Zoning Experiences from Solwara 1

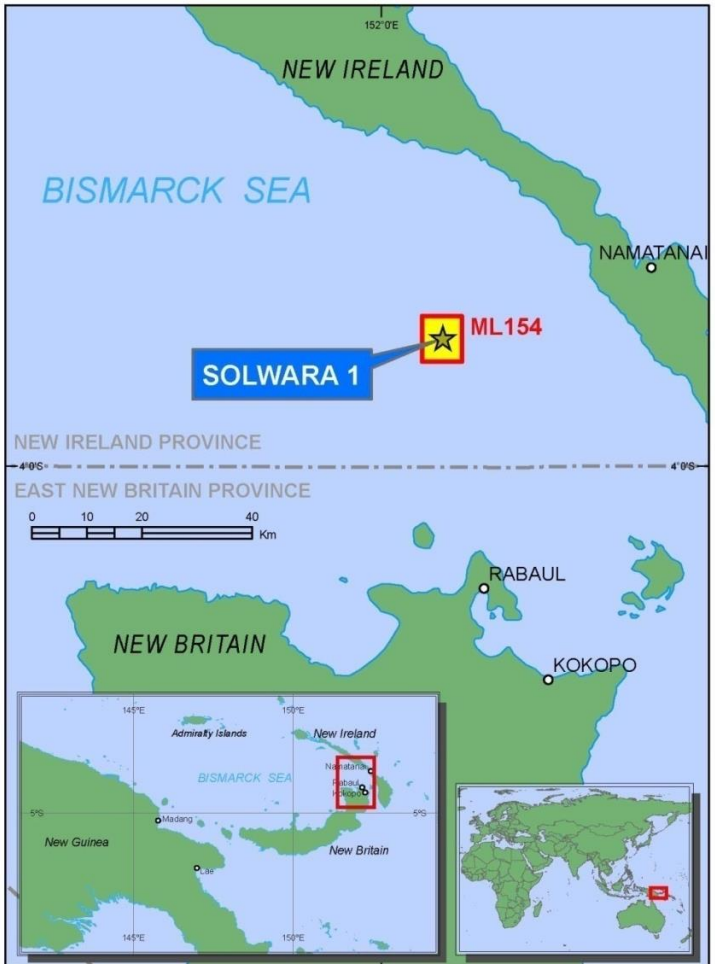
Dr Samantha Smith

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

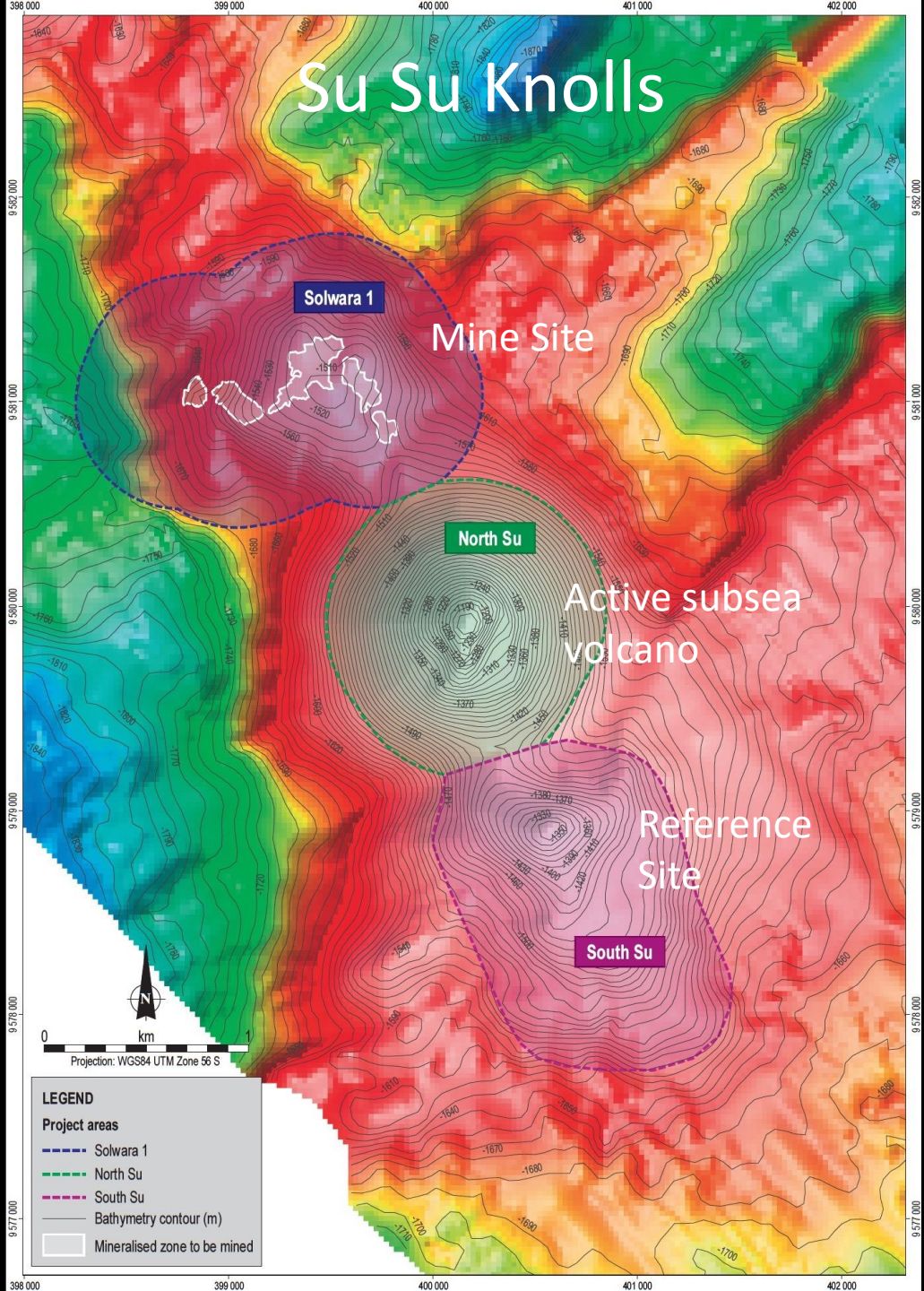
Berlin
27-29 September 2017

Images courtesy of Nautilus Minerals, Cindy Van Dover

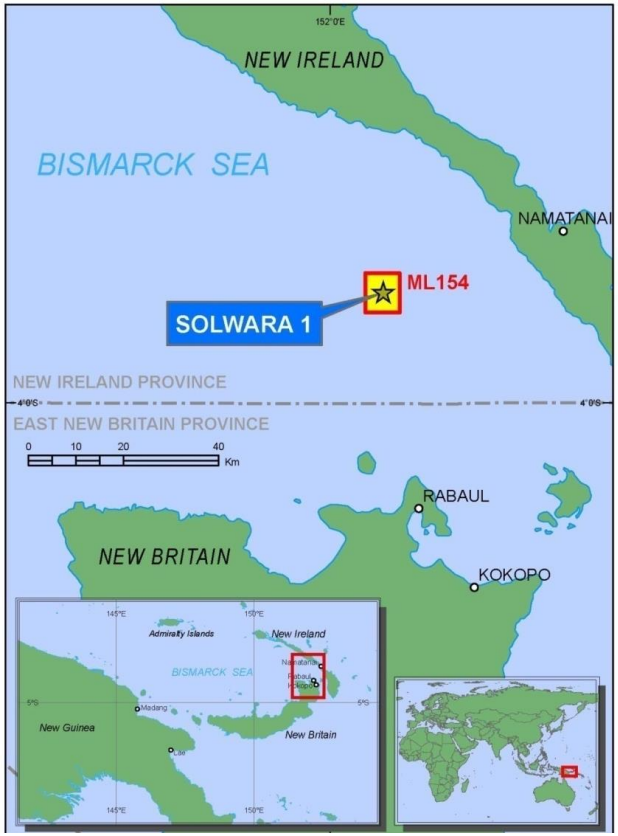
The Solwara 1 Project



- Bismarck Sea, PNG
- SMS Deposit
- 1600 m depth
- 30 km from nearest coast
- Small extraction area: 0.11 km^2
- Weakly active hydrothermal site


Su Su Knolls
Solwara 1
Mine Site
North Su
Active subsea volcano
Reference Site
South Su
398 000
399 000
400 000
401 000
402 000
9 582 000
9 581 000
9 580 000
9 579 000
9 578 000
9 577 000
0
km
1
Projection: WGS84 UTM Zone 56 S
LEGEND
Project areas
Solwara 1
North Su
South Su
Bathymetry contour (m)
Mineralised zone to be mined

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

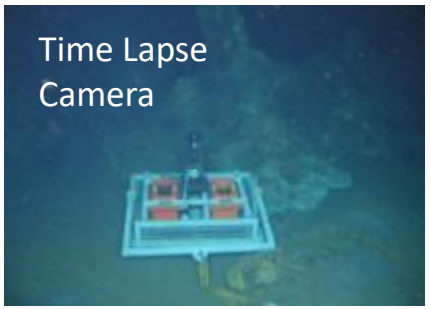
Classification	Domain	Tonnes	Cu (%)	Au g/t	Ag (g/t)	Zn (%)
Solwara 1 - Indicated @ 2.6% Cu Eq cut off	Total	1,030,000	7.2	5.0	23	0.4
Solwara 1 - Inferred @ 2.6% Cu Eq cut off	Total	1,540,000	8.1	6.4	34	0.9
Solwara 12 - Inferred @ 2.6% Cu Eq cut off	Total	230,000	7.3	3.6	56	3.6

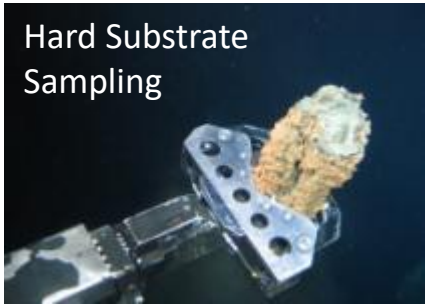
The news release dated November 25, 2011 regarding the resource estimate is available at: http://www.nautilusminerals.com/s/Media-NewsReleases.asp?ReportID=492567

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+0.00598*Ag.

Approach to EIA Studies

- 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



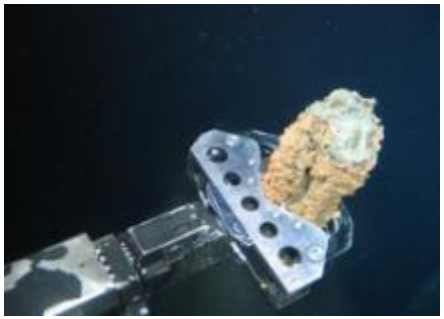


Additional objective: science will also benefit from additional deep sea studies conducted to obtain data for the EIS

Approach to EIA Studies

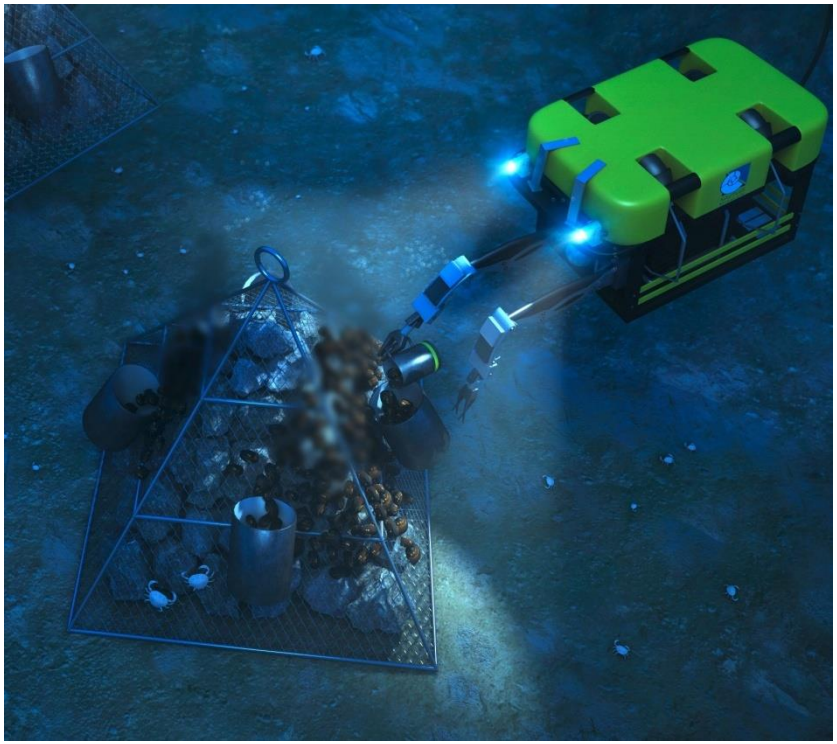
- Independent researchers
  - Freedom to publish
- Independent reviewers
  - Engaged by DEC
- Transparency
  - EIS and all supporting studies on website

- Duke University
- Scripps Institution of Oceanography
- University of Toronto, Canada
- Woods Hole Oceanographic Institute
- CSIRO, Australia
- Hydrobiology, Australia
- University of Papua New Guinea
- Coffey Natural Systems, Australia
- Rabaul Volcano Observatory, PNG
- Asia Pacific Applied Science Associates (APASA), Australia
- Australian National University
- Curtin University of Technology, Australia
- James Cook University, Australia
- Charles Darwin University, Australia



Images: Collecting chimney sample; collecting snail sample

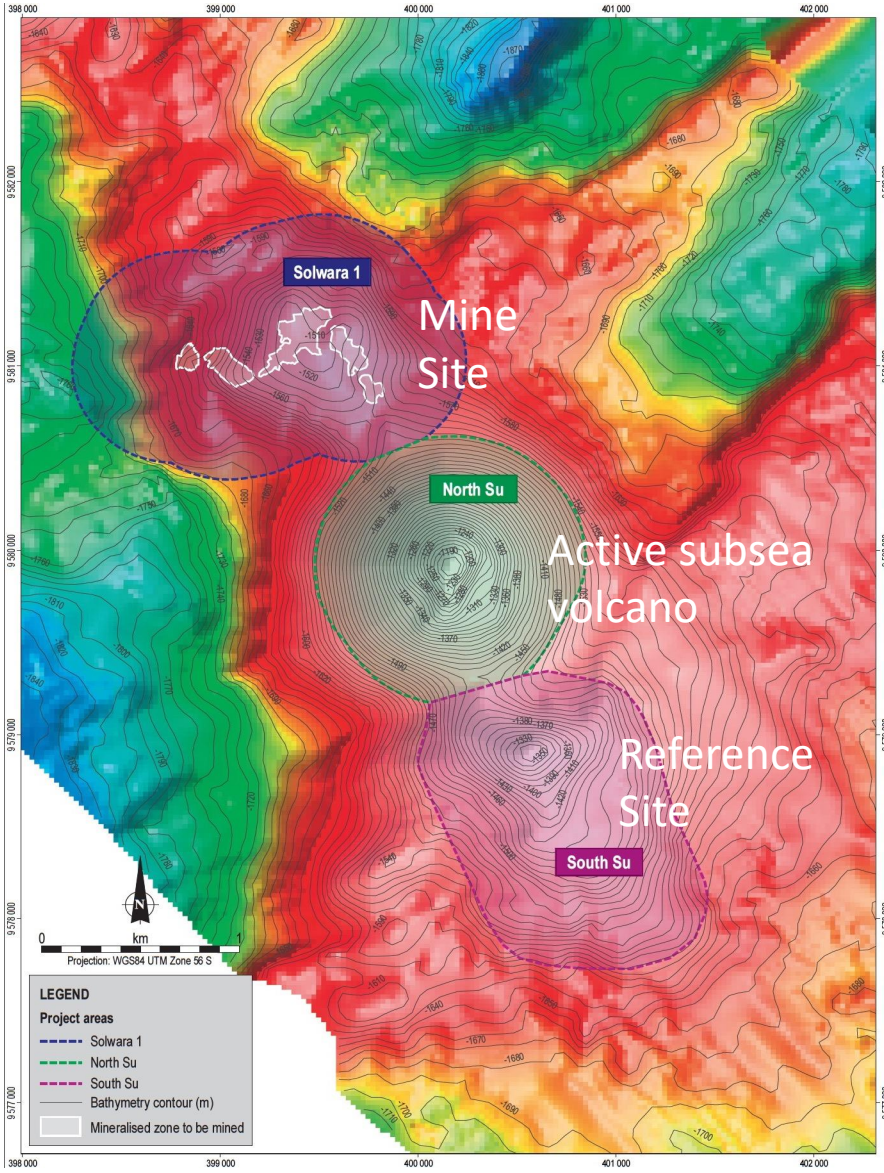
Minimising Impacts



Conceptual image showing a deep sea restoration activity: Animal relocation onto artificial substrates

- 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

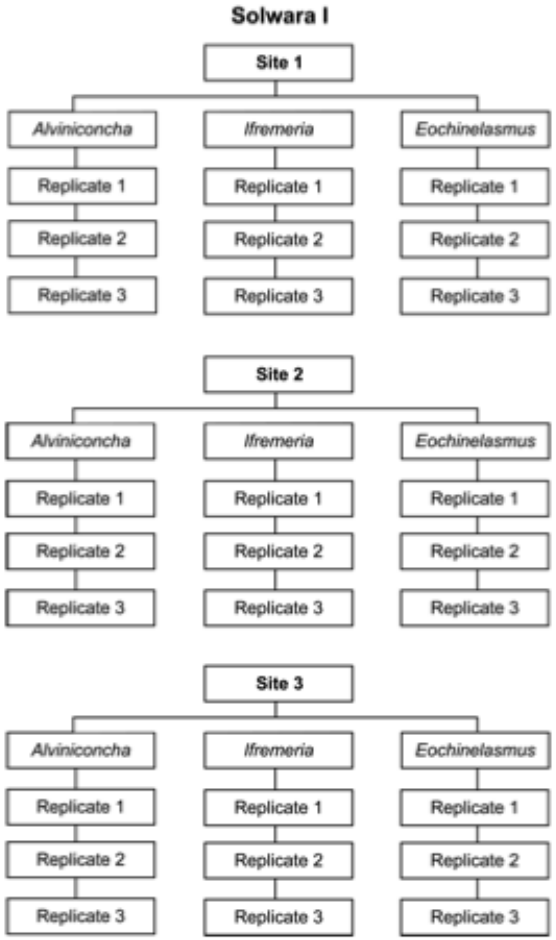
What was known when the decision was made to set aside South Su?

