NATIONAL MARINE SCIENCE COMMITTEE

# National Marine Science Plan

# Urban Coastal Environments Theme

# White Paper

## Abstract

Australia is an urbanized and a coastal nation with over 80 per cent of its population living within 50 km of the coast. Our coastal urban environments provide economic wealth and are the location for most of our transport, commercial, residential and defence infrastructure. They also fulfil important cultural, recreational and aesthetic needs, have intrinsic biological diversity values and provide essential ecosystem functions such as primary productivity, nutrient cycling and water filtration. Australia is in a period of pronounced economic development with a focus on resource extraction and infrastructure development, much of it centred on coastal hubs. The great challenge for coastal managers and policy makers is to balance multiple competing uses, and the impacts of those uses. Ten key science challenges are identified. Strategic coastal research, both applied and basic, is essential to underpin the repair and ongoing management of these high value ecosystems for improved productivity and enhanced cultural and conservation values.

## Background

Australia is truly a coastal nation with more than 80 per cent of Australians living within 50 km of the coast; in the capital cities that abut the coast, and increasingly in coastal towns and hamlets.

Looking forward, as human populations grow and commercial use and transport of natural resources via sea expands; our social, economic and ecological dependence on urban coastal environments can only increase. Ensuring that opportunities are realised and needs are met in an environmentally, economically and socially sustainable manner must be underpinned by short and long-term strategic, basic and applied, research that supports wise decision-making.

The purpose of this Urban Coastal White Paper is to articulate science priorities that relate to urbanised and developing coastal areas, drawing upon the following sub-theme papers: contaminants (Apte et al., 2014); biosecurity and non-indigenous species (Piola et al., 2014); climate impacts (Bishop et al., 2014); recreational fishing (Grifiths et al., 2014); indigenous research (Bayliss et al., 2014) and green engineering of coastal infrastructure (Dafforn et al., 2014), as well as a number of institutional submissions to the broader planning process, and shorter issue-specific papers on dredging (Jones, 2014) and microbial ecology (McDougald et al., 2014). We also make reference to other thematic white papers that consider the coastal environment: infrastructure (Turner et al., 2014); estuaries (Creighton et al., 2014); Marine Protected Areas (Kenchington et al., 2014); ecosystem health (Gillanders et al., 2014); physical modelling (Oke et al., 2014), and marine security and safety (Schiller et al., 2014).

Coastal research necessarily encompasses a broad range of biophysical and socio-economic disciplines and is carried out by scientists and engineers employed by universities, museums, federal agencies such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO) , the Australian Institute of Marine Science (AIMS), Geoscience Australia (GA), the Defence Science and Technology Organisation (DSTO), and the Bureau of Meteorology (BoM), as well as state and territory environment, fisheries, planning and climate agencies. Corporatized agencies and consulting companies, ranging from large multi-nationals to small single person entities, also provide a range of expertise, particularly for water quality management, infrastructure developments and their associated environmental approvals processes.

A number of major institutions maintain dedicated coastal research units /departments that can vary in size from less than 5 persons, and focused usually on a specific aspect of coastal research (e.g. geomorphology, contaminants), to more than 100 persons, as is the case with the multidisciplinary research undertaken by publically funded research agencies such as CSIRO, AIMS, The Australian Nuclear Science and Technology Organisation (ANSTO) and GA, to University based consortia such as the Sydney Institute of Marine Science (SIMS) and Western Australian Marine Science Institution (WAMSI).

Aboriginal Australians have lived in the coastal zone, using and managing coastal resources, for tens of thousands of years. Current indigenous-oriented coastal research is generally undertaken in partnerships between research institutions and Indigenous people, although independent research is also conducted by regional land councils and indigenous agencies.

Research on recreational fisheries has generally been conducted by State and Territory fisheries research agencies, although CSIRO and Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) become involved in some cases.

While it is difficult to estimate the total number of urban and coastal scientists, it would certainly be greater than 2,000 professionals. Professional societies such as the Australian Marine Science Association (membership ~ 1,000), the Australian Coral Reef Society (membership ~ 300), the Australian Society for Fisheries Biology (membership ~ 550) and the Society for Environmental Toxicology and Chemistry, Australia (membership ~ 300) are effective mechanisms for networking these diverse communities. Such groups are also advocates for science-based approaches to solving coastal issues; often producing evidence based consensus statements, such as those related to water quality, invasive pests, marine parks and dredging.

While these numbers indicate a significant commitment to coastal research in Australia, there are also significant challenges in carrying out the research necessary to manage and understand our critical coastal systems. For example, specific disciplinary areas have waxed and waned in response to largely issue-driven funding, and there is declining support for some key fundamental or enabling disciplines. This includes taxonomy: an area in which our capacity has diminished Australia-wide, despite the fact that new endemic benthic and pelagic species continue to be discovered every year. Similarly, there has been an attrition of once world-class expertise in marine biosecurity through a lack of resources and cohesive strategic direction. This leaves Australia vulnerable to increased incursions by non-native species as shipping activity increases. In other areas, Australian research is world-leading, notably in the areas of contaminant research, coral reef and tropical research, spatial planning and multiple-use research, sea level rise and coastal extremes and climate adaptation. It is important that this advantage is not lost due to a decline in research and development funding.

Other than ARC funding there are relatively few opportunities for fundamental research in urban coastal environments (e.g. CRCs). In the main, research programs such as environmental (e.g. NERP/ NESP), climate (NCCARF) and infrastructure (e.g. NCRIS) programs have provided funding for applied research to address specific coastal issues. More recently, funding for research through the levying of environmental offsets on some industrial developments has been used to address specific issues, such as the dredging research node coordinated by WAMSI. Additionally, as industries adopt a stronger environmental stewardship role, their philanthropic funding of coastal research has increased. A number of NGOs and charitable foundations now actively seek and direct funding from this source.

Nevertheless this mix of funding is piecemeal; often program specific, short-term, fragmented and duplicated. Internationally, funding for coastal research appears to be on a more secure footing, notably in Asia and the European Union. There, the importance of fundamental and applied urban coastal research is recognised as being critical to providing societal benefits, as well as increased regional trade.

## Relevance

With a continental coastline of ~ 36,000 km that spans 35° of latitude, Australia's coastal biodiversity and habitats are shaped by a wide range of climates, prevailing wave and tidal regimes from three surrounding oceans and the varied geological history of the continent. From World Heritage-listed coral reefs around northern Australia, to temperate rocky and sandy shores in the south, these coastal environments include more than 900 estuaries, 10,000 sandy beaches and 8,000 diverse islands within its maritime borders (Short and Woodroffe, 2009). Australia's coast has been shaped by severe events such as cyclones and floods, and climate change is now increasing the frequency and intensity of these hazards.

