MARINE MINING: INTEGRATED SOCIAL AND ENVIRONMENTAL RESEARCH IN THE DESIGN OF A NSW TEST CASE

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The pressure to consider marine mining operations is increasing as land-based mineral and bulk material deposits become harder to find, technologically more challenging and costly to extract. Furthermore, changing climate and sea level scenarios mean that coastal councils are considering beach nourishment strategies. Australia's vast territorial waters have the potential to be a new minerals frontier, but there is considerable community unease about seafloor exploration and mining activities, particularly around potential environmental impacts and sustainability.

In NSW, based on current demand, the likely initial focus for future marine mining will be the extraction of bulk commodities such as sand. The industry rationale for going offshore is the ability to access a large supply of mineral resources close to market with minimal mining infrastructure and waste, and simpler, less resource intensive materials processing compared to hard rock land-based alternatives.

In light of this national and local need, CSIRO has embarked on a multi-year project to measure and monitor controlled seafloor excavation in a defined test area off the NSW Central Coast. An integrated research program combines social and environmental research to inform the development of a framework for assessment and prediction of the environmental impact of marine mining on the continental shelf. It will also inform our understanding of the social acceptability of offshore exploration and mining, and seeks to define the boundary conditions required for approval.

A series of stakeholder workshops and 1:1 interviews has established that the debate is currently limited by a lack of regional baseline environmental data and rigorously tested models. Much more information is required for Australia to make informed decisions as to whether marine mining should progress. Environmental concerns dominate the wide range of reactions of stakeholders engaged in this study, but also included a need to understand the resource itself, relative costs and benefits, and the current legislative framework.

Introduction

There is an increasing interest in the seafloor as a potential source of mineral resources, for example precious metals, diamonds, sand and gravel for building and beach replenishment, and heavy minerals for rare metals. Internationally there is an established offshore mining industry, particularly for dredged continental shelf deposits such as sands and gravels, and placer deposits. Geological surveys of Australia's marine territory suggest that Australia has good prospects for several types of marine mineral resources, including: the seaward extension of terrestrial deposits (e.g. iron ore deposits in NW Australia), placer deposits of heavy minerals (e.g. rutile, gold) contained in ancient submerged beach deposits, and marine deposits of building sands (aggregates) (CSIRO-Geoscience Australia, 2006).

Based on current industry trends, the initial focus for the development of offshore mining in Australia is likely to be the extraction of bulk aggregate commodities such as sand. In NSW the demand for offshore sand comes from the Sydney building industry and coastal councils requiring sand for beach replenishment. The industry rationale for going offshore to mine sand is the ability to access a large supply of mineral resources close to market with minimal mining infrastructure and waste, and simpler, less resource-intensive materials processing when compared to hard-rock land-based alternatives

However, community and stakeholder acceptance is vital to the viability of the marine mining industries in Australia and influences planning decisions by government agencies and industry. Beaches and oceans are central to Australian culture, and consequently Australians may consider marine mining to be unacceptable based on the environmental and social impacts. Social research into public perceptions can inform technical assessments of industry viability so that it is responsive to the values and information needs of the community, and promotes community trust and confidence in the industry. In order to understand stakeholders' perspectives of benefits and concerns associated with a hypothetical expansion of marine exploration and mining in Australia, Boughen et al. (2007) carried out three workshops with government, industry and other marine exploration and mining stakeholders. These workshops confirmed that stakeholders were concerned about the potential impacts of marine exploration and mining, and that environmental impacts were most central to their concerns (Boughen et al, 2008). In addition they noted a lack of knowledge which stakeholders can refer to in order to obtain answers to their questions and concerns about the industry or weigh-up the costs and benefits of taking the Australian mining industry offshore.

To address this information need, CSIRO has embarked on a long-term multidisciplinary program of work which aims to understand and inform stakeholders' concerns about marine exploration and mining. A key element of this work will be a test case that measures and monitors the environmental impact of controlled seafloor excavation in a defined test area off the NSW Central Coast. This test case will provide a knowledge base for stakeholders which they can use to objectively evaluate the issues surrounding a marine mining industry. This paper provides a contextual overview of the study and shows how the integration of social and environmental research will inform the debate about the acceptability of marine exploration and mining in Australia.

