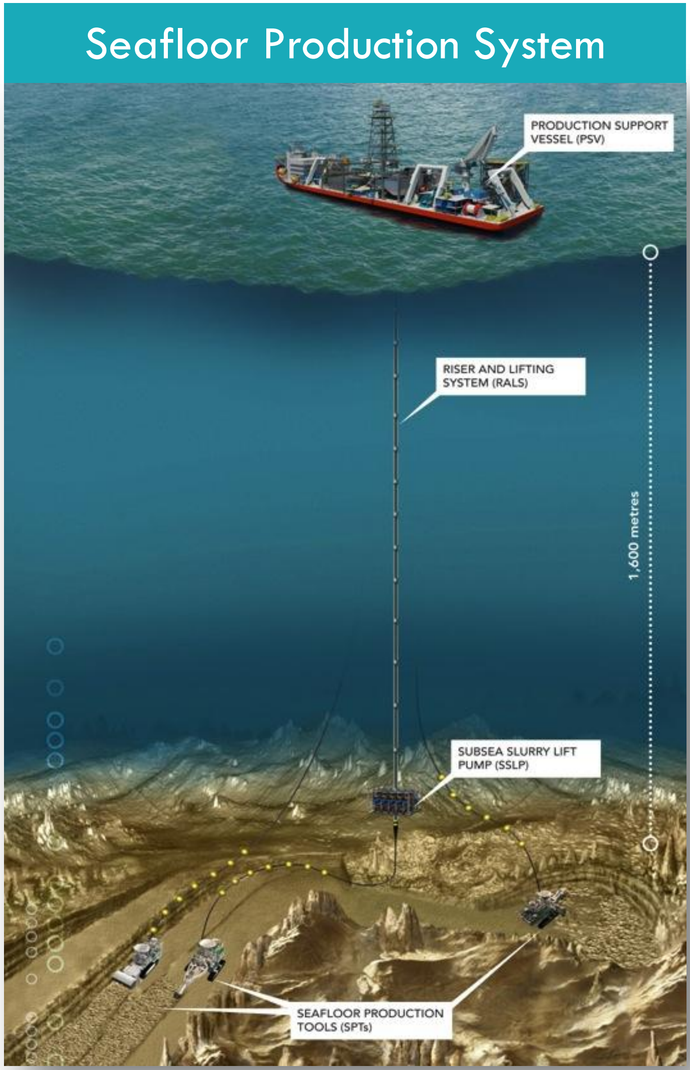
BASELINE ENVIRONMENTAL DATA COLLECTION

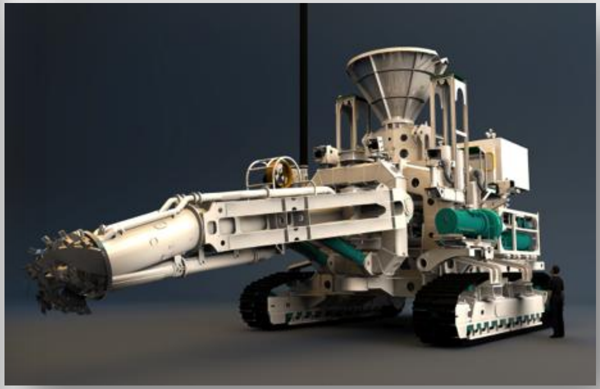
Solwara 1 Case Study

Industry-Academic Partnership

NAUTILUS Minerals Inc.

Duke NICHOLAS SCHOOL OF THE ENVIRONMENT
DUKE UNIVERSITY MARINE LAB





Images courtesy of Nautilus Minerals

Potential Impacts, Benthic Ecosystems

Physico-Chemical Impacts (Cause)
Loss of habitat
Modification (+ or -) of habitat quality
Modification of fluid flux regimes
Sediment plume and sedimentation
Light, noise
Filtration of bottom water near vents
Plumes from return water

Biological Impacts (Response)
Elimination or reduction of local populations
Decreased reproductive output
Loss of larvae, zooplankton in riser system
Local, regional, or global extinction of endemic or rare species
Decreased seafloor primary production
Altered trophic structure
Decreased diversity (genetic, species, habitat)
Mortality or impairment due to toxic sediments
Altered behaviors

Bold: Baseline data collected as part of the Duke-Nautilus Minerals partnership

Van Dover, in review, EMBS

Potential Impacts, Benthic Ecosystems

Potential Cumulative Effects
Chronic regional losses of: brood stock, genetic diversity, species, trophic interactions and complexity, resilience
Changes in community structure
Genetic isolation
Species extinctions
Species invasions
Potential loss of knowledge or other future opportunities

Van Dover, in review, EMBS

ISA 2004 Proceedings

Baseline data to include

- detailed habitat maps
- oceanographic circulation data
- microbial diversity, biomass, 1° productivity
- metazoan community structure
  - sulfide-associated
  - peripheral
  - reference
- genetic diversity of strategic species
- trophic relationships (including inactive sulfides)
- species ranges, degree of endemism
- specialized adaptations
- dose-response parameters

Nautilus Minerals EIS (available at NautilusCares website)

Coffey Natural Systems

Chapter Headings

1. introduction
2. viability of the project
3. policy, legal and administrative framework
4. stakeholder consultation
5. description of proposed development
6. development timetable
7. **description of existing environment**
8. socioeconomic environment
9. environmental impacts and mitigation measures
10. socioeconomic impacts, mitigation and management
11. accidental events and natural hazards
12. greenhouse gas emissions and climate change
13. environmental management, monitoring and reporting
14. study team
15. references
16. glossary

main report: 226 pages, plus appendices

Nautilus Minerals EIS (available at NautilusCares website)