Many parts of Australia's coastline, particularly those in urbanised areas, but also remote areas in northern Australia, are undergoing rapid industrial and/or residential development and are under threat from competing demands for the services derived from our coastal assets. Rapid and continuing coastal population growth and urbanization, catchment degradation, loss of coastal foreshore amenity, environmental impacts from industry, incompatible or unsustainable resource use, and climate change are some of the challenges that can result in conflict and where marine and coastal research plays an important role in supporting wise decisions. The sustainable management of Australia's coastal domain will therefore need to address the full range of economic, social, cultural and environmental values through enduring partnerships with key stakeholders including government, industry and community.

All tiers of Government and industry, be they coastal infrastructure or resource developers, manufacturing, transport or utilities, have a legislated role in decisions related to coastal development and approvals processes at scales that range from individual developments to regional and strategic planning, and consideration of matters of national significance (e.g. World Heritage issues on the Great Barrier Reef). In addition, the social-license for government and industry to operate derives from the community and is only gained by the transparent application of rigorous science. The research required therefore spans the provision of regional inventories and baselines, the development of appropriate thresholds for concern, identification of threatened and endangered species, to the consideration of cumulative impacts and multiple uses that allow for complex trade-offs and the effective use of environmental offsets.

Operationally, many industries must meet compliance objectives that include meeting criteria for environmental conditions and the development and implementation of mitigation strategies for catchments, and industrial contaminants released into coastal waters. These organisations require research that develops rapid and accurate diagnostic tools, establishes regionally specific water and sediment quality guidelines and enables accurate and efficient decision making in relation to marine off-sets. Emerging coastal industries including aquaculture, biofuels and marine renewables require research that enables them to move from the laboratory to the field and from pilot to operational. Local government and industry, and the insurance industry, require research that identifies ways to reduce the risks of extreme weather events and allows us to be better prepared.

Shipping accounts for 90 per cent of global commercial trade and is increasing by ~ 10 per cent per year; opening new trade routes and increasing the transport of species between continents. The prevention, detection and mitigation of marine pests (including marine diseases) requires research of benefit to industry (e.g. shipping and ports) and government, usually state agencies. There is a renewed interest in effectively addressing biosecurity issues, while the broader consideration of biofouling must continue to develop more effective methods that also minimize the consequences of such fouling to coastal infrastructure.

Recreational fishing is a significant subsistence, sporting and social activity that is undertaken primarily within the coastal zone by an estimated 3.36 million Australians. Although recreational fishers are an extractive resource user group with the potential to cause ecological impacts in the coastal zone, the activity also has social and economic benefits for Australian society. Given that recreational fisheries straddle the interface of fisheries, social and economic sciences, our understanding of the benefits and trade-offs of recreational fisheries operating in the coastal zone are currently in their infancy. Significant research is required across these three disciplines to better understand and manage the complex elements of recreational fisheries.

Aboriginal and Torres Strait Islanders are major stakeholders in the management and protection of Australia's natural and cultural coastal resources. Traditional Owners have cultural and legal rights, and responsibilities, to sustainably use and manage their extensive land and sea country. They have deep ongoing connections to both land and sea and recognize them as inseparable. This world-view requires research approaches and policy and management solutions that encompass indigenous perspectives, values, knowledge and aspirations from the outset.

Table 1 summarises the basis for why these stakeholder-groups need coastal science and the topics they need addressing. These needs are a complex mix of legislative requirements, geography and scale, community perception and technology development.

There is also very tangible evidence that many of end-user groups are now very strongly and publically articulating their research requirements, for example:

- The major priorities identified by the National Seachange Task Force (2014) are: (1) population pressures, (2) natural disaster resilience, (3) coordinated national approach to natural disasters and (4) legal risks associated with coastal planning.
- A 20 year long-term plan for Australian ecosystem management identifies 6 priority areas for action: enhancing relationships between scientists and end-users, supporting long-term research; enabling ecosystem surveillance; making the most of data resources; empowering the public with knowledge and opportunities, and facilitating coordination, collaboration and leadership (ESLTP Steering Committee 2014).

- The Great Barrier Reef Marine Park Authority (GBRMPA) has a science strategy and information needs document (GBRMPA 2014) and is currently develop a long-term research management plan that identifies coastal water quality and development, biodiversity and indigenous issues as priorities for research.
- Federal environmental (e.g. The National Environmental Research Program, NERP) and research infrastructure (National Collaborative Research Infrastructure Strategy, NCRIS) initiatives are demanding that funded research is framed by strong end-user need and engagement. Recent initiatives such as the National Environment Science Plan (NESP) require strong indigenous engagement and capacity building.
- The Fisheries Research and Development Corporation (FRDC) Indigenous Fisheries Reference Group (IFRG) identified key research, development and education priorities for indigenous participation in fishing and aquaculture in Australia, as part of a strategic and planned approach (FRDC 2012).
- The North Australian Indigenous Land and Sea Management Alliance (NAILSMA) identify two overarching priorities: (1) alignment of Indigenous aspirations for a healthy sea country with Australian Government regional and national marine conservation objectives and planning processes, and (2) development of an "Indigenous Sea Country Management Framework" as a strategic way forward (NAILSMA 2012).
- Most state governments have been through, or are currently conducting, coastal research prioritisation planning and their reports and documentation are available on environmental, planning and fisheries department websites associated with each state.

## Science needs

### *Science challenges*

To address the coastal stakeholder needs identified in the previous section requires the marine science community to draw upon the breadth of its disciplinary and institutional capabilities to meet the following ten overarching challenges:

1. *Better characterise coastal habitats, environment processes and define envelopes of natural variability*. Better understanding of 'when', 'where' and 'how rapidly' changes have occurred on the coast provides insight as to the natural envelope of variability and 'why' change may be occurring. This information is essential for informing decisions around natural resource management, and the development of effective mitigation and adaptation strategies. To do so requires the further development of sub-tidal mapping and monitoring methods, physical and biological observations technologies that resolve the often ephemeral events that characterise coastal environments, and sentinel and diagnostic methods that enable us to better explore, understand and monitor our coastal estate.
2. *Understand catchment contaminant pathways and define thresholds of concern.* Coasts are intimately connected to their adjacent catchment and vulnerable to activities that occur within them. Understanding impact pathways for current and emerging contaminants of concern, developing indicators of ecosystem health and defining system specific thresholds are essential to ensuring the functional and biotic integrity of coastal ecosystems.
3. *Address cumulative impacts and identify important stressor interactions*. Urban and coastal ecosystems are subject to multiple stressors simultaneously. The vast majority of applied and basic marine science has focused on individual stressors in isolation, ignoring the potential for additive, synergistic or antagonistic impacts. This impedes our ability to predict and manage urban coastal environments. A greater focus on stressor interactions and multiple use management is urgently required.
4. *Develop bio-observing technologies.* The increasing availability of high temporal-spatial resolution remotely sensed physico-chemical data has improved our ability to forecast and map these parameters. Such information streams have not been matched by the provision of biological data that might enable assessments of ecosystem state or trajectory. The rapid development of tools for molecular, visual and acoustic surveys of biotic habitats provides the opportunity to develop much needed national bio-observing systems. These systems should incorporate measures of biological diversity and ecosystem functioning.
5. *Understanding connectivity and resource use.* Understanding the impacts of the continual degradation and

loss of coastal and estuarine habitats, including consideration of the loss of productivity and ecosystem services, is required. As particular habitats are lost or altered, populations of animals and plants become fragmented and their population viability may be threatened. The disruption of physical processes can also undermine ecosystem structure. For example, sediment supply and dynamics are fundamental to coastal habitat formation and maintenance, and the first line of defence for urban infrastructure.

