Zoning Experiences from Solwara 1

Dr Samantha Smith

ISA Workshop on:
The Design of “Impact Reference Zones” and “Preservation Reference Zones” in Deep-Sea Mining Contract Areas

Berlin
27-29 September 2017

Images courtesy of Nautilus Minerals, Cindy Van Dover
The Solwara 1 Project

- Bismarck Sea, PNG
- SMS Deposit
- 1600 m depth
- 30 km from nearest coast
- Small extraction area: $0.11 \text{ km}^2$
- Weakly active hydrothermal site
Su Su Knolls

Solwara 1
Mine Site

Active subsea volcano

Reference Site

North Su

South Su
The Solwara 1 Project

- High grades
- Environment Permit - Dec 2009
- Mining Lease - Jan 2011
- Mining expected to commence in 2019, subject to funding

---

**NAUTILUS MINERALS RESOURCE ESTIMATES 2011**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Domain</th>
<th>Tonnes</th>
<th>Cu (%)</th>
<th>Au g/t</th>
<th>Ag (g/t)</th>
<th>Zn (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solwara 1 - Indicated @ 2.6% Cu Eq cut off</td>
<td>Total</td>
<td>1,030,000</td>
<td>7.2</td>
<td>5.0</td>
<td>23</td>
<td>0.4</td>
</tr>
<tr>
<td>Solwara 1 - Inferred @ 2.6% Cu Eq cut off</td>
<td>Total</td>
<td>1,540,000</td>
<td>8.1</td>
<td>6.4</td>
<td>34</td>
<td>0.9</td>
</tr>
<tr>
<td>Solwara 12 - Inferred @ 2.6% Cu Eq cut off</td>
<td>Total</td>
<td>230,000</td>
<td>7.3</td>
<td>3.6</td>
<td>56</td>
<td>3.6</td>
</tr>
</tbody>
</table>


Note: Resource estimates prepared by Ian Lipton, BSc (Hons), FAusIMM, Principal Geologist, Golder Associates Pty Ltd, Toowong, Queensland, Australia who fulfils the requirements to be a “qualified person” for the purposes of NI 43-101. Rounding may result in errors in reproducing the totals from the individual components shown in this table. Copper equivalent (CuEq) = 0.915*Cu+0.254*Au+0.00398*Ag.
Studies (note this is not an exhaustive list)

- Biology Studies:
  - Macrofauna (incl., DNA/genetic studies)
  - Benthic Habitat Assessment
  - Bioaccumulation
  - Bioluminescence

- Existing Resource Utilisation / Interaction with existing uses

- Hazard and Risk Assessment

- Hydrodynamic Modelling:
  - Cutting
  - Dewatering

- Noise and Light

- Oceanography (12 mo, full column)

- Sedimentation Rates (36 mo)

- Sediment Chemistry

- Video Survey (>100,000 obs)

- Water Quality

**Additional objective:** science will also benefit from additional deep sea studies conducted to obtain data for the EIS
Approach to EIA Studies

- Independent researchers
  - Freedom to publish
- Independent reviewers
  - Engaged by DEC
- Transparency
  - EIS and all supporting studies on website

Images: Collecting chimney sample; collecting snail sample
Minimising Impacts

• Strategies developed with a team of independent world experts.

• All strategies suggested were accepted by Nautilus.

• Protection measures include:
  – ‘Refuge Areas’ within Solwara 1
  – Animal relocation
  – Artificial substrates
Purpose of South Su

- Protection of representative organisms
- Reference area away from the impact of mining
- Provision of a stock population to aid recolonisation of mined areas (passive)
- Maintain regional biodiversity
What was known when the decision was made to set aside South Su?
Sampling Strategy

Hierarchical Sampling Scheme

- Field (Solwara 1, South Su)
  - Site x 3
    - Habitat x 3
    - Mound x 3

Repeated at South Su and for 3 “inactive” habitat types at both Solwara 1 and South Su
Key Findings

• Animal assemblages at South Su and Solwara 1 similar;
• Biodiversity higher at South Su;
• Whilst the animal assemblages were similar at both sites, they were not identical. For example, the mussel *Bathymodiolus manusensis* is found at South Su but it is not found at Solwara 1;
• Net near-bottom current flow is in a southeast to northwest direction (i.e. from South Su to Solwara 1), supporting the idea that passive swimmer/larval dispersal would occur in that direction too.
Seafloor Communities – ACTIVE

3 Main Habitat Zones at Solwara 1 and South Su

Solwara 1: low faunal densities and biomass in comparison to other hydrothermal systems worldwide

*Alvinocconcha sp.* – aka “Hairy Snails”

*Ifremeria nautilei* – aka “Black Snails”

*Eochionelasmus ohtai* – “Barnacles”
Seafloor Communities – INACTIVE

Keratoisis

Stalked barnacles

Hydroids

No significant difference between samples taken from Solwara 1 and South Su (reference site) with respect to the numerically dominant species
Plume Studies

Sediment bottom thickness surrounding the Solwara 1 site after simulating the full removal operation.
Plume Studies

Figure 3.4
A zoomed in comparison of the probability of exceeding 1/5,000 threshold concentration at any time over a one year period.

Discharge Temperature at 5.8°C

Discharge Temperature at 11.4°C
What did we learn post-EIS?
<table>
<thead>
<tr>
<th>Numerically Dominant Taxa at Manus Basin Vents</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bathymodiolus manusensis</strong></td>
<td>mussel</td>
<td>sessile</td>
<td>endosymbionts vent endemic</td>
</tr>
<tr>
<td><strong>Ifremeria nautili</strong></td>
<td>black snail</td>
<td>sessile; partial brooding</td>
<td>endosymbionts vent endemic</td>
</tr>
<tr>
<td><strong>Lepetodrilus sp</strong></td>
<td>limpet</td>
<td>sessile</td>
<td>vent endemic?</td>
</tr>
<tr>
<td><strong>Olgasolaris tollmanni</strong></td>
<td>limpet</td>
<td>sessile</td>
<td>not endemic?</td>
</tr>
<tr>
<td><strong>Chorocaris sp. 2</strong></td>
<td>shrimp</td>
<td>mobile</td>
<td>vent endemic?</td>
</tr>
<tr>
<td><strong>Munidopsis lauvensis</strong></td>
<td>squat lobster</td>
<td>mobile</td>
<td>not endemic</td>
</tr>
<tr>
<td><strong>Eochionelasmus ohtai</strong></td>
<td>sessile barnacle</td>
<td>attached</td>
<td>vent endemic?</td>
</tr>
<tr>
<td><strong>Vulcanolepas sp.</strong></td>
<td>stalked barnacle</td>
<td>attached</td>
<td>not endemic</td>
</tr>
</tbody>
</table>
### Numerically Dominant Taxa at Manus Basin Vents

<table>
<thead>
<tr>
<th>Marker</th>
<th>Genetic Differentiation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manus</td>
</tr>
</tbody>
</table>

#### Bathymodiolus manusensis
- Mussel
- COI
- msats

#### Ifremeria nautilei
- Black snail
- COI
- msats

#### Lepetodrilus sp.
- Limpet
- 42 nuclear loci

#### Olgasolaris tollmanni
- Limpet
- COI

#### Chorocaris sp. 2
- Shrimp
- COI
- msats

#### Munidopsis lauensis
- Squat lobster
- COI*
- msats

#### Eochionelasmus ohtai
- Sessile barnacle
- COI

#### Vulcanolepas sp.
- Stalked barnacle
- COI

### Genetic Differentiation Notes:
- `:` Population absent
- `X`: Population not sampled
- `?`: Relative migration rates (evolutionary timescale)
- `*`: 96% dominance by a single COI haplotype
Transferability to Other Sites?

• Possibly for other SMS sites (active)

• Possibly not for inactive sites / nodule sites:
  – Hydrothermal vents support large communities fueled by chemoautotrophic primary production – in contrast to the relatively low-biomass found on the deep seafloor, including nodule sites
  – Relatively high biomass, along with low biodiversity, and a small mine site (0.11 km$^2$), enabled a high sampling effort for key species at ACTIVE SITES
  – We struggled to get the numbers we needed for a robust statistical analysis at INACTIVE sites
Other Considerations

• Accessibility
• Solwara 1 is located in a sheltered basin = populations more ‘mixed’? (helps if thinking about population sources and sinks / connectivity?)
• Dynamics
• Visibility of what you are sampling
• Buffer zones? Or, just prove no impact?
Other Thoughts

• Learning doesn’t end with the submission of an EIS

• “Absence of certainty doesn’t mean absence of knowledge” (Fred McKenzie, as quoted by Philomene Verlaan)

• We don’t need to know everything to make reasonable management decisions

• Flexibility is important
Other Thoughts / Questions

• Setting aside South Su was just one strategy among a number of others

• Do PRZs/IRZs need to be permanent?
  – Lots of associated ‘sub-questions’

• Do we need to pre-define a buffer zone or just be able to demonstrate no impact?

• What is the appropriate / acceptable sampling effort at a low-biomass / inactive site? Are there species which should not be sampled?
CITATIONS

Plouviez S, LaBella AL, Weisrock D, Meijenfeld F von, Ball B, Neigel J, Van Dover C (In Preparation) Amplicon sequencing of 42 nuclear loci support directional migration between South Pacific populations of a hydrothermal vent limpet.


Dr Samantha Smith
samantha@blueglobesolutions.com
Return water plume discharged at 11.4 °C

LEGEND
- Bathymetry contour (m)
- Mineralised zone to be mined

Probability of exceedence
- 0% - 10%
- 11% - 20%
- 21% - 30%
- 31% - 40%
- 41% - 50%
- 51% - 60%
- 61% - 70%
- 71% - 80%
- 81% - 100%

Solwara 1
North Su
South Su
Plume Modelling
Volcanic Plume from North Su