

Earth Observation from Space is dependent on global partnerships because Australia lacks an independent national satellite capability. Reliance on foreign satellite systems means Australia cannot directly control user relevance of EOS data. In addition, increased investment in research, data interpretation and data processing including use of AI and ML is needed to reduce the risks of data oversimplification and analyse complex datasets. A constellation of earth observation satellites is needed to better monitor coastal and ocean dynamics, including the use of near-infrared imagery from geostationary satellites and could be a future investment area. Consideration of the role Australia wants to play in the satellite observing community is needed.

Research stations and aquaria

Access to experimental facilities and research stations is often hindered by availability and affordability. Space at facilities like SeaSim can be difficult to cost-effectively access, sometimes requiring specific institutional affiliations, although this should change in 2025 as the SeaSim moves to merit-based, funded access as a National Facility. Access to Antarctic stations is difficult for any researcher and requires project affiliation within the Australian Antarctic Division portfolio of projects. In addition, the distribution of marine research stations and facilities is dominated by tropical or major population locations, with a notable lack of stations in temperate and mid-latitude regions. Greater national-scale coordination is needed to maximise access, use and efficacy of existing capabilities.

Establishing a centralised database is a key future need to improve coordination and resource utilisation across research stations and aquaria facilities. Adopting integrated large-scale and long-term experiments among locations using standardised protocols could build a national view rather than local/regional knowledge. Ensuring facilities are appropriately resourced is necessary so that the financial burden is not placed solely on host organisations. Strategic location of infrastructure based on habitats or environmental conditions for cost-effectiveness is also a consideration. Increased coordination and streamlined access processes would improve alignment of research with experimental capabilities and match user demand with facility capacity, and supporting an agreed suite of standardised, interoperable instrumentation could increase collaboration and comparative research outputs and impact. As with RVs, a shared pool of instruments or equipment could be highly beneficial and reduce duplication.

Biological and geological reference collections

Biological and geological reference collections, while foundational, face challenges including reduced resourcing, insufficient space, and a lack of skilled staff, leading to a backlog of unprocessed specimens and hampering access. Biological collections vary in the extent to which they are digitised, and advanced technologies, such as -omics, have been applied to them. There is a need to enhance biological collections with -omic information (e.g., reference DNA libraries) to support modern techniques like environmental DNA (eDNA) analysis. The unlocking of new information from physical specimens across new domains is encapsulated in the ‘digital extended specimen’ concept, will create new research opportunities and value from collections. Increased digitisation of reference collections enhances biodiversity and geophysical information which can be made available through portals such as the Atlas of Living Australia (ALA) and the Global Biodiversity Information Facility.

Sufficient, long-term resourcing is required to strategically establish new collections, expand digitisation and the use of new technologies and address the backlog. There is also potential to integrate lab-based collections with museums and other facilities to increase access and use. These issues are relevant to biological and geological collections which both need support to improve access and be future-ready to support research.

Overarching issues

Human capacity and skills gaps

Research infrastructure requires skilled people to operate and maintain it. Valuing and retaining skilled technical staff is a priority, and filling capability gaps in skills and expertise is needed. Shortages in trained vessel crew, marine technicians, shore operators, taxonomists, data scientists, laboratory and support technicians and others must be addressed to ensure sustainability of research infrastructure.

Training programs also face limitations. An assessment of postgraduate training recommended establishing communication and extension activities to implement necessary changes. Expanding training programs, potentially using the CAPSTAN model (which trains students on *RV Investigator* voyages), could create formal, structured pathways for operational and technical roles. Developing national/regional training networks, facilitating knowledge exchange and staff mobility, and building a professional pipeline through well-defined career paths are necessary steps. Stable and sustained investment in staffing is seen as essential to attract and retain maritime professionals. Supporting employment transition pathways and re-skilling affected industries will also be necessary as the ocean economy changes.

Coordination and integration

Collaboration and coordination across the marine science community and with stakeholders are essential, yet fragmentation, duplication, competition, and a lack of cohesive voices remain barriers. Lack of coordination and collaboration impedes the ability to work at scales suitable for the complex issues marine researchers and decision-makers are facing. Streamlining administrative processes could improve collaboration in RVs, research stations, and aquarium facilities.

Industry engagement continues to be vital given the significant growth forecast for Australia's Blue Economy. Marine research infrastructure and data are needed to inform sustainable management, defence, industry operations, and decision-making. While connections are strengthening (e.g., IMOS links with industry), limited industry partnerships remain a barrier.