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

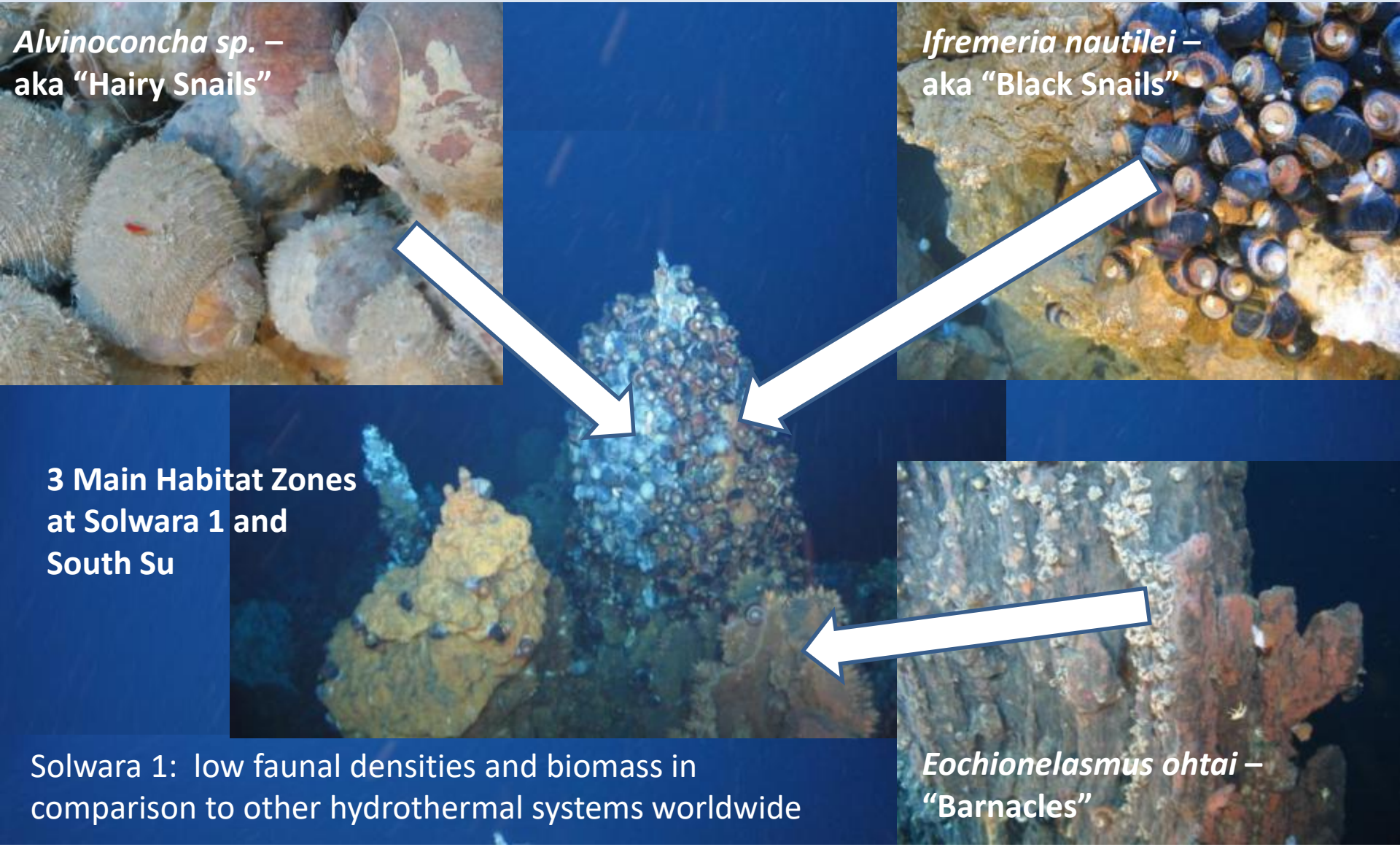


Collins et al. 2012

Key Findings

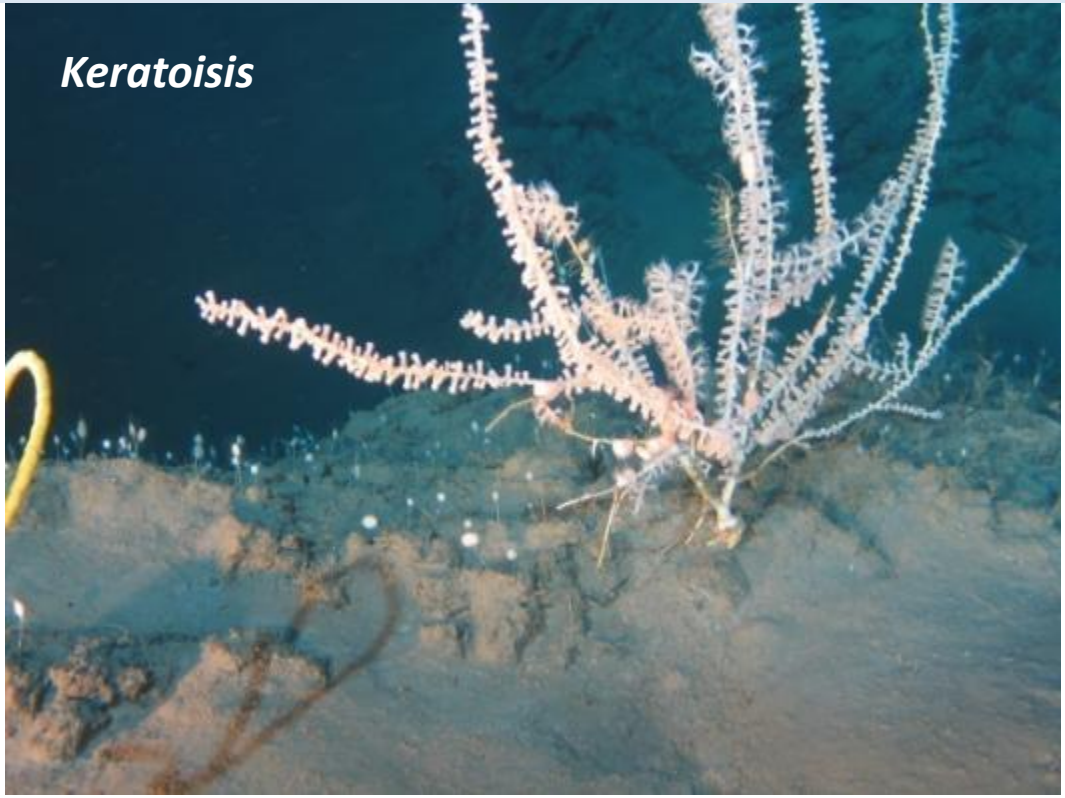
- Animal assemblages at South Su and Solwara 1 similar;
- Biodiversity higher at South Su;
- Whilst the animal assemblages were similar at both sites, they were not identical. For example, the mussel *Bathymodiolus manusensis* is found at South Su but it is not found at Solwara 1;
- Net near-bottom current 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.

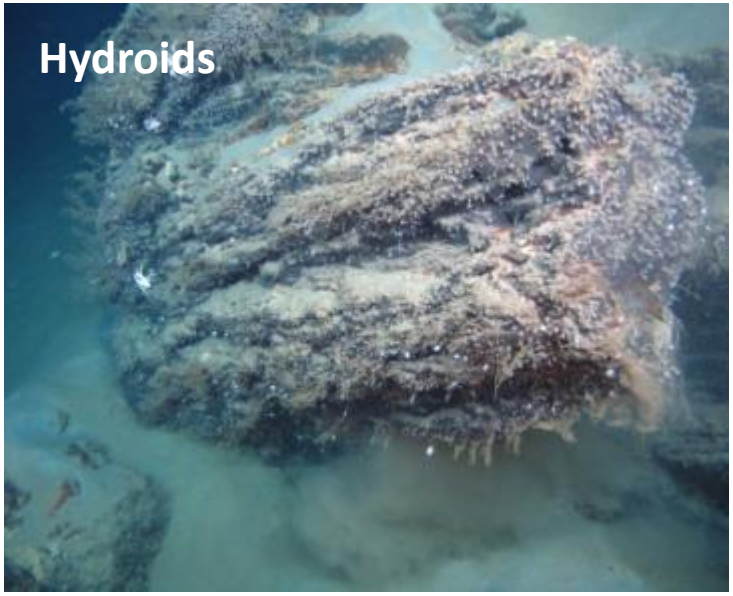
Seafloor Communities – ACTIVE



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

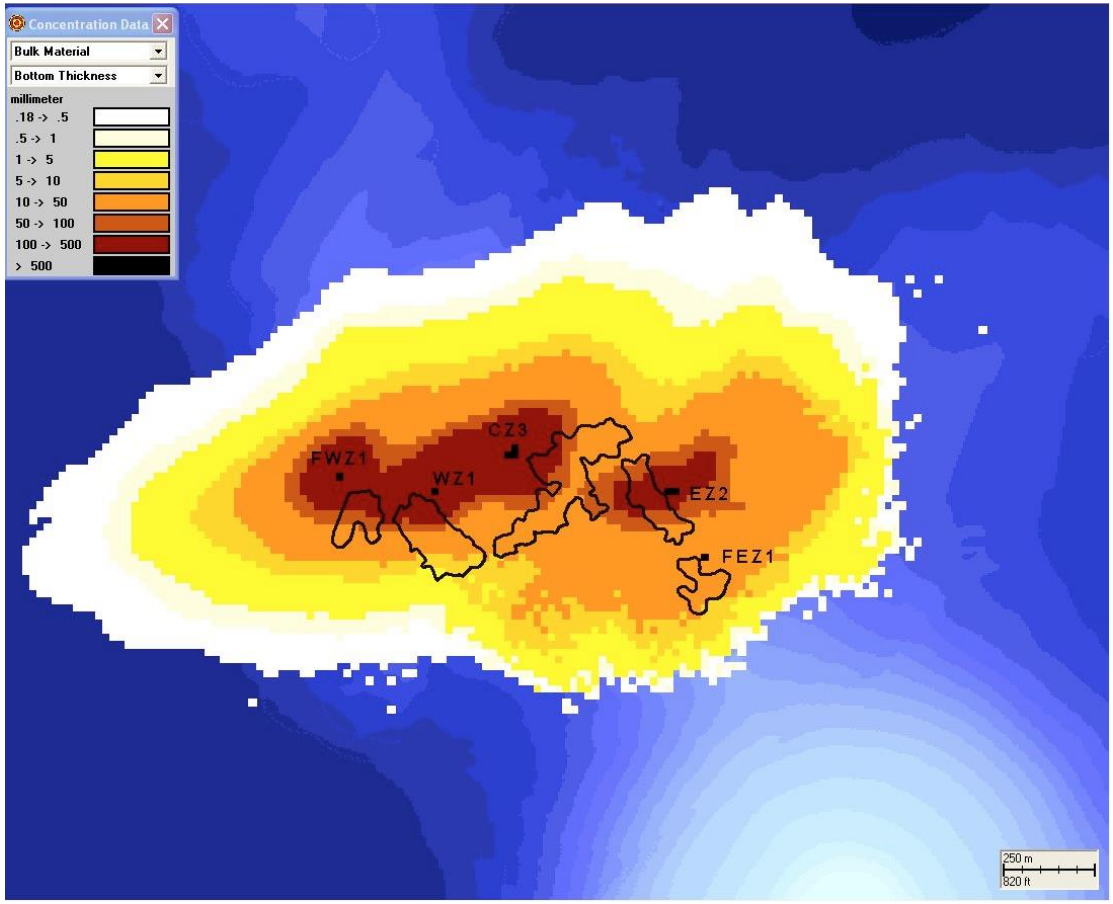
Seafloor Communities – INACTIVE





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

Plume Studies

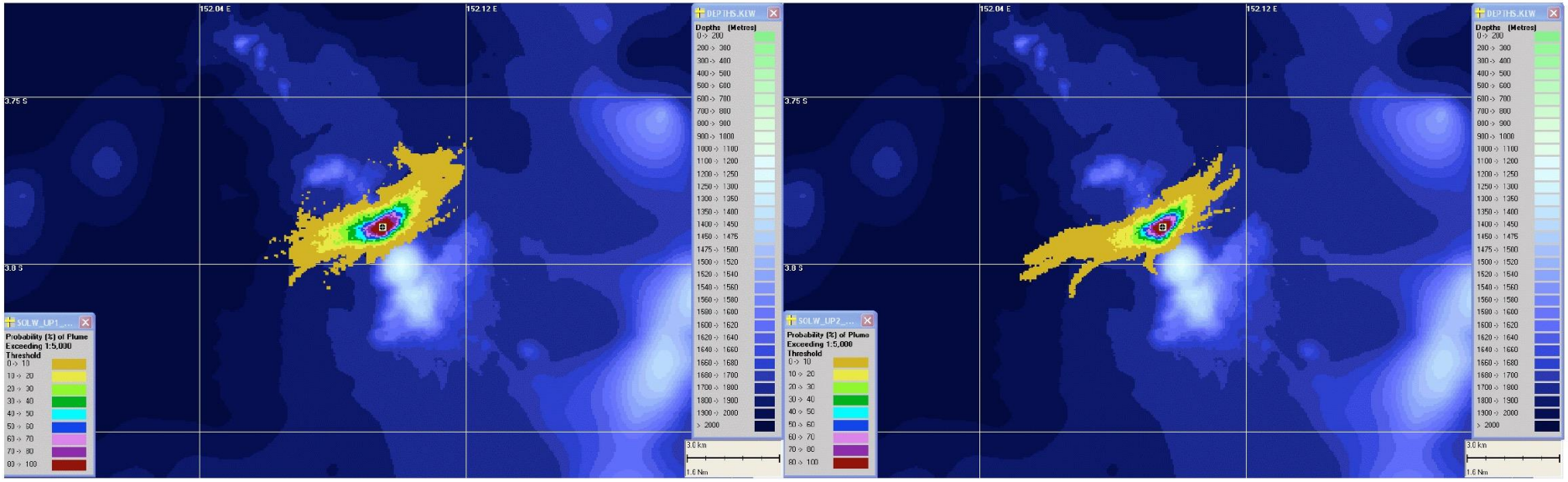


Sediment bottom thickness surrounding the Solwara 1 site after simulating the full removal operation.

Plume Studies

Figure 3.4

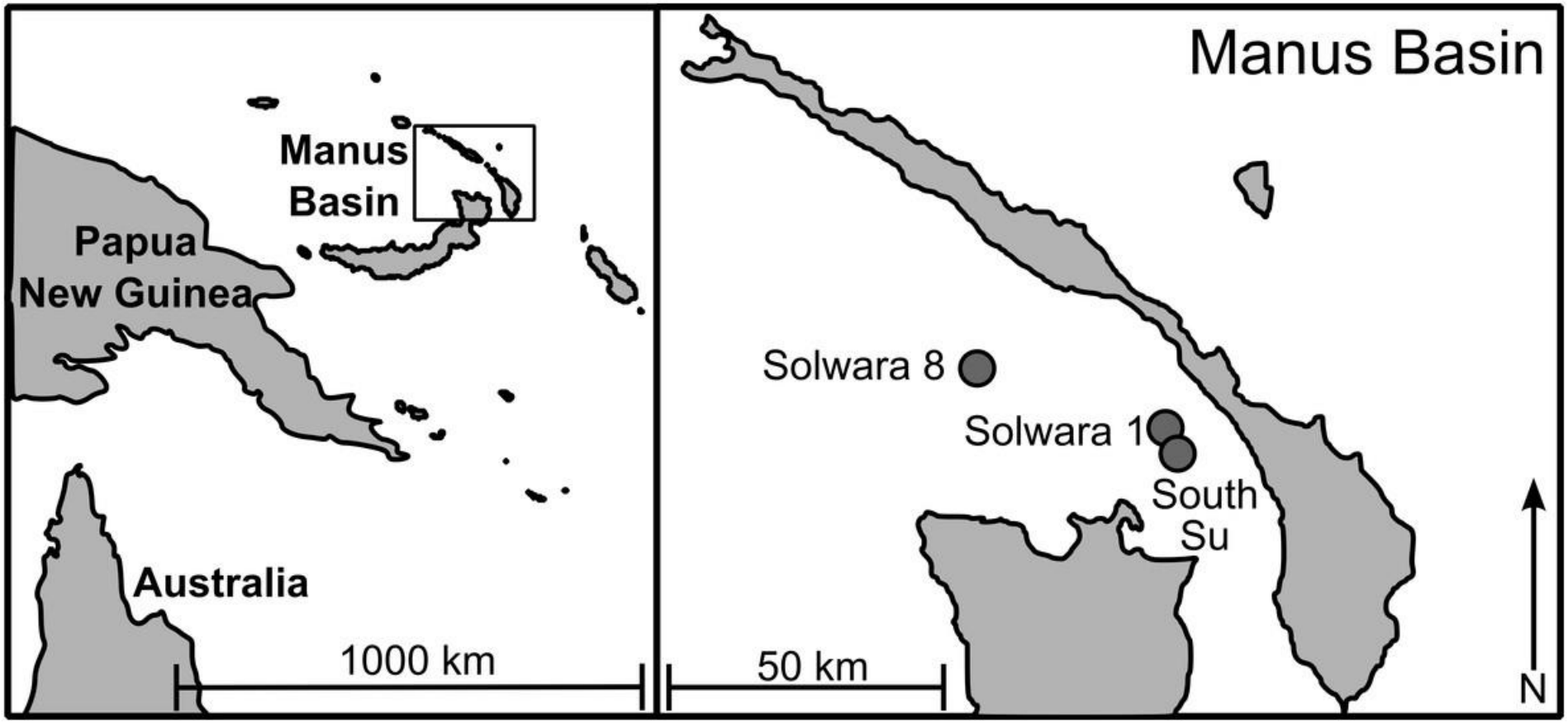
A zoomed in comparison of the probability of exceeding 1/5,000 threshold concentration at any time over a one year period



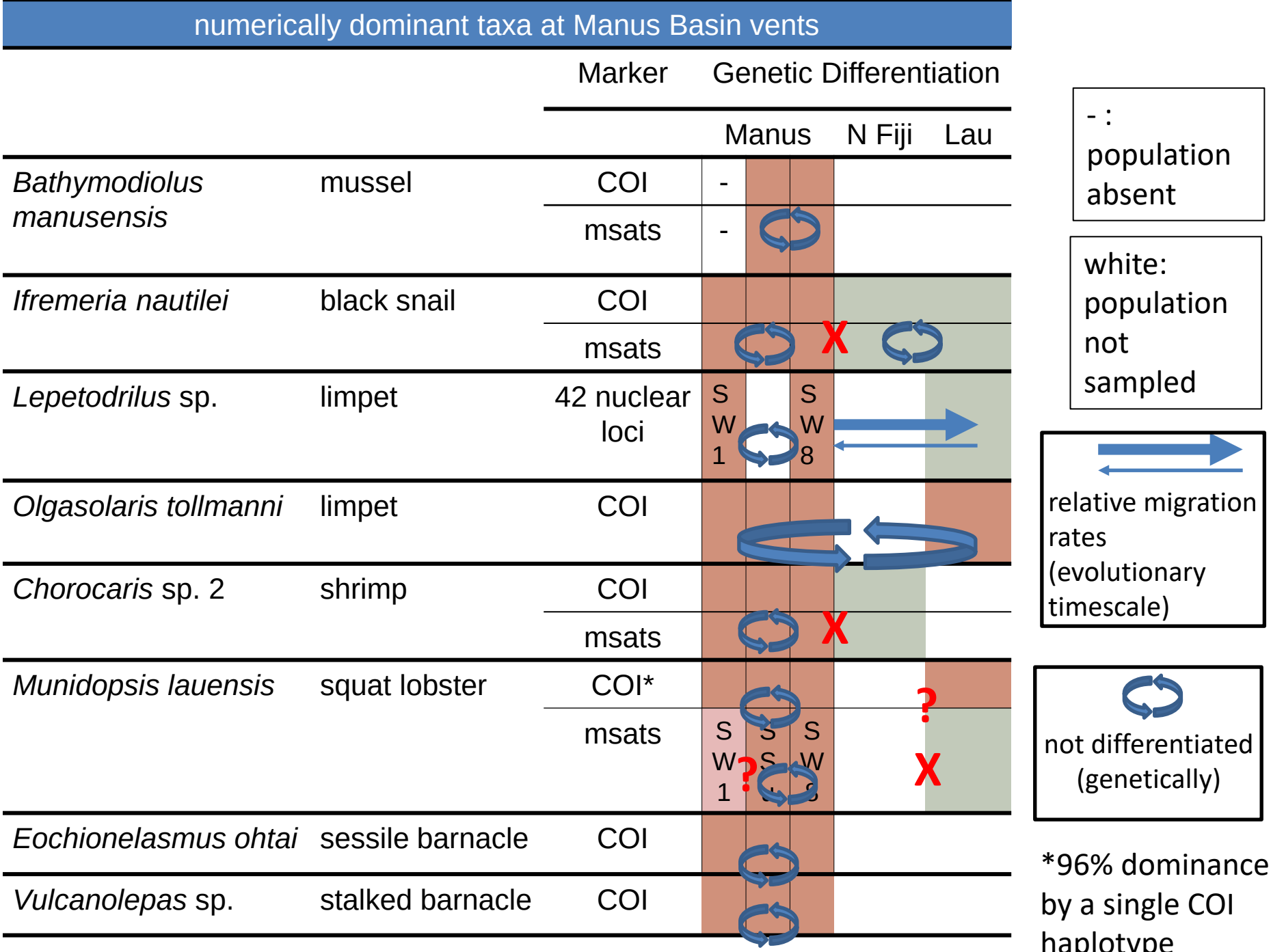
Discharge Temperature at 5.8°C

Discharge Temperature at 11.4°C

What did we learn post-EIS?


Manus
Basin
Papua
New Guinea
Australia
1000 km
Manus Basin
Solwara 8
Solwara 1
South
Su
50 km
N

numerically dominant taxa at Manus Basin vents			
Bathymodiolus manusensis	mussel	sessile	endosymbionts vent endemic
Ifremeria nautilei	black snail	sessile; partial brooding	endosymbionts vent endemic
Lepetodrilus sp	limpet	sessile	vent endemic?
Olgasolaris tollmanni	limpet	sessile	not endemic?
Chorocaris sp. 2	shrimp	mobile	vent endemic?
Munidopsis lauensis	squat lobster	mobile	not endemic
Eochionelasmus ohtai	sessile barnacle	attached	vent endemic?
Vulcanolepas sp.	stalked barnacle	attached	not endemic


numerically dominant taxa at Manus Basin vents
Marker
Genetic Differentiation
Manus
N Fiji
Lau
Bathymodiolus manusensis
mussel
COI
msats
Ifremeria nautilei
black snail
Lepetodrilus sp.
limpet
42 nuclear loci
SW1
SW8
Olgasolaris tollmanni
Chorocaris sp. 2
shrimp
Munidopsis lauensis
squat lobster
COI*
Eochionelasmus ohtai
sessile barnacle
Vulcanolepas sp.
stalked barnacle
- : population absent
white: population not sampled
relative migration rates (evolutionary timescale)
not differentiated (genetically)
*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 releatively 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.

Plouviez S, Schultz TF, McGinnis G, Minshall H, Rudder M, Van Dover CL (2013) Genetic diversity of hydrothermal-vent barnacles in Manus Basin. Deep Res Part I Oceanogr Res Pap 82:73–79

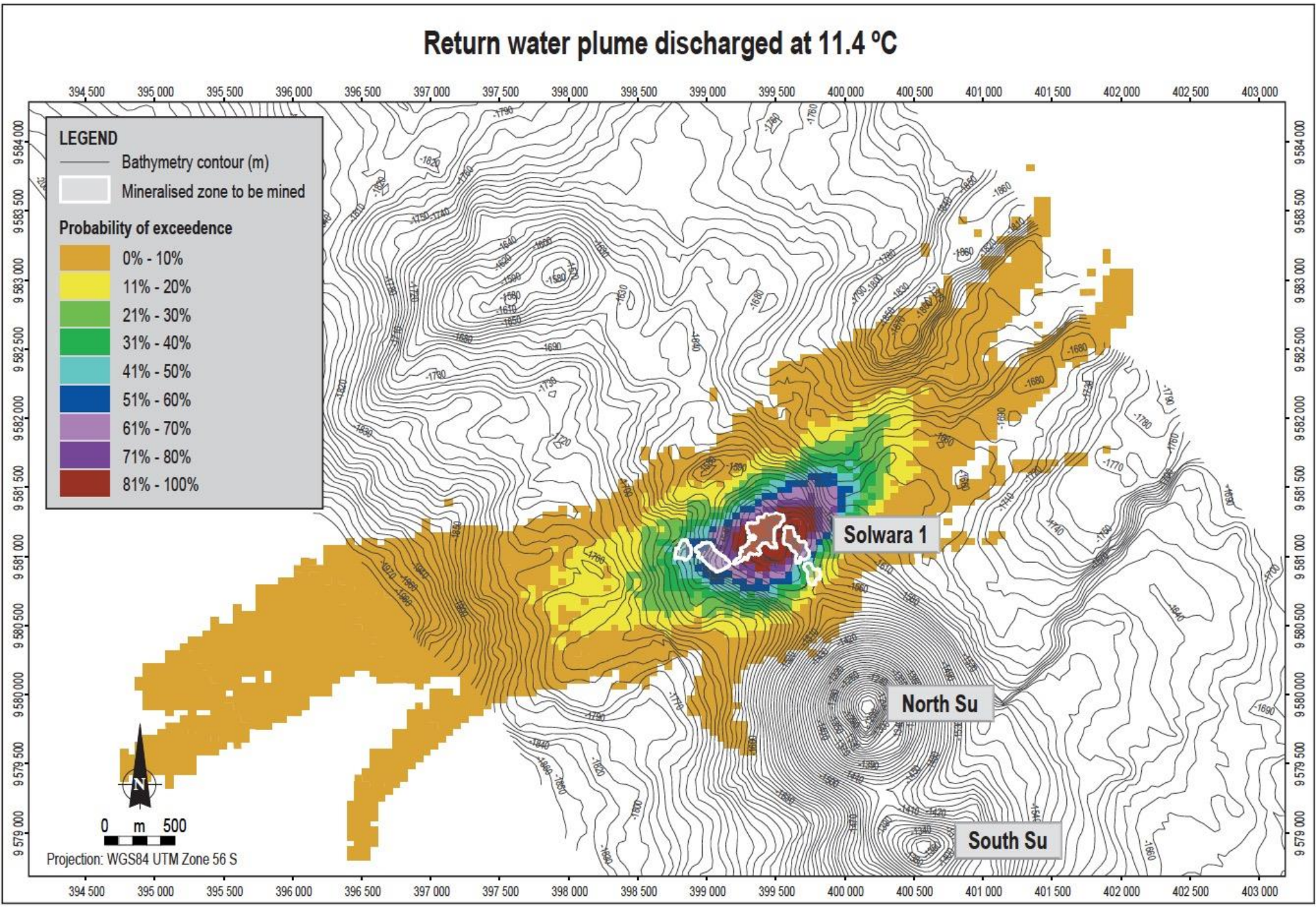
Thaler AD, Plouviez S, Saleu W, Alei F, Jacobson A, Boyle EA, Schultz TF, Carlsson J, VanDover CL (2014) Comparative population structure of two deep-sea hydrothermal-vent- associated decapods (*Chorocaris* sp. 2 and *Munidopsis lauensis*) from southwestern Pacific back-arc basins. PLoS One 9:1–13

Thaler AD, Saleu W, Carlsson J, Schultz TF, Van Dover CL (2017) Population structure of *Bathymodiolus manusensis*, a deep-sea hydrothermal vent-dependent mussel from Manus Basin, Papua New Guinea. PeerJ e3655

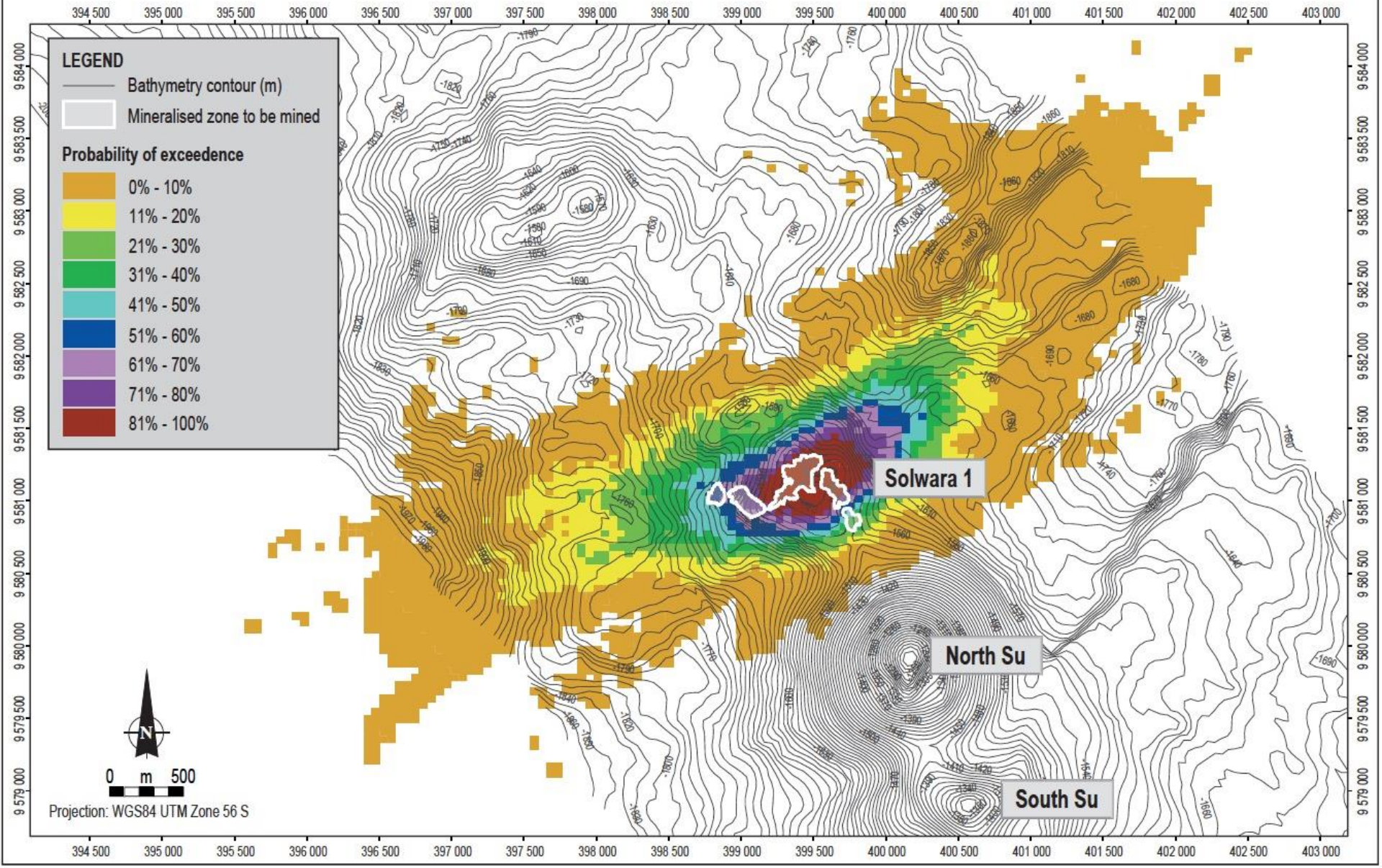
Thaler AD, Zelnio K, Saleu W, Schultz TF, Carlsson J, Cunningham C, Vrijenhoek RC, VanDover CL (2011) The spatial scale of genetic subdivision in populations of *Ifremeria nautilei*, a hydrothermal-vent gastropod from the southwest Pacific. BMC Evol Biol 11:372