Description of the existing environment

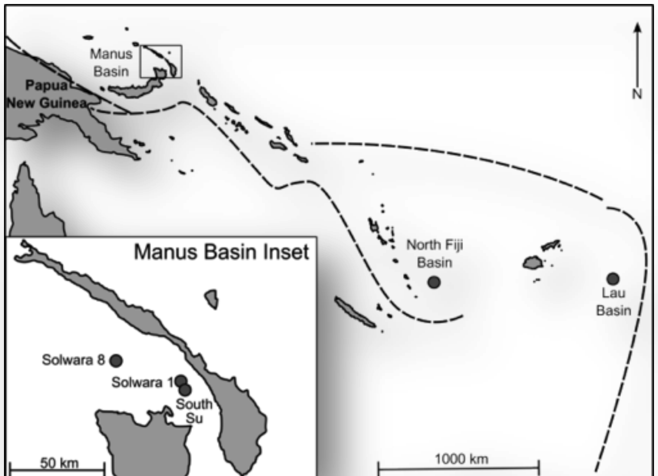
- general (tectonics, volcanics, tsunamis)
- studies completed
- **hydrothermal vents**
- meterology and air quality
- physical oceanography and deep sea sedimentation
- water quality
- sediment quality
- biological environment
- description of existing nearshore and onshore environment

Nautilus Minerals EIS (available at NautilusCares website)

Hydrothermal Vents

- introduction
- vent environment and biology
- issues and studies
  - prospect-level studies (Solwara 1, South Su)
    - ★ macrofauna of hard substrata (active, inactive)
      - comparisons to other hydrothermal sites
    - infaunal macrofaunal communities (active, inactive)
    - infaunal meiobenthos communities (active, inactive, abyssal plain)
    - ★ endemism (genetic approach)
    - fish

Setting



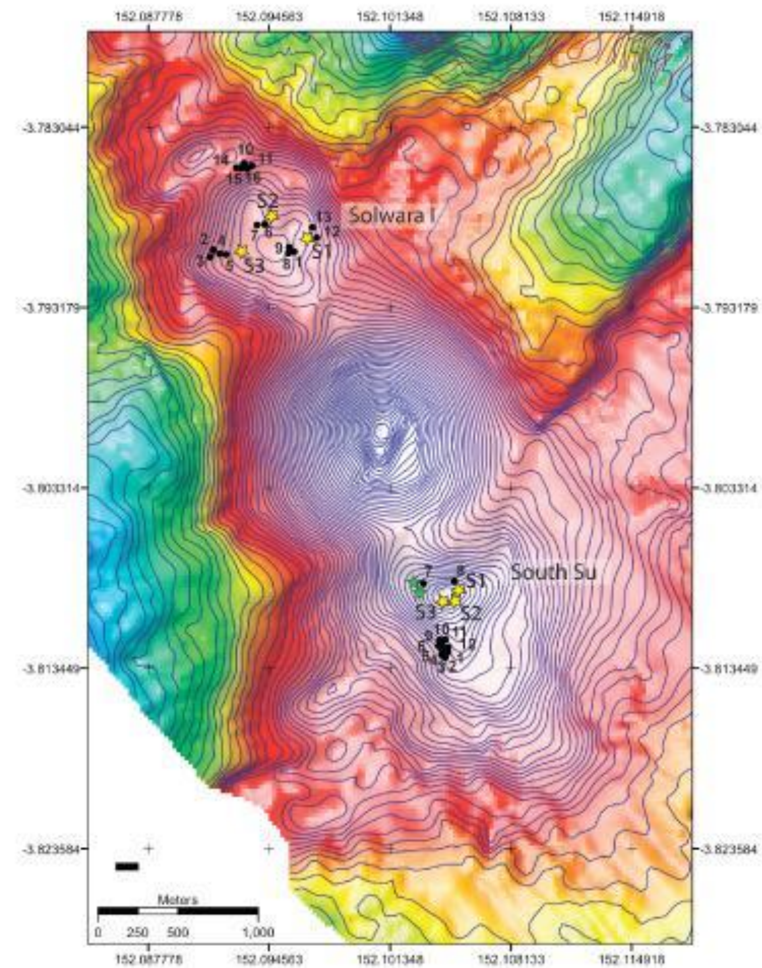
Solwara 1 Project

MANUS BASIN, PNG

Solwara 1: Extraction site

South Su: Reference Area*

*company-designated, with scientific input; to be untouched by mining

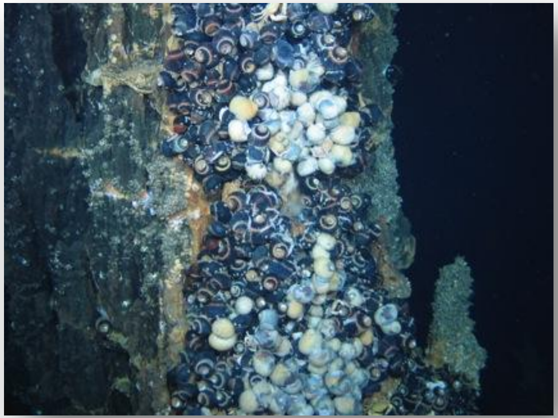


Nautilus Minerals

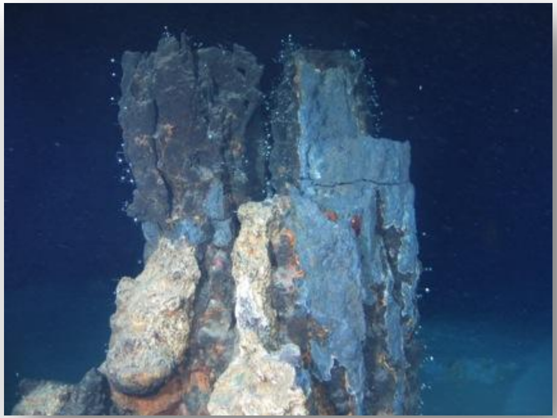
Setting: Solwara 1Active and Inactive

Active



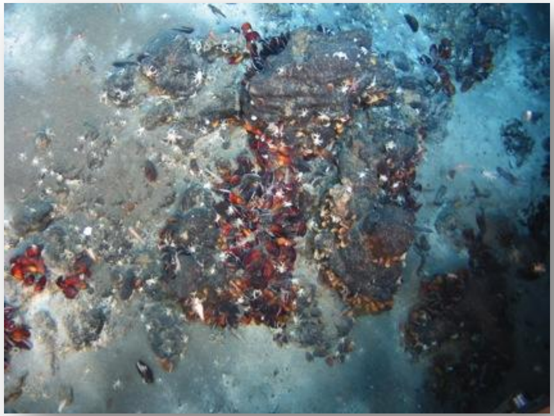


Inactive


Images courtesy Nautilus Minerals

South Su Mussels and Tubeworms






Images courtesy Nautilus Minerals

Trophic Relationships

Scientific Motivations:

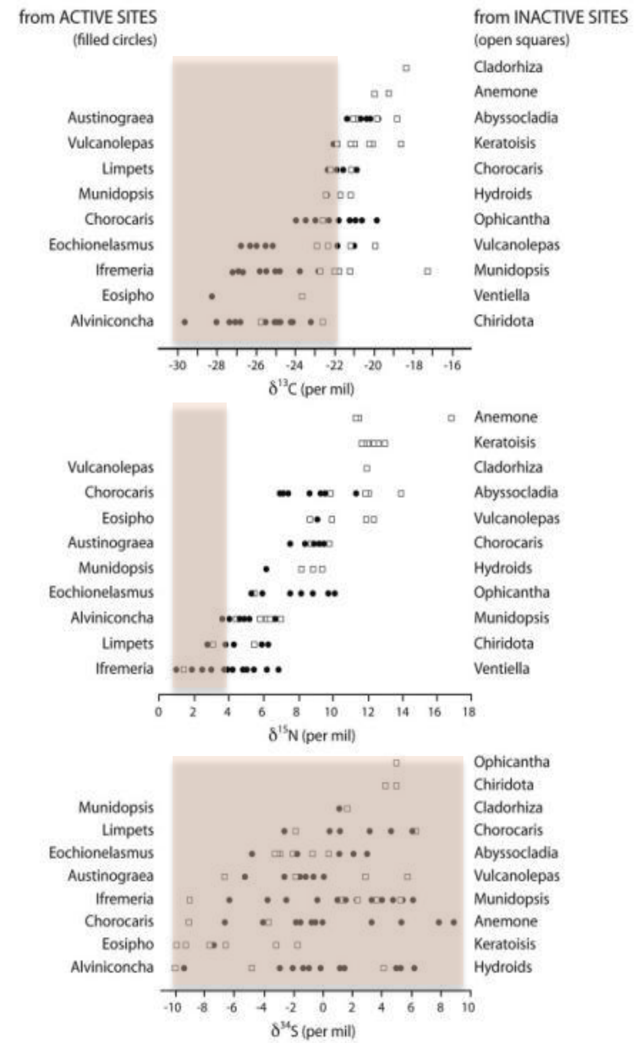
1) Understanding energy sources (sulfide oxidation vs methane oxidation)
2) Understanding the role of chemoautotrophic production in nutrition of peripheral fauna
3) Understanding trophic interactions

Approach:

C, N, S isotopic composition of animal tissues

Trophic Relationships

- Taxa at inactive sites consume chemosynthetically derived organic material



● Active sulfides

□ Inactive sulfides

Erickson et al 2009

Community Structure

Objectives

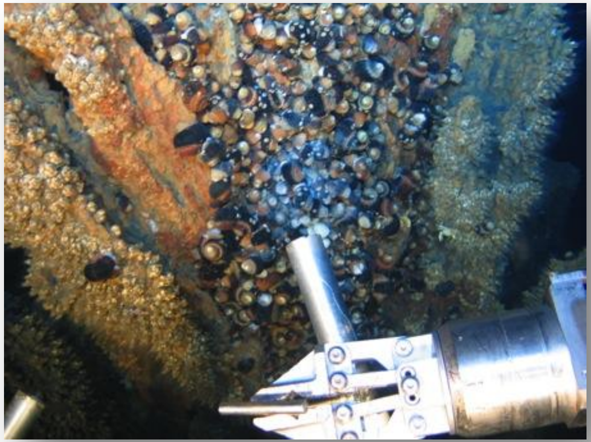
1. Describe spatial variation (patch-mound-site)
2. Efficacy of South Su as a Reserve

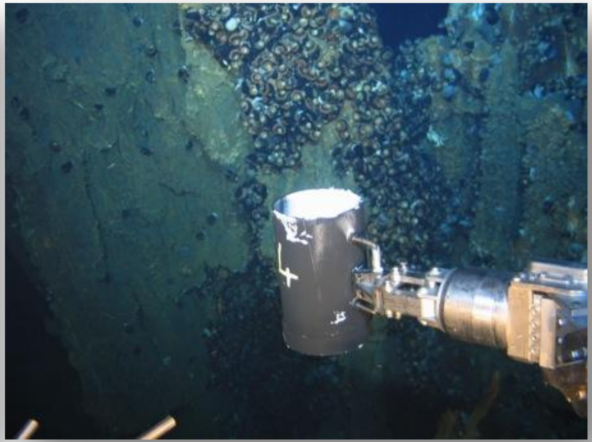
- Community structure comparisons
    - Species richness (univariate statistics)
    - Species composition (presence-absence)
    - Species-abundance relationships (multivariate statistics)
  - Inactive
  - Active
    - 3 assemblages (hairy snail, black snail, barnacle)