Future directions must include the integration of diverse knowledge systems, the knowledge, rights, capabilities, and aspirations of Indigenous people. While recognition is growing, the marine science community is still grappling with how best to integrate Indigenous values, rights and interests in Sea Country into the scientific process. Integrating Indigenous priorities and participation in access to and use of research infrastructure can help bridge this gap. However, this requires sufficient planning, resourcing and capacity to ensure Indigenous people can actively and effectively engage.

Catalysing collaboration between researchers and others, including industry, Indigenous voices, citizen scientists, decision-makers, and communities, should be a key goal. A culture change is needed to reduce anxiety and competition and encourage sharing and collaboration. Limited cross-sector meetings exacerbate duplication and siloing and the lack of a cohesive community voice is likely to limit the ability to secure substantial marine infrastructure investments.

Funding and resource barriers

Underpinning many of the gaps and barriers is insufficient funding. The number of offshore and coastal RVs and research days is inadequate due to lack of resources. IMOS is not funded at a high enough level to deliver at the scale of Australia's EEZ. Many gaps identified in 2014 have not been filled due to a lack of resources. The increasing cost of operations is outpacing research income, potentially leading to scaling back of infrastructure and loss of skilled staff if funding is not increased. Estimates in 2014 suggested infrastructure investment exceeding $3bn over the decade to 2025 was required just to implement critical requirements. These costs will only increase over the next decade as increasing rates of environmental change and greater demands for marine data to support industry development and government decision-making.

Funding security is a major issue. NCRIS funding for IMOS, MNF, CRVF and SeaSim is on a five-year cycle, while longer-term funding is needed for effective strategic planning and infrastructure stability. Funding for Antarctic and *RSV Nuyina* operations are on even shorter time scales. Funding timeframes for research infrastructure need to match the timeframes required for effective management and whole of life cycle planning (e.g., 10 or more years). A persistent challenge is the slow pace of replacement for ageing infrastructure. The rate of cost inflation and speed of technological advancement further reduce the ability to update equipment. More full life cycle thinking and forward planning are needed to inform scheduling and investment for upgrades to, or replacement of, existing infrastructure to avoid gaps and data loss. This includes timely planning for the replacement of major infrastructure such as RVs and observing infrastructure through to consideration of alternative technologies or approaches.

Conclusion

Overall, Australia's marine science infrastructure has a strong foundation built on key national facilities and programs like the MNF and IMOS. However, there is a complex web of knowledge gaps and barriers in Australian marine science, stemming from insufficient, unsustained and disparate funding, fragmented infrastructure and data management, inadequate human capacity and training pathways, and a lack of cohesive coordination and integration across the diverse stakeholders. Addressing these issues requires strategic investment, improved coordination, cultural shifts towards greater collaboration and inclusivity, and the development and adoption of new technologies and approaches to data management and knowledge translation. Successfully implementing these changes will require rising above institutional and disciplinary perspectives to support national facilities and prioritising investments to maximise success in a competitive funding environment.

Progress/Impact measurement

Sustaining and expanding marine research infrastructure is critical to meeting the needs of a range of end-users. Marine science enabled by research infrastructure delivers critical data for stakeholders across various sectors, such as:

- **Operational Use:** IMOS data directly informs weather and climate forecasting, oceanographic modelling for maritime industry and defence operations, and extreme event monitoring and response. Operational forecasting systems are direct outputs.
- **Resource Management:** Ecosystem and species monitoring data from IMOS, RVs and others support resource management decisions, including in Indigenous Protected Areas and Sea Country. Environmental DNA (eDNA) and other biological collections data underpin our understanding of species distributions. Research using these infrastructures underpin fishery harvest strategies, ensuring sustainable practices. *RV Investigator* voyages have led to seafloor mapping and species discovery. Experimental facilities support research on ecosystem responses and climate impacts.
- **Policy and Planning:** Marine data and research inform planning processes for coastal development, security, and conservation. Assessments like IMOS's State and Trends report and Australia's State of the Environment reports strengthen understanding for decision-makers. Integrated ecosystem assessments are being explored to support resource allocation and decision-making.
- **Capacity Building**: Programs like CAPSTAN train multidisciplinary marine scientists on RVs, preparing them for careers in industry and government. The Indigenous Time at Sea Scholarship supports Indigenous students.

Progress in marine science relies on marine research infrastructure as evidenced by over 300 mentions across all other NMSC white papers. The success of these infrastructure investments is evident in extensive research outputs, national and international collaborations and contributions to global initiatives. The value of marine infrastructure has also been directly demonstrated through a return on investment analysis which provided conservative estimates indicating IMOS is expected to yield a net present value to the Australian community of $8.3 bn over fifty years, generating $4.70 of benefit for every $1 of investment.

