Deep Sea Mining: Environmental Monitoring Assessment Challenges

Out of sight should NOT be out of mind…

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The Natural History Museum, London

One of the World's Major Biodiversity Centres

320 GIA-funded scientists working in six scientific areas:

Botany, Entomology, Library & Information Science, Mineralogy, Palaeontology and Zoology

Department of Life Sciences

150 scientists plus 90 post-docs and PhD students

60 million specimens in the National Collection ranging from whale skeletons to protozoa, plants to beetles

Research covers biodiversity discovery, evolutionary history, biomedical parasitology and environmental change

INING

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Facts and figures

- Funded under FP7 theme "*Sustainable management of Europe's deep-sea and sub-seafloor resources*" (Grant Agreement 603418)
- Project duration 3 years, starting 1 November 2013
- Project budget € 12.5 million; EC financial contribution € 9 million
- Consortium comprises 32 partners across 11 countries
- Partnership includes 8 SMEs and 4 industry partners
- Expertise includes marine scientists, policy experts, social scientists, technologists, …..

MIDAS is funded by the European Union's Framework 7 Programme under the theme "*Sustainable management of Europe's deep sea and sub-seafloor resources*", Grant Agreement 603418.

Taxonomic Standardisation Workshops

Environmental Monitoring–Main drivers

Deep sea is the last major frontier and increasing interest in exploitation of resources – oil & gas, mineral, fisheries.

However the deep-sea is also the final great scientific frontier on the planet – we are still exploring this environment.

Problem in assessing impacts from anthropogenic activities like mining.

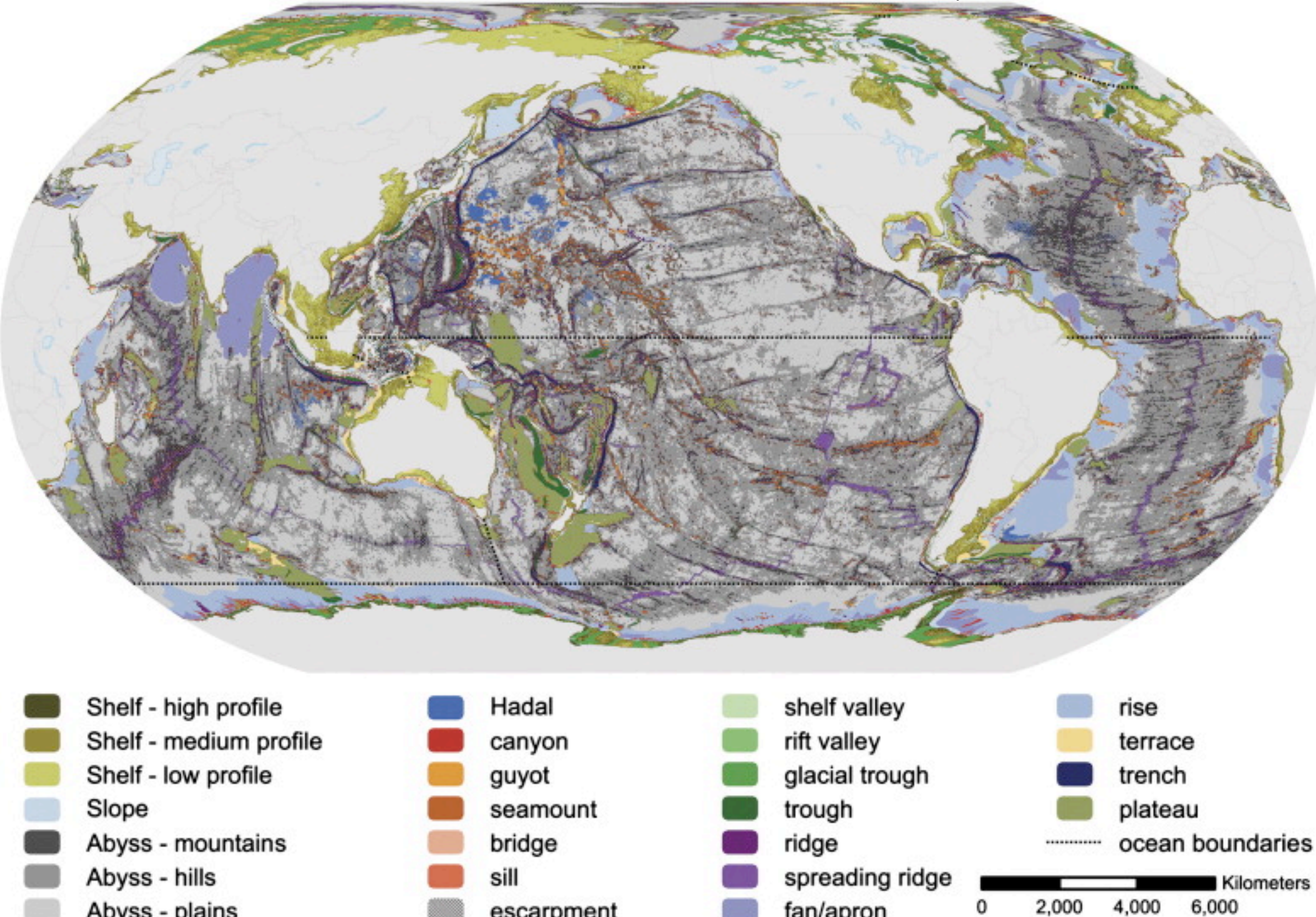
Knowledge of the ecology and distribution of fauna within and between mining sites and the surrounding region is crucial in developing management plans.

Without such knowledge it becomes almost impossible to determine the impact of resource extraction on a regional scale.

In effect how likely is it that such activities lead to the permanent extinction of species?

