National Marine Science Plan - ENERGY SECURITY Theme

Abstract

Energy security underpins Australia's domestic and export economy. Australia's vast marine estate of 13.5 million km^2 is largely underexplored and pre-competitive science outputs are needed to attract and sustain Industry investment in offshore energy. Energy security must be considered within the context of Earth System Science – in particular, interactions with the physical environment, including metoceanographic conditions, the biota and seabed, and sub-sea geologic sedimentary basins. Regional environmental baselines should be established to reduce compliance costs and ensure the efficient and sustainable development of resources. The development of a diversity of primary energy sources is needed to underpin Australia's domestic requirements, particularly for transport fuels, and to grow and sustain our export gas markets. To best achieve these outcomes requires coordination and collaboration between Industry, researchers and research entities, both nationally and internationally.

Background

Energy security for Australia means securing affordable, reliable, sustainable and diverse sources to underpin the domestic and export economy. *Prima facie*, as a net energy exporter Australia is secure; energy exports contributed $69 billion and employed more than 120,000 people in 2012-2013[1]. Exports shipped by sea, included coal, uranium, and natural gas. The Australian liquid natural gas (LNG) export market is predicted to grow from around 20 million tonnes per annum to 107 million tonnes by 2034[2]. Capital expenditure for new LNG projects currently approved or planned totals more than $170 billion. But more reserves are needed to sustain this growth and export income. And from a geological assessment, material, yet-to-be found, gas reserves will occur in offshore basins.

Despite energy richness, Australia is a net importer of the crude oil and refined petroleum products that underpin our domestic economy. More than 38 % of Australia's final energy use is employed in moving people and goods across the country[5]. Australia's net petroleum imports *cost* $11.7 Billion in 2013-2014 [3], and net imports are expected to grow by 3% per annum over the next 20 years[4].

Energy security cannot be focussed solely on resource extraction and exploitation, and neither can it be focussed on a single resource type. Energy production must be considered within the context of Earth System Science – in particular, given that the majority of Australia's energy resources are offshore, the interaction with the physical environment and biota of the water column and seabed, and sub-sea sedimentary basins will be key considerations. And there are increasing global societal demands for energy either from sources that produce less carbon dioxide, such as natural gas, or wind or wave energy; or conventional sources that capture and dispose of the produced carbon dioxide. Demand for carbon capture and storage (CCS) has introduced a new facet to energy security science and policy in Australia through the assessment of potential for secure offshore storage basins.

Australia's vast marine estate of 13.5 million km^2 is largely underexplored—less than 20% (by area) is under hydrocarbon exploration permit—and the potential for wave, wind and current energy is only beginning to be evaluated. Australia needs to assess the potential of these new renewable energy sources, but research in these fields is just developing. Also, petroleum activity is extending into deeper waters further from shore - recent technological advances have allowed offshore petroleum exploration in progressively deeper waters (current limit in Australia is 3000 m). There is also a move to *in situ* processing in the form of floating facilities and, potentially, subsea structures. New data and innovative research is required to assess and secure the energy potential of these new oceanic and frontier subsea resources.

Australia's marine estate is also home to a range of significant and highly biodiverse ecosystems - new techniques are also needed to effectively monitor the wider marine environment for potential short- and long-term impacts of the new types of petroleum and other energy developments. To achieve this requires planning, coordination, and collaboration between agencies, and integration of their complementary skills and capacity to undertake national systematic studies. Entities that contribute to geologic and hydrocarbon resource assessment studies and those concerned with relevant environmental studies are shown in Table 1.

Australian publicly funded research agencies (PFRA) with defined and diverse capabilities and programs that focus on Energy Security in the marine realm include the CSIRO Energy Flagship and the Oceans and Atmosphere Flagship; the Australian Institute of Marine Science (AIMS), Geoscience Australia, and some state agencies. Universities with well-developed energy security research programs include: Western Australia, Melbourne, Sydney, James Cook, and Tasmania, and are responsible for undergraduate and postgraduate teaching.

The marine realm presents its own challenges – namely the requirement for well-equipped and capable research vessels (the "Land Cruisers™" or "Land Rovers™" of the sea). The Australian Institute of Marine Science vessel R/V *Solander* plays an important role as a dedicated research platform in Northern Australian shelfal waters, while the recent and important addition of the R/V *Investigator* to Australia's small marine fleet has provided many new capabilities for marine science. In particular, *Investigator* has state of the art systems for seabed mapping, sub-bottom profiling, research geophysics to determine sub-seabed structures, and sediment and water column sampling. The *Investigator* will operate from the tropics to the ice edge of Antarctica, with the capability to effectively acquire data across the full range of ocean and seabed environments in Australia's marine estate. Importantly, the vessel has an expanded number of berths available for scientists and for training of undergraduates and postgraduates.

To understand the geology of offshore sedimentary basins it is essential to sample the basin rocks, which is achieved by drilling or, where possible, dredging. Without physical samples, for age dating and geochemistry, resource assessments remain speculative. The demonstration of organic rich rocks in the Great Australian Bight has stimulated a $1.2 billion exploration program by petroleum companies. Not all areas can be dredged, and offshore drilling is expensive: commercial oil drilling costs approximately $1 million/per day. Australia does not have a deep drill capability on any of its research vessels. And because of this, PFRA's must sustain and contribute to international collaborative research ventures such as the International Ocean Discovery Program (IODP), which has research vessels that can drill up to 6000 m below the seabed. IODP's annual operational budget is $US180 million, with the Australia-New Zealand IODP consortium contributing $US1.8 million per year to give us access to this program. The Australian-driven IODP proposal 884, designed to drill the black shales in the Great Australian Bight has attracted industry attention and support through proposed co-funding through the University of Adelaide.
We must also maintain or develop bi- and multilateral strategic partnerships with international entities that possess their own research drilling vessels such as the Japan Agency for Marine-Earth Science and Technology (JAMSTEC).

Table 1: Australian research entities with defined programs and complementary capabilities for application to energy security

Entity	Energy Waves	Energy Wind	Energy Subsea	Metocean	Seabed mapping	Bio-diversity biota	Regional Basin geology	Bio-geochem.	Funding
CSIRO	yes	yes	yes	yes	yes	**YES**		yes	Approp. + Consulting
AIMS				yes	**YES**	**YES**		yes	Approp. +Consulting
BoM				**YES**					Approp.
Geoscience Australia			**YES**		**YES**		**YES**	**yes**	Approp.
Universities CRC		**YES**			yes	yes	yes	yes	Approp. +Consulting
RAN/AHS					**YES**				Approp.

Relevance

The primary end-users are Industry, Government (through Regulators) and the Australian community. Energy exports contributed $69 billion and employed more than 120,000 people in 2012-2013[1]. Exports of natural gas (as LNG) from offshore basins rose strongly, up 21.1 per cent, to $13.4 billion in 2013[6].

The Australian marine estate, outside of the Territorial Seas, is administered by the Australian Government. For energy security, the key industries include:

- Energy companies
  - Conventional petroleum Exploration and Production (E&P), and their contract supply companies, all represented by the Australian Petroleum Production and Exploration Association (APPEA);
  - Renewable energy – seeking to exploit wave, current and wind energy;
- Fishing industry and recreational fishing, covering a variety vertebrates and invertebrate catch species;
- Nascent Carbon Capture and Storage industry – seeking offshore CO_2 geological storage sites; and
- Tourism; shipping; and offshore infrastructure suppliers, including pipelines and communications.

Policy and regulatory entities of the Australian Government, through various Portfolios (including Industry, Defence, Foreign Affairs and Trade, and Environment) and State and Territory governments are all beneficiaries of this research.

And in addition to national economic benefits created by exports and domestic industry, the Australian community will benefit through access to factual, verifiable, quality science outcomes to inform debate and decisions with regard to the 'social licence to operate' of the different industries. This evidence base allows for robust debate and decision making, replacing assertion and speculation that can dominate public debates.

For the last 47 years, offshore petroleum exploration and development activities have been regulated under various Australian Government Acts, including the *Petroleum (Submerged Lands) Act* 1967 emend, and the current *Offshore Petroleum and Greenhouse Gas Storage (OPGGSA) Act*

2013. The governance arrangements of the OPGGSA require companies to submit exploration program data (seismic/drilling/core/bathymetry, etc.) and interpretative reports to the Australian Government; which are made available after a defined period of confidentiality to all stakeholders. This is a proven efficient means of ensuring knowledge transfer for the communal good, and should be applied to all studies in the marine realm: a view supported by the Productivity Commission report[7] that considered environmental and bathymetric data.

Engagement with the national and international petroleum companies is evidenced by the uptake of petroleum acreage and the demand for annual presentation of opportunities through APPEA and at industry-relevant international meetings in Japan, China, South Korea, India, Singapore, Malaysia, and the US and UK. This function is carried out by Geoscience Australia in concert with the Department of Industry. Access to free (or cost of transfer) pre-competitive technical data provided by Geoscience Australia underpins the acreage release process, and attracts international capital for exploration. As an example, through Geoscience Australia, the Australian Government invested $6.1million in geological research of the Bight Basin, offshore southern Australia, from 1999-2007. The resulting pre-competitive information created two tranches of exploration; in 2003 an exploration well was drilled for ~ $53 million, and in 2013 companies began guaranteed exploration programs of $1.2 billion. Similarly research and promotion by Geoscience Australia, at a cost of ~$2 million, contributed to the uptake of acreage in the Browse Basin, with the subsequent discovery of the Ichthys Field, the largest reserves of liquid hydrocarbons (527 million barrels) in Australia since the 1960's discovery in the Bass Strait, and gas reserves that will support the $32 billion LNG infrastructure built by INPEX and its partners, for 40 years. Part of that infrastructure includes an offshore pipeline of 883 km, which is one of the longest subsea pipelines ever built and the longest in the southern hemisphere. These industrial projects provide jobs for Australians and contribute significantly to our export earnings and balance of trade.

Globally, Australia was the first country to release offshore acreage for the safe disposal of CO_2 and one block in the offshore Gippsland Basin, Victoria, is currently being evaluated. Elsewhere, offshore Northern Territory and Western Australia, pre-competitive data on potential storage areas is being studied by Geoscience Australia, and results are being released to Industy[8]; there is demonstrated interest in accessing these datasets. This work is part of Australia's assessment of methods to reduce greenhouse gas emissions from conventional energy sources.

The offshore petroleum industry has also benefitted from Australia's participation in the IODP, and its forerunner programs Deep Sea Drilling and Ocean Deep programs (DSDP and ODP), with access to deep stratigraphic cores from the Exmouth Plateau, Naturaliste Plateau, and the Tasmanian margin. Woodside Energy, for example, sent science personnel to the IODP Core repository in Japan in 2010, to study cores from a Late Triassic reef complex drilled on the NWS, which is now part of a new petroleum play and resulted in new discoveries to maintain the pipeline of investment: Geoscience Australia has incorporated results of IODP drilling in its annual acreage release. As noted earlier, there are industry proponents for a proposed IODP expedition in the Great Australian Bight.

