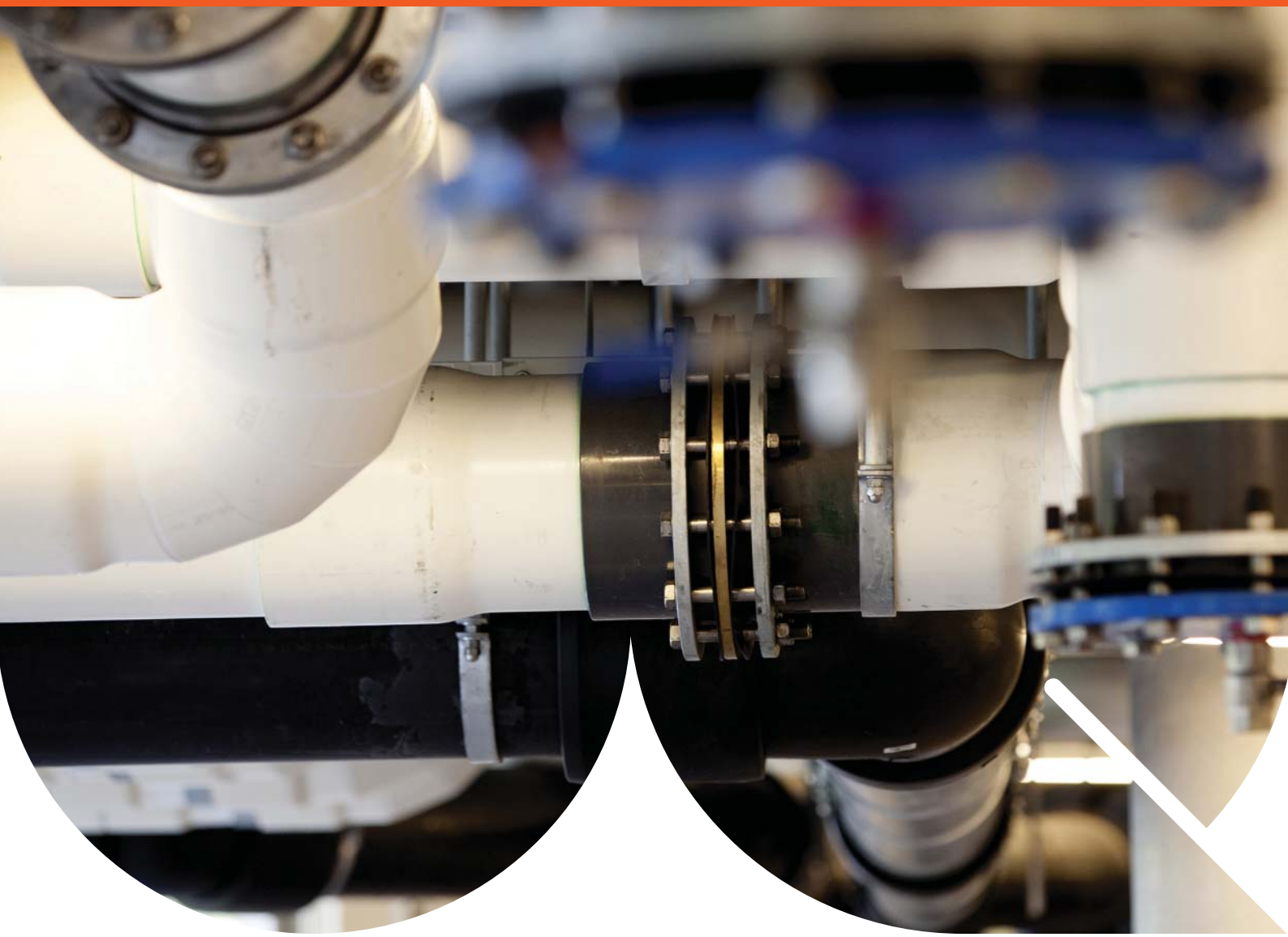

DEEP SEA BED MINING IN THE SOUTH PACIFIC

A background paper

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BACKGROUND PAPER

Deep Sea Bed Mining in the South Pacific

Dr Tina Hunter and Madeline Taylor

Given current interest in the area of deep-sea mining of mineral deposits, particularly with the Solwara 1 project undertaken by Nautilus Minerals off the coast of Papua New Guinea, this background paper provides basic information and an update regarding the minerals and the legal issues related to the extraction of deep sea minerals.[1]

1. Background and Context

Nautilus Minerals Inc. (Nautilus) is a sea floor mineral resource company, engaged in exploration for polymetallic seafloor massive sulphide deposits.[2] The company's primary project, Solwara 1 lies in the western Pacific Ocean near Papua New Guinea, and produces copper, gold and silver.[3] Nautilus Minerals plans to extract gold and copper from the bottom of the Bismarck Sea in PNG's Exclusive Economic Zone. The *Solwara 1* mine site is an estimated 50kms from Rabaul. Nautilus has secured or is in the process of applying for exploration rights to 534,000kms^2 of the sea floor in PNG, Tonga, the Solomon Islands, Fiji and New Zealand.[4]

Deep Sea Bed Mining has attracted criticism from activists of the DSM (deep-sea mining) Campaign who believe, according to The *Stockholm* and *Rio Declarations*, Free, Prior and Informed Consent, in adherence to the 'precautionary principle', should be imposed prior to the exportation and extraction of deep sea floor minerals.

