Counting the potential cost of Deep Sea-bed Mining to Fiji

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Executive summary

Fiji has been identified as one of the countries most vulnerable to declines in reef condition due to the high dependence on reef systems for key industries (tourism and fishing).

Much of the waters of Fiji and adjacent international waters include highly prospective deposits of copper, gold, zinc, silver and chemical elements. Extracting these resources is only now becoming feasible due to technological advances in Deep Seabed Mining (DSM). A large area of Fiji's waters is now subject to DSM exploration licenses. But very little is known of the risks DSM creates for key marine ecosystem services and the industries that reply on those services for both income and employment (e.g. tourism and fishing).

This desktop study seeks to identify, scope and broadly estimate the potential costs to Fiji associated with DSM. Only once those costs are understood, can Fiji confidently make robust policy decision about the amount, location and management of DSM within its waters.

Key findings from the study include:

- Because of the economic structure and technology use in the DSM sector, direct benefits accruing to Fiji from DSM operations are likely to be relatively small. The major benefits accrue from additional royalty and tax revenues associated with the production phase of DSM. The major value adding will occur outside the Fijian economy.
- There are a number of potential costs to tourism, commercial fishing, and other ecosystem services. However, these costs are poorly understood due to the current lack of information and data available on the risks DSM operations pose to the marine environment, the relationships between those risks and key sectors, and the economic value of affected sectors.
- Tourism is a key sector that is potentially at risk from DSM, particularly any loss of Fiji's reputation as a world-class marine tourism destination. Even relatively small reductions in overseas visitors can have significant economic consequences for tourism. For example, our economic modelling of the dive tourism sector indicates that a 5% decline in dive tourist visitation levels would reduce Fiji's Gross Domestic Product (GDP) by around FJD 14 million, and could result in the loss of in excess of 400 jobs.
- Commercial fisheries, particularly tuna could also be impacted from plumes and water column discharges causing disruptions to marine food webs. This is particularly the case for DSM exploration around seamounts and other marine zones that are vital to fisheries food webs and population dynamics. Even small reductions in catch rates can have large economic impacts. For example, our economic modelling for the commercial tuna fisheries sector found that a 5% reduction in catch rates would result in a 15% fall in value added and a 21% reduction in operating surplus/profit for the fishing industry. There would also be negative flow-on impacts in the processing sector.
- DSM will also have an impact on other ecosystem services such as carbon abatement and the existence value of biodiversity. In addition local residents derive cultural and subsistence benefits from the sustainable management and use of the marine environment. Little is known about the actual risks to those values in the Fiji context.

The bottom line is that, with the exception of increased royalty and tax revenues, DSM probably provides little benefit to Fiji. However, the risks and costs could be significant if not managed properly. Managing these risk would involve:

- Filling the significant knowledge gaps through a structured program of research and analysis undertaken in a transparent manner in conjunction with key stakeholder organisations.
- Using the outputs from the robust research to ascertain whether or not the risks of DSM outweigh the benefits before making any decision to facilitate the industry.

- Where sufficient data/information cannot be obtained, it would be prudent to evoke the precautionary principle and reverse the burden of proof to ensure DSM activity is postponed until sufficient information is available to ensure ecosystem form and function is not impaired by such activities, and risks to ecosystem services are acceptable and manageable.
- Establishing a robust suite of risk mitigation measures based on the risk mitigation hierarchy. This should include specific exclusion zones (avoiding risk), risk reduction and mitigation measures, and offsetting (if actually possible) and compensatory measures for residual damage. This will significantly reduce the risks and costs of DSM to the key tourism and fisheries sectors, and to other ecosystem services.
- The design and implementation of robust policies/regulations, particularly a royalties regime, to ensure Fiji captures a fair share of the economic benefits of DSM.

Fiji is in a unique position to ensure that if DSM does occur, the risks and costs can be mitigated through good management. But ensuring this will require the establishment of a robust suite of policies, regulations, management practices and benefit-sharing arrangements *now* to ensure Fiji is prepared for *future* DSM activities within its waters. If these arrangements were not in place, it would be difficult to justify undertaking DSM, as the risks could be too great.

1 Introduction and context

Fiji is world renowned for having some of the most biodiverse and pristine marine environments on Earth, particularly the Great Sea Reef (GSR). The GSR is the world's third longest continuous barrier reef system. It runs for over 200km from the north-eastern tip of Udu point in Vanua Levu to Bua at the north west edge of Vanua Levu, across the Vatuira passage. It covers an area of around 202,700 square kilometres.

Fiji has been identified by several global institutions including the International Union for Conservation of Nature, the World Resources Institute, and the United Nations Environment Programme as one of the countries most vulnerable to declines on reef condition due to the high dependence of reef systems for key industries (tourism and fishing), relatively high threat exposure if threats are not properly managed (e.g. overfishing and climate change), and a low level of adaptive capacity.[1]

Marine ecosystems are natural assets and a major source of ecosystem services to the people of Fiji. Any changes to the extent and condition of key marine ecosystems will have major economic and social consequences.

Much of the waters of Fiji and adjacent international waters include highly prospective deposits of copper, gold, zinc, silver and chemical elements. Rising global populations, incomes, and changing technologies, are all driving significant growth in worldwide demand for these deposits. Concurrently, economically viable deposits on land are becoming increasingly scarce. Hence, the focus of much of the exploration for new deposits is moving from terrestrial to marine environments.

However, the risks to marine environments of Deep Sea-bed Mining (DSM) including upstream and downstream activities are poorly understood. Furthermore, the potential risks to ecosystem services and their direct and indirect economic and social impacts are even less understood. It is therefore imperative to better understand these impacts to ensure Fiji is able to make informed and balanced decisions on the future development and operations of DSM.

The purpose of this study if to:

- Identify the extent to which DSM could provide benefits to the Fijian economy and community.
- Identify the potential risks to key ecosystem services attributable to DSM.
- Where possible, establish a quantifiable understanding of the potential magnitude of the risks to key ecosystem services that could be negatively impacted by DSM
- Identify appropriate policy interventions to mitigate/offset/compensate for adverse impacts and ensure equitable sharing of benefits from DSM.

Given the resources available, this modest desktop study is designed to identify key issues for analysis and consultation with the Fijian Government, DSM proponents, the International Seabed Authority, local stakeholder organisations, and local communities and industries that may be impacted by DSM activities. The purpose of this report is not to be definitive research.

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[1] For example see: World resources Institute (2012) Reef at risk revisited. Techera, E.J. and Troniak, S. 2009 Marine Protected Areas Policy and Legislation Gap Analysis: Fiji Islands, IUCN Regional Office for Oceania, Suva, Fiji.

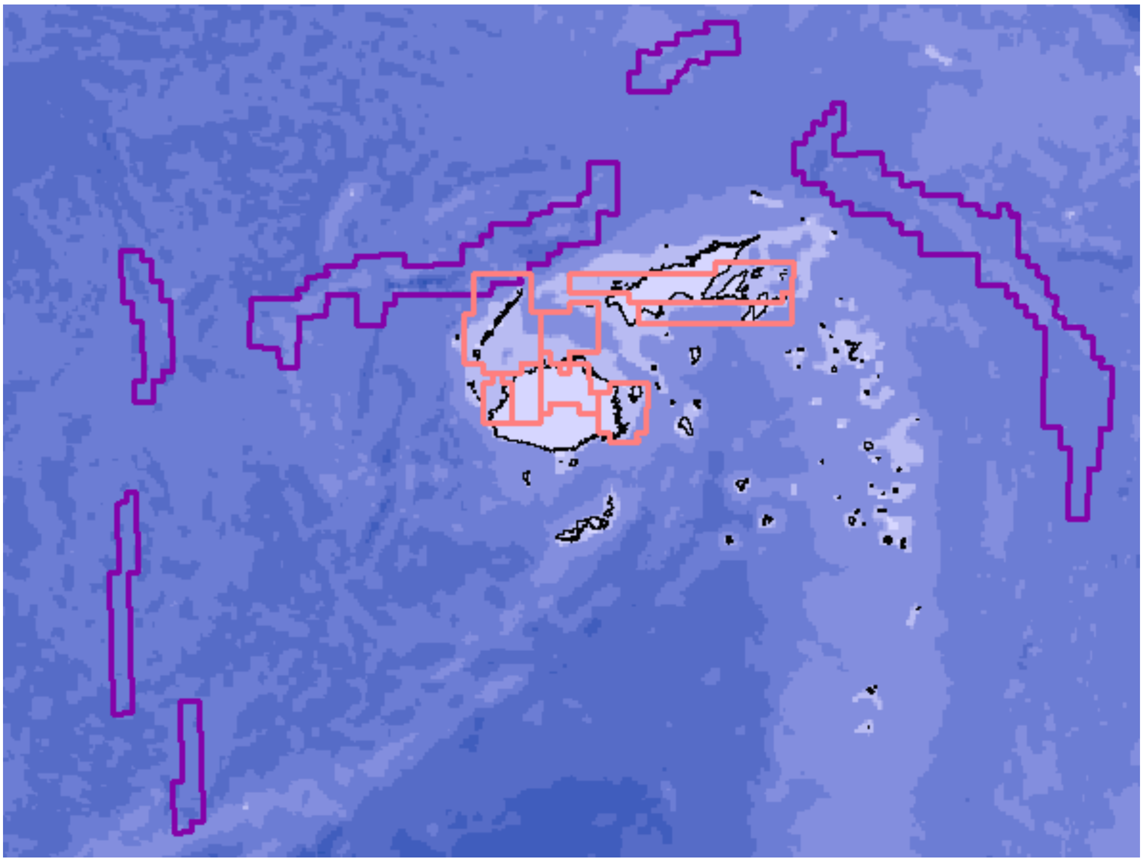
2 Deep-sea bed mining (DSM)

As the world population and economies grow, demand for known metals and rate earth elements continue. Whilst mining in terrestrial environments is well established, resources that are commercially viable to mine and process are becoming scarcer. Recently attention has turned to the potential to exploit deposits from sea floor (e.g. sulphates, manganese, cobalt). Often these resources are at depths in excess of 1,000 metres below the surface.

DSM sites are typically located around large areas of polymetallic nodules or hydrothermal vents (active or inactive). The vents create sulfide deposits containing valuable metals such as gold, copper, manganese, cobalt, and zinc. The mining process involves the extraction of deposits typically using hydraulic pumps or buckets that collect the ore that is transferred to the surface for processing. The primary interest in Fijian waters is for seafloor-massive sulphide, similar to current developments in Papua New Guinea.

To date there are no active DSM operations in Fiji. However, there has been a significant area of exploration licences issued. The scale and location of sea-bed exploration (purple) and oil exploration licenses (pink) are shown in the figure below.

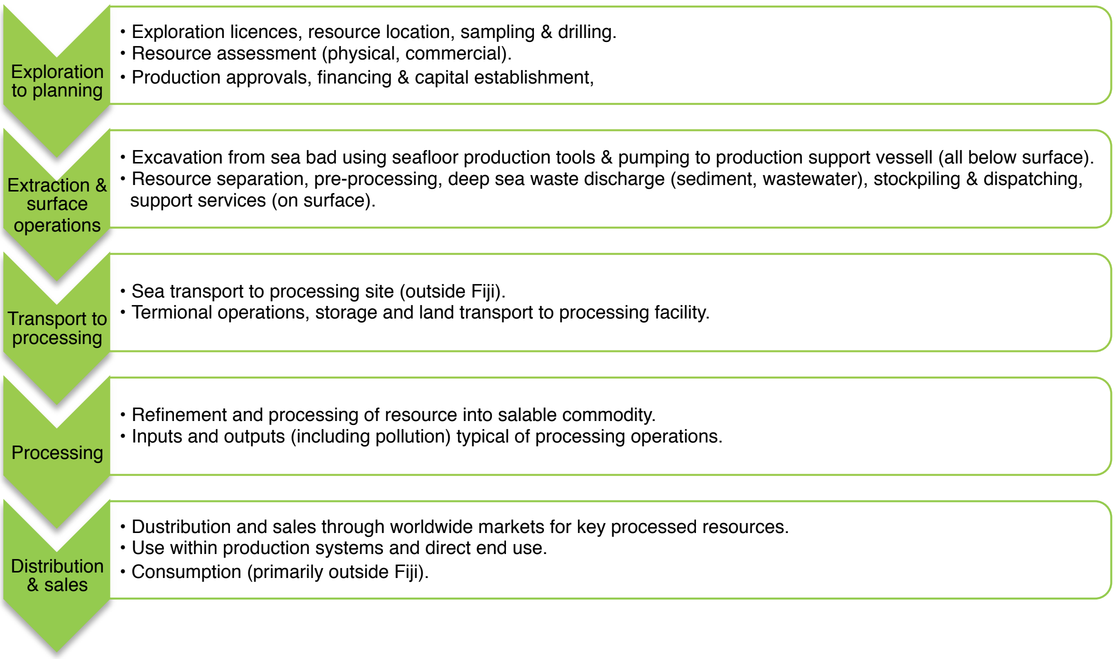
Figure 1: Location of deep-sea exploration and oil exploration licenses in Fiji



Source: Fiji Government

The key point to note is that some of the exploration licences are relatively close to reef systems and key fisheries. It should also be noted that while the exploration licences have been issued over a large area, ultimately mining would only occur directly on a fraction of that area. The commercial prospectively and likelihood of DSM occurring in Fijian waters is highly reliant on a number of technical and market considerations along the entire value chain from the presence and concentration of valuable resources, the costs of extraction and processing, market prices and distribution, and market conditions within the broader market. A simplified value chain for the deep sea-bed mining value chain can is shown in the figure below.

Figure 2: DSM value chain and key activities



Exploration to planning
- Exploration licences, resource location, sampling & drilling.
- Resource assessment (physical, commercial).
- Production approvals, financing & capital establishment,

Extraction & surface operations
- Excavation from sea bad using seafloor production tools & pumping to production support vessell (all below surface).
- Resource separation, pre-processing, deep sea waste discharge (sediment, wastewater), stockpiling & dispatching, support services (on surface).

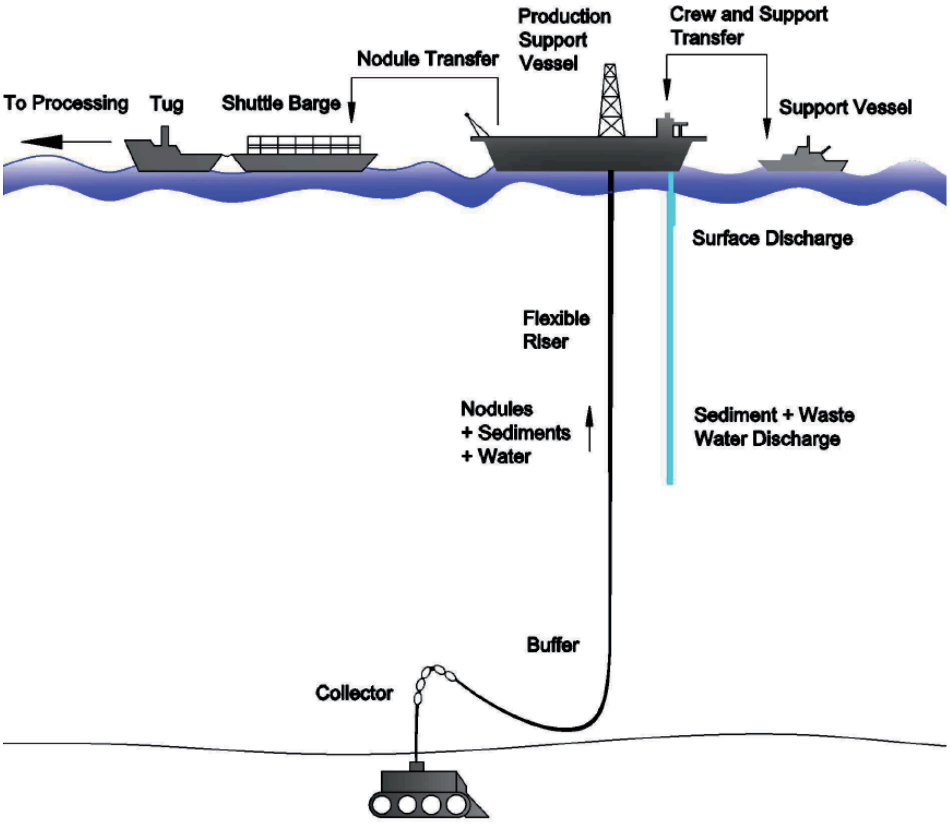
Transport to processing
- Sea transport to processing site (outside Fiji).
- Termional operations, storage and land transport to processing facility.

Processing
- Refinement and processing of resource into salable commodity.
- Inputs and outputs (including pollution) typical of processing operations.

Distribution & sales
- Dustribution and sales through worldwide markets for key processed resources.
- Use within production systems and direct end use.
- Consumption (primarily outside Fiji).

The bulk of the activity occurring in Fiji waters would be for the exploration, extraction and surface operations, and transport to the processing plant activities. This is shown in the figure below. Only limited value adding will occur in Fiji.

Figure 3: Deep-sea bed mining – conventional recover system



Source: Argwal et al. 2012. Feasibility Study on Manganese Nodules Recovery in the Clarion Clipperton Zone.

3 Economic benefits of DSM

It is potentially too early to tell what the prospects for large-scale DSM are in Fiji as the technology is still in its infancy, operations elsewhere are still a number of years off demonstrating viability, and a number of other potential developments are significantly closer to fruition (e.g. Solwara 1 in PNG, prospective deposits in Tonga and the Clarion Clipperton Fracture Zone of the Central Pacific). The timing and scale of developments in Fiji will ultimately be dictated by technical constraints on extraction, market prices for mined product, and the competitiveness of Fijian production (along the supply chain). The table below briefly outlines the key economic benefits attributable to DSM.

Table 1: Economic benefits of DSM

Benefit and description	Relative scale of benefits	Who benefits
Returns to mining companies. The major economic benefit from DSM will be the economic profits accruing to mine operators that are passed onto investors. It is most likely that foreign companies will develop DSM.	Potentially significant.	Shareholders of mining companies (largely foreign nationals).
Capital establishment phase. The types and levels of technology used in DSM are very advanced. Therefore, capital equipment will be almost exclusively imported, with little benefit to Fijian businesses. The most comparable project assessment from PNG indicates *"construction of all offshore Project components will occur at specialised international facilities and, at this stage, no construction is expected to occur within PNG."* (Naultilus Minerals Inc. 2010. p 5–18).	Potentially significant.	Foreign manufacturers.
Direct local employment. The capital intensive nature of extraction and surface operations results in relatively low levels of employment, and the skill and knowledge requirements of employees is often relatively higher given the technologies used. For example, the Nautilus Mineral Solwara 1 Project environmental impact statement indicates total employment of around 140 persons during the operational phase of the project. This indicates limited local employment opportunities in both an absolute and relative sense.[2]	Small.	Shared between expatriate professionals and locals.
Local inputs — operational phase. Much of the benefits to local communities from mining projects come from the provision of direct inputs to production, contracted services (often services for employees), and value adding in downstream aspects of the industry. However, the linkages between DSM and the provision of local inputs will be more tenuous as both capital (e.g. parts and machinery) and operational inputs (e.g. fuel) will have a high import component.	Small.	Majority of benefits accrue to overseas suppliers of inputs.
Consumer benefits (lower prices). Resources extracted in DSM projects are ultimately used in a wide variety of products (e.g. cobalt use in electronics). To the extent that DSM in Fiji results in lower worldwide prices for resources, some benefits may accrue to locals in the form of relatively lower prices for goods. However, the bulk of those benefits will accrue internationally where the bulk of the final products are consumed.	Potentially significant.	Majority accrues to overseas consumers.
Tax revenue. To the extent that profits from DSM accrue to companies domiciled (registered) in Fiji, or where Fijian taxation regimes apply, there will be benefits to the Fijian Government. Similarly, local employees will pay income taxes.	Company tax potentially significant. Income taxes negligible due to low employment.	Immediate revenues to Fijian Government, but benefits accruing to society are dependent on the efficiency of Government programs.

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[2] Based on employment and ore production data from the Nautilus Mineral Solwara 1 Project environmental impact statement and comparable data from terrestrial mines in the Pacific, it would appear that the employment intensity for deep sea mining is possible less than a quarter of the intensity for terrestrial mines. While this metric is relatively simplistic, it does demonstrate the fundamental differences in employment opportunities between deep sea and terrestrial mining developments.

Benefit and description	Relative scale of benefits	Who benefits
Royalties. Royalties are currently not a major source of Fijian Government revenue.[3] Royalties charged on the volume, value, or value added from resources extracted trough DSM would make a contribution to the income of the Fijian Government. Where these resources are used effectively, they will enhance the wellbeing of the community.	Potentially significant.	Immediate revenues to Fijian Government, but benefits accruing to society are dependent on the efficiency of Fijian Government expenditure.

Key findings

- The economic benefits from the establishment phase of DSM to Fiji are likely to be negligible, as the technology will be almost exclusively imported.
- The benefits to the Fijian economy and community from DSM operations are also likely to be negligible. This is due to the technologically advanced inputs for mining (when compared to terrestrial mining), the relatively low levels of local value adding and employment, and the fact that the bulk of the value adding (processing and use of materials) will occur outside Fiji.
- There will be benefits in the form of tax revenues and royalties for the Fijian Government. The extent of these benefits will be highly dependent on taxation arrangements, any royalties regime struck between the State and developers, and the effectiveness of the use of those resources by the Fijian Government.

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[3] The Fijian Budget estimates for 2016 indicate royalties account for around 2.3% of total Government revenue.

4 Potential economic risks and costs of DSM

This section outlines some of the key sources of risks from DSM, their potential impact on ecosystem services and the potential economic consequences of that risk.

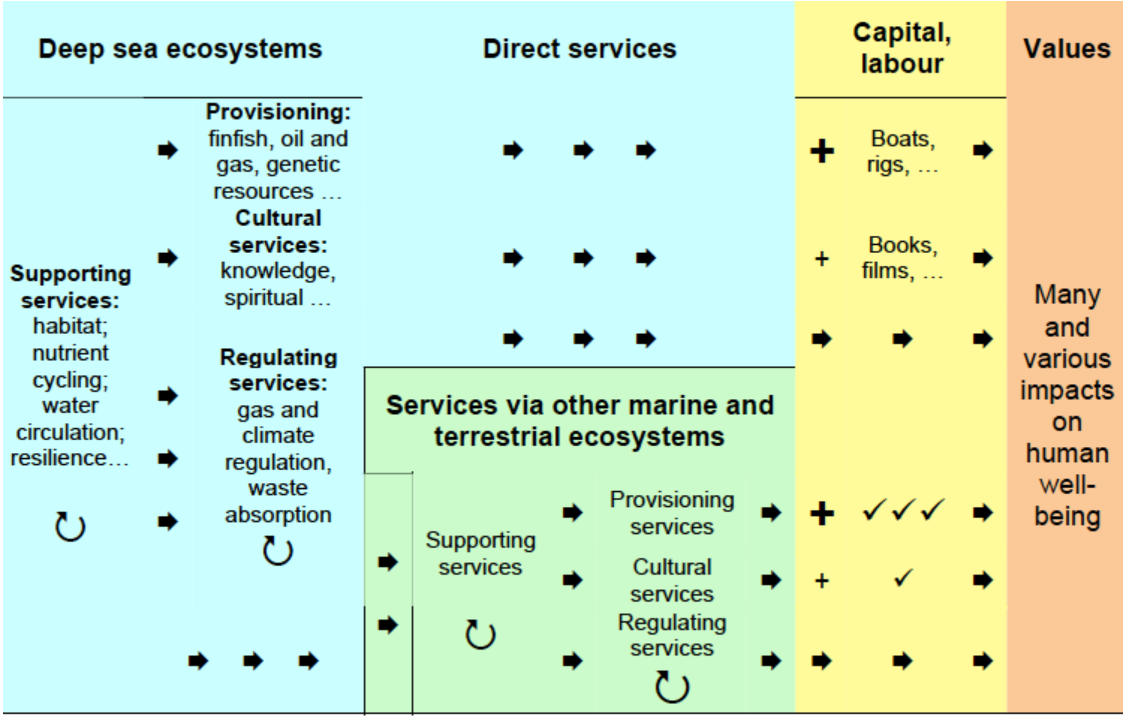
4.1 Physical risks

There are a number of sources of risks from DSM production systems that occur at different dimensions:

- Surface risks. This includes the physical presence of ships/platforms, noise, light, and surface discharges that occur from operations (including spills). This could also include any impact on local fisheries or tourism activities if the locations of those activities overlap.
- Midwater risks. The physical presence of riser pipes, discharges of processing water/waste, noise, light and tools going up and down. These impacts would likely be on fisheries and other ecosystem services.
- Seafloor risks. The physical disruption by seafloor production tools, sediment plume generation, tailing disposals, noise, habitat destruction, potential contamination from spills etc.[4] These would largely relate to the impacts on ecosystem services (e.g. food webs, biodiversity etc.).

The physical risks will have subsequent economic and social impacts on production fisheries, food security and welfare. It is the potential incremental changes in ecosystem services that represent the economic risks associated DSM. We have used a simplified ecosystem services framework[5] to identify and provide indicative values for some of the key risks related to DSM. The linkages between deep-sea ecosystems and human wellbeing are broadly shown in the figure below.

Figure 4: The linkages between deep sea ecosystems and human well being



Source: Armstrong et al. 2010. Ecosystem services of the deep sea

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[4] See Clark, M. 2013. Oceanic and deep-sea fishery resources of the Pacific: the potential impacts of Deep Sea Mining. Bertram, I. 2013. Socio Economic Impacts of resource Extraction. 4th Regional Training Workshop, Environmental Perspectives of Deep Sea Mineral Activities, Nadi, Fiji. December 2013. Cardno. 2016. An assessment of the costs and benefits of deep-sea minerals in the Pacific Island region.

[5] Millennium Assessment 2005. Ecosystems and human well-being: Current state and trends. Millennium Ecosystem Assessment, vol. 1. Island Press, Washington DC.

The ecosystem services framework sets out four main categories of ecosystem services:

- Provisioning services — products used by humans that are obtained directly from habitats and ecosystems (e.g. fish). Note: fisheries were identified as the key provisioning service and this is assessed in Section 4.3 of this report.
- Regulating services — benefits obtained through the natural regulation of habitats and ecosystem processes (e.g. climate regulation).
- Habitat — those functions necessary for the production of all other ecosystem services, that is they feed into provisioning, regulating and cultural services (e.g. genetic diversity).
- Cultural services — non-material benefits people obtain from habitats and ecosystems (e.g. tourism). Note: tourism has been identified as the key cultural service impacted and this is assessed in Section 4.2 of this report.

Other ecosystem services are assessed in Section 4.4 of this report. Using an ecosystem services approach enables linkages between the physical, social and economic risks associated with DSM to be clearly identified, articulated and valued where data permits. An overview of the economic valuation techniques that may be used for this project (depending on data limitations) is provided in Appendix A.

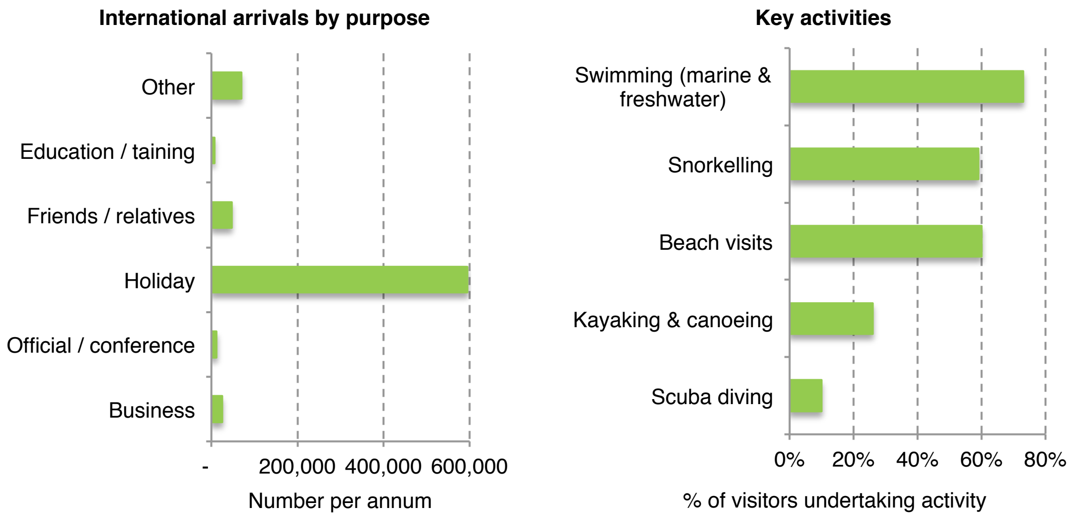
Key findings

- There are multiple sources of risks associated with DSM activities.
- These risks to the provision of ecosystem services have economic consequences.

4.2 Tourism

Tourism is one of the major Fijian industries and much of the country's appeal for visitors is the opportunity to undertake marine-based activities. There were over 750,000 international visitors to Fiji, of which 79% were holiday makers. Both the absolute number of holiday makers and their relative contribution to overseas arrivals has been increasing in recent years, with annual growth rates of 4-5%. This is shown in the figure of the left below. The Fiji Tourism Survey clearly demonstrates that marine-based and beach ecosystems are an important component of tourism demand.[6] The proportion of tourists undertaking key marine-based activities is shown in the figure in the right below.

Figure 5: Visitors by purpose and key visitor activities



Source: Fiji Bureau of Statistics

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[6] Verdone, M., Seidl, A. 2012. Fishing and Tourism in the Fijian Economy. Gland, Switzerland: IUCN. 20pp.

The table below show estimates of the contribution of tourism to the Fijian economy in 2015 using a 'tourism satellite account' methodology.[7] This includes:

- The direct contribution based on estimated direct tourism expenditure within Fiji such as accommodation, food, tours etc. (netting out purchases from other tourism businesses).
- The indirect contribution (e.g. construction of hotels, relevant government administration etc.).
- The induced contribution attributable to spending by people who are employed in the tourism sector.

The data shows that the direct contribution is in excess of one billion FJD, while the total contribution could be as high as 2.9 billion FJD. Direct employment is estimated at around 41,500 jobs.

Table 2: Economic contribution of tourism to the Fijian economy (2015)

Measure	Contribution to Gross Domestic Product (FJD million)	Contribution to employment (people employed)
Direct contribution	1,069	41,500
Indirect contribution	1,360	51,000
Induced contribution	465	20,000
Total	2,894	112,500

Source: World Travel and Tourism Council. 2015, Travel and Tourism. Economic Impact 2015. Fiji

It is estimated that tourism directly accounts for 13.7% of the Fijian economy and 12.3 % of employment. When compared to all other countries, it is clear that the relative importance of tourism in Fiji is relatively higher (13th highest relative contribution to a nation's gross domestic product in the world and the 17th highest in terms of direct employment.

The sector is also a significant contributor to total exports (> 40% of total exports, the 26th highest in the world) and total national annual capital investment (> 35%, the 4th highest in the world).

In the absence of unanticipated shocks (e.g. cyclones), the growth prospects for tourism in Fiji are very strong. The World Travel and Tourism Council forecasts for Fiji for the period to 2025 include:

- Growth in the terms of the contribution to Gross Domestic Product (GDP) by an average of 5.1% per annum.
- An increase on the importance of the sector from around 13.7% of total GDP in 2014 to 17.8% by 2025 (growth of 4% per annum).
- An increase in *direct* employment from around 41,500 jobs to in excess of 61,000 in 2025 (over 16.3% of total employment).

Key findings

- Tourism is one of the most important industries to the Fijian economy in terms of the contribution to gross domestic product, employment, export earnings, and capital formation.
- The relative importance if tourism in Fiji is higher than most other countries, including most in the Pacific.
- Tourism is also one of the sectors that is most exposed to risk attributable to DSM.

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[7] The Tourism Satellite Account is a standard statistical framework and the main tool for the economic measurement of tourism. The use of a 'satellite account' is an approach developed by the United Nations to measure the size of economic sectors that are not defined as industries in national accounts.

Dive tourism

The lucrative dive tourism market is potentially the most at risk from DSM. The Fiji International Visitor Survey (2009, the latest survey) found that 10% of all interventional visitors participate in scuba diving.[8] A detailed survey of 296 divers in 2011 found tourists that dive spend significantly more per visit than average tourists (FJD 5,050 compared to an average expenditure of around FJD 2,050). This figure is significantly higher in Vanua Levu (FJD 6,300) reflecting the additional time and money spent visiting the adjacent iconic Great Sea Reef.[9]

Based on the survey data collected in 2011, visitation statistics for 2015, and tourism expenditure and labour force data from the Fijian Bureau of Statistics, we have developed estimates of key economic indicators for the dive tourism market (table below).

Table 3: Estimated tourism expenditure by dive tourists by key region (2015)

Region	Expenditure (FJD million)	Profit to tourism sector (FJD million)	Wages (FJD million)	Taxes and levies (FJD million)	Direct employment (persons)[10]
Viti Levu	64	37	4	10	1,160
Pacific Harbour (Viti Levu)	30	18	2	5	540
Vanua Levu / Taveuni	42	18	2	5	770
Mamabuca / Yasawa	40	18	2	4	730
Total	176	91	10	25	3,200

Source: MainStream Economics and Policy

Key findings

- The dive tourism sector is potentially the tourism sub-sector most at risk from damage to marine ecosystems attributable to DSM.
- Divers make a significant contribution to the broader tourism sector, including generating economic activity that provides employment for up to 3,200 people.

4.2.1 Potential impact on tourism

The potential costs to the tourism industry from DSM come for two distinctly different types of risk:

- Firstly, the risk of direct damage to sites of interest to tourists (e.g. a fuel spill from surface operations). This is a physical risk with economic consequences for the tourism industry. The likelihood of this risk is significantly mitigated though the surface operating procedures of DSM[11], while the consequence would be dependent on the location of the spill and the response of the operator to the incident. Given the location of current DSM exploration permits (see Figure 1), the consequences of such a spill to the tourism industry could be relatively low except when operations are located adjacent to the Great Sea Reef.
- Secondly, the indirect effect that the existence of DSM near iconic tourism assets such as the Great Sea Reef has on Fiji's share of worldwide marine-based tourism. This is a reputational risk with economic consequences.

It is this reputational risk that potentially has a significantly greater and more pervasive cost to the Fijian tourism industry than any direct risk. This is particularly the case as international

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[8] Anon., 2009. Fiji International Visitor Survey 2009 Report. Ministry of Public Enterprises, Communications, Civil Aviation & Tourism, pp. 97.

[9] Vianna. G, Meeuwig. J, Pannell. D, Sykes. H, Meekan. M. 2011. The socio-economic value of the shark-diving industry in Fiji. Australian Institute of Marine Science. University of Western Australia. Perth

[10] These estimates assume the ratio of direct employment to direct expenditure in the dive tourism sector is the same as the broader tourism sector.

[11] Cardno estimate the probability of a material spill is very (less than 0.04%). Cardno. 2016. An assessment of the costs and benefits of deep-sea minerals in the Pacific Island region.

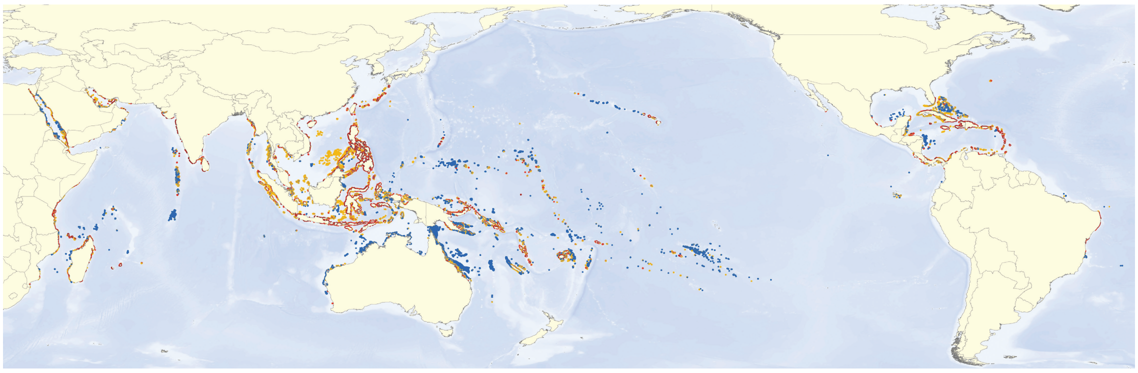
visitors will chose between destinations (e.g. Fiji, Australia, Belize) based on the perceptions of the condition of the marine environment. Holding all other variables constant (e.g. differences in the cost of a trip to competing countries), anything that negatively impacts on the perceived quality of the marine environment, will have a subsequent impact on visitor levels.[12] To the extent that Fiji can maintain the condition of its reef system and avoid actions that negatively impact on the perception of its reef systems, Fiji's share of worldwide marine-based tourism should increase over time.

Based on worldwide comparisons, many of the coral reef systems in Fiji are generally in relatively good condition[13] and currently face lower levels of threat than many of the reef systems in other regions that are competing for international marine-based tourism. For example:

- The inshore reefs of the Great Barrier Reef in Australia have lost a significant proportion of coral cover and fish abundance due to multiple threats including terrestrial runoff, coral bleaching and crown of thorns.[14]
- Many of the reefs in the Caribbean and most of the reefs in South East Asia are already in decline due to local threats including fishing pressures and terrestrial runoff.[15]

The figure below shows the relative risks to worldwide reef systems, where blue indicates a lower level of threat, while orange and red indicate higher levels of threat. To the extent that Fiji can maintain its reef systems in good condition and other systems decline (e.g. in South East Asia), it would be reasonable to expect Fiji will capture a greater share of the rapidly growing marine-based tourism sector in the longer-term.

Figure 6: Worldwide reefs at risk



Source: World Resources Institute. 2011. Reefs at risk revisited

Previous research in Australia has demonstrated that declines in the extent and condition of marine ecosystems that underpin tourism will have significant impacts on visitation levels.[16] A major study by Kraght et al found that hypothetical reductions in coral cover, coral diversity and fish diversity of 80%, 30% and 70% respectively, are shown to lead to a 59% decrease in the number of reef-trips taken by divers and snorkelers.[17] Furthermore, a study based on surveys of dive operators found that even consumer perceptions of reef decline have negative impacts, as international dive tourists choose other destinations.[18]

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[12] Huybers, T. and Bennett, J. 2003. Environmental management and the competitiveness of nature-based tourism destinations. Environmental and Resource Economics, 24, 213-233.

[13] Although it should be noted fishing pressures and terrestrial runoff pose threats to some reef systems.

[14] Queensland Government. 2013. Great Barrier Reef. Scientific consensus statement.

[15] World Resources Institute. 2011. Reefs at risk revisited.

[16] Mahalic, T. 2000. Environmental management of a tourist destination: A factor of tourism competitiveness. Tourism Management, 21, 65-78.

[17] Kraght, M., Roebelling, P. and Ruijs, A. 2006. Effects of Great Barrier Reef Degradation on Recreational Demand: A Contingent Behaviour Approach.

[18] Binney, J. 2009. The recreational dive and snorkelling industry in the Great Barrier Reef: profile, economic contribution, risks and opportunities

These relationships are not known in the Fiji context. However, even very small declines in visitation due to the perceived negative impacts of DSM could have significant impacts on the tourism sector.

Key findings

- Many of Fiji's reef systems are in relatively good condition and face lower levels of threat than reef systems in other countries competing for international marine-based tourists.
- The risks of DSM to the tourism sector relate to both the direct damage to marine ecosystems (a potentially relatively minor risk), and through reputational risks potentially resulting in a reduction in Fiji's share of the international marine-based tourism sector (a largely unknown, but potentially significant risk if research from other locations is a guide).

4.2.2 The potential costs to tourism (scenario modelling)

Because the relationship between DSM and the impact on dive-tourist visitation is unknown, we have developed a simple economic impact assessment model that can analyse the likely impacts of any reduction in the Fiji's market share of international dive tourism. The model is based on the direct expenditure outlined in Table 3, and the same relationships for indirect and induced contributions from Table 2.

We have then assessed the impacts on gross domestic product (GDP)[19], tax revenues and employment from reductions in dive tourists (1%, 5%, 10% reductions). The findings from our modelling are shown in the table below.

Table 4: Hypothetical impacts of reductions in dive-tourism international visitors

Region	Reduction in GDP (FJD million)	Reduction in taxes and levies (FJD million)	Employment (persons)
1% reduction in dive-tourism visitors			
Viti Levu	1.1	0.3	31
Pacific Harbour (Viti Levu)	0.5	0.1	15
Vanua Levu / Taveuni	0.5	0.1	21
Mamabuca / Yasawa	0.5	0.1	20
Total	2.7	0.7	87
5% reduction in dive-tourism visitors			
Viti Levu	5.6	1.4	157
Pacific Harbour (Viti Levu)	2.7	0.7	74
Vanua Levu / Taveuni	2.7	0.7	104
Mamabuca / Yasawa	2.7	0.6	99
Total	13.7	3.4	434

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[19] Using the income approach where profits to businesses and wages are summed.

Region	Reduction in GDP (FJD million)	Reduction in taxes and levies (FJD million)	Employment (persons)
10% reduction in dive-tourism visitors			
Viti Levu	11.2	2.8	315
Pacific Harbour (Viti Levu)	5.4	1.3	147
Vanua Levu / Taveuni	5.4	1.4	207
Mamabuca / Yasawa	5.4	1.2	197
Total	27.4	6.8	867

Source: MainStream Economics and Policy

The key points to note include:

- The impacts on annual GDP are significant. Even a 1% decline in dive tourism visitation would reduce the value of the economy by FJD 2.7 million per annum, while a 10% reduction equates to over FJD 27 million per annum. If a DSM operation resulted in a 10% loss of Fiji's market share for the life of the operation (say 30 years), the losses to the Fijian economy could be in excess of FJD 530 million.[20]
- Government revenue from taxes and levies could also be reduced by millions.
- The greatest impact at a local level is likely to be the loss of jobs (around 90 jobs for every 1% reduction in the number of dive tourists). Even a 1.5% decline in the dive tourism industry would eliminate as many jobs as one fully operational DSM operation.
- Given the fact that the World Travel and Tourism Council expect significant long-term growth for the Fiji tourism sector, these estimates are likely to be underestimates.

It should also be noted that the reliability and accuracy of the data used in this analysis is limited. Therefore the accuracy of the estimates developed in this scenario modelling should be treated with caution.

Key findings

- The impact of any DSM operation on Fiji's share of the international dive tourism sector are largely unknown, but studies undertaken elsewhere suggest a decline in market share should be expected based on a loss of Fiji's reputation as a world-class destination for international tourism.
- Even small declines in visitation could have significant impacts on GDP, revenue from taxes and levies, and regional employment.
- A 10% reduction equates to over FJD 27 million per annum. If a DSM operation resulted in a 10% loss of Fiji's market share for the life of the operation (say 30 years), the losses to the Fijian economy could be in excess of FJD 530 million.

4.3 Fisheries

Fisheries are a major commercial industry in Fiji, producing around 13,500 Mt of fish in 2014. However, volumes have declined in recent years due to management (overfishing) and damage to habitat (particularly pollution). The figure below shows commercial fisheries production data for 2006 to 2014. It should be noted that divisional and smaller area data is not available. The key points to note include:

- The overall declines in catch volumes (down around a third over the period), particularly for Albacore).

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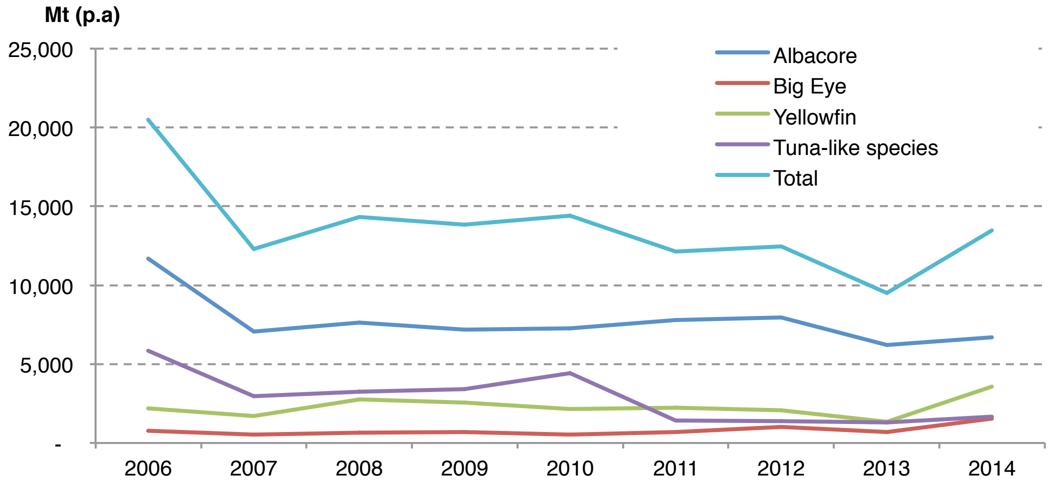
[20] We have calculated this as the present value of reduction to GDP over a 30 year period as the DSM recovery equipment is moved around multiple locations using a 3.05% discount rate (see Appendix for calculation of discount rate).

- The significant dominance of tuna, albeit with variations in the composition of the catch between years.

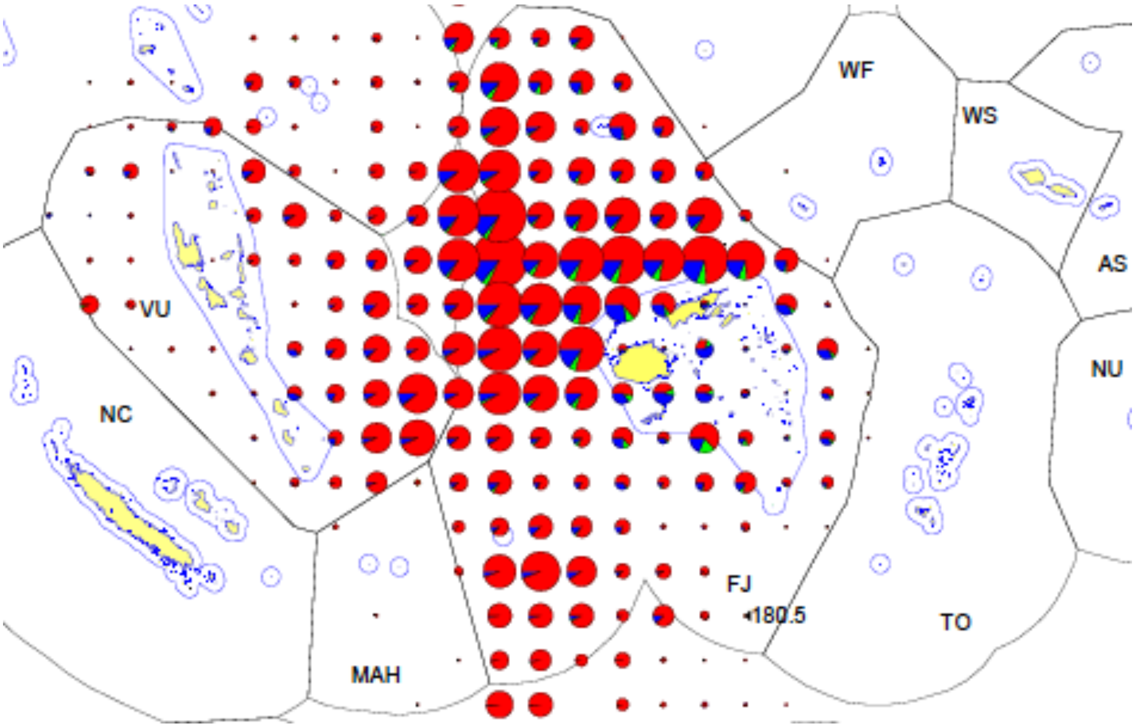
Figure 7: National commercial tuna fisheries production 2006-2014



Source: Anon., 2010 & 2014. Annual scientific report to the western and central Pacific Fisheries Commission. Part 1. Information on fisheries, research and statistics

The concentration of national tuna fishing effort within Fijian waters is shown in the figure below.

Figure 8: Focal areas for national Tuna fishing effort



Note: Red = Albacore; blue = Yellowfin; green = Big eye

Source: Amoe, J. 2011. Annual scientific report to the western and central Pacific Fisheries Commission. Part 1. Information on fisheries, research and statistics 2010.

Much of the tuna fishery activity is concentrated to the north-west of the Yasawa Islands and the Great Sea Reef, both areas that clash with DSM exploration licenses. Time series divisional and smaller scale production data is generally not publicly available. However, based on available data for the inshore catch, the Central, Northern and Western Divisions contribute 25%, 36% and 39% to the national total respectively.[21]

Fisheries are also a significant industry to coastal communities, contributing around FJD 117 million (1.8%) to Fiji's GDP with only limited fluctuations from year to year in more recent times. This is shown in the table below.

Table 5: Fisheries contribution to GDP

Sub-sector	2012 (FJD million)	2013 (FJD million)	2014 (FJD million)
Subsistence	36.4	36.7	36.7
Informal	6.2	6.3	6.3
General Government	2.1	2.8	3.2
Non-General Government	69.7	69.5	70.7
Total	114.5	115.3	116.9

Source: Fiji Bureau of Statistics

The table below shows a number of the key economic variables for the commercial sector for the periods 2008 and 2011. This indicates a decline in the economic prosperity of the sector, which is consistent with data indicating the size of the Fijian long-line fleet is contracting (both in absolute numbers, but also the average vessel size (as larger vessels are deployed elsewhere). The table also shows key economic valuables as a % of the value of gross output.

Table 6: National commercial fisheries production (key economic valuables)

Economic variable	2008	2011	% change (2008 to 2011)
FJD indicators			
Gross output	98,827,690	88,964,966	-10%
Intermediate consumption (on business inputs)	60,982,619	58,976,605	-3%
Value added	37,845,071	29,988,361	-21%
Wages and salaries	7,877,978	6,409,072	-19%
Consumption of fixed capital	4,717,227	2,668,949	-43%
Operating surplus	25,249,866	20,910,340	-17%
% of value of gross output			
Gross output	100%	100%	
Intermediate consumption (on business inputs)	62%	66%	
Value added	38%	34%	
Wages and salaries	8%	7%	
Consumption of fixed capital	5%	3%	
Operating surplus	26%	24%	

Source: Fiji Bureau of Statistics. 2014. A study of the agriculture, forestry and fishing industries 2011

The key points to note include:

- As catch volumes in Fijian national waters have been declining, commercial fishing operators are only partly able to reduce input costs (intermediate consumption, wages and salaries, and the consumption of fixed capital).[22] In conjunction with relatively flat real prices

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[21] Areki, F. 2014. Economic Value of the Great Sea Reef. Literature Review and Desktop Analysis.

[22] FFA. 2015. Tuna economic indicators report

for product,[23] this has resulted in significant declines in profit (indicated by the declines in operating surplus).

- The commercial fisheries sector in Fiji is already under significant economic stress as it transitions to more sustainable harvest levels.

It should also be noted that there is also a significant volume of tuna processed in Fiji (around 17,600 Mt in 2014). This volume is remaining constant, as processing facilities have diversified more into the other products where necessary to maintain industrial throughput. Processing costs in Fiji are near the lower end of the Pacific nations, but significantly higher than Asian countries. These cost differentials will place constraints on the ability of the processing sector to remain commercially viable if catch rates decline further.[24]

Commercial fisheries account for about 1,600 – 1,700 jobs for local crew, while a further 2,000 people are employed in processing and other ancillary functions on land.[25] Average daily wages are around FJD 25-30. This employment is extremely important on regional centres where opportunities in the formal labour market are limited.

Key findings

- Commercial fishing is dominated offshore fishing, with annual production now around 13-14,000 MT per annum. Production levels are down on 10 years ago.
- While the sector is still a major contributor to GDP (around FJD 117 million, or 1.8% of Fiji's GDP), the sector has struggled to cope with decreasing catch volumes and limited abilities to restructure and adjust. This makes the sector economically vulnerable to further external shocks.
- Significant volumes of fish are also processed each year (around 17,600 Mt), much of it for the export market.
- Commercial fisheries account for about 1,600 – 1,700 jobs for local crew, while a further 2,000 people are employed in processing and other ancillary functions on land.

Around 30-35% of the value of the fishing sector is attributable to the subsistence fishery, a major source of protein and implicit income for much of the community. Subsistence fishers are primarily rural residents, where coral reef fisheries is their primary protein source, and their dominant source of cash income. It is estimated that annual per capital fish consumption is around 36 kg. Census data indicates average adult earnings in rural areas of Fiji at around FJD 3,000, and average household sizes in excess of 5 persons. Clearly the loss of subsistence fishing opportunities at the local scale would have a significant impact on household budgets through the need to buy protein substitutes.

Available data indicates that Fiji's subsistence fisheries potentially employ over 3,000 people in terms of full-time equivalent jobs. However, subsistence fisheries are a key economic activity in many coastal zones and very few of those involved in the sector have knowledge and skills that can be transferred to other sectors.[26]

Key finding

- Subsistence fishing is both a vital sector and source of livelihoods, particularly in coastal rural areas where other economic and employment options are limited.

4.3.1 Potential impact on fisheries

There are a number of potential key sources of risk to fisheries. These depend on a number of factors.

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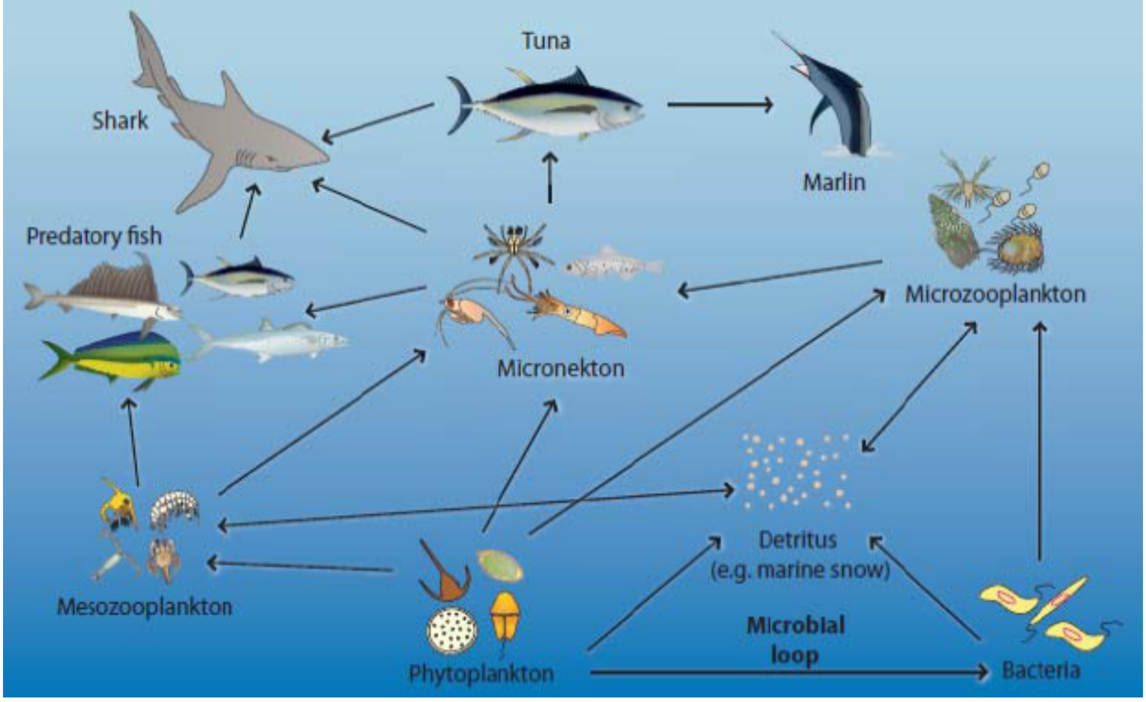
[23] FFA. 2015. Tuna economic indicators report
[24] FFA. 2015. Tuna economic indicators report
[25] FFA database.
[26] FAO. Undated. Fishery and Aquaculture Country Profiles. The Republic of the Fiji

Firstly, the depth of any spills or disturbances will have an impact on risks. Target pelagic species such as tuna typically live in the surface mixed layer (< 200 metres). Risk to fisheries in this zone will largely be attributable to surface spills and other discharges.

The greater risk is perhaps more likely to occur in the mesopelagic zone (200 – 1,000 metres), potentially due to spills and other unintended discharges,[27] any loss of habitat (particularly on seamounts that are highly prospective for DSM and important for fish spawning), and increased concentrations of pollutants that could impact directly or indirectly on the tuna food web.[28] The tuna food web is shown in the figure below.

Figure 9: Tuna food web and contaminated zooplankton/micronekton



Source: Bertram, I. 2013. Socio Economic Impacts of Resource Extraction. 4th Regional Training Workshop, Environmental Perspectives of Deep Sea Mineral Activities, Nadi, Fiji. December 2013.

If damage occurs to the seamount benthos (flora and fauna), recovery is likely to be very slow (if at all) and in effect, local fisheries may be lost permanently where fauna cannot readily migrate to other seamounts. There will also be some risks from damage to the bathypelagic zone (>1,000 metres). The role of the vertical structuring of marine ecosystems and the relative importance of deep-sea ecosystem functions is poorly understood.

The second major risk factor is the location of DSM activities. The impact if unintended spills from the production support vessel etc. could be significant if these spills occur near coastal and reef fisheries. The concurrence of DSM prospectively and fishing prospectively around seamounts in the mesopelagic zone demonstrates a potential direct conflict between the interests of the two sectors.[29] Seamount operations are potentially the main concern for the tuna fishery, and these risks will also be exacerbated by broader ocean currents expanding the area of risk.[30]

While research to date has identified these potential risks, any quantitative understanding of their likelihood and consequences to key fisheries is not available at this time. For this reason, research is already occurring to enable a more comprehensive understanding of these risks.

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[27] E.g. leakages from riser pipes, chemical spills etc.

[28] Clark, M. 2013. Oceanic and deep-sea fishery resources of the Pacific: the potential impacts of Deep Sea Mining.

[29] Morato T, Hoyle SD, Allain V, Nicol SJ. 2010. Tuna Longline Fishing around West and Central Pacific Seamounts. Klimley AP, ed. PLoS ONE. 2010;5(12):e14453. doi:10.1371/journal.pone.0014453.

[30] Clark, M. 2013. Oceanic and deep-sea fishery resources of the Pacific: the potential impacts of Deep Sea Mining. 4th Regional Training Workshop, Environmental Perspectives of Deep Sea Mineral Activities, Nadi, Fiji. December 2013

Key findings

- There are risks from DSM to fisheries, particularly surface mixed layer attributable to spills, and impacts on habitat and food webs in the mesopelagic zone. These risks will be greater where DSM is occurring nearer to coastal fisheries and around seamounts.
- Generally the direct and indirect risks of DSM to fisheries are not well understood and a very precautionary approach to any DSM activities would be prudent.

4.3.2 The potential costs to fisheries (scenario modelling)

There are effectively two types of economic impacts that may have economic consequences for the commercial fishing industry:

- Firstly, temporary geographical displacement of commercial fisheries where clashes occur between DSM and preferred fishing grounds.
- Secondly, where direct or indirect damage triggers a contraction in the commercial fishing sector.

While there may also be impacts on inshore and subsistence fisheries, these would appear to be significantly less likely due to the location and/or depth of DSM activities. Therefore, we have not developed any quantitative scenarios for inshore and subsistence fisheries in this project.

Displacement costs

There will be potential for locational conflict between DSM activities and tuna fishing, particularly around seamounts. This will not exclude fishing altogether. Rather commercial fishers will be displaced to substitute fishing grounds (i.e. effort shift occurs). This has occurred elsewhere, including in Lihir (PNG) where consumer concerns about contamination of fishing grounds closer to Lihir Mine have resulted in local commercial operators travelling to substitute fishing grounds.[31]

To the extent that these alternative areas are further from Suva where most tuna is landed for processing or trans-shipping,[32] there will be an additional cost to the industry without a corresponding increase in catch or revenue. Therefore it is possible to establish hypothetical cost estimates per vessel based on increased variable costs (wages and fuel) attributable to the additional costs incurred to access substitute fishing grounds.

Using industry economic data (from Table 6), we have developed a simple economic model to assess the annual economic impact on a *single* offshore commercial vessel from a range of displacement scenarios (low, medium, high). This is shown in the table below including the key parameters used to develop the scenarios (e.g. number of crew, number of additional days of steaming required per trip to use substitute fishing ground), the economic impacts (changes in variable costs per annum), and changes in key economic performance indicators (inputs costs and operating surplus/profit).

The key points to note include:

- While the scenarios are hypothetical, they are similar to actual displacement that has occurred in other impacted tuna fisheries in PNG.[33]
- The major cost of displacement will be the additional fuel required to travel to substitute fishing grounds.
- Even limited displacement can have significant impacts on the profitability of vessels because revenues remain constant while variable costs increase. For example, our high scenario only assumes an additional 1.5 days of travel per fishing trip, yet profits could reduce by around 40%.

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[31] MainStream Economics and Policy. 2014. Economic valuation of environmental damages from the Lihir Gold Mine

[32] FAO. Undated. Fishery and Aquaculture Country Profiles. The Republic of the Fiji

[33] MainStream Economics and Policy. 2014. Economic valuation of environmental damages from the Lihir Gold Mine

Table 7: Hypothetical annual cost of displacement (per commercial vessel)

Economic variable	Low scenario	Medium scenario	High scenario
Scenario economic parameters used			
Number of fishing trips per annum	6	10	14
Number of crew	10	12	14
Daily wage cost (FJD per crew member)	25	28	30
Additional days steaming per trip	0.5	1.0	1.5
Additional fuel use (litres/vessel/day)	1,800	2,000	2,200
Average fuel price (FJD/litre)[34]	1.50	1.50	1.50
Economic Impacts			
Additional wage costs per annum (FJD)	750	3,300	8,820
Additional fuel costs per annum (FJD)	8,100	30,000	69,300
Total additional costs (FJD)	8,850	33,300	78,120
% increase in input costs	2%	6%	15%
% reduction in operating surplus/profit	5%	18%	41%

Source: MainStream Economics and Policy

Key findings

- Any displacement of fishing to substitute grounds will result in an increase in variable costs for commercial fishing vessels (wages and fuel), while revenues would remain constant.
- Even limited displacement can have significant impacts on the profitability of vessels.

Contraction in the commercial fishing sector

Where permanent direct or indirect damage to fishing grounds occur (e.g. reduced take per catch effort, loss of habitat, negative impacts on food web, loss of market access etc.), there will be a contraction of the sector.

The likelihood and scale of any potential contraction are not known. Therefore, we have modelled a number of hypothetical scenarios to better understand the costs of an industry contraction, specifically the impact of reductions in catch rates (1%, 5%, 10%). Results of the modelling are shown in the table below.

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[34] During the period December 2015 to February 2016, the average diesel price in Fiji was FJD 1.54. http://www.globalpetrolprices.com/Fiji/diesel_prices/

Table 8: Sector-wide impacts of reductions in catch rates

Economic variable	Current estimates	Reduction in catch rates		
		1%	5%	10%
Economic estimates (FJD per annum)				
Gross output	88,964,966	88,075,316	84,516,718	80,068,469
Intermediate consumption (business inputs)	58,976,605	58,976,605	58,976,605	58,976,605
Value added	29,988,361	29,098,711	25,540,113	21,091,864
Wages and salaries	6,409,072	6,409,072	6,409,072	6,409,072
Consumption of fixed capital	2,668,949	2,668,949	2,668,949	2,668,949
Operating surplus/plus	20,910,340	20,020,690	16,462,092	12,013,843
% changes in key economic indicators				
% change in value added		-3%	-15%	-30%
% change in operating surplus/profit		-4%	-21%	-43%

Source: MainStream Economics and Policy

The key points to note include:

- While reductions in catch rates reduce revenues, it isn't necessarily possible to reduce costs to offset reductions in revenue because many costs are effectively fixed.
- The greatest impacts will occur on value added and operating surplus/profit.
- Even small reductions in catch rates can have large impacts on value added and operating surplus/profits. For example, a 5% reduction in catch rates would result in a 15% fall in value added and a 21% reduction in operating surplus/profit for the fishing industry.
- Recent declines in the national catch volumes for Fiji have resulted in a number of vessels moving to overseas fisheries. This has had a negative impact on direct and indirect economic activity and employment in the sector. Any further declines in catch rates attributable to damage from DSM would have similar impacts.

Key findings

- Any declines in catch rates attributable to DSM would result in reductions in industry revenue, without opportunities to offset these losses through reducing costs.
- Even small reductions in catch rates can have large impacts on value added and operating surplus/profits, and ultimately, the commercial viability of some commercial fishing operators.

4.4 Other ecosystem services

The deep-sea marine environment provides an array of ecosystem functions, goods and services, many of which contribute significantly to human wellbeing. The deep sea and the deep marine floor form an extensive and complex system that is linked to the rest of the planet in exchanges of matter, energy and biodiversity, and the functioning of deep sea ecosystems is crucial to global biogeochemical cycles.[35]

There are a number of sources of damage to the sea floor from DSM activates, primarily:[36]

- Those relating to the seafloor mining tool, specifically direct damage and increased sediment from the movement of the tool along the seafloor and the ore cutting/drilling activities. In addition re-sedimentation, and smothering of the sea floor is also likely to occur. This

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[35] Armstrong, Claire W., et al. (2010). 'Ecosystem goods and services of the deep sea.' *Deliverable* D6 2: 68.

[36] Naultilus Minerals Inc. 2010. Solwara 1 Project. Environmental Impact Statement

damage is effectively permanent and may eliminate the bulk of the ecosystem services in the area directly impacted.

- Damage from the side casting of waste materials that are below mine-grade cut off. This waste is dumped adjacent to mine sites. This activity is likely to severely diminish any ecosystem services from this area.
- Any risks associated with return water plumes via the subsea slurry pump (typically discharged 25-50 metres above the sea floor). Discharges from dewatering and slurry will have impacts on benthic organisms and potential water column effects with increased turbidity, smothering, and the potential for the discharge of contaminants into very sensitive receiving environments. Where concentrations exceed the assimilative capacity of the ecosystem, ecosystem functions and subsequent ecosystem services will be impacted.[37] The damage attributable to this activity will be highly reliant on the concentrations and accumulation from plumes of discharge.
- Damage from spills and accidents on the surface around the barges and support vehicles etc.

Despite these multiple sources of risk, their impact on ecosystem services is poorly understood, and a precautionary approach to DSM activities would be prudent.[38]

Key findings

- DSM operations create multiple threats to sea floor ecosystem services, lower water column/pelagic zones, and potentially to surface waters from the risk of spills.
- These risks and their impact on ecosystem services are poorly understood and a precautionary approach would be prudent.

4.4.1 The potential cost of damage to ecosystem services

A benefit transfer approach has been used to assess the potential cost of damage to ecosystem services attributable to DSM. An overview of benefit transfer and other relevant valuation approaches is provided in Appendix A.

Remarkably little, however, is known in quantitative terms about the economic flow of values from the deep-sea environment compared to terrestrial ecosystems or coral reefs. As noted by Nunes and Ghermandi,[39] only 34 of the 1,310 estimates of monetary values of ecosystem services that are included in the Economics of Ecosystems and Biodiversity Ecosystem Services Valuation Database[40] pertain to the marine environment and open oceans. In a recent study seeking to value the deep sea, Jobstovgt et al.[41] acknowledge a dearth of empirical studies that quantify the non-market benefits of protecting deep-sea areas. In the most comprehensive assessment of the ecosystem goods and services provided by the deep-sea marine environment undertaken to date, Armstrong et al.[42] note a lack of evidence on monetary values of deep-sea ecosystem services and biodiversity as one a fundamental research gap.

As part of this project we undertook an extensive review of the existing literature into the valuation of deep-sea ecosystem services. This review identified 38 relevant studies (see reference list). A systematic literature review and meta-analysis of deep-sea valuations is currently being undertaken by the report's authors in collaboration with academics from Griffith

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[37] We are not aware of any peer reviewed research to estimate the assimilative capacity of the marine environment relating to proposed DSM in Fiji.

[38] Clark, M. 2013. Oceanic and deep-sea fishery resources of the Pacific: the potential impacts of Deep Sea Mining. Bertram, I. 2013. Socio Economic Impacts of resource Extraction.

[39] Nunes, Paulo ALD, and Andrea Ghermandi. (2013). 'The Economics of Marine Ecosystems: Reconciling Use and Conservation of Coastal and Marine Systems and the Underlying Natural Capital.' *Environmental and Resource Economics* (2013): 1–7

[40] See: http://www.teebweb.org/.

[41] Jobstvogt, N., Hanley, N., Hynes, S., Kenter, J., & Witte, U. (2014). 'Twenty thousand sterling under the sea: Estimating the value of protecting deep-sea biodiversity.' *Ecological Economics*, 97: 10–19.

[42] Armstrong, Claire W., et al. (2010). 'Ecosystem goods and services of the deep sea.' *Deliverable* D6 2: 68.

University and The Australian National University. This analysis, however, was not complete at the time of writing this report.

In one of only two studies to explicitly attempt to place a monetary value on the loss of ecosystem services from deep sea mining (in this case the Solwara 1 project off the coast of Papua New Guinea), Batker and Schmidt[43] employ terrestrial values to provide an estimate of the value of the seabed. In particular, they employ terrestrial values identified for cloud forests in the Intag region of Ecuador. They justify this decision on the basis that "…there are no existing studies that have established the economic value of deep seabed natural capital goods and services" (p. 80) and that the Intag region is a unique and sensitive ecosystem with similar qualities to the seabed off Papua New Guinea. The reported net present value of the ecosystem impacts in 2014 US dollars is $605,871. The authors note that their approach "…assumes that the deep seabed is at least as valuable as cloud forests in terms of biological control, habitat & nursery, and genetic resources. As cloud forests are some of the most productive and biodiverse ecosystems on the planet, this represents a highly cautious and "conservative" approach to valuation of Solwara 1 impacts, and is more likely to result in an overestimate of impacts than an underestimate" (p.81). It should be noted that this work has been questioned as the substitute environmental asset used for value transfer (cloud forests) is not comparable at all, and no attempt was taken to assess remediation/restoration values for marine assets as a meaningful comparator.

In addition to the questionable application of terrestrial values from Ecuador to the deep sea off the coast of Papua New Guinea, there are a number of reasons to doubt the veracity of the monetary estimates contained in this report:

- Despite identifying ten ecosystem services that are present in the seabed, monetary values are only attributed to three: (1) biological control, valued at USD 26 per hectare per year; (2) habitat & nursery, valued at USD 1,464 per hectare per year; and (3) genetic resources, valued at USD 277 per hectare per year.
- The estimated area of impact is limited to the direct footprint of the mine area (14 hectares) and, therefore, does not include the area affected by the plume from side casting and return water plumes.
- A discount rate of 4% is employed. As outlined in Appendix B, a more appropriate discount rate is 3.05%.
- The impacts are values over 100 years rather than in perpetuity. Adjusting Batker and Schmidt's calculations to address points three and four only would increase the net present value of the ecosystem impacts by over 30% (to $810,623).

The second study seeking to explicitly place a monetary value on the loss of ecosystem services from DSM is produced by Cardno.[44] In this report (again in the context of the Solwara 1 project off the coast of Papua New Guinea) the authors employ a replacement cost approach that relies on Habitat Equivalency Analysis (HEA). The basic premise underlying HEA is that all of the services flowing from a habitat can be treated as a single composite ecological service. If an action results in a reduction in the quantity of the composite ecological service produced by the impacted habitat, the public can be compensated via a restoration project that creates composite ecological service at some other site (i.e. an offset). The cost of implementing the restoration project is the service replacement cost.

The HEA metric employed by Cardno is the Discounted Service Acre Years (DSAYs) where one Service Acre Year represents a composite measure of all of the services flowing over the course of one year from one acre of the habitat. The chosen discount rate is 7%.

DSM activity is assumed to result in an initial service loss of 85% within the mining footprint. This results in the expected loss of services of 367 deep-sea vent DSAYs. Employing equivalency

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[43] Batker, D. and Schmidt, R. (2015). 'Environmental and social benchmarking analysis of the Nautilus Minerals Inc. Solwara 1 Project', Earth Economics, Tacoma, Washington.
[44] Cardno, (2016). 'An Assessment of the Costs and Benefits of Mining Deep-sea Minerals in the Pacific Island Region: DSM Cost-Benefit Analysis / Pacific Community', SPC Technical Report SPC00035.

ratios from Peterson et al.[45] the authors calculate that the loss could be offset by the creation of 40 wetland DSAYs. The estimated cost of creating these (and hence the estimated monetary value of the loss of ecosystem services from the deep sea mine) is $454,000 (2016 USD).

In the absence of a study based on primary data collection from the region surrounding the proposed deep sea mining site(s) in Fiji, our preferred approach is to rely on ecosystem service valuation estimates put forward by de Groot et al.[46] In this paper, the authors classify and value ecosystem services according to the Millennium Ecosystem Assessment framework.[47]

Adapting the estimates of de Groot et al. for the deep-sea ecosystem potentially affected by the development of DSM in Fiji, and excluding food and tourism to avoid double counting, yields a total economic value of FJD 162 per hectare per annum. This figure excludes tourism and fisheries values as they are accounted for in Sections 4.2 and 4.3. This is shown in the table below.

Table 9: Deep sea annual ecosystem service values

Service type	Service	Reported value (Int.$/ha/year, 2007 price levels)	2016 FJD
Provisioning			
	Food	Assessed elsewhere	Assessed elsewhere
	Raw materials	8	17
Regulating			
	Climate regulation	65	135
Habitat			
	Genetic diversity	5	10
Cultural services			
	Recreation	Assessed elsewhere	Assessed elsewhere
Total economic value		**78**	**162**

Source: MainStream estimates based on de Groot et al. 2012[48]

Because this value is highly uncertain, in our analysis we have also run estimates of damage based on a cost per area +/- 50% of the value from de Groot. The costs will also be dependent on the area of the sea floor impacted by the mining activities (area mined, sidecast area and plume area). Effectively the bulk of ecosystems will be lost in perpetuity from areas directly mined and the sidecast area, while areas impacted by plumes only may recover in the very long-run (depending on location specific circumstances).

Very little is understood of the real area impacted and this would be highly dependent on the scale of operations. The best available guide to scale is the recent EIS for the Solwara 1 project in PNG, as this represents the impacts of a typical single operation (sea floor and surface). That project is likely to directly mine an area of approximately 14 ha per annum (excluding sidecast and plume damage).[49] In the absence of any specific information of the area impacted by a DSM operation, we have a assumed a minimum area of 14 ha per annum (based on Solwara 1), and a maximum area of 28 ha to allow for damage from the sidecast and plume damage. We have

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[45] Peterson, C.H., M. Wong, M.F. Piehler, J.H. Grabowski, R.R. Twilley, and M.S. Fonseca. 2007. 'Estuarine habitat productivity ratios at multiple trophic levels' Final Report to NOAA Office of Response and Restoration, Assessment and Restoration Division, Silver Spring, MD.

[46] de Groot, R., Brander, L., van der Ploega, S., Costanza, R., Bernardd, F., Braat, L., van Beukering, P. (2012). 'Global estimates of the value of ecosystems and their services in monetary units.' *Ecosystem Services*, 1, 50–61.

[47] Millennium Assessment (2005). 'Ecosystems and human well-being: Current state and trends.' *Millennium Ecosystem Assessment*, vol. 1. Island Press, Washington DC.

[48] de Groot, Rudolf, et al. (2012). 'Global estimates of the value of ecosystems and their services in monetary units.' *Ecosystem Services* 1.1 (2012): 50–61.

[49] Naultilus Minerals Inc. 2010. Solwara 1 Project. Environmental Impact Statement

also assumed that the damage is permanent, and therefore it is appropriate to capitalise this figure in perpetuity. Therefore, we estimate that for each DSM operation of a similar scale to the Solwara 1, it is likely to cause annual damage to ecosystem services (excluding tourism and fishing) of between FJD 37,200 to 223,200 as shown in the table below.

Table 10: Deep-sea ecosystem service values lost from a single DSM operation (losses per year of operations)

Value estimate	Low	More likely	High
Area lost (ha)	14	21	28
Value per ha pa (FJD)	81	162	243
Discount rate	3.05%	3.05%	3.05%
Total economic cost per year of operation	$37,200	$111,600	$223,200

Source: MainStream estimates based on de Groot et al. 2012[50]

Whilst these estimates are relatively modest, they do represent residual damage after all avoidance and mitigation actions are undertaken. Furthermore, the costs will accumulate for the period the DSM operations are being undertaken in Fijian waters. For example, if a DSM operation is continues for a period of 30 years over multiple sites the cost of the ocean bed ecosystem services lost could be as high as FJD 6.7 million.

There are also potential costs to ecosystem services associated with unplanned releases on the surface (e.g. fuel spills). Cardno (2016) has developed estimates of both the probability and potential severity of these risks.[51] These risks are valued at around FJD 40,100 per annum for the life of the DSM operations, or around FJD 1.2 million over a 30-year operation.

Key findings

- There is a significant lack of information and data available to establish robust estimates of the value of ecosystem services lost attributable to DSM operations.
- The cost to ocean floor ecosystem services (excluding tourism and fishing) from a single DSM operation is potentially in the range of FJD 37,200 to FJD 223,200 per annum (or up to FJD 6.7 million over 30 years).
- The value of the risk to surface ecosystem services (excluding tourism and fishing) from a single DSM operation is potentially around 40,100 per annum (or FJD 1.2 million over 30 years).
- These estimates are based on very limited number of studies undertaken elsewhere and their reliability to inform decision-making is limited.

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[50] de Groot, Rudolf, et al. (2012). ‘Global estimates of the value of ecosystems and their services in monetary units.’ *Ecosystem Services* 1.1 (2012): 50–61.

[51] Cardno, (2016). ‘An Assessment of the Costs and Benefits of Mining Deep-sea Minerals in the Pacific Island Region: DSM Cost-Benefit Analysis / Pacific Community’, SPC Technical Report SPC00035.

5 Looking forward

This section is designed to provide insight into future policy, planning and management considerations of DSM in Fiji.

5.1 Benefits vs. costs

As outlined in Section 3 of this report, the economic benefits of DSM are potentially significant, but primarily accrue to DSM operators and owners. These entities are largely foreigners. The benefits to the Fijian economy through the provision of upstream and downstream inputs and services to DSM operations are likely to be negligible due to the high levels of technology employed, the high propensity for inputs to be imported, and the fact that processing will be undertaken overseas. The high technology levels employed in DSM also mean that employment opportunities for Fijian nationals are likely to be limited.

Depending on the profitability of DSM operations and the financial structures of financial arrangements for DSM operations, there could be significant taxation revenue from DSM accruing to the Fijian Government. Similarly, mining royalties could be significant, but they are highly reliant on the royalty regimes and the calculation methodologies employed.

The costs of DSM largely relate to the residual risks to ecosystem services that are not managed through the management of DSM operations. The costs will be dominated by:

- Impacts to tourism activity, incomes and employment related to any loss of Fiji's share of international marine-based tourism activity. These impacts are largely unknown, but could be very significant.
- Impacts on the fishing sector (primarily commercial tuna fisheries) due to either negative impacts on the food web and ultimately fish production, and though higher catch costs (where commercial operators may have to travel further to access substitute fishing grounds).
- Any losses of other ecosystem services, particularly on the ocean floor.

It should be noted that the extent and value of both the benefits and costs of DSM in Fiji are still largely unknown.

Ultimately for Fiji, any decision to proceed with DSM becomes an assessment of the trade-offs between any tax and royalty revenues (accruing to the central government) versus the costs to regions where DSM is actually occurring (potentially reduced tourism, fisheries, and the loss of other ecosystem services).

Key findings

- It should be noted that the extent and value of both the benefits and costs of DSM in Fiji are still largely unknown. Benefits will largely be in the form of additional tax and royalties revenues, while costs will occur at a local level to tourism, fisheries, and deep-sea ecosystem services.
- Ultimately for Fiji, any decision to proceed with DSM becomes an assessment of the trade-offs between tax and royalty revenue, and the cost to the tourism, fishing and other ecosystem services.
- Uncertainty of both the benefits and costs of DSM to Fiji would suggest a measured and cautious approach to the development of the sector is prudent.

5.2 Knowledge and information gaps

In undertaking this study, it has become very apparent that there are significant knowledge and information gaps relating to DSM in general[52] and virtually no specific information and knowledge

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[52] ECORYS. 2014. Study to investigate the state of knowledge of DSM Final Report under FWC MARE/2012/06 - SC E1/2013/04

to underpin robust decision-making and policy development in Fiji. This infers a precautionary approach is warranted. *"The significant risks and uncertainties surrounding deep seabed mining implicate strict application of the precautionary principle. Little is known about seafloor mining technology, its efficacy, safety, and the impacts that may arise from the process. In addition, the deep-sea environment is a unique and diverse realm that has not been extensively researched and is not well understood. Both of these uncertainties warrant unprecedented caution and attention before proceeding with full-scale development of deep seabed mining."* (Mitchell. 2012. P4)[53]

The information and knowledge gaps generally fall into four broad categories:

- The relatively poor understanding of physical risks.
- Virtually no understanding of relationships between physical risks and economic consequences.
- The likely direct and indirect value of economic consequences.
- Efficient and equitable mechanisms to distribute the benefits of DSM.

The table below summarises some of the key knowledge and information gaps, the consequences of those gaps, and potential actions to address those gaps. It should be noted that while much of the work recommended below could be undertaken concurrently, finalisation of some actions would require some sequencing. For example, the robust evaluation of economic consequences of DSM could not be finalised until the physical risks of DSM and the relationships between physical risks and broad economic consequences are first understood.

It would be prudent to support and work with the research community, industry and governments at all levels to address these uncertainties in the short to medium term.[54]

Key findings

- There are multiple gaps in information and knowledge that constrain Fiji's ability to make informed policy decisions on DSM issues.
- It would be prudent to address these gaps in the short to medium term to ensure Fiji has a sufficiently robust scientific evidence base to underpin informed policy decision-making.

Table 11: Key knowledge and information gaps

Knowledge or information gap	Implications of gap	Potential actions to address gap
Understanding of physical risks. The body of knowledge relating to the physical risks of DSM to the marine environment is relatively limited, particularly relationships between DSM and: food webs, fish abundance, water quality, coral extent and condition, and other deep-sea ecosystem functions.	This lack of understanding inhibits the ability to develop appropriate policies and a lack of information may result in DSM occurring in high-risk locations.	Support the continuation of basic research to understand the physical impacts of DSM. Develop spatial risk assessments (likelihood, consequence, risk) to identify the relative risk of alternative DSM sites. This could be based on key parameters such as depth, fish abundance, distance to communities and coastal fishing, distance to reefs and tourism spots, oceanography, gradient of seamount etc. This information would be used to establish areas where DSM was not appropriate, establish areas of relatively high risk where additional risk management is appropriate, and areas where the risks are relatively lower.

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[53] Mitchell., E. 2012. Legal Opinion on the Application of the Precautionary Principle to Deep Seabed Mining in the Pacific Region. U.S. Office, Environmental Law Alliance Worldwide (ELAW). August 2012

[54] It should be noted that there is already formal research and policy development activities underway (e.g. SPC's work).

Knowledge or information gap	Implications of gap	Potential actions to address gap
Understanding of relationships between physical risks and economic consequences. Overall, knowledge on deep-sea ecosystem processes and connectivity to economic values is insufficient and fragmented.	Unless these relationships are understood, it is not possible to develop robust measures of the benefits and costs of DSM, and the effectiveness of alternative management options.	Building on studies of the physical impacts of DSM, three key areas of study are probably necessary: 1. Tourism. This would require use of approaches such as contingent behavior surveys to understand and quantify the relationships between the risk of DSM and tourists behavior (e.g. visitor numbers and activities). 2. Fishing. This would require the development and use of regional bio-economic models of key fisheries to understand the relationships between changes in the ecosystem and fisheries (e.g. catch rates). 3. Other ecosystem services. Establish broad quantitative estimates of relationships between damage from DSM and other key ecosystem services (e.g. carbon abatement).
Value of economic consequences is poorly understood. Robust economic values for the tourism and fisheries sectors are generally not available, particularly at smaller geographic scales relevant to DSM policy making.	Inconsistencies and unavailability of data means benefits and costs of DSM cannot be adequately evaluated. This creates the risk of poorly informed policy development.	Building on existing data, work with the Fijian tourism and fisheries department to establish more regionally relevant datasets of visitation, gross expenditure, fishing production etc. Expand and improve surveys of the tourism and fishing operators and develop industry-specific economic impact models. Run models and use results to inform future policies relevant to DSM.[55]
Distribution of the benefits. The value of benefits (local inputs, taxes, royalties etc.) and their distribution across the Fijian community are largely unknown.	The establishment of royalties policies will have a significant impact on the overall level of benefits captured by Fiji, while the distribution of benefits is vital as many of the risks are relatively localised.	Support and build on current work being led by SPC relating to appropriate royalties regimes. Develop a better understanding of the distribution of benefits, and ways to ensure local communities that face the risks of DSM developments, also receive a reasonable share of the benefits.

Source: MainStream

5.3 Policy recommendations

While there is a major emphasis on developing robust policies relating to DSM management in the Pacific, we believe the key areas requiring more robust policy approaches are:

- A highly precautionary approach to risk mitigation. Where risk mitigation cannot be demonstrated to an acceptable level using robust, peer-reviewed and transparent science-based information, the DSM activities should not be undertaken.
- Ensuring that the economic benefits from DSM are shared appropriately with the Fijian Government and community (as legal custodians of the resources).

These are outlined below.

5.3.1 Risk mitigation

The potential costs of DSM to Fiji are highly reliant on the risks to key ecosystem services. The risk mitigation hierarchy could inform the development of any policy and planning for future DSM activities.

The hierarchical mitigation approach, as outlined in the figure below, is widely regarded as general best practice for managing social and environmental impacts. First introduced by

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[55] Note: These models would build

Mitchell,[56] the mitigation hierarchy has subsequently been adopted by the United Nations and a formal application of the mitigation hierarchy is now required by law in many jurisdictions.[57]

Figure 10: The risk mitigation hierarchy

Source: Adapted from PricewaterhouseCoopers, 2010.

According to the mitigation hierarchy, efforts should first be made to prevent or avoid impacts, then efforts should be made to minimise and reduce impacts, and finally efforts should be made to repair or restore adverse effects. After these steps have been taken, any significant residual effects should be addressed via an environmental offset. If an offset is not possible, which is highly likely in the case of DSM, compensation is required. Note that compensation is the least desirable approach and should only be considered after the other elements have been completed. Throughout our analysis for this project we have identified a number of practical risk mitigation policies, plans and actions consistent with the mitigation hierarchy that could be undertaken. These are outlined in the table below, including the potential impacts on DSM investments and operations. It should be noted that this analysis is far from comprehensive.

Table 12: Potential risk mitigation interventions (policies, plans and actions)

Risk mitigation intervention	Reduces which risk?	Potential impact on DSM operations
Location choice. Avoiding / reduce material risks to tourism and fishing through restricting locations of DSM exploration and activities to areas where risk are negligible. This would infer restricting activities closer to the Great Sea Reef, known fisheries, deposits in shallower waters, and closer to coral reef systems and land forms.	This will significantly reduce the indirect risk to tourism (perceived damage to key sites), fisheries (lower likelihood of damage to food web), and damage to other economic activity from surface discharges (spills). This action would still result in residual damage to some ecosystem services.	This would restrict the area of potential DSM activity and potential number of sites. There may be some marginally higher variable costs to operators (e.g. fuel) where available DSM sites are more remote from supplies and/or downstream processing facilities.

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[56] Mitchell, J., 1997. *Mitigation in environmental assessment — furthering best practice*. Environmental Assessment 5, 28-29.

[57] PricewaterhouseCoopers, 2010. *Biodiversity offsets and the mitigation hierarchy: A review of current application in the banking sector*, a study completed on behalf of the Business and Biodiversity Offsets Programme and the UNEP Finance Initiative.

Risk mitigation intervention	Reduces which risk?	Potential impact on DSM operations
Strict environmental conditions. Reduce risks via maintaining strict environmental conditions imposed on DSM operators. For example: return discharge must be as close as practicable to sea floor to avoid plume spread; operators must have emergency spill plans and procedures etc.[58]	This reduces the risks to ecosystem services in situ.	These costs are part of any commercial mining enterprise and would not result in a project being non-viable unless the environmental risk and associated management costs were extremely significant (i.e. the location was inappropriate).
Performance and site rehabilitation bonds and insurances. Ensure damaged sites can be restored/repaired as much as practicable through the requirements for site rehabilitation and performance bonds. These funds would be held by a reputable third party to be used for rehabilitation and repair works only.	Reduces the scale and magnitude of residual risks to ecosystem services after sites have been mined. Reduces risk that resources are not available for rehabilitation and repair work after mining has ceased.	These requirements and instruments are common for terrestrial mining activities and form a typical cost of operations. However, restoration is virtually impossible in deep-sea environments.
Offsets where possible. After risks have been avoided, reduced, repair has occurred, but residual risk and damage remains, consideration should be given to the feasibility of offsetting residual damage. For example, if DSM operations cause damage to some fish breeding sites, enhancement of alternative fish breeding habitat could be used as an offset.	This should only apply to residual risk and damage.	Offsets are becoming increasingly common for terrestrial mining activities, usually as part of a broader suite of actions to reduce risks and damage from mining operations. The use of offsets can provide opportunities for more effective means to achieve required environmental obligations. However, their applicability in the case of deep-sea projects may be very limited (if at all).
Compensation. Where risks and associated costs cannot be entirely eliminated (e.g. residual loss of fisheries or tourism), it would be appropriate to compensate local communities impacted.	Residual risks and associated costs.	Compensation for losses is common in many Pacific nations for terrestrial mining activities. Note: Compensation should be treated and calculated separately from any sharing of economic returns via taxation on profits or royalties.
Transparent environmental monitoring, evaluation and reporting. Comprehensive monitoring, evaluation and reporting arrangements should be put in place for both for DSM direct impacts (e.g. damage to sea floor) and indirectly impacted sectors (e.g. tourism).	This ensures risks and costs are better understood (including indirect risks and costs) and that more efficient mitigation actions can be undertaken to address risks.	These actions are commonplace with best practice terrestrial mining. However, monitoring indirect impacts is often not done well due to the additional complexities of identifying and quantifying causal linkages.
Research. Continue to actively participate and encourage research into the impacts of DSM, and the benefits, risks and costs of DSM (including their distribution). Current research initiatives under the SPC – EU Deep Sea Minerals Project may provide baselines for further research.	The risks of DSM are relatively poorly understood. Research will enhance our understanding of risks and our ability to effectively and efficiently manage those risks.	It would be appropriate for DSM companies to actively participate in research through the provision of information to underpin assessments and monitoring. A research levy to fund priority research may also be appropriate.[59]

Source: MainStream analysis

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[58] Note the environmental impact statement and associated risk management activities for the Solwara 1 DSM operation in PNG provide insight into what is practicable.

[59] Research levies are common in many industries in developing countries. However, this initiative is most successful where the research priorities are independently established.

If *all* of these interventions can be implemented, the adverse risks and costs of DSM to Fiji could be significantly reduced.

It is also prudent to ensure there are specific “stop points” within the decision-making process where a DSM project can be stopped where it is clear risks cannot be mitigated or are unacceptable. These decisions should be made *before* the project commences, not as part of an adaptive environmental management regime.

Key findings

- There are multiple interventions that could be adopted to significantly mitigate the risks of DSM operations to the Fijian economy and community.
- The risk mitigation hierarchy provides a meaningful way to manage risks.
- Even after mitigation, there will be situations where the risks are not acceptable, and the DSM project should not proceed.

5.3.2 Sharing the economic benefits of DSM

As discussed in Section 3 of this report, the bulk of the benefits associated with the production and use of materials from DSM accrue to foreign nationals (e.g. shareholders of mining companies). However, the risks and costs outlined in Section 4 will be borne by regional Fijian communities. Therefore the importance of establishing robust and efficient taxation and royalty regimes is very high to ensure the Fijian community share in the benefits from DSM. There are generally four approaches to established royalties regimes:

- Ad valorem based on a % of the production value (e.g. 2%).
- Commodity specific based on a fixed charge per unit (e.g. FJD/tonne).
- Profit-based / resource rent based on a % of net income or economic rent.
- Price-based, based on both a production value and a commodity price scale (higher commodity prices have higher rates).

Establishing robust royalty regimes could be more complex for DSM than typical mining operations as processing (and detailed measurement of valuable minerals etc. extracted) occurs overseas. In this absence of a simple auditable measurement of resources, proxies may need to be established as the basis for calculating royalties.

None of these royalty approaches is universally superior and should not be considered in isolation from other forms of government revenue including corporate taxes, any duties on imported inputs, and potentially any bonus paid by the developer on receipt of the production approval.[60]

Different approaches are more relevant to different parts of the production cycle and become more relevant under different levels of profitability. It should also be noted that the costs of designing and administrating some royalties regimes are higher (e.g. resource rent royalties) and the tradeoffs between the efficiency of the royalty regime and administration costs need to be assessed.

A stylised government revenue profile is shown in the figure below showing when and how the different sources of revenue may apply.

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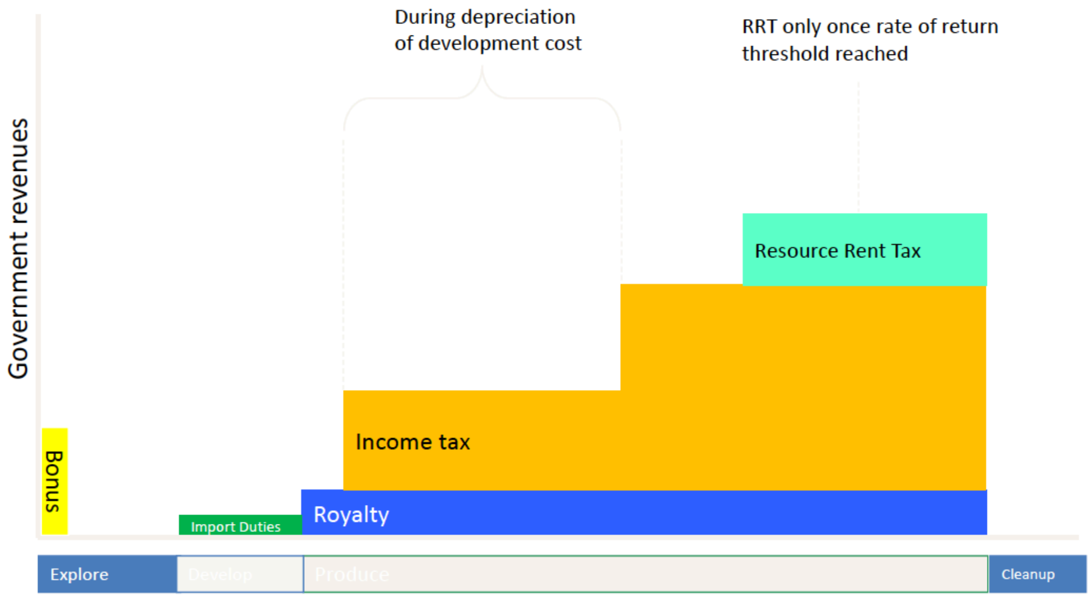
[60] Burns., L. 2014. Legislative Design of the Fiscal Regime for Seabed Mining

Figure 11: Stylised government revenue profile



Source: Mullins., P. 2014. Designing a Fiscal Regime for Deep Sea Mining

Significant work will be required in the short to medium term to develop a cohesive suite of revenue policies for DSM, particularly the royalties regime. This should build on the work already underway trough programs such as the SPC-EU Deep Sea Minerals Project and work underway by the International Seabed Authority. It would be prudent to ensure both a basic royalties regime is in place as well as a resource rent tax (applied to excessive profits).

In addition to the careful design of revenue policies, the distribution of those revenues across the Fijian community via the provision of services and infrastructure will also be important. This is particularly considering some regions will bear the bulk of the economic risks from DSM and may (reasonably) expect a share of the benefits accrue to that regional also. This will be extremely important to ensure community acceptance of DSM.

Key findings

- Significant work will be required in the short to medium term to develop a cohesive suite of revenue policies for DSM, particularly the royalties regime.
- Consideration will also need to be made to ensure regions that will bear the bulk of the economic risks from DSM receive a share of the benefits.

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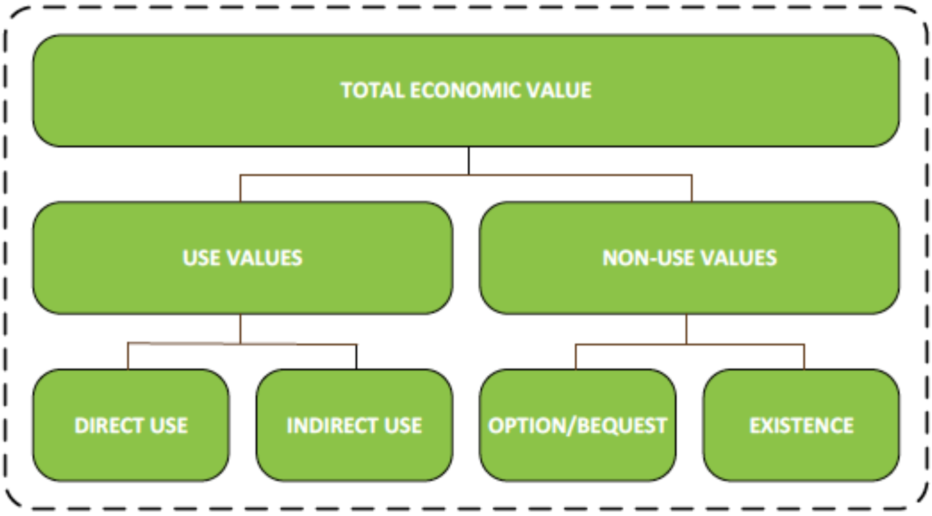
Appendix A – Economic valuation techniques

Normally a Total Economic Valuation framework would be used to establish comprehensive estimates of the costs of DSM in Fiji (see figure below). This ensures that both obvious values (e.g. direct use values like fishing production) and non-use values (e.g. existence values such as waterway health) are incorporated as much as practicable.

Figure A1: A simple representation of the Total Economic Valuation framework



Valuation techniques and sources of data

When seeking to estimate monetary costs and (particularly) benefits of a proposal, a number of possible valuation techniques can be used depending on the assessment method, as well as data and resource constraints. The techniques are generally separated into market price methods (where values are revealed through market transactions) and non-market valuation (where a suite of approaches can be used to estimate economic values that are not revealed through market transactions).

A key challenge for this project has been to identify, scope and estimate the economic value of different types of impacts using the most appropriate technique, and within the project's data and resource constraints. Different approaches to economic valuation are shown in the table below.

Table A1: Alternative economic valuation approaches

Method	Based on…	Useful for…
Market-based techniques		
Market values	Actual market transactions	Where there are established markets (e.g. tourism)
Productivity-based	Inputs to production of commercial goods	Changes in fishing productivity
Replacement cost	Costs of replacing a service or avoiding costs	Cost of protein replacement for fisheries lost

Method	Based on…	Useful for…
Non-market based techniques		
Hedonic pricing	Values of goods traded in related markets (e.g. housing)	The recreational and aesthetic value of improvements in inshore reef condition
Travel cost	Costs incurred in visiting a site	Valuing tourism, recreation, or cultural use of a site
Stated preference techniques (contingent valuation, choice modelling)	Surveys and community willingness to pay to protect an asset	The value of the existence of biodiversity and ecosystem functions

Box A1: Benefit transfer

Benefit transfer is a method of estimating the value of a change in an environmental good or service at a (target) site using information from an existing study (or studies) conducted at another (source) site. This approach is useful when a primary study for the target site is not possible due to time and/or budget constraints. It is important to note that benefit transfers can only be as accurate as the initial study (studies).

In practice, the benefit transfer method typically involves searching relevant empirical literature to identify existing studies that value effects similar to those in which the researcher is interested. For example, if estimating recreational fishing values are the objective of the study, values for recreational fishing at a particular target site may be estimated by applying measures of recreational fishing values from a study conducted in another (source) site (preferably one with similar characteristics).

Once a relevant study (or studies) has been identified, the researcher needs to apply the results found in the study to his/her economic analysis. In general, this can be done in one of two ways:

1. By applying a direct transfer of the unit value estimate from the existing study (studies); or
2. By using the functional form and parameter estimates presented in the existing study (studies), along with data representing the characteristics of the target site.

The first approach is the simpler of the two methods, however is heavily dependent on the comparability of the source and target sites. The second approach is more complex, but avoids many of the shortcomings associated with the first approach and is generally preferred if time and budget allow.

In this project we have primarily relied on a number of techniques, specifically:

- For tourism, we have developed scenarios and estimates based on existing market values and using a productivity-based approach, where changes in the condition of the marine environment attributable to DSM result in changes in the volume and value of tourism activity.
- For fishing a productivity-based approach is also used, drawing on existing market data and previous research.
- For other ecosystem services, we have used a benefit-transfer approach based on a review of approximately 38 studies. This study used a variety of non-market valuation techniques.

Appendix B: Choice of societal discount rate

A social discount rate reflects a society's relative valuation of today's wellbeing versus future well-being. Choosing an appropriate social discount rate is crucial for benefit-cost analysis (and other forms of project/policy/program evaluation) when the benefits and costs of the proposal are spread over multiple time periods. In essence, the purpose of the social discount rate is to place a present day value on costs and benefits that occur in the future. A relatively high social discount rate, by attaching less weight to benefits and costs that occur in the future, favours proposals with benefits occurring at earlier dates. In contrast, a relatively low social discount rate favours proposals with benefits occurring at later dates. Choice of social discount rate affects not only the *ex-ante* decision of whether a proposal should go ahead, but also the *ex-post* evaluation of its performance.[61]

Many of the environmental damages associated with deep sea mining are long lived and will, therefore, affect not only the current generation but many generations to come. In order to place a present-day value on the cost of environmental damages to future generations, it is necessary to choose an appropriate social discount rate. Following Ramsey,[62] a social discount rate can be expressed as follows:

$$r = \rho + \eta . g$$

Where r is the social discount rate, ρ is the pure rate of time preference, η is the elasticity of the marginal utility of consumption, and g is the growth rate of consumption per capita. There is some debate in the economic literature about the value of these parameters. This debate has received much attention in recent years due to the need to evaluate alternative climate change policies (climate change policies are somewhat unique in that they are expected to yield benefits and costs over multiple future generations).

In regards to the pure rate of time preference (ρ), the question is one of how much importance we should place on the welfare (or wellbeing) of future generations. A value of zero means that the welfare of future generations is treated equally to that of present generations, a positive value means that the welfare of future generations is reduced or 'discounted' compared to present generations. Many[63] argue that a pure rate of time preference that is close to zero is most appropriate, thus placing (almost) no discount on the welfare of people in the future just because today these people are young or not yet born. Values of ρ found in the literature range from 0.1 to 3%, with most values clustered around 1%.

The elasticity of the marginal utility of consumption (η) is a measure of society's concern for equity in income distribution. It is widely accepted that an additional dollar of income means less to the welfare of the rich than to that of the poor. If we assume that future generations will have higher incomes and wealth than current generations, it is reasonable to value future income at a lower rate than current income. As noted by Garnaut,[64] there are compelling arguments for using a value of 1.[65] In contrast, Dasgupta[66] argues that a value of 1 implies the distribution of wellbeing among people doesn't matter much and that a higher value should be used. Empirical estimates suggest values for η range from 1% to 2%. We have estimated a range of social discount rates based on values for η of 1, 1.5 and 2.

Predicting future per capita economic and consumption growth rates (g) is fraught with difficulty. In the absence of an alternative compelling argument, historical long-run trends are used as an

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[61] Asian Development Bank (2013). Cost-benefit analysis for development: A practical guide. Mandaluyong City, Philippines.

[62] Ramsey, F. (1928) A mathematical theory of saving, *Economic Journal*, 38: 543-559.

[63] See for example: Sen, A. (1961) On optimising the rate of saving, *Economic Journal*, 71: 479-496.

[64] Garnaut, R. (2008) The Garnaut Climate Change Review: Final Report, Cambridge University Press, Melbourne.

[65] This position is also supported by: Quiggin, J. (2008) Stern and his critics on discounting and climate change: An editorial essay, *Climatic Change*, 89: 195-205.

[66] Dasgupta, P. (2007). Commentary: The Stern Review's economics of climate change, *National Institute Economic Review*, 199: 4-7.

indicator of future growth prospects. The per capita average economic growth rate for Fiji between 1961 and 2013 (the longest verifiable time series available) was 1.5%.[67]

Using this approach we estimate the social discount rate to be between 1.75% and 4.35%, with a mid-range estimate of 3.05%. It is this range of discount rates that is used in the BCA.

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[67] The World Bank Group (2013) World Bank Development Indicators. Available: http://data.worldbank.org/country/fiji. Accessed 9 April 2015.