Context

The marine exploration and mining industry

Although approximately 60% of the Earth's surface lies below 2000 metres depth within the oceans and much of it is unexplored, we can predict with confidence that both the shallow continental margins and the ocean basins harbour a large variety of mineral resources. Globally and historically marine mining has occurred within the inner continental shelf in waters < 200 m depth. Commodities that have been mined are predominantly unconsolidated sands and gravels used for building aggregates but include diamonds, heavy minerals and tin (Scott et al., 2006; Rona, 2008). In 2000, the estimated global annual production of marine sand and gravel was approximately 193 million tonnes (Mt), with Japan contributing 70 Mt, Netherlands 36, United States 31, United Kingdom 24, Denmark 18, Germany 7, Belgium 3, France 3, Poland 0.5, and Norway 0.1 (Rona, 2008). At a cost of approximately US$15/tonne, this amounts to US$3000 million per annum.

In terms of technology to explore and work on the seafloor, the petroleum industry has been the leader since the 1970s. Today, about one third of the world's petroleum production comes from offshore and is growing as technology allows for increasingly deeper installations (Scott et al., 2006). In Australia, the recently announced giant gas field development in the Greater Gorgon area on the NW Shelf will involve the building of seafloor infrastructure at the well head in water depths of approximately 1300 m with 145 km of tie-back pipeline across challenging seafloor terrain to Barrow Island (Flett et al., 2009). Similarly, the newly discovered Jupiter oilfield lies 5250 m below the seabed in 2187 m of water (Petrobras, 2008) and in the Gulf of Mexico production is occurring in the Thunder Horse field at water depths of 1844 m (BP, 2008).

Currently, Australia has a small marine mining industry that is mainly confined to dredging of carbonate sand offshore of Fremantle in Western Australia. This operation supplies calcium oxide and produces lime for the gold and alumina and cement industries. In Moreton Bay, Queensland, bay deepening/dredging has led to offshore aggregate by-products being used for the expansion of the Brisbane airport (Queensland EPA, 2006). These operations are both long-lived, having commenced production in the 1970s, and are generally accepted by the local community. In order to understand the extent of Australia's potential offshore mineral resources, the Wealth from Oceans Flagship, in partnership with Geoscience Australia and all of the state and territory geological surveys, produced the *Australian Offshore Mineral Locations map* in 2005 which provided the first insight into the varied mineral prospectivity of Australia's territorial waters (CSIRO-Geoscience Australia, 2006).

Demand in the Sydney region:

In 2003-2004, Sydney used over 27 million tonnes (Mt) of quarried fine and coarse aggregates with a value of approximately $366 million (ACIL Tasman, 2006). Based on past consumption trends, analysts forecast demand for aggregates in the Sydney Basin (from Newcastle in the north to Wollongong in the south to Lithgow in the west, Figure 1) will increase to more than 300 Mt by 2040 (Figure 2, Pienmunne and Whitehouse, 2001). Although the production of coarse and fine aggregates actually fell between 2001 and 2004 by an average of 9.9% per annum (ACIL Tasman, 2006), this reflects fluctuations in the construction industry and it is clear that the overall trend in demand is upward (Figure 2) and new sources of aggregates will be required.