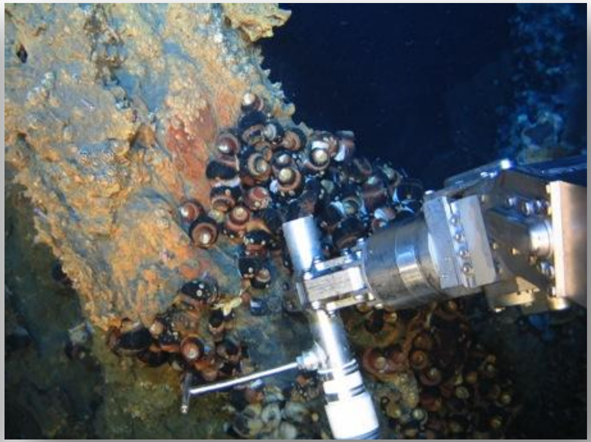
Active Sites: Sampling

0.25 m^2

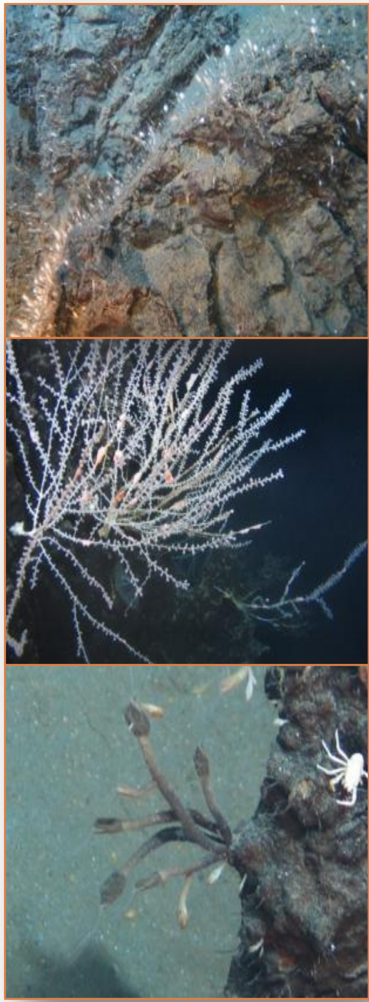
Suction – Scoop – Suction

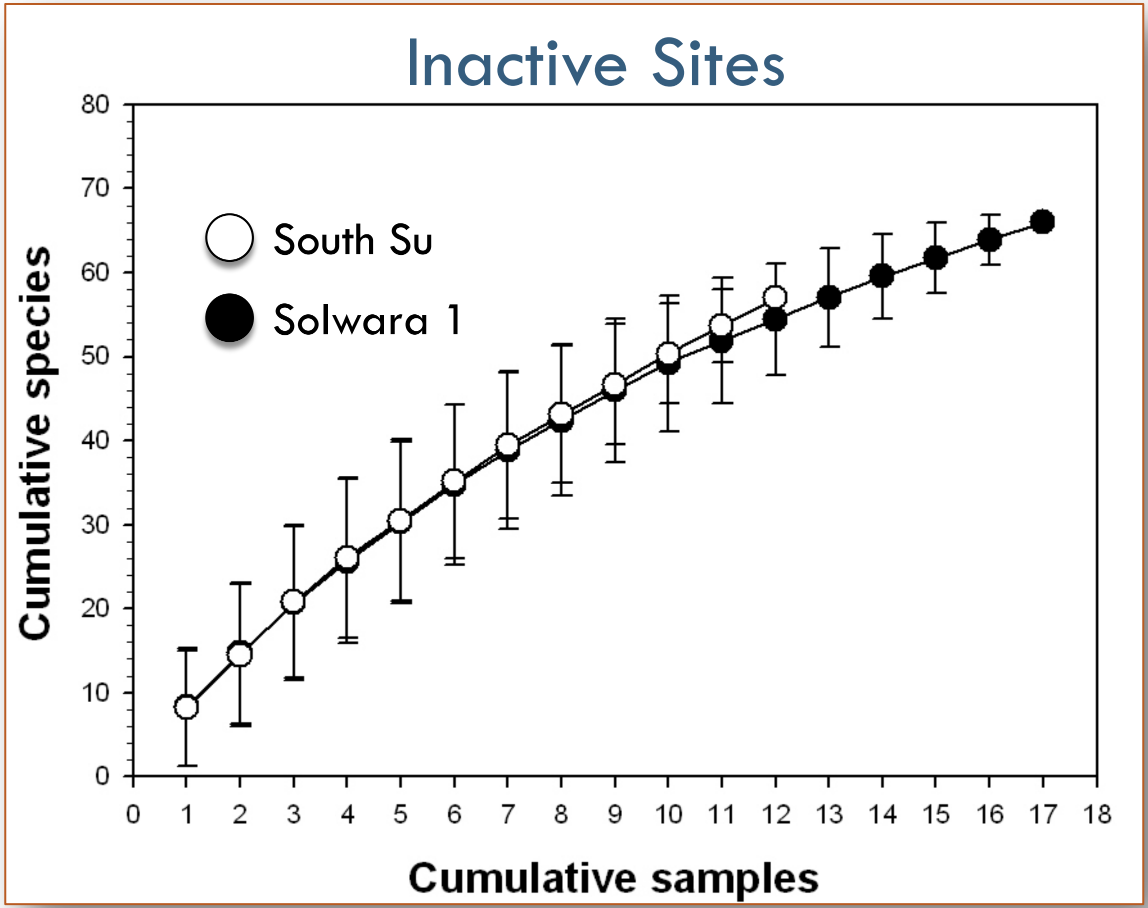






Species Richness (species-effort curves)