According to Rosenbaum and Lowrey:

> On the deep sea floor, along chains of volcanic mountains lie thousands of hydrothermal vent formations. These are like underwater hot springs, spouting black clouds of metal sulphides. The foci of DSM are the deposits laid down over thousands of years around the hydrothermal vents. The metal sulphide particles settling around the vents develop into huge mounds. These are known as Sea-floor Massive Sulphides. They can grow to millions of tonnes in mass.[5] They are rich in zinc, copper, silver, gold, rare earths and other minerals.

[1] Disclaimer: This paper provides background information only. It is not intended to be a comprehensive consideration of all issues in relation to the activity, not to constitute legal advice.
[2] Helen Rosenbaum and Natalie Lowrey, 'Deep Sea Mining- The Pacific Experiment' (2013) < http://www.foe.org.au/chain-reaction/editions/117/deep-sea-mining>.
[3] The company's major shareholders include Metalloinvest, CIS, which Anglo American and MB Holdings. The company is headquartered in Toronto, Canada. The company's strategy has been to identify exploration activities and to secure licences for the development of the resources.
[4] Helen Rosenbaum and Natalie Lowrey, 'Deep Sea Mining- The Pacific Experiment' (2013) < http://www.foe.org.au/chain-reaction/editions/117/deep-sea-mining>.
[5] Helen Rosenbaum and Natalie Lowrey, 'Deep Sea Mining- The Pacific Experiment' (2013) < http://www.foe.org.au/chain-reaction/editions/117/deep-sea-mining>.

This background paper informs the debate on the management and regulation of DSM internationally, and specifically in relation to the PNG Solwara 1 project.

2. International and National Regulatory systems for Deep-Sea Mining

DSM is primarily regulated by the national legislation according to the jurisdiction where a proposed mining project is located within the exclusive economic zone or legal continental shelf of a country. Consequently, developing nations without strong environmental legislation and protocols, such as PNG, may witness irreversible environmental damage from DSM within their waters. The only DSM mining project governed by national legislation is the Nautilus Minerals project in PNG, governed by the *Mining Act* (1992) and *Environmental Act* (2000) respectively. The *Mining Act* (1992) states all minerals in PNG and PNG waters are owned by the national government and controls all exploration, processing and transport of minerals. According to section 6 of the *Environmental Act (2000)*, an Environmental Impact Statement to permit mining is required, 'with further conditions including installation of monitoring equipment, undertaking an environmental management program, baseline studies and a rehabilitation program'.[6] The *Mining Act* (1992) may grant third parties, such as Nautilus, the right to explore and produce minerals pursuant to the tenement system. The mining rights acquired by private parties upon the grant of a mining lease include the right to explore, which requires a prescribed minimum amount one exploration in the licence area, and develop resources once discovered. The *Mining Act* (1992) also gives preference to holders of exploration licences applying for mining licences in respect of the land the subject of an exploration licence.[7]

In New Zealand the *Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act (2012)*, has recently been passed which manages the DSM environmental effects beyond a 12 nautical mile limit. The Mineral Resources Authority, established in 2006 is the statutory authority to promote, manage and regulate the mining industry in PNG and makes recommendations to the minister in relation to grants and renewal of licences and related issues. The *Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act (2012)*, may provide a 'best practice' legislative example t for countries like PNG to regulate DSM. For example, *Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act (2012)* provides that in preparing the regulations, the minister must establish a public notification process, and take into account any comments received. The minister must also consider:

- Cumulative effects;

[6] P.C. Collins, P. Croot, C. Carlsson, A. Colaco, A. Grehan, K. Hyeong, R. Kennedy, C. Mohn, S. Smith, H. Yamamoto, A. Rowden. 'A primer for the environmental impact assessment of mining at seafloor massive sulfide deposits'(2013) *Mar. Policy*, 42, 198–209.

[7] Kim Liversley and Daniel Murnane, *PNG* (2014) < http://www.gadens.com.au/News/Documents/GTDT%20Mining%202013%20-%20Papua%20New%20Guinea.pdf>.

- The effects on the environment or existing interests of allowing an activity with or without a marine consent, including the effects that may occur in New Zealand or in the waters beyond the continental shelf;
- The effects on human health that may arise from effects on the environment;
- The importance of protecting the biological diversity and integrity of marine species, ecosystems and processes;
- The importance of protecting rare and vulnerable ecosystems and the habitats of threatened species;
- New Zealand's international obligations;
- The economic benefit to New Zealand of an activity; the efficient use and development of natural resources;
- The nature and effect of other marine management regimes;
- Best practice in relation to an industry or activity;
- The desirability of allowing the public to be heard in relation to an activity classified as a discretionary activity; and
- Any other relevant matter.[8]

All areas that do not fall under the Exclusive Economic Zones or legal continental shelf are beyond national jurisdiction regulation. The international regime for the deep seabed is governed by the *United Nations Convention on the Law of the Sea 1982,* which was renegotiated in 1994. The deep-sea bed area governed by the *United Nations Convention on the Law of the Sea 1982* prescribes the area and its resources[9] to be the common heritage of mankind,[10] to be used for peaceful purposes only.[11]

The renegotiation of the *United Nations Convention on the Law of the Sea 1982* led to the inauguration of the *International Seabed Authority* (ISA). Under the *United Nations Convention on the Law of the Sea 1982*, the 'Enterprise', acting on behalf of the ISA, must carry out its exploitation activities by joint ventures in accordance with 'sound commercial principles' and the provisions of the *Marrakesh Agreement 1994*. Pursuant to the Agreement relating to the Implementation of Part XI of the *United Nations Convention on the Law of the Sea of 10 December 1982 1994* Annex IV, 'the 'Enterprise' shall carry out exploration and exploitation activities on the seabed and ocean floor and subsoil beyond the limits of national jurisdiction, through joint ventures with national undertakings'. The ISA holds overall responsibility for the operation of the international regime and comprises of the following:

[8] *Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012*, ss 32, 33.
[9] *United Nations Convention on the Law of the Sea 1982* art 133 para (a) defines the resources as 'all solid, liquid or gaseous resources in situ in the Area at or beneath the seabed, including polymetallic nodules'.
[10] *United Nations Convention on the Law of the Sea 1982* arts 136 ('The Area and its resources are the common heritage of mankind'), 137 para 2 ('All rights in the resources of the Area are vested in mankind as a whole …'), 137 para 3 ('No state or natural or juridical person shall claim, acquire or exercise rights with respect to the minerals recovered from the area …').
[11] *United Nations Convention on the Law of the Sea* 1982 art 141.

(1) An Assembly (ibid Pt XI arts 159-160) comprising all parties to the Convention;

(2) A Council (ibid Pt XI arts 161-165) which comprises 36 members elected by the Assembly to represent various interest groups. It works through an Economic Planning Commission (ibid art 164); and

(3) A Legal and Technical Commission: ibid art 165.[12]

Dispute resolution provisions provide for the compulsory settlement of deep seabed disputes by either the *International Tribunal for the Law of the Sea*,[13] or through international commercial arbitration.

For parties adopting the *United Nations Convention on the Law of the Sea*, which includes Papua New Guinea,[14] the ISA regulations[15] govern the exploration and exploitation of DSM. According to sections 6 and 7 of the ISA regulations, Contractors must establish environmental baselines against which impacts from mining activities can be assessed, carry out environmental monitoring programmes, and take measures to prevent, reduce, and control pollution and other hazards to the marine environment.[16]

The ISA created general recommendations as a template for an EIS in an ISA workshop in 2011.Iit is expected that any EIS submitted to the ISA will 'substantially comply' with these recommendations. The template includes the following terms:

- A description of the offshore environment, including the biological environment;
- A description of the effects on individuals, communities, populations and meta-populations, within the pelagic, mid-water and benthic environments; and
- Developers must also submit an Environmental Management Plan, including sections on mitigation and management, monitoring, and reporting.[17]

Codes of conduct by the *InterRidge Statement of Commitment to Responsible Research Practices* and the *International Marine Minerals Society Code for Environmental*

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[12] LexisNexis, *Halsbury's Laws of Australia* (online) (2013) 'Deep Seabed'.

[13] United Nations Convention on the Law of the Sea 1982 arts 186-188.

[14] UN, *Status of the United Nations Convention on the Law of the Sea, of the Agreement relating to the implementation of Part XI of the Convention and of the Agreement for the implementation of the provisions of the Convention relating to the conservation and management of straddling fish stocks and highly migratory fish stocks* (2014) < http://www.un.org/depts/los/reference_files/status2010.pdf>.

[15] International Seabed Authority, *Mining Code* (2014) < http://www.isa.org.jm/en/mcode>:

> To date, the Authority has issued Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area (adopted 13 July 2000) which was later updated and adopted 25 July 2013; the Regulations on Prospecting and Exploration for Polymetallic Sulphides in the Area (adopted 7 May 2010) and the Regulations on Prospecting and Exploration for Cobalt-Rich Crusts (adopted 27 July 2012). These regulations include the forms necessary to apply for exploration rights as well as standard terms of exploration contracts.

[16] P.C. Collins, P. Croot, C. Carlsson, A. Colaco, A. Grehan, K. Hyeong, R. Kennedy, C. Mohn, S. Smith, H. Yamamoto, A. Rowden. 'A primer for the environmental impact assessment of mining at seafloor massive sulfide deposits'(2013) *Mar. Policy*, 42, 198–209.

[17] Boschen, R.E., Rowden, A.A., Clark, M.R., and Gardner, J.P.A., 'Mining of Deep-sea Seafloor Massive Sulfides: A Review of the Deposits, their Benthic Communities, Impacts from Mining, Regulatory Frameworks' (2013) 84 *Ocean and Coastal Management*, 54-67.

Management of Marine Mining (IMMS) also govern DSM activities at deposits. According to Collins et. al,:

> The InterRidge Statement acknowledges that scientific research can affect communities at hydrothermal vents and signatories agree to avoid activities that can impact the sustainability of vent communities or lead to long-term degradation of vent sites, including avoiding non-essential collections and transplanting material between sites.[18]

It is suggested by Hoaglang et. al, that the MMS may 'help to fill policy voids at both national and international levels'.[19] Following the precedent of the *Rio Declaration 1992*,[20] the IMMS is a voluntary code containing environmental principles for a number of agents including, scientists, mining operators and regulatory bodies. A 'precautionary' approach is adhered by in the IMMS, which encourages environmental best practice, transparency, involvement of local and scientific communities and responsible and sustainable development. The 'precautionary' definition encompasses the 'reasonable likelihood of serious or irreversible harm to the marine environment, and invoking no risk-benefit or cost-effectiveness tests for taking actions to avoid potential harm'.[21] The IMMS is applied in part to the Nautilus Minerals' plan for exploiting the Solwara-1 site in the Manus Basin off Papua New Guinea by 'crushing the ore on the seabed, lift it hydraulically to a surface vessel, dewater the ore, and pump the fluid back to the seafloor, with the aim of minimizing impacts to pelagic ecosystems'.[22]

a. The Solwara 1 Environmental Impact Statement

An Environmental Impact Statement (EIS), assessing potential environmental impacts of DSM on the marine environment is mandatory for potential projects, pursuant to the *International Seabed Authority Regulations*. In 2008, The EIS for the Solwara 1 Project was submitted to the PNG Department of Environment and Conservation. According to Luick, 'in 2009 the Department issued the final environmental permit for the development of the Solwara 1 project, followed by the granting of a 20-year mining lease in January 2011'.[23]

An EIS must 'incorporate an overall assessment of the mining project, providing managers with proposed measures to minimise environmental impact and maximise legislative

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[18] P.C. Collins, P. Croot, C. Carlsson, A. Colaco, A. Grehan, K. Hyeong, R. Kennedy, C. Mohn, S. Smith, H. Yamamoto, A. Rowden. 'A primer for the environmental impact assessment of mining at seafloor massive sulfide deposits'(2013) *Mar. Policy*, 42, 198–209.

[19] Hoagland et. al, 'Deep-sea mining of seafloor massive sulphides' (2010) <https://darchive.mblwhoilibrary.org/bitstream/handle/1912/3121/Hoagland%20et%20al%20%5B011110%5D.pdf?sequence=1>.

[20] *Rio Declaration on Environment and Development*, Nairobi: UNEP (1992) <http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=78&ArticleID=1163>.

[21] International Marine Minerals Society, Code for Environmental Management of Marine Mining (2011) <http://www.immsoc.org/IMMS_downloads/2011_SEPT_16_IMMS_Code.pdf>.

[22] Porter Hoagland, Stace Beaulieu, Maurice A. Tivey , Roderick G. Eggert, Christopher German , Lyle Glowka, Jian Lin, 'Deep-Sea Mining of Seafloor Massive Sulfides' (2010) 34 *Marine Policy* 728-732.

[23] John L Luick, *Physical Oceanographic Assessment of the Nautilus EIS for the Solwara 1 Project* (2012)<http://www.deepseaminingoutofourdepth.org/wp-content/uploads/EIS-Review-FINAL-low-res.pdf>.

compliance'.[24] An EIA must also involve 'evaluating the probable environmental impacts of a proposed project or development, taking into consideration beneficial and adverse socio-economic, cultural and human-health impacts'.[25] Both an independent review by Professor Richard Steiner[26] and the DSM campaign's first report, published in November 2011,[27] raised significant concerns about gaps in the Solwara 1 EIS. Mitigation strategies that reduce the likelihood of environmental damage should be identified in an EIS. However, there has been criticism that the Solwara 1 EID has overlooked comprehensive mitigation strategies for the sustainability of the project.

In November 2012, the DSM campaign released a review[28] of the sections of the EIS that describe the currents and the vertical water movements (upwelling) at the Solwara 1 site. The review focused on these oceanographic properties as they are vital for determining the level of risk that coastal communities and marine ecosystems will be exposed to. The review found that the oceanographic aspects of the EIS suffer from a lack of scientific evidence.

Local communities in Papua New Guinea and the Pacific are protesting against DSM. This has included the presentation of a petition with over 24,000 signatures to the PNG government calling for Pacific governments to stop experimental seabed mining. Pacific women have promoted the 'stop experimental seabed mining message at the international Rio+20 conference in Brazil'.[29] New Zealand communities have come together to campaign against the mining of black sands in the deep seas. Similarly, in March 2013, the Pacific Conference of Churches 10th General Assembly held in Honiara, Solomon Islands, passed a resolution to stop south Pacific DSM.[30]

b. Intellectual Property Rights

Michael Johnston, Nautilus president and CEO, states that Nautilus has been willing to provide Papua New Guinea ownership of intellectual property rights. However, as noted by Johnston, 'many of the deeds covering proprietary technology and subsea mining methods, which Nautilus and several partners developed over the years, did not contain clauses

[24] P.C. Collins, P. Croot, C. Carlsson, A. Colaco, A. Grehan, K. Hyeong, R. Kennedy, C. Mohn, S. Smith, H. Yamamoto, A. Rowden. 'A primer for the environmental impact assessment of mining at seafloor massive sulfide deposits'(2013) *Mar. Policy*, 42, 198–209.

[25] Boschen, R.E., Rowden, A.A., Clark, M.R., and Gardner, J.P.A., 'Mining of Deep-sea Seafloor Massive Sulfides: A Review of the Deposits, their Benthic Communities, Impacts from Mining, Regulatory Frameworks' (2013) 84 *Ocean and Coastal Management*, 54-67.

[26] Richard Steiner, 'Independent Review of the Environmental Impact Statement for the proposed Nautilus Minerals Solwara 1 Seabed Mining Project, Papua New Guinea', *Bismarck-Solomon Seas Indigenous Peoples Council* <deepseaminingoutofourdepth.org/resources>.

[27] Helen Rosenbaum, 'Out of Our Depth: Mining the Ocean Floor in Papua New Guinea', *Deep Sea Mining Campaign*, deepseaminingoutofourdepth.org/report

[28] John Luick, 'Physical Oceanographic Assessment of the Nautilus Environmental Impact Statement for the Solwara 1 Project – An Independent Review', *Deep Sea Mining Campaign* <deepseaminingoutofourdepth.org/report>

[29] Porter Hoagland, Stace Beaulieu, Maurice A. Tivey , Roderick G. Eggert, Christopher German , Lyle Glowka, Jian Lin, 'Deep-Sea Mining of Seafloor Massive Sulfides' (2010) 34 *Marine Policy* 728-732.