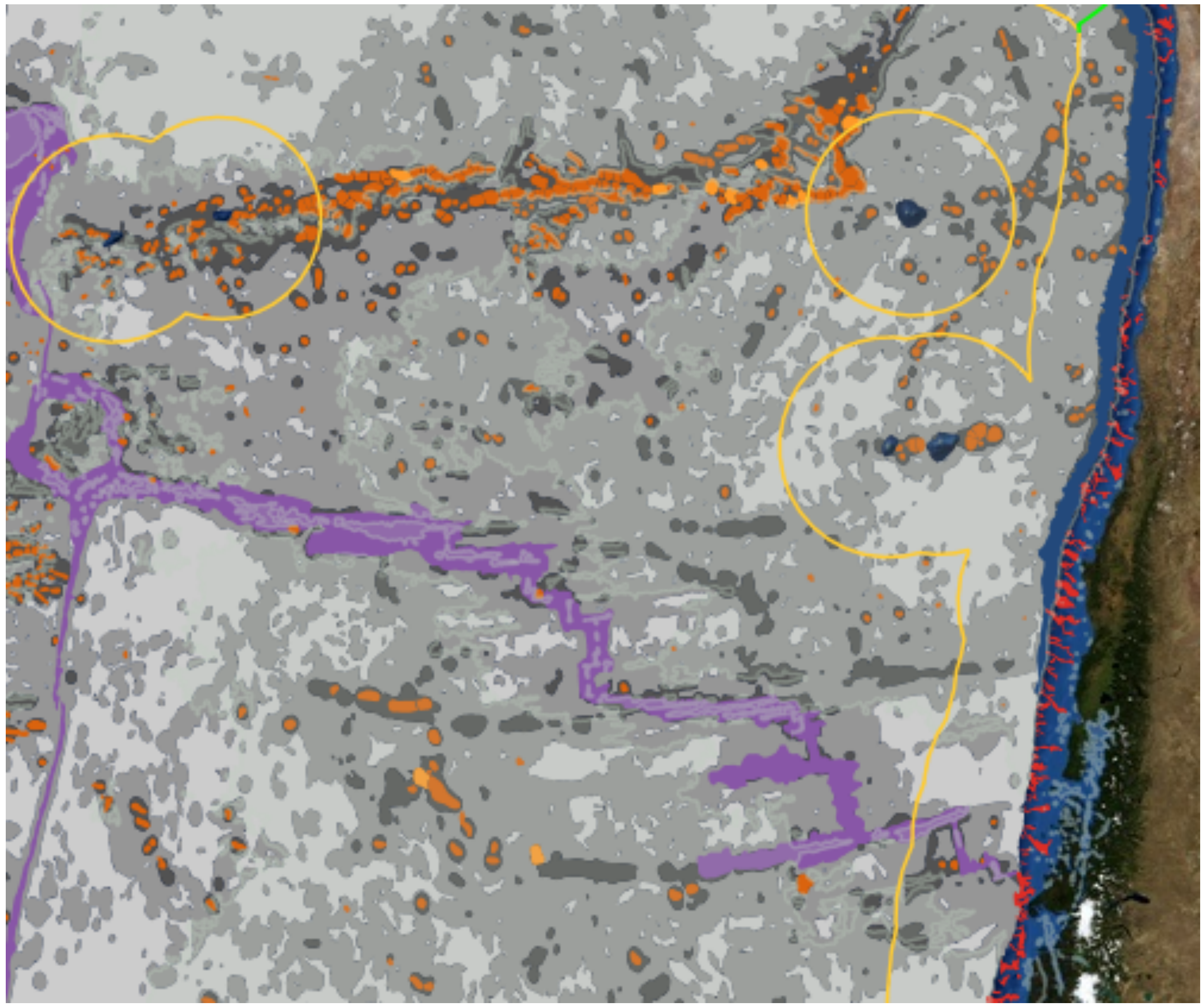
How likely is it that our activities lead to environmental and human harm?

Challenge: What do we mean by the "deep sea"



Geomorphological heterogeneity in the SE Pacific adjacent to the Chile margin

- Trenches
- Canyons
- Seamounts
- Methane Seeps
- OMZ
- Abyssal plains and hills
- Sediment slope and rise
- Spreading ridges



ENVIRONMENTAL, LEGAL AND TECHNICAL CHALLENGES FOR DEEP SEA MINING
Ministerio de Relaciones Exteriores - Santiago, Chile

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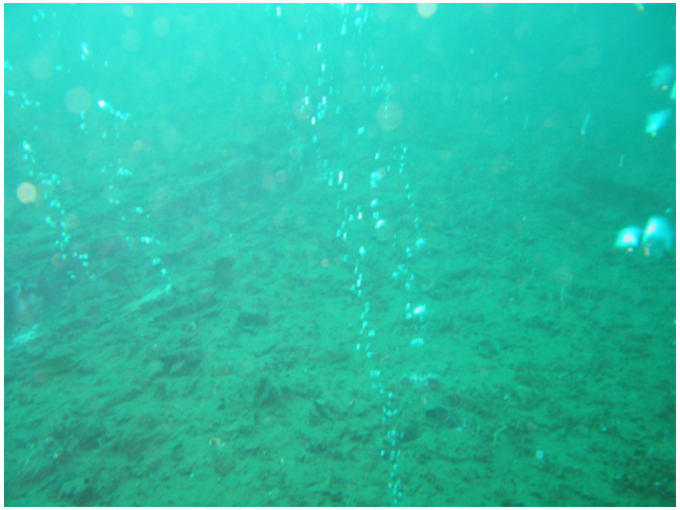
Habitat heterogeneity