Dr Samantha Smith
samantha@blueglobesolutions.com

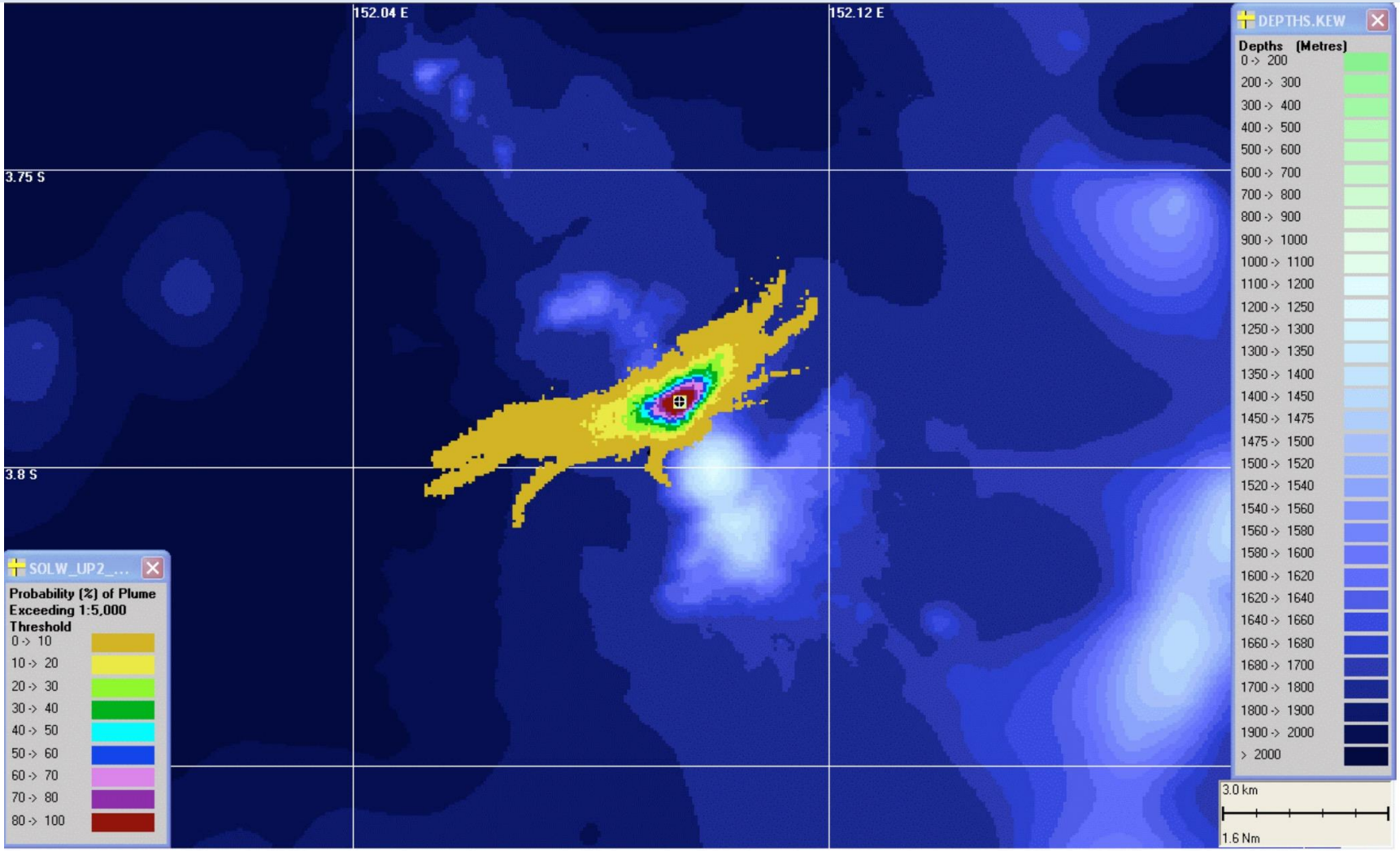
Return water plume discharged at 11.4 °C

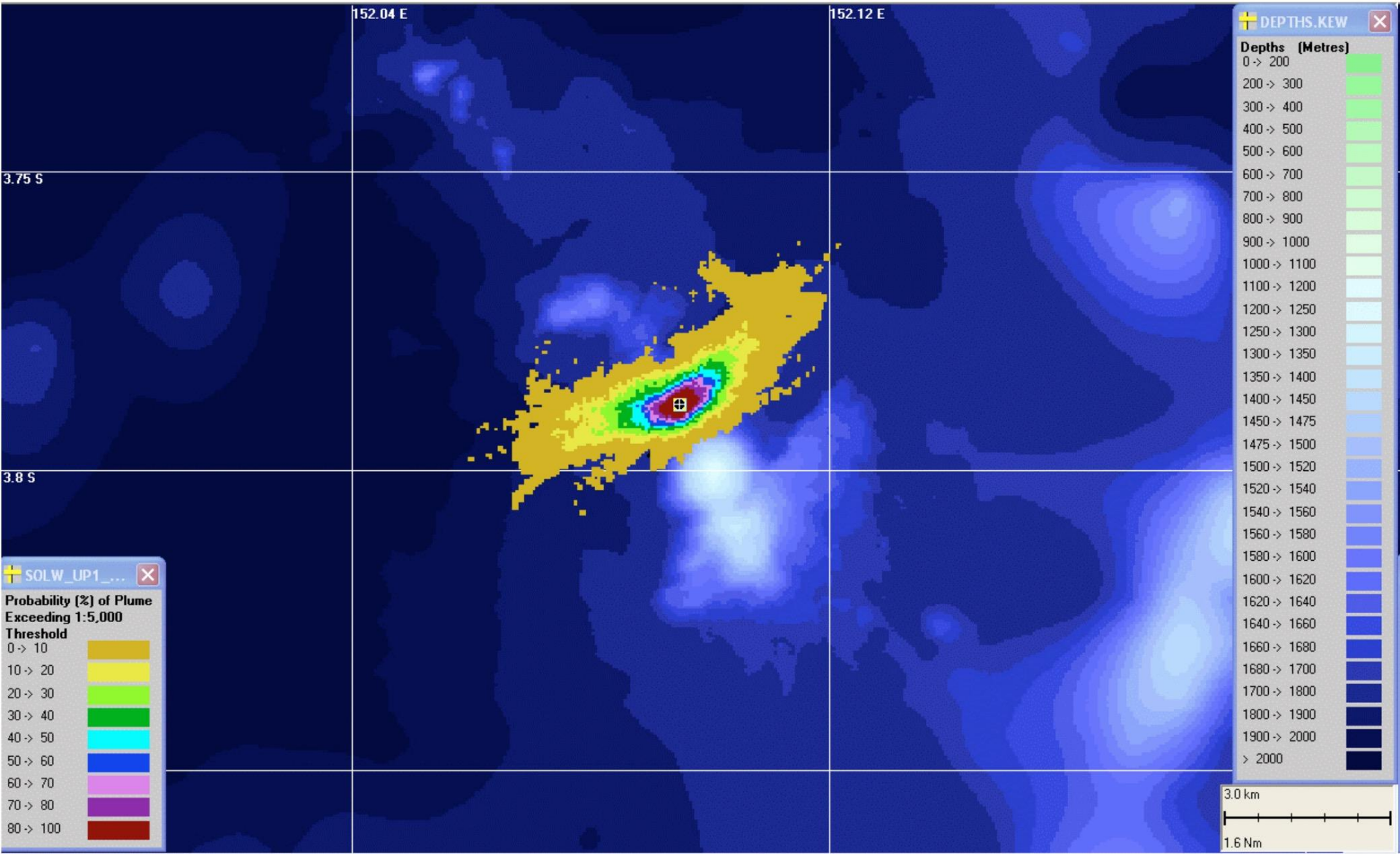


Return water plume discharged at 5.8 °C



Plume Modelling




152.04 E
152.12 E
3.75 S
3.8 S
SOLW_UP1_...
Probability (%) of Plume Exceeding 1:5,000 Threshold
0 -> 10
10 -> 20
20 -> 30
30 -> 40
40 -> 50
50 -> 60
60 -> 70
70 -> 80
80 -> 100
DEPTHS.KEW
Depths (Metres)
0 -> 200
200 -> 300
300 -> 400
400 -> 500
500 -> 600
600 -> 700
700 -> 800
800 -> 900
900 -> 1000
1000 -> 1100
1100 -> 1200
1200 -> 1250
1250 -> 1300
1300 -> 1350
1350 -> 1400
1400 -> 1450
1450 -> 1475
1475 -> 1500
1500 -> 1520
1520 -> 1540
1540 -> 1560
1560 -> 1580
1580 -> 1600
1600 -> 1620
1620 -> 1640
1640 -> 1660
1660 -> 1680
1680 -> 1700
1700 -> 1800
1800 -> 1900
1900 -> 2000
> 2000
3.0 km
1.6 Nm

Volcanic Plume from North Su