6. *Incorporate quantitative and qualitative social and cultural perspectives into coastal decision-making*: There is an increasing awareness that social and ecological systems are integrally connected and research agendas that bridge the gap between the biophysical and social sciences are required if we are to gain long-term economic, social and cultural benefits while population and development pressures continue on our coasts. Without further research on the networks and dynamics of socio-ecological systems, much existing and future biophysical research will remain under-utilised.
7. *Develop, test and apply eco-engineering approaches.* In considering how to either protect and repair coastal systems there is a need to apply eco-engineering (or green engineering) approaches to address issues such as coastal re-nourishment, dune stabilization, re-establishing submerged aquatic habitat, reinstating environmental flows within estuaries, infrastructure design and habitat restoration that encourages recolonisation by endemic species.
8. *Develop methods to mitigate coastal hazards*. From a human and infrastructure perspective coastal hazards are numerous and diverse, and all need development of better prevention, monitoring, forecasting and management responses. For example threats from shipping spills, sea level rise and extreme weather events, invasive species, harmful algal blooms, and jellyfish all require a nationally coordinated coastal knowledge program that is delivered effectively to all stakeholders.
9. *Improve data coordination and discoverability.* Better national coordination and access to data – most recently in the House of Representatives enquiry *Managing our coastal zone in a change climate* (HORSCCWEA, 2009) – is required to ensure the efficient provision of coastal information services including planning for sustainable coastal development managing resource use and threatened species and planning for extreme events. The challenge is to provide federated and customised views of disparate and multi-modal data holdings via open-access web services underpinned by standards, provenance and visualisation.
10. *Support the development of urban/coastal industries.* The Australian economy is heavily reliant on urban/coastal activities, including a substantial export trade by sea and thriving local and international tourism and recreation industries. The efficient and sustainable development of these industries requires technological advances for coastal construction and natural resource extraction and the development of ecosystem monitoring tools that enable relevant and reliable assessments, trusted by both industry and community stakeholders. The current government's *Industry Innovation and Competitiveness Agenda* requires better translation of research into commercial outcomes (Australian Government, 2014) which in the case of marine research may include renewable energies, aquaculture, biotechnology and defence.

### *Approach*

To meet these challenges the following multi-tiered strategy is required:

(i) Undertake fundamental research to underpin risk analysis and identify threats.

(ii) Develop research capacity that is capable of rapid response to immediate threats as they arise.

(iii) Develop research strategies for monitoring stressors and impacts and for the development of pro-active approaches to new technologies and approaches to mitigation.

(iv) Develop and implement long-term strategic research to anticipate future and emerging threats.

To effectively meet these needs over short- and long-term frames our science will need to:

1. Use risk-based approaches that incorporate multiple lines of evidence within transparent frameworks.
2. Integrate across the catchment-coast continuum and make spatially explicit the connectedness of coastal habitats.
3. Incorporate socioecological and economic research, including indigenous perspectives, into knowledge

creation and decision-making.

4. Develop predictive capability that informs event detection, provision of information to assist disaster, to prepare readiness and response to extreme events, or to explore scenarios particularly those relating to the evaluation of management levers.
5. Support long-term coastal research sites, both in developing and near-pristine environments. This will lead to the identification of quantitative relationships between physical and biological processes and their response to anthropogenic stressors and can represent processes within models.
6. Transform current monitoring practices to move from narrow single purpose, single agency programs to regional collectives that amalgamate a range of publically available biological and physical observational data that can be used, scaled and customised by multiple parties, and used to better calibrate and validate a range of models.
7. Identify solutions that include the use of scenarios to identify best mix of management interventions, and the testing and application of innovative eco-engineering approaches.
8. Work with marine and coastal industries to develop technologies or provide information that can be commercialised or used in day-to day operations or strategic planning.
9. Develop capability to provide access to better information, including near real-time data processing and forecasting, that facilitates anticipatory and responsive decision-making, guidelines, and community networks.
10. Develop multi-disciplinary research teams and effective partnerships with industry, researchers and government.

### *Key outcomes and benefits*

1. Stronger alignment with national policies for sustainable development, biodiversity conservation, the national innovation and competitiveness agenda, and Indigenous aspirations for equity and livelihoods.
2. Accurate maps of coastal estate including biological diversity and ecosystem function maps to assist in regional planning.
3. Improved management of key coastal natural and cultural assets in response to increasing development pressures, particularly in the north.
4. Identification of trade-offs and better prioritization and decision-making regarding the use and development of coastal resources.
5. More efficient, relevant and reliable monitoring and assessment that provides effective reporting, as well as fore sighting of trends.
6. Better preparedness and resilience to natural disasters and extreme weather events.

## Perspective

### *Specific science priorities for the next 5, 10 and 20 years*

The specific science priorities for urban and coastal environments for the next 5, 10 and 20 years as identified in sub-theme papers on contaminants (Apte et al., 2014), biosecurity and non-indigenous species (Piola et al., 2014), climate impacts (Bishop et al., 2014), recreational fishing (Griffiths et al., 2014), indigenous research (Bayliss et al., 2014) and green engineering of coastal infrastructure (Dafforn et al., 2014), are summarised in Table 2. While this paper has addressed some key research needs of indigenous coastal communities, further consultation is crucial with respect to this stakeholder group and is specified in the priorities. Recreational fishing interests also require further attention, and socio-economic research issues generally are only superficially addressed in this paper, as well as other NMSP themes, suggesting additional effort in this regard is required

Furthermore, when so much of urban coastal research is issue-driven it is hard to foresee the importance of basic research over longer timeframes. However, there is a clear need for both strategic and curiosity-driven long-term research programs if we are to ensure both a future for the coast and an innovation-based future.