Each of the major habitats supports a diverse and different fauna

Seamounts- biodiversity hotspots

Methane seeps



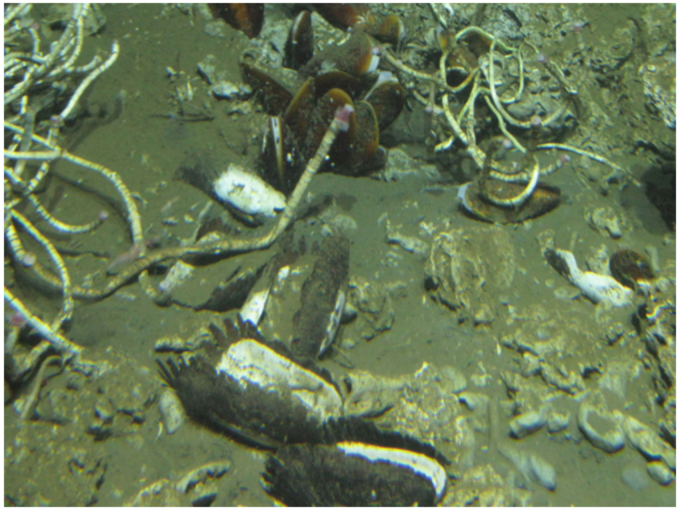


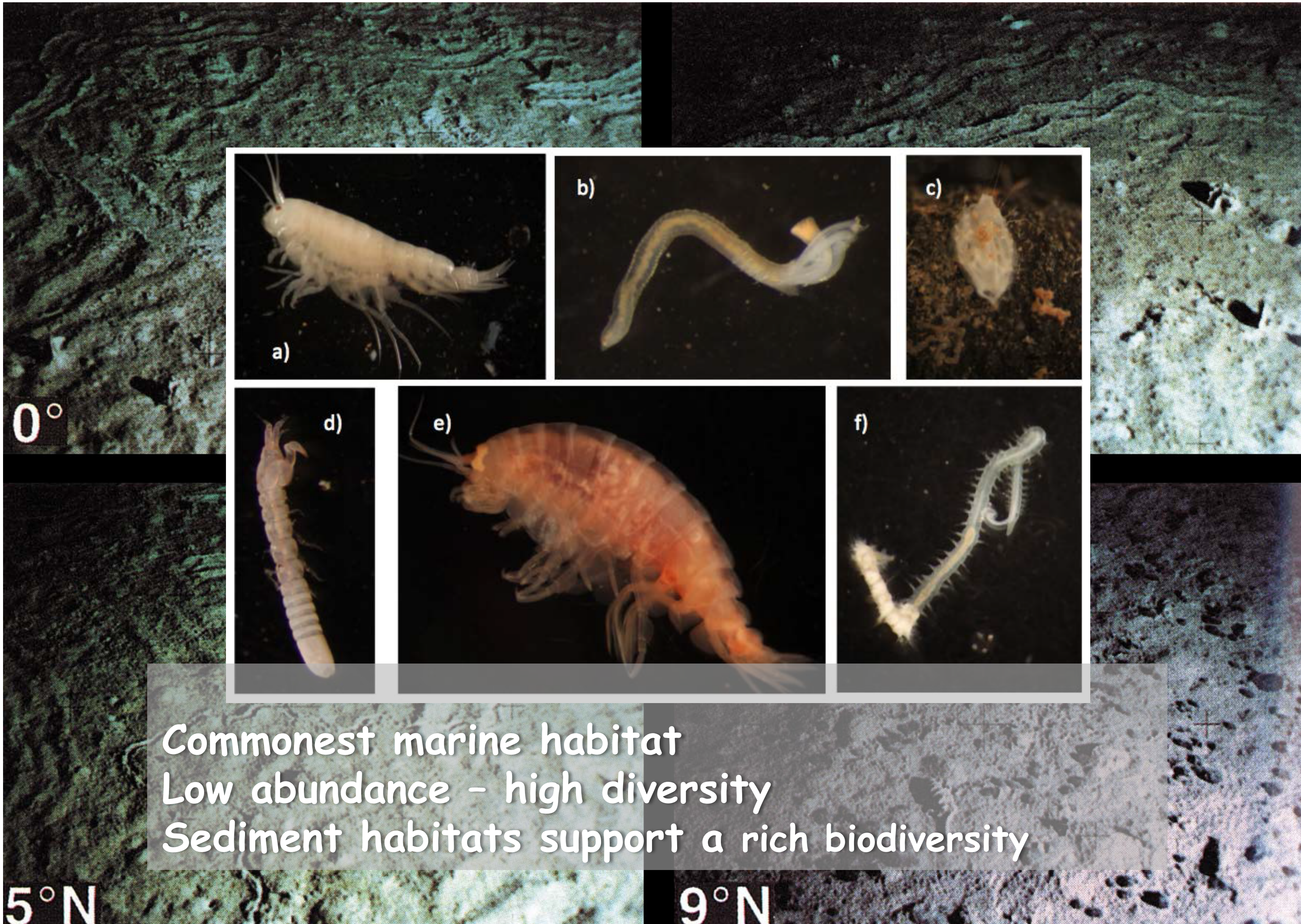
Image from NOAA

Common along active margins
High biomass but relatively low species richness
Ecologically distinct fauna – relying on symbiosis and methane
High endemism - Each new methane seep has new unique species