[30] Dawn Gibson, 'Call for impact research', 11 March 2013, *Fiji Times* <fijitimes.com/story.aspx?id=227482>.

allowing for a third party, such as the Papua New Guinea government, to gain benefit as partner and owner of the intellectual property rights'.[31]

In November 2011, an arbitrator's award was grated that PNG was in breach of the agreement between parties to purchase 30% of the Solwara 1 Project. The declaration ordered PNG to pay 30% of project expenditure within a reasonable time after the award. Nautilus has clarified PNG must comply with the order by 23 October 2013, of the amount of $118 million. The PNG government has now paid $113 million in escrow for the production of Solwara 1 to Nautilus. Michael Johnston, Nautilus president, has confirmed the 30% PNG interest will include intellectual property rights, after contention from mining partners to allow PNG to gain a direct 30% ownership of intellectual property rights.[32]

3. Potential Environmental and Ecological Impacts

Conditions around the hydrothermal active sites host unique ecosystems such as 'communities of organisms dependent on the metal- and sulphide-rich vent fluids that support the chemosynthetic bacteria at the base of the food web'.[33] Barometric pressure is extremely high at these depths, the mineral chemistry results in high acidity, and very hot water from the vents mixes with very cold sea water from the sea bottom. However, these unique ecosystems can be compromised with direct and indirect impacts from DSM.

Potential ecological risks include, high-turbidity, and potentially toxic sediment plumes resulting from mining activities likely to impact upon benthic communities downstream.[34] DSM risks the possibility of upwelling and currents carrying mine-derived metals towards the coastline. For example, stocks of tuna and other migratory species may become contaminated by heavy metals and the health of communities and ecosystems across the Pacific could be affected.[35]

These ecosystem risks could lead to the decolonisation of these unique ecosystems during recovery of DSM. There is little known about these ecosystems, other than two studies conducted at PNG,[36] concerning the connectivity of these ecosystems or the spatial distribution of ethnic fauna during DSM.

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[31] Klip Keen, 'Nautilus CEO Opens Up on PNG Dispute' (2013) *Australian Mining*.

[32] Johnston described sensitive negotiations over the past few months in which Nautilus had to go to its partners, "household names" in the dredging business he gave as examples, to convince them to redraw the deeds to allow the Papua New Guinea government to gain direct 30-percent ownership of the intellectual property rights. Kip Keen, 'Nautilus CEO Opens Up on PNG Dispute (2013) <http://www.mineweb.com/mineweb/content/en/mineweb-junior-mining?oid=179127&sn=Detail>.

[33] Boschen, R.E., Rowden, A.A., Clark, M.R., and Gardner, J.P.A., 'Mining of Deep-sea Seafloor Massive Sulfides: A Review of the Deposits, their Benthic Communities, Impacts from Mining, Regulatory Frameworks' (2013) 84 *Ocean and Coastal Management*, 54-67.

[34] D. Gwyther, 'Environmental Impact Statement, Solwara 1 Project' Nautilus Minerals Niugini Limited, Main Report Coffey Natural Systems, Brisbane (2008).

[35] Pacific NGOs step up Oceans Campaign at Rio+20, *Island Business*, June 15 2012, <deepseaminingoutofourdepth.org/pacific-ngos-step-upoceans-campaign-at-rio20>.

[36] P.C. Collins, R. Kennedy, C.L. Van Dover, 'A biological survey method applied to seafloor massive sulphides (SMS) with contagiously distributed hydrothermal-vent fauna' (2012) *Mar. Ecol.-Prog. Ser.*, 89–107, A.D. Thaler, K. Zelnio, W. Saleu, T.F. Schutltz, J. Carlsson, C. Cunningham, R.C. Vrijenhoek, C.L. van Dover, 'The

Consequently, management strategies to conserve these unique ecosystems whilst enabling economically viable DSM operations will require a robust legislative framework and comprehensive environmental and ecological studies of DSM. However, as stated by the ISA, there is 'considerable gaps in our understanding of the ecology of SMS deposits that prevent the refining of existing legislation to better manage activities at SMS deposits'.[37]

As of November 2012, the ISA has granted exploration contracts in the Clarion–Clipperton Zone (CCZ), an area of the seabed of about six million km^2, with water depths of between 4000 and 6000 m, located in the Eastern Central Pacific Ocean and bounded to the North and South by the Clarion and Clipperton Fracture Zones. In July 2012, the Council of ISA approved an Environmental Management Plan (EMP) for the CCZ, this framework is based on scientifically driven principles to create protected areas alongside areas assignment for exploration. Although the CCZ contracts are only in preliminary stages, the sustainable development of deep sea resources in the CCZ could be considered the 'best practice' for an sustainable ecosystem approach to future DSM projects.

Marine life varies with the depth of water. At the Solwara 1 site the ocean may be divided into three broad zones:

- The *Surface Mixed layer* which is the upper water column between ~0 - 200m and contains mostly pelagic fish species including tuna, squid and sharks. Other animals known to exist in the zone include dolphins, turtles and migrating whales.
- The *Mesopelagic Zone* which is the mid water column between ~200 - 1000m and where amongst others squid and occasional short visits by, for example, tuna in search of prey and migrating whales may occur.
- The *Bathypelagic Zone* is the bottom water column, deeper than ~1000m where animals typical of active hydrothermal vent sites such as gastropods, shrimp, crabs, and barnacles, occur. Away from venting, animals present include bamboo coral, stalked barnacles, hydroids and others. Other animals observed include octopus, swimming sea cucumbers, chimera, and deep-sea fish species. Although the impacts to the seafloor, its hydrothermal chimneys and associated vent fauna, have been identified as the main defining environmental issue for this project, there may be impacts throughout all three zones. The process of impact assessment was approached through internal risk assessment of issues at each step of the process.[38]

No study to date has investigated the effects of high pressure on the toxicity of chemicals in organisms. As high pressure has a strong influence on chemical reactions and on biochemical and physiological processes, this will likely interact with the toxicity of pollutants during DSM. Information on the toxicity of chemicals associated with deep-sea exploitation is essential to develop sustainable guidelines and regulations for environmental risk

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spatial scale of genetic subdivision in populations of Ifremeria nautilei, a hydrothermalvent gastropod from the southwest Pacific' (2011) *BMC Evol. Biol*., 11 12.