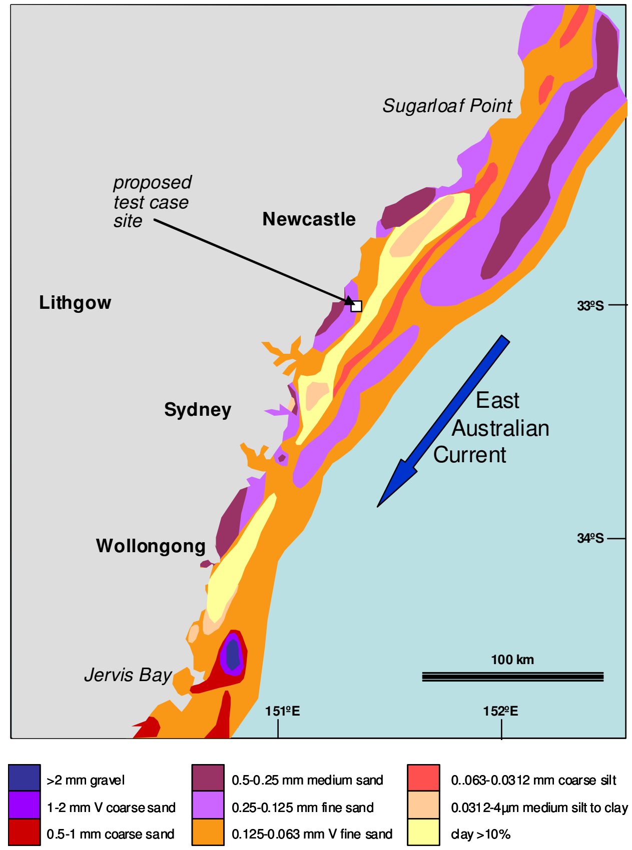

Figure 1. Maps showing the distribution of grain size of surface sediment on the continental shelf and upper slope south of 32ºS (Davies, 1979, Keene et al., 2008) and location of the proposed test case site.

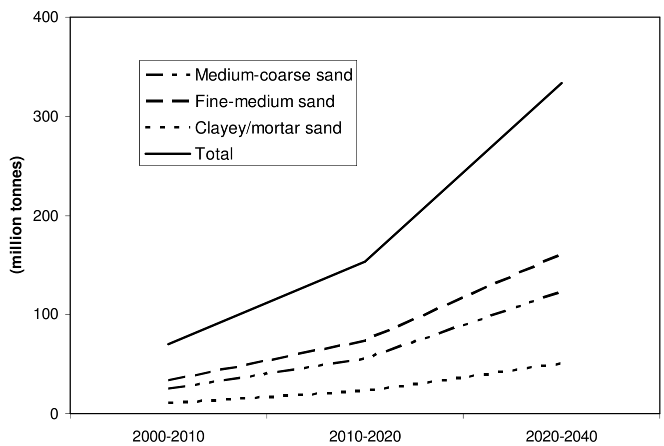

Figure 2. Predicted demands for construction sand based on past consumption rates (using high population estimate). After Pienmunne and Whitehouse (2001)

Resource security for the Sydney Basin is low, and established near-market supplies of construction materials, particularly for the Sydney metropolitan area, are dwindling.

Historically important sources of aggregates, such as the Kurnell sand dunes (fine to medium well sorted marine sands) and Penrith Lakes (medium to coarse sand and gravel) are being phased out (Pienmunne and Whitehouse, 2001). Major identified undeveloped resources in the Sydney region include friable sandstones at Maroota (72 Mt) and on the Somersby Plateau (3000 Mt), which require energy and water intensive crushing, cleaning and sorting (Pienmunne and Whitehouse, 2001).

With increasing demand, resources will have to be imported from outside the Sydney Basin. Stockton Bight, north of Newcastle, contains approximately 23 Mt total resource of fine grained sands but is predicted to be exhausted soon after 2020 (Pienmunne and Whitehouse, 2001). Mineable deposits on the Newnes Plateau, located on the edge of the Wollemi Wilderness, have a measured total resource of 583 Mt, with 64 Mt as a reserve under consent. Friable sandstones in the Southern Highlands, (19 Mt under consent of approximately 900 Mt reserve) and fine to medium grained sand (2.8 Mt under consent of approximately 8 Mt reserve) in the Shellharbour/Kiama district are also potential targets. Issues surrounding the exploitation of these deposits include high energy and water consumption during processing (particularly for friable sandstones), transport costs for the more distant deposits, and the potential environmental impact.

Climate change impacts are also likely to add to the demand for aggregates. Historically small volumes of offshore sand deposits have been used to mitigate erosion of beaches (Whitehouse, 2007). However, with the projected impacts of climate change it is likely that beach nourishment will be required. In recognising this likely demand the Sydney Coastal Councils Group has undertaken a scoping study of the environmental, physical, social and economic aspects of utilising beach nourishment in the Sydney region (SCCG, 2008).

Thus the Sydney region is faced with a significant shortfall in locally derived, quality coarse and fine aggregates. Fine-grained, clean sands are particularly short in supply and marine sand deposits will become increasingly attractive to industry and all levels of government as the potential source of raw material. It should be noted, however, that targeting offshore aggregate resources in NSW is not new. A series of applications for exploration and mining off the NSW coast have been lodged with the state and federal governments since the 1960s for heavy minerals and 1980s for sands and gravels. To date none have been granted (Whitehouse 2007).