Methane seeps

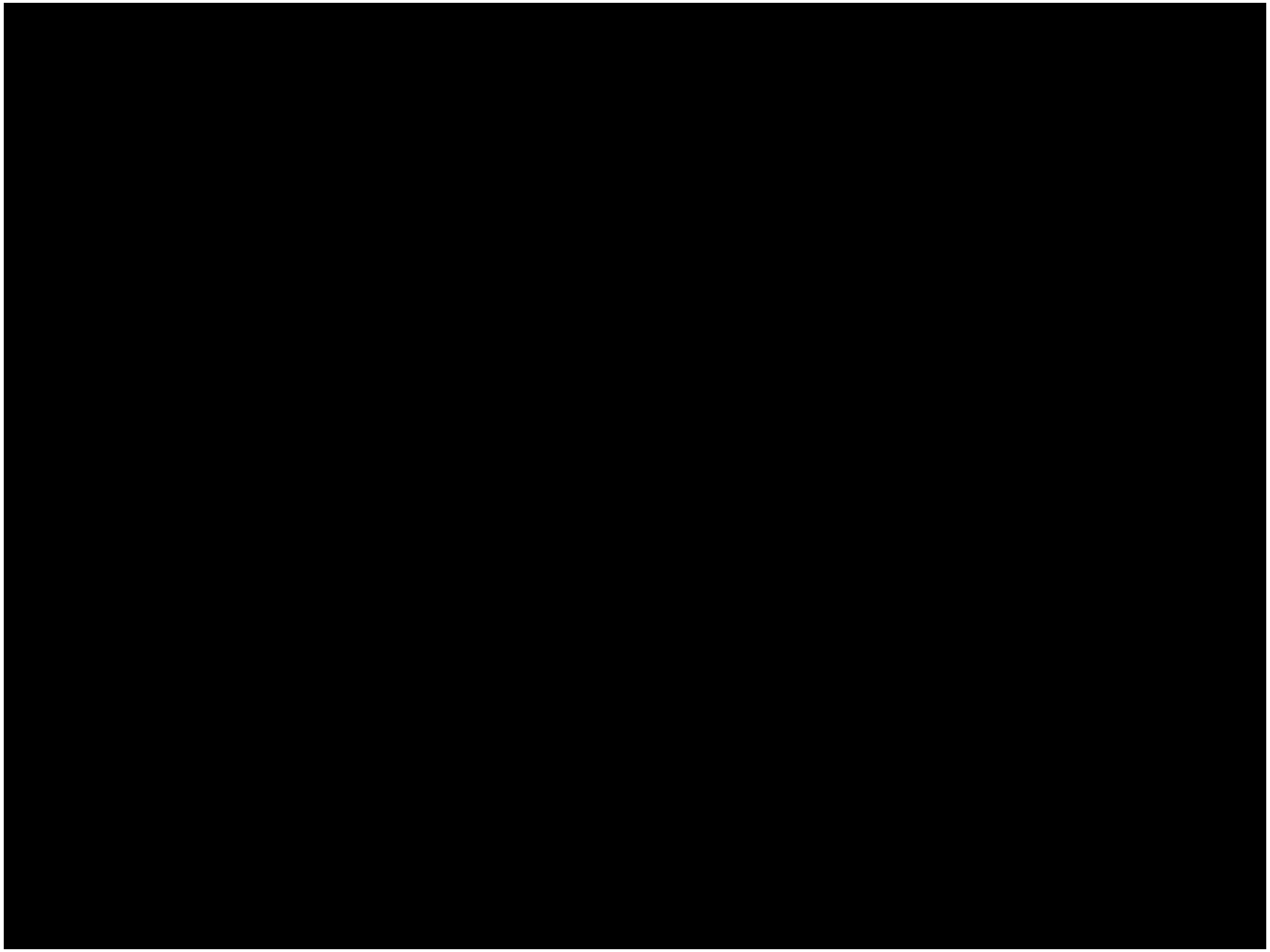
Mud volcanoes — large seabed structures with diameters of 1–10 km formed by gas, pore fluids and mud eruptions. These structures are characterized by seafloor elevations with a centrally pointed, flat or crater-like top14.
Pockmarks — depressions in the sea floor, also resulting from gas eruption, but usually of smaller size than mud volcanoes (10–1,000 m). Upward fluid flow and microscale currents are assumed to prevent them from filling with sediments13.
Gas chimneys — subseafloor structures visualized by seismic records as noisy or blank zones. They can extend kilometres into the sea bed and form large pipes that facilitate the upward migration of gas13.
Hydrate mounds — formed by surficial deposits of gas hydrate at the sea floor. This hilly seafloor landscape forms through the expansion of gas hydrate accumulations and the escape of buoyant chunks of hydrates18, 80.
Carbonate slabs — carbonate precipitates that cement large areas of sea floor. They form under anoxic conditions from the anaerobic oxidation of methane. Outcropping carbonate cements can be detected acoustically by multibeam backscatter signals

Sediment habitats



Commonest marine habitat
Low abundance – high diversity
Sediment habitats support a rich biodiversity