Capability could be further enhanced through co-design processes with end-users to ensure relevance, improving connectivity and communication across sectors, establishing clear pathways for science outputs to inform policy and industry operations, and developing user-friendly data platforms and tools.

Explicitly tracking the use of marine data in models and forecasts can help identify gaps and maximise value. Promoting a culture of collaboration and sharing also facilitates adoption.

Impact on society and science is currently measured through publications, operational outputs, reports, and stakeholder engagement. Measurement could be improved by explicitly tracking the uptake of science in policy and industry decision-making. Developing better metrics for societal and economic return on infrastructure investment beyond traditional academic outputs is needed. Integrating social, cultural, and economic data with environmental data in assessments (e.g., integrated ecosystem assessment, ocean accounts) can provide a more holistic measure of impact.

Dependencies and priorities

Realising the vision for Australia's marine science over the next decade, and enabling the science needed to align with national priorities, is dependent on strategically addressing key infrastructure and capability requirements.

Major Innovations and Technologies for Acceleration/Upscaling:

Secure and Scale Up RV Funding: Sustain *RV Investigator* operations at full year operations beyond 2028, *RSV Nuyina* dedicated science operations at 60 days/year and maximising its scientific underway capability, and fund a modern, national coastal RV fleet within the next decade. Why: Essential for sustained observations, surveys, and access across Australia's vast marine estate, supporting national priorities and reversing current declines in operational capacity.

Secure and Scale Up IMOS Funding: Sustain and expand IMOS beyond 2028, including increases to meet growing operating costs, expansion to cover spatial and data gaps for key variables. Why: Provides foundational long-term data series critical for understanding climate change, ocean state, and ecosystem health and informing industry, policy and other decision-making.

Establish Coordination Mechanisms: Implement national coordination frameworks for RVs, stations/aquaria, and data management. Why: Reduces fragmentation, duplication, improves access, utilisation, and allows for strategic investment.

Establish Integrated Coastal Infrastructure: Create a nationally coordinated coastal capability (e.g. CoastRI). Why: Climate change impacts will be primarily experienced at the coast where most Australians live. Data on coastal conditions and coastline change are needed to inform planning, risk mitigation, and decision-making.

Next-Generation Sensors: Widespread deployment of advanced sensors for critical parameters (carbon, nutrients, sound, biology) and enhanced mapping tools (multibeam sonars, coring) on RVs and observing networks. Why: To improve climate models and fill significant knowledge gaps.

Integrate Indigenous knowledge: Develop a nationally coordinated approach to integrate Indigenous peoples, Traditional knowledge, rights, capability, and aspirations. Why: Provides the best knowledge base for management, enhances research impact, and supports culturally endorsed activities and frameworks.

Specialised Training: Programs developing technical and operational skills for marine infrastructure and in the analysis and visualisation of the data derived from the systems require expansion and formalisation. Why: Fills staffing and skills gaps to help support infrastructure and research activities.

Improve Connectivity and Communication: Connectivity and communication can be improved through establishing cross-sectoral forums, developing centralised portals/registries for infrastructure and data visibility, co-designing research programs with stakeholders, developing national guidelines and standards, and investing in science communication and translation mechanisms. Why: A more connected research community will increase productivity, efficacy and impact.

Quantum of Investment Required

NATIONAL MARINE SCIENCE COMMITTEE

The 2014 white paper estimated over $3bn investment over the decade to 2025 was required to meet critical requirements. Given rising costs, technological advancements, and the need to address persistent and emerging gaps, a similar or likely greater quantum of investment, potentially in the range of several billion dollars over the next decade, will be required for major items and innovations such as:

- Sustained, long-term operational funding, replacement and expansion of key national facilities (RVs, IMOS).
- Investing in new sensor technologies and autonomous systems including retrofitting existing assets.
- Investment in coordination capability for RVs, research stations and aquaria.
- Investment in specialist and technical skills development training.
- Establishment of cross-sector meetings and other fora to increase coordination and collaboration.

Prioritising these investments must align with the national priorities outlined in documents like the SOP (Climate Action, First Nations, Protect and Restore, Industry), Australia's National Science and Research Priorities, and the grand challenges identified in previous plans (marine sovereignty/security, energy/food security, biodiversity, urban coasts, climate change). A strategic approach focusing on building integrated capability, not just individual assets, is essential.

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