With continuing rapid urbanisation and development, the need to make sound management decisions about Australia's coastal estate has never been greater. There is now a sense of urgency as decisions as to where to

develop and what to conserve are often being made in the absence of reliable information. As a result, many urban/coastal science priorities over the next 5 years are focused on addressing these issues, in particular the need to develop, test and apply:

1. Mapping methods (e.g. multi-beam, LiDAR, earth observation (e.g. the Landsat datacube) and autonomous vehicles that provide for rapid and comprehensive spatial mapping of terrestrial and aquatic coastal habitats (including species distributions) and the acquisition of detailed nearshore bathymetry that is required for navigation and to underpin the development of models used to support coastal decision-making.
2. Methods that better assess cumulative impacts of developments such as those occurring in the Gladstone region or along the Pilbara and Kimberley coast.
3. Develop whole-of-region and nested high-resolution integrated hydrodynamic, biogeochemical and ecological 'catchment to coast' models that can be readily applied to assess specific coastal scenarios including cumulative impacts, multiple use options, regional connectivity.
4. Analytical and ecotoxicological methods to measure and assess the environmental exposure, fate and impacts of new contaminants (microplastics, antibiotics, endocrine-disrupting chemicals and others).
5. Improved methods for rapid detection of invasive marine species – including, molecular probes, para-taxonomic tools and the application of remote surveillance and inspection technologies to assess extent of vessel biofouling.
6. Improved understanding of the role of microbial communities in controlling rates of turnover of material flux and the potential to initiate and/ or regulate biological events including spawning, disease and die-offs.
7. Methods that can be applied for restoration of estuarine and coastal habitats (e.g. effective seagrass, mangrove and macroalgae replanting and bivalve-bed restoration).
8. Eco-engineering approaches that can be applied to coastal infrastructure development such as harbours (e.g. artificial reefs and walls, contouring of dredged benthic habitats, effective beach renourishment and coastal defence from extreme events).
9. Develop empirical and process–based methods that can be used to forecast environmental and climate conditions and identify particular coastal hazards (e.g. coastal flooding and storm surges, king tides, harmful algal blooms, contaminant release) that assist operational decision-making by government and industry.
10. Nationally and internationally compatible approaches to better data and information management to allow enhanced discovery of data products and services.
11. Incorporate indigenous perspectives, into strategic basic and applied knowledge creation.
12. Concepts, models, and processes to record, recognise and incorporate customary indigenous knowledge and management techniques into coastal resource management.
13. Consistent protocols and monitoring & evaluation frameworks for the ongoing understanding of the biophysical, economic, social and cultural value and aspirations of indigenous coastal resource use, and associated risks to/pressures on those values.
14. Long-term monitoring of the dynamics of recreational fisheries, including catch, effort, participation, social wellbeing and economic contribution, at regional, state and national levels.
15. Better understand the social and economic costs and benefits of coastal recreational fishing including improved survey designs and development of registries and portals that allow a better assessment of who recreational fishers are, how they behave, what the cost/benefits are including economic flows, and changing use and access to recreational fishing areas.
16. Omics methods – ecogenomics, transcriptomics – to better assess coastal issues as broad as measuring biodiversity of sediment infauna, microbial functional processes, marine invasive species detection and oil spill remediation.
17. New remote sensing technologies (e.g. VIIRs, Sentinel, GOCI) that will provide higher spatial and temporal resolution synoptic data the can be used to measure water column parameters (e.g. chlorophyll, TSS, SST) benthic habitat and bathymetry and coastal vegetation. Australia must play an

important role in the calibration and validation of these sensors and the development of new products such as phytoplankton functional groups and primary productivity products.

18. Methods to quantify and value the importance of carbon sequestration in Australian coastal ecosystems (e.g. mangroves, seagrass, saltmarsh), evaluate the significance coastal acidification in vulnerable parts of Australia (e.g. GBR) and develop and evaluate carbon capture and storage technologies that could be applied in coastal systems (e.g. Gippsland).

By 2020 much of the above research will still need to continue but will increasingly be tested and applied operationally into guidelines, observing systems, information systems models and infrastructure, including:

1. Developing a comprehensive database on contaminant distributions in marine systems (that include baseline contaminant concentrations in Australian estuaries and coastal waters).
2. Developing a comprehensive database of biological diversity distributions that includes type specimens for invertebrate macro-fauna that are linked to molecular barcode sequences to enable broad scale, and rapid biomonitoring programs and assessments.
3. Fundamental ecotoxicological and ecological studies that will underpin the next generation of water quality guidelines (due mid 2020s) and guidelines for dredging and operation of infrastructure.
4. Integrating mixture toxicity, hormesis and bioavailability (incorporating site-specific physicochemical properties) into ecological risk assessment methods.
5. More comprehensive application of risk-based approaches that take into account multiple stressors to address issues including contaminants, disease, over-fishing, marine pest incursions and climate change and climate extremes, and also consider the sociological factors impacting the uptake of risk mitigation strategies by stakeholders.
6. Assess implementation of models for valuing indigenous catchment management and coastal and marine ecosystem service provision.
7. Assess and adapt mechanisms for deriving indigenous benefits from sustainable development and the mitigation of negative development impacts.
8. Development of coastal and estuarine observatories/designation of demonstration sites that foster trans-disciplinary research.
9. Establishing climate-resilient infrastructure based on eco-engineering approaches.
10. Capacity for monitoring and enforcement of biofouling and ballast water regulations that reduce the risk of marine pest incursion.
11. Guidelines for foreshore development that incorporate ecological functions into the built environment.
12. Best practice port development and expansion guidelines.

By 2035 the Australian population is predicted to have grown to nearly 34 million with Perth and Brisbane to have over 3 million residents each and Sydney to have over 7 million (http://stat.abs.gov.au/). Continued development of northern Australia, increased shipping and ports infrastructure to meet greater global trade, and predicted increases in climate extremes will only magnify the issues facing our coasts. Science-based solutions are needed to:

- Map, monitor and understand Australia's dynamic estuarine and coastal ecosystems.
- Blue economy and eco-engineering approaches and also indigenous perspectives to protect coastal services.
- Develop forecasting capability and infrastructure to mitigate and recover from natural and anthropogenic coastal hazards including storms, storm surge, flooding and erosion.

### *Why Australia needs to do this work and how we link to international efforts in coastal research*

Our coastal environment is unique in many respects. Australia is an old, weathered continent with high levels of biodiversity and endemism. As a consequence, many areas of overseas research are not directly applicable to the Australian situation. The diversity of coastal systems in Australia, reflected in the diversity of habitats (e.g. coastal lagoons, coral reefs, estuaries, salt marshes, mangroves), means that science for our coasts needs to be flexible

and tailored to suite the issues and needs at hand. These immediate tactical needs, however, should not detract from the long-term strategic need to undertake basic research on under-studied habitats.

However, many of the issues faced by our coastal estate, and our management of it, are also being confronted around the world, particularly continued population growth and urbanisation of coastal areas, cumulative impacts from multiple users (i.e. fisheries, aquaculture, shipping, tourism, oil/gas exploration), and vulnerability to sea level rise and climate extremes.

Australian marine science needs to work closely with other international research partners through collaborative initiatives to effectively address these issues. In the Indo-Pacific region, Australia must continue to play a strong leadership role through the application of its science capability to:

- Develop and coordinate sustained coastal observing technologies and information systems that can be used throughout the region.
- Provide ongoing support for calibration and validation of satellite sensors in the southern hemisphere.
- Develop risk-based and decision support tools for multiple use management.
- Conduct tropical coastal biology, ecology and ecotoxicology.
- Apply coastal forecast and warning systems and technologies.
- Provide training and other capability training opportunities to developing nations and small island nations.

## Realisation

### *Infrastructure*

Long term support for physical and chemical observations and modelling will be required to meet increased monitoring and surveillance of Australia's urban and coastal environments, specifically:

- Ongoing commitment to sustained observations spanning a network of regionally representative coastline and estuarine reference stations throughout Australia, including water quality, biodiversity, ecosystem functioning, bioinvasion, habitat quality, shoreline and nearshore bathymetry.
- Designation and resourcing of several long-term estuarine and coastal research sites that integrate research across the coastal continuum, from microbes to macrofauna, to develop a more complete understanding of coastal ecosystem processes, connectivity, feedbacks and capacity for change.
- Implement surveillance monitoring of estuarine and coastal assets, by ensuring access to existing archives of current satellite data and develop new methods and products to take advantage of the generation, high-resolution polar orbiting geostationary and airborne sensors.
- Support experimental - both laboratory and field based – infrastructure around Australia such as: AIMS SeaSim aquarium, SIMS, and university research stations.
- Harness NCRIS computer infrastructure to develop a coordinated public-access coastal knowledge hub.
- Develop infrastructure to access real-time data-streams to underpin emergency preparedness.
- Coastal vessels are required to complement the recent investment in large oceanographic vessels (i.e., R.V. Investigator).

### *Training and capacity building*

- University training needs to be improved, particularly in the areas of ecotoxicology, risk assessment, modelling and environmental genomics. It is noted that the parallel growth of environmental bioinformatics as a discipline will be necessary to realise significant advances.
- Training in interdisciplinary research methods should be a high priority.
- Maintain or re-build national research expertise in marine contaminants analysis, ecotoxicology, taxonomy, sedimentology, biogeochemistry, oceanography and ecology.

- Develop methods and support training for non-scientists (local government, NRM groups, and Indigenous rangers) to assist in the collection of data and the maintenance of monitoring equipment.

### *Funding*

- Coordinate funding on coastal-zone issues, focussing on sustainable ecosystem management that enhances collaboration across university and government institutional boundaries.
- Fund initiatives that favour interdisciplinary and cross-disciplinary team approaches.
- Develop formal programs/initiatives to promote international collaboration on marine contaminant risk assessments (including the thousands of new chemicals registered for use by industry and agriculture each year) and to enable the setting of regionally specific guidelines.
- Develop a more directed and strategic use of offset funding to test coastal innovations that may have wider practical application to dealing with particular coastal issues. For example, *Building With Nature Australia* (www.bwnaus.org), was recently established to bring together scientists, engineers governments and industry to undertake case studies to test potential innovations in ports and industrial waterways (e.g. Cockburn sound), and urbanised seaways (e.g. Sunshine Coast). Another example is the recently launched World Harbour Project (http://sims.org.au/research/long-term-projects/world-harbour-project/), an international collaboration initiated by SIMS that brings together researchers from major ports around the world to share knowledge and test designs for best practice and management of harbour environments. The concept of a clearinghouse that makes publically available this information including best practice guideline is critical to this collaboration.
- While there is clearly a need for the provision of science in the design, methodology development and assessment of monitoring programs, discretionary research funds should not be used to support ongoing operational monitoring.

### *Coordination and collaboration*

- Provide a forum for identifying integrated strategic marine management and for setting spatial management priorities across multiple sectors.
- Developing eco-engineering solutions will require much closer collaboration between scientists and engineers, plus the funding and a commitment to scientifically test a range of bold innovations of sufficient scale. Where successful, this knowledge should be shared to understand how these innovations could be applied in other settings.
- Establish a National Marine Pest Science Network to provide high-level scientific and technical advice to support policy and program development around national marine biosecurity and marine pest science. This Network would also provide strategic direction (encompassing research, development, extension and monitoring) to committees and funding bodies such as the Marine Pest Sectoral Committee (MPSC), National Biosecurity Committee (NBC), AGMIN, FRDC and others as required.
- Establish multidisciplinary research initiatives across universities and institutions to allow research on the impacts of environmental change on marine ecosystems and the economic consequences with more direct links to policy.

### *Information access, knowledge transfer and adoption*

- Build upon and support NCRIS investments in data and computational infrastructure such as the TERN Australian Coastal Ecosystem Facility (www.acef.org.au), the IMOS AODN (http://portal.aodn.org.au/) to provide better access to coastal data. Further, use coastal issues as a focus for drawing capability from other facilities such as ANDs, ALA, AURIN and AUSCOPE to demonstrate the benefits of collaborative infrastructure to address national priorities.
- Targeted investment in coastal databases, including existing databases such as the National Exposure Database (NEXIS); National Elevation Data Framework portal (NEDF) and the National Foundation Spatial Data Framework (NFSDF), as well as new databases, including a national registry of recreational fishers and a portal on recreational fisheries,

- Nurture the ongoing development of nationally and internationally consistent open data standards, vocabularies, provenance, as well as the discovery of data services and adoption of modern web frameworks and methodologies (e.g. for visualisation). This will help to improve access to fundamental data which are used by scientists to better understand key coastal features and processes.
- Educate government, industry and communities to make better use of coastal information services in decision-making.
- Translate coastal research to best-practice and 'how to' guidance on coastal issues such as dredging, coastal modelling, water and sediment quality standards, restoration methodologies, coastal and eco-engineering and emergency preparedness. Make this information available through a clearinghouse of coastal information and encourage adoption by regulator and environmental consulting and analysis sectors to improve the quality, consistency and efficacy of environmental approval processes.
- Facilitate regular workshops to inform regulators and industry of coastal knowledge advancements, and exchange programs between research providers and coastal environmental and infrastructure managers to improve our understanding of knowledge needs and to strengthen science capability within these management and operating agencies.

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## References


Australian Government, (2014). *Boosting the commercial returns from research*. Discussion paper. http://education.gov.au/news/discussion-paper-boosting-commercial-returns-research-released

ANZLIC (2014). *The Australian and New Zealand Foundation Spatial Data Framework: Making common foundation data ubiquitous across Australia and New Zealand*. Edition 2. ANZLIC - the Spatial Information Council, Canberra. http://www.anzlic.gov.au/__data/assets/pdf_file/0017/47321/FSDF_Booklet_edition_2_web.pdf

Ecosystem Science Long term Plan Committee, E. S. (2014*). Foundations for the future: A long-term plan for Australian ecosystem science*.

FRDC (2012). *Indigenous Research, Development and Extension (RD&E). Priorities for Fishing and Aquaculture* - endorsed at the Cairns Forum 2012 - November 2012. Fisheries Research Development Corporation. http://frdc.com.au/knowledge/publications/fish/Pages/21-1_articles/Indigenous-research-priorities-endorsed.aspx

DCCEE (2009). *Developing a national coastal agenda*. Department of Climate Change and Energy Efficiency.

GBRMPA (2014). *Great Barrier Reef Marine Park Authority Science Strategy and Information Needs* 2014-2019. Townsville, Great Barrier Reef Marine Park Authority.

House of Representatives Standing Committee on Climate Change, Environment and the Arts (2009). *Managing our coastal zone in a changing climate: The time to act is now*, Commonwealth of Australia.

OPSAG (2013). Marine Nation 2025: Marine Science to Support Australia's Blue Economy. Oceans Policy Science Advisory Group.

NAILSMA (2012). *North Australia Indigenous Land and Sea Management Alliance. National Indigenous Sea Country Workshop*. Mary River, Darwin Northern Territory 8 –10 May 2012.

National Seachange TaskForce, (2014). *Current Australian Coastal Issues. Summary of recommendations by the National Sea Change Taskforce in relation to national issues facing Australia's coastal communities*. 9 pp.

Short A.D. and Woodroffe C.D. (2009). *The Coast of Australia*. Cambridge University Press. 288 pages.

State of the Environment Committee (2011). *Australia State of the Environment 201*1. Independent report to the Australian Government Minister for Sustainability. Department of Environment, Water, Population and Communities, Canberra.

Stocker L, Kenchington R, Kennedy D and Steven A (2012a). *Introduction to Australian coasts and human influences*. In, R. Kenchington, L. Stocker, D. Wood (Eds.), Sustainable Coastal Management and Climate Adaptation: Lessons from Regional Australia. CSIRO Publishing, Collingwood, Victoria (2012), pp. 1–27.

***NMSP Theme and White papers:***

Apte, S.C. et al. (2014). *Coastal contamination*. Urban coastal environments white paper. National Marine Science Plan.

Bayliss, P., and Barber (2014). *Indigenous Coastal Knowledge & Research Priorities*. Urban coastal environments white paper. National Marine Science Plan.

Bishop et al. (2014). *Climate change impacts and adaptation in the urban coastal environment.* Urban coastal environments white paper. National Marine Science Plan.

Creighton et al. (2014), *Australia's estuaries, embayments and nearshore marine environments*. Biodiversity Conservation and Ecosystem Health white paper. National Marine Science Plan.

Dafforn, K., et al. (2014). *Green engineering and marine urban development*. Urban coastal environments white paper. National Marine Science Plan.

Gillanders, B., et al.(2014) *Ecosystem health*. Biodiversity Conservation and Ecosystem Health white paper. National Marine Science Plan.

Griffiths, S. (2014) *Recreational Fisheries in Australia*. Urban coastal environments white paper. National Marine Science Plan.

Jones, R. (2014). Dredging impacts. Urban coastal environments white paper. National Marine Science Plan.

Kenchington, R., et al. (2014) *Marine Protected Areas*. Biodiversity Conservation and Ecosystem Health white paper. National Marine Science Plan

Oke et al. (2014) *Coastal and Shelf Oceanography in Australia.* Dealing with changing climate white pape. National Marine Science Plan.

Piola, R. et al, (2014). *Biosecurity and Marine Pests in Coastal Waters*. Urban coastal environments white paper. National Marine Science Plan.

Schiller et al. (2014). *Sovereignty, security, natural hazards* Theme white paper. National Marine Science Plan.

Turner et al. (2014), Establishment of a National Coastline Observatory Facility. Infrastructure white paper. National Marine Science Plan.

## Tables

**Table 1: End users and their coastal research needs**

| Coastal End-user | Research Required to: | Research Into: |
|---|---|---|
| *Federal Government:*<br>Dept. of Environment<br>NOPSEMA<br>DRET<br>Dept. of Agriculture<br>DPM&C<br>AIATSIS | Meet legislative requirements for (1) assessment of developments under EPBC act, (2) Strategic environmental assessments and (3) meeting obligations under international treaties and commitments and (4) national & international obligations under Native -Title and other Indigenous legislation/policies<br>Inform and improve the National System for the Prevention and Management of Marine Pest Incursions (the National System).<br>Underpin the revision of water and sediment quality guidelines | Threatened species and processes.<br>Cumulative impacts.<br>Thresholds and guidelines.<br>Resource assessment surveys Improved NIS monitoring methods and programs.<br>Marine pest management and eradication strategies.<br>Pre-emptive identification and management of future 'next pests'.<br>Cultural values & Indigenous resource use.<br>Improved ecosystem monitoring methods.<br>Organism responses to contaminants. |
| *State & Territory Governments:*<br>Natural resource<br>Primary Industries<br>State and Regional Development<br>Environment Protection | Planning, development approvals including Sacred Site authorities<br>Provide region-specific assessment of NIS/marine risks and areas of impacts.<br>Provide a coordinated implementation of The National System in alignment with other state/territory jurisdictions.<br>Provide knowledge on specific environmental problems in order to aid decision making. | Assessment and prioritisation of environments at risk to NIS/marine pests.<br>Improved NIS monitoring methods and programs.<br>Impact assessment on cultural values/sacred sites.<br>Risk assessment of systems subject to multiple stressors. |
| *Local Governments and Councils*: | Inform development approvals, planning. | Impacts of sea level rise and extreme events. |
| *Industry:*<br>Oil & Gas<br>Mining<br>Renewable Energy<br>Manufacturing<br>Ocean Renewables<br>Utilities | Development approvals, compliance monitoring, social license to operate.<br>Assessment and understanding of impacts of NIS/marine pests.<br>Ongoing operational problems (e.g. water quality, spillages etc.).<br>Develop technologies. | Understanding of impacts of marine pests on ecosystem health and functioning.<br>Risk assessment of impacts of NIS/marine pests on marine industries and operations.<br>Co-management of renewable resources (e.g. fisheries).<br>Ecosystem response to contaminants, recovery and resilience.<br>Hydrodynamics. |
| *Ports and Shipping:* | Meet legislative and ongoing operational requirements including development and maintenance activities.<br>Improved understanding of ports as hubs of NIS arrivals and spread and management strategies to address this.<br>Understand the impacts of oil spills, antifoulants, increased shipping traffic and other environmental stressors. | Operational data.<br>Dredging science.<br>monitoring of marine invasive species<br>Improved port design and operation for the control of NIS establishment and spread.<br>Understanding of internal borders for managing the dispersal and establishment of marine pests.<br>Ecosystem response to contaminants, recovery and resilience. |
| Insurance Industry | Prediction of the effects of climate change and sea level rise on coastal communities. | |
| *Community:*<br>Conservation groups<br>Recreational fishers<br>Schools<br>Primary Industry | Improved port design and operation for the control of NIS establishment and spread.<br>Understanding of internal borders for managing the dispersal and establishment of marine pests. | Foster the development of 'citizen science' to fill some information gaps that are otherwise difficult to cover, and help engage and educate communities.<br>Identify community and sectoral attitudes, |

| Coastal End-user | Research Required to: | Research Into: |
|---|---|---|
| agencies (e.g. farmer commercial fisher, aquaculture)<br>Catchment/NRM groups<br>Coastal resident associations | Meet community and sectoral information needs regarding marine resource use, urbanisation effects, climate change adaptation, etc.<br>Development of long term sustainable regional plans which balance the needs to community and industry. | information needs, and priorities regarding national coastal and marine research. |
| *Indigenous interests:*<br>Land councils<br>NRM agencies and ranger groups<br>Traditional owners<br>Coastal residents | Land Rights and Native Title holders. | Inventory of cultural values/resource use, strategic regional assessment frameworks that integrates indigenous ecological knowledge.<br>Non-statutory:<br>As above but in partnership with land Councils & local Aboriginal land/sea management groups, research providers, all levels of government, NGOs and other stakeholders. |

Table 2: Specific science priorities for the next 5, 10 and 20 years for coastal research

| Priorities | 5 years | 10 years | 20 years |
|---|---|---|---|
| *Contaminants* | Development of analytical and ecotoxicological methods to measure and assess the environmental exposure, fate and impacts of new contaminants (microplastics, antibiotics, endocrine-disrupting chemicals and others).<br>Development and application of ecogenomic methods to assess the effects of contaminants on marine communities (research that will lead to a step-change in biomonitoring practices).<br>Developing models to predict the concentration and biological effects of exposure to contaminants at variable scales and time frames. | Developing a comprehensive and accurate database on contaminant distributions in marine systems (environmental information systems) which include baseline contaminant concentrations in Australian coastal waters.<br>Fundamental ecotoxicological and ecological studies that will underpin the next generation of water quality guidelines (due mid 2020s).<br>Integrating mixture toxicity, hormesis and bioavailability (incorporating site-specific physicochemical properties) into ecological risk assessment methods. | Defining best practice monitoring and measurement protocols for use in Australia. Includes cost-effective monitoring and application of proxies/surrogates and use of remote sensing.<br>Developing improved spatial and biogeochemical models to link landscape management, changes in land condition (both inland and coastal), and changes in anthropogenic inputs to allow prediction and protection of marine resources.<br>Understanding sub-lethal and chronic effects of mixtures of chemicals and on marine organisms and improving the understanding of effects of sequential exposure to chemicals, toxicity of parent compounds and degradation products. |
| *NIS* | Develop Australian-compliant in-water cleaning technologies for all vessel types.<br>Test risk assessment process underpinning Australia's Ballast Water Management framework.<br>Develop improved methods for rapid detection of invasive marine species – including, but not limited to, molecular probes.<br>Studies of biology/ecology of priority invasive marine species (reproduction, competition, life cycle).<br>Test efficacy of options for eradication of marine pests.<br>Revise the National Monitoring Network to be more cost-effective and adaptable ensuring uptake and implementation<br>Develop remote inspection tools to assess extent of vessel | Tools for assessment, identification of risk and treatment of biofouling in vessel niche areas<br>Foster the establishment of researcher networks for marine biosecurity and pest research.<br>Develop training and capability building initiatives in areas such as marine pest assessments.<br>Understand sociological factors impacting the uptake of risk mitigation strategies by stakeholders. | |

| Priorities | 5 years | 10 years | 20 years |
|---|---|---|---|
| | biofouling, in particular for niche areas.<br>Develop risk models that predict the probability of invasion at strategic Australian ports.<br>Para-taxonomic tools for rapid and robust identification of pest species to support monitoring.<br>Assess risk-reduction achieved using diverse management strategies, incl. benefit-cost-trade-offs. | | |
| *Green engineering and marine urban development* | Continued research into the potential for multipurpose designs that provide important ecosystem services should be a priority.<br>Where coastal development or reconstruction of hard coastal defences is occurring in Australia, managers need to consider whether an alternative method such as managed retreat is more appropriate. Scientific modelling [52] may be a useful tool in helping identify whether managed retreat is a viable management option in specific areas.<br>Managers need to plan where and when artificial structures should be built within the coastal seascape. Strict guidelines on the construction should be set, incorporating their possible footprint, when unavoidable, as well as a context-specific spatial planning (i.e. each type of structure will have specific guidelines and recommendations). | As research in this field progresses the efficacy of designs for multipurpose artificial structures should be examined with a systematic review and meta-analysis.<br>Data needs to be generated assessing the success of managed retreat and soft engineering as effective coastal defence in Australia, including the restoration of biodiversity and ecological functioning.<br>Development of an Australian Marine Spatial Information System (AMSIS) will be essential to support spatial planning of artificial structures in the coastal and offshore zone. This could incorporate data and support from the current AMSIS initiative by Geoscience Australia. | Research needs to be incorporated into marine policy for sea level rise and coastal management, and operational guidelines written for end users.<br>Comprehensive zoning plans for the marine and coastal zones of Australia will be needed to aid decision makers and ensure that spatial planning for marine artificial structures meets the needs of multiple stakeholders.<br>Monitoring and revision of offsetting policies will be necessary to match the progress in green engineering and increasing/changing pressures from marine development. |
| *Indigenous coastal research* | Planning: Develop and implement a National Indigenous Marine Research Plan, ensuring the participation of key indigenous stakeholders and coordination with existing local and regional plans<br>Partnership: Establish a network of long-term partnerships between marine research and education providers and coastal indigenous communities<br>Capability: Develop indigenous knowledge and capability through direct support for indigenous students, researchers, resource managers, and traditional knowledge holders<br>Knowledge: Develop concepts, models, and processes to record, recognise and incorporate customary indigenous knowledge and management techniques into coastal | Resource ongoing implementation of the National Indigenous Marine Research Plan<br>Assess progress of indigenous marine research against criteria/targets established in National Indigenous Marine Research Plan.<br>Revise plan following assessment of implementation<br>Reward successful researcher-community partnerships, and grow and deepen the partnership network, targeting key areas of indigenous, scientific and/or geographic need.<br>Expand indigenous capability development, focusing on early career indigenous marine scientists and coastal resource managers | Ensure the ongoing implementation and revision of the National Indigenous Marine Research Plan.<br>Assess the evolution of research partnerships with coastal communities for effectiveness for future needs.<br>Assess the progress of generating early, mid-career, and senior indigenous marine scientists and coastal managers.<br>Develop new models for indigenous business development and indigenous benefits from sustainable coastal resource use appropriate for 2035 |

| Priorities | 5 years | 10 years | 20 years |
|---|---|---|---|
| | resource management.<br>Rights and interests: Generate regional assessments of indigenous values, rights and interests in coastal and marine territories to support wider understanding of indigenous roles in catchment planning, coastal governance, and co-management.<br>Connectivity: develop models for valuing indigenous catchment to coast co-management and the ongoing indigenous provision of coastal ecosystem services.<br>Development: support the realisation of indigenous benefits from sustainable coastal development through research aiding indigenous business planning, partnerships, and the mitigation of negative impacts.<br>Custom: Develop a consistent protocol and monitoring & evaluation framework for the ongoing understanding of the biophysical, economic, social and cultural value of indigenous coastal resource use, and associated risks to/pressures on those values.<br>Integration: Coordinate and integrate Indigenous-specific marine research needs with the wider program of socio-economic research required to meet national sustainable resource management and development priorities. | Investigate at a national scale the wider Australian community understanding of indigenous rights, values, and interests in marine and coastal territories to assess potential for long-term co-management arrangements.<br>Assess implementation of models for valuing indigenous catchment management and coastal and marine ecosystem service provision.<br>Assess and adapt mechanisms for deriving indigenous benefits from sustainable development and the mitigation of negative development impacts.<br>Continue monitoring of the scale and significance of indigenous coastal resource use and the implications of changing environmental, socio-economic, demographic, and technological influences.<br>Assess and continue to support the implementation of long-term climate adaptation needs for coastal indigenous communities.<br>Coordinate and integrate indigenous-specific marine research needs with the wider program of socio-economic marine research required to meet national sustainable resource management and development priorities. | onwards.<br>Assess the implementation of mature indigenous co-management regimes in key coastal locations across Australia to support further establishment.<br>Assess and continue to support the implementation of long-term climate adaptation needs for coastal indigenous communities.<br>Continue to coordinate and integrate indigenous-specific marine research needs with the wider program of socio-economic marine research required to meet national sustainable resource management and development priorities. |
| *Climate change* | Establish a Coastline Observatory to provide baseline data on Australia's coastal and estuarine environments, and to provide data against which to test the predictions of newly emerging coastal models.<br>Establish a network of sentinel sites at which biological and physico-chemical changes are monitored over long time periods to elucidate trends and provide a baseline for assessing climate change impacts. The sites should be selected such that they include tropical, subtropical and temperate ecosystems, in estuaries and the coastal ocean, and should span urban contexts ranging from capital cities, regional centres and smaller urban settlements.<br>Establish impacts of multiple stressors on keystone species, | Better functional models linking catchment pressures to ecosystem response are needed to understand and predict the implications of potential interactions between increased coastal development and climate change. These models need to be suitable for application to different systems (e.g. riverine estuaries, ICOLLs, lakes) and need to consider primary producers (seagrass and macroalgae), invertebrates and fish. | |

| Priorities | 5 years | 10 years | 20 years |
|---|---|---|---|
| | and on their adaptive capacity to climate change.<br>Models are needed that forecast socio-economic impacts of climate change under the various adaptation scenarios. | | |
| *Cumulative impact research* | Improved linkage of catchment-to-coast interaction in modelling and impact assessments.<br>Improving our knowledge/baseline assessments of marine ecosystems in Northern Australia that will undergo industrialisation/urbanisation. | Developing risk assessment approaches and models that take into account multiple stressors such climate change, a cocktail of contaminants and salinity.<br>Development of coastal observatories/designation of demonstration sites that foster trans-disciplinary research. | Regional and local scale models of ecosystem health that take into account multiple stressors such climate change, a cocktail of contaminants and salinity. |

## Acronyms

| | |
|---|---|
| ACEF | Australian Coastal Ecosystem Facility |
| AIMS | Australian Institute of Marine Science |
| AFMA | Australian Fisheries Management Authority |
| AGMIN | Agricultural Ministers' Forum |
| AgNorth CRC | Northern Australia Agricultural Cooperative Research Centre |
| AIATSIS | Australian Institute Aboriginal Torres Strait Islander Studies |
| ALA | Atlas of Living Australia |
| ANDs | Australian National Data Services |
| AODN | Australian Oceanographic Data Network |
| ARC | Australian Research Council |
| AURIN | Australian Urban Research Infrastructure Network |
| BoM | Bureau of Meteorology |
| CBD | Convention on Biological Diversity |
| CDU | Charles Darwin University |
| CFC | Caring for Our Country |
| CRC | Cooperative Research Centre |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| DoE | Commonwealth Department of Environment |
| DSTO | Defence Science and Technology Organisation |
| EPA | Environmental Protection Authority |
| EU | European Union |
| FRDC | Fisheries Research and Development Corporation |
| GA | Geoscience Australia |
| GOCI | Geostationary Ocean Color Imager |
| GBR | Great Barrier Reef |
| GBRMP | Great Barrier Reef Marine Park |
| GBRMP | Great Barrier Reef Marine Park Authority |
| HORSCCWEA | House of Representative Standing Committee |
| IAS | Indigenous Advancement Strategy |
| IFRG | Indigenous Fisheries Reference Group |
| IMAREST | Institute of Marine Engineering Science and Technology |
| IMOS | Integrated Marine Observing System |
| IPA | Indigenous Protected Area |
| IUCN | International Union for the Conservation of Nature |
| JCU | James Cook University |
| LWF | CSIRO Land and Water Flagship |
| MAFF | Queensland Department of Agriculture, Fisheries and Forestry |
| MPSC | Marine Pest Sectoral Committee |
| NBC | National Biosecurity Committee |
| NCCARF | National Climate Change Adaptation Research Facility |
| NAILSMA | North Australia Indigenous land and Sea management Alliance Pty Ltd |
| NCRIS | National Collaborative Research Infrastructure Strategy |
| NEDF | National Elevation Data Framework |
| NERP | National Environmental Research Program |
| NESP | National Environmental Science Program |
| NEXIS | National Exposure Database |
| NGO | Non Government Organisation |
| NLC | Northern Land Council |
| NNTT | National Native Title Tribunal |
| NRM | Natural Resource Management |
| MPA | Marine Protected Area |
| O&A | CSIRO Oceans & Atmosphere Flagship |
| PM&C | Prime Minister and Cabinet |
| RD&E | Research, Development and Enterprise |
| SIMS | Sydney Institute of Marine Science |
| SST | Sea Surface Temperature |
| TERN | Terrestrial Ecosystem Research Network |
| TFM | Traditional Fisheries Management |
| TFK | Traditional Fishing Knowledge |
| TNC | The Nature Conservancy |
| TRaCK | Tropical Rivers and Coastal Knowledge |
| TSRA | Torres Strait Regional Authority |
| TSS | Total Suspended Solids |
| UNDRIP | UN Declaration on the Rights of Indigenous Peoples |

| | |
|---|---|
| UNESCO | United Nations Environmental Scientific Cultural Organisation |
| UWA | University of Western Australia |
| VIIRS | Visible Infrared Imaging Radiometer Suite |
| WAMSI | Western Australian Marine Science Institute |
| WI | Wetlands International Pty Ltd |
| WoC | Working on Country |
| WWF | World Wide Fund for Nature |