Manganese Nodule Field of the Clipperton Clarion Zone



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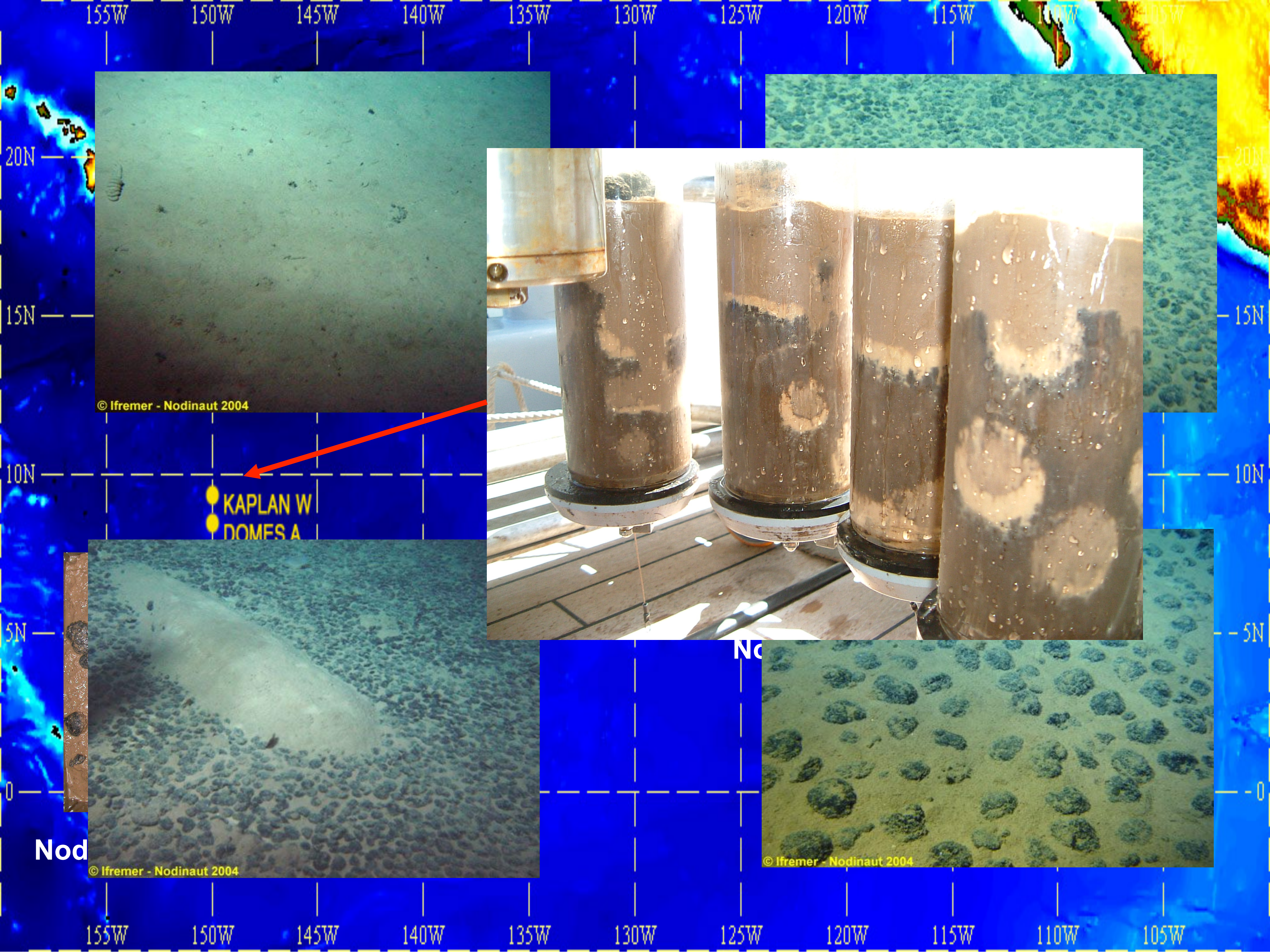
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Current State Of The Art: Gap Analysis

Biodiversity and Biogeographic Information

Taxonomy

Taxonomic keys and resolution-was the literature comprehensive?
Collections–were collections being archived and were they available?
What mechanisms were available to exchange information and data?

Sampling

Sample coverage–what was being collected and the spatial coverage
Molecular samples/data–being taken?
Sampling standardisation – are the same approaches being made using comparable protocols and equipment?

Biogeographic data

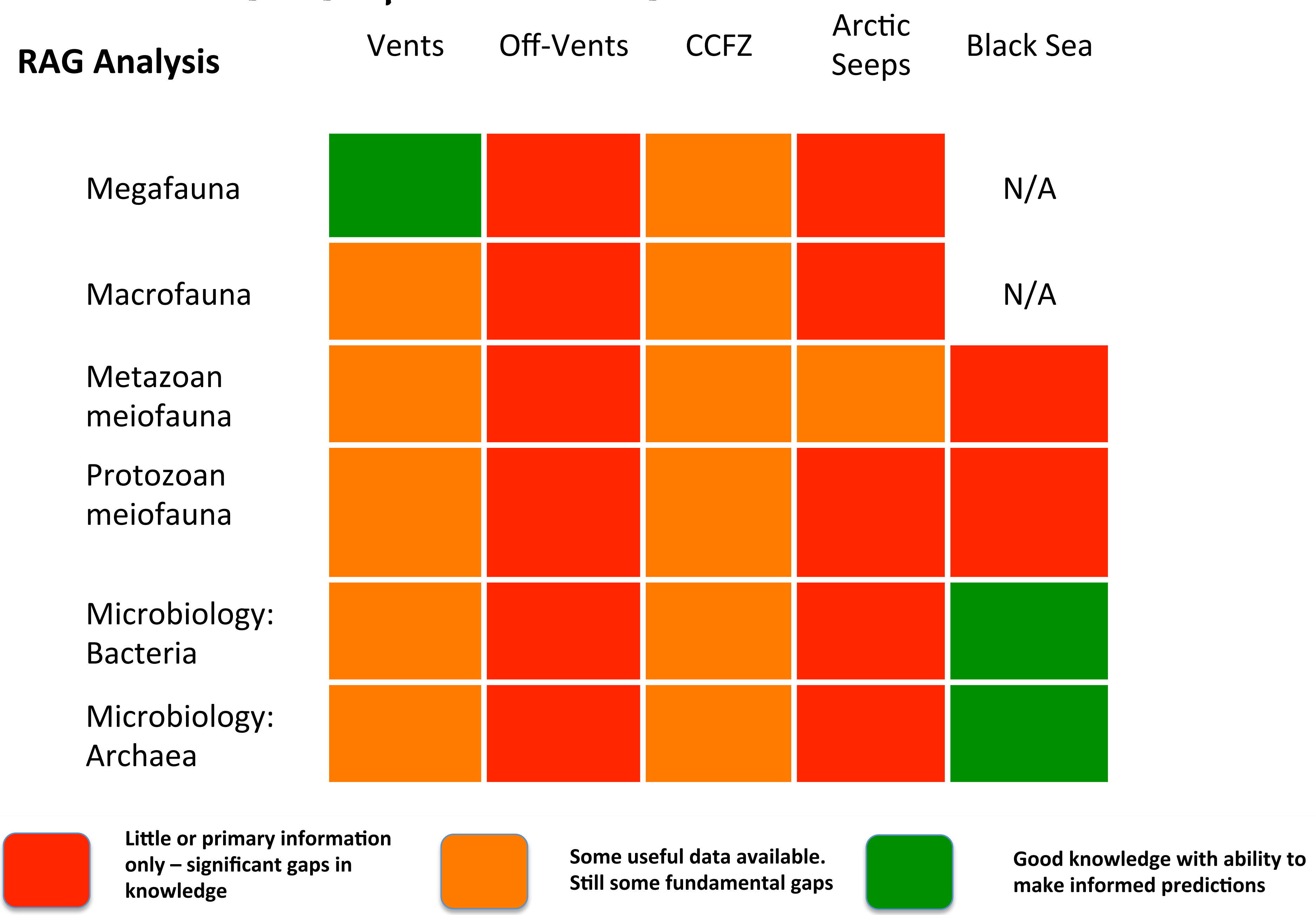
Current knowledge on evolution and ecological drivers of biogeographic patterns (is it supported by molecular and phylogeographic approaches?)