Australia's east coast marine sand bodies

The east Australian continental shelf, which extends approximately 1500 km from Bass Strait to the Great Barrier Reef, is a wave-dominated environment, characterised by an overall northward dispersal of shelf sands with local variations due to coastline morphology (Roy and Hudson, 1986). Compared to continental shelves globally, this relatively narrow stretch of shelf has an anomalously thin cover of young sediments, perhaps less than 500 m thick (Roberts and Boyd, 2004), which are divided into nearshore and inner shelf sands, mid-shelf sands and muddy sands, and outer shelf calcareous sands (Ferland, 1991; Roy, 1998). It is widest between Sydney and Sugarloaf Point (53 km at Newcastle) and Moreton Island and Fraser Island (75 km) and narrows to 16 km off Jervis Bay (Boyd et al., 2004).

The deposits likely to be considered for offshore mining in NSW occur as sand lenses on the inner to mid continental shelf, in particular offshore from the Sydney Basin, between Jervis Bay and Sugarloaf Point (Figure 1; Boyd et al., 2004; Keene et al., 2008). The lenses of sand occur in water depths of 20-120 m adjacent to prominent bedrock headlands. These large volume deposits of clean, unconsolidated sands form a series of linear bodies parallel to shore (5-35 km long, 1-5 km wide) (Ferland, 1991; Keene et al, 2008). The lenses are up to 40 m in thickness and, together with inner shelf sand sheets, contain large volume sand deposits (>100 Mt) which are suitable for construction uses such as concrete aggregate, industrial applications (glass manufacture) and for beach nourishment (Whitehouse, 2007).

The continental shelf is also characterised by a series of submerged coastal barriers that have been subject to extensive reworking by high-energy storm waves. These ancient shorelines have moderate potential for heavy minerals, principally rutile and zircon (Whitehouse 2007), and were the subject of exploration campaigns from the 1960s to 1980s (Whitehouse, 2007). These shorelines result from sea-level fluctuations from repeated transgression and regression cycles over the last 125 thousand years (Roberts and Boyd, 2004).

The need for independent multidisciplinary research

Ocean and beaches have an important place in the Australian culture and lifestyle (Brown and Spink, 1997) and so the environmental and social impact of mining on the seafloor may be considered unacceptable. Analyses of social attitudes towards offshore oil mining development, have concluded that negative attitudes tend to be prevalent where there is: (1) a high level of competition for coastal resources; (2) an economy dependent on the amenity values of the coast; and (3) existing industries depend on the retention of relatively pristine environmental conditions (Gramling and Freudenburg, 2006). These conditions prevail in Australia, where > 85% of the population is lives within 50 km of the ocean and there are many well-developed competing marine industries (OPSAG, 2009). Indeed, public concern has already proven influential in decision-making for marine exploration and mining, as illustrated by the case of Sydney Marine Sands (Johns 2008). In this case, applications in 2000 and again in 2003 by Sydney Marine Sands for licences to explore for marine aggregates in Commonwealth waters off NSW, were refused by the Minister based on community concern and a lack of support from the NSW Government.

Understanding the impact and acceptability of marine exploration and mining activities is a complex problem and requires an independent and multidisciplinary approach. Social research aims to understand stakeholders' reactions to marine exploration and mining and the values and concerns underpinning those reactions. Environmental impact measurements and assessment methods, informed by the social research, provides unbiased information to enable stakeholders to better evaluate their boundaries for acceptability of offshore aggregate exploration and mining. This iterative approach, which is the one favoured by CSIRO for this study (Figure 3), where stakeholders' responses to initial findings inform and refine the environmental impact studies, will build an independent and sophisticated knowledge base that can be used to inform regulation of the offshore aggregate exploration and mining industry.

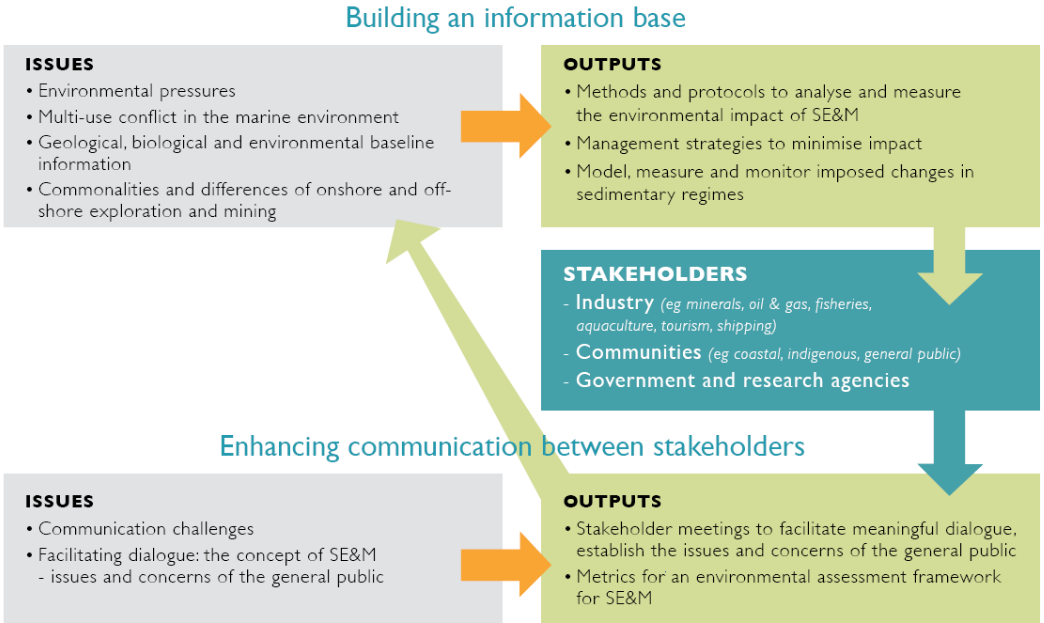

Figure 3. CSIRO's integrated approach to environmental impact studies and social viability studies to deliver scientifically tested tools for use in the assessment of marine exploration and mining projects.

Social Research

The initial phase of CSIRO's multidisciplinary research program involved delineating important opportunities and barriers for marine exploration and mining in Australia. Two desktop studies reviewing international (Tsamenyi et al., 2007) and Australian (Johns, 2008) marine mining activity were used to provide an understanding of the industry context. Three stakeholder workshops were also carried out to examining the social acceptability of the industry in Australia (Boughen et al., 2008). From these activities, it was concluded that any future Australian marine mining industry would be highly dependant on our ability to improve the knowledge-base underpinning the regulatory regime, to generate open and transparent communications between stakeholders, and improve the understanding of policy and regulatory processes (Boughen et al., 2008).

The second phase of this research program is currently underway. This phase of the research focuses aims to provide a more specific understanding of the issues associated with mid shelf exploration and mining, in particular for aggregates. After developing a stakeholder map for marine mining in Australia, interviews and workshops were carried out with representatives of each stakeholder group (see Table 1). Workshops involving the general public were held in Newcastle and Brisbane to represent communities with fairly high involvement in mining and some exposure to existing seafloor aggregate mining (Brisbane). Participants for these workshops represented the spectrum of the voting population in their community in terms of gender, educational background, ethnicity, and age.

Stakeholder Group	*Level*	*No. of participants*
Legislative authorities	federal	4
	state	6
Government	Federal	2
	Local	1

Industry	marine mining (1 international)	5
	Terrestrial mining	1
	Other marine industries	6
Investors		1
Non-government organizations		3
Social researchers		2
General public	Brisbane	7
	Newcastle	12
TOTAL		50

Table 1. Participants in the stakeholder interviews and workshops

The workshops and interviews were intended to address three objectives. First, they explored stakeholders' initial reactions to idea of seafloor exploration and mining. Second, they identified what information stakeholders would need to make a decision about the acceptability of marine exploration and mining in Australia, and in particular, what environmental questions and concerns needed answering. Third, they informed the design of CSIRO's test case by exploring stakeholders' expectations regarding the objectives, location and timeframe for the environmental impact research.

Reactions to marine exploration and mining

Analysis of stakeholder interview and workshop data revealed that stakeholders' reactions to the term "seafloor exploration and mining" tended to fall into one of three categories. Most common were concerns about the notion of taking mining activity into the offshore environment. Amongst community representatives, these environmental concerns had a particularly emotive tone, with some participants even describing themselves as feeling emotional or scared about the proposition. Another type of reaction was to provide a fairly informed definition or discussion about marine exploration and mining activity occurring in Australia and overseas. Finally, a small group of participants commented positively on the potential for marine exploration and mining to offer a cleaner, safer and more innovative mining technology.

These reactions confirmed that environmental concerns predominate in stakeholders' thinking about marine exploration and mining. However, most stakeholders appeared sufficiently open to the proposition to seek more information to help them weigh up the costs and benefits of the industry.

Information needs

Discussions with stakeholders about the acceptability of marine exploration and mining activity also defined four categories of information that were sought by stakeholders:

1. Likely locations, resource types, technologies and processes involved in off shore exploration and mining activities.
2. The environmental impact of marine exploration and mining activity.
3. A cost–benefit analysis associated with marine exploration and mining incorporating social and economic impacts in addition to environmental impacts
4. The frameworks and processes that would be used to govern industry development, including regulation of the industry and public consultation

Questions about environmental impact

From the stakeholder input four key questions specific to issues of environmental impact emerged:

1. How will marine exploration and mining activity affect marine life?
2. How will exploration and mining activity affect coastal features, and more specifically, beaches?
3. What are the potential impacts associated with accidents and extreme weather events?
4. What is the potential for rehabilitation and remediation?

These discussions highlighted a lack of confidence in the science required to provide a full picture of the impact of offshore exploration and mining activities.

Feedback regarding CSIRO's environmental research

In discussions about objectives for CSIRO's test case research, stakeholders stressed the need to provide a comprehensive understanding of the impact of mining on the marine environment. Stakeholders consistently emphasised the value of collecting extensive baseline data. They also noted a need to understand how representative the research findings were and the extent to which they could be applied to other ecosystems and other types of activity. Some stakeholders suggested that as community perceptions and concerns were already having an impact on the development of the industry in Australia, the research should focus on answering these concerns. Other participants thought that the research should inform policy by identifying likely important issues and the threshold of acceptability to stakeholders.

When discussing the location for the research, participants recommended carrying out the research in an area where there was good pre-existing knowledge of the local marine environment. They also recommended carrying out the research in an area that was representative of potential extraction sites but avoiding areas of significant biodiversity value. Some suggested that case studies be undertaken using existing operations whilst others believed that the research should avoid other industries and users to avoid possible negative impacts. Suggestions regarding the timeframe for the research ranged from 1 to 10 years (most commonly 5 years) but some participants avoided specifying a timeframe, suggesting instead that this decision should be informed by initial findings from the test case, thus improving our understanding of recovery rates.

Environmental impact studies

The NSW central coast contains the required elements for a representative test case for marine mining: resource demand, social concern and unclear environmental implications. Therefore, using stakeholder feedback to help guide the design of the monitoring framework, CSIRO is preparing to undertake a project to determine the nature of the environmental impact due to anthropogenic activity, and its likely long term effects The test case will be located in a defined test area off the NSW Central Coast and is the first study of its kind in Australia. In the UK a similar experiment was run from 1990 to 1998 (Kenny and Rees, 1996, 1998). Their findings identified a seasonal sediment transport component in disturbed sediments, a rapid recovery and re-colonization of the site in terms of total biomass, but a considerable change in the species assemblage. Importantly, the recovery rates were measured in an area of high natural disturbance (large tidal range) which contrasts to conditions typical of offshore NSW – that is small tidal range, moderate currents and dominated by sands and finer grained deposits. Impact studies for Australian ecosystems have been carried out for estuaries (e.g. Hossain et al., 2004; Fraser an Hutchings, 2006) and selected shelf environments (e.g. Great Barrier Reef; Poiner et al., 1998; shallow seagrass meadows; Skilleter et al., 2006), but no long term and comprehensive experiments have been conducted for offshore sand and gravel-dominated systems in Australia.

This current project will undertake a program of scaled dredging activities in which changes can be controlled, measured and monitored. Specifically by monitoring and investigating changes in benthic faunal assemblages over several years it will lead to a better understanding of the recovery rates of sand-based shelf ecosystems following anthropogenic disturbances. This knowledge, together with the characterisation of the geomorphology, sedimentology and ecology of the area, will provide input into and increase the accuracy of predictive models designed for Australian sandy ecosystems. The models will produce whole of system output by combining the powers of ecosystem modelling and dynamic sediment modelling.

Test case design

Using a Before-After-Control-Impact (BACI) approach, the aim is to run a fully integrated experiment that will measure the extent of the impact and recovery rates by, for example, changes in sediment characteristics (grain size, geomorphology etc) and biological indicators such as biodiversity and community structure. In particular, critical indicators relevant to anthropogenic activities such as marine mining, will be measured and will focus on the physical, chemical and biological changes as outlined in Scheltinga et al. (2004) (Table 2) . While these objectives are derived from the scientific literature, they also link to the environmental concerns identified by stakeholders in the interviews and workshops. Specifically, in exploring the biological condition, they will provide an understanding of effects of seafloor mining on marine life. In exploring more physical parameters, they address stakeholder concerns about effects of mining activity on coastal features.

Physical-chemical condition	• Sedimentation rates (local and regional sediment budget) • Nutrient and pollutant contents (released through disturbance of sediments) • Turbidity (distribution of fines – disruption of benthic fauna) • Water current patterns
Biological condition	• Algal blooms due to shifts in current • Benthic microalgae biomass • Biomass – microalgae and epiphytes per unit area • Pest species – opportunistic colonisation after disturbance
Habitat extent	• Extent/distribution of key habitat types and subtidal microalgae • Seagrass depth range

Table 2. Critical indicators relevant to seafloor mining (after Scheltinga et al, 2004)

The study area (Figure 1) includes three target areas and three up-current control areas (approximately 1 nm^2 each) in water depths of between 45 and 75 m. The test will be subdivided into pre, during and post dredging operations, and following stakeholder recommendations, will use existing data (eg satellite data going back nearly a decade) to extended the study baseline data wherever possible. Also in line with stakeholders' feedback, one of the key tasks for the test case will be identifying the minimum and optimal times required to continue monitoring a site.

Surveying will involve video transects of the area and detailed bathymetric mapping. Various sampling techniques will be used to investigate the sedimentology and benthic fauna as well as the nature of the water column. It is also hoped to use two new monitoring technologies: sensitive hydrocarbon sensors and ecogenomic analysis. The dredging activity is in the design stage with considerations such as depth of disturbance and area of disturbance being critical. Key to the design is an assessment of the balance between simulation of real commercial dredging with true-to-life results against scaled activities which may provide erroneous data and not be useable for modelling. Furthermore, to address stakeholder concerns around the direct impact of the test case itself, a preliminary survey will identify the key habitats and species present and a risk analysis conducted to ensure the protection of vulnerable ecosystems.

Once initial findings from the test case are available, they will be fed back to stakeholders. This information will inform stakeholders' evaluations of the acceptability of offshore aggregate exploration and mining. Stakeholders' responses to these initial findings, explored through the social research component of the program may result in further refinement of the monitoring system, thus contributing to the development of a sophisticated knowledge base that should inform regulation of the offshore aggregate exploration and mining industry.

Conclusions

Overall, there is not only potential for development of Australia's marine mining industry, but a strong industrial case in NSW for offshore aggregate mining to support Sydney's building industry and beach nourishment needs. Despite this, the already high level of community concern surrounding industry development is regarded as a potential barrier to industry development. There is therefore a need to manage potentially conflicting demands on the marine environment and understand the potential (or probable) impact of extracting resources from the seafloor. This requires an integrated approach using stakeholder engagement, in tandem with the development of a scientific knowledge base, to understand the social, economic and environmental implications of such activity.

The most common concern of the stakeholders engaged in this study relates to the environmental impact of marine exploration and mining. Other concerns centre around social and economic issues, for example a cost-benefit analysis and governing issues. Their issues and concerns, combined with results from studies overseas, have been used directly in the design of a test case to measure and monitor the environmental impact of anthropogenic seafloor activity that mimics marine mining. The test case will determine the most appropriate indicators to provide the basis for future assessment of impact on the ecosystem of seafloor exploration and mining. Data from the field study will contribute directly to a baseline knowledge bank that will be used to generate and constrain computer simulations of seafloor activity. These dynamic models will combine the powers of ecosystem modelling and dynamic sediment modelling to help determine the degree to which potential indicators can reflect changes in ecosystem health. This will lead to scientifically supported risk analysis and the development of comprehensive and integrated management strategies.

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