[37] International Seabed Authority, *Environmental Management of Deep-Sea Chemosynthetic Ecosystems: Justification of and Considerations for a Spatially-based Approach* (2011) ISA Technical Study Series International Seabed Authority, Kingston, Jamaica.

[38] Kaul Gena, 'Deep Sea Mining of Submarine Hydrothermal Deposits and its Possible Environmental Impact in Manus Basin, Papua New Guinea' (2012) *Procedia Earth and Planetary Science* (5), 226-233.

assessments and comprehensive laws and policy managing environmental impacts of DSM.[39]

3.1 Water Use and Discharge

Potable water on the production support vessel (PSV) for the project will be obtained by two 35-kL/day reverse osmosis desalination plants, resulting in brine production of up to 82 kL/day that will be discharged to the sea. According to Gena, salinity will typically be double the salinity of the seawater, but is not expected to have any material impact due to dilution. Pre-treatment requirements for the desalination plants such as chlorination, bromination, dechlorination, coagulation and filtration may lead to waste requiring further treatment prior to discharge.[40]

3.2 Water Quality

Impacts on water quality may occur due to accidental hydraulic fluid leaks, fuel spills during transfers at the site of the Production Support Vehicles (PSVs), ore spills during transfer to barges and bulk ore carriers, and in extreme cases, due to accidental collisions resulting in loss of vessels. Equipment malfunctions may result in the loss of material from the Riser, which could be lost to the seafloor. These incidences could affect water quality and consequently seafloor ecosystems and surface waters.[41]

3.3 Noise and Vibration

Transmission of noise from operating machinery through the water is an important consideration due to the presence of marine turtles, dolphins, purposes and whales, most of which are protected by international conventions.[42] It has been identified that the most likely source of noise which may cause disturbance is from the vessel power generation, particularly dynamic positioning of the production vessel. These sounds may be audible (e.g., to whales) at up to 600 km, however at long ranges the sounds will not be greatly above that of background ocean noise, depending on sea surface conditions. The maximum distances for specific received level thresholds being exceeded show that it would not be until an animal approached closer than 1.1 km from the source that the levels would be greater than 140 dB. Harmful effect to whales is unlikely as literature suggests behavioural avoidance at levels generally between 130 to 140 dB. According to Gena, 'the operational noise associated with the DP (propulsion) system of the mining vessel is continuous over a wide frequency bandwidth. Animals may suffer signal-masking effects at similar ranges up to approximately 15 km'.[43]

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[39] Mestre et.a;, 'Exploitation of deep-sea resources: The urgent need to understand the role of high pressure in the toxicity of chemical pollutants to deep-sea organisms' (2014) 185 *Environmental Pollution*, 269-371.
[40] Kaul Gena, 'Deep Sea Mining of Submarine Hydrothermal Deposits and its Possible Environmental Impact in Manus Basin, Papua New Guinea' (2012) *Procedia Earth and Planetary Science* (5), 226-233.
[41] Kaul Gena, 'Deep Sea Mining of Submarine Hydrothermal Deposits and its Possible Environmental Impact in Manus Basin, Papua New Guinea' (2012) *Procedia Earth and Planetary Science* (5), 226-233.
[42] Kaul Gena, 'Deep Sea Mining of Submarine Hydrothermal Deposits and its Possible Environmental Impact in Manus Basin, Papua New Guinea' (2012) *Procedia Earth and Planetary Science* (5), 226-233.
[43] Kaul Gena, 'Deep Sea Mining of Submarine Hydrothermal Deposits and its Possible Environmental Impact in Manus Basin, Papua New Guinea' (2012) *Procedia Earth and Planetary Science* (5), 226-233.

3.4 Sedimentation and dewatering

According to John B et. al, 'prior to mining, pre-stripping of unconsolidated surface sediment will be required. It is anticipated that approximately 130,000 t of unconsolidated sediment and 115,000 t of competent waste rock will be moved within the mining zones'.[44] Unconsolidated sediment will be disposed of a number of locations adjacent to the mining area. No significant geochemical changes are expected to occur as the unconsolidated sediment and competent waste material will remain near the seafloor. Relocation of low-grade material will also minimise sediment re- suspension and plume generation. This will discharge material horizontally along the seafloor to minimise plume formation and improve the rate of material settling to the seafloor. The wastewater plumes from dewatering will be discharged close to its point of origin in order to mitigate any impact in the water column shallower than 1300 m. Discharge plumes of the slurry wastewater is therefore not expected to impact fish and other animals in the mid (~200 to 1000 m) and upper (0 to 200 m) water column.[45]

4. Sea Floor Exploration and Mining Industry in Australia

DSM in Australia appears to be a response to the following trends:

- Technological advances in the cable laying, marine diamond mining and deep water oil and gas sectors, which reduce the technological challenges and capital intensity of sea floor mining operations:[46]
- High metal prices;
- Depletion of terrestrial mines;
- New discoveries; and [47]
- A shift in prospecting away from highly regulated international waters to exclusive economic zones, which are controlled by Coastal States.[48]

The Australian offshore Minerals Location Map[49] and Australia's expanded marine jurisdiction indicates the strong development of a marine minerals sector in Australia. Due to a submission lodged by Australia in 2004, the UN Commission expanded Australia's exclusive economic zone by over 2.5 million square kilometres in 2008.[50] The *Australian*

[44] John B, Simon H., Phil J., Erich H., Peter C., Andrew S., Peter M., Ian L.. 'Solwara 1 Offshore Production System Definition and Cost Study' (2010), 1-275.
[45] John B, Simon H., Phil J., Erich H., Peter C., Andrew S., Peter M., Ian L.. 'Solwara 1 Offshore Production System Definition and Cost Study' (2010), 1-275.
[46] Halfar, J., Fujita, R.M., 'Precautionary management of deep-sea mining' (2002) *Marine Policy* 26 (2), 103–106.
[47] Littleboy, A., Boughen, N., 'Exploring the Social Dimensions of an Expansion to the Seafloor Exploration and Mining Industry in Australia' (2007) *CSIRO Wealth From Oceans Flagship*, Sydney.
[48] Damien Giurco and Carlia Cooper, 'Mining and Sustainability asking the right questions' (2012) 29 *Minerals Engineering* 3-12.
[49] CSIRO, Geoscience Australia, *Australian Offshore Mineral Locations First Edition* (1:10000000 Scale Map) (2006) Geoscience Australia, Canberra.
[50] Damien Giurco and Carlia Cooper, 'Mining and Sustainability asking the right questions' (2012) 29 *Minerals Engineering* 3-12.:

Offshore Minerals Location Map illustrates Australia's mineral wealth to extend offshore. 'Identified offshore resources include those in the near shore (marine aggregate, carbonate sands, heavy mineral sands, tin, diamonds and other alluvia's), extensions of onshore mineralisation (aluminium, coal, copper, iron ore, manganese, and tungsten), and deep marine minerals (phosphorites, deep marine sulphides, manganese nodules and crusts)'.[51] As a new and emerging technology, deep-sea mining offers the potential to influence global systems of mineral production and use, however the scientific, technological and environmental studies of DSM should be carried out in Australia in order to minimise impacts and to guarantee a long term balance between exploitation and protection.

5. What is the current depth of understanding in relation to deep-sea mining?

Due to the high-grade ores found within Seafloor Massive Sulphide, the commercial interests of mining, government and scientific stakeholders alike will only increase. Seafloor Massive Sulphides can occur at depths up to 5000 m where vent hydrothermal fluids have temperatures exceeding 450°C. There are significant hurdles scientifically due to the lack of understanding of metal transfer and concentration processes in DSM.[52]

The lack of knowledge of deep-sea ecosystems must be overcome in order to ensure the mineral impacts and marine protection in DSM areas. Communities of vent endemic species, together with diverse associated organisms, are expected to be impacted severely by mineral extraction.[53] Consequently, there is an urgent need 'to develop evidence-based criteria for the setting of conservation objectives at hydrothermal vent sites for the sustainable and responsible management of SMS resources'.[54]

Environmentalists against the exploitation of hydrothermal vents call for an outright ban of all environmentally exploitative actions until scientist can create provide knowledge of deep-sea biodiversity and ecosystems, based on which recommendations are made for environmentally-friendly exploitation of resources. Similarly, the argument for exploitation with a *laissez faire* approach without adherence to scientific, technological and environmental measures during DSM is unsustainable. A balance must be struck to ensure economic viability and biodiversity protection[55].

The 'precautionary' principle, as outlined IMMS Code, to consider biological resource potential and value of living organisms at potential marine mining sites as well as the mineral

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Covering over 10 billion square kilometres, Australia's marine jurisdiction is significantly larger than that of the Australian continent, which covers approximately 7.7 billion square kilometres).

[51] Damien Giurco and Carlia Cooper, 'Mining and Sustainability asking the right questions' (2012) 29 *Minerals Engineering* 3-12.

[52] Patrick Colman Collins et al, 'A primer for the Environmental Impact Assessment of mining at seafloor massive sulfide deposits' (2013) 42 *Marine Policy* 198-209.

[53] C.L. Van Dover, Mining seafloor massive sulfides and biodiversity: what is at risk? (2010) 68 *ICES Journal of Marine Science* 341–348.

[54] P.C. Collins, B. Kennedy, C.L. Van Dover, 'A biological survey method applied to Seafloor Massive Sulphides. (SMS) with contagiously distributed hydrothermal-vent fauna' (2012) 452 *Marine Ecology Progress Series* 89–107.

[55] Patrick Colman Collins et al, 'A primer for the Environmental Impact Assessment of mining at seafloor massive sulfide deposits' (2013) 42 *Marine Policy* 198-209.

resource potential and value can provide a 'best practice framework' for DSM.[56] The *1992 Rio Declaration* states that, according to the precautionary principle, a lack of scientific certainty should not preclude states from adopting cost-effective measures to control environmental risks. Further, the recent VentBase workshop (May 2012) provided a forum for stakeholders and scientists to discuss issues surrounding SMS exploration and exploitation.[57] This forum recognised the requirement for a primer document, which would relate concepts underpinning Environmental impact Assessment (EIA).[58]

6. Management of Deep Sea Bed Mining

According to the ISA, while the legal and economic management of DSM is specific to country policy, management objectives should include goals for all ecosystems affected by DSM including 'protect(ing) the natural diversity, ecosystem structure; function and resilience of… vent communities'.[59] Mitigation strategies of DSM are an important to manage potential impacts of DSM. Enhancing the recruitment and re-establishment of biota following DSM is also recommended by the IMMS Code. The ISA stipulates this can be achieved by establishing seabed biota within impact reference zones and preservation reference zones. As stated by Boschen et.al, 'Impact reference zones are used to assess the effects of activities on the marine environment whilst preservation reference zones are areas where there is no mining to ensure representation of an un-impacted seabed biota'.[60]

An example of a potential impact or preservation reference zone is the South Su reference site, located 2kin upstream of Solwara 1. This site could provide an effective temporary relocation site for larvae for re-colonisation of Solwara 1after DSM. Nautilus is proposing to enhance the re-colonisation of larvae through quasi-permanent refuge areas, where the temperature is too great for the seafloor mining tool to operate (>35 °C), to enable local retention or organisms to resupply the mining zone of Solwara 1. Nautilus also proposes to deploy artificial hard substrata for recolonisation by slow-growing sessile taxa such as corals in regions where inactive SMS deposits have been mined.[61]However, a range of characteristics and ecological factors must be taken into account for the decolonisation potential of species and potential mitigation strategies. Nautilus has also created a mining tool with a suction mouth for minimal escape of suspended material during cutting. Consequently, the risk of exposure to toxic plumes is limited by reducing the escape of suspended material through the suction and releasing the waste 25-50m above the seabed.

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[56] Boschen, R.E., Rowden, A.A., Clark, M.R., and Gardner, J.P.A., 'Mining of Deep-sea Seafloor Massive Sulfides: A Review of the Deposits, their Benthic Communities, Impacts from Mining, Regulatory Frameworks' (2013) 84 *Ocean and Coastal Management*, 54-67.

[57] Southern Fried Science, *Vent Base* (2012) < http://www.southernfriedscience.com/?p=12907>.

[58] Patrick Colman Collins et al, 'A primer for the Environmental Impact Assessment of mining at seafloor massive sulfide deposits' (2013) 42 *Marine Policy* 198-209.

[59] International Seabed Authority, 'Environmental Management of Deep-Sea Chemosynthetic Ecosystems: Justification of and Considerations for a Spatially-based Approach' (2011) ISA Technical Study Series International Seabed Authority, Kingston, Jamaica.

[60] Boschen, R.E., Rowden, A.A., Clark, M.R., and Gardner, J.P.A., 'Mining of Deep-sea Seafloor Massive Sulfides: A Review of the Deposits, their Benthic Communities, Impacts from Mining, Regulatory Frameworks' (2013) 84 *Ocean and Coastal Management*, 54-67.

[61] D. Gwyther, Environmental Impact Statement, Solwara 1 Project Nautilus Minerals Niugini Limited, Main Report Coffey Natural Systems, Brisbane (2008).

Comprehensive baseline studies are essential to investigate and manage impacts from DSM mining. According to the ISA, the study should analyse geophysical, ecotoxicology geochemical, geological and oceanographic of seasonal and inter-annual variation in environmental parameters.

The VentBase workshop also recommends that:

> A paradigm shift is required whereby the perceived uniqueness of individual marine ecosystems are subsumed to a generalised approach where vents are viewed as another habitat within the seascape. Only by a harmonization in approach, with methodologies as equivalently rigorous to those established for the coastal zone, can we ensure that vent ecosystems are afforded management standards mandated by the precautionary principle.[62]

The ISA requires an annual report to detail the implementation and monitoring of the outlined monitoring program. Solwara 1 in PNG is also subject to national requirements for monitoring programmes under the *Environmental Act 2000*, with Nautilus having developed a detailed plan both for baseline studies and subsequent monitoring. It is important to note that management and monitoring programs must be evaluated against pre-determined decision rules in order to be effective in management responses. Green recommends the use of to BACI (before-after-control-impact) or Beyond BACI to design baseline, impact and long-term monitoring at both temporal and spatial scales.[63] DSM must effectively manage ecosystems in adherence to the 'precautionary principle' to form robust scientific conclusions within deep sea studies within multiple sites.

7. Conclusions

The impacts of DSM will range across a plethora of marine environments, across jurisdictions with both short and prolonged durations. Although there is no single precedent for the international legislation regulating DSM, the ISA is the most authorities' body encouraging best practise in DSM activities. Various codes issued by stakeholders to encourage comprehensive environmental management in activities at DSM deposits also exist. However, it is a significant regulatory challenge to create suitable management and mitigation of DSM to ensure protection of the marine environment without more information on DSM ecology. There is coherence among the ISA and IMMS code that DSM mining should include management objectives, a comprehensive environmental impact assessment, and implementation of suitable mitigation strategies and establishment of a long-term monitoring program. Furthermore, the adoption of a 'precautionary' principle to ensure environmental impacts of deep-sea mining must be properly understood and accounted for, in order to inform marine spatial planning and subsequent adaptive management within

[62] P.C. Collins, R. Kennedy, J. Copley, R. Boschen, J. Forde, J. Se-Jong, D. Lindsay, L. Marsh, V. Nye, A. Patterson, H. Watanabe, H. Yamamoto, J. Carlsson, A.D. Thaler, 'VentBase: developing a consensus among stakeholders in the deep-sea regarding environmental impact assessment for deep-sea mining' (2013) *Mar. Policy,* 42, 334–336.

[63].H. Green, *Sampling Design and statistical Methods for Environmental Biologists* (Wiley, New York, 1979).

regulation is needed. The ISA serves as a tangible example of good governance from an international body regulating the DSM.

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Helen Rosenbaum, 'Out of Our Depth: Mining the Ocean Floor in Papua New Guinea', *Deep Sea Mining Campaign* <deepseaminingoutofourdepth.org/report>

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