Assessment from the MIDAS project

Gap Analyses: Knowledge Grid

	Megafauna	Macrofauna	Metazoan meiofauna	Protozoan meiofauna	Microbial Bacteria	Microbial Archaea
Taxonomic knowledge	Good general knowledge	Limited to a few taxa. Mostly OTU	Limited to a few taxa	Foraminifera and Xenophypohores	Limited	Limited
Keys, literature	Available for many groups	Some available, mostly primary literature	None available	None	N/a	N/a
Collections	Many	Few, not available	Some	Some	Sequences	Sequences
Mechanism to exchange taxonomic information	little exchange of information between contractors	No exchange or intercalibration	No exchange or intercalibration	Mostly academic excahnge	No. Data available via external databases such as GenBank	No. Data available via external databases such as GenBank
Sampling – type	Mostly Video and still imaging	Quantitative and qualitative samples	Quantitative samples	Quantiitative	Quantitative	Quantiative
Molecular sampling	Little	Only some contractors	Some but limited	Some but limited	All molecular	All molecular
Sampling - standardisation.	For video and stills but not for specimesn.	No. Use of gear is based on ISA standards but new gear being introduced	Possibly ISA have standards which apply	Limited	Limited	Limited
Biogeographic data	Some but based on morphotypes not actual specimens	Some but scattered in scientific literature. Spatial coverage insufficient	Some taxa –	Some	Some but limited to a few areas	Some but limited to a few areas

Biogeographic knowledge: current stat of the art



Environmental Monitoring - the basic premise

To understand effects of potential impacts the things we need to know are:

What organisms are to be found? – Taxonomy

How many there are and how they live? – Ecology

How widespread they are? – Biogeography

There is both a spatial and a temporal aspect to these questions:

We need to know how organisms vary across the Area and also how they vary with time

Challenges in environmental monitoring in the deep sea

Effective monitoring requires:

Good quality sampling programmes –

Reflects the environmental heterogeneity and local ecological conditions

Ecologically meaningful

Using appropriate technologies

Time series – To track 'natural' from anthopogenic change, e.g. seasonality, major events like El Nino, etc.

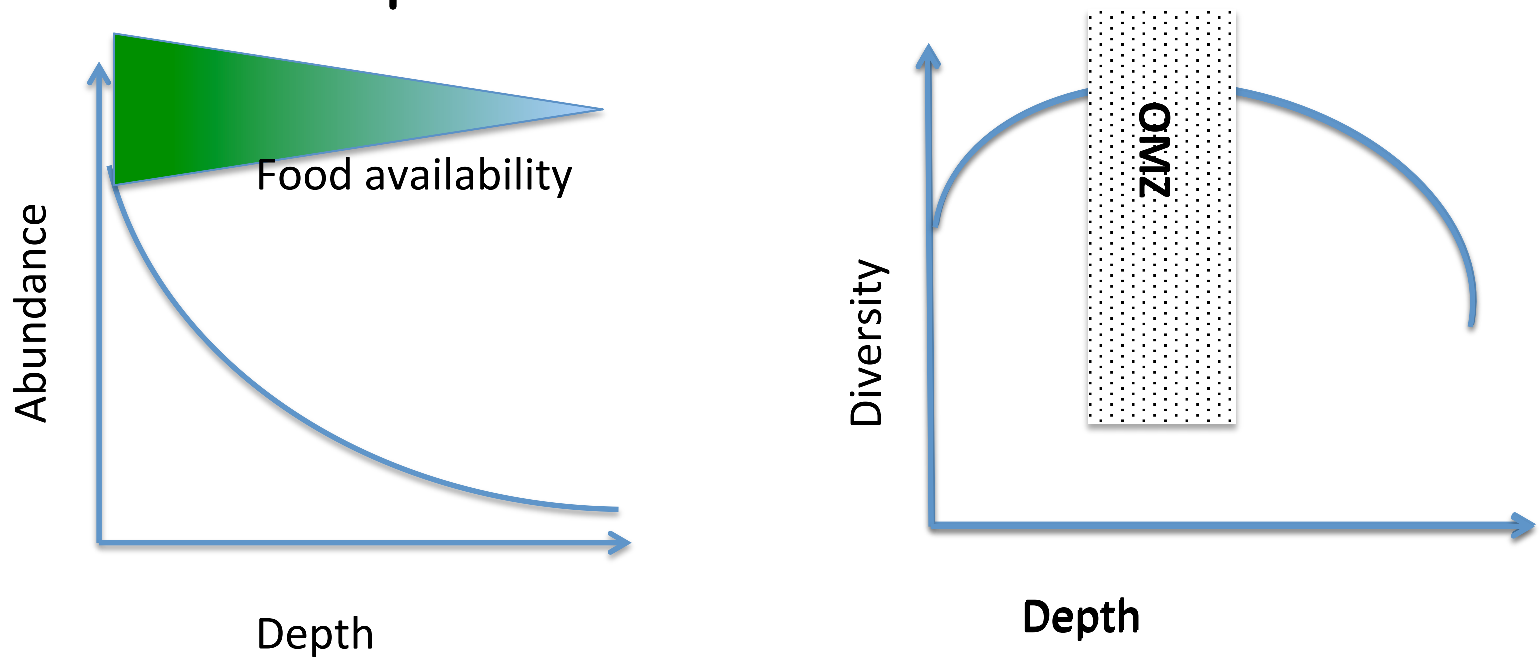
Good quality data – starts with good taxonomic resolution