As noted above, the quest for energy security needs to be assessed in context of the contested space that is the Australian marine estate, in order for environmental outcomes to be met through measurement and monitoring of the effects of the industry on the marine environment. To do this requires a national systematic mapping of marine environmental baselines. In addition to studies carried out by PFRAs to assess, establish, and support the establishment of the Commonwealth marine reserves network targeted, regional-scale environmental baseline studies have been supported by multi-million dollar input by petroleum companies BP, Chevron, INPEX, Woodside, Shell, Conoco Phillips and PTTEP into collaborative studies involving the CSIRO, AIMS, universities and state government science agencies. This is in addition to compliance environmental studies required for offshore exploration permitting. The importance of collaboration around environmental data management and access is also increasingly being recognised by both Government and Industry, with recent initiatives such as the I-GEMS project providing a pathway towards increased sharing of information. Despite this, there is a pressing need to develop a nationally-consistent and comprehensive marine environmental baseline for all of Australia's marine estate, with an initial focus on regions with energy production and exploration activities.

Outside of the petroleum industry, there is growing demand for rigorous, testable, quality science about the marine environment to inform the public, NGOs and other specialist communities. Ultimately, the community through government will approve the social licence of all industries to operate in Australia's marine estate.

Science needs

Table 2: Key science questions and outputs to address Energy Security.

Time Horizon	Energy Security - Questions	Science outputs
5 years	What are the linkages between seabed communities and environments and what do they tell us about offshore prospectivity and environmental sensitivities?	Complete three exemplars of high resolution seabed mapping for environmental and resource assessment including predictive spatial models of the distribution of sensitive communities.
	What are the long term effects of offshore exploration and production on marine organisms?	Determine the effects of noise generated by exploration and development of resources on marine life.
		Establish ecotoxicology effects and thresholds for key Australian marine species using hydrocarbons from known producing fields, and discoveries
		Develop tools and experimental data to track and predict the fate hydrocarbons and dispersants following an oil spill
		Develop HPC/HPD services to synthesise, analyse, and access regional seabed, subsea, and satellite data to assist Industry
		Develop at least one regional plan for coordinated and comprehensive environmental baselines
10 years	How can remote sensing technologies be developed to improve our understanding of offshore prospectivity?	Complete seabed mapping of un-explored areas of the Australian Marine Jurisdiction
		Complete wave and wind energy profiles adjacent to existing and developing energy sinks (ports, cities)
		Develop and apply a robust methodology to rank Australia's offshore geologic basins for energy resource assessment and environmental sensitivities
		Establish a program to systematically and routinely assess fluid and gas seepages from the seafloor.
	How does the dynamic geological history of Australia affect the relative prospectivity of offshore sedimentary basins?	Determine the hydrodynamic history of Australian offshore sedimentary basins to assess effects on productivity of conventional hydrocarbons and disposal of CO_2
	How resilient is the marine environment to resource development and unplanned incidents?	Establish a monitoring program to assess exogenous noise in the marine environment.
		Implement a fully coordinated environmental baseline in one region
20 years	What are key indicators required to monitor and ensure sustainable development of energy resources?	Complete environmental modelling for Australia's marine jurisdiction: remote monitoring of CO_2 storage sites and performance of wave and wind platforms
	How can we apply HPC/HPD to better predict energy prospectivity and CO_2 storage capacity to ensure long term energy security?	

Coordinated national science priority areas and good science governance
All submissions stressed the importance of a coordinated response to addressing Energy Security; all recognised the need for an Earth Systems Science approach that includes understanding the effects on the marine environment. Current research on the effect of noise on marine fauna, for example, is limited and there are increasing unsupported claims of adverse effects of selected species. Research areas required to support new developments of energy resources needs collaboration between science providers and industry.

Currently there are key knowledge and information gaps – reflecting the size of Australia's marine jurisdiction, the limited number of blue-water vessels, and the lack of a coherent, actionable science plan that maximises the complementary marine science programs of the respective research organisations and industry players. Table 2 summarises the relevant science questions to address these gaps.

The first action – within the first 2 years – is to define and rank priority geographical areas for targeted research based on the intersection of the various science drivers, and then to determine the governance of the various elements that need to be brought together to effectively address the key science questions in each region. For example, use of the R/V *Investigator*, whole of government coordination between PFRA programs, including university research and alignment of supporting grants (ARC and similar) and teaching requirements.
An additional initial action is to enable a coordinated approach with government and industry to develop a comprehensive environmental baseline and data sharing arrangements in NW Australia.

Conventional hydrocarbons, and carbon storage sites: need for pre-competitive data
There are at least 40 offshore geologic basins, but less than 20% (by area) are under current exploration or production permit. The levels of knowledge, of the dynamic geological history of these basins that is required to assess resource potential for conventional hydrocarbons and potential for CO_2 storage, is highly variable, from rudimentary to reasonably detailed (in currently producing areas). Even in well documented areas, fundamental underpinning science is still required.

Geophysical data (seismic, magnetic, and gravity) is required to define the shape and structure of the sub-seabed sedimentary basins. These data are acquired remotely from ships and satellites: with greater certainty from shipboard information. Rock properties are determined from sampling, dredging and deep drilling and coring. Not all areas are suitable for dredging, and Australia has limited ability to drill; we therefore require strategic science alliances to access this very expensive, but essential capability. Membership of IODP, and alliances with other marine agencies, e.g. JAMSTEC, IFREMER, NIWA, GEOMAR, and commercial providers are strategies to meet this need (see above).

In addition to geologic structure, the key to resource exploration is the presence of hydrocarbon source and evidence of a functional petroleum system. Natural seepage surveys, using shipboard or satellite techniques, provide valuable insights into the presence of active petroleum systems and can therefore be used to map out prospective areas as well as areas that can be rejected for CO_2 storage. Marine surveys that are directed at mapping seabed features provide good value for money as they can cover vast offshore areas at relatively low cost. In addition to assisting in exploration, seabed mapping underpins regional marine planning and environmental studies (see below).

Renewable energy – wave, current, and wind
Wave, current, and wind energy assessments utilise oceanographic data provided by BoM/CSIRO and digital elevation data for the seabed and adjacent land, as well as infrastructure information. There is a considerable resource of wave energy in Australia, and from a resource perspective, it is non-limiting and a viable means of adding to Australia's future low emission energy needs in the long term.

Globally, the industry is at a very early stage, with no commercial wave energy plants operating anywhere in the world: provision of pre-competitive data should attract industry to explore this potential resource, within the next 5-10 years. The CSIRO has undertaken early assessments of the wave resource and recently commenced a project funded by ARENA to develop an Australian wave energy atlas, and carry out experiments to look at impacts of energy extraction from wave energy devices on the surrounding hydrodynamics.

The key challenges include: understanding the characteristics of the resource and effects of climate change on that resource; understanding impacts of wave energy extraction on the marine environment, including ecological risk associated with changes in hydrodynamics and acoustics. To address the current deficiency in the observational wave record, a nationally coordinated observational dataset is an imperative which can be used to maintain checks on developed numerical models.

Accessing data
The conventional and renewable energy industries are global industries, and all companies seek to lower exploration and development risk by accessing data and information. In contrast to many of its "energy competitors", Australia is a relatively underexplored and high-cost nation, and renewable technologies capturing wave energy and offshore wind energy are not yet at a commercial stage. To reduce technical uncertainty (and therefore cost) related to resource exploration and development companies need ready and easy access to marine data and information. Information to assist the offshore energy industry is currently provided free or at the cost of transfer, with outstanding returns on publicly invested research moneys(see above). Data programs have focussed on geophysical data related to resource prospectivity but increasingly environmental sensitivities are being seen as a risk-factor for exploration and development, which emphasises the value of environmental data as an additional layer of precompetitive information.

In addition new paradigms for data access and modelling need to be developed.

High performance computing (HPC) and High Performance Data (HPD, machine-to-machine readable) are essential for modelling and understanding earth processes in the context of Earth System Science, including fluid movement within the basin. Equally important is the storage and curation of digital data – one 3D seismic survey may generate several hundred TBytes of data, and the demonstration of workflows to produce outputs.

Currently there are too few scientists with computational skills to undertake this work – and this aspect of training must be addressed.

Environmental baselines and assessment of potential impacts – multiple use, challenges
Australia's marine ecosystems are incompletely documented and their dynamics and resilience are not adequately understood. Representative areas of our diverse marine habitats and features have recently been established in Marine Protected Areas in selected parts of Australia's marine estate. While hydrocarbon exploration and production is not permitted in special zones in these areas, most of Australia's offshore basins continue to be explored and developed, with the corresponding requirement that environmental risks are well documented and adequately managed.

The Industry and all other stakeholders' need to conduct their activities according to the relevant guidelines and observe any restrictions that may be in place. The social licence to operate in Australia's offshore basins requires stakeholders to demonstrate that adequate measures are in place to minimise environmental impact and that they are able to implement rapid responses to unforeseen incidents. The potential impacts on marine ecosystems from existing exploration and production activities is generally poorly understood and the information base from which the risks of impacts can be estimated, and mitigation measures developed, is incomplete in many areas.

Oil spill impacts have received recent attention, in particular since the Australian Montara oil spill and Gulf of Mexico Macondo disaster. AIMS and CSIRO have played a major role in assessing the impacts for the Montara event. Ideally, management of potential impacts needs to include a regional perspective, taking into account the full range of habitats and ecological processes whose integrity needs to be preserved. Currently each lease operator manages its permit conditions within the context of its lease, leading to piecemeal accumulation of baseline data across a region. There are opportunities to derive significant efficiencies and new knowledge through improved integration and coordination of baseline studies.

Regional scale collaborative research programs can better support sustainable development and monitoring for potential future impacts. Typically such initiatives require multidisciplinary, multi-institutional programs, where collaborative consortia of major marine research institutions undertake closely linked research themes over a number of years. The Great Australian Bight Ecosystem Study, supported by BP, and the Browse Basin/NW Australia environmental baseline and spill response programs, supported by Shell and INPEX, are two recent examples. Beyond specific exploration or development related programs such as these, by progressively integrating data from individual, lease-specific projects the environmental information base can be expanded. To achieve this requires environmental data to comply with relevant data standards, be actively managed for the long term by appropriate custodians and be easy to access.

One of the common impacts on marine biota associated with offshore activities is underwater noise and vibration. Marine seismic surveys, geotechnical drilling, petroleum drilling, increased vessel traffic, construction, pile driving, dredging, decommissioning are sources of intense underwater noise associated with offshore petroleum. We know very little about underwater noise and vibration emission and impacts from FLNG and subsea technology. Much less research has focused on the effects of renewable energy development than from seismic surveying on the marine environment and organisms, for example.

The propagation of sound and, as such, noise and vibration impacts are site-specific and species-specific, and depend on the local physical oceanographic environment (bathymetry, temperature and salinity profiles, seafloor geology). It is therefore difficult to extrapolate from one area or species to another.

All marine mammals use sound actively and passively; all fish studied to-date use sound. Crustaceans and larvae use sound. Sound travels farther underwater than any other cues (e.g. light, chemicals for smell and taste). Vibration affects sessile animals. Recent research shows that biofouling is largely noise and vibration mediated.

An important but poorly understood issue for most marine habitats is the impact of multiple stressors (both natural and anthropogenic) acting over different time scales. These cumulative impacts can have a major impact on the health and resilience of populations, communities and ecosystems. For example, animals already stressed due to limited food resources may have a harder time coping with the additional stress of noise, pollutants or impacts such as elevated temperature related to climate-change.

Perspective

Key science questions and outputs are summarised in Table 2.
Priorities for the next two decades include the following initiatives

1. **Offshore exploration and production of hydrocarbons**: need for precompetitive data and analysis to identify potential resources and understand environmental sensitivities (see Table 2 for detail)
2. **Renewable Energy**: additional studies needed to quantify potential resources (see Table 2 for detail)

3. **Environmental outputs:** *cross- cutting issues in relation to Energy Security*
   a. Design of a regional assessment and monitoring plan and gap analysis tool for NW and Northern Australia – 5 year priority

More efficient use of marine monitoring data can be achieved through the development of a 'monitoring/baseline gap analysis approach' ideally utilizing standard monitoring protocols and methodology that identifies where the information gaps are in relation to the different needs of industry and government (links to the White Paper: Discovery, Prediction and Monitoring"). The analysis should include cumulative impacts as well as an understanding of regional issues

   b. Develop and test a predictive model of benthic habitats and communities for reefs and shoals.

Ultimately the ability to predict habitat response to operational activities and major incidents is a key goal. This would build on marine baseline data to:

- predict what communities are likely to exist in un-surveyed areas, based on key physical parameters such as bathymetry, seabed topography, sediment type, exposure to waves and storms etc.; and
- predict how these communities will change when subject to different impacts – based on an understanding of what the key drivers of change are and how they interact.

This type of modelling would require information on the significance and rates of key ecological processes (recruitment, connectivity, growth, response to storms) and bathymetric data is required at a regional scale.

   c. Improved modelling and prediction of sea surface and sub-surface transport oil spills and genetic connectivity.

Oil spill modelling and prediction of spill trajectory during an event requires high resolution surface current velocity and direction models and real-time data, as well as detailed bathymetric data. A potential emerging issue requiring this information is the introduction and transport to oceanic reefs and shoals of marine pests resulting from bulk LNG carriers loading direct from proposed Floating LNG production facilities.

   d. Improved understanding of tropical hydrocarbon ecotoxicology

Quantifying the risk to coral reefs from accidental hydrocarbon releases requires an understanding of the sensitivity of reef-building invertebrates to condensates and dispersants (used to manage slicks). This critical ecotoxicology data is almost non-existent for relevant tropical species. As a result, management, regulatory agencies and industry currently rely on potentially inappropriate sensitivity data for non-reef species when assessing the risks of development.

e. Improved prediction of impacts of offshore development and hydrocarbon spills on key marine fauna

Turtles, sharks and whales have been the subject of population surveys over the last two decades. However, there have been limited attempts to use these data to quantify spatial distributions, identify critical habitats and model distributions and abundances, Priority areas for the predictive modelling of these biota are the NW Shelf, Kimberley, and Great Australian Bight.

Realisation

Australia's existing marine infrastructure is inconsistent with the size of its marine estate and therefore is almost inevitably a limiting factor in the progression of Australia's marine science as a whole. This reality sets the stage for the long-term operation of marine infrastructure, particularly in energy security which calls for large and expensive platforms.

The recently completed R/V *Investigator* brings new and important capabilities to Australian marine science. However, an appropriate governance structure for scheduling the vessel is essential to maximise the return on investment. Governance processes must reconcile competing factors in the allocation of vessel time, including the need to work strategically. For maximum efficiency, the R/V *Investigator* may require geographic sector scheduling, i.e. working in a specific sector, perhaps for several seasons, before moving to the next sector. Geographic sector scheduling is a simple yet powerful high-level framework for governance of the facility.

Additional improvements to facilitate marine science could include: co-ordination and alignment of marine agencies work programs (regular science workshops and planning days); development of a one-stop-shop for accessing marine data and information; including the R/V Solander as part of the marine national facility; setting up a pool of marine equipment from the various government funded research agencies for the national facility, etc.

The Australian-New Zealand consortium funding for IODP expires at the end of 2015, and future funding is a critical issue. Numerous expeditions are planned or proposed for our region after 2015 and the value for Australia will be greatly diminished if we are no longer IODP members. For example, the Great Australian Bight IODP proposal, has attracted industry attention, with proposed co-funding through the University of Adelaide, but should our IODP membership lapse, co-funding would not be allowed and the chances that the expedition would go ahead would be greatly reduced.

Implementation of a strategy to develop regional environmental baselines for managing environmental issues associated with the offshore energy industry requires detailed planning and collaboration, and would include:

(i) A staged Implementation
(ii) Develop a single Regional Plan
(iii) Easy access to existing data
(iv) An continuous improvement approach

(v) Joint participation and effective collaborative oversight with Industry

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Attachments

Formal submissions to the Energy Security theme

1. Submitted by Geoscience Australia (TRIM D2014-192349)

MANAGING OFFSHORE INDUSTRY ENVIRONMENTAL DATA TO IMPROVE ENVIRONMENTAL OUTCOMES AND REDUCE GREEN TAPE

Introduction

The offshore petroleum industry acquires marine data to fulfil legislative requirements under the Environment Protection and Biodiversity Conservation (EPBC) and Offshore Petroleum and Greenhouse Gas Storage Acts (OPGGSA). The cost of this data acquisition is borne by the industry proponent. However, under these Acts, proponents have not been required to lodge marine environmental data when submitting Referrals or Environmental Plans. As a consequence, the data are not available to contribute to the national marine environmental knowledge base. A program to actively manage these data is required to ensure that they are archived and available to:

- provide regional context for future marine development proposals,
- better inform the management of Australia's marine estate, and
- contribute to integrated data products such as national and regional-scale characterisations of the marine environment.

Background

Reviews of the regulation of Australia's offshore oil and gas industry have identified a range of reforms required to improve the efficiency of government regulation and environmental oversight. A fundamental proposed reform is to actively manage marine environmental data and better employ it in the regulation process.

- The Hawke review of the EPBC Act identified potential efficiency gains through the development of landscape-based assessment processes and collection of regional baseline datasets (The Hawke *Independent Review of the EPBC Act, 1999* (chapters 10 and 13, 2009). The Hawke review suggested that '*automatic recognition of processes*' (assessments against regional datasets) may be achievable through comparison of site-specific environmental features with landscape-scale data, and thereby streamline the environmental assessment process.
- In 2009 the Productivity Commission recommended that all environmental data collected by industry relating to Commonwealth, coastal and inland waters reside with a central agency, Geoscience Australia (GA). (*Review of Regulatory Burden on the Upstream Petroleum (Oil and Gas) Sector,* Recommendations 6.1 and 6.3, 2009).

Furthermore, there has been growing support within the Australian Government to develop a more strategic plan for marine science, and to improve management of data for Australia's maritime jurisdiction.

- The review of Oceans Policy (TFG International, 2002) identified the need for a 'strategic vision for marine scientific research and marine data management' to underpin marine planning and maximise value for money research.

- The National Framework for Marine Research and Innovation (2009) prepared by the Oceans Policy Advisory Group (OPSAG) "advocates a renewed national effort in marine science through nationally coordinated research involving all marine science providers and users". In particular identifying a national approach and industry engagement is of key importance (p5).
- In 2010, the *Montara Commission of Inquiry* found "the need to better integrate Operational and Scientific (or environmental) Monitoring efforts, including ensuring that any Scientific Monitoring is adequate, peer reviewed and timely." (Recommendation 88 and 90)

In May 2010 the Australian Government announced an initiative to address the environmental information needs of the nation – *The National Plan for Environmental Information* (NPEI). This program, delivered through Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) and the Bureau of Meteorology (BOM), aims to provide a "long term approach to building and improving our environmental information database" (SEWPaC, 2010). A component of this program will require an integrated Government approach to effectively manage marine environmental data for Australian waters.

Significance / Outcomes

Centralised management and accessibility of marine environmental data will provide benefits to the offshore oil and gas industry and the Australian Government through access to consistent, robust environmental data at the regional and national-scale (Table 1) to:

- support evidence-based decision making;
- streamline management, delivery and analysis of environmental data;
- improve consistency and transparency between government, industry and the public;
- enhance the national marine information base; and
- reduce regulatory burden on industry and government through open access to a common set of marine environmental data.

A range of additional benefits will also be generated through centralised archival and management of industry data (Table 1). Most notably, access to additional data will:

- improve the ability to predict the distributions of marine habitats and biodiversity;
- better inform marine hazard assessments, such as oil spills;
- support the management of the Commonwealth's Marine Regions; and
- help to build a body of knowledge that will contribute to the assessment of cumulative impacts, in line with recommendations from the Montara Commission of Inquiry, the Hawke review of the EPBC Act, and the OPSAG National Framework for Marine Research and Innovation.

Table 1: Benefits generated through the implementation of a data management program for marine data collected by industry for EPBC Act and OPGGSA assessments.

Area Benefited	Description	Outcome
Pre-competitive assessments	Improved data for pre-competitive industry assessments	- Identification of potential risks and hazards and environmental issues prior to lodging a bid
Emergency Response	Additional data for emergency response modelling (such as spill models)	- Improved environmental data for emergency response planning - Baseline data to assess impacts
Hazard Reduction / Risk Assessment	Additional data for hazard reduction / risk assessment → improved risk assessment	- Reduced risk - Improved options to minimise risks - Better plans to respond to potential risks
Knowledge Gaps	Single location of data provides review potential to Identify knowledge gaps	- Better informed marine science programs
Cumulative Impact Assessment	Recording environmental condition on a regional scale	- Identification of existing and potential future cumulative impacts
Monitoring	Long-term collection of data with baseline data for independent post-activity change detection and environmental monitoring	- Improved ability to identify changes and assess impact on local and regional areas - Improved management decisions based on better data and predictions
State of Environment Reporting	Improved baseline and trend data for state of environment reporting	- More robust reporting for offshore areas and better informed environmental management
MPA Management and Review	Improved scientific data to contribute to MPA baselines and for future reviews of zoning.	- Assessment of MPA performance - Better knowledge of the regional significance of biota/habitats
New science	Improved data accessibility	- Access to new data for biodiversity characterisations and modelling - Re-use of data in new types of applications

Approach to Offshore Environmental Data Management

Wider access to environmental data collected as part of various regulatory approvals and monitoring will assist in the robustness and timeliness of environmental assessments, and public confidence in those assessments whilst reducing green tape. This can be achieved by:

1. **Broadening interpretation of the data management and environment regulations to require all environmental data under a title to be submitted to the regulators**
   - Recognises the long-term value of marine environmental data to Australia.

- Provides the regulator with the information necessary to assess whether industry are setting appropriate environmental targets and their performance in meeting these.
- Promotes use of consistent data standards and best practice environmental assessment and monitoring techniques by industry.

2. **Centrally archiving environmental data acquired by the offshore oil and gas industry**
    - This ensures preservation of a valuable resource that represents the majority of marine environmental data acquired each year in Australian waters.
    - Central archiving allows data to be re-used for a range of purposes, realising its full value to the Nation.
    - Preserves information necessary to understand long-term patterns of environmental change, including climate change.
3. **Integrating existing data to create national baseline marine environmental datasets**
    - Improved accuracy and resolution of environmental information that underpins Government policy and decision making.
    - Improved efficiency, clarity and certainty of approvals for offshore activities by providing common comprehensive, authoritative information to Government, regulators and industry.
    - Allows for understanding and consideration of cumulative environmental impacts of offshore activities.
    - Contextual information necessary to interpret local environmental data (e.g. within a title) and distinguish between natural variation/change and environmental impacts.
4. **Publicly delivering national marine environmental baseline datasets**
    - Transparent industry and government environmental decision making and environmental performance
    - Increased efficiency of environmental management by reducing duplication of expensive environmental data collection by industry/government/research institutions.
    - Best possible data is available for scientific research across all sectors, resulting in development of improved environmental information and practices for Australia's unique marine environments.
    - Baseline information is available to inform rapid emergency response and independently assess impacts of events such as oil spills.
5. **Understanding of gaps in Australia's marine environmental information and understanding**
    - More effective and targeted government funding of environmental research and data acquisition resulting in more effective policy, regulation and management.

2. Submitted by:

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Abstract

Natural seep research in Australia have three major components: petroleum exploration, benthic habitat mapping, and developing science for optimum oil spill responses. Australian marine scientists have a proven track record in world best practice through their active engagements in national and international research partnership with multinational oil companies and academia. Recently, the Australian Marine National Facility obtained the state-of-the-art research vessel RV *Investigator.* However, Australia lacks related infrastructure and capability needed to extend exploration capability in frontier basins in depths up to 4,000 m. This requires government investment in critical infrastructure and the personnel to operate this infrastructure. More targeted exploration in Australia's maritime jurisdiction will improve the economic contributions from Blue GDP and reduce environmental impacts of offshore activities

Background

The area of Australia's marine jurisdiction is the third largest of all nations - more than double its landmass. Ninety five per cent of Australia's petroleum production comes from offshore sedimentary basins, valued at $27 billion in 2012. The projected income from the oil and gas sector is $66 billion by 2020 (3.5 per cent of the national economy). As the population continues to grow, so too does the demand for petroleum. This increasing demand requires continued exploration, with attention shifting to frontier basins located further offshore, in deeper waters and remote from infrastructure.

The exploitation of petroleum resources from oceans must be balanced with the conservation of critical ocean ecosystems. Striking this balance requires improving our understanding on two levels:

1. On a fundamental level, improvements must be made to our scientific knowledge of the hydrocarbon processes linking the geosphere, hydrosphere and atmosphere;
2. On a more regional level, further, detailed knowledge about Australia's vast and varied marine systems, their resources and the operation of their ecosystems is needed. At present, most of the Australian EEZ is very poorly characterised.

Scientists from CSIRO and Geoscience Australia are working on these issues through research into natural submarine hydrocarbon seeps. Submarine cold seeps refer to the escape and venting of oil, gas, water and sediments through faults and fractures to create various geo-bio-structures on the seabed. From a petroleum perspective, natural hydrocarbon seepage is the surface manifestation of a deeply buried system in which migration, and probably also generation, is currently active. Seep sampling offers unique information about the deeper geological structure and lithologies from which the seep is sourced, and through the study of the composition and age of the associated gas and traces of hydrocarbons insight may be offered about the source rocks and geochemical conditions at depth (Ivanov et al. 1996). From a marine ecosystem perspective, in the absence of sunlight in the deep ocean, seep sites are the place where energy rich seeping fluids provide ideal locations for deep biosphere habitat formation. Microorganisms that extract energy from reduced inorganic compounds (chemoautotrophs) are concentrated in vent effluents or form symbiotic relationships with deep sea fauna and become primary producers in these deep-sea ecosystems. From an environmental point of view, seeps are the interface between the geo-sphere and bio-sphere where the exchange of greenhouse gases between the earth, oceans and atmosphere occurs over time. Geological emission of methane is now considered to be an important greenhouse gas source acknowledged by the IPCC (Intergovernmental Panel for Climate Change) in its Fourth Assessment Report (Denman 2007) and geological seepage will be considered as a new category in the UNECE/EMEP Task Force Emission inventory Guidebook (Etiope 2009).

One of the major components of submarine seep research is to understand how oil and gas evolve during their migration from seabed to sea surface. Questions such as how seeped oil and gas impact the marine ecosystems during their residence in the water column and the exchange of hydrocarbons over the water atmosphere interface still need to be answered. This has direct relevance in having robust scientific understandings of these processes in preparedness for potential future oil spills.

Australian scientists are world renowned for their work in the areas of natural hydrocarbon seeps and oil spill response. For example Geoscience Australia have performed world leading research on hydrocarbon seeps through government funded research programs aimed at enhancing Australia's offshore prospectively. Similarly CSIRO have been involved in industry funded, natural seeps surveys both in Australia but also in the Gulf of Mexico. In addition CSIRO has also been involved in developing understandings of marine hydrocarbon processes and evolution as part of their research during and subsequent to the Deepwater Horizon incident in the Gulf of Mexico in 2010 often in collaboration with other internationally recognised organisations such as NOAA.

Relevance

- Hydrocarbon seep research will contribute substantially to lowering the risks associated with frontier basin investment and exploration in deep water offshore Australia for both government (in terms of offshore prospectivity) and the petroleum industry.
- Efficient and sustainable exploitation of seafloor resources will be facilitated by systematically collected, high resolution, benthic habitat mapping. Mapping is needed because the geological and physical environment of the Australian EEZ is extremely complex, in part because it ranges from tropical seas to sub-polar oceans. This research will also reveal unique and likely endemic faunal communities, and provide the context necessary to consider the implications for their conservation.
- Research on hydrocarbon processes linking geosphere, hydrosphere and almosphere will establish base line of green house gas emissions from natural seepages for Australian offshore areas.
- Research will increase national capability to respond effectively to any new oil spill incidents around Australian coasts.
- Diffusion of scientific knowledge will contribute to informing the Australian public's interest in, and concern about, exploitation of national assets in the offshore EEZ.
- Finally, this area of research will help policy makers and manages to better evaluate the trade-offs between maximum economic potential from our marine jurisdiction, and environmental sustainability.

Science needs

Data gap:

The fundamental challenges to understand natural seep systems in deep water stem from the scales of investigation required, and the temporal and spatial variability of seeps. Firstly, the surface expressions of seep features are typically centimetre to meter in scale. Their detection and subsequent sampling relies on very high resolution seabed mapping. Secondly, natural seep systems are transient in space and time (Tryon et al. 1999, Leifer et al. 2004, Greinert et al. 2006). Lastly, little is known about the fate of the released oil and gas in the water column, and its impact on marine life and exchange with the atmosphere.

Methane input into the atmosphere from seeps at water depths of less than 200 m has been/can be clearly observed and measured. However, recent publications suggest contradictory views on how much methane reaches the atmosphere from natural seeps located in deeper waters. Repeated offshore surveys reveal that vigorous fluxes of hydrocarbon expulsion can be terminated in an interval of hours (Heeschen et al. 2003). Even repeated surveys give only snapshots of the seafloor at discrete times, and a full appreciation of the temporal variability can only be achieved with high resolution, long term and frequentmonitoring (Talukder 2012). Until recently, there has been limited success in detecting active seepages around offshore Australia (Logan et al. 2010). However, use of newly developed and integrated technologies during marine surveys has led to discover several active seep sites in different offshore basins. Thus, in order to identify natural seepages, assess base line and evaluate their environmental impact around Australian coasts, research must adopt two simultaneous processes: expanding seep exploration using new and integrated technologies and long term monitoring of newly discovered active seep sites. Seep detection and monitoring in real time is a big scientific and technological challenge. As global science players, Australian scientists need to further develop their current work to adopt and integrate technologies for seep detection and data display in near real time.

The first step towards the optimum estimation of marine resources in the Australian marine jurisdiction is the comprehensive mapping of its benthic habitats. The need for additional mapping data is put in perspective by considering that by Feb 2012, only 12% of Australia's EEZ had been mapped with multibeam echosounders: 10,599,967 km^2 mapped and roughly 60,000,000 km^2 unmapped (Geoscience Australia, unpublished estimate). Additional capability in the form of Australia's new research vessel, RV *Investigator*, has the potential to substantially enhance and add to existing bathymetric mapping in the EEZ.

Key outcome/ national benefit

- On a five year horizon: expanded frontier basin exploration in the NW Shelf further offshore and defining new frontier basins in the Great Australian Bight. A sustained program of high resolution mapping will increase our national capability to exploit and manage Australia's marine jurisdictions progressively further offshore.
- On a ten year horizon: complete high resolution seabed mapping of relevant areas of the remaining unmapped Australian EEZ. Detect and characterize major natural seep systems and associated benthic habitats on the outer continental margins and slope areas of the NW, W and S of the continent, and in new frontier basins south of Tasmania and in the Tasman Sea. Development of new marine instrumentation, especially sensor technologies, for real time hydrocarbon detection and monitoring in the water column and sea surfaces in an integrated package.

- On a 20 year horizon: full appreciation of deep sea hydrocarbon processes and their long term impact on geosphere, hydrosphere and atmosphere (whole of EEZ net carbon fluxes) occurring in Australia's offshore marine areas. More targeted exploration of all frontier basins in Australia's maritime jurisdiction will improve the economic contributions from Blue GDP and reduce environmental impacts of offshore activities. .

Perspective

At present, natural seep research in Australia have three major components: petroleum exploration, benthic habitat mapping, and developing science for optimum oil spill responses. From petroleum exploration perspective, immediate science priority is to expand seep research in new frontier basins further and further deep water. Geographic extension of research area should be at par with research capability and infrastructure developments through innovation and integrations. Evaluating frontier deepwater basins is an expensive proposition with high risks and high rewards. Conventional deep sea mapping methods are not effective. Sampling live oil and gas from natural seeps through sensing technologies in real time can provide the most incontrovertible and cost effective information for frontier basin prospectivity assessment. At the technological front, Australian seep reseach needs to enhance its current focus to develop and integrate technologies for near time sensing instrumentations. However, the development of real time multicomponent hydrocarbon sensing technologies with a very wide dynamic range is a significant challenge, which makes it a priority science area. It will require international and industry collaborations.

Successful detection and sampling of active natural seepages will help define new petroleum provinces, however, creating offshore permits for petroleum industry with environmental licence will require detail understanding of hydrocarbon processes in the submarine ecosystems. The comprehensive assessment of the impacts of hydrocarbon fluxes on the biosphere and unravelling the connections between Earth, ocean and atmosphere constitute another Big Science objectives. Deciphering the spatial and temporal variability of cold seep fluxes in global oceans will require global efforts. World leading organizations working in this domain include: National Oceanographic Centre, Southampton in UK, GEOMAR and MARUM in Germany, Woods Hole Oceanographic Institution, Scripps Institution, MBARI and NOAA in US. Several international/intergovernmental organizations are International Ocean Discovery Program (IODP), Intergovernmental Oceanographic Commission (IOC) and the Intergovernmental Panel on Climate Change (IPCC). Australian seep research community are actively engaged in global stages. In 2010, after the BP Deepwater Horizon incident in the Gulf of Mexico (GoM), the CSIRO scientists conducted a series of marine surveys in the area and discovered significant active natural seepages around the spill area. The impact of these discoveries led BP and US NRDA (Natural Resource Damage Assessment) Authority to set up the most comprehensive seep study program ever done in the GoM. CSIRO scientists have played a major role in all stages from initiations, developments and successful completion of the seep program (Talukder et al. 2013, Crooke et al. 2015). By establishing the Australian seepage baseline, variability through exploration on its vast and varied continental margins, Australian seep research can better partner with major global research partners.

Detail understanding of the marine environment and how hydrocarbons interact within it is a prerequisite for oil spill response and understanding long term impacts. Australia requires comprehensive and specific knowledge about geological, biological and physical oceans along

Australian coast lines. Continuous high resolution mapping will keep increasing our capability. The sensing (chemical, acoustic, radar, satellite), data integrating and GIS systems development applicable to seep mapping and tracking are a key for improved rapid-response data gathering in an oil spill situation. This capability overlap is an area of strength in the Australian science community but requires further development over the medium term to be fit for the wide range of climatic and oceanographic conditions experienced in the Australian marine jurisdictions. Another dimension of science enterprise is needed to match detection and tracking with practical and rapidly deployable containment and clean-up solutions, better described within the environmental ocean science priorities.

Realisation

Australian marine scientists have a proven track record in world best practice through their active engagements in national and international research partnership with multinational oil companies and academia. Recently, the Australian Marine National Facility obtained the state-of-the-art research vessel RV *Investigator* which will facilitate collection of relevant and high quality data from frontier regions around. However, Australia lacks related infrastructure and capability needed to realise these data. Specifically, Australia has no scientific capacity in deep water, work-class Autonomous Underwater Vehicles (AUV) or Remotely Operated underwater Vehicles (ROV). The RV *Investigator* has the capability to launch and operate AUVs and ROVs, and this will be tested and developed in 2016 by using vehicles hired and loaned from the US. In order to extend exploration capability in frontier basins such as the Great Australian Bight, Australia must develop its own deep sea exploration capability to enable research work in depths up to 4,000 m. RV *Investigator* is capable of undertaking bathymetric surveys in 4,000 m water depth but requires the assistance of an AUV or ROV to do so at the high resolution required for frontier exploration.

Key infrastructure and capability requirements:

- AUV with research capability up to 4000 m water depths: this autonomous vehicle is capable of performing many of the survey duties of oceanographic vessels and comes mounted with Side Scan Sonar, Sub bottom profiler, Multibeam Echo sounder, Digital still camera, CTD sensors, Acoustic Doppler Current Profiler, Turbidity sensors, Hydrocarbon sniffer, Laser optical plankton counte and magnetometer. This system will be used for very high resolution shallow sub-seabed, seabed/benthic habitat mapping and geochemical characterisation in the water colum.
- ROV with research capability up to 4000 m water depth: though many of the sensor pay loads are the same for AUV and ROV, but ROV is needed for forward looking sonar scanning and video observation and for targeted and controlled sampling in and around seep locations that have been identified by geophysical mapping.
- X-band Radar: This is a ship mounted radar systems that can track oil slicks on the sea surface in real time during the survey, and its configuration and directionality and connectivity need to be suitable to integrate into a multi-sensing package for seep mapping and investigation.
- EM302 multibeam echo-sound systems: this can detect hydrocarbon in the water column in real time during the survey at frequencies targeted to average methane bubble size and is indispensible for tracking plumes to seep locations in deep waters.
- Access to satellite remote sensing platforms e.g. the ESA Sentenel program

Funding and coordination

For the entire marine, fisheries and oceanographic research communities, the Australian National Marine Facility has only one deep sea state of the art marine research vessel, RV *Investigator*, with an operational budget for 180 days sea time a year. Ship time allocation will be major constraint. In addition there is limited national capacity to perform high resolution deep water marine surveys. This requires government investment in critical infrastructure and the personnel to operate this infrastructure. Programs which utilise this capability are envisaged as both being direct government funding (in the case of precompetitive data collection), collaborative funding, government/industry joint funding for the national benefit as well as fully industrially funded research. The development and maintenance of this capability and skills combined with the key science questions that will be answered through their deployment are important in maintaining our international standing and being able to better characterise and understand our deep marine environment.

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3. Curtin University

3.1 LIDAR Team, Remote Sensing and Satellite Research Group. Curtin University

Abstract

Two areas where Curtin University has capability in supporting aspects of a national energy security strategy are:

- the direct measurement of fugitive emissions / greenhouse gas emissions specifically using (i) Coherent Doppler LIDAR [CDL] for regional monitoring of winds coupled with (ii) either *in situ* or direct measurement of fugitive emissions / greenhouse gas concentrations using Differential LIDAR [DIAL] which when taken together yield regional fluxes, and

- assessment of the suitability of potential offshore / coastal wind energy sites with respect to both directly measured [using CDL] and numerically modelled wind fields [using WRF] and

- addressing the efficient operation of wind farms through optimization of turbine performance by utilizing CDL real-time upwind information assimilated into wind prediction models.

Background

Curtin has the brief within CRC CARE I and II to undertake the wind modelling and wind measurement program the latter using coherent Doppler LIDAR [CDL]. The latter enables wind speed and direction to be measure remotely at ranges of typically 15 to 20 km radius providing regional surface and elevated wind information from one location covering an area 300 to 400 km^2.

The Team at Curtin that has been working for some 5 year comprises 2 academic staff, a project manager, 2 PhD level research scientists and 3 PhD students.

The project acquired a CDL through the CRC and has operated the unit in a number of projects in Africa [on the Lake Turkana Wind Farm – largest in Africa], the UK, South America and in the Pilbara region of WA.

The numerical modelling work involves the Weather Research Forecasting [WRF] that is widely used around the world for a wide range of applications. It models wind flows [speed and direction] and its output may be assimilated into finer computational fluid dynamics models [eg Open FOAM] for more detailed studies of flow around manmade structures (such as turbines). The wind farm research involves CDL measurements, WRF modelling and assimilating LIDAR data into WRF. The Pt Hedland work involved a similar mix of tools.

The work is funded primarily but CRC partners but significant funding has come from wind farms, from air quality management projects [Port Hedland Port Authority; BHP]; coal fired power station operators; cement companies. To our knowledge we are not aware of any other Australian research group engaging in this research work.

Relevance

As noted any industry that has issues with air quality from chimney stacks etc may find LIDAR technology valuable. However, in the offshore oil and gas industry leakage of gases such as methane and CO2 are quite high during operations and not well monitored. For example the FLNG platform will become significant sources of fugitive gases. To monitor the flux of gases escaping from such operations one needs the capability to monitor significant areas around a facility and to acquire data on both concentration of species and information on the wind speed and direction. LIDARS [CDL for winds and DIAL for concentrations] achieve these objectives and enable fluxes of emissions to be assessed. Further, reliability of LIDARs is now quite high and they may be left running and logging data 24/7 for extended periods.

One such project where we are working with the CRC and Chevron is on the CO2 geosequestration project on Barrow Island. LIDASR monitoring is ideally suited to such a project because the location of sources is not actually known. Gases could leak to the surface from any location on the Island or through the seabed adjacent to the Island.

Science needs

Curtin and the CRC do not yet have a Differential LIDAR (DIAL) for monitoring trace gases. However, it has negotiated a demonstration project with a US research team that has an operational instrument. So experience with DIAL is an important gap.

While post-processing of field acquired data is well in hand there is room for further development to perform near real-time processing of LIDAR [both CDL and DIAL] to ensure that critical information for either site assessment or for management / operational decisions is available. For example LIDAR data may need to be assimilated into the numerical wind forecasting models to improve wind farm generation efficiency or at the geosequestration site to identify new sources of sub-sea escape of fugitive gases. The time line for these software developments needs to start now.

Just as the iron ore mining industry has moved to have its ore rail system and the ore dump trucks operated by remote computer-controlled systems offshore wind farm will need to move toward similar solutions. Progression of these types of developments are probably best undertaken in close collaboration with the relevant industries as they strive to become more viable economically. This requires demonstration plants etc to be constructed to evaluate and fine tune these autonomous systems. The timeline for this phase is probably 1 - 5 years.

Perspective

Australia lags well behind many countries [Germany, Denmark, Sweden, UK, France] in the technologies associated with wind turbine developments. There are some niche opportunities that may arise from vertical axis turbines for specialised applications and also for enabling operation of turbines in higher wind regimes without encountering major challenges in strengths of turbine blade materials. {Now to 10 years).

There are also opportunities at alternative sites to those presently being selected. Current wind turbine sites are sought for their consistent moderately high winds. However, it is highly likely that systems designed for efficient operation in what are relatively low winds sites. This opens up the opportunity for Bernoiulli Turbines where one uses Bernoulli's equation to enhance wind speeds. (Now to 10 years).

Fugitive emission monitoring using fully autonomous regional area laser-based sensing technologies [recommended by CSIRO in the Ottway Basin Study] need significant development and refinement in order to become robust systems with low failure rates. We are not aware of such technologies that are anywhere near operational systems presently. The focus is still very much on the sensing technologies.(5-10 years).

Professor Mervyn Lynch, Dr Brendan McGann, Mr John Sutton, Dr Frank Yu, Dr Francois Jeanneret – Curtin University

3.2 Miles Parsons & Christine Erbe, Centre for Marine Science & Technology, Curtin University, Perth, Western Australia

Background

Offshore petroleum is moving into deeper and deeper waters further from shore. Processing is moving from shore to site, in the form of floating structures. We're moving from FPSO's to FLNG's. The next step might be subsea processing.

At the same time, Australia is looking to follow Europe in terms of developing renewable energies, including tidal, wave, current and wind power.

It is vital not only to focus on research and development for the exploration and production of these energy resources, but also to develop techniques to monitor the wider environment for potential short- and long-term side-effects of these new activities, to research potential impacts and to develop means for mitigation.

Relevance

There are a multitude of stakeholders in the marine environment. The offshore petroleum industry aims to develop offshore oil & gas. The fishing industry is concerned about impacts from offshore petroleum development (e.g. seismic surveying) on their resource. Native groups want to preserve their marine resources for subsistence purposes and beyond. NGO's and environmental groups want to protect the marine ecosystem from any exploitation. The tourism industry wants infrastructure to support tourists, but to keep areas otherwise undeveloped and pristine. Etc. The challenge is to manage any future development in a sustainable way.

Science needs

The potential impacts on the marine ecosystem from existing and new technology are generally poorly understood.

Oil spill impacts have received quite a bit of attention, in particular since the Montara oil spill. Ecotoxicology is still an active field of research (e.g. Prof. Monique Gagnon, Curtin University).

One of the impacts common to both petroleum and renewable energies is underwater noise and vibration. Marine seismic surveys, geotechnical drilling, petroleum drilling, increased vessel traffic, construction, pile driving, dredging, decommissioning are sources of intense underwater noise associated with offshore petroleum. We know very little about underwater noise & vibration emission and impacts from FLNG and subsea technology.

Renewable energies also produce noise, during construction and operation. Much less research has gone into impacts from renewable energy development than from seismic surveying for example.

The propagation of sound, and as such noise and vibration impacts are site-specific and species-specific, and depend on the local physical oceanographic environment (bathymetry, temperature and salinity profiles, seafloor geology). It is difficult to extrapolate from one area or species to another.

All marine mammals use sound actively and passively; all fish studied to-date use sound. Crustaceans, larvae use sound. Sound travels farther underwater than any other cues (e.g. light, chemicals for smell & taste). Vibration affects sessile animals. Recent research shows that biofouling is largely noise & vibration mediated and can be mitigated using noise & vibration.

Something that has not been studied at all in the marine environment is the impact of multiple stressors. Animals already stressed due to limited food resources, do they have a harder time coping with noise or climate change? How do different stressors add and accumulate?

Perspective

Suggested needs for R&D for environmental monitoring and impact assessment from the development of any offshore energies:

- Passive acoustic monitoring is a cheap and long-term means of monitoring the environment and potential impacts, however, research is still needed into baseline conditions, soundscape characterisation (and how it changes naturally in space and time), catalogues of sound sources (biological and anthropogenic)
- Passive acoustic recording of operational sounds for performance management and fault detection
- Sonar imaging technology. Off-the-shelf sonars are routinely used by industry for seafloor mapping, but with some future R&D can also effectively be used for the detection of seeps (detection, classification, quantification); the detection of megafauna (hazard mitigation for both facilities and fauna); the detection of internal waves and sediment plumes (protection of facilities)
- Multi-beam mapping of local habitats (baseline and on-going monitoring); and of in-water fauna (baseline and on-going monitoring)
- Short-range multi-beam monitoring of equipment (maintenance, performance and fatigue management)
- Much of the exploration, processing and monitoring will be remote; we need to move to autonomous technology for monitoring, including real-time monitoring, and mitigation (e.g. autonomous gliders for metocean monitoring, Chevron-Curtin University collaboration; autonomous passive acoustic buoy for real-time megafauna detection in construction zones, Chevron-Curtin University collaboration)

Environmental impacts, long-term and ecosystem impacts are very complex and cause-effect relationships are difficult to tease apart. Much better collaboration is needed between physicists, engineers, acousticians and biologists and ecologists to understand ecosystem impacts and to develop efficient monitoring tools.

4. Submitted by

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Environmental Aspects of Offshore Oil and Gas Development

Abstract

Marine environment knowledge gaps represent unknown or difficult to quantify management and business risks for both the offshore oil and gas industry and regulatory authorities. In general environmental assessments are carried out to address specific individual permit applications. The application of baseline data accumulated in a piecemeal manner for environmental assessments is not sufficient, as it is not likely to provide a regionally consistent and comprehensive database for rigorous science based decision making. There are opportunities to derive significant new knowledge from future environmental work undertaken by the research sector and. Through regional data gap analyses, collection and co-ordination of additional data, together with central management, integration, interpretation and (where feasible) sharing of environmental data, there is an opportunity to significantly improve the management of risk for both government and industry.

Background

Recent events have shown that despite advances in technologies and improvements in contingency plans, accidental oil spills and blowouts remain a risk to both industry and environmental managers. Evaluations of the environmental impacts of offshore oil and gas resource development have primarily been conducted in Europe or North America, following major oil spills and this work dominates the literature with over 1700 papers on the last 4 major spills. Australia's contribution to this literature has been comparatively modest with 14 reports and 1 scientific paper published on the Montara well blowout in 2009. Research institutions in Norway and Canada focused on the assessment of potential environmental impacts of offshore oil and gas activities are well supported by both industry and government. The US National Oceanographic and Atmospheric Administration, the US Environmental Protection Agency and the Department of Interior also have branches that are focused on this area of research. This national level of coordinated and concentrated research is not present in Australia, although three recent developments (see below) indicate a trend towards a collaborative approach.

Improved understanding of the marine environment, the drivers behind ecosystem integrity and the pathways and potential scales of interaction with industry activities are increasingly forming an ongoing and continually updated backdrop for offshore oil and gas development in Australia.

Knowledge gaps about the environment can represent unknown or difficult to quantify business risks. These gaps could influence the design and location of offshore facilities, the range of development options able to be soundly evaluated, or the ability of a company to define and continually improve its environmental performance, or to assess its role in any unexpected environmental changes. In areas where there are recognised sensitive environments there is a heightened need, frequently addressed through support for marine research, to demonstrate good environmental stewardship and protect industry's reputation and social licence to operate.

Offshore exploration and development draws on environmental knowledge and research as required for its planning, approvals and compliance needs. The private consulting sector, which can be a significant employer of marine science graduates and post-graduates in Australia, services a major proportion of industry's routine marine survey and analysis requirements. Where technical innovation and larger scale or specialist environmental research is a key requirement, industry frequently engages with the universities and public funded research agencies.

Australian researchers from multiple institutions have had over two decades of continuous and direct engagement with companies operating in Australia's major province of oil and gas development on the NW Shelf, Timor Sea and southern Australia. This has resulted in the provision of objective marine environmental information and advice to industry in support of sustainable development and conservation, often drawing on reviews or synthesises of environmental information collected for industry by private sector consultants. Future environmental research in support of sustainable offshore energy is likely to continue current ways of engagement with the private and public environmental sector, but also move to greater levels of synthesis and predictive modelling. Industry is more than ever open to the value of regional scale data, to benchmark and provide context for their individual activities, but also in recognition, particularly post- Macondo and Montara, that the potential environmental footprints of their activities extend and overlap across multiple leases. Robust and extensive environmental data will go hand in hand with improved environmental (impact, effects or status) prediction.

Relevance

Offshore resource exploration, development and production in Australia waters is active westward from Bass Strait across the Great Australian Bight and northwards along the Western Australian coast into the Timor Sea. Many of Australia's offshore petroleum reserves contributed $21 billion to the economy in 2009-10. By 2020, these are expected to contribute more than $60 billion, effectively tripling the sector in ten years. The amount of liquefied natural gas exported from Australia is expected to increase by a factor of 5 in the next twenty years. Tropical NW Australia, now the dominant region of both national production and known reserves, is experiencing an unprecedented oil and gas industry expansion. In 2012 NW Australia offshore oil and gas industry delivered capex investment of $130bn (Deloitte Access Economics (2013) *Advancing Australia. Harnessing our Comparative Energy Advantage)*. Australia's national production of LNG is estimated to increase from 12 mtpa in 2005 to 94 mtpa in 2016, the majority of new production delivered from offshore NW WA projects. In 20012-13 Australia exported 29.3 MT of LNG with a value of $13.7bn.

In the aftermath of Australia's first major oil spill, the Montara wellhead blowout, The Borthwick Commission of Inquiry (2011) found major deficiencies in the response and has supported previous findings of a Productivity Commission Report (2009) on the need for coordinated regulation of offshore activities and management on environmental data. The Borthwick Inquiry also recommended that pre-designed, fit for purpose monitoring programs should be speedily implemented following incidents. From this it is clear that rigorous and effective monitoring strategies and technologies need to be developed, implemented and continually improved to ensure that the full spatial and temporal scale of any impact is understood, that the influence of other stressors on any potential ecosystem decline are not attributed to petroleum resource development, and that conversely, the influence of petroleum resource development on ecosystem health is not mistakenly attributed to other stressors.

Direct end users of research into the environmental impacts of offshore oil and gas development will be the oil and gas industry, the Australian Maritime Safety Authority (AMSA – whose role it is to respond to oil spills from shipping), and the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA – which regulates the offshore oil and gas industry) and Australian public. Industry will benefit from this research because it will facilitate their permitting process, enable them to demonstrate that their activities are not having major environmental impact (as required by the Offshore Petroleum and Greenhouse Gas Storage Act 2006) and maintain a societal license to operate. NOPSEMA will benefit because this research will enable the enforcement of appropriate regulation. AMSA will benefit because they will have a realistic idea of the impact of any oil that is accidently released into the marine environment as well as any mitigation measures used (such as chemical dispersants). AMSA will also have appropriate baselines to compare the recovery efforts to. The indirect beneficiaries of this research will be participants in the fisheries and tourism sectors, who are dependent on intact marine ecosystems for their livelihoods; recreational users of marine ecosystems (snorkelers/divers; beachgoers; recreational fishermen) and all Australians because of the greater energy security that development of the national resources will afford.

Current legislation requires that oil and gas operators demonstrate that development of offshore oil and gas resources be sustainable. The current guidelines also stipulate that robust monitoring programs need to be coupled with pre-impact baseline data to maintain a societal licence to operate. Following the Montara well blow-out and the perceived inadequate response, a new regulatory agency, NOPSEMA, was formed. Among the responsibilities of this agency is to ensure that off-shore oil and gas operators have an adequate environmental plan as well as an oil spill management plan. The need for these documents have provided a new framework for Australian researchers to collaborate with the oil and gas industry. The outcome from such collaborations will enable industry to conduct its operations in an environmentally stainable manner and to maintain their societal license to operate.

This monitoring is not only a requirement under the Offshore Petroleum and Greenhouse Gas Storage Act (2006), it is part of Australia's obligations under the United Nations convention on the Law of the Sea. Specifically, the convention states that Nations have the right to exploit their natural resources and the duty to protect and preserve the marine environment (Article 193). Article 200 requires scientific research into marine pollution, Article 204 requires monitoring of marine pollution and Article 205 requires publication of these results.

Some of the key regulatory drivers that require additional marine science research include:

- improved prior planning for optimized infrastructure location to minimize environmental footprint;
- site specific assessments of biological and physical attributes to generate an improved understanding of the receiving environment as part of lease retention or operating obligations;
- environmental monitoring in the event of a spill, including the establishment of appropriate environmental baselines to inform environment damage assessment;
- better integration of 'operational' and 'scientific' monitoring;
- reducing the time taken to implement scientific monitoring;
- the utilisation of water sampling undertaken during the response to inform assessments of the transport, fate and impact of dispersed oil;
- improved rigor of detailed design and implementation aspects of scientific monitoring; and the efficacy of monitoring triggers.;
- improved capability (e.g. oil spill countermeasure technologies) and capacity to respond to accidental spills

There are opportunities to derive significant new knowledge, with the existing and future environmental work undertaken by industry, through improved integration. Currently each lease operator manages its permit conditions within the context of its lease, which requires the collection of environmental data. Environmental assessments are carried out to address specific individual permit applications, are frequently undertaken by commercial consultants and often proceed in isolation from studies in adjacent leases or in comparable areas. Such an uncoordinated approach is characterised by the use of disparate data collection methods, a lack of overarching data management to facilitate assimilation across leases, data redundancy, critical spatial or discipline gaps and variable accessibility of data held in commercial hands.

Piecemeal accumulation of baseline data across the region as leases are developed is not efficient, takes a long time to accumulate, frequently results in duplication of effort, is less likely to result in regionally consistent and publically available data, and likely to cost far more than a single coordinated baseline program.

As demonstrated in the Montara and Macondo (Gulf of Mexico) incidents, a moderate to large hydrocarbon spill can potentially impact a huge area. Since an effective baseline requires information at possible impact and non-impacted reference (control) sites, the area over which environmental data is required may be many times the area of the lease.

These events have raised awareness that regional scale research programs will have a key role in supporting sustainable development and adequately monitoring for possible future impacts. Typically such initiatives require multidisciplinary, multi-institutional programs, where collaborative consortia of major marine research institutions undertake several closely linked research themes over a number of years. The Great Australian Bight Ecosystem Study, supported by BP and the Browse Basin environmental baseline and spill response programs supported in NW Australia by Shell and Inpex are two recent examples. Beyond specific exploration or development related programs such as these, data collected in collaboration with industry can be scaled beyond individual lease footprints by progressively integrating knowledge from individual, lease-specific projects. This requires research organizations that can bring to bear standard methodologies and long lived data management structures.

Evidence of end-user engagement includes a history of and ongoing support for marine research activities from Shell, Inpex, Woodside, PTTEP, Conoco Phillips, BP, and BHP Billiton Petroleum. Recently, more formal collaborations to jointly conduct research with and for industry have developed. These are the formation of a research consortium, drawing on the WAMSI partnership, to develop a comprehensive approach to baseline monitoring and oil spill response for Shell and Inpex; the Gas Industry Social & Environmental Research Alliance to foster collaborative research relating to LNG and coal seam gas development; and the Great Australian Bight Research Program involving a consortium of research agencies and BP to improve environmental understanding in areas of potential development in the Bight.

Science needs

Compared to other Australian tropical marine jurisdictions the Australian major offshore petroleum province, NW and Northern Australia are environments with little existing information. For example oceanic reefs and shoals in NW WA are dynamic systems where rapidly changing habitat cover and diversity has been observed. In many cases changes in habitats, for instance the loss of sea grass beds at Vulcan shoal have been considered to be the result of physical oceanographic drivers (storms, waves etc.). However, due to the remote nature of these systems there is a paucity of real time ocean observation data to confirm such assumptions.

With the expansion of the NW offshore oil and gas industry, increasing activity in the Timor Sea including the Joint Jurisdictional area, northern Australia Bonaparte Basin and Joint Petroleum Development Area there is a requirement for marine science knowledge and information to meet regulatory approval and compliance requirements. In a similar vein, Commonwealth and State marine park managers have a requirement for marine environment assessments and habitat characterization providing the technical basis to underpin management decisions. Currently government and industry are conducting and commissioning environmental surveys of the area in response to specific issues and needs without any coordination of these efforts or any strategic plan for the development of a regional baseline understanding of the current status of the region and the key drivers of distribution and change in communities.

The Great Australian Bight is now an area of considerable exploration activity with seismic surveys and exploratory wells to be drilled on the continental slope in depths of 1000-3000m. The highly productive region is home to great white sharks and iconic marine mammals such as whales, seals, dolphins and seabirds. It produces 25% of Australia's seafood production by value and it supports Australia's largest commercial fishery by volume, the South Australian Sardine Fishery, as well as the valuable southern bluefin tuna fishery. Nonetheless it is poorly understood.

In order to determine the potential impact of industry activity and spill events on marine habitats there is a need to understand the ecosystem processes and their natural levels of variability. This involves the need to establish a fit-for-purpose baseline database against which post-spill observations can be compared to determine the extent, severity and persistence of the spill and to assess effectiveness and endpoints for of oil spill response operations. In addition, for risk analysis, a detailed understanding of oceanographic drivers of spill transport is required in order to model and predict spill trajectory and 'zones of potential impact'.

From an offshore oil and gas industry environmental management perspective marine science knowledge and information required by industry and regulators to meet approval, monitoring and compliance requirements includes:

- Identifying knowledge gaps and developing proposals to address them, - this includes
  - identification of new and existing marine habitats, for example submerged banks and shoals that have yet to be subject to habitat/ecological survey
  - Marine community composition, dynamics (survival, growth, reproduction, migration) and biogeochemical processes.
  - Temporal changes in habitat composition, dynamics and process rates, drivers of change (natural and anthropogenic), and rates of change.
  - Identification of impact of exploration acoustic and geophysical techniques on marine fauna.
  - Oil and condensate ecological impact assessment (stressors, Eco toxicity, population and individual species response etc.)
  - Consideration of environmental impacts from operational waste discharges (production water, drilling muds and fluids) and marine noise.
  - Storm surge, wave, tide, cyclone data (Oceanographic information).

- Improved methodologies to identify, quantify and characterize oil spilled at sea
- Improved understanding on the transport, fate and behavior of crude oil, condensate and refined products that may impact Commonwealth waters,
- Continuous development and improvement of national standards including an integrated monitoring and evaluation framework and scientific data to support the improvement of industrial process controls,
- Tools and approaches to assist with streamlined processes, such as environmental approvals,
- MetOcean research with direct relevance to industry providing greater certainty of the ocean operating environment (waves, wind and currents) including refinement and validation of oil spill trajectory modelling.
- Development and evaluation of improved oil spill countermeasures including operational guidelines for their use,

- Dispersant protocols and standards to determine efficacy, toxicity, and impact (if any) of dispersant use,
- Methods to validate recovery from oil spills, including analysis of available options
- Developing and evaluating risk-based assessments such as net environmental benefit analysis (NEBAs) for selection of oil spill response technologies,
- Assessment of the impact of marine noise both through seismic surveys and also through normal operations
- De-commissioning of offshore structures
- Technology transfer to the private sector,
- Cross-cutting research such as
  - Methods to assess cumulative impacts on ecosystem structure and function
  - Multiple-use – interactions with other sectors that explicitly takes into account social and economic considerations
  - Social license to operate
- Further science to develop advanced sensors and monitoring technologies, including the design and implementation of post spill operational and scientific monitoring program(s).
- Identification and efficacy of monitoring triggers.
- Development of methodologies to identify operation endpoints for spill response operations (i.e. How clean is clean?)
- Application of modelling and predictive tools.
- Understanding of potential environmental impact of new technologies such as Floating Liquid Natural Gas facilities

The scientific capability and institutional capacity required to address these requirements includes: habitat mapping, community dynamics and processes, genetic connectivity, physiology, reproduction, recruitment growth, and survival, physical and biological oceanography, modelling, prediction, ecotoxicity, biogeochemistry, mega fauna, fish, benthos, socioeconomics.

Government, Industry, Community Benefit

Regional analyses allow for better risk assessments, increased certainty for industry and potentially reduced regulatory burden.

Additional data collection and appropriate co-ordination and central management of environmental data (and release of non-commercially sensitive data sourced from the oil and gas sector) potentially improves the management of risk.

In addition to cost savings and more timely environmental approvals, the across-industry benefits potentially include improved transparency, increased public confidence, enhanced social license to operate and enhancing the attractiveness of Australia's offshore oil and gas sector for investment by the global oil and gas industry.

Benefits to government include demonstrable proof that the obligations for conservation and management of the living resources associated with the rights for active exploration (and production) are being met.

Technology transfer of methodologies and processes developed from this program will support commercial interests within Australia in a global market.

Perspective

Australian marine ecosystems are varied (Australian jurisdictional waters range from the tropics to Antarctica) and contain many unique species that would not be included for risk assessments done elsewhere in the world. Much of the petroleum reserves in offshore Australia are gas condensate, not oil, and are not represented in the ecological impact assessments conducted for other traditional oil or for shipping. In addition, the high UV radiation may increase the impacts of exposure to many of the components of oil. Australia's low nutrient waters will both allow UV radiation to penetrate to greater depths and could limit the growth of hydrocarbon-degrading bacteria, which will act to extend the residence time of oil in water relative to other, better-studied locations. Thus, an accurate risk analysis for our oil and gas sector must include region specific studies.

One of the highest priorities will be the creation of baselines that describe the normal structure and function of Australian marine ecosystems. This is especially important given that the areas to be exploited (the Great Australian Bight; the Northwest Shelf) are home to economically, ecologically and culturally important species and are not yet well defined scientifically. It is critical that these studies be commenced before any substantial activity is undertaken, as impacts may occur as a result of exploration (i.e. seismic activity, drilling, increased ship traffic, shading from structures) as well as from operational or accidental release of petroleum products. By describing the pre-activity baseline ecosystem structure and function, it will be possible to better identify and quantify a degraded ecosystem.

This monitoring should be informed by continual improvement of techniques (including ocean models) and of equipment to perform the studies. The increased knowledge of normal baseline ecological states, characterization of toxicological response, and improved monitoring technologies and models will be a significant benefit in the event of a marine incident. Also, the results of these studies and the data and processes that led to these results need to be publically accessible. This transparency will allow the issues around oil and gas development and any accidental discharges, which are typically controversial, to be framed in fact, as these issues will be discussed in the media.

The conduct of rigorous risk assessment and monitoring programs must include toxicological studies with species that are locally and regionally relevant, using local oils and condensates. Similarly, studies on oil spill treatment agents such as chemical oil dispersants should cover all products approved for use within our region. The ecological impacts of operational waste discharges (e.g. produced water, drilling muds and fluids) including exposure to methane, glycol, and hydraulic fluids associated with exploration and production activities are require further investigation in Australian waters

Toxicological endpoints need to taken beyond just the descriptive standardised laboratory endpoints, which may not translate directly to subtle changes in organisms fitness experienced in the field as a result of low-level continuous exposure to contaminants. This understanding will also let us extrapolate from subtle changes to organism health and fitness to potential impacts to population and community function and thereby let us predict the potential interactive effects of multiple stressors.

Other stressors such as marine noise from exploratory seismic operations as well as production activities must be considered in the future. In addition, as the full lifespan of offshore oil and gas operations must be considered, the potential environmental impacts associated with the decommissioning of offshore facilities must be considered.In addition to the need for rigorous and compressive baseline and post-spill monitoring there is a need for enhanced coordination of activities at a regional scale. Below, we outline the merits of this approach and describe how it could be implemented

1. **Design of a regional assessment & monitoring plan and gap analysis tool for Australia – 5 year priority**

Significant marine habitat assessment and monitoring programs are being undertaken by individual oil and gas companies to provide the basis to environment plans or operational and scientific monitoring programs. In addition, habitat assessments are commencing in State marine park areas. There is some geographical overlap between the various individual assessments, and whilst the final deliverables and outcome required are determined by the specific end-user, there are many common issues and information requirements (such as marine habitat baseline assessment). Coordination of these efforts on a regional basis will improve efficiency and synergy from the various efforts that are underway or planned in the area. More efficient use of marine monitoring regional data can be achieved through the development of a 'monitoring/baseline gap analysis approach' - ideally utilizing standard monitoring protocols and methodology that identifies where the information gaps are in relation to the different needs of industry and government. Clearly, the industry related opportunities such a plan will deliver for environmental knowledge need to be further integrated into a broader national strategy, as outlined in the needs "White Paper: Discovery, Prediction and Monitoring" covering the 10 and 20 year horizons.

Cumulative impacts refers to the direct and indirect impacts of a number of different actions or other influences on the environment which, when considered together, have a greater impact than each action or influence considered individually. Cumulative impacts may refer to existing or ongoing impacts (e.g. from existing infrastructure in an area). Cumulative impacts also encompass the predicted cumulative effect of a number of projects proposed for an area (e.g. multiple production facilities in a region), or other predicted long-term trends in the environment (e.g. ocean temperature rise). To achieve holistic, whole of ecosystem, impact assessments, to allow regional planning and especially to accommodate the longer term (temporal) component of activities (i.e. cumulative impacts), requires a detailed knowledge of baseline conditions as well as an understanding of neighbouring activities. Temporal based information is required to determine natural change from potential impacts resulting from activities.

Outputs

- Implementation of baseline marine environment data 'gap analysis' decision support tools to assess if existing data is 'fit for purpose' to determine impact of oil/condensate spill on marine ecosystem receiving environment.
- Design and execution of long term monitoring programs – new tools, methods, application of technologies to assessment and monitoring.
- Identified key natural drivers of change in N and NW marine systems to differentiate natural and anthropogenic stressors.
- Mapping and assessment of previously unassessed marine habitats
- Establish national marine environmental baselines data management/information platform and decision support system

2. Develop and test a predictive model of benthic communities on reefs, shoals and the upper slope

Ultimately the ability to predict habitat response to operational activities and major incidents associated with anthropogenic activities is a key goal. Build on marine baseline data to:

- predict what communities are likely to exist in unsurveyed areas based on key physical parameters such as bathymetry, topography, sediment type, exposure to waves and storms; and
- predict how these communities will change when subject to different impacts – based on an understanding on what the key drivers of change are and how they interact.

In order to build the model additional information on the significance and rates of key ecological processes (recruitment, connectivity, growth, response to storms) and bathymetric data is required at a regional scale.

3. Surface and subsurfance transport oil spills and genetic connectivity

Oil spill modelling and prediction of spill trajectory during an event (both surface releases and blowouts) requires real time high resolution data on current velocity, direction information and plume dynamics.

Information on the physical processes in the upper water column and surface is critical in developing a fundamental understanding of the potential physical drivers of genetic connectivity between geographically isolated reef and shoal systems, for instance the transport of coral gametes. A potential emerging issue requiring this information is the introduction and transport to oceanic reefs and shoals of marine pests resulting from bulk LNG carriers loading direct from proposed Floating LNG production facilities.

4. Tropical and temperate hydrocarbon fate, behaviour and ecotoxicology

There is a need to better understand the environmental fate and behaviour of petroleum hydrocarbons at risk of being spilled within Australian waters, as natural weathering processes will influence the transport and bioavailability of the residual oil. Mesocosm (wave tank) studies and field trials are needed for the conduct of experiments under realistic environmental conditions. These studies should also include chemically dispersed oil to provide data for the selection of spill response options based on Net Environmental Benefit Analysis (NEBA).

In Australian waters, quantifying the risk to coral reefs and benthic systems from accidental hydrocarbon releases requires an understanding of the sensitivity of reef-building invertebrates such as corals, macroalgae (e.g. *Halimeda*), and sponges to condensates and dispersants (used to manage slicks). This critical ecotoxicology data is almost non-existent for relevant tropical species. As a result, management, regulatory agencies and industry currently rely on potentially inappropriate sensitivity data for non-reef species when assessing the risks of development or designing responses to spills. There is a pressing need to develop a suite of hydrocarbon ecotoxicity protocols based on representative tropical reef species. There is a strong ecological, marine science and environmental toxicology community with Australia, so capacity will only need to be refocussed, not developed entirely anew. Intellectual capability will not be an impediment to reaching any of these goals.

5. Marine Fauna predicting impacts of offshore development and hydrocarbon spills

Turtles, sharks and whales (fauna have been the subject of population surveys over the last two decades, however, there have been limited attempts to use these data to quantify spatial distributions and identify critical habitats, notably in areas of significant offshore oil and gas activity (NW Shelf, Kimberley and GAB). Quantitative analysis of movement patterns, diets, abundance and distribution of fauna across the NW coast of WA and the Kimberley and their use of habitats is required. Ultimately, this goal will allow us to determine if current monitoring strategies are providing information to identify critical sites, and to modify programs to achieve that goal, as well as allowing the identification of sensitive fauna habitats with regard to offshore oil and gas stressors and spill modelling predictions.

Requirement

There is an immediate requirement for the science priorities articulated. With respect to Australia's N and NW marine environments there is generally limited pre-existing information and data on marine ecosystems, compared to other offshore industry jurisdictions such as the Gulf of Mexico and North Sea and other parts of Australia such as the Great Barrier Reef. The North West and Great

Australian Bight (GAB) are characterized by their remoteness, poor access and lack of availability of marine science infrastructure. In addition offshore Oil and Gas expansion in the NW is taking place in close proximity to iconic marine ecosystems such as Ningaloo Reef, Scott Reef, and Rowley Shoals. Projects currently entering the development and production phase including Shell Prelude, Inpex Ichthys and Woodside Browse have predicted 25-30 year lifespans, indicating a long term requirement for monitoring and temporal environmental baseline updating.

The current Australian offshore Oil and Gas sector is undergoing dynamic and rapid commercial development, introducing 'world first' new offshore technologies such as Floating Liquid Natural Gas (FLNG) processing facilities. The world first Shell Prelude FLNG facility is scheduled to commence production in 2017, 200Km off the coast of WA. In addition Australia has a relatively new offshore regulatory regime with the current regulator (NOPSEMA) only commencing operation in 2012.

Realisation

1. Regional environmental baselines Strategy

Implementation of a strategy to develop regional environmental baselines for managing environmental issues associated with the offshore Oil and Gas industry would include:

(vi) A staged Implementation
(vii) Develop a single Regional Plan
(viii) Easy access to existing data
(ix) An continuous improvement approach
(x) Joint participation and effective collaborative oversight

The design and implementation of a fully integrated system will require significant changes in the way in which both government, academic and private sector researchers would operate and cooperate. This will likely be possible only through a process of staged evolution which demonstrates both short-term and long-term value against invested resources, achieves equity and builds trust between the contributing partners, and accumulates a knowledge base that grows in utility and impact.

While it is likely that a fully comprehensive and integrated regional assessment will require significant additional resources, the first stage in implementation should be to consolidate existing efforts and data and to develop an agreed vision for the program and this could be achieved with a more modest initial investment. This could then be followed by more detailed plans to fill in environmental information gaps in the existing activities and to develop agreed responsibilities conducting these additional activities. Initial steps would be:

- Further develop the case
- Discuss implementation and governance models
- Consolidate existing environmental assessment and monitoring data
- Develop a detailed description of an integrated regional assessment (the "single plan")
- Develop a cost-sharing model
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To deliver regional baselines requires an offshore Oil and Gas industry/government regulator/research sector partnership/consortium approach. Industry currently invests significant resources in environmental baseline assessment; on a 'project by project' basis the resourcing is significant. However, on the whole, there is no long term multi company coordinated program. Potential resourcing strategies may include the development of an Offshore Oil and Gas Industry focused CRC bid, or investing resources from future oil and gas industry project environmental offset programs.

2. Marine environmental decision support –online system

The primary impediment to realisation of the goals outlined in this paper is access. All aspect of the work outlined here, from study selection and design to final data presentation and conclusions must be accessible to and understandable by the general public. In addition, these databases should be maintained with as close to "real time" accessibility as achievable. Geoscience Australia CSIRO and AIMS are considering the development of a national marine environmental decision-support system aiming to 'enhance the benefits derived from its marine estate and maintain high environmental management standards'. The system will directly support recurring types of decision making related to marine natural resource exploration and development, environmental planning and management, as well as government marine policy objectives more broadly. A key aim is to empower end users to derive highly relevant information from marine data by providing easy access and guidance to targeted and relevant bodies of information; to organise, filter, synthesise and visualize the information in a clear and concise manner; and then to provide outputs in a ready-to-use form. Resources are required to establish this capability to provide derived, targeted, practical information.

3. Marine vessel infrastructure

The remote operating environment of marine areas subject to oil and gas development in NW and GAB requires vessel based research platforms capable of operating in the open ocean this capability is currently delivered by the new marine national facility RV Investigator and AIMS research vessel RV Solander.

4. Supporting Infrastructure

The recently commissioned AIMS research aquarium facility 'SeaSim' provides a world-class experimental facility for tropical marine organism research. SeaSim provides critical infrastructure for the development of tropical hydrocarbon ecotoxicity for corals, seagrass and sponges proposed in this White Paper. In addition wave tanks to allow experimental evaluation of the efficacy of dispersants would provide important support for work on oil spill research.

CSIRO is actively building at-sea systems for the identification and characterization of oil and chemically dispersed spills at sea. This includes the construction of containerized laboratories for to provide real-time data to support decision making during oil spill response operations

Key Impediment-Objective based regulatory regime

The current offshore Oil and Gas regulatory approach administered by NOPSEMA is based on an 'objective' approach. Essentially the industry 'proponent' putting a case forward that baseline data is available, fit for purpose, management and assessment protocols for receiving environments are in place and adequate etc. for consideration and approval by the regulator. In our view one of the key weaknesses in the current regulatory regime posing an impediment to holistic, regional marine environment management is that there are no requirements for acquiring baseline data, or to make data publically available.

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