Images courtesy Nautilus Minerals

Collins et al. 2012

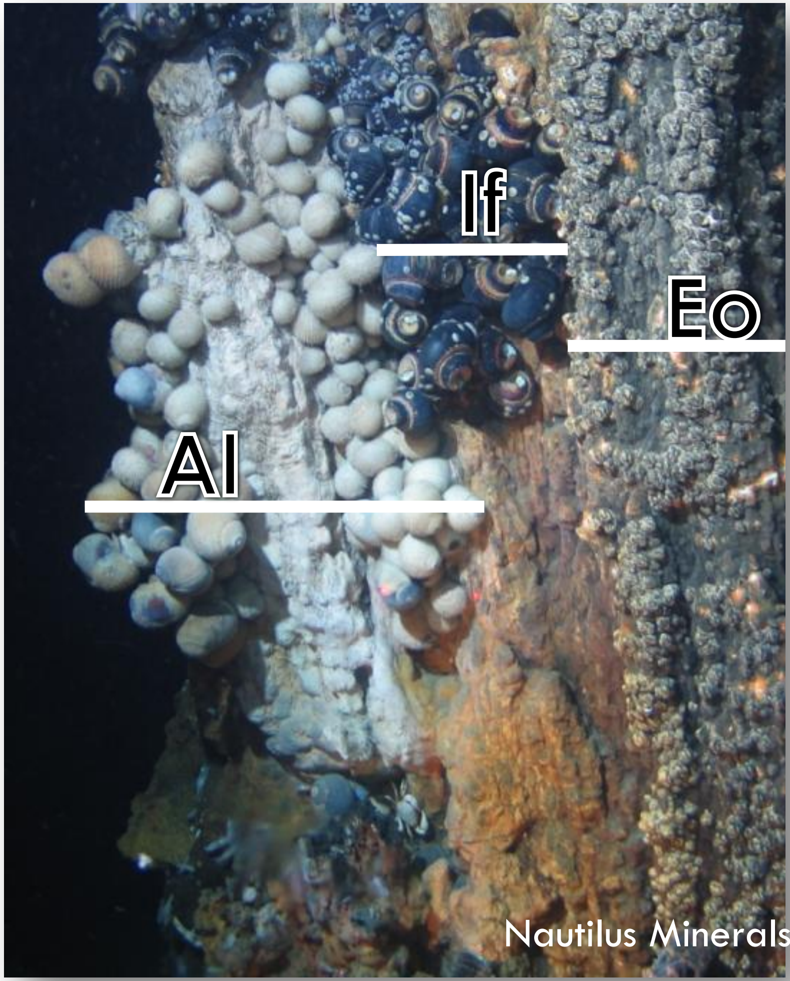
Active Sites

Indicator Habitats

IF *Ifremeria*

Eo *Eochionelasmus*

Al *Alviniconcha*

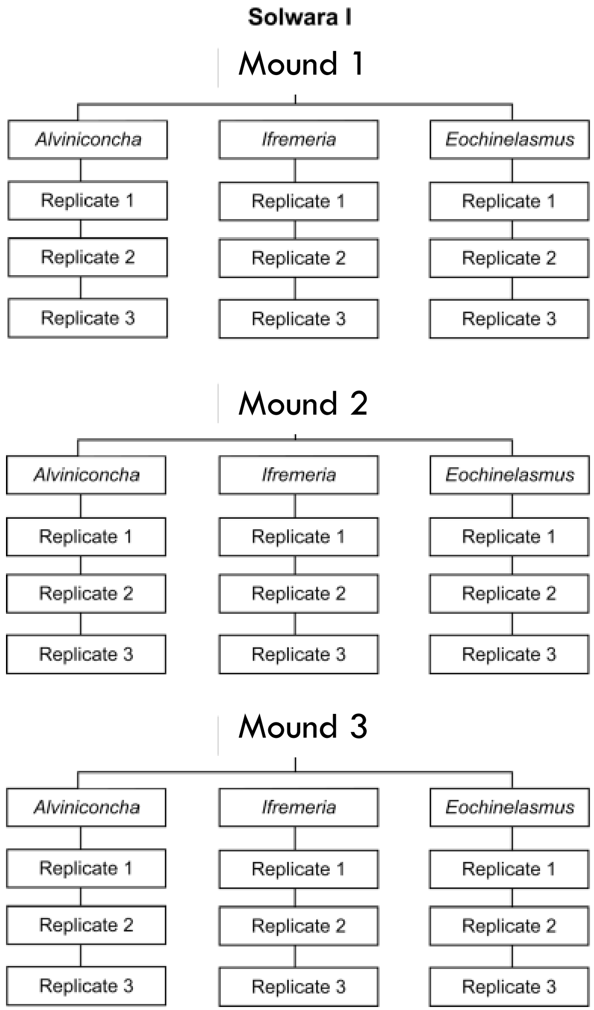


Active Sites: Sampling Scheme

Nested Sampling

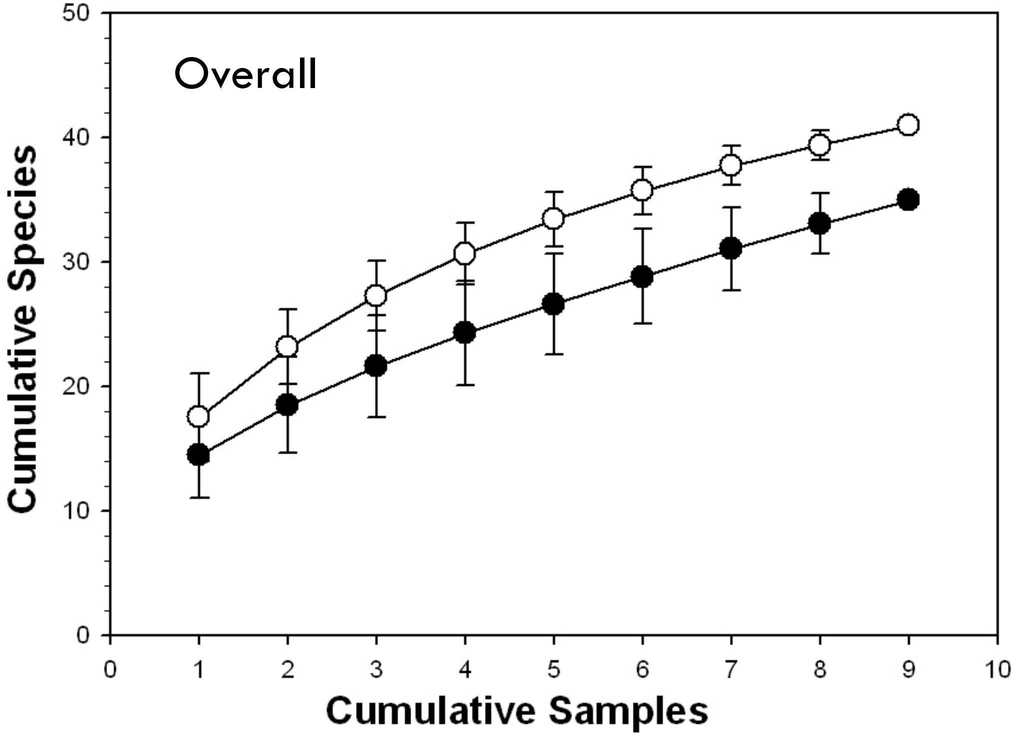
single time point, to date

low-T chemical data not collected



Collins et al. 2012

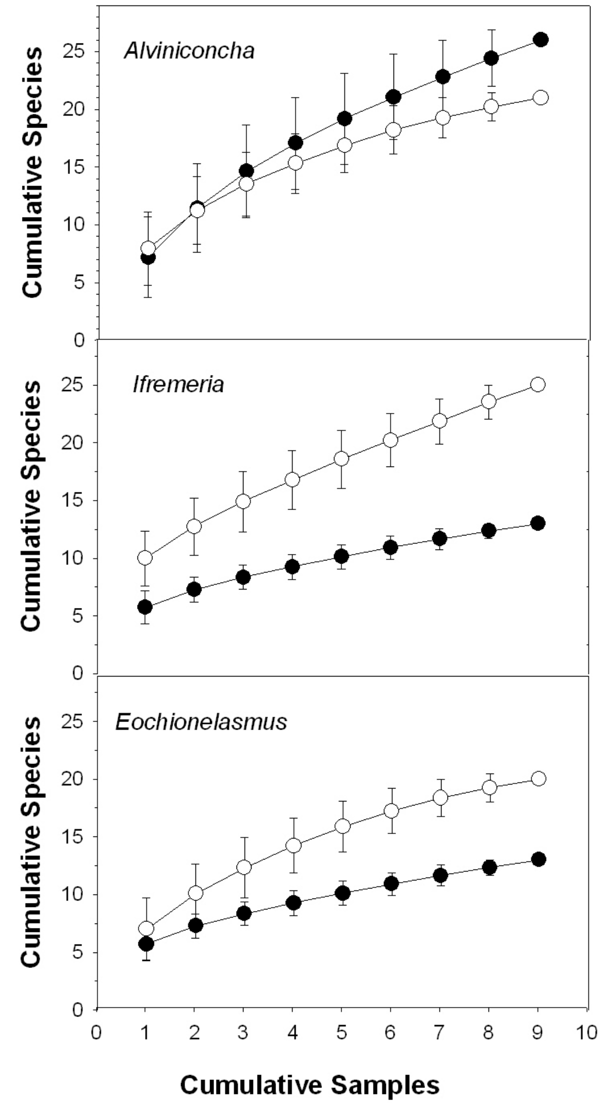
Active Sites: Species Richness



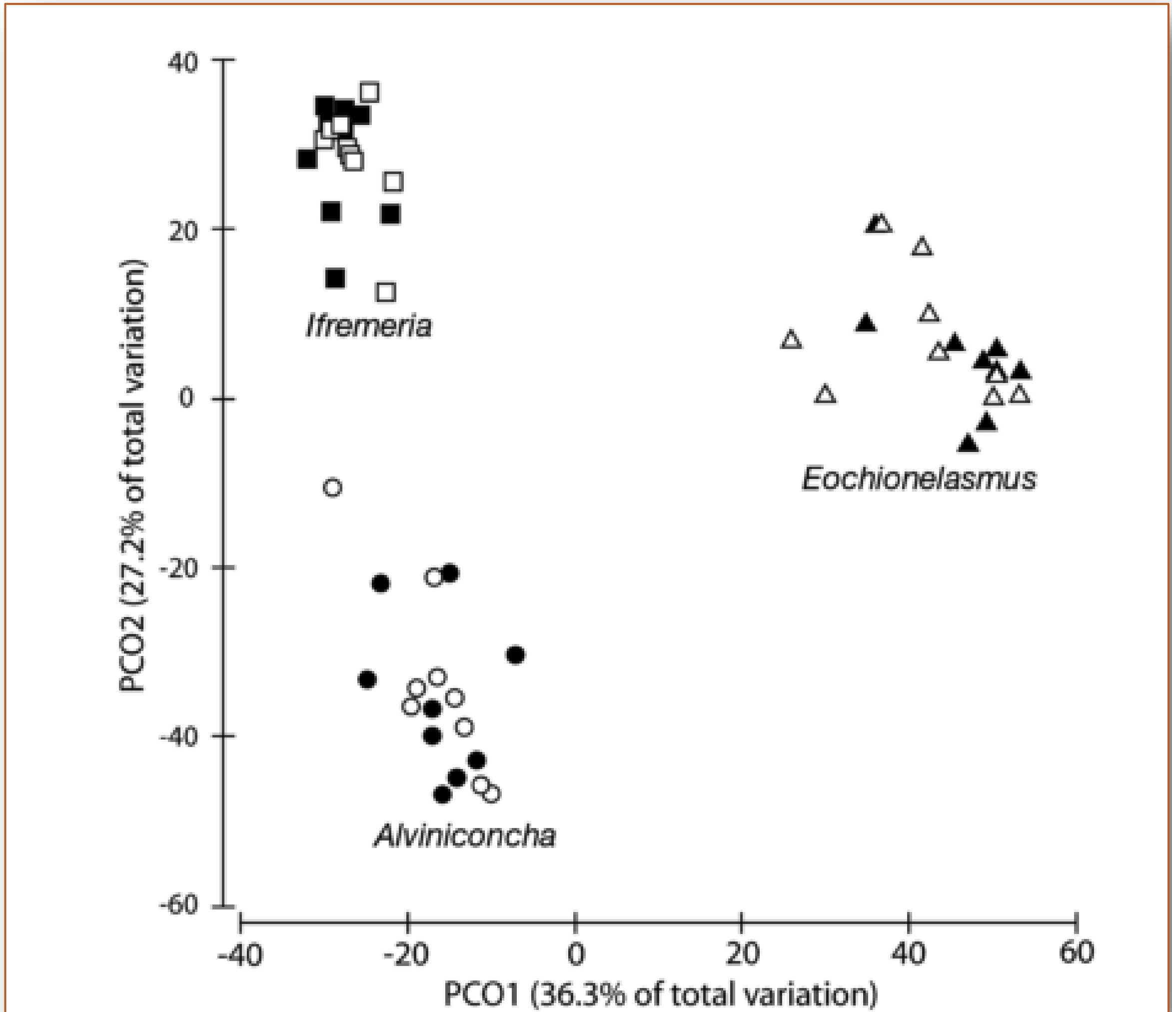
Solwara 1

South Su

Collins et al. 2012



Active Sites: Multivariate Comparisons



Community Structure

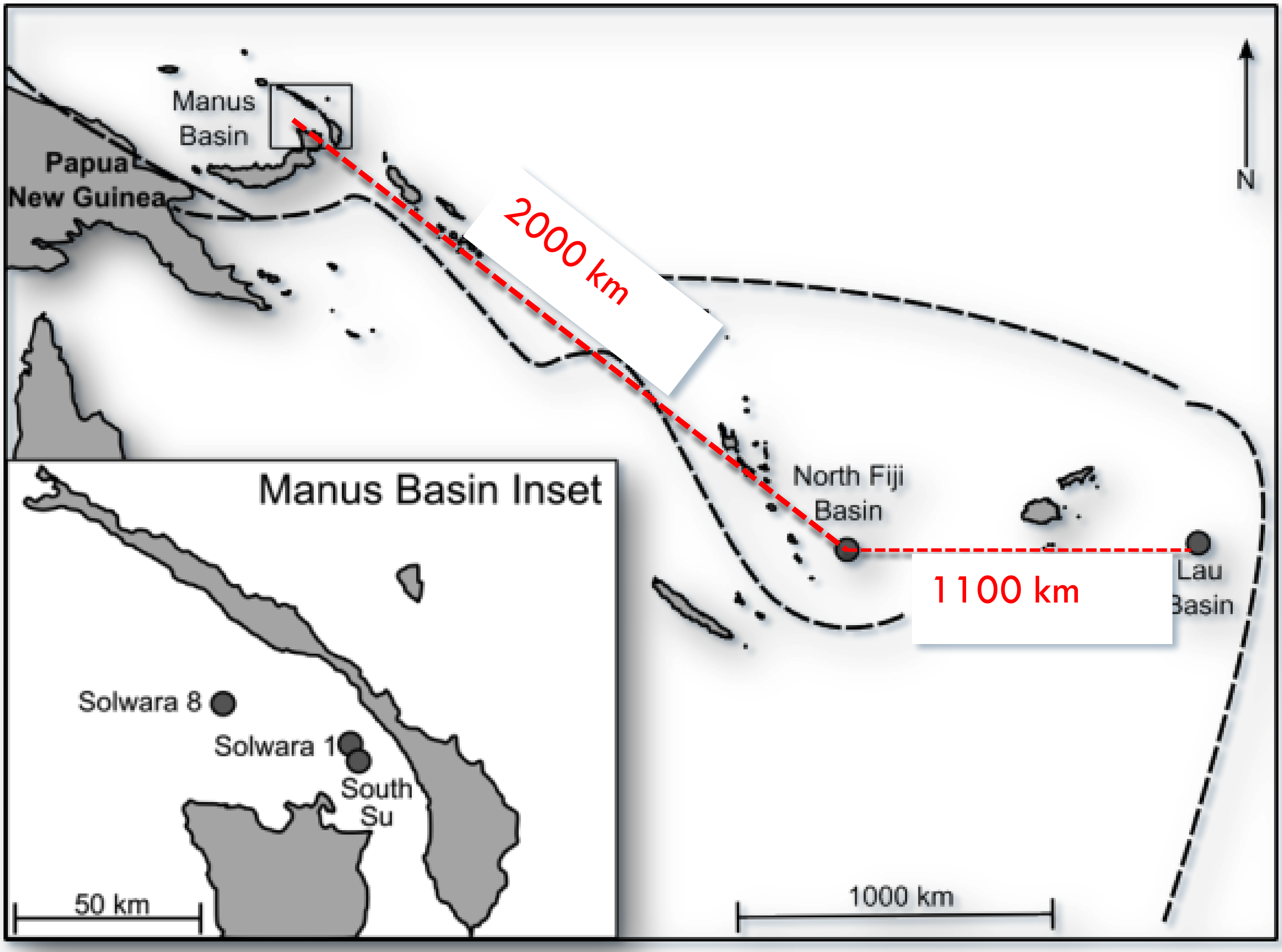
species-abundance

■ ▲ ● Solwara 1

□ △ ○ South Su

Collins et al. 2012

Connectivity Studies



Connectivity Studies

A selection of numerically dominant taxa at Manus Basin vents			
Ifremeria nautilei	black snail	sessile; partial brooding	holobiont; vent endemic
Olgasolaris tollmanni	limpet	sessile	deep sea?
Chorocaris sp. 2	shrimp	mobile	vent endemic?
Munidopsis lauensis	squat lobster	mobile	deep sea
Eochionelasmus ohtai	sessile barnacle	attached	vent endemic?
Vulcanolepas sp.	stalked barnacle	attached	deep sea?

Scale bars = 1 cm

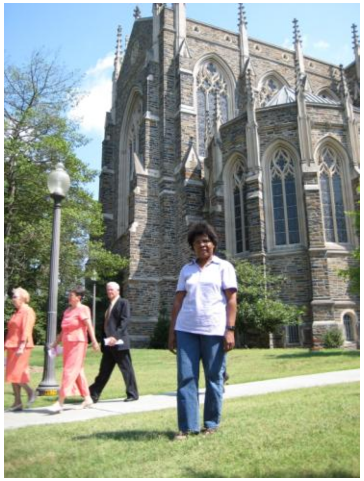
Illustrations by Karen Jacobsen

NOTE: some unpublished data in this slide was shared as privileged information during this workshop. It is customary to withdraw this information in informally distributed ppts until the full scientific review process is complete. If you have questions about the data or wish to see the manuscripts once they are published, please contact me: clv3@duke.edu

		Marker	Genetic Differentiation		
			Manus	N Fiji	Lau
Ifremeria nautilei Thaler et al.	black snail	COI			
		msats			
Olgasolaris tollmanni Plouviez et al.	limpet	COI	data withheld pending publication		
		RAD-tag			
Chorocaris sp. 2 Thaler et al.	shrimp	COI	data withheld pending publication		
		msats			
Munidopsis lauensis Thaler et al.	squat lobster	COI	data withheld pending publication		
		msats			
Eochionelasmus ohtai Plouviez et al.	sessile barnacle	COI			
Vulcanolepas sp. Plouviez et al.	stalked barnacle	COI			

Training

PNG Interns
Martha Mungkaje
William Saleu*
Hosea Gomuna
Freddie Alei



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*and the ISA

Lessons Learned

- Replicate sampling, species-effort curves, and multivariate analyses of community structure (species-abundance matrices) are robust methods for establishing baselines and for comparing sites
- Patch and mound level of detail proved not to be critical for community structure comparisons or for connectivity studies in the Solwara Project
  - could reduce subsequent time-series baseline effort
  - findings may allow for simplified monitoring approaches

Lessons Learned

- Samples for trophic studies, community structure, and connectivity should be collected on the same expedition and be targeted based on habitat maps
  - Non-trivial, labor intensive
  - Requires careful sample preservation, logging, and coding
- Shore-based effort is of long duration in an academic setting; work is done by undergraduate and graduate students
  - Advantages
    - true costs are heavily subsidized by university resources (faculty salary, student stipends and tuition, instrumentation, other)
    - pressure to publish in peer-reviewed journals (data sharing, context)
    - contributes to training the next generation of scientists and leaders

Lessons Learned

- Nautilus-supported PNG traineeships at Duke contribute to project productivity and capacity building
  - criteria for selection are important
    - ability to adapt to work independently, to adapt to a different academic and social culture
  - peer- or near-peer mentoring is important

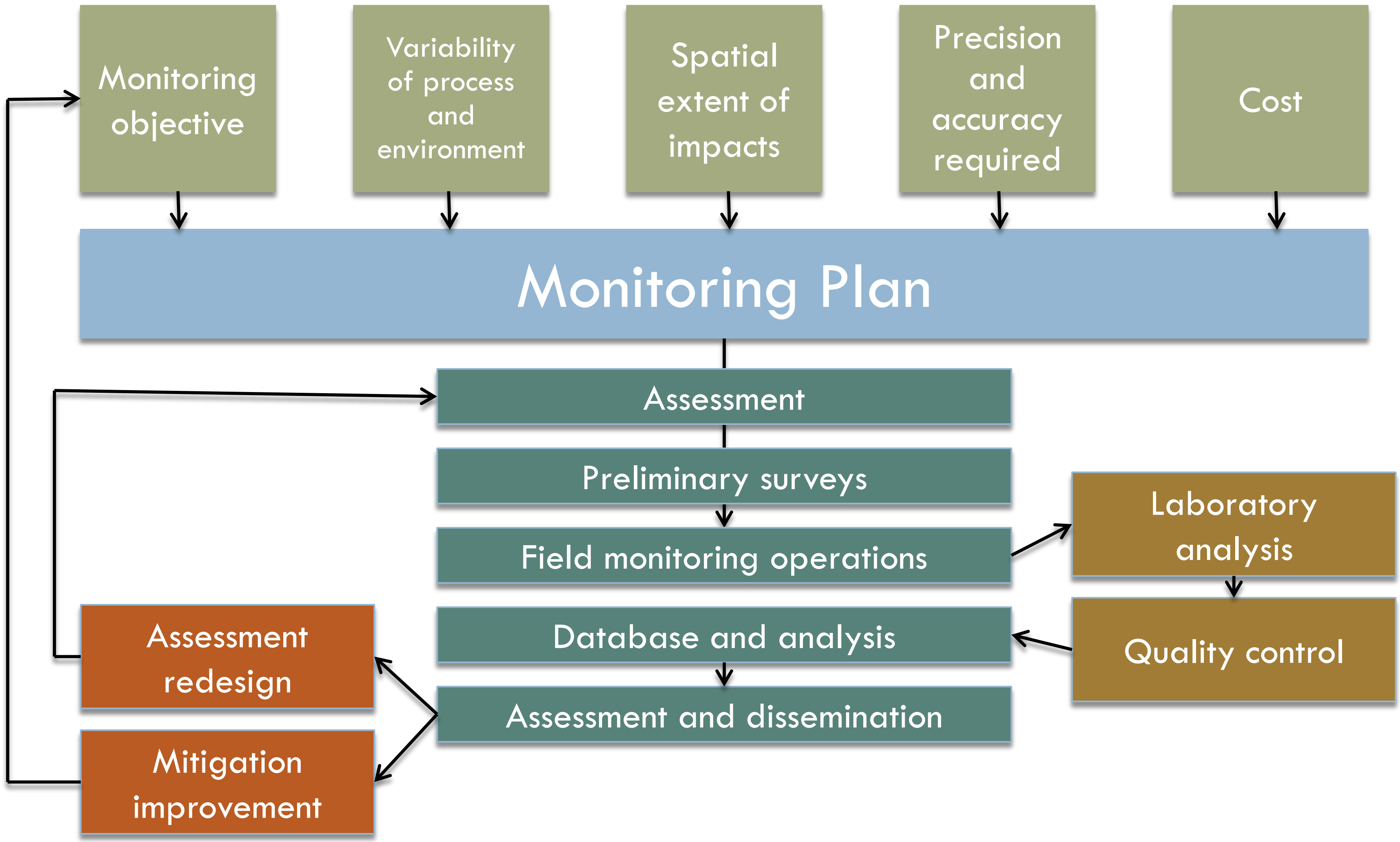
Opportunities

- Scientific value can be as great as the management value in early stages of baseline development
- High-resolution geo-referenced habitat mapping and imaging using an AUV is a new opportunity
- Ground-truthed, regional ceanographic models for LaGrangian transport are extremely useful for testing hypotheses and interpreting genetic data; critical for environmental management
- Rad-TAG sequencing approach is relatively low-cost and high resolution method for assessing population structure and directionality of gene flow

Key Points

- Major disturbances and potential impacts of mining on hydrothermal vent ecosystems have been identified
- Baseline data on community structure for Solwara 1 and South Su include quantitative metrics against which recovery from a mining event can be assessed, so long as natural variability is assessed prior to mining
- Population genetic data for key indicator species in Manus Basin indicate that the scale of the management unit is at the basin level (rather than patch, mound, or site)

Toward a monitoring plan, assessment



Training

Marine Conservation Summer Institute

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- 5-week residential course
- taught by Duke faculty
- with global fellows

2014 themes include deep-ocean stewardship and international law

~$7000 includes tuition, room & board