Good data storage and access – specimen and sample archiving, open access to data helps establish reliable and reproducible information

Communication and clear regulations

Challenge: Sampling the Deep Sea

The effect of depth

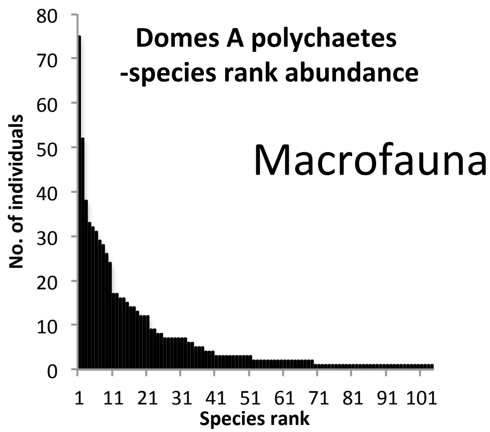


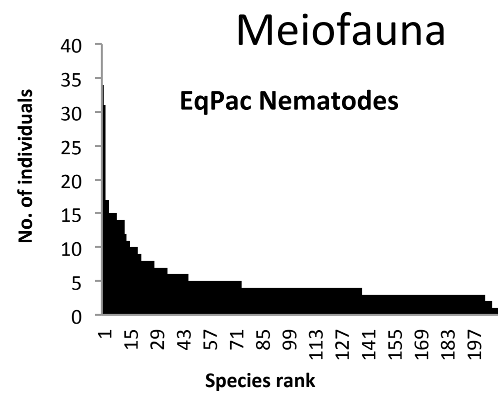
Food decreases dramatically as you get deeper
Decreasing abundance/biomass – making sampling a problem
Diversity/number of species increase with depth but then decreases

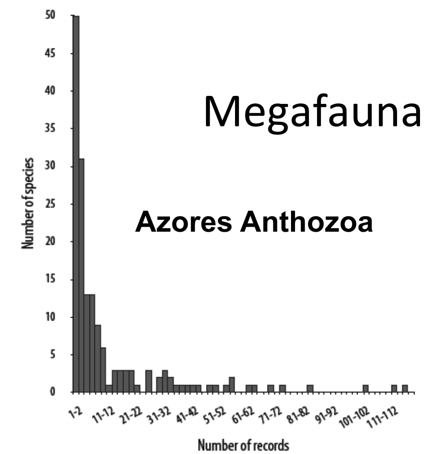
Bathymetric effects affect sampling strategies

Sampling: Species richness

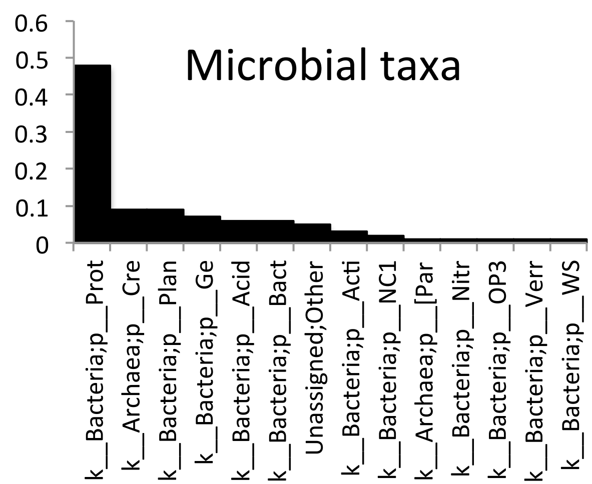
Deep-sea samples are characterised by high numbers of species with low abundance





