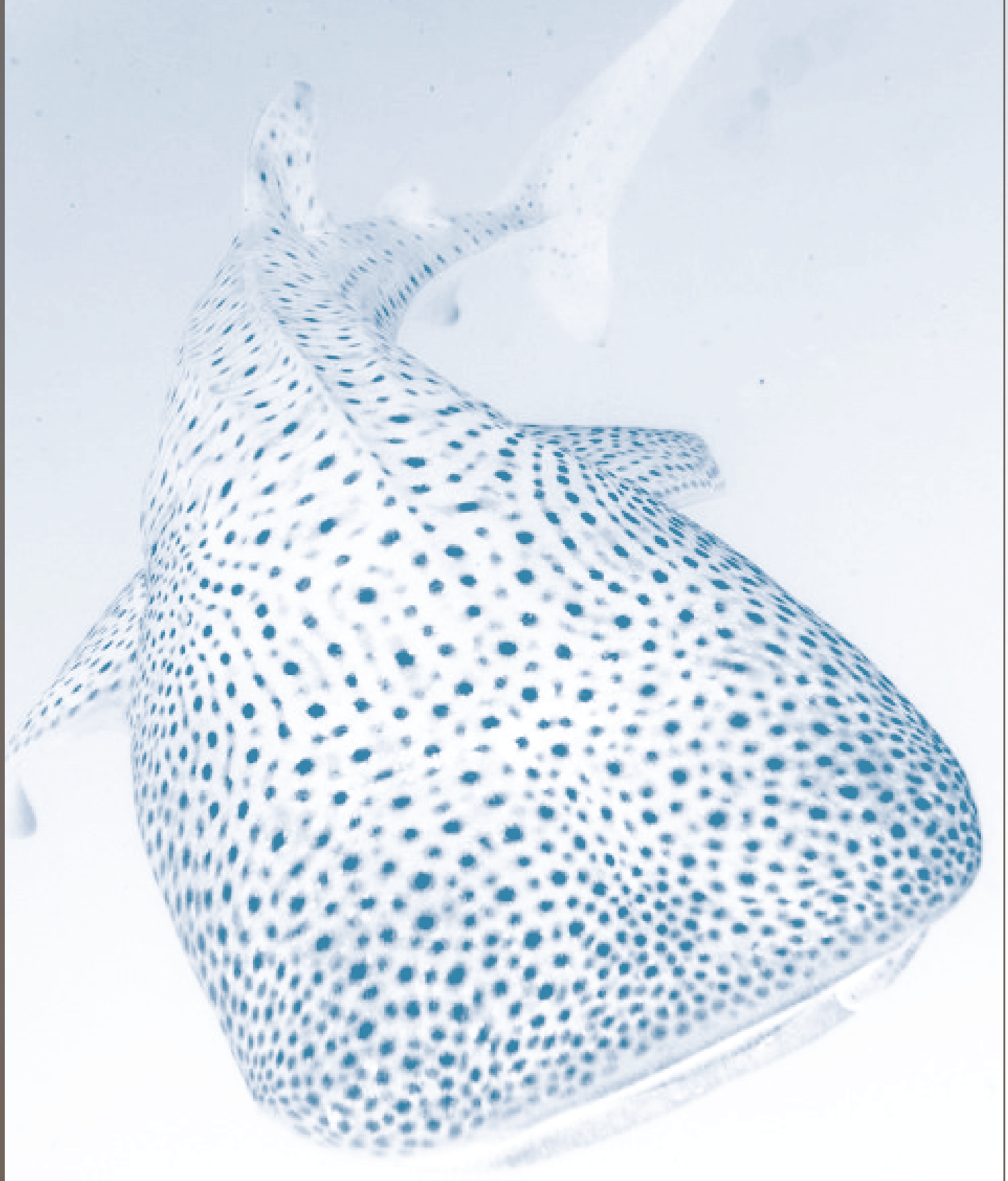

THE BLUEPRINT FOR MARINE SCIENCE 2050 **REPORT**

Research directions to enhance industry competitiveness and government effectiveness in the marine environment off Western Australia

INTRODUCTION

AN INDEPENDENT REPORT TO ALL STAKEHOLDERS BY THE BLUEPRINT STEERING GROUP

This ***Blueprint for Marine Science 2050*** (the Blueprint) is an independent, objective assessment of the participating stakeholders' priorities for future marine research in Western Australia.

The Blueprint is stakeholder focussed to ensure any resulting research agenda is guided by real world priorities.

This process has provided a sobering picture of the work required to underpin efficient and sustainable development of our ocean to 2050. There is a great deal we still need to learn if we are to make informed decisions about activities that are increasingly marginal, costly and contentious.

Aside from the priorities identified, this process has begun the important across-sector conversation about the work ahead. This conversation must be continued and expanded as we acknowledge the need for greater collective understanding of our ocean beyond just the project, fishery, or marine park scale.

We encourage Governments of all levels, industry and the research sector to review the Blueprint and to actively support the coordinated, decadal program of research and innovation that is needed.

Some of the priorities identified in this document are not new. However, the limited progress in some areas indicates that a more coordinated approach is required.

As such, we recommend ongoing monitoring of progress and periodic replacement of this Blueprint. It is imperative that this process of review is continued and adapts to evolving priorities.

While not the focus of this assessment, we also acknowledge that fundamental research and the pursuit of knowledge is a critical component of an innovative society. It is our hope that the outcome focussed research that this Blueprint may trigger will also contribute to developing and retaining expert capability in Western Australia and leverage additional opportunities for this fundamental research.

We also congratulate the Western Australian Marine Science Institution for taking the strategic initiative to commission this independent process, and thank it for the trust placed in the Steering Group to oversee this process.

This summary report and the full Blueprint for Marine Science 2050 can be found at **www.wamsi.org.au/blueprint**

Alistar Robertson (Independent Chair) on behalf of:
Heather Brayford A/Director General WA Department of Fisheries
David Carter CEO Austral Fisheries
John Gunn Chair National Marine Science Committee
Jennifer McGrath Executive Director WA Department of Premier and Cabinet (Office of Science)
Colin Scott Subsea & Pipeline Manager, Wheatstone Upstream Project Chevron Australia
Patrick Seares CEO WAMSI
Luke Smith Principal Environmental Scientist Woodside Energy
Stuart Smith CEO NOPSEMA
Paul Vogel Chair WA EPA

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Disclosure and Disclaimer

This report has been prepared by Australian Venture Consultants Pty Ltd (ACN: 101 195 699) ('AVC'). AVC has been commissioned to prepare this report by the Western Australian Marine Science Institution, and has received a fee from the Western Australian Marine Science Institution for its preparation.

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Consultation

The Western Australian Marine Science Blueprint has been developed via a highly consultative process that has involved direct semi-structured interviews with a range of stakeholders and experts in the Western Australian marine environment, as well as a series of stakeholder seminars and workshops.

Individuals who generously provided access to their knowledge through the direct interview process are listed in Table 1 below.

TABLE 1 – INTERVIEWEES

Stakeholder Group	Interviewees
Commercial Fishing Industry	David Carter, Chief Executive Officer, Austral Fisheries Hamish Ch'ng, Director, Far West Scallops John Harrison, Executive Officer, Western Australian Fishing Industry Council Ian Taylor, former Chair, Western Australia Abalone Council
Community	Leyland Campbell, Principal Policy Officer, Recfishwest Andrew Rowland, Chief Executive Officer, Recfishwest Peter Yu, Chair, North Australian Indigenous Land and Sea Management
Environmental NGOs	Paul Gamblin, Manager – Marine Protected Area Program, WWF Australia
Marine Aquaculture Industry	Brad Adams, Chief Executive Officer, Two Oceans Abalone Desiree Allen, Managing Director, Marine Produce Australia Erica Starling, Director, Latitude Fisheries
Oil and Gas Exploration and Production Industry	Tom Baddeley, Manager Government and Community Relations, Santos Matt Coomber, Government & Public Affairs Adviser, Apache Jan Flynn, Senior Metocean Engineer, Shell International E&P Samantha Jarvis, Environmental Team Lead, Santos Steve Kauffman, Engineering Manager, Shell Development Australia Russell Lagdon, Environmental Manager, Chevron Geoff Wake, Metocean Engineer, Woodside
Offshore Engineering and Technical Services Industry	Jason Antenucci, Principal Engineer, DHI Water and Environment Steve Buchan, Managing Director, RPS Metocean Tim Dallas, Business Development Manager – Subsea, Technip Chris Dolan, General Manager Business Acquisition, DOF Subsea Terry Griffith, Regional Technology Leader and Principal Pipeline

Stakeholder Group	Interviewees
	Engineer, Wood Group Kenny Jorgen Eric Larsen, Managing Director – Australia, DHI Water and Environment Janette Roberts, former Australian Chair, Kvaerner Lauren Schmied, Senior Engineer, DHI Water and Environment Keith Spence, Chairman, Clough Engineering, National Offshore Petroleum Safety and Environmental Management Authority Raymond Steedman, Principal Consultant, GHD
Scientific Research Sector	Kym Bills, Chief Executive Officer, Western Australian Energy Research Alliance Mike Burbridge, Executive Director, Australian Sustainable Development Institute, Curtin Christine Erbe, Centre for Marine Science and Technology, Curtin University Ming Feng, Principal Research Scientist Centre for Marine and Atmospheric Research and Centre for Environment and Life Science, CSIRO Kim Friedman, Principal Research Scientist, Department of Parks and Wildlife Euan Harvey, Professor of Marine Science, Curtin University Greg Ivey, Deputy Dean (Research) – Faculty of Engineering, Computing and Mathematics, The University of Western Australia Greg Jenkins, Director, Australian Centre for Applied Aquaculture Research, Challenger Institute of Technology Gary Kendrick, Professor – Marine Ecology, The University of Western Australia Peter May, Deputy Director, Australian Bureau of Meteorology Hector Lozano-Mentes, Marine Ecologist, CSIRO Alexandra McManus, Director Centre of Excellence Science Seafood and Health, Curtin University Tim Molttman, Director, Integrated Marine Observing System Miles Parsons, Research Fellow - Centre for Marine Science and Technology, Curtin University Charitha Pattiaratchi, Professor – Physical Oceanography, The University of Western Australia Steve Rogers, WA Science and Business Leader, Australian Institute of Marine Science Andy Stevens, Theme Leader (Coastal Research), Wealth from Ocean's Flagship, CSIRO David White, Shell Professorial Chair in Offshore Engineering - Centre for Offshore Foundation Systems, The University of Western

Stakeholder Group	Interviewees
	Australia
Seaborne Logistics	Brad Kitchen, Director – Environment and Heritage, Pilbara Ports Authority Paul Toussaint-Jackson, Managing Director, Australian Floating Decks
State and Commonwealth Government Regulators	Kimberley Dripps, Deputy Secretary, Australian Government Department of Environment Janelle Eagle, Environment Manager – Environment Effects, National Offshore Petroleum Safety and Environmental Management Authority Rick Fletcher, Executive Director – Research, Western Australian Government Department of Fisheries Gavin Guyan, General Manager – Safety and Integrity, National Offshore Petroleum Safety and Environmental Management Authority Tom Hatton, Chair, Western Australian Marine Parks and Reserves Authority Paul Vogel, Chair, Western Australian Environmental Protection Authority

In addition to the interviews, a series of workshops were also held. The participants in these workshops are listed in Table 2 below.

TABLE 2 – WORKSHOP ATTENDEES

Forum	Attendees
Discussion Paper Seminar	Luke Smith, Environmental Scientist Manager, Woodside Damien Hills, Associate Director – Environment and Safety, APPEA Andrew Rowland, Chief Executive Officer, RecfishWest Mike Burbridge, Executive Director, Australian Sustainable Development Institute, Curtin University Matthew Tonts, Director of the Centre for Regional Development, The University of Western Australia Tom Hatton, Principal Consultant, Thomas Hatton Environmental Consulting Steve Rogers, Science and Business Leader WA, AIMS Ray Steedman, Chair, WAGOOS John McMath, Chief Executive Officer, Western Rock Lobster Council Kris Browne, Manager-International Science Collaboration, Department of Industry Ray Masini, Manager – Marine Ecosystems Branch, Office of the Environmental Protection Authority Steve Buchan, Managing Director, RPS Metocean

Forum	Attendees
	Dan Caughan, Supervising Scientist – Stock Assessment and Data Analysis, Department of Fisheries
	Tania Ashworth, General Manager – Environment, Department of State Development
	Ian Briggs, General Manager Environmental Policy, Department of Mines and Petroleum
	Peter Davies, Pro Vice-Chancellor – Research, The University of Western Australia
	Tracy Parker, General Manager – Oceans Institute, The University of Western Australia
	Shaun Collin, Premier's Fellow, The University of Western Australia
	Mark Bailey, Managing Director, BMT Oceania
	Paul Gamblin, Global Oceans Campaign Manager, World Wildlife Foundation
	Kim Friedman, Principal Research Scientist, Department of Parks and Wildlife
	Glenn Moore, Curator of Fishes, Western Australian Museum
Marine Environmental Regulation Workshop	Paul Vogel, Chair, Environmental Protection Authority
	Kim Taylor, General Manager, Office of the Environmental Protection Authority
	Darren Foster, Director, Office of the Environmental Protection Authority
	Gordon de Brouwer, Secretary, Department of the Environment
	Michelle Andews, Deputy Director General, Department of Mines and Petroleum
	Dan Caughan Supervising Scientist – Stock Assessment and Data Analysis – Department of Fisheries
	Janelle Eagle, Environment Manager – Environment Effects, National Offshore Petroleum Safety and Environmental Management Authority
	Margaret Byrne, Director – Science and Conservation, Department of Parks and Wildlife
	Michelle Reynolds, Chief Executive Officer, WorkCover WA
Fisheries and Aquaculture Workshop	Haidee Vandenberghe, Department of Premier and Cabinet
	Rob De Roach, Associate Director, BMT Oceanica
	Stuart Smith, Former Director General, Department of Fisheries
	Heather Brayford, Acting Director General, Department of Fisheries
	Dan Caughan Supervising Scientist – Stock Assessment and Data Analysis – Department of Fisheries
	Matt Watson, Australian Fisheries Outreach Officer, Marine Stewardship Council
	Brett McCallum, Executive Officer, Pearl Producers Association
	John Harrison, Chief Executive Officer, Western Australian Fishing Council
	Norman Moore, Chairman, Australian Fisheries Management Authority
	Tina Thorne, Executive Officer, Aquaculture Council of Western Australia

Forum	Attendees
	Rick Fletcher, Executive Director – Research, Department of Fisheries
Offshore Oil and Gas Environment Workshop	Michaela Dommisse, Lead Environmental Advisor – Marine, INPEX Libby Howitt, Chief Environmental Advisor, Apache Energy Luke Smith, Chief Environmental Scientist, Woodside Brenton Chatfield, Senior Environmental Specialist, ConocoPhillips Asha Jogia, ConocoPhillips Tom Baddeley, Manager – Government and Community Relations - Santos Tim Cooper, Senior Environmental Specialist, BHP Billiton Petroleum Damien Hills, Associate Director – Environment, APPEA
Coastal Local Government Workshop	Vanessa Jackson, Policy Manager – Planning and Improvement, Western Australian Local Government Association Craig Perry, Coastal Project Coordinator, City of Cockburn Rodney Hoath, Director – Coastal Information, Department of Transport Gary Rogers, Manager – Procurement and Projects, City of Rockingham Laura Stocker, Associate Professor – Sustainability, Curtin University Vivienne Panizza, Planning Manager, Department of Planning Melanie Bainbridge, Sustainability Officer, City of Fremantle Joanne Ludbrook, City of Mandurah Mark Langdon, Manager – Environmental Services, City of Mandurah Michael Aspinall, Shire President, Shire of Gingin Caroline Perks, Climate Change Coordinator, Western Australian Local Government Association

EXECUTIVE SUMMARY

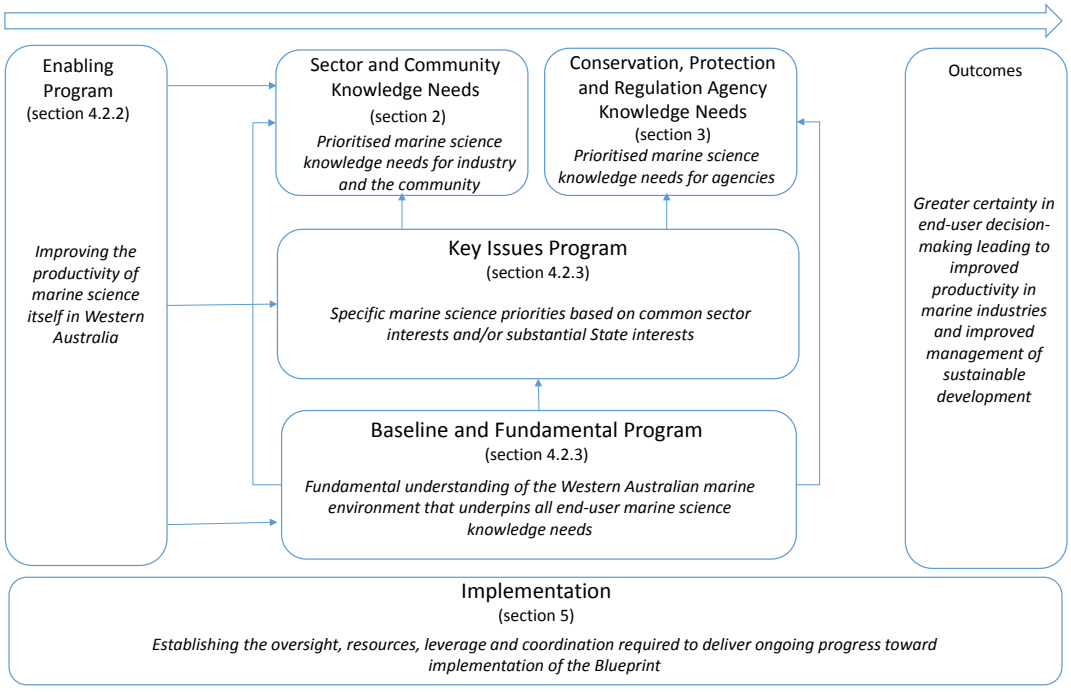
The Western Australian Marine Science Blueprint 2050 (the 'Blueprint') is an end-user driven strategic framework for marine science priorities in Western Australia that will underpin the sustainable development of Western Australia's marine environment.

The Blueprint was commissioned by the Western Australian Marine Science Institution (WAMSI) in recognition that priorities for future research relating to the Western Australian marine environment must be shaped by the short and long term knowledge needs of those in government, industry and the community responsible for decisions affecting that environment.

The strategic marine science task as outlined in the Blueprint is substantial and there must be a concerted effort across all sectors that interact with the Western Australian marine environment, including agencies responsible for protection, conservation and regulation of that environment, and the scientific sector, to better coordinate and harness marine science resources toward this task. In the absence of this effort, both development and protection decisions will continue to be made in an uncertain environment, resulting in decision outcomes that are either highly precautionary or which encompass risk.

The Blueprint was developed through a review of existing data and literature and in consultation with more than 170 primarily end-users of marine science knowledge across government, industry and the community, as well as the scientific sector that produces that knowledge. A methodical and consultative process was used to derive the framework of marine science priorities for the State.

The result of this process is a framework of interrelated marine science activities that must be acted on the ensure that future government, industry and community decisions pertaining to the marine environment are based on an optimal knowledge base, reducing risk and improving the productivity that results from those decisions. The following figure both illustrates the relationship between the marine science activities and outcomes, and serves as a guide to the structure of the Blueprint.



The Blueprint recommends that marine science effort in Western Australia is prioritised to deliver:

1. The identified knowledge priorities of industry sectors, community and government agencies responsible for the conservation, protection and regulation of the marine environment:
   a. More than 100 knowledge priorities have been identified

2. Enabling programs that make the undertaking of marine science in Western Australia more productive and effective than is currently the case:
   a. Cost effective monitoring
   b. Data sharing
   c. Improved certainty in modelling

3. Baseline and fundamental research programs to provide knowledge that is required to underpin research that addresses the sector and management knowledge needs:
   a. Consolidation and synthesis of existing marine science data, information and knowledge pertaining to the Western Australian marine environment
   b. Enhanced understanding of regional oceanography
   c. Enhanced understanding of biodiversity and habitat
   d. Enhanced understanding of marine ecosystems function

4. Key Issues research programs that are priorities for the State:
   a. Cumulative impacts
   b. Decommissioning of offshore infrastructure
   c. Biosecurity
   d. Remediation of impacted ecosystems
   e. Enhanced productivity
   f. Social license to operate

Particular aspects and geographies of early importance are defined for enhanced focus within these themes in the main report.

The challenge outlined in the Blueprint is substantial but Western Australia is well placed to address these challenges with an excellent marine research capability and a strong existing collaborative framework to build on.

However, changes are required to how marine science is approached in Western Australia. This includes:

- Ongoing monitoring of progress against the Blueprint and five-yearly updates
- Substantial and ongoing funding for strategic research from all sectors
- Improved end-user oversight and knowledge transfer efforts for strategic research programs
- Enhanced private-public collaboration

While challenging, the Blueprint presents an opportunity to target future investment and research into areas that will make a substantial difference to the economic, social and environmental prosperity that can be delivered from our marine environment.

1. About the Western Australian Marine Science Blueprint 2050

1.1. What is the Western Australian Marine Science Blueprint 2050

The Western Australian Marine Science Blueprint 2050 (the 'Blueprint') is an end-user driven strategic framework for physical, chemical, biological and social research that is designed to address the currently known knowledge needs of sectors that interact with, and managers of, the Western Australian marine environment, as well as to establish an understanding of likely future knowledge needs in the marine environment. It is a strategic research framework that will underpin the sustainable development of Western Australia's marine environment across all sectors.

Table 3 below summarises the key aspects of the Blueprint.

TABLE 3 – KEY ASPECTS OF THE BLUEPRINT

Aspect	Description
Project Resourcing and Governance	The development of the Blueprint has been funded by the Western Australian Marine Science Institution (WAMSI). The study that has resulted in the Blueprint has been overseen by an independent Steering Group comprised of government, industry and scientific interests in the Western Australian marine environment (see Exhibit 1).
Independently Developed	While funded by WAMSI, the Blueprint has been developed independently by Australian Venture Consultants, a strategic planning and analytics consulting firm with expertise in mission oriented, multi-sector strategic scientific planning.
A Consultative Process	A key aspect of the development of this Blueprint is the highly consultative process through which it has been developed. In addition to an extensive literature review, the primary input to the study has been a series of semi-structured interviews and workshops involving over 120 experts and stakeholders in the Western Australian marine environment, including end-users of scientific knowledge pertaining to the Western Australian marine environment. Exhibit 2 describes the methodology used to develop the Blueprint. Tables 1 and 2 list individuals who have contributed their knowledge to the Blueprint process.
Geographic Focus – the Western Australian Marine Environment	The key area of focus of the Blueprint is the coastal, near-shore and offshore marine environment in Western Australian and Commonwealth Waters, as well as Australia's Exclusive Economic Zone, between the Northern Territory-Western Australian border and the South Australian-Western Australian border. Of relevance are also global ocean systems to the extent that they affect this body of water (the 'Western Australian marine environment'). An overview of the key biological and physical features of the Western Australian marine environment is contained in Online Appendix 2.
Time Horizon	While the immediate focus of the Blueprint is knowledge requirements for the next 15 years, the Blueprint has a horizon of 35 years. This will allow the Blueprint to give consideration to knowledge needs that will be required to understand and manage: ▪ The impact of a larger economic development footprint in the Western Australian marine environment; ▪ The development and impact of a growing coastal community and

Aspect	Description
	associated coastal infrastructure; ▪ The impact of climate change; ▪ Increased conflicts between industrial, community and environmental uses of the marine estate; ▪ Decommissioning of offshore infrastructure; and ▪ The development of new industries that interact with the marine environment.
Intended Audience	The Blueprint is a public resource. It is intended that it will be used to guide and support the research planning and direction of a range of organisations, including: ▪ The scientific research sector and funders of that research; ▪ Industries operating in the Western Australian marine environment; ▪ Government instrumentalities operating in the Western Australian marine environment; ▪ State and Commonwealth policy-makers and marine estate managers; ▪ Coastal shires and communities; ▪ Traditional owners and managers of sea country; ▪ Commonwealth trade and foreign affairs agencies with an Indian Ocean and Southeast Asian focus; and ▪ Environmental non-government organisations.
Planning Context	The Blueprint has been developed in the context of a number of existing, national institutionally aligned marine research strategies. The Blueprint is designed to complement these strategies and by focusing on issues specific to the Western Australian marine environment, provide regional resolution to these existing plans. Other marine science plans include those produced by the National Marine Science Committee, Bureau of Meteorology, Fisheries Research and Development Corporation and Integrated Marine Observing System. These marine research plans are summarised in Online Appendix 1. The Blueprint has also been developed in a context that is set in part by management plans pertaining to the Western Australian marine environment. Such plans include those set by Western Australian catchment managers and Natural Resource Management Groups, as well as Traditional Owner cultural heritage and environmental management plans such as the Bardi Jawi Indigenous Protected Area Management Plan.
Implementation of the Blueprint	The Blueprint is necessarily a high-level strategic framework that identifies marine science knowledge needs of a large number of sectors that interact with the Western Australian marine environment, as well as government agencies responsible for the conservation, protection and regulation of that environment. The priorities highlighted in this Blueprint are areas where resources should be better marshalled to ensure detailed planning, costing and resourcing of specific research programs and projects.
A Living Document	As research pursuant to this Blueprint progresses, industry and communities develop and the climate changes, new knowledge needs pertaining to the Western Australian marine environment will become apparent. Similarly, there is potential for significant impact from unexpected natural events or anthropogenic activity to emerge. As such, it is intended that this Blueprint will be reviewed, via a consultative process, every five years.
Online Appendices	Supporting this Blueprint is an information-rich resource of Online Appendices that provide significant descriptive information pertaining to and supporting the analysis in this Blueprint. The Online Appendices are listed in Exhibit 3 of this report and can be accessed at http://www.wamsi.org.au

1.2. Why is the Blueprint Necessary?

The impetus for this Blueprint came from WAMSI's view that Western Australia's marine science research priorities must be driven by the knowledge needs of end-users on both short and long-term horizons. More specifically, a Blueprint for marine science in Western Australia is necessary for the following reasons:

- When compared to the terrestrial environment, the current knowledge base pertaining to much of the marine environment is relatively limited;
- A number of factors are driving substantially increased human and economic interaction with the Western Australian marine environment which will result in escalated social, economic and environment conflict over marine resources, the effective management of which will require a substantially enhanced marine science knowledge base;
- For several reasons (including cost, research capability and timing of need for information), the scientific research required to improve the knowledge base must be prioritised; and
- There needs to be a collective understanding of the marine science priorities so that investments in scientific capability are directed towards supporting those priorities.

1.2.1. Knowledge pertaining to much of the marine environment is limited

Mankind's relatively limited understanding of the ocean environment is unfortunately usually only illuminated in the event of environmental disasters such as the 2009 Montara oil spill in the Timor Sea or the 2010 Maconda oil spill in the Gulf of Mexico, or in the event of human tragedy such as the 2004 Indian Ocean earthquake and tsunami or the disappearance of Malaysia Airlines flight 370 in March 2014.

Accelerating the development of our knowledge of the marine environment will become increasingly paramount as man's interaction with less familiar ocean environments continues to escalate. For example, over the past 40 years, the limitations of offshore hydrocarbon production has advanced from depths of less than 300 metres to production systems that operate in depths of up to 3,000 metres[1]. Designing equipment for and conducting operations in these less familiar environments requires a much deeper understanding of ocean processes and systems. Similarly, as the marine environment changes in response to the changing climate, the ability to predict these changes and their outcomes will be critical to managing investment and operating decisions in industries such as commercial fishing, as well as managing the marine conservation estate.

The need for a substantially enhanced knowledge of the marine environment is perhaps nowhere more evident than in the case of Western Australia. Unlike much of the world's coastlines, the coastline of Western Australia has only been subjected to European settlement and industrialisation for approximately the past 200 years and this has been relatively limited to the impact of commercial fishing, including historical whaling, nutrient run-off from agricultural regions, development of parts of the Pilbara coast and comparatively limited (when compared to other industrialised parts of the world) industrial and urban development in the South West of the State.

Similarly, in comparison to many other marine environments, historical scientific exploration of the Western Australian marine environment has been limited.

[1] Bai, Y. And Bau, Q. (2012), *Subsea Engineering Handbook,* Elsevier, Oxford

1.2.2. Drivers of an Enhanced Marine Science Knowledge Base

Importance of marine ecosystem services to Western Australia

In terms of both location and culture, Western Australians are largely a coastal people. Most Western Australians live in or near coastal regions, value the relatively pristine nature of Western Australia's marine environment and routinely interact with that marine environment for leisure and/or cultural purposes. The Western Australian marine environment provides a range of natural resources that underpin key industries critically important to the standard of living in Western Australia such as fishing, oil and gas, tourism and logistics (shipping and ports). Finally, and most importantly, the marine environment plays a key role in regulating the environmental and climatic conditions in Western Australia. Known as *marine ecosystem services*[2], the many features that comprise the Western Australian marine environment such as estuaries, mangroves, seagrass meadows, intertidal zones, rocks and shell reefs, coral reefs, shelfs, canyons and so on provide a range of services including food for humans and animals, energy resources, biological regulation, nutrient cycling, climate regulation, storm protection, erosion control and cultural and recreational services.

Unprecedented scale of development

Over the past decade, Western Australia has experienced one of the most significant and protracted periods of private capital investment in its history. Since 2004, a total of approximately A$254 billion (at current prices) has been invested in the expansion of existing and development of new resources (primarily iron ore and offshore oil and gas) projects[3]. As at April 2014, there was A$116 billion of capital investment associated with resources projects in Western Australian that were either under construction or committed. There was also an additional 44 resources projects in Western Australia with an associated capital investment of A$58 billion that were at feasibility stage[4]. While some of the projects currently at feasibility study stage may achieve final investment decision and proceed to construction, it is widely recognised that the Western Australian resources industry is passing through a period of peak construction[5&6], with a significant number of large projects now transitioning to a long-term operational phase and fewer new construction projects commencing.

Figure 1 below summarises the status of the major resources industry projects in Western Australia that have been recently completed or are currently under construction.

[2] Leslie, H. and McLeod, K. (2007), 'Confronting the challenges of implementing marine ecosystem-based management', *Frontiers in Ecology,* 5(10), pp. 540 -548
[3] Australian Bureau of Statistics (2014), *Private New Capital Expenditure and Expected Expenditure by Industry: March Quarter Update*
[4] Bureau of Resource and Energy Economics (2014), *Resources and Energy Major Projects,* Australian Government, Canberra
[5] Australian Workforce and Productivity Agency (2012), *Resources Sector Skill Needs,* Australian Government, Canberra
[6] Business Council of Australia (2013), *Securing Investment in Australia's Future: Report of the Costs Task Force*

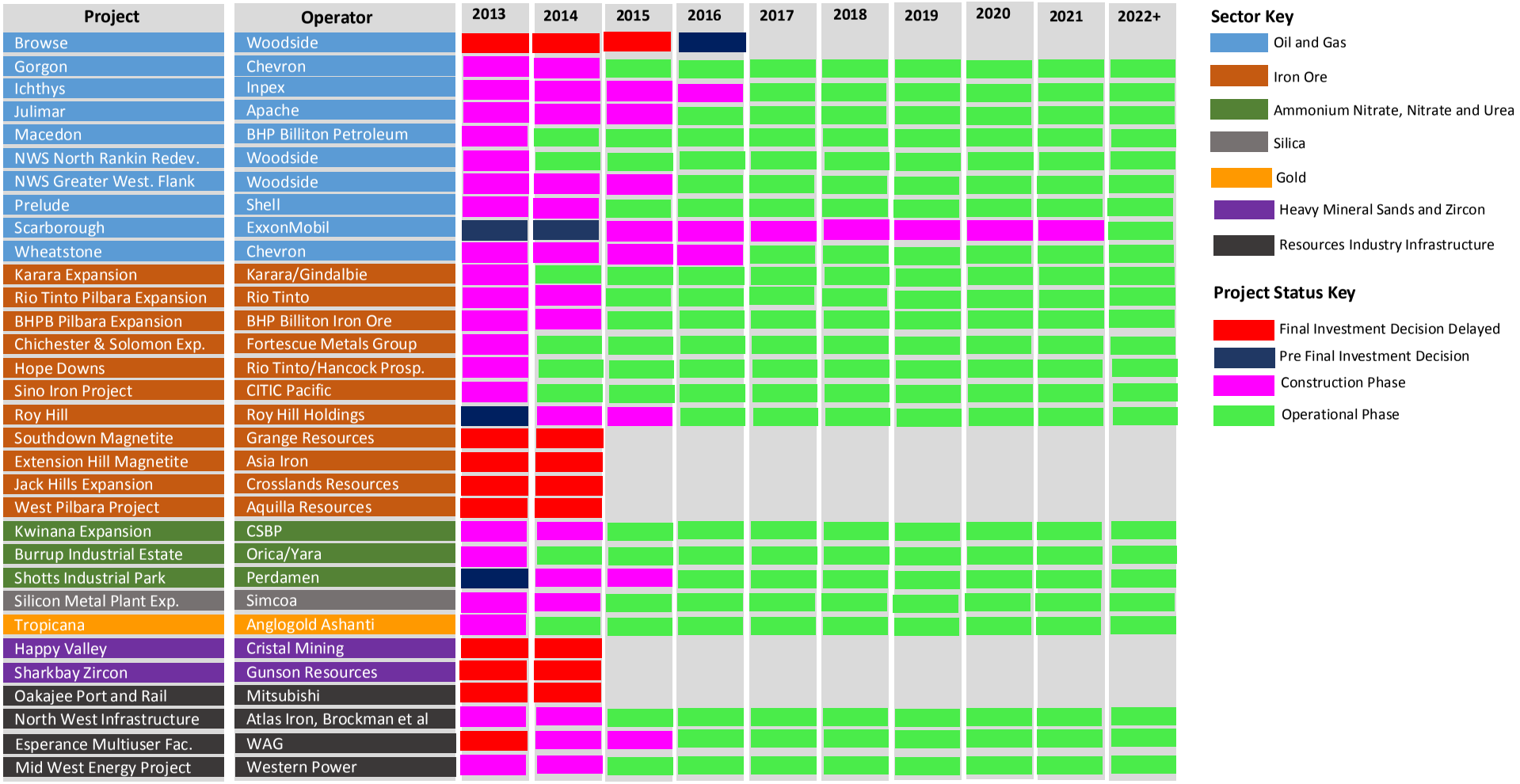


FIGURE 1 – WESTERN AUSTRALIAN RESOURCES INDUSTRY PROJECT PIPELINE

The extent to which these projects interact with the Western Australian marine environment is significant. For example of the projects listed in Figure 1:

- The 10 oil and gas projects are all offshore projects that revolve around significant fixed or floating topside infrastructure, subsea installations, pipelines and/or shore based processing facilities;
- The 11 iron ore projects all involve the export of significant volumes of iron ore through existing and planned ports in the Pilbara, Midwest or Great Southern regions of the State; and
- Two of the resources industry infrastructure projects are port facilities.

There are specific knowledge gaps pertaining to the Western Australian marine environment that need to be addressed so that management of these projects from an engineering, operational systems and environmental perspective can be optimised.

A growing coastal population

During the 15-year period 1990 to 2005, the residential population of Western Australia grew by 25 percent from 1.6 million people to 2 million people[7]. Over the decade since 2004, the Western Australian population has increased by a further 25 percent to 2.5 million people, primarily as the result of net interstate and international migration into Western Australia driven by the expanding resources industry.

Over the same decade the population of Perth has grown by 28 percent from 1.48 million to 1.90 million residents, whereas the population of regional Western Australia has grown by 24 percent from 0.50 million residents to 0.62 million residents. The vast majority of regional Western Australians reside in the South West of the State.

As discussed in detail in Online Appendix 11, the Western Australian population resides primarily in coastal communities. Managing the growth of these communities will require a better scientific base on which to design and manage coastal urban development and infrastructure against the risk of inundation and erosion, and to manage the increased pressure on the marine environment that results from increased commercial and recreational interaction with that environment.

Australia's Role in the Indian Ocean Century

The Indian Ocean has emerged as one of the world's most important regions from a global trade, energy security and strategic security perspective. There are 37 sovereign nations with shores on the Indian Ocean. Collectively these nations have a total population of approximately 2.6 billion people, or approximately 40 percent of the world's population. The region contains a number of unstable regimes and civil conflicts, as well as the 'Arc of Islam', which spans from Northern Africa, through the Middle East and the Sub-continent to South East Asia. In addition to the Indian Ocean littoral nations, China and the United States have significant strategic interests in the region.

With respect to trade, 30 percent of the world's seaborne trade passes through Indian Ocean ports and 50 percent of the world's seaborne containerised traffic passes through Indian Ocean seaways[8]. With regards to energy security, 66 percent of global oil transport

[7] Australian Bureau of Statistics (2013), *Australian Demographic Statistics, December 2013,* Cat. 3101.0, Australian Government, Canberra

[8] Kyurshid, S., Bishop, J. and Natalegawa, M. (2013), 'Putting out to sea', *The Hindu.com,* (www.thehindu.com/opinion/op-ed/putting-out-to-sea-a-new-vision/article5305845.ece

passes through Indian Ocean seaways and 55 percent of global oil reserves and 40 percent of global natural gas reserves are located within the jurisdiction of Indian Ocean rim nations[9].

While the Australian population represents only 0.8 percent of the population of Indian Ocean Rim nations, the coastline of Western Australia represents approximately one-sixth of the Indian Ocean shoreline (excluding Antarctica). The Western Australian landmass is rich in many natural resources, but sparse in population and infrastructure.

South Africa, India and Australia are the only Indian Ocean Rim countries that have developed world-class marine scientific capability. These nations will play a key role in understanding and planning for the impact of the emerging strategic importance of the Indian Ocean on the marine environment, as well as how ocean systems influence development in the Indian Ocean.

1.2.3. Consequences of a Sub-optimal Knowledge Base

Sub-optimal knowledge pertaining to the Western Australian marine environment manifests itself in the form of risk in the strategic, policy and operational decisions made by stakeholders in that marine environment. The most significant risk is that actions that are taken or not taken on the basis of ill-informed decisions result in the degradation or loss of marine ecosystem structure, function and integrity and hence loss of the marine ecosystem services discussed in Section 1.2.2.

Similarly, poor understanding of the Western Australian marine environment can result in inadequate design or operating specifications for coastal and offshore infrastructure that can ultimately result in financial loss, irreparable environmental damage, and/or endangerment to human life.

In the absence of sound scientific knowledge, these risks are typically mitigated by either application of the precautionary principle, or by accepting the inherent risks in the interests of a substantial public benefit. The precautionary principle presents two fundamental risks in its own right. Firstly, there is no way of knowing that the strategy has been adequately precautionary, potentially placing at risk important marine ecosystem services, coastal and offshore infrastructure and human safety. Secondly, the use of the precautionary principle may be unnecessarily sterilising parts of the marine estate from economic or cultural activity, or building in unnecessary operating costs resulting in a productivity or quality of life penalty.

1.2.4. The Need to Coordinate and Prioritise the Acquisition of Marine Knowledge

As a result of the number of issues associated with managing the Western Australian marine environment and the range of stakeholders interacting with that environment, there are many reasons to prioritise multi-sector investment in a marine science research program that is designed to address the limited knowledge base. These are summarised in Table 4.

[9] Ibid 8

TABLE 4 – REASONS FOR COORDINATION AND PRIORITISATION OF MARINE SCIENCE RESEARCH IN WESTERN AUSTRALIA

Reason	Description
Many knowledge gaps	Much of the marine environment is relatively under-explored from a scientific perspective, resulting in a plethora of scientific hypotheses that can be the subject of research. Not all of these are aligned with the immediate or future decision needs of stakeholders in the marine environment.
Multi-disciplinary nature of marine science	The disciplines of scientific expertise that are relevant to studying the marine environment are many and diverse, including various fields of physics, chemistry, biology, ecology and mathematics, as well as the social sciences. Coordinating research in these disciplines to address the identified priorities across the sectors interacting with the marine environment requires a strategic research framework that is owned by industry, government and the research community.
Cost	Conducting marine field research remains a costly exercise and costs in Western Australia are exacerbated by the remoteness of the marine environment, and a relative lack of marine science infrastructure throughout most of the State. As such, investments in research need to be guided by a strategic research framework that identifies priorities and facilitates the efficient allocation of resources to addressing those priorities. This includes directing investments in marine science capability building to areas that support the priorities that are identified by the framework. The implications of high research cost in this regard are exacerbated by a general trend toward decreased government funding for scientific research in Australia.
Diverse participation	There are a large number of diverse public sector organisations that undertake marine scientific research in Western Australia, including a range of universities from across Australia, CSIRO, Department of Parks and Wildlife, Australian Institute of Marine Science, Department of Fisheries, Bureau of Meteorology, the marine science consulting sector and the Royal Australian Navy. A strategic research framework is required to align the activities of these organisations to address priorities where possible.
Private sector capacity	Significant marine science capacity resides in the oil and gas industry and companies servicing that industry. A strategic research framework is required to identify where there is alignment and to present opportunities for collaboration and knowledge sharing within and across sectors.

2. Sector Research Priorities

The knowledge needs discussed in this section represent those that are espoused by the key sectors that interact with the Western Australian marine environment. They represent knowledge that is required to address challenges and opportunities faced by these key sectors and should be the focus of end-user oriented research.

The individual sectors are discussed as follows:

- **Commercial Fishing, Marine Aquaculture, Aboriginal Customary Fishing, Recreational Fishing and Fishing Charter Sectors**
  While the commercial fishing, fishing charter and marine aquaculture sectors are commercial activities, and the Aboriginal customary and recreational fishing sectors represent community interactions with the marine environment, these sectors are discussed together as there is significant commonality in marine science priorities and the regulation of these sectors.

- **Offshore Oil and Gas Sector**
  This section discusses the marine science priorities of the offshore oil and gas industry that is currently concentrated in the North West of the State, but may within the timeframe of this Blueprint expand into other offshore provinces in Western Australia where marine science knowledge is relatively limited.

- **Shipping and Ports**
  This section discusses the marine science priorities of the ports and shipping services that operate along the Western Australian coastline and which are fundamental to Western Australia's export oriented economy.

- **Catchment and Coastal Development and Coastal Communities**
  This section discusses the marine science priorities of sectors that are based on land, but which interact with the Western Australian marine environment including activities in catchment areas, marine tourism, seawater desalination and salt production. It also discusses the marine science priorities of coastal communities and developers and managers of coastal infrastructure.

- **Future Marine Industries**
  This section identifies future and emerging marine based industries in Western Australia and the marine science priorities that are required to underpin the potential development of those industries.

- **Protection and Regulation of the Western Australian Marine Environment**
  This section discusses the marine science priorities of the various government agencies responsible for managing and regulating the Western Australian marine environment and activities that occur within that environment.

2.1. Commercial Fishing, Marine Aquaculture, Aboriginal Customary Fishing and Recreational and Charter Fishing Sectors

Wild marine organisms are harvested from the Western Australian marine environment by the commercial fishing sector, Aboriginal customary fishing practices, recreational fishers and the fishing charter component of the marine tourism sector. The Western Australian marine environment is also the natural resource that supports the State's marine aquaculture sector.

2.1.1. Commercial Fishing Sector

Sector Overview

Commercial fisheries exist along the entire coast of Western Australia in State and Commonwealth waters. The sector has a strong heritage in Western Australia and has historically been a significant contributor to Gross State Product (GSP). Historically, the industry has underpinned the social fabric of several Western Australian coastal communities and has been a significant employer in many of those communities. The current status, trends and key issues facing specific fisheries that comprise the Western Australian commercial fishing sector are discussed in detail in Online Appendix 4.

Consistent with the global trend, the volume of seafood produced by Western Australian fisheries has decreased over the past decade, albeit at a higher rate. As illustrated in Figure 2[10] below, the total volume of seafood produced by the Western Australian fishing industry decreased by 55 percent and the total value of that seafood decreased by 35 percent during the period 2002-03 to 2011-12, with total value increasing in 2012-13.

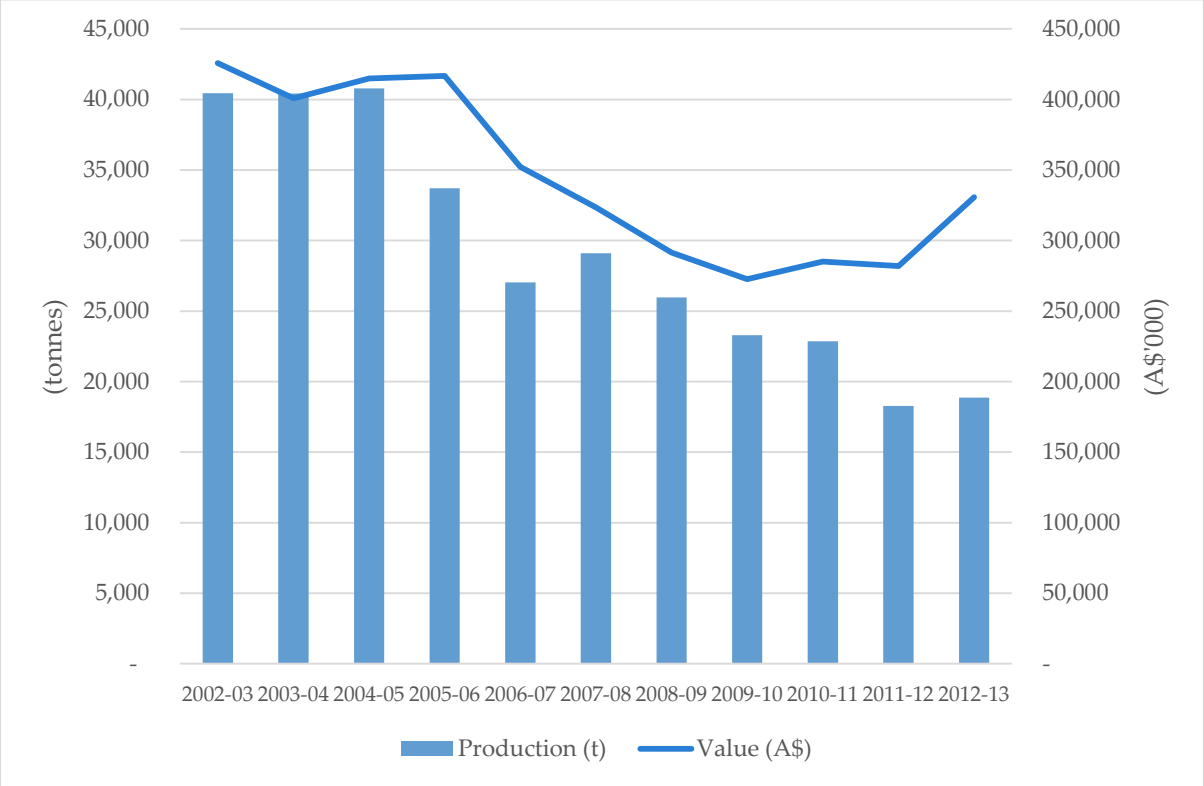


FIGURE 2 – HISTORICAL GROSS PRODUCTION VOLUME AND VALUE – WESTERN AUSTRALIAN COMMERCIAL FISHERIES

Fisheries targeting crustacean species (primarily western rock lobster and prawns) account for approximately 80 percent of the total value of the Western Australian commercial fishing industry, mollusc species (primarily abalone and scallops) 10 percent and finfish species (primarily demersal species) 10 percent[11]. Some of these species have experienced a

[10] Fisheries Research and Development Corporation (2012), *Australian Fisheries Statistics,* Department of Agriculture, Australian Government, Canberra

[11] Fisheries Research and Development Corporation (2012), *Australian Fisheries Statistics,* Department of Agriculture, Australian Government, Canberra

decrease in production due to a regulated decrease in fishing effort in response to physical and biological events and have reduced recruitment levels or affected distributions. The level of scientific understanding of the processes that affect this varies among fisheries.

Western Rock Lobster Fishery

A single species, the western rock lobster (*Panulirus cygnus*), has accounted for an average of 67 percent of the total value of production from the Western Australian fishing industry over the 10 years preceding 2011-12[12]. Despite a significant increase in the unit value of western rock lobster, the value of the fishery decreased from just under A$300 million per annum in 2005-06 to approximately A$170 million in 2011-12[13]. Both production volume and value increased in 2012-13. This is illustrated in Figure 3 below.

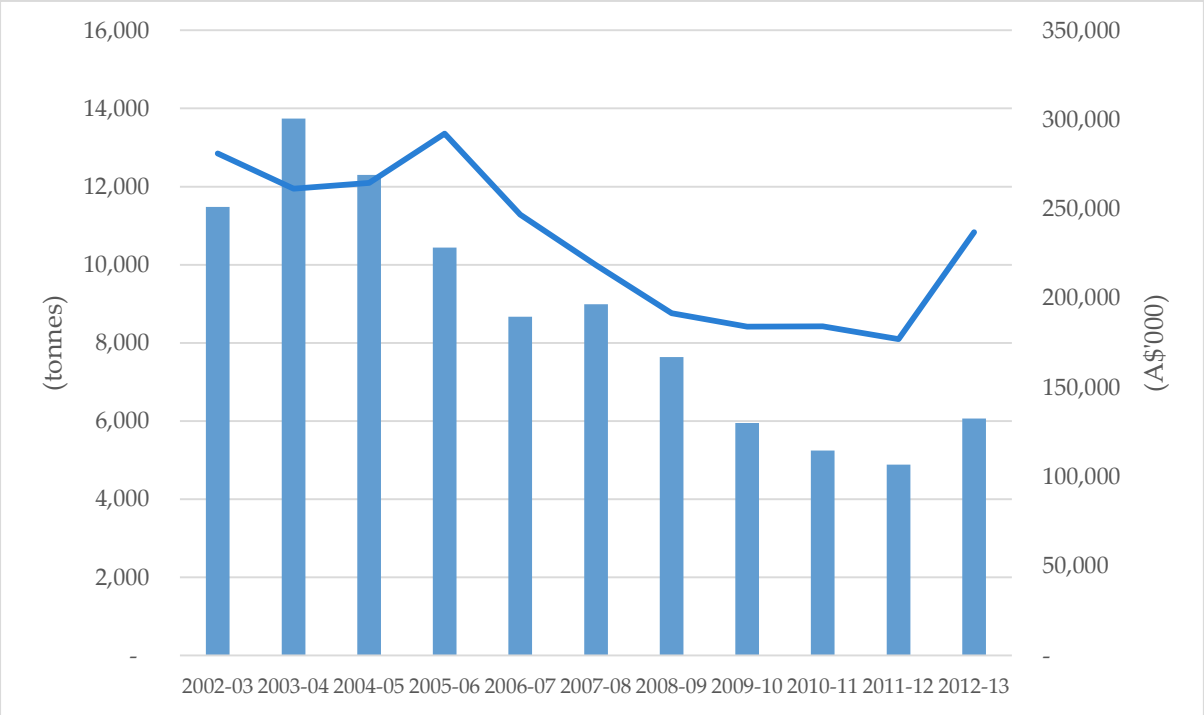


FIGURE 3 – WESTERN ROCK LOBSTER PRODUCTION

The reduction in catch was a direct result of management actions taken to deal with a period of low recruitment that occurred from 2006 to 2009. The combination of improved recruitment in recent years and a shift to quota-based management has seen both the catch and value increase significantly in recent times[14]. The value for 2014 is forecast to recover close to $300 million, but based on a production quota of approximately 6,000 tonnes.

A key factor in determining western rock lobster stocks is the post-larval (puerulus) recruitment. Puerulus recruitment is understood to be affected by a number of factors

[12] Ibid, 11
[13] Australian Bureau of Agriculture and Resource Economics and Fisheries Research Development Corporation, *Australian Fisheries Statistics,* 2002-03 to 2011-12, Australian Government, Canberra
[14] "Less is more for WA lobster fishers", Fisheries Research and Development Corporation, *FISH*, Vol 21 No 2, June 2013, p28.

including strength of the Leeuwin Current and intensity of low-pressure systems generating westerly winds.

Prawn Fisheries

A range of prawn species is caught commercially across Shark Bay, Exmouth Gulf, Onslow, Nickol Bay, Broome and Kimberley prawn fisheries in the North of the State, as well as from the South West Trawl Fishery.

As a result of the reduction in commercial take, together with generally softer prices between 2004-05 and 2009-10, the total value of Western Australian prawn fisheries declined from approximately A$46 million in 2002-03 to approximately A$28 million in 2009-10. As a result of slightly improved volumes and price, the value of the industry improved over the 2010-11 and 2011-12, before both production volume and value declined to their lowest in over decade in 2012-13. This is illustrated in Figure 4[15] below.

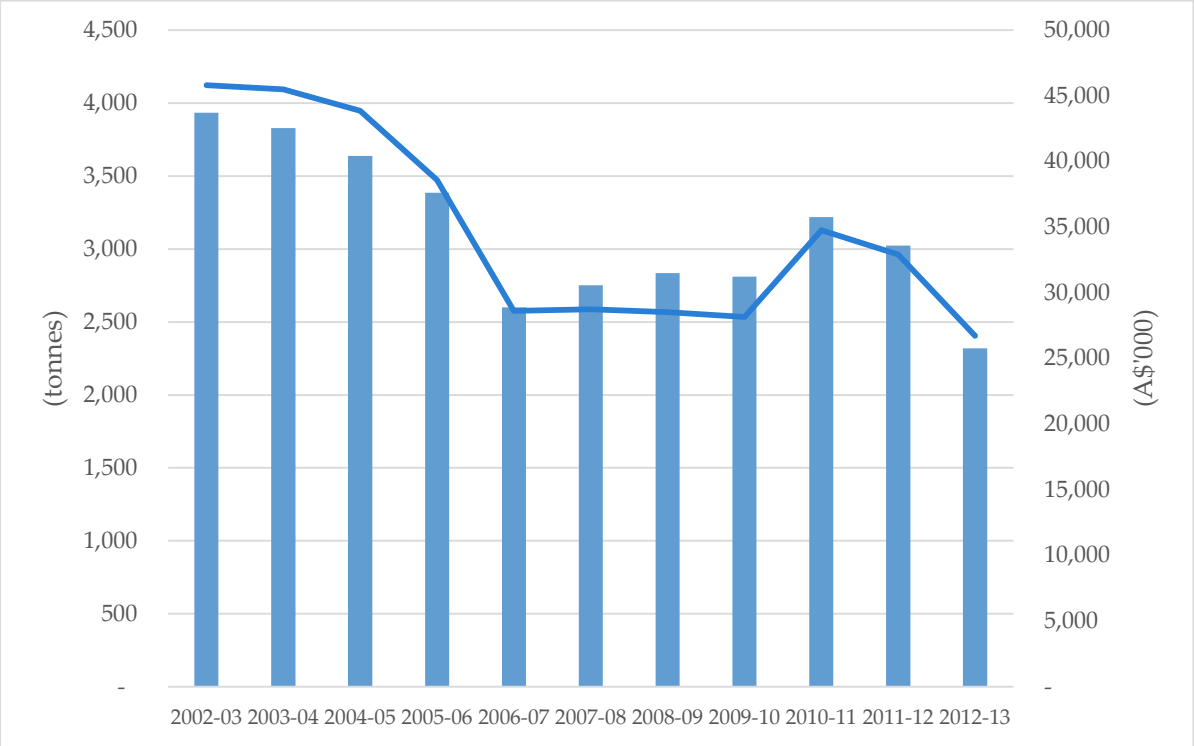


FIGURE 4 – WESTERN AUSTRALIAN PRAWN PRODUCTION

Abalone Fisheries

The target species of the commercial abalone sector in Western Australia are the greenlip (*Haliotis laevigata*), brownlip (*Haliotis conicopora*) and Roe's (*Haliotis roei*) abalone. Greenlip abalone account for an average of 57 percent of the total volume of commercially caught

[15] Australian Bureau of Agriculture and Resource Economics and Fisheries Research Development Corporation, *Australian Fisheries Statistics,* 2002-03 to 2011-12, Australian Government, Canberra

abalone in Western Australia. Brownlip abalone, which is taken from the same fishery account for a further 13 percent and Roe's abalone account for 30 percent[16].

While the volume of Western Australian abalone production has decreased over the past decade, it has, despite the 2010 marine heatwave event, been relatively stable in recent years. However, as a result of market competition and a high Australian dollar, the value of that production has been on a declining trend over the past decade[17].

This is illustrated in Figure 5 below.

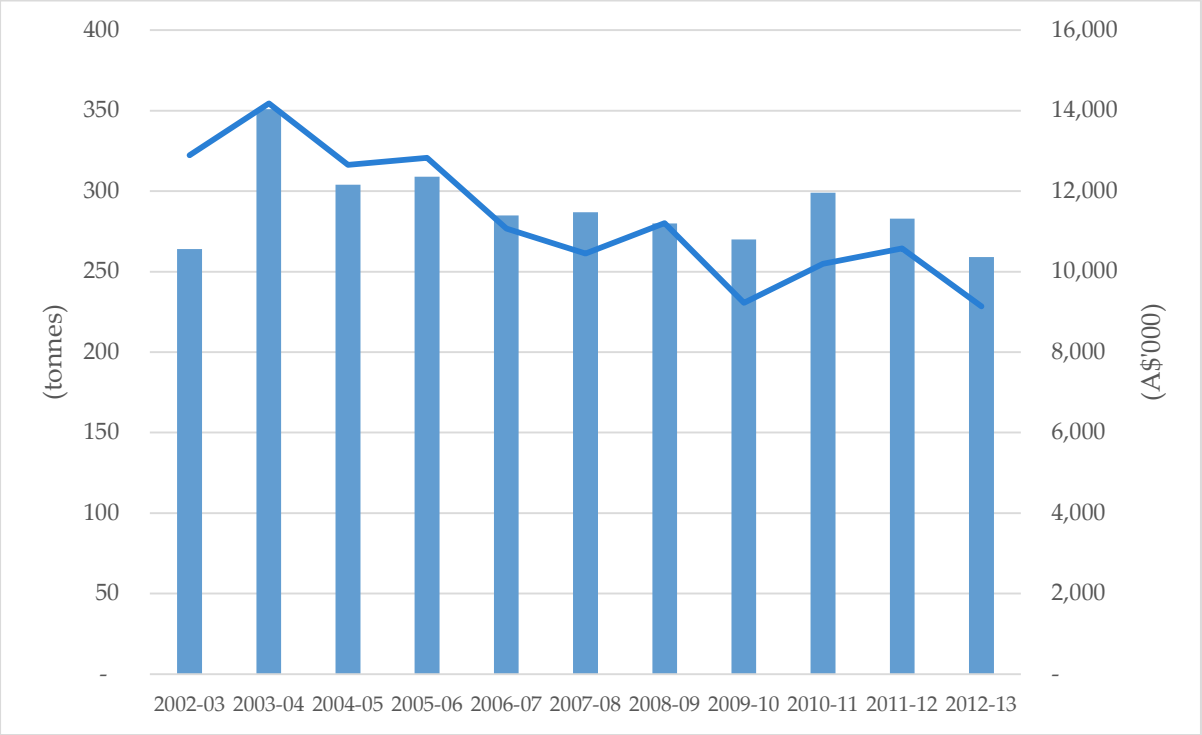


FIGURE 5 – WESTERN AUSTRALIAN ABALONE PRODUCTION

The 2010 marine heatwave event had a significant impact on the smaller Roe's abalone fishery, resulting in closure of operations in Kalbarri. The greenlip and brownlip fishery on the southern coast has also reported slower growth rates since the marine heatwave.

Scallop Fisheries

While several species of scallop can be found off the Western Australian coast, only the saucer scallop (*Amusium balloti*) exists in adequate abundance to support a commercial fishery. Annual production from Western Australian saucer scallop fisheries is highly variable, as the recruitment and distribution of commercially harvestable concentrations of saucer

[16] Department of Fisheries, *State of the Fisheries and Aquatic Resources Reports,* 2005-06 to 2012-13, Western Australian Government, Perth

[17] Australian Bureau of Agriculture and Resource Economics and Fisheries Research Development Corporation, *Australian Fisheries Statistics,* 2002-03 to 2011-12, Australian Government, Canberra

scallops is highly variable year to year and very sensitive to changes in physical, chemical and biological ocean conditions. This is illustrated in Figure 6[18] below.

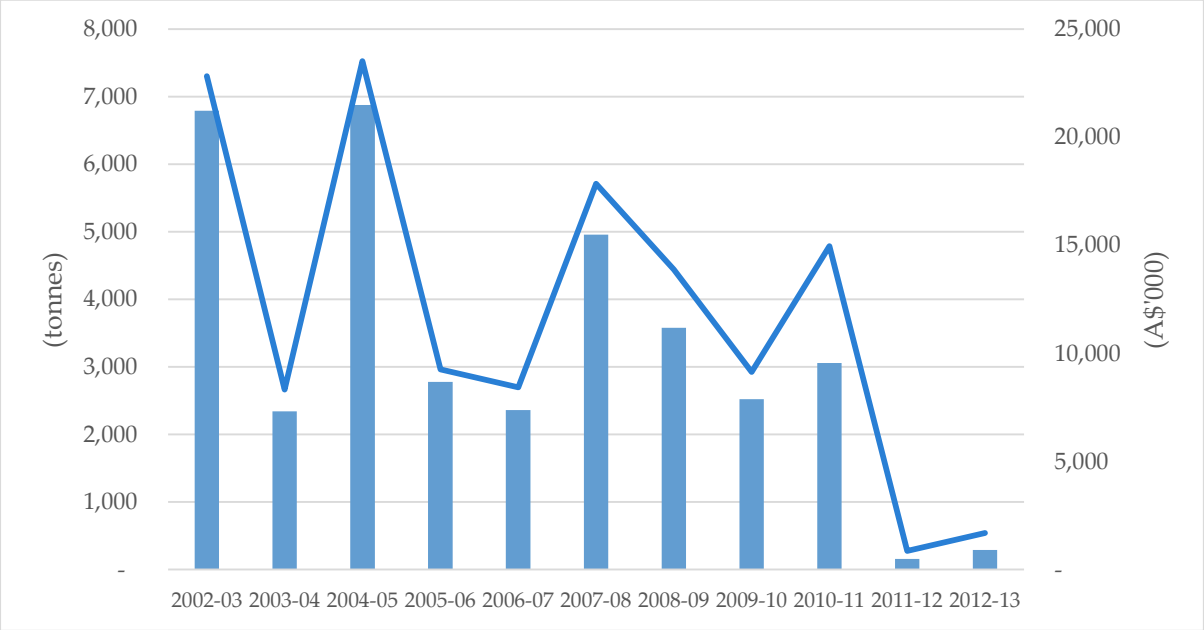


FIGURE 6 – WESTERN AUSTRALIAN SAUCER SCALLOP PRODUCTION

Finfish Fisheries

Finfish that are caught commercially in Western Australia include various demersal, shark, pelagic, near-shore and estuarine and baitfish species. Collectively, demersal species account for an average 60 percent of the value of commercial finfish production[19]. The volume of the commercial demersal finfish catch decreased from a peak of approximately 4,570 tonnes in 2003-04 to just under 2,800 tonnes in 2012-13. Tropical snapper species have consistently accounted for approximately 50 percent of the volume and value of the commercial demersal finfish take during this period[20].

Knowledge Needs

Sector-wide Knowledge Needs

As discussed, the significant decline in the value of the Western Australian commercial fishing industry has been the result of a number of factors. Structured declines that are the result of regulatory intervention are reasonably likely to be able to be accommodated or adapted to by the industry, as industry is typically consulted throughout the decision process that leads to those interventions. Furthermore, reductions can be an industry response to market conditions including the competitive advantage that sustainable production can provide in certain markets.

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[18] Australian Bureau of Agriculture and Resource Economics and Fisheries Research Development Corporation, *Australian Fisheries Statistics,* 2002-03 to 2011-12, Australian Government, Canberra

[19] Fisheries Research and Development Corporation (2012), *Australian Fisheries Statistics,* Department of Agriculture, Australian Government, Canberra

[20] Australian Bureau of Agriculture and Resource Economics and Fisheries Research Development Corporation, *Australian Fisheries Statistics,* 2002-03 to 2012-13, Australian Government, Canberra

However, the possibility of sudden and/or long-term changes in catch that result from factors over which the industry has limited control, such as unexpected changes to key environmental drivers (e.g. water temperature, currents etc), invasive species and/or cumulative impacts on ecosystems from other anthropogenic activity, present a significant ongoing risk to the viability of the industry. New knowledge that leads to a better understanding of the ecosystems that support fisheries and the ability to predict changes to those ecosystems will be increasingly important to risk management in the fishing industry.

Of particular contemporary concern to the commercial fishing industry is the impact of increased marine noise, particularly in the Pilbara region on the distribution and behaviour of target species. While these concerns focus primarily on the impact of seismic noise profiles associated with oil and gas exploration and development, they also include general noise associated with increasing vessel traffic, fixed and floating production infrastructure and subsea infrastructure.

In the longer term, climate change will result in changes to the Western Australian marine environment, such as increased ocean temperature and acidification. This will affect the habitats of commercial species and in some cases, the species themselves. For example, changes in water temperature, may see some tropical species move further south and ocean acidification may increase or decrease the growth rates of invertebrate species. Understanding the impact of these phenomena on the nature and viability of fisheries in the future will assist in investment decisions.

The global growth of aquaculture and trends in community attitudes toward certain commercial fishing practices may mean that volumes in some commercial fisheries will have limited future scope for significant growth. As such, ensuring that these fisheries remain viable in a current or potentially lower future production volume environment is critical. This will require knowledge and technology that improves predictability of the impact of environmental changes, the efficiency of the catch targeting process and operations more generally, particularly in an operating environment which is likely to see major input costs such as diesel increase.

Potential new fisheries, such as a small pelagic fish fishery that can supply low-value fish protein markets in the developing world, may prove to be important future avenues of growth for the industry. New knowledge and technologies that can make existing and new fisheries technically, economically and environmentally sustainable, as well as competitive in global markets now and into the future, will become increasingly important.

As with all sectors of the economy that interact with the Western Australian marine environment, the significant portion of the Western Australian marine environment that is now the subject of marine conservation reserves and parks is of growing concern to the industry. While the portion of this conservation estate that is the subject of sanctuary zones is relatively limited, the impact of potential changes in zoning policy and regulation on the area that can be fished commercially now, and on future fisheries, presents an ongoing risk to the industry. It is also unclear how marine conservation areas affect the productivity of fisheries that close to those conservation areas. In addition, an expanding footprint of offshore resources exploration and development activity, increasing coastal residential and industrial development and increasing recreational boating activity are all potential threats to the industry.

Some species that are targeted commercially such as western rock lobster, demersal finfish, some pelagic finfish and abalone are also popular species among recreational and/or

charter fishers. Ensuring a correct balance between users of the fisheries resource will create an ongoing tension that will increasingly need to be addressed by a deeper understanding of the social, economic and environment factors underpinning that balance (see Section 3). Of particular concern to the commercial fishing sector is that community understanding of fishery resource allocation should be based on this scientific knowledge, rather than emotive issues.

While the analysis in Online Appendix 4 suggests that the State's commercial fisheries have very limited impact on marine ecosystems, public perception of the industry is variable. Ensuring that public perception is based on sound science will be an ongoing challenge for the industry. This is particularly important for sectors that are dependent on trawling systems such as the prawn and scallop fisheries that are more commonly perceived by the wider public to be associated with habitat destruction and non-retained by-catch.

Needs of Specific Fisheries

Some fisheries, such as western rock lobster and in particular, saucer scallops, experience significant annual variation in commercial catch volumes and/or location of commercially harvestable stocks. Future western rock lobster catch is highly predictable four years in advance through the analysis of peurulus recruitment. However, understanding of the issues that affect puerulus recruitment is limited. In the case of saucer scallops, the commercial catch varies dramatically from year to year and even when there is a strong commercial catch, locating commercially harvestable stocks is an inefficient and challenging task. Understanding the physical, chemical and biological ocean systems that affect scallop recruitment and settlement, would greatly improve the productivity of this fishery.

The 2010-11 marine heatwave had a dramatic impact on the Roe's abalone fishery on the west coast, closing operations in Kalbarri. Anecdotally, greenlip and brownlip commercial fishing operators on the South coast are reporting slower growth rates since this event. Understanding the likely frequency and cause of these events would assist in operational planning and long term assessment of the viability of the abalone fishery and could also have broader applications.

Finally, increasing ocean acidification presents a considerable risk to all Western Australia's invertebrate fisheries, which represent the vast majority of value produced by the commercial fishing sector.

Research Priorities

Table 5 below summarises the specific knowledge needs of the commercial fishing sector, together with the key risks and/or opportunities that knowledge will address and areas of scientific investigation that are expected to underpin the acquisition of that knowledge.

TABLE 5 – MARINE SCIENCE PRIORITIES OF THE COMMERCIAL FISHING SECTOR

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
Environmental Impact Assessment and Management	**Marine Habitat and Ecosystems Baselines and Fundamental Science** Enhanced understanding of target species habitat leading to more efficient and effective methods of habitat assessment and an improved understanding of the relationship between marine conservation areas and specific commercial fisheries	Ensuring ongoing sustainable production for the commercial fishing sector through effective management of the ecosystems that support the fishery. Enhanced ability to predict changes in fisheries resulting in improved investment and operating decisions.	High	Ecosystems, species, modelling
	Marine Habitat and Ecosystems Baselines and Fundamental Science Enhanced understanding of the populations of wildlife that interact with the commercial fishing sector to better identify the nature of any risks	Ensuring commercial fishing is not presenting unacceptable risk to wildlife.	High	Ecosystems, species
	Cumulative Impacts on Marine Habitats and Ecosystems Enhanced understanding of the cumulative impacts on the ecosystems that underpin fisheries productivity enabling a better understanding of the impact other marine industries have relative to the commercial fishing sector and the impact of those other sectors on the commercial fishing sector itself	Ensuring ongoing sustainable production for the commercial fishing sector. Enhanced ability to predict changes in the fisheries.	High	Ecosystems
Design and Operation of Marine Infrastructure and Activities	**Productivity** Development of technologies and practices that improve the efficiency of targeting and catching fish.	Ensuring a productive and competitive commercial fishing sector by reducing unit operating costs.	High	Technology, species
	Productivity Enhanced understanding of the timing and impact of climate events, particularly marine heatwaves, on the	Ensuring ongoing sustainable production for the commercial fishing sector. Enhanced ability to predict changes in fisheries	High	Species, metocean, ecosystems

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
	State's fisheries	resulting in improved investment and operating decisions.		
	Productivity Enhanced understanding of the impact of ocean acidification on fisheries targeting invertebrate species and establishing the capability to predict the location and rate of increase in acidification	Ensuring ongoing sustainable production for the commercial fishing sector. Enhanced ability to predict changes in fisheries resulting in improved investment and operating decisions.	Medium	Species, metocean, ecosystems
	Physical Oceanographic Baselines and Fundamental Science Enhanced understanding of oceanographic processes affecting the midwest and Southwest coasts that impact on western rock lobster peurulus settlement that leads to improved predictability of catch	Ensuring a productive and competitive western rock lobster fishery. Enhanced ability to predict changes in the western rock lobster fishery resulting in improved investment and operating decisions.	Medium	Metocean, ecosystems, modelling
	Productivity Development of new product either through new knowledge that leads to the development of new fisheries, or new product from existing fisheries (excluding downstream processing)	Ensuring a productive and competitive commercial fishing sector. Creating pathways for growth of the commercial fishing sector.	Medium	Technology
	Biosecurity Improved technologies and methods for monitoring and managing the impact of invasive marine species including those that originate from anthropogenic activities	Ensuring ongoing viability of the commercial fishing sector.	Medium	Technology, species
	Productivity Development of technologies, methods and/or markets that optimise non-retained by-catch, particularly in the	Ensuring ongoing sustainable production for the commercial fishing sector by minimising its impact on non-target species.	Medium	Technology, markets, species

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
	trawl fisheries	Creating new value for the commercial fishing sector through new products.		
Marine Data Collection, Management and Modelling	**Marine Environmental Monitoring and Modelling** Development of technology and methods that improve the efficiency and effectiveness of monitoring stocks, by-catch, habitats and ecosystems that underpin the productivity of fisheries for the purpose refining stock assessment and supporting management and operational decisions	Ensuring ongoing sustainable production for the commercial fishing sector. Enhanced ability to predict changes in fisheries resulting in improved investment and operating decisions.	High	Modelling, technology
Community Support for the Sector	**Social License to Operate** Enhanced understanding of community attitudes toward the commercial fishing sector and the development of tools to better inform the community on the sector	Ensuring ongoing community support for the commercial fishing sector.	High	Social science

2.1.2. Marine Aquaculture Sector

Sector Overview

There are currently two established marine aquaculture sectors in Western Australia, as well as two emerging sectors. The status, key trends and issues facing the Western Australian marine aquaculture sector in Western Australia are discussed in detail in Online Appendix 5.

While globally wild-capture fisheries production is declining, aquaculture (in the marine and freshwater environment) is the fastest growing animal based food producing sector in the world and currently accounts for approximately 41 percent of global fish production[21]. The Asian region accounts for approximately 90 percent of global aquaculture production[22].

Despite Western Australia's extensive coastline and not insignificant private and public sector investment in the sector, a range of challenges have meant that a diverse marine aquaculture sector of scale is yet to emerge in Western Australia. The two established sectors are the blue mussel (*Mytilus galloprovincialis)* sector, located in Cockburn Sound and the South Sea pearl (*Pinctada maxima)* sector, located on the Pilbara and Kimberley coasts. There is an emerging marine finfish sector comprised of a single commercial sea cage operation growing barramundi (*Lates calcarifer*) in Cone Bay on the Kimberley coast and trials involving temperate species such as mulloway (*Argyrosomus hololepidotus)*and yellowtail kingfish (*Seriola lalandi)* on the Mid West coast (Geraldton). Additionally there is an abalone ranching project under development on the southern coast (Bremer Bay and Augusta).

Aquaculture is also being explored by the Department of Fisheries in collaboration with the Aquaculture Unit at the Challenger Institute as a mechanism for breeding stock for the purposes of restocking species that are targeted by the growing recreational sector.

South Sea Pearl Production

The most established and largest aquaculture sector in Western Australia revolves around the culturing of South Sea pearls. This sector is comprised of several operations on the Pilbara and Kimberley coastline. The value of the Western Australian aquaculture pearling sector has decreased from approximately A$120 million in 2006-07, to approximately A$80 million in 2012[23]-13, primarily as a result of competition in global jewellery markets and the global financial crisis. Indeed, next to western rock lobster it is the second most valuable fishing and aquaculture sector in the State.

Blue Mussel Production

Native blue mussels have been grown in Cockburn Sound for approximately the last two decades and several farms have operated in Fremantle Port Authority waters in Cockburn Sound during that time. Production from these operations is sold exclusively to the local

[21] FAO Fisheries and Aquaculture Department (2012), *The State of World Fisheries and Aquaculture,* Food and Agriculture Organisations of the United Nations, Rome
[22] FAO Fisheries and Aquaculture Department (2012), *The State of World Fisheries and Aquaculture,* Food and Agriculture Organisations of the United Nations, Rome
[23] Australian Bureau of Agriculture and Resource Economics and Fisheries Research Development Corporation, *Australian Fisheries Statistics,* 2002-03 to 2012-13, Australian Government, Canberra

restaurant market. The growth of this sector has been limited by scale restrictions in Cockburn Sound, and the absence of export opportunities for the product. In recent times the sector has also experienced production challenges that are believed to be associated with larger than normal crab recruitment in Cockburn Sound and therefore more juvenile mussels being eaten by the larger number of crabs.

The volume of blue mussels produced from Cockburn Sound has decreased from approximately 750 tonne in 2005-06 to 240 tonnes in 2012-13. The sector currently produces value of approximately $1.0 million[24].

Finfish Production

For the past seven years, Marine Produce Australia has been growing barramundi in a sea-cage system located at Cone Bay, approximately 100 kilometres north of Derby off the Kimberley coast. The current operation is comprised of 16 sea cages with total stock of about 1,400 tons, producing approximately 1,200 tons of barramundi a year under a license for total production of 2,000 tons per year. Most of the harvest is sold as fresh fish to major seafood distributors in capital cities across Australia, who then on-sell the product, primarily to high-end restaurants. This operation is not as yet profitable. However, it is expected that recent Environmental Protection Authority approval to expand operations will facilitate expansion that will deliver the necessary economies of scale.

For the past several years mulloway, followed by yellowtail kingfish sea cage trials have been conducted in Champion Bay adjacent to the Port of Geraldton. These trials have been conducted with a view to establishing a validated production system that can then be deployed on existing aquaculture licenses at the Abrolhos Islands, approximately 80 kilometres off the coast of Geraldton. The principal proponent of these trials is Indian Ocean Fresh Australia, supported by Challenger Institute of Technology, Batavia Coast Marine Institute, Department of Fisheries and Midwest Development Commission. These trials are ongoing.

Greenlip Abalone Production

Ocean Grown Abalone is a joint venture between two wild capture abalone businesses, 888 Abalone and Two Oceans Abalone. The operation involves growing spat at two onshore facilities at Bremer Bay to juvenile abalone and then transferring juvenile stock to an artificial reef at Flinders Bay, Augusta, where the abalone mature to market size and are harvested by divers.

Aquaculture for Marine Species Stock Enhancement

Fish can also be produced by aquaculture systems for the purpose of restocking wild stocks of threatened species or species whose stocks are depleted by recreational or commercial fishing. Trials have been conducted for a number of species by the Department of Fisheries in collaboration with the Challenger Institute including Swan River prawns and black bream (*Acanthopagrus butcheri*) for the Blackwood River. In more recent times, restocking trials have focused on marine species such as mulloway in the Midwest region.

[24] Australian Bureau of Agriculture and Resource Economics and Fisheries Research Development Corporation, *Australian Fisheries Statistics,* 2002-03 to 2012-13, Australian Government, Canberra

Knowledge Needs

It is evident from the discussion in Online Appendix 5 that there is a need to determine whether a marine aquaculture industry in Western Australia is economically viable based on current production technologies. As such the immediate knowledge needs of the sector are those that support this objective.

As a result of Western Australia's comparative regional cost disadvantage, high-value products and/or economies of scale are likely to be key ingredients for commercial sustainability in marine aquaculture production. However, this must be supported by new knowledge that enhances productivity by reducing capital and operating costs so that product from both established and emerging operations remains competitive in local and regional markets.

The ability of current ventures in ocean grown barramundi, yellowtail kingfish and greenlip abalone to develop into sustainable enterprises will be critical in setting a foundation for a marine aquaculture industry in Western Australia. As such, new knowledge generation should be focused on supporting this outcome and creating pathways for growth from this foundation.

There has been some history of community resistance in Western Australia, particularly with sea-cage finfish operations in close proximity to towns. This was illustrated by the Esperance community's resistance to a proposed trial of bluefin tuna ranching near the Recherche Archipelago. It is important that the industry is able to ensure that community attitudes and perceptions are based on science.

Using aquaculture for stock enhancement has the potential to ensure that adequate stocks of species popular among recreational fishers are maintained, underwriting this important pastime for Western Australians (see Online Appendix 12) and relieving the tension between the commercial and recreation sectors, particularly in demersal finfish fisheries (see Section 2.1.4).

Research Priorities

Table 6 below summarises the specific knowledge needs of the marine aquaculture sector, together with the key risks and/or opportunities that knowledge will address and areas of scientific investigation that are expected to underpin the acquisition of that knowledge.

TABLE 6 – MARINE SCIENCE PRIORITIES OF THE MARINE AQUACULTURE SECTOR

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
Environmental Impact Assessment and Management	**Marine Habitats and Ecosystems Baselines and Fundamental Science** Determination of the zone of impact on the marine environment from sea cage operations within established Western Australian marine aquaculture zones and the extent to which the impacts of sea cages, particularly on the seafloor below the cages can be reversed	Ensuring a sustainable marine aquaculture sector and developing a basis for more efficient project approvals processes.	High	Ecosystems, metocean
	Marine Habitats and Ecosystems Baselines and Fundamental Science Development of knowledge that underpins the case for a scaled approach to environmental impact assessment for smaller marine aquaculture project proposals	Basis for a more efficient project approvals process for low impact marine aquaculture projects, leading to sector growth.	High	Ecosystems, metocean
	Marine Habitats and Ecosystems Baselines and Fundamental Science Enhanced understanding of the impact of tropical marine aquaculture on tropical marine ecosystems	Ensuring a sustainable marine aquaculture sector.	Medium	Ecosystems, metocean
	Productivity Identification of new near-shore and offshore locations that are environmentally, economically and socially suitable for the establishment of new marine aquaculture zones	Ensuring a pathway for expansion of a sustainable and competitive marine aquaculture sector.	Low	Ecosystems, metocean, economics, social
Design and Operation of Marine Infrastructure	**Productivity** Development of knowledge that supports and leads to the demonstration of the economic viability of marine aquaculture using established production systems within Western Australian	Ensuring the fundamental basis for a productive and competitive marine aquaculture sector	High	Economics

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
and Activities	marine aquaculture zones			
	Productivity Enhanced understanding of fish health issues associated with the production of particularly barramundi in tropical waters and yellowtail kingfish in temperate waters off the Western Australian coast that lead to efficient preventative management practices and effective treatment	Ensuring a productive and competitive marine aquaculture sector in species that are the focus of current commercial production and trials.	High	Animal health, species
	Productivity Identification of new production systems technology that can be used to enhance the productivity of production within existing Western Australian marine aquaculture zones	Ensuring a productive and competitive marine aquaculture sector by seeking opportunities to reduce capital and operating costs and grow the production base.	Medium	Technology, economics
	Productivity Development of new knowledge that leads to the identification of tropical species suitable to production from marine aquaculture methods	Ensuring a productive and competitive marine aquaculture sector by identifying new species that can potentially be sustainably and commercially grown in existing marine aquaculture zones with scale.	Low	Species, technology, economics
	Productivity Identification and development of new technology that facilitates offshore marine aquaculture in Western Australia	Ensuring a productive and competitive marine aquaculture sector by creating pathways for future growth.	Low	Technology, species, economics
Marine Data Collection, Management and Modelling	N.A.			
Community Support for the Sector	**Social License to Operate** Enhanced understanding of coastal community and other coastal users attitudes towards various types marine aquaculture	Ensuring ongoing community support for the marine aquaculture sector	High	Social sciences

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
	operations in near-shore waters			

2.1.3. Aboriginal Customary Fishing

Sector Overview

Aboriginal people are significant stakeholders in the Western Australian marine environment from a historical, cultural, knowledge and legal perspective. For many Australian Aboriginal cultures, fish and other marine resources have been an important source of food, as well as a key component of many cultural and social practices for thousands of years and remain so today. Furthermore, many coastal areas and features, inshore reefs or marine outcrops, as well as inshore and offshore islands along the Western Australian coast are of significant cultural value to Aboriginal people. The fact that key aspects of the Western Australian marine environment have been so deeply embedded in Aboriginal life for such a long period of time means that significant knowledge pertaining to the Western Australian marine environment resides with Aboriginal people.

Most Aboriginal customary fishing takes place in inshore and coastal waters that are relatively more accessible to customary fishing practices and targets species such as mullet, catfish, tropical snapper, bream, barramundi, mussels, mud crabs, prawns and oysters[25]. While some traditional methods of catching fish such as spear, hand collection and customary traps are still used, these traditional methods have gradually been replaced by modern methods such as nets, traps and lines in most instances. Some customary fishing practices involve harvesting marine resources in protected areas and/or harvesting species that are protected and may otherwise not be taken (see Online Appendix 12).

Despite the importance of the marine environment to Aboriginal people and the knowledge of the marine environment that Aboriginal people possess, data pertaining to Aboriginal customary fishing is scarce. A survey undertaken some 14 years ago suggests that an estimated 37,000 Aboriginal and Torres Strait Islander peoples living in the North of Australia, which is equivalent to 91.7 percent of the Aboriginal and Torres Strait Island peoples living in Northern Australia at the time, fished at least once in 2000-01[26]. This activity is comprised of pure customary fishing (i.e. fish that are taken solely for customary practices), fishing for subsistence, recreational fishing and recreational fishing and/or fishing for subsistence that involves customary fishing.

Knowledge Needs and Research Priorities

There is a need to better understand the nature of customary fishing and its impact. Such an assessment should be led by Aboriginal people and supported by the scientific sector. There is a considerable knowledge resource pertaining to the Western Australian marine environment that resides with Aboriginal people that must be utilised in this assessment, and could bring considerable value to decision-making by other stakeholders in the Western Australian marine environment.

In some remote parts of the coast, it is only local Aboriginal people who consistently interact with the marine environment and as such the only significant body of knowledge pertaining to such areas is Aboriginal knowledge. This is an important resource that can potentially be

[25] Henry and Lyle (2003) IN: Department of Fisheries (2014), *Recreational Fishing Guide,* Government of Western Australia, Perth
[26] Ibid, 25

better harnessed for the management of remote parts of the Western Australian marine environment.

The key knowledge needs pertaining to Aboriginal customary fishing relate primarily to enhanced understanding of Aboriginal marine cultural values and development of a framework to incorporate these values into a standard marine estate management and regulation process. This includes working with Aboriginal groups as a source of knowledge on the marine environment and as a resource to help manage the marine environment. This is discussed further in Section 3.

2.1.4. Recreational and Charter Fishing Sector

Sector Overview

The level of participation in recreational fishing in Western Australia is almost twice the national average, with approximately 740,000 Western Australians, or 33 percent of the State population participating in a recreational fishing activity at least once a year. Western Australia also has the highest per capita recreational vessel ownership of any state or territory in Australia. Online Appendix 12 provides a detailed overview of the status, trends and issues associated with the recreational fishing sector in Western Australia.

The Western Australian marine environment offers a very diverse range of shore and vessel based recreational fishing activities along the entire coastline. Recreational fishers are able to target a wide range of species using different techniques such as line fishing, netting and diving using hand collection or spears. Recreational fishing effort also varies considerably, ranging from handline fishing from a jetty to sophisticated recreational fishers who use fast vessels and technology to effectively target catch.

Size and bag limits apply to recreational fishing for most species. However, because of the extent of coastline in which recreational fishing takes place and the diversity of recreational fishing methods and effort, it is difficult to ascertain the precise size of the recreational catch.

Table 7 provides an estimate of the recreational catch associated with some of the Western Australian commercial fisheries.

TABLE 7 – ESTIMATED RECREATIONAL CATCH FOR SELECTED SPECIES

Fishery	Estimated 2012 Recreational Catch	Percentage of the Total 2012 (commercial and recreational) Catch
Western rock lobster	118 tonne	1.7
Roe's abalone	32 tonne	32.3
West Coat blue swimmer crab	87 tonne	31.8
West Coast near-shore and estuarine	108 tonne	39.0
West Coast demersal scalefish	159 tonne	61.0
Inner Shark Bay scalefish	24 tonne	11.7
Shark Bay blue swimmer crab	1 tonne	0.9
Mackerel fishery	68.1 tonne	17.1
North Coast crab fishery	3.4 tonne	22.1
Greenlip-brownlip abalone fishery	0.03 tonne	Negligible

Recreational fishing also has an important multiplier effect on the State economy. Not only does it support bait and tackle retail, charter boat operations and associated supply chains, it is also a major driver of regional tourism. It has been estimated that the recreational fishing industry directly contributes approximately A$2.5 billion to the national economy each year[27].

Related to the recreational sector is the fishing charter sector, which is also part of the marine tourism sector. It is estimated that the total catch from fishing charters in 2011-12 in Western Australia was 96.6 tonnes of demersal species, which is equivalent to approximately 3 percent of the total commercial demersal finfish take. Fishing charters operate in several fisheries along the Western Australian coast with the West Coast Demersal Fishery accounting for approximately 40 percent of the total take of the fishing charter sector[28] (see Online Appendix 6).

Knowledge Needs

The key knowledge needs of the recreational and charter fishing sectors are those that demonstrate the impact of these sectors on marine ecosystems (so that the sector's relative impact can be assessed, minimised and communicated), managing the impact of a

[27] Ridge Partners (2010) IN: Fisheries Research and Development Corporation (2013), *Australian Fisheries Statistics 2012,* Australian Government, Canberra
[28] Department of Fisheries (2013), *Status Reports of the Fisheries and Aquatic Resources of Western Australia: State of the Fisheries,* Western Australian Government, Perth

growing sector, and rendering recreational fishing more accessible while protecting the important ecosystems that underpin the sector and the interests of other stakeholders in the Western Australian marine environment.

Research Priorities

Table 8 below summarises the specific knowledge needs of the recreational fishing sector, together with the key risks and/or opportunities that knowledge will address and areas of scientific investigation that are expected to underpin the acquisition of that knowledge.

TABLE 8 – MARINE SCIENCE NEEDS OF THE RECREATIONAL FISHING SECTOR

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
Environmental Impact Assessment and Management	**Cumulative Impacts on Marine Habitats and Ecosystems** Enhanced understanding of the likely ecosystem and habitat impact of a growing recreational fishing sector	Ensuring sustainable recreational and fishing charter sectors through understanding and predicting the impact of the growth of these sectors on marine ecosystems	Medium	Ecology
Design and Operation of Marine Infrastructure and Activities	**Marine Habitat and Ecosystems Baselines and Fundamental Science** Evaluation of the utility of Fish Attraction Devices (FADS) and artificial reef technology with respect to enhancing accessibility of recreational fishing and reducing the sector's impact on key natural ecosystems	Ensuring sustainable recreational and fishing charter sectors and facilitating growing recreational and fishing charter sectors by better understanding the impact that FADS and artificial reefs have with respect to the conservation of natural ecosystems and managing a growing recreational and charter fishing sector.	Medium	Ecology
	Marine Habitat and Eco-systems Baselines and Fundamental Science Evaluation and trials of stock enhancement programs for key marine species based on aquaculture production of stock	Ensuring sustainable recreational and fishing charter sectors and facilitating growing recreational and fishing charter sectors through sustainable intervention in the form of stock enhancement.	Medium	Species, ecology
Marine Data Collection, Management and Modelling	**Marine Environmental Monitoring and Modelling** Development of technology and methods that improve the efficiency and effectiveness of monitoring and quantifying the recreational catch, with a specific focus on the non-boat catch	Ensuring sustainable recreational and fishing charter sectors through expanded cost-effective monitoring of catch.	High	Technology, ecology, species
Community Support for the Sector	N.A.			

2.2. Offshore Oil and Gas Sector

Sector Overview

The Western Australian offshore oil and gas sector[29] involves a range of exploration, development and production projects that target and produce crude oil, condensate, liquefied petroleum gas (LPG) and liquefied natural gas (LNG) for export markets, as well as natural gas for the domestic market. A detailed overview of the sector, its status, trends and issues is contained on Online Appendix 7.

While petroleum titles cover a significant area of the Western Australian marine environment:

- All current production activity is focused on the Carnarvon and Bonaparte Basins (with the exception of some very limited production from the Perth Basin);
- All development activity is focused on the Carnarvon and Browse Basin; and
- The vast majority of exploration activity is focused on the Carnarvon and Browse Basin.

This is illustrated by the red boxes in Figure **7** below.

[29] The *Western Australian offshore oil and gas sector* refers to activities in the Western Australian marine environment as defined for the purposes of this Blueprint (i.e. all activities in State and Commonwealth Waters and the EEZ between the Western Australian-Northern Territory and Western Australian-South Australian borders.

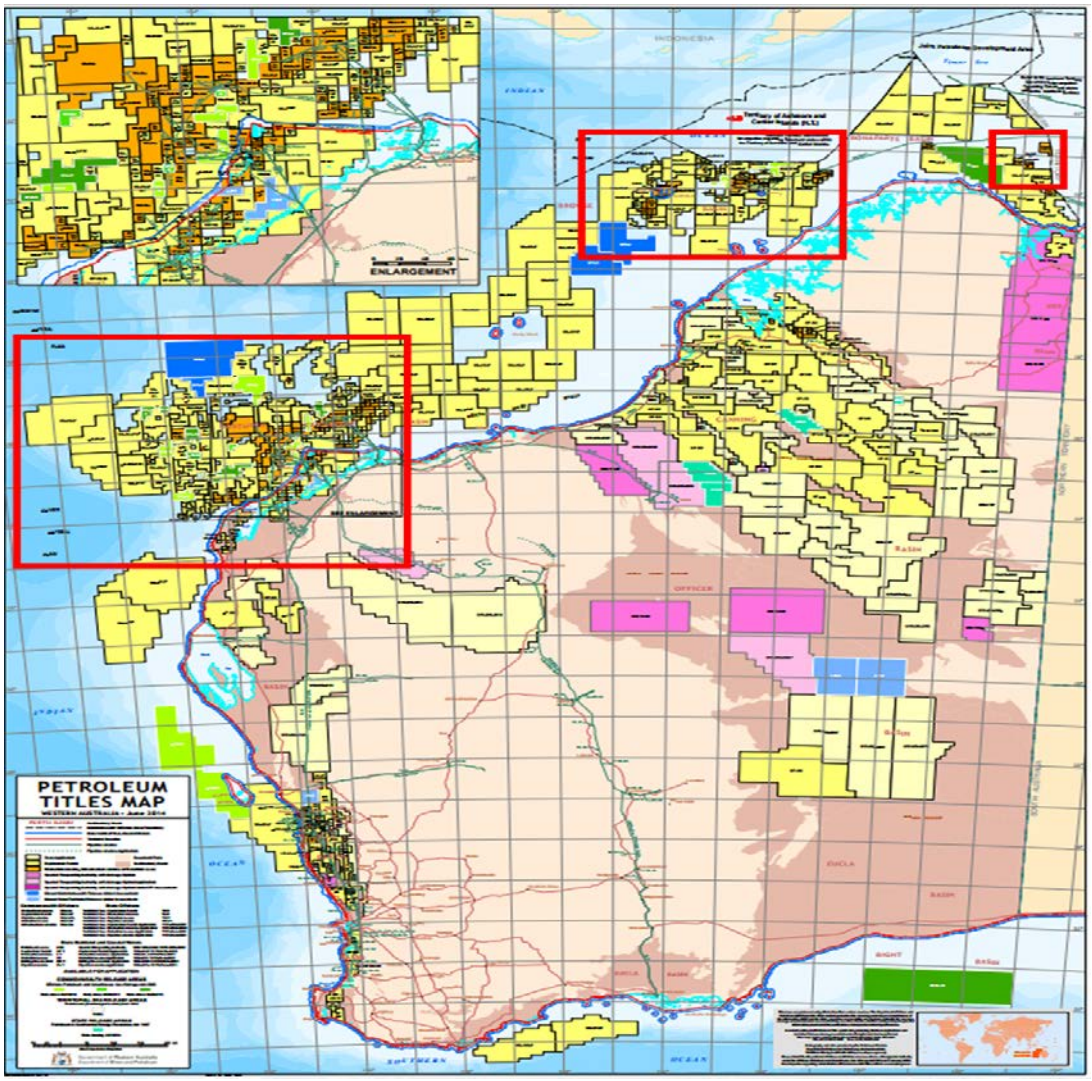

FIGURE 7 - WESTERN AUSTRALIAN PETROLEUM TITLES (JUNE 2014)

CURRENT GAS RESERVES ACROSS THE CARNARVON, BROWSE AND BONAPARTE BASINS ARE ESTIMATED TO BE APPROXIMATELY 157 TRILLION CUBIC FEET OF GAS. APPROXIMATELY 60 PERCENT OF THESE RESERVES ARE IN THE CARNARVON BASIN, 22 PERCENT IN THE BROWSE BASIN AND 17 PERCENT IN THE BONAPARTE BASIN[30]. IN 2013, PRODUCTION ASSETS OFFSHORE FROM WESTERN AUSTRALIA PRODUCED 40.6 MILLION BARRELS OF CRUDE, 36.6 MILLION BARRELS OF CONDENSATE, 7.9 BILLION CUBIC FEET OF LPG, 887.9 BILLION CUBIC FEET OF LNG AND 377.3 BILLION CUBIC FEET OF DOMESTIC GAS. WITH THE EXCEPTION OF 2.2 PERCENT OF THE STATE'S CRUDE PRODUCTION (WHICH WAS PRODUCED FROM A SINGLE ASSET IN THE OFFSHORE PERTH BASIN) AND 6.8 PERCENT OF DOMESTIC GAS (WHICH WAS PRODUCED FROM A SINGLE ASSET IN THE BONAPARTE BASIN AND MARKETED IN THE NORTHERN TERRITORY), ALL OF THIS PRODUCTION WAS SOURCED FROM OFFSHORE ASSETS IN THE CARNARVON BASIN.

Carnarvon Basin

In 2013, 39.7 million barrels of crude was produced from the Pyrenees (BHP Billiton Petroleum), North West Shelf Joint Venture (Woodside), Mutineer/Exeter (Santos), Stybarrow (BHP Billiton), Wandoo (Vermillion), Barrow Island (Chevron), Stag (Apache), Vincent (Woodside), Thevenard Island (Chevron) and Varanus Island (Apache) Projects in the Carnarvon Basin. Approximately 36.5 million barrels of condensate was also produced from the North West

[30] Department of State Development (2013), *LNG in Western Australia: Fact Sheet,* Western Australian Government Perth.

Shelf Joint Venture (Woodside), Pluto (Woodside), Varanus Island (Apache) and Devil Creek (Apache) projects, with the North West Shelf Joint Venture accounting for approximately 90 percent of that production. In the same year 890 billion cubic feet of LNG was produced from the North West Shelf (Woodside) and Pluto (Woodside) projects and approximately 300 billion cubic feet of natural gas was provided to the domestic market by the North West Shelf Joint Venture (Woodside), Varanus Island (Apache), Devil Creek (Apache) and Macedon (BHP Billiton Petroleum) Projects.

There is also a number of new projects currently under construction in the Carnarvon Basin, including Chevron's Gorgon and Wheatstone projects, as well as a number of projects at various stages of planning such as ExxonMobil's Scarborough project.

Browse Basin

Located off the coast of the Kimberley Region of Western Australia, the Browse Basin is currently not in production. However, the Ichthys (INPEX Corporation) and Prelude (Shell) projects are currently under construction and Woodside is scheduled to make final investment decision on its Browse Project by July 2016. ConocoPhillips and PTTEP led projects are actively exploring in the Browse Basin.

Bonaparte Basin

The only production from the Western Australian marine environment in the Bonaparte Basin is from ENI's Blacktip Project, which pipes gas production to an onshore processing facility in Darwin. Other pre-investment decision projects in the immediate region include the Bonaparte Gas Project (GDF Suez and Santos), which is at a pre- Front End Engineering and Design (FEED Phase)) and the Cash-Maple Gas Project (PTTEP).

Future Exploration and Development

While the current focus of the Western Australian offshore oil and gas industry is the Carnarvon, Browse and Bonaparte Basins, it is probable that within the timeframe of this Blueprint other areas of the Western Australian marine environment will become the focus of oil and gas exploration and possibly development and production. Because the current areas of oil and gas industry focus in Western Australia are somewhat underexplored and almost certainly under-developed, it is very difficult to determine when and where future oil and gas operators may turn their focus. The Bight Basin is the focus of some contemporary exploration and it is not unreasonable to expect that activity in the part of the Bight Basin within the Western Australian marine environment will become an area of focus within the timeframe of this Blueprint. The Southern Ocean will present very different physical and biological marine science challenges to those in the North West of the State.

Knowledge Needs

Defining the marine science knowledge needs of the offshore oil and gas sector is complex. Knowledge required to support design, engineering, operational and environmental risk management decisions change as projects transition through the exploration, appraisal, development, construction, operational and completion and decommissioning phases of the project lifecycle. For example during the:

- Exploration phase, the noise profile and environmental considerations of seismic surveys is a key need;

- Appraisal and development phases, the cumulative environmental impact of drilling multiple wells in a locality is a key consideration;
- Design and construction phase, knowledge that informs optimal design specifications that meet operational requirements over time (e.g. mitigate the impact of change water temperature through the column on hydrate formation) and the environmental impact of activities such as dredging or pipeline laying are key considerations;
- Operational phase, knowledge that informs efficient, safe and effective operational and environmental decisions and processes becomes paramount; and
- Completion and decommissioning phase, knowledge that results in competent and desirable completion outcomes at the lowest cost is a focus.

There are also marine science knowledge needs, such as metocean conditions and processes and shallow geotechnical and geophysical knowledge that inform planning and operations required across many, if not all, of the project lifecycle phases discussed above. These knowledge needs inform aspects of design and operations, environmental impacts and oil spill impact assessment and response strategies. Furthermore, the offshore oil and gas industry has an acute need for science outputs in the form of implementable technical solutions or programs that support industry risk management processes, rather than simply collect knowledge.

Knowledge needs also vary according to the nature of operations, which can broadly be defined as pipeline or floating system dependent projects. Pipeline projects deliver hydrocarbons from an offshore production facility such as a platform and associated subsea infrastructure to an onshore processing facility via a subsea pipeline (or network of pipelines) where the processed hydrocarbons are sold into the domestic market and/or exported via petroleum carriers. Floating projects process the hydrocarbons on-board a vessel that is permanently or semi-permanently moored near the production system and unload hydrocarbons to carriers at sea. Obviously, some projects involve elements of both types and the distinction between pipeline and floating projects with respect to knowledge needs is more significant from an engineering perspective than an environmental perspective.

Figure 8 below illustrates this classification for some key current Western Australian offshore projects.

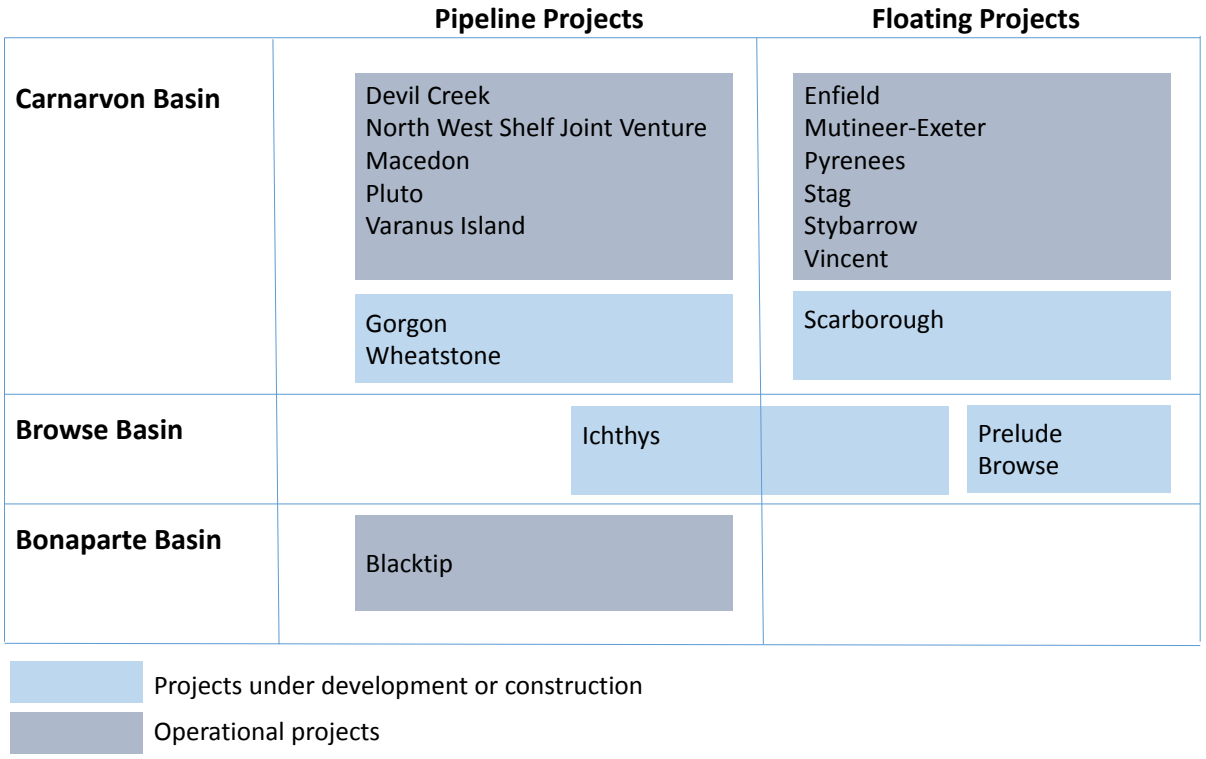

FIGURE 8 – WESTERN AUSTRALIAN OFFSHORE PIPELINE AND FLOATING PROJECTS[31]

Knowledge needs pertaining to pipeline dependent projects primarily revolve around those that inform the structural integrity and environmental impact of fixed offshore infrastructure such as platforms and pipelines. The knowledge needs of floating systems projects primarily revolve primarily around informing operational procedures, such as at-sea loading and the environmental impact of the interaction between the on-board processing systems and the marine environment, including the cumulative impact of multiple facilities in a region. However, as the industry moves to deeper water and more remote locations, understanding of marine environmental engineering inputs to drive economic field development is critical.

It should also be noted that some oil and gas projects involve the development of port infrastructure, including dredging, and are always associated with an increase in vessel traffic in the form of various survey and service vessels and, in some cases, petroleum carriers. The knowledge needs of the shipping and ports sector are discussed in Section 2.3.

Further complicating a definition of key knowledge needs for the oil and gas sector is the fact that the oil and gas industry operates in a different market for scientific services compared to other sectors that interact with the Western Australian marine environment. Unlike the other sectors, the scientific capacity and capability that resides within the oil and gas companies and their service providers is very significant and is the key source of scientific knowledge services for the industry. It is this capability that typically plays the important role of transitioning new knowledge into risk-based processes that in many instances lead to implementable technical solutions or programs.

[31] The Scarborough Project (ExxonMobil/BHP Billiton Petroleum) is not as yet under development, but has been noted in this figure for the purposes of illustrating that FLNG is being considered as the basis of design for future projects in the Carnarvon Basin.

Sector-wide Knowledge Needs

While it needs to be stressed that oil and gas sector knowledge needs are very application specific (and, therefore, very solution specific), industry-wide knowledge needs for the offshore oil and gas industry can be broadly classified according to the following key areas:

- Deeper understanding of the physical ocean environment in which offshore assets are deployed and operated and how this environment may change over time;
- Deeper understanding of the impact of offshore exploration, development and operations, including potential hydrocarbon contamination incidents, on the natural marine environment and other users of the marine estate;
- Options for decommissioning of offshore infrastructure; and
- Management of an ongoing social license to operate.

Before designing and deploying offshore infrastructure, oil and gas companies undertake extensive monitoring and modelling of the physical ocean environment in the immediate vicinity of the development. However, over the medium and longer term, that immediate environment is affected by changes on a regional and global scale, including changes that may be the result of climate change. While regional-scale models for the Carnarvon Basin and to a lesser extent the Browse Basin exist, the spatial resolution and extent of longitudinal data on which these models can be validated and refined is limited. The resulting risk associated with the absence of validation of these largely stochastic models means that designs and operating procedures adopt very conservative approaches which carry a potential productivity penalties including in the form of unnecessary capital expenditure and development timeframes associated with over-engineering and higher operating costs associated with unnecessary operating procedures. Alternatively, the models may prove to be inadequately conservative in the future, requiring further investment to ensure integrity. For example, engineering design standards are typically set to ensure the structure can survive what is understood to be, based on existing data and modelling, a one-in-10,000-year storm event for the location. If the existing data and modelling proves to be overly conservative, the operator will have incurred unnecessary cost. But if the existing data and modelling proves to be optimistic, further investment in the form of reinforcing structural integrity will be required, or the asset will potentially be compromised.

More competent data sets pertaining to all aspects of the physical and metocean environment (thermal structure of the marine environment, waves, swell, currents, eddy currents, solitons, extreme weather events, etc) on a regional scale is required to refine and validate the models that are used for design purposes.. This modelling is also critical to understanding the potential extent of environmental impact of hydrocarbon spills and how to respond to those spills should they occur.

Collecting extensive metocean and marine environmental data is expensive and in some environments can present OHS challenges. The development of remotely operated monitoring equipment that does not require frequent manned intervention is important to the industry for reducing the costs and OHS risk associated with monitoring the marine environment.

Because the horizon of the Blueprint is 2050, issues associated with decommissioning of offshore assets are relevant. As illustrated in Figure 9 below, a number of offshore oil and gas projects in Western Australia will reach, or will be approaching, the end of their expected operational life.

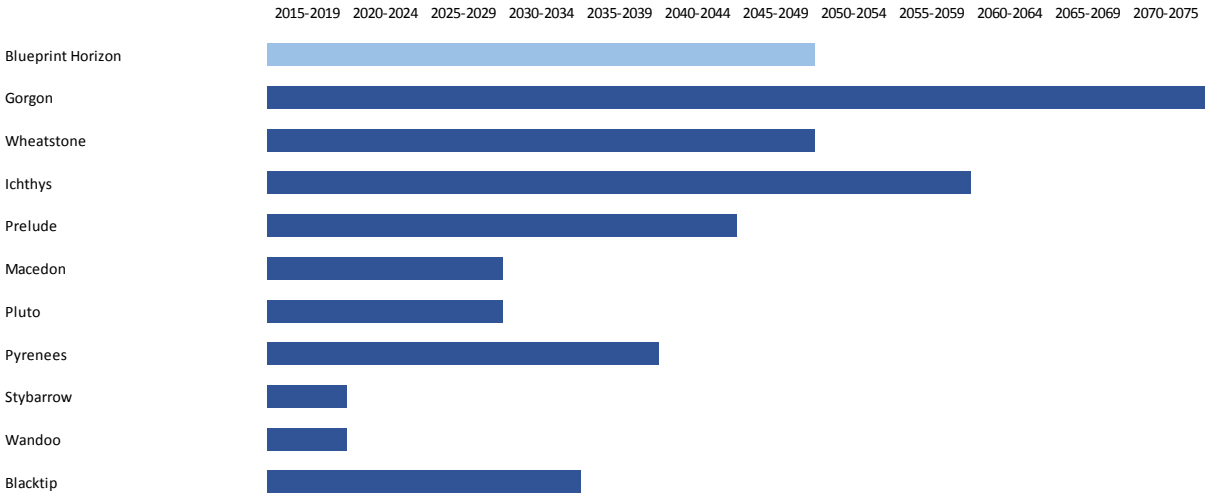

FIGURE 9 – EXPECTED OPERATIONAL LIFE OF SELECTED WESTERN AUSTRALIAN OFFSHORE OIL AND GAS PROJECTS

Ecosystems naturally form around offshore infrastructure, which may have conservation, commercial or social (recreational) value. Removing infrastructure also affects the decommissioning risk profile. Understanding the value of ecosystems that have developed around offshore infrastructure and the risk associated with decommissioning options will become increasingly important for the industry and other stakeholders. Furthermore, it is reasonably common for the expected life of offshore infrastructure to be increased as a result of further utility being identified. New design and environmental impact knowledge will be required to understand the risks associated with extending the life of offshore infrastructure and measures that might be necessary to mitigate those risks.

The physical footprint of the offshore oil and gas industry in Western Australia is small both in the context of the overall WA marine environment and when compared to other offshore oil and gas regions such as the North Sea and Gulf of Mexico. Nevertheless, its activities are the subject of significant focus of the conservation sector and other users. Other industries such as the commercial fishing industry are becoming increasingly concerned with the potential of the oil and gas industry to restrict their access to fisheries, or the impact of the marine noise profile associated with the industry on the productivity of fisheries. Similarly, the oil and gas sector is eager to demonstrate that the cumulative impact of its activities, compared to other pressures, is relatively limited.

There is also a need for the sector to be able to demonstrate, through management and mitigation processes underpinned by robust science that the industry can operate with minimal impact on the Western Australian marine environment and other stakeholders, including the WA community.

Pipeline Project Knowledge Needs

The profile and therefore knowledge needs of pipeline projects is distinct from that of floating projects from two main perspectives. Firstly, there are knowledge needs that pertain to the

design, maintenance and impact of long subsea pipelines that deliver hydrocarbons from the offshore production facility to shore-based processing facilities. Secondly, in the case of LNG projects, there are typically knowledge needs pertaining to the development and maintenance of shipping channels (dredging) that facilitate LNG carrier access to export facilities.

As the projects discussed in Online Appendix 7 are commissioned and further developed, and new projects emerge, the network of long-distance subsea pipelines and shipping channels will become larger. From an engineering perspective, managing issues such as pipeline stability will be paramount. From an environmental perspective understanding the impact of pipelines and channels on ecosystem connectivity, the ecosystems that develop around the pipelines and channels and the management of the dredging process, including dredging spoil will be paramount.

Floating Project Knowledge Needs

Some floating projects will involve pipelines. However, their specific knowledge needs can be distinguished from pipeline projects by the need for knowledge that optimises the effectiveness of at-sea processing and offloading of hydrocarbons.

As discussed in Online Appendix 7, there are numerous FPSO production systems operating in the Carnarvon Basin. In the Browse Basin, new FLNG technology is being deployed at the Prelude project and will likely be the basis of design for the Browse Project. Side-by-side unloading operations associated with FLNG are complex from the point of view that they must be continuous. Furthermore, there is substantially less physical ocean data in the Browse Basin on which predictions pertaining to the operating environment for FLNG can be based.

Both FPSOs and FLNG platforms are, by their nature, dependent on riser technology. Managing the impact of drag on vessel stability caused by fouling of risers will become an increasingly important design and operational challenge.

In all instances, understanding the cumulative impact of the subsea production systems, anchoring systems and on-board processing systems of multiple such facilities in a region will become increasingly important.

Research Priorities

Table 9 below summarises the specific knowledge needs of the offshore oil and gas sector, together with the key risks and/or opportunities that knowledge will address and areas of scientific investigation that are expected to underpin the acquisition of that knowledge.

TABLE 9 – MARINE SCIENCE NEEDS OF THE OFFSHORE OIL AND GAS INDUSTRY

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
Environmental Impact Assessment and Management	**Marine Habitats and Ecosystems Baselines and Fundamental Science** Development of extensive regional marine biodiversity and habitat baseline data along the North West Shelf	Ensuring a sustainable offshore oil and gas sector on the North West Shelf through improved engineering design and operating decisions. Improving the efficiency of project approvals processes.	High	Ecology
	Cumulative Impacts on Marine Ecosystems Development of new knowledge that defines the cumulative noise profile of offshore industry (seismic, shipping and offshore infrastructure) in the North West and determines the impact of that noise profile on key marine ecosystems in the North West Shelf	Ensuring a sustainable offshore oil and gas sector on the North West Shelf and determining the impact of the oil and gas sector on other users of the Western Australian marine environment, particularly the commercial fishing sector.	High	Ecology
	Cumulative Impacts on Marine Ecosystems Enhanced understanding of the cumulative impacts of offshore systems (multiple wells, FPSO and FLNG facilities, pipelines, service vessels etc) operating within a sub-region on marine ecosystems in that sub-region of the North West Shelf through the exploration, development and operational phase, including noise and water quality impacts, potential ecotoxicology etc.	Ensuring a sustainable offshore oil and gas sector on the North West Shelf by determining the cumulative impact of the interaction of concentrated floating systems with the marine environment.	High	Ecology
	Productivity Determining the risk profile, cost benefit and liability issues associated with leaving specific decommissioned infrastructure *in situ*	Ensuring that Western Australia remains a competitive jurisdiction for investing in offshore oil and gas production by creating a pathway around de-risked options and certainty for project completion and decommissioning.	Medium	Ecology, technology, economics, legal, social sciences
	Marine Habitats and Ecosystems Baselines and Fundamental Science	Ensuring a sustainable offshore oil and gas sector on the North West Shelf by determining the cumulative	Medium	Modelling, metocean,

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
	Enhanced understanding of the role that bottom boundary layer currents and seabed mobility play in marine ecosystem connectivity on the North West Shelf	impact of pipeline oriented projects.		ecology
	Marine Habitats and Ecosystems Baselines and Fundamental Science Development of technologies and methods that result in more effective and efficient benthic rehabilitation techniques on the North West Shelf	Ensuring a competitive and sustainable offshore oil and gas sector on the North West Shelf by creating certainty that the sector can cost-effectively restore disturbed benthic ecosystems.	Medium	Technology, ecology
Design and Operation of Marine Infrastructure and Activities	**Productivity** Enhanced understanding of the likely impact of changing water temperature profile in the North West Shelf on hydrate formation in subsea production equipment	Ensuring a productive and competitive offshore oil and gas industry in the North West Shelf through cost effective prediction and management of hydrate formation.	High	Metocean, technology
	Physical Oceanographic Baselines and Fundamental Science Enhanced understanding of bottom boundary-layer current profiles and seabed mobility as inputs to design specifications for subsea equipment and pipelines in the North West	Ensuring a productive and competitive offshore oil and gas industry in the North West Shelf through the development of cost-effective methods for ensuring the integrity of subsea equipment and pipelines.	High	Modelling, metocean, technology
	Productivity Enhanced understanding of the physics and biology of marine fouling in the North West that leads to more effective and efficient management of fouling on subsea equipment, particularly risers	Ensuring a productive and competitive offshore oil and gas industry in the North West Shelf through efficient management of the impact of fouling of subsea risers on floating systems.	High	Ecology, technology, species

	Productivity Enhanced understanding and parameterisation of wind fields around the vortex of tropical cyclones that leads to enhanced design and operational decisions	Ensuring a productive and competitive offshore oil and gas industry in the North West Shelf through better design and more efficient operational decision making in the event of tropical cyclones.	Low	Metocean, technology
	Biosecurity Improved technologies and methods for monitoring and managing the impact of invasive marine species	Ensuring a sustainable offshore oil and gas sector on the North West Shelf by creating certainty that the sector can identify and manage invasive marine species that might be introduced through oil and gas related shipping.	Medium	Technology, species
Marine Data Collection, Management and Modelling	**Marine Environmental Monitoring and Modelling** Synthesis of environmental data associated with dredging and port construction over the past decade and the development of models that can be used to support future projects	Ensuring a productive and competitive offshore oil and gas industry in the North West Shelf through more efficient future project design and approvals processes.	High	Modelling, ecology, metocean
	Physical Oceanographic Monitoring and Modelling Identification of existing and development of new datasets that underpin enhanced certainty in modelling the environmental impact of potential oil-spills in the North West Shelf to underpin future approvals processes and to ensure optimal response to the unlikely event of an oil spill. This includes the development of structures under which data can be share by operators such as the I-GEMS project.	Ensuring a sustainable offshore oil and gas sector on the North West Shelf by creating certainty that the sector can respond effectively to any hydrocarbon spill that might occur on the North West Shelf. A more productive project approvals process.	High	Modelling, ecology, metocean
	Physical Oceanographic Monitoring and Modelling Enhanced resolution in collection of North West regional physical ocean data (water temperature, wave kinematics, salinity, solitons, currents, seabed mobility etc) that lead to greater model certainty for regional oceanographic processes to underpin design and operation of offshore infrastructure	Ensuring a productive and competitive offshore oil and gas industry in the North West Shelf through greater certainty in design criteria and operational decision making.	High	Modelling, metocean, technology

	Marine Environmental Monitoring and Modelling Development of new technologies that improve the efficiency and effectiveness of collecting marine environmental data including the development of automated remote data collection technology	Ensuring a productive and competitive offshore oil and gas industry in the North West Shelf through the ability to cost effectively and safely acquire large volumes of marine data in remote and dangerous environments.	High	Technology
Community Support for the Sector	**Social License to Operate** Enhanced understanding of community attitudes toward the offshore oil and gas sector and the development of tools to better inform the community on the sector	Ensuring ongoing community support for the offshore oil and gas sector.	High	Social sciences

2.3. Ports and Shipping

Sector Overview

The Indian Ocean has become strategically important for energy, bulk commodity and general freight logistics. In congruence with this trend, coupled with increased traffic associated with Western Australia's growing minerals and petroleum production, there has been substantial growth in the frequency of container, bulk commodity and petroleum carrier traffic at Western Australian ports servicing international markets. In the case of the ports of Dampier in particular, there has also been a significant increase in offshore oil and gas service vessel traffic. The status, trends and issues of the ports and shipping sector in Western Australia are discussed in detail in Online Appendix 9.

There is a total of eight main regional ports in Western Australia operated by the Southern, Fremantle, Mid West, Pilbara and Kimberley Port Authorities. These are the Ports of Esperance, Albany, Bunbury, Fremantle, Geraldton, Dampier, Port Hedland and Broome. In addition there are 13 ports operated by other entities on the mainland coast, as well as ports on the Christmas and Cocos (Keeling) Islands. The total number of vessels visiting the main regional ports has grown from approximately 9,400 in 2009 to almost 13,200 in 2013[32]. Approximately 50 percent of this traffic is associated with the Port of Dampier. This is illustrated in Figure 10 below.

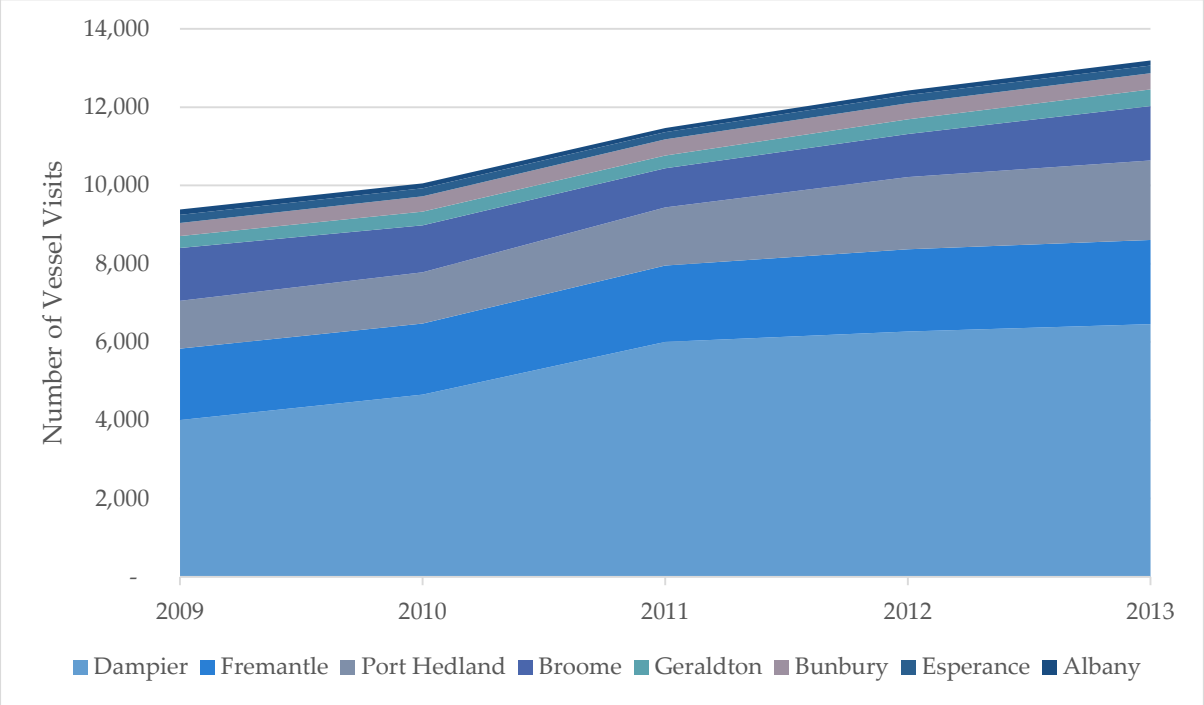

FIGURE 10 – VESSEL CALLS AT MAIN REGIONAL WESTERN AUSTRALIAN PORTS

There is also a number of new ports either under construction or being planned for the Western Australian coastline, including the Port of Ashburton, Port of Anketell and the Oakajee Port and Rail Project. Potential port facilities have also been identified as part of any future development at James Price Point.

[32] Ports Australia (2014)

Knowledge Needs

Because ports exist along the entire coast of Western Australia, each will have specific knowledge needs pertaining to their operations and future development plans. For example, proposed marine reserves have, in the past, encroached on the planned operating area of Anketell Port and the frequency of infra-gravity wave events present operational risks for the ports of Esperance, Bunbury and Geraldton. Nevertheless, there are a number of issues that are common to all ports.

Dredging of navigation channels, particularly with respect to ports in the North of the State is a major management challenge in terms of both cost and managing the environmental impact of the dredging activity and dredging spoil. As the need for dredging increases, alternatives to at-sea dumping of dredge spoil and technologies that mitigate the need for dredging will become increasingly important.

In the case of ports located on the Pilbara coastline, resources project proponents play a key role in the development of channels (dredging) and other port infrastructure that supports their operations. In such cases, the Port Authorities generally work with project proponents to assist and facilitate such developments. Project proponents generate very significant amounts of physical and biological data as a result of these development, much of which is retained as proprietary. There is opportunity to achieve greater efficiencies in port operations and design and approvals for future port projects through the sharing of port development data between the private and public sector.

Increased shipping activity into the Western Australian marine environment substantially increases the risk of invasive species (non-indigenous marine species and pathogenic bacteria or viruses) being carried into the environment and subsequently placing ecosystems, biodiversity and the productivity or viability of other sectors at risk. Statutory responsibility for marine biosecurity lies with the Commonwealth Department of Agriculture, Forestry and Food and the Western Australian Department of Fisheries, with both agencies having powers under their respective legislative jurisdictions for the management of marine pests. Nevertheless, Western Australian ports are required to work closely with these government authorities to monitor and respond to marine pests. As such, the statutory authorities with responsibility for the ports need efficient and effective means of detecting invasive species within port waters and knowledge that can assist them in containing and destroying introduced species.

Finally, a major factor in determining the competitiveness of a port is access to efficient sea-lanes. Increased offshore development and expanding marine parks and reserves, potentially risks diverting sea-lanes and rendering established ports less competitive. Ports need to ensure knowledge exists that supports planning to minimise unproductive disruption to sea-lanes.

Research Priorities

below summarises the specific knowledge needs of the ports and shipping sector, together with the key risks and/or opportunities that knowledge will address and areas of scientific investigation that are expected to underpin the acquisition of that knowledge.

TABLE 10 – MARINE SCIENCE NEEDS OF THE PORTS AND SHIPPING SECTOR

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
Environmental Impact Assessment and Management	**Marine Environmental Monitoring and Modelling** Synthesis of environmental data, including Marine Environmental Quality Data, associated with dredging and port construction over the past decade and the development of models that can be used to support future projects.	Ensuring a knowledge base for more efficient and effective design of new ports and port expansions in the future. More efficient port projects approvals process.	Medium	Modelling, metocean, ecology
Design and Operation of Marine Infrastructure and Activities	**Marine Habitats and Ecosystems Baselines and Fundamental Science** New knowledge that leads to enhanced precision in marine conservation reserve and offshore project boundaries so that the efficiency of maritime connectivity of Western Australian ports is not unduly adversely affected	Ensuring productive and competitive Western Australian ports by maintaining cost effective connectivity to major shipping lanes.	High	Ecology
	Biosecurity Improved technologies and methods for monitoring and managing the impact of invasive marine species	Ensuring a sustainable Western Australian shipping and ports sector by supporting the ability of the ports and other authorities to rapidly and cost effectively detect and manage invasive species	Medium	Technology, species
	Physical Oceanographic Baselines and Fundamental Science Enhanced understanding and predictability of infragravity waves that leads to the development of technology and practices for more efficient and safe operations in ports affected by infragravity waves	Ensuring productive and competitive Western Australian ports that are affected by infragravity waves by creating efficient and safe methods for operating in an infragravity wave environment.	Low	Metocean, technology
	Productivity Development of technologies and port operations practices that reduce the need for extensive dredging	Ensuring productive, competitive and sustainable Western Australian ports by reducing the need for investment in dredging and dredging approvals	Low	Technology

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
	(i.e. floating port systems technology, transhipment technologies etc) and create productive applications for dredging product (i.e. dredged materials)	processes. Sustainable Western Australian ports through reducing the need for dumping dredge spoil at sea.		
Marine Data Collection, Management and Modelling	**Physical Oceanographic Monitoring and Modelling** Enhanced resolution in collection of regional wave, swell and current data that leads to better and more certain predictive wave, swell and current models to support navigation decisions	Ensuring productive and competitive Western Australian ports by optimising navigation pathways to and from Western Australian ports.	Low	Modelling, metocean
Community Support for the Sector	N.A.			

2.4. Catchment and Coastal Development and Communities

As discussed in the introduction to this Blueprint there are several onshore sectors that impact on the Western Australian marine environment. These are discussed in this section.

2.4.1. Development in River Catchments

Although urban and rural development and industry within river catchment areas is not classed as marine industries, they still interact with the marine environment. This interaction is caused by:

- Sediment, nutrient, carbon and contaminants that are produced by development that enter rivers as run-off within the catchment, ultimately entering the marine environment at the discharge point of the river;
- Other waste (plastics, fishing line etc) product that enters rivers, ultimately entering the marine environment at the discharge point of the river; and
- Deliberate diversion of water flows from rivers, which affects the volume and/or location of the discharge.

Compared to many other coastlines around the world, Western Australia has relatively few large rivers that discharge into the marine environment. Indeed, the volume of run-off from Australian rivers as a whole is among the lowest in the world. In Australia, there is an inverse relationship between annual variation in the volume of run-off of a river and the size of its catchment[33].

The main focus of concern with respect to the impact of run-off of sediment, nutrient, carbon and contaminants are river catchments in key agricultural region such as the South Coast, South West and Mid West-Gascoyne Region. There are a number of river systems, particularly the Ord River, Swan-Canning Rivers, Serpentine-Murray-Harvey Rivers and several rivers in the South West of the State in which the catchment is characterised by significant agricultural, mining and urban development leading to relatively high levels of nutrient and other load flowing into estuarine and coastal systems.

In the longer term, a changing climate is likely to result in increasing frequency and intensity of tropical cyclones in the North West of the State, which will bring changes in flooding and river-flow patterns. This, combined with increased development, may impact on near-shore marine ecosystems in the North West. With respect to the diversion of flow, the principal focus is the impact of the diversion of flow from the Ord River Irrigation Area, as well as the many dams located in the South West. Online Appendices 2 and 8 discuss river catchments and associated issues in Western Australia in detail.

Knowledge Needs

The knowledge needs of inland industries that impact on the Western Australian marine environment primarily pertain to those that support their ability to articulate their impact in the environmental impact assessment process (see Online Appendix 3) associated with those projects and manage that impact on an ongoing basis. Some of these knowledge needs

[33] Finlayson, B. and McMahon, T. (1988) 'Australia versus the rest of the world: a comparative analysis of streamflow characteristics', IN: *Fluvial Geomorphology of Australia',* Warner, R. (Ed.), Academic Press, Sydney

also pertain to managers of the marine estate with respect to rectifying historical damage or regulating activity in the future.

Furthermore, there is a need to understand how changes in flooding and river flow patterns that are likely to occur as the result of climate change, combined with increased development in the North West, will impact on near-shore coral reefs and other marine ecosystems in the Pilbara region.

Research Priorities

Table 11 below summarises the specific knowledge needs of sectors that impact on river catchments, together with the key risks and/or opportunities that knowledge will address and areas of scientific investigation that are expected to underpin the acquisition of that knowledge.

TABLE 11 – MARINE SCIENCE NEEDS OF SECTORS THAT IMPACT ON RIVER CATCHMENTS

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
Environmental Impact Assessment and Management	**Marine Environmental Monitoring and Modelling** Development of baseline levels of sediment, nutrient, carbon and contaminant run-off in major Western Australian river systems	Sustainable future development in river catchment areas by creating a baseline on which the run-off footprint of future development can be assessed.	High	Hydrology, chemistry
	Cumulative Impacts on Marine Habitats and Ecosystems Enhanced understanding of the likely impact of reduced rainfall on flows into major Western Australian estuaries, coastal and near-shore ecosystems.	Knowledge on which to base interventions to ensure the maintenance of estuarine, coastal and near-shore marine ecosystems	High	Ecology, hydrology
	Marine Habitats and Ecosystems Baselines and Fundamental Science Development of technologies and methods for enhanced remediation of impacts of legacy sediment, nutrient, carbon and contaminant run-off on major Western Australian river systems and estuaries	Knowledge on which to base interventions that help restore Western Australian estuarine environments that have been affected by historical run-off.	Medium	Ecology, technology, chemistry
	Cumulative Impacts on Marine Habitats and Ecosystems Enhanced understanding of the likely impact of abstraction from rivers on estuarine and coastal environments in Western Australia, including impacts on biodiversity and threatened species	Sustainable future development in river catchment areas through the ability to predict the estuarine, coastal and near-shore impact of abstraction from rive systems.	Medium	Hydrology, ecology
	Cumulative Impacts on Marine Habitats and Ecosystems Further understanding of the impacts of sediment, nutrient, carbon and contaminant run-off on estuarine, coastal and near shore ecosystems in Western Australia	Sustainable future development in river catchment areas through the ability to predict the cumulative impact of activity on estuarine, coastal and near-shore ecosystems.	Low	Ecology, chemistry

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
Design and Operation of Marine Infrastructure and Activities	N.A.			
Marine Data Collection, Management and Modelling	**Marine Environmental Monitoring and Modelling** Synthesis of existing data and the development of new data that underpins modelling of the expected sediment, nutrient, carbon and contaminant loading that is likely to result from agricultural and urban development in major Western Australian river systems	Sustainable future development in river catchment areas through the ability to predict the impact of that development on estuarine, coastal and near-shore marine environments.	Medium	Modelling, metocean
Community Support for the Sector	N.A.			

2.4.2. Other Inland Industry Interactions

Approximately 55 percent of Perth's fresh drinking water is supplied by two municipal seawater desalination plants that have been commissioned over the past decade. The Perth Seawater Desalination Plant located in Kwinana draws intake water from Cockburn Sound and discharges concentrated brine back into the Sound. The Southern Seawater Desalination Plant located at Binningups draw water from and discharges brine into the Indian Ocean off Binningup Beach. Reverse osmosis seawater desalination plants are also being increasingly used to supply fresh drinking water to northern coastal towns such as Karratha and Onslow, where populations are expected to grow in response to new resources projects in the vicinity of those towns.

The other main onshore industry interaction is salt production. Salt is produced through evaporative production systems on the Western Australian coast at Port Hedland, Dampier, Lake McLeod and Useless Loop.

As far as the scope of this Blueprint is concerned, the main focus of knowledge needs pertaining to seawater desalination is the environmental impact of the seawater intake and brine discharge systems. With respect to salt production, the main knowledge needs pertain to the environmental impact of the onshore coastal evaporation systems.

The seawater desalination and salt production sectors are discussed in detail in Online Appendix 8.

2.4.3. Coastal Communities and Infrastructure

Sector Overview

Western Australia has a largely coastal population. Approximately 90 percent of the Western Australian population resides in the South West, including the greater Perth metropolitan area, Peel, South West and Great Southern regions.

Over the 15-year period between 1990 and 2004, the residential population of Western Australia grew by 25 percent from 1.6 million people to 2 million people. Over the decade since 2004, the Western Australian population has increased by a further 25 percent to 2.5 million people, as the rapidly expanding resources industry has driven net interstate and international migration into Western Australia[34]. The population of Perth alone has grown from approximately 1.5 million people in 2004 to 1.9 million in 2013[35].

Approximately 75 percent of Western Australians reside in the coastal capital, and 62 percent of the population in regional Western Australia reside in Local Government Areas with coastal boundaries. Like Perth, the population of these areas has grown over the past decade, from just under a total of 300,000 residents in 2004 to approximately, 375,000 residents today[36].

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[34] Australian Bureau of Statistics (2013), *Australian Demographic Statistics, December 2013,* Cat. 3101.0, Australian Government, Canberra

[35] Australian Bureau of Statistics (2014), *Regional Population Growth,* Cat. 3218.0, Australian Government, Canberra

[36] Australian Bureau of Statistics (2014), *Regional Population Growth,* Cat. 3218.0, Australian Government Canberra,

Within this regional coastal population, the majority of residents live in the main coastal towns. In 2013, approximately 37 percent of Western Australia's regional population resided in the main coastal towns of Albany, Busselton, Bunbury, Geraldton, Karratha, Port Hedland and Broome[37] and the population of most of these towns is expected to continue to grow

This increase in population has driven an increase in the number of new residential dwelling approvals in the State. Indeed, approximately 42,000 more new homes have been approved in Western Australia over the past decade compared to the previous decade[38]. While the greatest growth in new dwelling construction has been in Perth, new dwelling construction has also increased in regional Western Australia.

Coastal infrastructure that supports these growing communities include beachfront residential and commercial property developments, residential canal developments such as those in and around Mandurah, and recreational marinas. Indeed there are currently 25 coastal recreational marinas along the Western Australian coastline.

The impacts of this coastal community on the Western Australian marine environment include coastal infrastructure, concentration of leisure and cultural interactions with the marine environment, marine oriented enterprise and urban waste.

A detailed analysis of the status, trends and issues associated with coastal development in Western Australia is contained in Online Appendix 11.

Knowledge Needs

Scientific knowledge pertaining to growing coastal communities and associated infrastructure is required primarily by local governments to support their planning activities and infrastructure maintenance decisions, by developers to support design of coastal infrastructure, by regulators of coastal infrastructure such as the Department of Transport which regulates most of the small marinas along the Western Australian coastline, and by managers of the coastal marine ecosystems such as the Department of Parks and Wildlife.

A key knowledge requirement is oceanographic modelling and inputs to that modelling that allow these stakeholders to predict the nature and impact of events such as inundation, sedimentation and erosion on coastal infrastructure.

Because a significant portion of this coastal development revolves around estuary environments, particularly the Swan-Canning and Peel estuaries, understanding the impact of this development on the health of the estuarine environment is paramount. For developments along the coast, including marinas, understanding their impact on the transportation of sediment and seaweed along the coast is also important, as is their impact on coastal erosion.

Of similar importance is understanding the likely impact of rising sea levels that result from climate change on coastal inundation to inform coastal planning and infrastructure planning.

Local shires also need to understand the social, environmental and economic values that their constituents ascribe to the coastal environment in order to make effective decisions

[37] Australian Bureau of Statistics (2014), *Regional Population Growth,* Cat. 3218.0, Australian Government, Canberra

[38] Australian Bureau of Statistics (2014), *Building Approvals Australia,* Cat. 8731.0, Australian Government, Canberra

that impact on those values. A contemporary issue for local governments is the development of clear delineation of liability and rights with respect to protecting coastal infrastructure among stakeholders in that infrastructure.

Research Priorities

Table 12 below summarises the specific knowledge needs of coastal development, together with the key risks and/or opportunities that knowledge will address and areas of scientific investigation that are expected to underpin the acquisition of that knowledge.

TABLE 12 – MARINE SCIENCE NEEDS OF COASTAL DEVELOPMENT

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
Environmental Impact Assessment and Management	**Marine Habitats and Ecosystems Baselines and Fundamental Science** Enhanced understanding of the hydrodynamics and ecosystems function of estuarine environments that leads to improved planning and management of the impact of development on those environments	Knowledge that underpins improved sustainability of coastal development.	Medium	Ecology, hydrology
	Cumulative Impacts Enhanced understanding of the cumulative impact of anthropogenic activities and natural events on estuarine and coastal environments	Knowledge that underpins improved design of coastal infrastructure and management of community and economic interactions with the marine environment in coastal communities.	High	Ecology, hydrology
Design and Operation of Marine Infrastructure and Activities	**Productivity** Determination of the respective legal liability and rights of local shires, State Government, freehold tile holders and project proponents with respect to taking pre-emptive or reactive measures to mitigate or manage the impact of coastal inundation, erosion and/or sedimentation	Improved efficiency and effectiveness in decision-making pertaining to implementation of actions in response to coastal inundation, erosion and/or sedimentation, or to mitigate coastal inundation, erosion and/or sedimentation.	High	Legal
	Productivity Enhanced understanding of the long-term impact of changing peak sea level, long-period waves, decadal tides etc on specific categories of coastal infrastructure	Knowledge on which the design of maintenance and redevelopment plans for coastal infrastructure can be based and implemented.	Medium	Technology
Marine Data Collection, Management and Modelling	**Physical Oceanographic Monitoring and Modelling** Enhanced resolution in collection of regional physical ocean data that lead to greater model certainty in risks of coastal inundation, erosion and sedimentation (including establishing a platform for data sharing across coastal local	Knowledge that underpins improved design of coastal infrastructure and on which the design of maintenance and redevelopment plans for coastal infrastructure can be based and implemented.	High	Modelling, metocean

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
	government areas)			
Community Support for the Sector	**Social Licence to Operate** Enhanced understanding of the social (cultural and recreational), economic and environmental values that communities attribute to specific coastal environments along the Western Australian coastline	More informed decision-making with respect to investments in, design of and management of public coastal infrastructure.	Low	Social

2.5. Future Industries

The Blueprint has identified a number of emerging and future potential industries that have the potential to exhibit significant interaction with the Western Australian marine environment. These include marine bio-prospecting, ocean energy and subsea mining.

Marine Bioprospecting

Marine bio-prospecting refers to the systematic search for, and development of, new sources of chemical compounds, genes, micro-organisms and other valuable products from the natural marine environment.

Perceptions as to the prospectivity of Western Australia's marine biodiversity vary. Protagonists argue that the fact that the source waters of the Leeuwin Current are influenced by the Indonesian Throughflow, which passes through areas of South East Asia home to highly concentrated and immense marine biodiversity (see Online Appendix 2). This, combined with the relatively under-explored nature of much of Western Australia's marine environment, suggests that there is likely immense marine biodiversity that could be the source of new useful biological products. However, sceptics argue that it is likely that the economics of marine bio-prospecting in Western Australia will prove less attractive than other regions of the world that demonstrate much higher marine biodiversity densities, such as many parts of the Asian marine environment.

Regardless, the absence of legislation to facilitate intellectual property rights that might arise from bio-prospecting is often cited as the reason why there is limited marine bio-prosecting activity in Western Australia. It is unlikely that any investment in this area will eventuate until there is a clear pathway for the establishment of intellectual property rights associated with discoveries.

Ocean Energy

Ocean energy includes tidal, wave and ocean thermal energy and may also include wind energy that is harnessed from marine-based wind turbines. The total tidal kinetic energy on average at any one time on the continental shelf adjacent to Western Australia accounts for approximately 60 percent of the total in Australian waters[39]. The North West Shelf in particular has significant kinetic energy density, potentially rendering areas within the North West Shelf suitable for deployment of tidal energy generation systems. However, the South West coast has potential for the application of wave energy systems.

The temperature difference that exists through the water column as a result of the sun's solar radiation heating surface waters creates thermal energy that can be converted into electrical energy through ocean thermal energy converters. Sharp differences in water temperature which occur in deeper parts of the North West ocean environment may be suitable for harnessing ocean thermal energy.

Ocean-sourced renewable energy has not historically been a major focus of investment in Western Australia, primarily as the result of the relative capital and operating cost benefits associated with many terrestrial renewable resources such as wind, solar and tidal and the

[39] Geoscience Australia (2010), *Australian Energy Resource Assessment, Geoscience Australia,* Canberra

immediate suitability of many parts of Western Australia for particularly wind and solar generation.

Subsea Mining

Subsea mining involves extracting non-petroleum minerals from ocean mining sites that are usually located around large areas of polymetallic nodules, manganese crusts or active and extinct hydrothermal vents, which create sulphide deposits that can contain a range of metals. Given the cost of subsea mining compared to terrestrial mining, particularly in a minerals rich province such as Western Australia, the economic viability of subsea mining is likely to be some time away.

Marine Tourism

Marine tourism includes a wide range of tourist activities that interact with the marine environment. Currently, the segment of the marine tourism sector that has the greatest impact on the Western Australian marine environment is charter fishing, which is discussed in Section 2.1.4.

There are numerous other segments of the marine tourism sector that interact with the Western Australian marine environment including diving charters, whale watching, coastal cruises, coastal holidaying and coastal trekking and camping. Indeed, Western Australia's pristine beaches and oceans are frequently cited as a major tourism asset.

While not future industries as such, the relatively innocuous impact of these activities and their current small scale means that they currently don't have significant knowledge needs. However, within the timeframe of this Blueprint it is foreseeable that they may grow in scale to the extent that a deeper understanding of the cumulative impacts of these activities needs to be better understood.

Knowledge Needs of Future Industries

The knowledge needs of the potential future new marine industries in Western Australia are still emerging and as yet unclear. Stakeholders have identified that the priority is broadly to establish foundation physical, biological and economic knowledge that will underpin a better understanding of the viability, opportunities and challenges that these industries might face in Western Australia.

It is envisaged that the development of this foundation knowledge will lead to a clearer science plan for these emerging industries before the next review of the Blueprint.

Research Priorities

Table 13 below summarises the specific knowledge needs of potential future Western Australian marine industries, together with the key risks and/or opportunities that knowledge will address and areas of scientific investigation that are expected to underpin the acquisition of that knowledge.

TABLE 13 – MARINE SCIENCE NEEDS FOR POTENTIAL NEW MARINE INDUSTRIES IN WESTERN AUSTRALIA

Potential Future Industry	Foundation Knowledge Need	Relative Priority	Primary Area of Research	Other Relevant Areas of Research
Marine Bio-prospecting	**Productivity** Identification of specific high value compounds for which the Western Australian marine environment might be more prospective than other regions	Medium	Species	
	Productivity Development of technologies that might lead to rapid identification of such compounds	Medium	Technology	
Ocean Energy	**Physical Oceanographic Monitoring and Modelling** Enhanced resolution in collection of regional physical ocean data (water temperature, wave kinematics, salinity, solitons, currents etc) that lead to greater model certainty for the identification of suitable locations for future offshore energy infrastructure	Medium	Modelling	Metocean
	Productivity Analysis that leads to a deeper understanding of the economics and competitiveness of ocean energy in the Western Australian energy generation mix, or as a source of project specific energy demand	High	Economics	Ecology
Subsea Mining	**Productivity** Preliminary analysis of subsea prospectivity for specific minerals within the Western Australian marine environment leading to resource estimates	Low	Geoscience	

Productivity Assessment of the suitability of current subsea mining technology for offshore Western Australia	Low	Technology	
Productivity Assessment of the economic, social and environmental sustainability of a potential future subsea mining industry in Western Australia	Low	Economics	Social, Ecosystems

3. Conservation, Protection and Regulation of the Western Australian Marine Environment

All of the sectors discussed in Section 2 of this Blueprint undertake initiatives to conserve a variety of marine environmental values and to ensure that their marine based activities are sustainable. However, it is the government sector that has primary responsibility, and ultimate accountability, for ensuring marine environmental function, services, species and biodiversity are conserved and appropriately managed, and that the community's expectations for a clean and healthy ocean are met.

The State and Commonwealth Governments manage the conservation of the Western Australian marine environment through three principal mechanisms:

- **Conservation of the Marine Environment**
  This involves ongoing research, monitoring and adaptive management of the Western Australian marine environment to understand marine biodiversity and the function of marine ecosystems, and to take action to conserve important marine environmental and biodiversity values. This includes a Western Australian network of Commonwealth and State marine parks and reserves, gazetted protected species that are actively managed by conservation authorities and formal fisheries management arrangements that deliver ecologically sustainable outcomes including the conservation of fish and their habitats.

- **Development Project Approvals Process**
  This revolves around legislated requirements for planned developments that impact on the marine environment to be formally assessed. There is a requirement for development projects that have the potential to have a significant impact on the marine environment to be referred to the Environmental Protection Authority (EPA), which may then assess the project based environmental review documents produced by the project proponent. Projects for which a significant environmental impact has not been identified are still assessed for potential environmental impact by various government agencies in accordance with jurisdiction and legislative requirements.

- **Regulation of Activities that Intersect with the Marine Environment**
  Regulations that are administered and enforced by a range of agencies based on their legislative jurisdiction covering the range of commercial, leisure and cultural activities that are undertaken in the marine environment.

Informing the development and implementation of policies, management plans and regulation that give effect to these mechanisms is a marine environmental monitoring and scientific research function that is undertaken by various government agencies such as the Department of Parks and Wildlife and Department of Fisheries and supported by external research providers such as universities and Commonwealth research agencies. Education and communication programs ensure wide stakeholder awareness of the conservation, protection and regulation framework and its rationale.

In the context of a significant management portfolio and limited resources, and in the face of scientific uncertainty, government agencies are increasingly adopting a combination of evidence-based and risk-based approaches to managing the marine environment. This

involves using the best available knowledge to identify key risks to the marine environment, understanding the causes of those risks, the potential extent and severity of impact associated with each risk and best methods to mitigate the risk and/or address its impact. Marine science can provide the critical knowledge required to underpin and inform risk-based approaches to environmental management and regulation. It also underpins continual improvement through the design of targeted environmental monitoring programs, interpreting the results and applying the lessons learnt through feedback loops built into these regulatory and management frameworks.

3.1. Conservation of the Marine Environment

The State and Commonwealth governments protect representative aspects of the Western Australian marine environment through declaration and management of the Western Australian marine conservation estate. This estate is comprised of a network of Commonwealth and State marine parks and reserves. In addition, gazetted protected species and targeted fish species that may occur anywhere within the Western Australian marine environment are actively managed and protected. There is also a comprehensive suite of fisheries management arrangements that contribute to the conservation of aquatic resources within an ecologically sustainable development framework.

3.1.1. Western Australian Marine Conservation Estate

A comprehensive, adequate and representative marine reserve system plays a pivotal role in conserving marine biodiversity. Marine parks and reserves are created to represent the animals, plants and ecosystems in each marine bioregion. They are areas of the marine environment where integrated management frameworks are applied to conserve some areas in their natural state, providing key locations for science, tourism, recreation and wildlife and nature appreciation, while allowing sustainable use of marine resources in other areas. Off the Western Australian coast, marine parks and reserves have been declared by both State and Commonwealth governments.

Approximately 30 percent of the North West Marine Bioregion and 40 percent of the South West Marine Bioregion are the subject of Commonwealth Marine Reserves. There are a total of 23 Commonwealth Marine Reserves off the Western Australian coast. Of these 23 reserves, 19 are new (declared in 2012) and four are existing Commonwealth Reserves.

Figure 11 below illustrates the location of Commonwealth Marine Reserves in the North West and South West Bioregions.

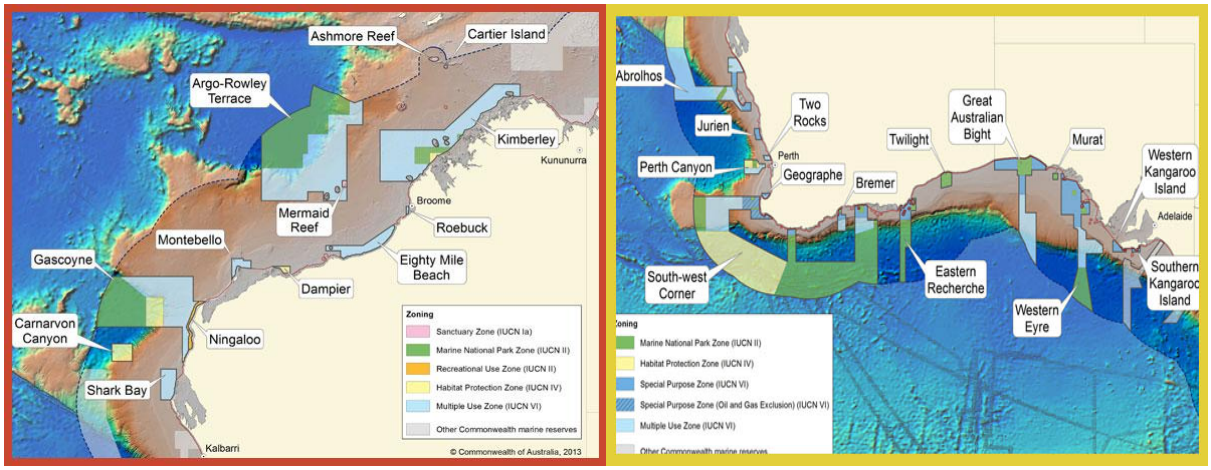


FIGURE 11 – LOCATION OF COMMONWEALTH MARINE RESERVES OFF THE WESTERN AUSTRALIAN COAST

Western Australian Government marine conservation areas are categorised as marine nature reserves, marine parks or marine management areas. There are currently 16 marine reserves vested with the Marine Parks and Reserves Authority and managed by the Department of Parks and Wildlife, 13 of which are marine parks, two are marine management areas and one is a marine nature reserve. There are proposals to establish four additional marine parks and one additional marine management area. Together these existing and proposed reserves will protect and manage approximately 40 per cent or about 50,000 square kilometres of the State's coastal waters.

Figure 12 below illustrates the location of Western Australian State marine parks and reserves.

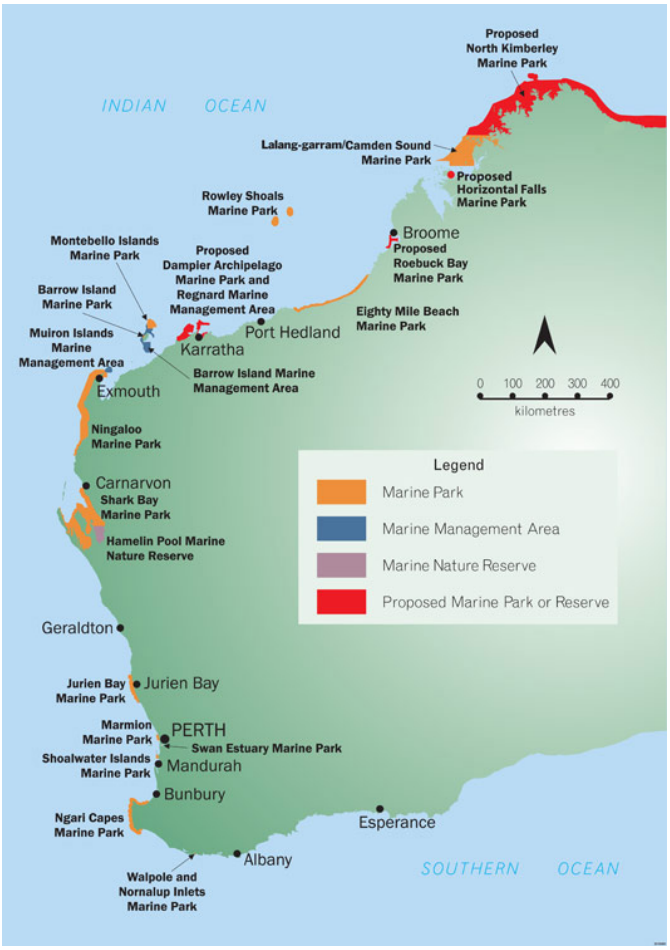


FIGURE 12 – LOCATION OF WESTERN AUSTRALIAN MARINE PARKS AND RESERVES

At both State and Commonwealth levels, it is intended that the framework for the management of each area be articulated in a Management Plan developed and adopted by the relevant statutory authority. Management Plans provide for reserves to be divided into separate zones to manage the activities that can be undertaken within those zones, so that an appropriate balance can be achieved between conservation and sustainable use of marine resources. Management plans developed by the State include opportunities for input from Aboriginal traditional owners, stakeholders and the broader community. In some cases, for example in the Kimberley region, marine parks will be jointly managed under formal agreements with traditional owners.

In State marine parks, Sanctuary Zones provide the highest level of conservation for marine habitat and wildlife. They are 'no-take' zones where commercial fishing, aquaculture, recreational fishing, exploratory drilling and oil and gas production activities are excluded. They do, however, allow recreation and tourism activities that do not compromise the conservation values in those zones. Other zones include 'general use', 'special purpose' and 'recreation' zones and activities permitted within these zones vary across parks according to specific Management Plans and orders or regulations that might be in place. Zoning is one tool in a suite of management approaches for marine parks and reserves that includes education, public participation, research, monitoring and enforcement.

In March 2013, management plans were approved for the new network of Commonwealth marine reserves in Western Australia. Under the current Federal government, these management plans were subsequently 'set aside' and a review is currently in progress. Management arrangements for these new reserves will not be implemented until this review is complete. Management arrangements for existing Commonwealth marine reserves at Ningaloo Marine Park, Mermaid Reef, Ashmore Reef and Cartier Island will remain in place until this review is completed and new management plans come into effect.

A detailed discussion of the geography, biodiversity and anthropogenic interactions for each of the State and Commonwealth parks and reserves within the Western Australian marine conservation estate is set out in Online Appendix 3.

Commonwealth marine reserves are managed under the jurisdiction of the *Environmental Protection and Biodiversity Conservation Act (Cth) 1999*. This Act also provides for the protection of specific marine species. The Commonwealth Department of the Environment is the responsible agency for this Act. However, management of Commonwealth marine reserves off the Western Australian coastline is in the process of being devolved to the Western Australian Department of Parks and Wildlife under bilateral agreements. Agreements are already in place for the Commonwealth waters of Ningaloo Marine Park and Mermaid Reef near the State Rowley Shoals Marine Park.

State marine parks and reserves are managed under the jurisdiction of the *Conservation and Land Management Act 1984*, while marine fauna and flora are managed throughout State waters under the *Wildlife Conservation Act 1950*. The Department of Parks and Wildlife is responsible for administering these Acts. Threatened or specially protected marine fauna are often mobile and occur both inside and outside the marine parks and reserves system, and therefore require management across jurisdictions. Such fauna may be the subject of specific management programs or recovery plans and some species may also be included in marine reserve management plans, where relevant.

To the extent that the relevant legislation provides the Department of Fisheries with the responsibility to regulate all fish species, it too plays a key role in the protection of fish resources within marine parks and the broader Western Australian marine environment. Under the objects of the *Fish Resources Management Act 1994,* the Department of Fisheries is responsible for the management of fish resources, including the development and management of fisheries and aquaculture and the conservation of fish and other aquatic resources and their habitats. The Department uses a risk and evidence-based approach to develop and implement management arrangements designed to deliver ecologically sustainable outcomes within the marine environment. A variety of management tools are used including spatial and temporal closures, gear restrictions, measures to minimise interaction with threatened, endangered and protected species and habitat protection measures. Under the Offshore Constitutional Settlement, the Department's fisheries management responsibilities extend out to the 200 nautical mile limit of Australia's EEZ. The Department of Fisheries is also responsible for aquatic biosecurity and undertakes programs for the management and control of harmful aquatic organisms including invasive marine species and fish diseases within State waters.

3.2. Development Approvals Process

In Western Australia, the most substantive element of the project approvals process with respect to activity in the marine environment is the environmental assessments process that is overseen by the independent Environmental Protection Authority (EPA). Development projects that could potentially have a significant impact on the marine environment are referred to the EPA for a decision on whether the impacts are significant enough to warrant formal assessment. Before a project that is assessed can proceed, it must be approved by the Minister on the recommendation of the EPA. The EPA bases its assessment and recommendations on an Environmental Impact Statement (EIS) prepared by the proponent. An EIS is a detailed scientific investigation into the potential impact of the project on key aspects of the marine environment that must be supported by empirical data. The EIS must also set out specific impact mitigation strategies and a plan for monitoring, reporting and managing the residual environmental impact of the project.

For projects that are identified as unlikely to have a significant impact on the marine environment, provisions for assessing and managing the environmental impact of those activities are contained in various legislation.

If the project has the potential to significantly impact on matters of national environmental significance in State and/or Commonwealth Waters, the *Environmental Protection and Biodiversity Conservation Act (Cth) 1999* and regulations are triggered. There are bilateral discussions occurring between the Commonwealth and State with a view to accrediting State approvals processes for the purposes of approving actions that may have a significant impact on matters protected under the *Environmental Protection and Biodiversity Conservation Act (Cth) 1999.*

A similar approach has been taken with respect to the National Offshore Petroleum Safety and Environmental Management Authority's approvals processes in Commonwealth waters.

3.3. Regulation of Activities That Intersect with the Western Australian Marine Environment

ALL ACTIVITIES UNDERTAKEN WITHIN THE WESTERN AUSTRALIAN MARINE ENVIRONMENT MUST BE UNDERTAKEN IN ACCORDANCE WITH THE PROVISIONS OF VARIOUS STATE AND COMMONWEALTH LEGISLATION. THE RELEVANT LEGISLATION, RESPONSIBLE AGENCIES AND OTHER OVERSIGHT BODIES ASSOCIATED WITH THAT LEGISLATION ARE SUMMARISED IN TABLE 14 BELOW.

TABLE 14 - STATE AND COMMONWEALTH LEGISLATION, AGENCIES AND OTHER GOVERNMENT INSTRUMENTALITIES WITH JURISDICTION IN THE WESTERN AUSTRALIAN MARINE ENVIRONMENT

Legislation	Responsible Agency	Other Oversight Bodies
Historic Shipwrecks Act (Cth) 1976	Western Australian Museum	n.a.
Environmental Protection (Sea Dumping) Act (Cth) 1981	Commonwealth Department of the Environment	n.a.
Environmental Protection and Biodiversity Conservation Act (Cth) 1986	Commonwealth Department of the Environment (some management responsibility devolved to the Western Australian Government)	n.a.
Fisheries Administration Act (Cth) 1991	Commonwealth Department of Agriculture (some powers devolved to the Western Australian Department of Fisheries)	Australian Fisheries Management Authority
Australian Marine Safety Authority Act (Cth) 1990	Commonwealth Department of Infrastructure and Regional Development	Australian Marine Safety Authority
Fisheries Management Act (Cth) 1991	Commonwealth Department of Agriculture (some powers devolved to the Western Australian Department of Fisheries)	Australian Fisheries Management Authority
Native Title Act (Cth) 1993	Commonwealth Attorney General	n.a.
Offshore Petroleum and Greenhouse Gas Storage Act (Cth) 2006	Commonwealth Department of Industry	National Offshore Petroleum Safety and Environmental Management Authority
Wildlife Conservation Act (WA) 1950	Western Australian Department of Parks and Wildlife	n.a.
Mining Act (WA) 1978	Western Australian Department of Mines and Petroleum	n.a.
Western Australian Marine Act (WA) 1982	Western Australian Department of Transport	n.a.
Petroleum (Submerged Lands) Act (WA) 1982	Western Australian Department of Mines and Petroleum	n.a.
Conservation and Land Management Act (WA) 1984	Western Australian Department of Parks and Wildlife	Marine Parks and Reserves Authority
Environmental Protection Act (WA) 1986	Western Australian Department of Environment Regulation; Office of the Environmental Protection Authority	Environmental Protection Authority
Fish Resources Management Act (WA) 1994	Western Australian Department of Fisheries	n.a.
Port Authorities Act (WA) 1999	Western Australian Department of Transport	Kimberley Ports Authority Pilbara Ports Authority Midwest Ports Authority Southern Ports Authority
Offshore Minerals Act (WA) 2003	Western Australian Department of Mines and Petroleum	n.a.

Of the agencies listed in table 14 above, the agencies and authorities discussed in the following subsections rely significantly on enhanced knowledge of the marine environment for their ongoing effective operations.

3.3.1. Western Australian Department of Parks and Wildlife

The Department of Parks and Wildlife manages the State's 16 marine parks and reserves, conserves and manages native animals and plants, supports Aboriginal people in protecting their culture and heritage on parks and reserves, and supports access to, managed use and enjoyment of the State's marine wildlife and natural areas. The department develops and implements policies, provides advice to support environmental impact assessments and other government decision-making processes, undertakes research and monitoring, manages marine tourism and recreational activities in parks and reserves, and delivers community education programs.

Under Commonwealth-State bilateral agreements that are currently under negotiation, it is highly likely that the Department will also play a substantive role in managing Commonwealth parks and reserves in the Western Australian marine environment.

3.3.2. Western Australian Department of Environment Regulation

The Department of Environment Regulation is responsible for issuing licensing and work approvals, assessing levels of compliance with environmental regulation, enforcing contraventions of environmental regulation and reviewing and advising on reform of environmental regulation.

3.3.3. Western Australian Office of the Environmental Protection Authority

The Office of the Environmental Protection Authority supports the EPA in conducting environmental impact assessments and developing policies to protect the environment. The OEPA also monitors compliance with Ministerial conditions related to approvals.

3.3.4. Western Australian Department of Fisheries

The Department of Fisheries is responsible for the administration and management of fisheries in Western Australia. Under an Offshore Constitutional Settlement arrangement with the Commonwealth, the Western Australian Department of Fisheries currently has responsibility for the management of most fisheries resources within the Western Australian jurisdiction out to the 200 nautical mile EEZ limit.

The Department also has responsibilities for policy development, research, monitoring, compliance, community education, and marine safety services. The Department's role includes the regulation of fisheries and fishing activities, including the fisheries impact on habitat and all fish species. Integrated management through interaction with, and response to, the community, industry, other government agencies and groups with an interest in the optimal use of aquatic resources is an important part of the management process.

3.3.5. Western Australian Department of Transport

The Department of Transport has jurisdiction over shipping and boating activities in the Western Australian marine environment. While it is the responsible agency for the legislation pertaining to the operation of Western Australia's ports, the individual port authorities are responsible for the operation of those ports.

3.3.6. National Offshore Petroleum Safety and Environmental Management Authority

The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) is responsible for regulating safety and environmental impact of the offshore petroleum industry in Commonwealth waters.

NOPSEMA is charged with regulating all offshore areas in Commonwealth waters, as well as designated coastal waters where functions have been conferred. Jurisdictions where functions to regulate are not conferred on NOPSEMA remain the responsibility of the relevant state or territory department.

3.3.7. Australian Maritime Safety Authority

The Australian Marine Safety Authority (AMSA) is a statutory authority that is responsible for:

- Promoting maritime safety and protection of the marine environment;
- Preventing and combating ship-sourced pollution in the marine environment;
- Providing infrastructure to support safety of navigation in Australian waters; and
- Providing a national search and rescue service to the maritime and aviation sectors.

Further details on the scope of authority, key activities and legislative instruments relating to these agencies is set out in Online Appendix 3.

Knowledge Needs

Government agencies that have the ultimate responsibility for ensuring marine environmental function, services, species and biodiversity are conserved and appropriately managed have significant marine science needs.

Agencies responsible for defining, declaring and managing the marine conservation estate require knowledge that ensures representative ecosystems have been identified and adequately protected within the marine conservation estate. This requires knowledge pertaining to biodiversity and habitat inventories in locations as well as the connectivity between ecosystems. They also need to ensure that the marine conservation estate and zoning arrangements within that estate are not unnecessarily sterilising parts of the marine environment and preventing other uses. Knowledge is also required to manage the marine conservation estate. This requires knowledge that allows those who monitor the health and condition of those estates to identify and determine the nature and source of external influences on the health and condition of those estates (particularly with respect to differentiating between natural and anthropogenic pressures) and to develop actions to remediate degraded estates where necessary.

Agencies responsible for determining and managing individual species at risk require knowledge that ensures at-risk species have been identified and that the plan for protecting and recovering those species is suitable and effective.

In the case of the project approvals process, the onus is largely on the project proponent to demonstrate the environmental impact of the proposed development, as well as a method for monitoring and managing the environmental impact of the proposed development. However, agencies responsible for assessing Environmental Impact Statements and management plans require adequate knowledge to assess the reasonableness of the analysis, claims and commitments made by project proponents. They also require knowledge to underpin continuous improvement in the environmental assessment, monitoring and compliance process. This will benefit both project proponents and regulators as it will render approvals processes more efficient.

Regulation of the environmental impact of commercial, leisure and cultural activities within the marine environment requires knowledge that underpins the nature of regulatory interventions, including allocation of sustainable marine resources among users, and regulatory responses to changing conditions. Marine safety regulation also requires knowledge to underpin best-practice regulation of operations in the marine environment.

Research Priorities

Table 15 below summarises the specific knowledge needs of regulators of the marine environment, together with the key risks and/or opportunities that knowledge will address and areas of scientific investigation that are expected to underpin the acquisition of that knowledge.

TABLE 15 – MARINE SCIENCE PRIORITIES OF AGENCIES RESPONSIBLE FOR THE CONSERVATION, PROTECTION AND REGULATION OF THE WESTERN AUSTRALIAN MARINE ENVIRONMENT

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
Environmental Impact Assessment and Management	**Marine Habitats and Ecosystems Baselines and Fundamental Science** Development of extensive localised and regional biodiversity value and habitat baseline data in parts of the Western Australian marine environment that are currently or in the future likely to be the subject of conservation and/or potentially impacted by development, including near-shore fauna habitats	Enhanced basis for more evidence based conservation and management policy and regulation formulation and decision making that delivers a higher degree of certainty and more efficient project approvals and compliance processes.	High	Ecology
	Marine Habitat and Ecosystems Baselines and Fundamental Science Enhanced understanding of the marine microbial systems that underpin all marine biological activity in the Western Australian marine environment	Enhanced understanding of ecosystem function and structure that further de-risks conservation and management policy and regulation formulation and decision-making.	High	Ecology
	Physical Oceanography Baselines and Fundamental Science Enhanced understanding of the extent, nature and mechanisms of connectivity between key ecosystems in the Western Australia, with a particular focus on connectivity with those ecosystems that are the subject of conservation and/or impacted by current or likely future development	Enhanced basis for more evidence based conservation and management policy and regulation formulation and decision making that delivers a higher degree of certainty and more efficient project approvals and compliance processes.	High	Ecology, metocean
	Cumulative Impacts on Marine Ecosystems Enhanced understanding of the resilience of key Western Australian marine ecosystems to climate, specific anthropogenic activities and the cumulative impacts of	Enhanced basis for more evidence based conservation and management policy and regulation formulation and decision making that delivers a higher degree of certainty and more efficient project approvals and compliance processes.	High	Ecology

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
	these events			
	Marine Environmental Monitoring and Modelling Synthesis of environmental data associated with dredging and port construction over the past decade and the development of models that can be used to support the approvals process of future projects	More efficient approvals and compliance processes.	High	Modelling
	Marine Habitats and Ecosystems Baselines and Fundamental Science Enhanced understanding of the value of and risks associated with 'man-made' ecosystems such as those that form around offshore infrastructure such as platforms or subsea pipelines	More certain and informed policy and regulation formulation and decision-making pertaining to the decommissioning of offshore infrastructure and project completion requirements.	Low	Ecology
Design and Operation of Marine Infrastructure and Activities	**Marine Habitats and Ecosystems Baselines and Fundamental Science** New knowledge that contributes to greater precision in defining the boundaries of the marine conservation estate and zoning within those marine conservation estates	Enhanced basis for more evidence based conservation and management policy and regulation formulation and decision making that delivers a higher degree of certainty, leading to more efficient allocation of sustainable marine resources.	Medium	Ecology
	Social Licence to Operate New knowledge that results in improved resource allocation decisions between various stakeholders in the Western Australian marine environment	More informed marine resource allocation decisions, particularly with respect to the fisheries resource that maintains stakeholder confidence in the regulator.	Medium	Economics, ecology, social sciences
	Biosecurity Improved technologies and methods for monitoring and managing the impact of invasive marine species	More informed and efficient management of biosecurity risk	Medium	Technology, species

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
	Social Licence to Operate Enhanced understanding of Aboriginal marine cultural values and development of a framework to incorporate these values into a standard marine estate management and regulation process	Better policy and regulation decisions that address Aboriginal marine cultural values, harness Aboriginal knowledge of the marine environment and work with Aboriginal people with respect to management of the Western Australian marine environment.	Medium	Social sciences
	Marine Habitats and Ecosystems Baselines and Fundamental Science Enhanced understanding of the efficacy of marine conservation reserves in maintaining or improving regional environmental function	Optimised conservation and management policy decisions that give effect to conservation as well as improving the productivity of sustainable marine resources outside of the conservation zone.	Low	Ecology
Marine Data Collection, Management and Modelling	**Marine Environmental Monitoring and Modelling** Identification and synthesis of all data pertaining to the Western Australian marine environment that has been collected by the private sector, academia and various State and Commonwealth government agencies	More efficient and effective use of existing data in policy and regulatory formulation and decision-making.	High	Data governance, modelling
	Marine Environmental Monitoring and Modelling Identification of a set of efficiently measurable variables that serve as pre-emptive indicators of changes to aspects of the Western Australian marine environment.	Development of a platform for cost-effective prediction of changes, and the causes of those changes in the marine environment, leading to more efficient and effective policy and regulatory responses	High	Ecology, species, modelling
	Marine Environmental Monitoring and Modelling Establishing cross-sectorial standards for collecting and reporting key marine environmental data	Development of a platform through which marine data collected by various stakeholders can be efficiently and effectively shared for the purposes of more efficient and effective policy and regulation formulation and decision-making.	High	Data governance, modelling
	Marine Environmental Monitoring and Modelling Development of new technologies that improve the	A platform that delivers marine data at a spatial and temporal scale that results in greater certainty and efficiency in policy and regulation formulation and	High	Technology

End User Knowledge Need Theme	Specific End User Knowledge Need	Risk and/or Opportunity Orientation	Relative Priority	Primary and (other areas of research)
	efficiency and effectiveness of collecting marine environmental data	decision-making.		
	Physical Oceanographic Monitoring and Modelling Identification and synthesis of all data pertaining to the physical oceanography of the Western Australian marine environment that has been collected by the private sector, academia and various State and Commonwealth government agencies to inform assessment such as ecosystem connectivity and to model oil spills	A platform that delivers marine data at a spatial and temporal scale that results in greater certainty and efficiency in policy and regulation formulation and decision-making.	High	Data governance, modelling, ecosystems
	Marine Habitats and Ecosystems Baselines and Fundamental Science New knowledge that leads to the development of a framework for prioritising the location and nature of marine environmental monitoring within the Western Australian marine environment	A platform that delivers marine data at a spatial and temporal scale that results in greater certainty and efficiency in policy and regulation formulation and decision-making.	Medium	Ecology, modelling
Community Support for the Sector	**Social Licence to Operate** Enhanced understanding of the social (cultural and recreational), economic and environmental values that communities attribute to specific coastal environments along the Western Australian coastline and tools for more effective communication of the science that supports marine regulatory decisions.	Ensuring ongoing community confidence in the government's ability to manage the Western Australian marine environment, such that marine environmental function, services, species and biodiversity are conserved and appropriately managed, and that the community's expectations for a clean and healthy ocean are met.	Medium	Social sciences

4. State-wide Marine Science Priorities

The knowledge needs that sectors and government agencies have identified as having the greatest impact on their current and future operations are discussed in detail in Section 2 and Section 3 respectively. Research programs that directly target these knowledge needs will have the most significant impact and are the priorities for the State.

This section identifies the broad scope of marine science research programs that are, based on the sector specific knowledge needs identified in this Blueprint, priorities for the State of Western Australia. It must be stressed that even though there is some high-level commonality among sector end-user needs, as a result of the specific location and end-use application of the knowledge needs within individual sectors, specific research projects developed under these broad programs will always need to be designed to address the specific knowledge needs of end-users in the sectors.

4.1. Commonality in Sector Research Priorities

There is reasonable commonality among the sectors with respect to the high-level knowledge needs of:

- Marine habitat and ecosystems baseline and fundamental science
- Physical oceanographic baselines and fundamental science
- Cumulative impacts on marine ecosystems
- Marine environmental monitoring and modelling
- Physical oceanographic monitoring and modelling
- Biosecurity
- Sector productivity
- Social licence to operate

Figure 13 below summarises the frequency of high and medium priorities assigned to the high-level knowledge needs by each of the sectors. The light blue boxes identify where the sector has one high-level knowledge need ranked as a high or medium relative priority. The medium blue boxes identify where the sector has two high-level knowledge needs ranked as a high or medium relative priority. The dark blue boxes identify where a sector has between three and five high-level knowledge needs ranked as a high or medium relative priority. Where high-level knowledge needs have been identified for a sector, the primary and other areas of scientific research that will be needed to address these knowledge needs have also been identified.

	Commercial Fishing	Marine Aquaculture	Recreational Fishing	Offshore Oil and Gas	Ports and Shipping	Development in Catchment Areas	Coastal Development and Communities	Future Industries	Conservation, Protection and Regulation
Marine Habitat and Ecosystems Baselines and Fundamental Science	Ecology, species, modelling,	Ecology, metocean	Ecology, species	Ecology, modelling, metocean, technology	Ecology	Ecology, technology, chemistry	Ecology, hydrology		Ecology, modelling
Physical Oceanographic Baselines and Fundamental Science	Metocean, ecology, modelling			Modelling, metocean, technology				Modelling, metocean	Ecology, metocean
Cumulative Impacts on Marine Ecosystems	Ecology		Ecology	Ecology		Ecology, hydrology	Ecology, hydrology		Ecology
Marine Environmental Monitoring and Modelling	Modelling, technology		Technology	Modelling, ecology, metocean, technology	Modelling, metocean, ecology	Hydrology, chemistry, modelling, metocean			Modelling, data governance, ecology, species, technology
Physical Oceanographic Monitoring and Modelling				Modelling, ecology, metocean, technolgy			Modelling, metocean		Data governance, modelling, ecosystems
Biosecurity	Technology, species			Technology, species	Technology, species				Technology, species
Productivity	Technology, species, metocean, ecology, markets	Economics, animal health, species, technology		Metocean, technology, ecology, species, economics, legal, social sciences			Legal, technology	Species, economics, ecology, technology	
Social Licence to Operate	Social sciences	Social sciences		Social sciences					Economics, ecology, social sciences

FIGURE 13 – WESTERN AUSTRALIAN SECTOR COMMONALITY AMONG HIGH LEVEL END-USER NEEDS

Marine Habitat and Ecosystems Baselines and Fundamental Science

Research designed to address marine habitat and ecosystems baselines and fundamental science knowledge needs has the broadest application across the sectors discussed in this Blueprint, with future industries being the only sector that does not have an immediate knowledge need in this category. The reason that future industries don't have an immediate knowledge need in this area is most likely that their physical location is not yet identified. The sectors with the most knowledge needs in this category are the marine aquaculture and offshore oil and gas, as well as government agencies responsible for conservation, protection and regulation of the Western Australian marine environment, followed by the commercial and recreational fishing sectors.

Marine Environmental Monitoring and Modelling

Given that marine habitat and ecosystems baselines and fundamental science form the most common category of knowledge needs, it is not surprising that improved marine environmental monitoring and modelling has the next broadest application across the sectors, with marine aquaculture, coastal development and communities, and future industries being the only sectors without immediate knowledge needs in this category. The sectors with the most knowledge needs in this category are the oil and gas and development in catchment sectors, as well as government agencies responsible for conservation, protection and regulation of the Western Australian marine environment.

Cumulative Impacts on Marine Ecosystems

Similarly, it is not surprising that measuring, predicting and evaluating cumulative impacts on marine ecosystems is broadly applicable to a relatively large number of sectors. Research that addresses cumulative impacts on marine ecosystems is the third most broadly applicable category, with high and medium priority relevance to the offshore oil and gas, development in catchments, commercial fishing and recreational fishing sectors, as well as government agencies responsible for conservation, protection and regulation of the Western Australian marine environment

Productivity

Research that addresses productivity of operations in the marine environment, such as that which results in new deployable technologies, engineering design and operational practices is a relatively high priority for most sectors. It is particularly important to commercial sectors operating in the Western Australian marine environment such as the commercial fishing and oil and gas sectors, as well as sectors yet to demonstrate commercial viability at scale, such as the marine aquaculture sector and identified future marine industries. It is also a priority for managing coastal infrastructure.

Physical Oceanographic Baselines and Fundamental Science

Research that improves physical oceanographic baseline knowledge and fundamental science is important to the commercial fishing and offshore oil and gas sectors, as well as the identified future industries and government agencies responsible for conservation, protection and regulation of the Western Australian marine environment. There is a risk that the relative importance of this category is understated, as it is a key input to understanding connectivity between marine habitats and ecosystems as well as to further refining and underpinning confidence in localised metocean modelling. This is recognised by the prominence of

metocean science in addressing various environmental, ecosystems and modelling related knowledge needs.

Physical (Usually Project Scale) Oceanographic Monitoring and Modelling

Like physical oceanographic baseline knowledge and fundamental science, this category of knowledge need is important to all sectors as it informs decisions pertaining to the impact of ocean systems on their specific activities. For many sectors its relevance has been captured in the metocean aspects of ecological and modelling knowledge needs. It is not surprising that it is of particular unique important to the offshore oil and gas and coastal development sectors, as the localised oceanographic models that inform the design and operations of permanent and semi-permanent offshore or coastal infrastructure are critical to informing design and managing risk associated with the longer term structural and operational integrity of that infrastructure. It is also of importance to government agencies responsible for conservation, protection and regulation of the Western Australian marine environment because it informs assessment of ecosystem connectivity and responses to incidents such as hydrocarbon spills or search and rescue operations.

Biosecurity

Research that leads to improved biosecurity is important to the commercial fishing sector with respect to ensuring commercial stocks are not threatened by invasive species. It is important to the oil and gas and ports and shipping sectors, as international shipping is a key vector for invasive species. Finally it is important to the government agencies that have legislative responsibilities for managing invasive marine species.

Social Licence to Operate

Public perceptions of the impact that various sectors have on the Western Australian marine environment is variable. As such, the operations of various sectors are often perceived as controversial and the focus of political or media attention. It is important that public perception of these sectors is grounded in sound science, rather than emotive issues. Research that underpins this objective is particularly important to the commercial fishing, marine aquaculture and offshore oil and gas sectors. It is also important to agencies charged with conserving, protecting and regulating the marine environment so that they maintain community confidence in their ability to manage that environment, such that marine environmental function, services, species and biodiversity are conserved and appropriately managed, and that the community's expectations for a clean and healthy ocean are met.

4.2. State-wide Marine Science Priorities

Notwithstanding the specificity of the marine science that is required to meet the end-user needs articulated in Section 2 and Section 3 of this Blueprint (owing to the location, data and application specificity of the knowledge needs), State-wide marine science priorities emerge from this analysis of knowledge needs.

The first priority is to establish a level of baseline understanding of marine biodiversity, ecosystems and physical ocean processes in the Western Australian marine environment that underpins an adequate understanding of risk in relation to the identified key issues within the Western Australian marine environment. Enabling this baseline understanding is the capability in terms of expertise and cost-effective technology to collect adequately representative

biodiversity, ecosystems and physical ocean data at adequate spatial and temporal resolution. This capability and baseline understanding can then be used to address key marine science issues for the State.

A definition of the key marine science issues for the State is difficult because there are numerous stakeholders with different perspectives of what the priorities should be. Similarly, there are numerous criteria, such as economic or social benefit delivered by the user of that knowledge that can be used to rank priorities. The approach that this Blueprint has taken to determining key marine science issues for the State is based on issues associated with the current and/or future viability of industry sector(s) that are key to the Western Australian economy, the ability of the State to conserve, protect and regulate its marine environment, or maintaining the cultural importance of the marine environment for Western Australian communities. The fact that these key issues will change over time is the main reason that this Blueprint will be reviewed every five years. The methodology used to develop this Blueprint is discussed in Exhibit 2.

Pursuant to this process, State-wide marine science priorities are discussed under the following programs and priority themes:

- **Baseline and Fundamental Program**
  These are strategic research programs that build the baseline knowledge of physical, biological and chemical marine systems that support and are characteristic of the Western Australian marine environment. This knowledge is required to underpin research projects that target the specific end-user knowledge needs of the sectors that interact with the marine environment. The priority themes in this program are:

  - Marine baseline data and knowledge synthesis;
  - Enhanced understanding of regional oceanography;
  - Enhanced understanding of marine biodiversity and habitats; and
  - Enhanced understanding of marine ecosystem function and how marine ecosystem structure and function will respond to human-induced change at a local and regional level.

- **Enabling Program**
  These are programs focused on important areas of applied science that underpin the capability in marine science necessary to deliver baseline and fundamental programs, key issues programs and research projects targeting the specific end-user needs articulated in Section 2. The priority themes in this program are:

  - Cost-effective marine monitoring and data management; and
  - Improved certainty in marine predictive modelling.

- **Key Issues Program**
  These are large, multi-sector relevant (possibly multi-disciplinary) strategic research programs that fulfil knowledge needs of significant State interest because they underpin the current and/or future viability of industry sectors that are key to the Western Australian economy, the ability of the State to conserve, protect and regulate the marine environment or maintaining the cultural importance of the marine environment for Western Australian communities. The priority themes in this program are:

  - Measuring, predicting and evaluating cumulative impacts on marine ecosystems;
  - Decommissioning of offshore infrastructure and management of 'artificial' ecosystems that form around offshore infrastructure;

- Biosecurity;
- Remediation of marine ecosystems;
- Enhancing the productivity of marine operations ,and
- Social licence to operate in the Western Australian marine environment.

Figure 14 below illustrates conceptually the relationship between these research programs (and their priority themes) and the ultimate impact on end-user sectors. Details of the research programs are provided in Table 16, Table 17 and Table 18 below.

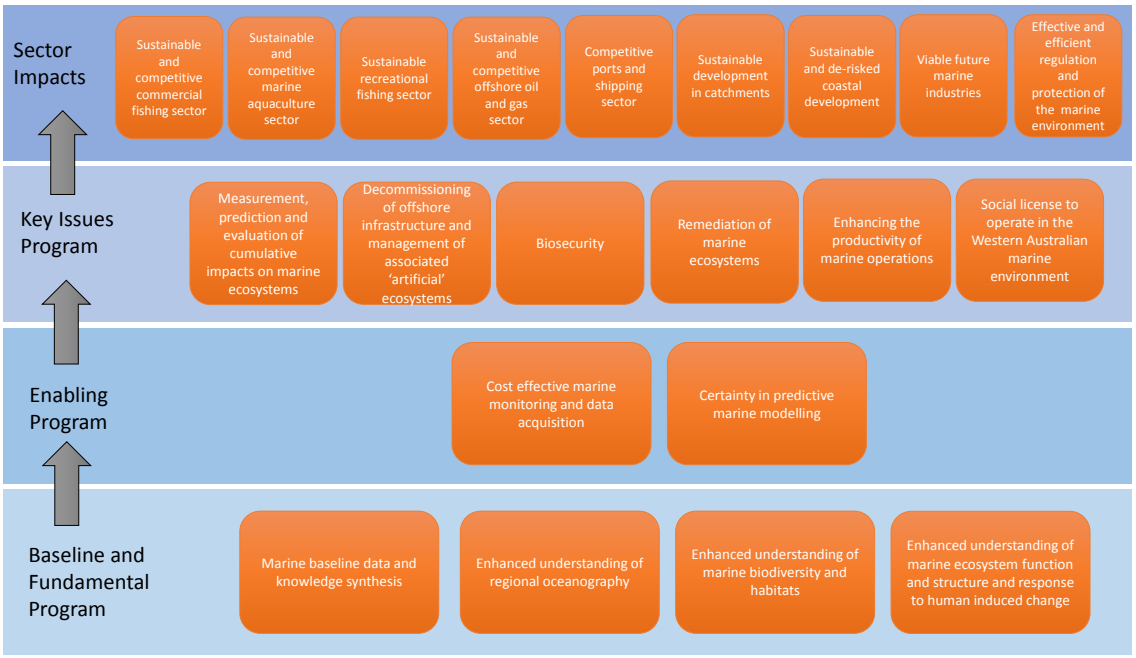


FIGURE 14 – RELATIONSHIP BETWEEN STATE-WIDE RESEARCH PROGRAMS AND END-USER SECTORS

4.2.1. Baseline and Fundamental Research Program

Table 16 summarises the priority themes in the baseline and fundamental program that are marine science priorities for Western Australia. All stakeholders in the Western Australian marine environment are beneficiaries of the outcomes of the priority themes in this program, as those outcomes provide fundamental information and knowledge that underpins priority themes in the enabling and key issues programs.

TABLE 16 - BASELINE AND FUNDAMENTAL PROGRAM PRIORITIES

Priority Themes	Description and Key Priorities
Marine baseline data and knowledge synthesis	Over the past several decades a significant amount of data and knowledge pertaining to the physical ocean environment and processes, marine biodiversity and ecosystems in the Western Australian marine environment has been acquired by public sector organisations for research, policy development and regulation, and by industry for project approvals, environmental monitoring, infrastructure design and operational decision making. Knowledge pertaining to the Western Australian marine environment has also been accumulated by Aboriginal Western Australians over the course of the past 40,000 years. In order to optimise the outcomes of future marine science in terms of efficient allocation of limited marine research funding (particularly with respect to expensive field work) and quality of research outcomes, there is an urgent need to comprehensively identify existing data and knowledge and to synthesise this into a clear and detailed definition of the 'state-of-the-art'. This should be reviewed on a decadal basis to ensure it remains contemporary. It should be noted that this is a very complex and potentially expensive task. Key priorities: ▪ Develop a protocol whereby all strategic marine research undertaken in Western Australia publishes an early synthesis of collected existing information. ▪ Identification of Aboriginal knowledge of marine ecosystems and integration of this knowledge and Aboriginal people into scientific and management programs ▪ Identification of priority trend and baselines for synthesis, potentially through cross- sector agreements ▪ Synthesis of collective Pilbara and North West Shelf data and knowledge (completion of WAMSI Dredging Node and UWA-CSIRO PMCP) ▪ Entire Western Australian marine environment for priority trend and baseline data
Enhanced understanding of regional oceanography	A deeper understanding of physical oceanographic processes at a regional scale is critical to understanding the dynamics of all physical, chemical and biological marine processes that occur within the Western Australian marine environment at regional and localised scales. As such, it underpins further understanding of the connectivity of ecosystems and the impact of natural and anthropogenic events that occur regionally and globally on the Western Australian marine environment and the ecosystems it supports. Most importantly, an enhanced understanding of regional oceanography improves and de-risks localised oceanographic modelling that is a key focus of specific sectors operating in the Western Australian marine environment.

Priority Themes	Description and Key Priorities
	Key priorities: ▪ North West Shelf regional oceanography with a particular focus on systems impacting oceanography in the offshore Carnarvon Basin, Exmouth Sub Basin and Browse Basin hydrocarbon provinces and associated offshore infrastructure; near-shore environments relating to ports, transport, dredging activities and coastal development; as well as hydrocarbon spill impact risk assessment in the region ▪ Regional oceanography that impacts the Mid West, South West and Southern offshore, near-shore, coastal and estuarine environments to inform environmental protection policy, operating decisions in high value crustacean and mollusc fisheries operating in that region and coastal development in that region ▪ Enhanced understanding of regional Indian Ocean, particularly Western Australian rainfall relationships, impacts of catchment run off and the physical processes of estuarine environments in Western Australia to inform onshore and coastal development, regulation and estuarine and near shore remediation
Enhanced understanding of marine biodiversity and habitats	A deeper understanding and inventory of the extent and variability of marine biodiversity and habitats that exist within the Western Australian marine environment is required to inform evidence and risk-based regulation, conservation estate decisions and sustainable marine industries. With the Western Australian resources industry currently transitioning from a construction to operational phase with respect to offshore infrastructure and port infrastructure, research that underpins regulatory efficiency and effectiveness for future expansions phases should be an increasing focus. Key priorities and timelines: ▪ Eastern Pilbara to lower Kimberley near-shore environment relating to ports, key transport pathways and dredging activities, as well as coastal development around current and projected population centres ▪ Perth to Dunsborough near-shore and coastal development areas ▪ Existing western rock lobster, scallop, abalone and demersal finfish fisheries ▪ Likely future areas of concentrated offshore infrastructure on the North West Shelf and Browse Basin
Enhanced understanding of marine ecosystem function	Understanding how the ecosystems in the Western Australian marine environment that support its marine biodiversity and habitats is critical in recognising the natural and anthropogenic pressures they can sustain before the key ecosystem services they provide are compromised, and whether or not impacts from pressures on these ecosystems are reversible. This involves the role of microbial activities in ecosystem and water column nutrient cycling, resilience in changes in water temperature and currents, interrelationships and interdependence of trophic levels and connectivity of marine ecosystems. Key priorities and timelines: ▪ Understanding of the role of microbial activities in ecosystem and water column nutrients and resilience to anthropogenic or climate-driven changes ▪ Interrelationships and interdependence of trophic levels ▪ Connectivity of marine ecosystems, particularly between the relatively highly impacted North West Shelf and connected areas ▪ Understanding eco-toxicology of sensitive environmental receptors ▪ Identification of population movements of protected or at-risk marine species

Priority Themes	Description and Key Priorities
	▪ Genetic interconnectivity of populations of protected or at-risk species ▪ Threatened or at-risk species population level resilience to anthropogenic pressure and natural/climate change ▪ Understanding how ecosystem structure and function will respond to human cumulative induced change at a local and regional level

4.2.2. Enabling Program

Table 17 below summarises the themes in the enabling program that are priorities for enhancing marine science capability in Western Australia. As with the baseline and fundamental program, all stakeholders in Western Australia's marine environment are beneficiaries of the outcomes of the priority themes in this program, as those outcomes provide fundamental information and knowledge, as well as information and knowledge generation capability that underpins priority themes in the key issues program.

TABLE 17 – ENABLING PROGRAM PRIORITIES

Priority Themes	Description and Key Priorities
Cost-effective marine monitoring and data acquisition	As a result of remoteness and harsh conditions, undertaking ongoing physical or biological monitoring activities in the Western Australian marine environment is expensive. The development of technologies in areas such as remote sensing and automated underwater vehicles to improve the cost-effectiveness of collecting data from the marine environment and reduce the OHS risk associated with that activity will ultimately result in a greater volume of reliable, in some cases, real-time data on which research programs and management plans can designed and undertaken, Key priorities: ▪ Identification of a set of efficiently measurable variables that serve as pre-emptive indicators of changes to aspects of the Western Australian marine environment ▪ Development of new technologies for improving the cost effectiveness of and safety associated with acquiring marine environmental and metocean data in near-shore turbid and deep offshore environments ▪ Development of cross-sectorial standards for collecting and reporting key marine environmental and metocean data ▪ Development of a framework for prioritising the location and nature of marine environmental monitoring and oceanographic observing within the Western Australian marine environment
Improved data sharing	Given the expense of acquiring data in the marine environment, significant efficiencies in marine science research can be obtained through the effective sharing of data between actors within sectors and across the sectors. While publicly collected data should be more openly available, some data collected by the private sector is considered commercially sensitive. However, if collected in accordance with agreed standards and classifications, this data could eventually contribute to wider knowledge base once it is considered no-longer confidential. Key priorities: • Expansion or adaptation of I-GEMS metadata collection system as a mechanism to allow assessment of current datasets • Adoption of national best practice data management and accessibility standards by all public research and governance institutions • Development of protocols for determining whether private sector data is commercially sensitive and a process for disclosing non-sensitive data ▪ Ongoing cross sector process to agree on the specific and critical historic datasets supporting priorities in this Blueprint and negotiation to secure access to these datasets

Certainty in marine modelling	While physical oceanographic and ecological models pertaining to key aspects of the Western Australian marine environment exist, the validation of those models is based primarily on localised data and very limited wide-resolution regional data. There is an urgent need to integrate these models with wider physical and biological data sets of greater resolution to improve and validate these models in order to reduce the risk associated with decisions that are based on these models. Effort should also be given to establishing consistent approaches to modelling that allow users of that modelling to more easily understand and validate the accuracy and reliability of modelling outputs.

4.2.3. Key Issues Program

Table 18 below summarises the key issue themes that are State-wide priorities for marine science in Western Australia.

TABLE 18 – KEY ISSUES PROGRAM PRIORITIES AND STAKEHOLDERS

Priority Themes	Description and Key Priorities	Key Stakeholders in Outcomes
Cumulative impacts on marine ecosystems	Strongly related to the priority themes in the baseline and fundamental programs is a need to be able to predict and determine the specific individual as well as cumulative impacts of the various sectors and natural events on marine (offshore, near-shore, coastal and estuarine) ecosystems in the Western Australian marine environment. This is required by regulators to protect the marine environment and by individual sectors to determine and manage their impact on the marine environment for approvals and operational purposes. Key priorities: ▪ Definition of the noise profile from seismic, offshore infrastructure and shipping in the North West and the cumulative impact of this noise profile, including short and long term impacts of the noise profile on species and ecosystems and other users of the marine resource ▪ Understanding the cumulative impact of multiple, concentrated oil and gas offshore systems (multiple wells, FPSO and FLNG facilities, pipelines, service vessels etc) through the exploration, development and operational phase in a particularly region (particularly the Exmouth Sub-basin and Browse Basin) on localised and regional marine ecosystems (including noise and water quality impacts, potential ecotoxicology etc.) ▪ Mapping of potential cumulative impacts of coastal and near-shore activities in the Perth to Dunsborough and Pilbara regions ▪ Definition of thresholds for key ecosystem indicator species and conditions from cumulative effects in priority areas, including consideration of geographic connectivity of species	Commercial fishing, recreational fishing, offshore oil and gas, catchment development, coastal development and communities and government agencies

Decommissioning of offshore infrastructure and management of 'artificial' ecosystems	Improved understanding of risks associated with decommissioned offshore infrastructure, the liability for managing those risks and the ecological and recreational value of ecosystems that form around that infrastructure will become an increasingly important issue in the Western Australian marine environment as increasing amounts of offshore infrastructure associated with the oil and gas industry approaches the end of its useful or design life. Managing the effect of artificial ecosystems on the performance of offshore infrastructure over the life of that infrastructure will also become increasingly important. Furthermore, a deeper understanding of the potential use of artificial reef and fish attraction devices to cater for a growing recreational fishing sector will be required as this sector continues to grow, as well as an assessment of the potential impact of these artificial systems on the commercial fisheries. Regulators will require an understanding of the impact that these ecosystems have on species population and connected natural marine ecosystems. <u>Key priorities:</u> ▪ Assessment of the risk profile, cost benefit and liability issues associated with in situ decommissioned offshore infrastructure in the North West ▪ Assessment of the impact of degrading offshore infrastructure on localised water quality ▪ Assessment of the recreational value of marine ecosystems that have formed around offshore infrastructure in the Carnarvon Basin and Exmouth Sub-basin ▪ Assessment of utility and impact of multiple fish attraction devices and artificial reefs along the South West coast on natural ecosystems and stocks of key species targeted by the recreational and commercial sector	Commercial fishing, recreational fishing, offshore oil and gas, government agencies
Biosecurity	Increased connectivity between the Western Australian marine environment and other parts of the global ocean system, primarily as a result of vessel movements, combined with the potential for future intensive marine animal production in the form of marine aquaculture is resulting in marine biosecurity becoming an increasingly important issue for the State. For sectors such as commercial fishing where invasive species can place fisheries at risk, the sustainability of the sector is at stake. For sectors such as shipping that can be vectors for invasive species, liability and social license to operate issues are of concern. For the regulators, invasive species can be a key threat to the marine conservation estate. <u>Key priorities:</u> ▪ Development of technologies to rapidly identify invasive marine organisms at sites of likely introduction (e,g. ports, marine aquaculture facilities etc) ▪ Development of technologies to improve the cleaning or management of ship borne invasive species	Commercial fishing, oil and gas, shipping and ports, government agencies
Remediation of marine ecosystems	Protection of the marine environment requires that the impact of anthropogenic pressures on marine ecosystems is minimised, and where there is an impact, opportunities for reversing that impact are optimised. As development that interacts with the Western Australian marine environment continues to increase and the largely coastal population of Western Australia continues to grow, the ability to remediate ecosystems in the Western Australian marine environment will become paramount in facilitating and managing that growth.	Marine aquaculture, recreational fishing, offshore oil and gas, catchment development, coastal development and communities, government

	The development of methods for effective remediation of ecosystems will both enhanced opportunities for development in the marine environment, as well as create opportunities for the reversal of legacy impacts. Key priorities: ▪ Studies that determine the reversibility of the seafloor impacts of sea cages in marine aquaculture operations in the Kimberley and Midwest near shore environments and the Abrolhos Islands as well methods to ensure reversibility is optimised ▪ Evaluation of the use of aquaculture in marine stock enhancement programs for at risk species ▪ Development of technologies and methods that result in more effective and efficient benthic rehabilitation techniques on the North West Shelf ▪ Development of technologies and methods for enhanced remediation of the impacts of legacy sediment, nutrient, carbon and contaminant run-off on major Western Australian river systems and estuaries	agencies
Enhancing the productivity of marine operations	All of the priority themes identified in this Blueprint ultimately impact on the productivity of marine operations. However, because undertaking operations, particularly commercial operations, in the Western Australian marine environment is particularly costly ,specific priorities with respect to improving the productivity of those operations are addressed. With the offshore oil and gas industry transitioning into an operations phase, the commercial fishing industry stabilising at lower than historical production volumes and the economic sustainability of emerging and future sectors being fundamentally dependent on achieving a competitive level of productivity, research that underpins productivity improvement in these sectors will be important to their future growth. Key priorities: ▪ Research that underpins the development of technologies or methodologies that improve the efficiency of targeting and catching fish, including those that reduced non-retained by-catch ▪ Research that leads to the development of new sustainable fisheries or fisheries product in Western Australia ▪ Research that underpins the development of new technologies or methodologies that improve the efficiency of marine aquaculture in Western Australia ▪ Research that underpins design of offshore infrastructure and/or improved operating practices that enhance the productivity of operations in the offshore oil and gas sector in the North West ▪ Research that underpins more efficient processes for determining legal liability and rights of various stakeholders in coastal infrastructure with respect to taking pre-emptive or reactive measures to mitigate or manage the impact of coastal inundation, erosion and/or sedimentation, as well as informing risk-management in the design of coastal infrastructure	Commercial fishing, marine aquaculture, offshore oil and gas, coastal development and communities
Social license to operate in the Western Australian marine environment	A key element of maintaining social licence to operate in the marine environment is understanding the cultural and economic aspects of the community's interaction with the marine environment and the values, attitudes and beliefs that the community prescribes to aspects of the marine environment. It is only with this understanding that sectors that require a social license to operate in the marine environment can design their activities so that they meet community expectation and ensure that the community is informed on the aspects of their interaction with the marine environment that are important to the community.	Commercial fishing, marine aquaculture, offshore oil and gas and government agencies

5. Implementation of the Blueprint

This Blueprint has identified a wide range of knowledge needs at both an end-user specific State-wide level for which the current portfolio of knowledge pertaining to the Western Australian marine environment is unable to adequately address. This manifests itself in the form of uncertainty with respect to the future economic viability and sustainability of sectors and community activities and uncertainty with respect to the risk being adopted government agencies in policy and regulatory decisions.

However, the significant and highly consultative effort that has gone into establishing this Blueprint will only yield dividends if it is implemented in a strategic, resourced and sustained manner. This will require the industry, community, government and research stakeholders identified in this Blueprint to work together to marshal resources and focus the collective marine science effort on sector and State-wide priorities identified in this Blueprint.

5.1. Monitoring and Review of the Blueprint

Ensuring that the Blueprint progresses toward implementation will require ongoing monitoring of activities aligned with the Blueprint and a periodic review of the Blueprint. An effective monitoring and review program will require a governance structure that performs a custodial role for the Blueprint. This structure needs to be expertise based and should be designed such that assessment processes and assessments are transparent and such that conflicts that could arise from vested interests are minimised and easily managed. This role could potentially be performed by existing structures such as the Western Australian Marine Science Institution or the Western Australian Government Office of Science.

In addition to ongoing monitoring of progress toward addressing the sector and State-wide priorities identified in this Blueprint, the Blueprint itself should be reviewed on a five yearly cycle with the next review scheduled for 2020. Each review would be overseen by the custodial governance structure and should include the following:

- A detailed synopsis of specific achievements and challenges with respect to addressing the knowledge needs identified in this Blueprint;
- A detailed assessment of the impact of research that has successful addressed knowledge needs identified in this Blueprint and consequences of knowledge needs that have not been adequately addressed;
- An independent assessment of contemporary end-user knowledge needs; and
- Recommendations for changes to the Blueprint for the subsequent five year period.

5.2. Delivery of Timely, End-User Oriented Marine Science Knowledge Products

A premise of the Blueprint is that improved coordination and focus of the limited resources available to support the marine scientific research effort on the end-user knowledge needs as articulated in Sections 2, 3 and 4 will result in a much greater impact of that research effort. Where research is able to acutely align with specific end-user knowledge needs, the likelihood of end-user funding to support that research will also be much greater.

To this end, research groups and end-users are encouraged to work together to define, resource and execute research programs and projects aligned with this Blueprint.

5.2.1. Specific Sector and Government Agency Knowledge Needs

The research sector is encouraged to work with the sectors and agencies discussed in Sections 2 and 3 to clearly understand the specificity of their knowledge needs and to design research programs and projects that deliver solutions to those needs. End-users should be partners in the research programs and projects to ensure that the program or project remains end-user solution oriented. This relationship should go beyond one of just funding, to a true collaboration where the partners are involved in designing, managing and reviewing the program or project, as well as in the delivery of the outcomes.

5.2.2. Baseline Research Programs

The baseline research programs require a broad and long term approach to research that is collaborative from a disciplinary and sector perspective.

It is recommended that a more cooperative or coordinated approach to these baseline programs is implemented with ongoing enhanced sharing of information, adopting common approaches where possible, integrating projects between parties to add-value and improve outcomes and continued review the short term priorities to encourage investment in those areas.

Within the longer term objective of the baseline programs, short-term priorities will emerge from time to time based on newly identified anthropogenic or natural pressures. These should be resourced in addition to the long-term objective of the programs, rather than at their expense.

5.2.3. Enabling Research Programs

The enabling programs represent an ongoing exercise in ensuring that baseline data and fundamental knowledge that currently exist and which is generated from the baseline programs discussed in this Blueprint are optimally synthesised into models and other knowledge products that can be used to enhance research capability.

The enabling programs should ensure that these models and knowledge products can be optimally used to underpin research deigned to address the wide spectrum of end-user knowledge needs identified in this Blueprint and that the enabling programs progressively improve the quality of knowledge and de-risk the outcomes of research that is designed to address those knowledge needs.

5.2.4. Key Issues Programs

The key issue research programs are those where answers could potentially be provided in 3-5 years through concerted effort and funding, and provide answers for decisions requiring this information within the next 5-10 years.

Program plans should be developed to allow research providers to focus on delivering particular elements incrementally but in a structured manner. For these programs targeted investment is recommended given the urgency and/or importance of some of these knowledge gaps.

5.3. Planning Detailed Research Programs

The Blueprint for Marine Science identifies the key priorities for strategic research in Section 4. To progress any programs in these areas, detailed planning must be undertaken to identify the specific research and related activities required, the inter-dependencies with other programs and projects, and provide costing that can form the basis of an investment decision.

Competent planning should be developed with both researchers and end-users involved and with substantial ownership of the end-users in determining the outputs required.

Planning processes must be flexible and acknowledge that the Blueprint was a broad approach to identify priorities across all sectors and that higher priority elements of programs may be highlighted through detailed planning.

Detailed planning should be progressed for research programs supported through high level discussions identified in section 5.5 below.

5.4. Collaboration

The Blueprint shows that the research sector is substantial and complex. It includes a highly diverse participation of public institutions in marine research, and a highly competent private sector capability that is in the case of Australia, perhaps unique to Western Australia, by virtue of the relative scale of its offshore oil and gas sector.

In terms of research, collaboration will be necessary due to the multi-disciplinary capability required to address the gaps raised in the Blueprint and the dispersed nature of capability between multiple institutions. Priority should be given to improving the collaboration between the public, private and consulting sector, both in the planning and delivery of strategic research and related activities.

In terms of enabling efficiencies in marine science, there will need to be cross-sector negotiation and collaboration to improve innovation efforts, sensible consistency of approaches, data sharing, knowledge transfer and other opportunities to improve the productivity of marine science in Western Australia.

On-ground efficiencies through consistent and interoperable approaches in areas such as applied processes, data collection, management and sharing are likely to be achieved through industry adopted standards, regulatory guidelines and/or communities of practice.

5.5. Funding

Substantial and ongoing funding is required to ensure identified knowledge needs are developed prior to the time it is required to support activities in the marine environment and prepare for future waves of development.

Incremental progress will continue to be made against the sector based knowledge needs (Section 3) through normal research granting processes, and through project scale approval, safety and operational related industry funded research (including environmental offsets where relevant). However, the acceleration of important elements of the baseline and

fundamental research program, and the timely delivery against the key issues programs (Section 4) will require multi-million dollar per year investment into strategic programs on a sustained basis.

It should be noted that a near appropriate scale of investment is currently in place through several strategic research programs operating off Western Australia. However, these mostly end in 2017 and are solely delivering State government or industry approval related strategic research.

The sources of major program funding include direct State and Commonwealth Government grants, industry, publicly funded research organisation strategic funds, and the direction/re-direction of major granting processes or existing research programs.

The key challenges associated with securing additional funding the research targeted at addressing the knowledge needs identified in this Blueprint include:

- A 2015-16 economic and budgetary environment that presents limited latitude for additional allocation of State or Federal funds to science;
- As the resources industry passes through the current construction phase to an operational phase, research that directly addresses operational efficiencies will likely increasingly take precedence over that which supports project approvals, potentially limiting the scope of available industry funding; and
- Some industry sectors, particularly emerging industries, have less financial capacity to support strategic research.

A high level dialogue between the stakeholders in this Blueprint is recommended to explore funding option for the priorities articulated in this Blueprint.

Exhibit 1: Blueprint Project Steering Group

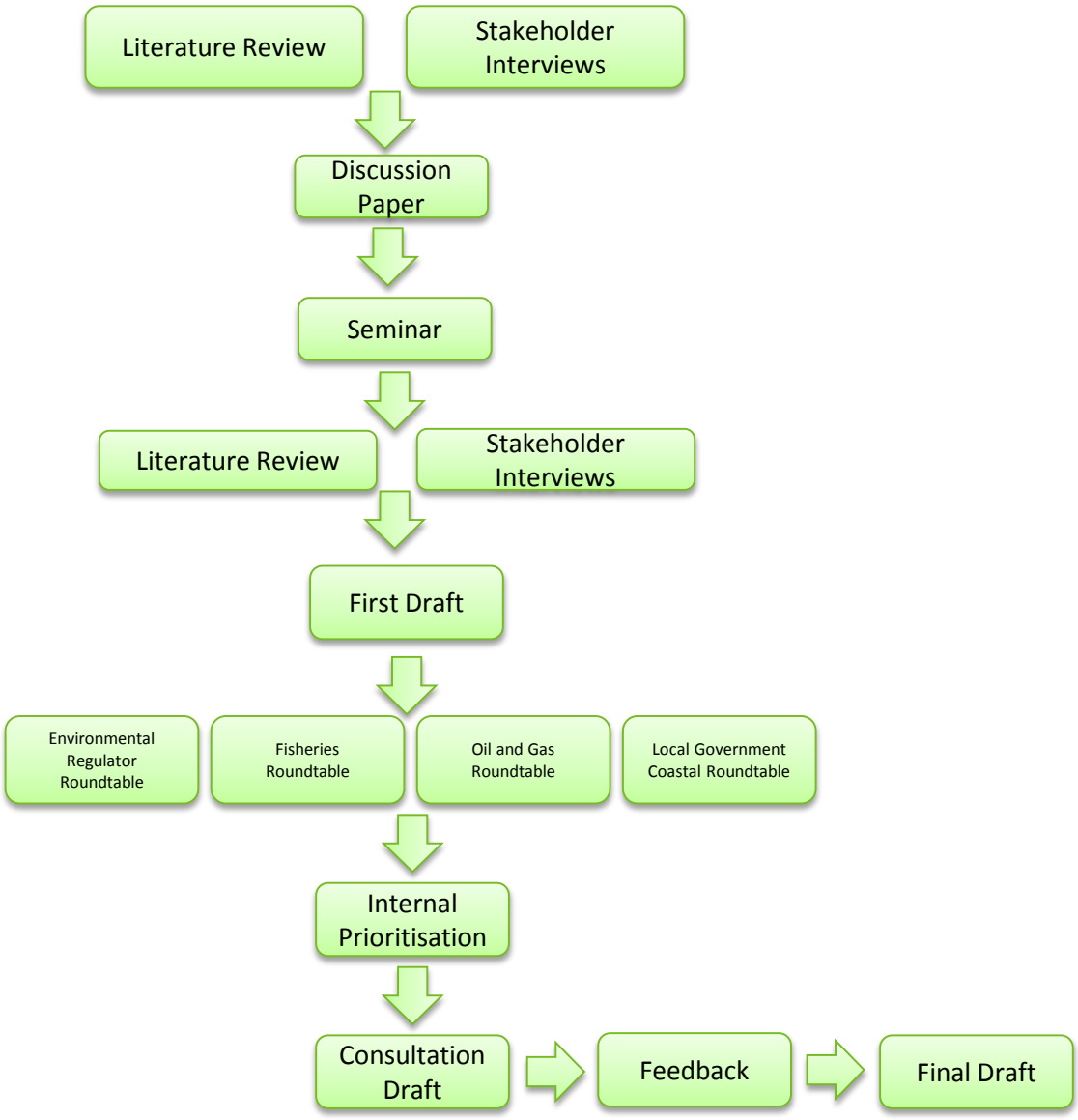
The study that has resulted in the Western Australian Marine Science Blueprint has been overseen by a steering group comprised of the following stakeholders and experts in the Western Australian marine environment:

- Emeritus Professor Alistar Robertson (Independent Chair)
- David Carter, CEO, Austral Fisheries
- John Gunn, Chair, National Marine Science Committee
- Colin Scott, Manager, Subsea and Pipelines, Chevron Australia
- Luke Smith, Chief Environmental Scientist, Woodside
- Jennifer McGrath, Executive Director, Office of Science, Department of Premier and Cabinet
- Heather Brayford, Acting Director General, Department of Fisheries
- Stuart Smith, CEO, National Offshore Petroleum Safety and Environmental Management Authority
- Paul Vogel, Chair, Environmental Protection Authority
- Patrick Seares, Chief Executive Officer, Western Australian Marine Science Institution

Exhibit 2: Methodology

The methodology to develop this Blueprint has involved a rigorous independent analysis that has revolved primarily around a detailed review of contemporary literature and extensive consultation with marine science, marine industry and community experts and stakeholders.

The figure below summarises the methodology used to develop this Blueprint.



Initial data collection through review of contemporary literature and semi-structured interviews with experts and key stakeholders commenced in early 2014. In July 2014, a discussion paper titled *Toward a Western Australian Marine Science Blueprint 2050: Discussion Paper* was published. This document presented an overview of the Western Australian marine environment, anthropogenic interactions with the Western Australian marine environment, the role for science and emerging key areas of scientific investigation as identified by the analysis to date. This paper was launched and discussed at a seminar and panel discussion in late July 2014.

The Discussion Paper was used as a tool to solicit further feedback and input from stakeholders and experts. The literature review, semi-structured interview and analytical process continued through to October 2014.

In November 2014, the first internal draft of the Blueprint was produced. Feedback from this internal draft was ascertained from the Steering Group, as well as through four sector specific workshops.

Through analysis of the data collected through the interview process, knowledge needs were prioritised on a sector basis. From this analysis State-wide priorities were developed.

Exhibit 3: Online Appendices

The following online appendices can be accessed at www.wamsi.org.au

Online Appendix	Subject
1	Other Australian Marine Science Plans
2	The Western Australian Marine Environment
3	Protection and Regulation of the Western Australian Marine Environment
4	Western Australian Commercial Fishing Sector
5	Western Australian Marine Aquaculture Sector
6	Western Australian Marine Tourism
7	Western Australian Offshore Oil and Gas Industry
8	Western Australian Onshore Industries that Interact with the Marine Environment
9	Western Australian Ports and Shipping Sector
10	Future Western Australian Marine Industries
11	Rapidly Growing Coastal Communities and Urban Development
12	Western Australian Culture and the Marine Environment

THE BLUEPRINT FOR MARINE SCIENCE 2050 **REPORT**

Research directions to enhance industry competitiveness and government effectiveness in the marine environment off Western Australia

THE BLUEPRINT FOR MARINE SCIENCE 2050 IS THE TRIGGER FOR AN ONGOING TRANSFORMATIONAL EFFORT TO IMPROVE THE IMPACT AND BENEFITS, OF MARINE SCIENCE. THROUGH REAL COMMITMENT TO DELIVERING THE BLUEPRINT THERE WILL BE A TANGIBLE BENEFIT TO WESTERN AUSTRALIA'S MARINE INDUSTRIES, TO THE PROTECTION OF THE ENVIRONMENT AND TO THE CONSOLIDATION OF PERTH AS THE CENTRE FOR MARINE SCIENCE AND EDUCATION ACROSS THE INDIAN OCEAN.

THE BLUEPRINT FOR MARINE SCIENCE 2050 FULL REPORT WAS PREPARED BY AUSTRALIAN VENTURE CONSULTANTS UNDER THE GUIDANCE OF THE INDEPENDENT STEERING GROUP.

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