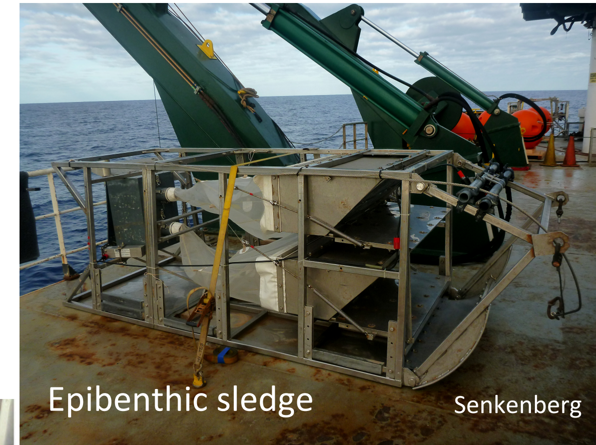


Typical sampling results in long tails of 'rare' or singleton species

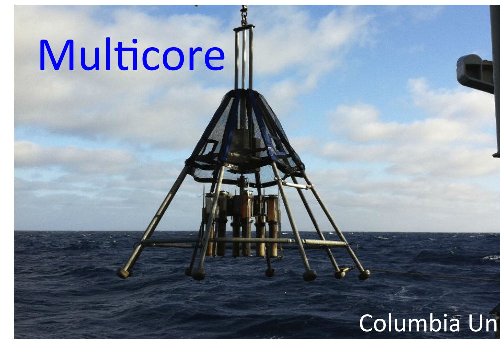



Boxcore

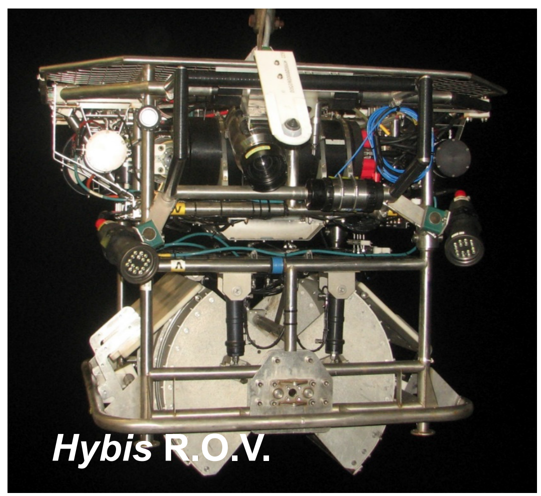

RRS James Cook

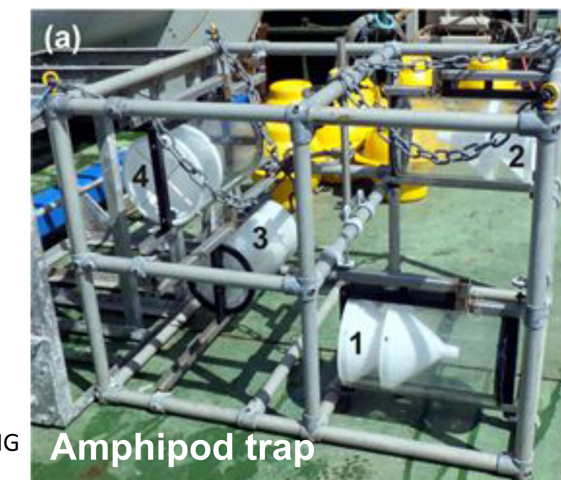

Epibenthic sledge
Senkenberg


Agassiz trawl


Multicore
Columbia Uni


Megacore


Hybis R.O.V.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Amphipod trap

Deep-sea Sampling

Needs a lot of equipment – often expensive equipment!
Each habitat needs specific gears to sample effectively.

Sampling programme
For deep-sea habitats often there is not enough environmental information.

Need good preliminary surveys

The number of samples, as well as a suitable sampling gear often cannot be defined in advance.

Need to adequately resource the first exploratory phases

Sampling designs should be chosen by the extent of the heterogeneity of habitat /environment not just by pure economics.

ISA Workshop Recommendations

a. Define an area for research on potential impacts.
b. Take samples randomly in the research area as a preliminary survey.
c. Make a species cumulative curve, and then estimate the number of samples required.
d. Design the sampling programme accordingly.

Challenge : High Quality Data
Assessing deep-sea biodiversity

Differences between shallow water and deep-sea systems

Shelf seas

- Shelf faunas are often well known and described.
- There are good resources and people to do environmental assessments.
- Collecting is straightforward.

Deep-sea studies

- Most deep-sea habitats are characterised by many unknown species.
- Large number of species from deep sea have not been formally described, often identified only as species *A* etc.
- This makes comparison between studies difficult.

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Challenge: Generating high quality data
Taxonomic standardisation

Issue: Increased sampling will result in more specimens from unknown species.

This will require increased taxonomic effort.

Increasing the capacity of all actors is essential if rigorous, plausible and robust scientific data is to be produced. Generating results which will withstand the scrutiny of external review and criticism.

There are a number of ways to make sure that quality of data is being produced:

Ensure the competency of the taxonomic community and build on existing expertise. It takes years to become an expert.

Integrate modern methods such as molecular analyses.

Hold intercalibration and expert workshops to enable researchers and contractors to exchange information and knowledge. This mechanism improves the skill base.

Exchange and visiting scientist programmes to enable researchers to work up material and make the data available.

Fund this taxonomic work – experts cannot do this for free.

Challenge – Good data storage and access

Environmental studies in shallow-water frequently take many good samples and are identified by competent people.

But the samples are never stored in a museum or collection facility where other people can study them.

The data from reports is often embargoed and never released or inhabits the twilight world of 'grey literature' .

This procedure actually inhibits good environmental monitoring. There is no connection between different areas being studied to see if wide-scale change is happening. Quality Control and Quality Assurance are compromised.

Access to collections and data is actually part of the audit process. You need the specimens to check whether the basic data was generated competently or not.

All too frequently the samples and specimens are thrown away and the data lost on some hard drive somewhere!

Challenge – Good data storage and access

Data management is essential given the potential volumes of data being produced by environmental monitoring programmes. Good data management practices are critical to establish the standards before mining activity.

During monitoring
Joint working groups on key subjects such as taxonomy, biodiversity assessment, sampling & processing can ensure standards are developed and maintained.

Mobilising existing expertise between contractors and between contractors and academic researchers would speed up data processing, accuracy and address key questions which need to be addressed before mining can start.

Establishing protocols for the sorting and long-term storage of samples and specimens is essential as is funding to make this happen

Challenge: Communication and Good Regulation

The current paradigm used in environmental monitoring works roughly as follows:

Contract tendered

↓

Lots of companies bid and one is awarded the contract

↓

Work is done. Client gets report

↓

Next contract

→

Many different consulting companies may end being involved over the course of a long-term monitoring programme

Challenge: Communication and Good Regulation

The problems with this arrangement is that:

1) it only works if the fauna is well known and the company has competent taxonomists.

2) The reports and the material stay with the client and the company so there is no external scrutiny. No QA.

3) For monitoring unless the same company keeps getting the contract there is no guarantee of continuity between contracts unless overtly specified.

4) No means of providing continuity because the specimens are not available.

5) None of the new species have been described in the scientific literature because there is no time or money in the contract to do so.

Leads to poor quality monitoring and can fail to detect the changes which were being monitored for.

Challenge: Communication and Good Regulation

Establishing clear regulations to ensure that deep-sea environmental monitoring is effective.
Based on good scientific principles reflecting the complexities of the various deep-sea ecosystems likely to be encountered.

Within the practices and protocols of monitoring in the deep-sea, taxonomy is a key underpinning activity which needs to be supported and resourced properly if the monitoring is to have any scientific and societal credibility

Certain elements need to be considered as integral to the monitoring process such as sample storage and data access. Adequate resources need to be factored into contracts to allow this to happen.

Deep-sea Environmental Monitoring – the Great Potential

Monitoring should not merely be seen as a task which is carried out to fulfil some regulatory requirement.

Monitoring has the ability to provide important information on the biodiversity of the deep ocean, on the processes which affect life and to make an important contribution to the understanding of the planet. The challenge is now to make that happen and to communicate the knowledge generated by such studies to the wider world.

This work is based on contributions of researchers from the following institutions:

Funding support from: