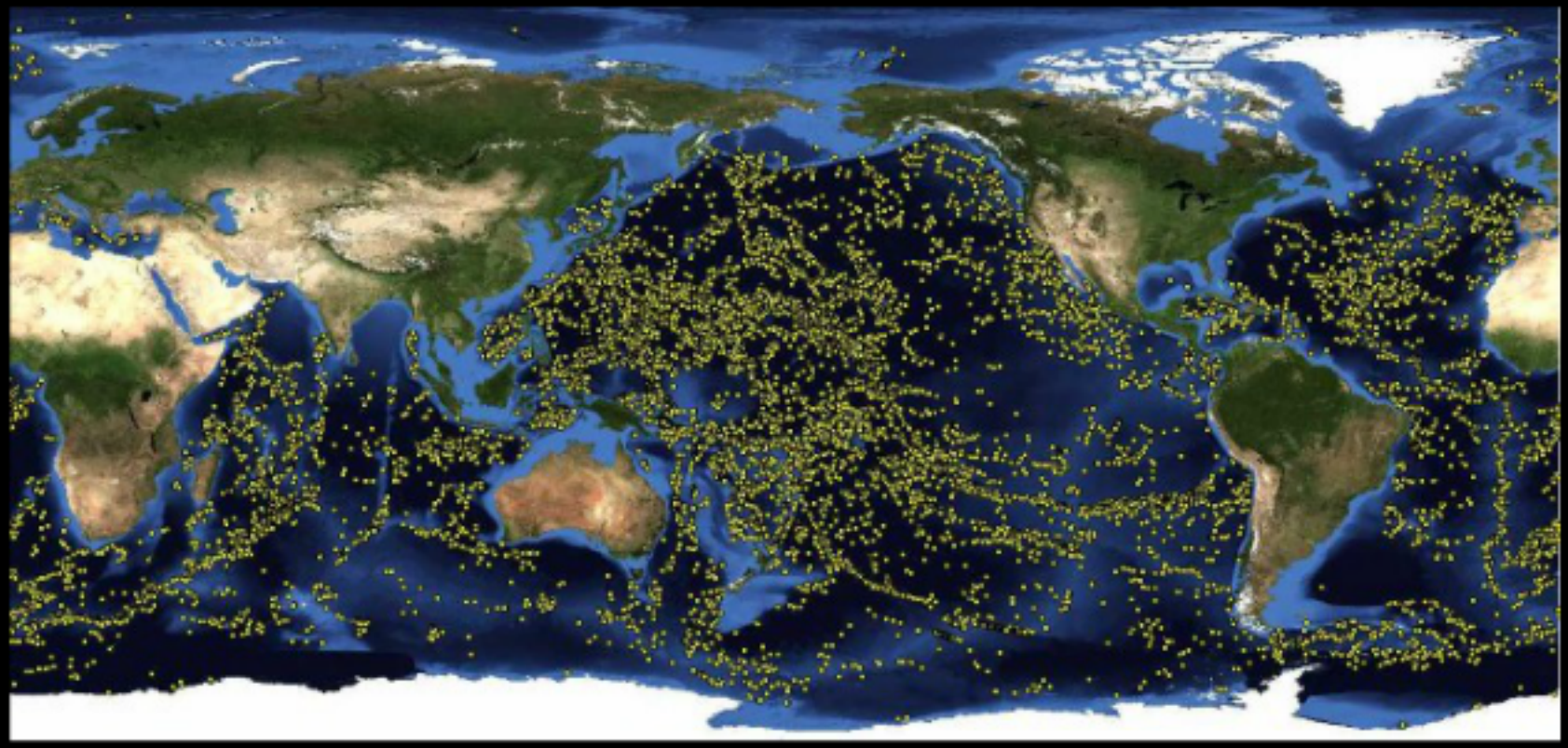
Biology of Cobalt-Rich Crusts

What is the habitat?
Who are the inhabitants?
What do we know about their biology?
- Longevity
- Connectivity and endemicity

The Cobalt rich crust habitat

Areas with enhanced currents that remove sediments
So, normally areas associated with abrupt seafloor topography
Primarily on seamounts and ridges (and plateaus)
800 – 2500 m depth
Western and central Pacific region good for crusts

Global Distribution of Seamounts



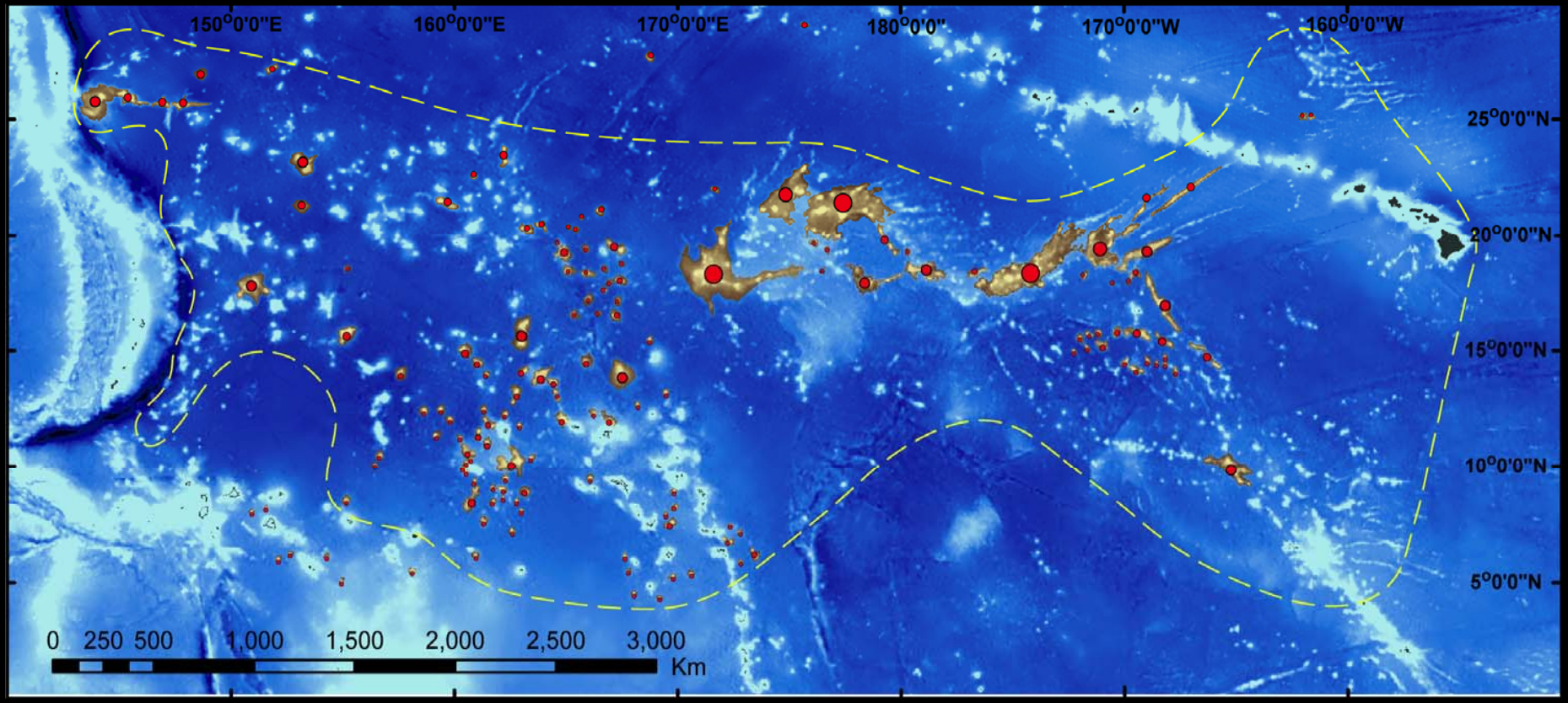
- 14,000 large seamounts (elevation > 1,500 m)
- Could be as many as 200,000 seamounts, knolls, pinnacles (Hillier & Watts 2007)

Seas Around Us - Kitchingman & Lai 2004

USGS
science for a changing world

Courtesy Jim Heins

Map of most permissive area in global ocean



From Hein et al., 2009

Dashed line encloses largest region in global ocean with permissive conditions for development of thick, metal-rich crusts

USGS
science for a changing world

The Cobalt rich crust habitat

Areas with enhanced currents that remove sediments
So, normally areas associated with abrupt seafloor topography
Primarily on seamounts and ridges (and plateaus)
800 – 2500 m depth
Western and central Pacific region good for crusts

Old hardgrounds associated with good currents at moderate depths
Prime habitat for attached filter feeders and associated communities
- Corals (hard, black, fan, and soft)
- Echinoderms (starfish, crinoids, brittle stars)
- Sponges (basket, glass, massive)

and all their little friends

The Cobalt rich crust habitat

Disclaimer:

I am going to consider the entire potential crust habitat as described above

It is not clear to me that much of this extent (for example above 1500 m depth) will be mined, especially in this region.

Based on current technology and metal prices, it is unlikely that there will be mining at the shallower end of the crust range, and that is the end with highest biomass and most lush communities.

So, deposits of interest to all of you, in the next 20 years, are unlikely to have the diversity of the shallower communities.

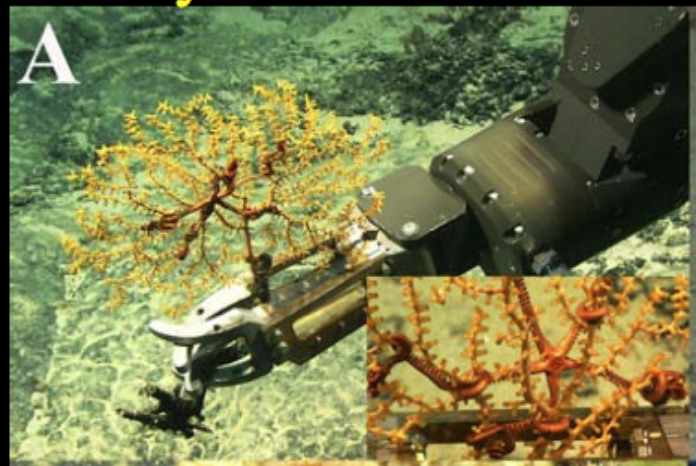
However, I am reminded of the constantly changing values of the "land based reserves", as technology and metal prices change…

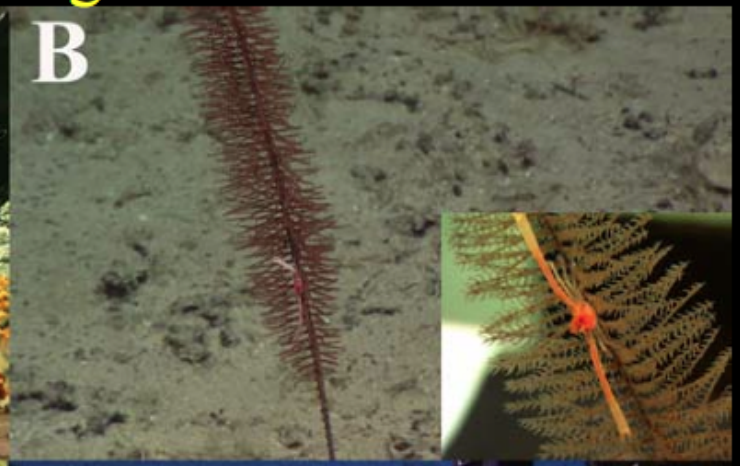
Cobalt-rich crust fauna

Corals and Sponges can host a diverse, and often productive community including a variety of benthic invertebrates and fishes

Host-associate systems on the New England and Corner Rise Seamounts

octocoral *Paramuricea* brittle star *Asteroschema*





black coral *Parantipathes* & chirostylid crab

scleractinian coral *Lophelia pertusa* & polychaete worm *Eunice*

octocoral *Metallogorgia* & brittle star *Asteroschema*

octocoral *Candidella* & brittle star *Ophioplinthaca* & scaleworm *Gorgoniapolynoe*

brittle star *Ophioplinthaca* & *L. pertusa* & *Desmo-phyllum dianthus*

Shank ISA 2006

Corals

Scleractinia

Octocorallia

Antipatharia

Stylasterida

NOAA Ocean explorers & IFREMER

Deep sea corals grow slowly and live a long time

Hard corals can form reefs that grow slowly over many thousands of years

Individual Octocorals (sea fans) and black coral colonies can live for thousands of years.

Much of the crust fauna are very long lived

Table 1 Examples of age estimates of seamount invertebrate megabenthos

Faunal group	Age (years)	Method	Reference
Glass sponge	440	Ring count	Samadi et al. 2007
Stalked crinoid	340	^{14}C dating	Samadi et al. 2007
Zoanthid (*Gerardia* spp.)	400–900	^{14}C dating	Roark et al. 2006
Zoanthid (*Gerardia* spp.)	1800	^{14}C dating and ring count	Rogers et al. 2007
Gorgonian coral	67–2377	^{14}C dating	Roark et al. 2006
Bamboo coral	35–197	^{14}C and ^{120}Pb dating	Rogers et al. 2007
Biogenic habitat (accumulated)	1000–50,000	U/Th dating	Rogers et al. 2007

From Clark et al., 2010

What is the scale of endemicity to deep sea hardgrounds?

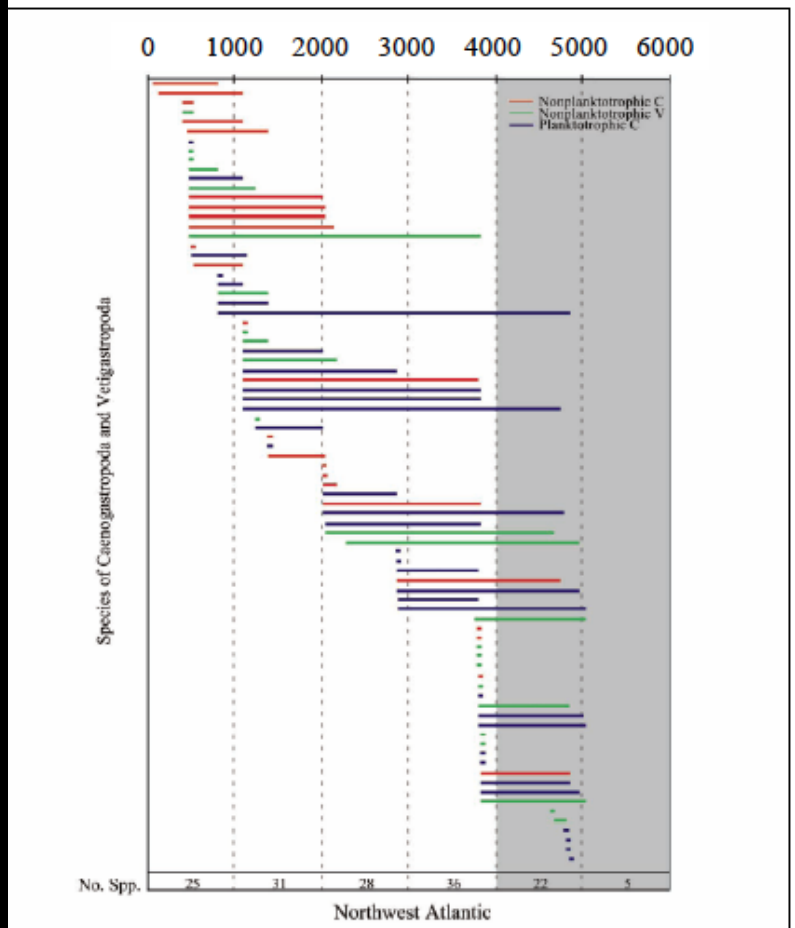
- This is a critical question to evaluate the ecological/environmental impacts of mining cobalt crusts.
  - If some animals are only associated with one or a few seamounts, then each individual seamount must be carefully considered
  - If the fauna is globally distributed, then larger scale management plans are more appropriate

- Unfortunately, the answer is not black and white
  - Early studies suggested that there was a very high degree of endemicity associated with seamounts.
  - As more and more data is being collected and analyzed it is becoming clear that although there are examples of very localized populations for some places and species, many, if not most species are more widely distributed

What is the scale of endemicity to deep sea hardgrounds?

- Depth is a key variable both on a single seamount or slope, or when comparing seamounts.

- The depth between 800 and 2500 meters will include animals that can only live at a subset of this range.



Depth range of snails along continental slope

From Rex 2005

What is the scale of endemicity to deep sea hardgrounds?

Other key factors include

Intrinsic factors (species or taxa specific):
Adult mobility
Reproductive biology
Larval biology: development time and dispersal distance

Extrinsic factors
Oceanographic currents that restrict connections or facilitate them
Proximity of suitable habitats
Oceanic environmental variable that affect larval survival
(temperature, food, predators)

From Rex 2005

What is the scale of endemicity to deep sea hardgrounds?

Biodiversity

South Australian Seamounts

297 species of animals on 14 seamounts

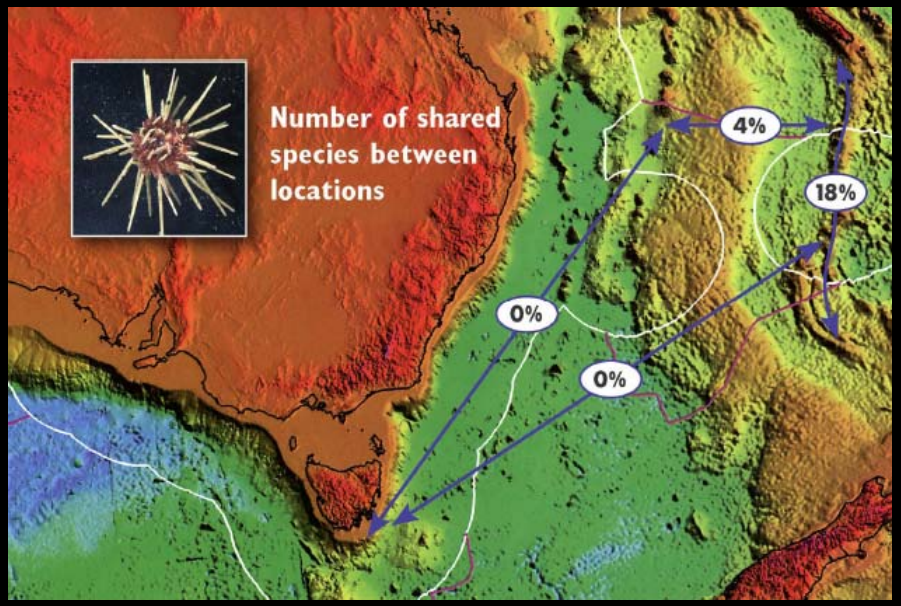
16 - 33% are new to science and potential endemics

Low overlap in species present on different seamounts

Even lower co-occurrence of species on different chains

Richer de Forges et al (2000)

Until recently is was “accepted” that there was an inherent high degree of endemicity



Two slides from presentations to the ISA in 2006 showing unique species and very local endemicity.

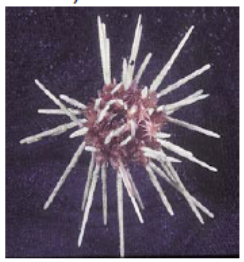
Koslow ISA 2006, Roberts ISA 2006

What is the scale of endemicity to deep sea hardgrounds?

New paradigm? -- Galapagos of the deep

High endemism from high degree of reproductive isolation leading to local evolution/speciation

- Topographic rectification of currents isolates seamounts & ridges
- Evolution of reproductive strategies to limit loss outside seamount/ridge system
  - Limited larval duration or none at all (Parker & Tunnicliffe 1994)

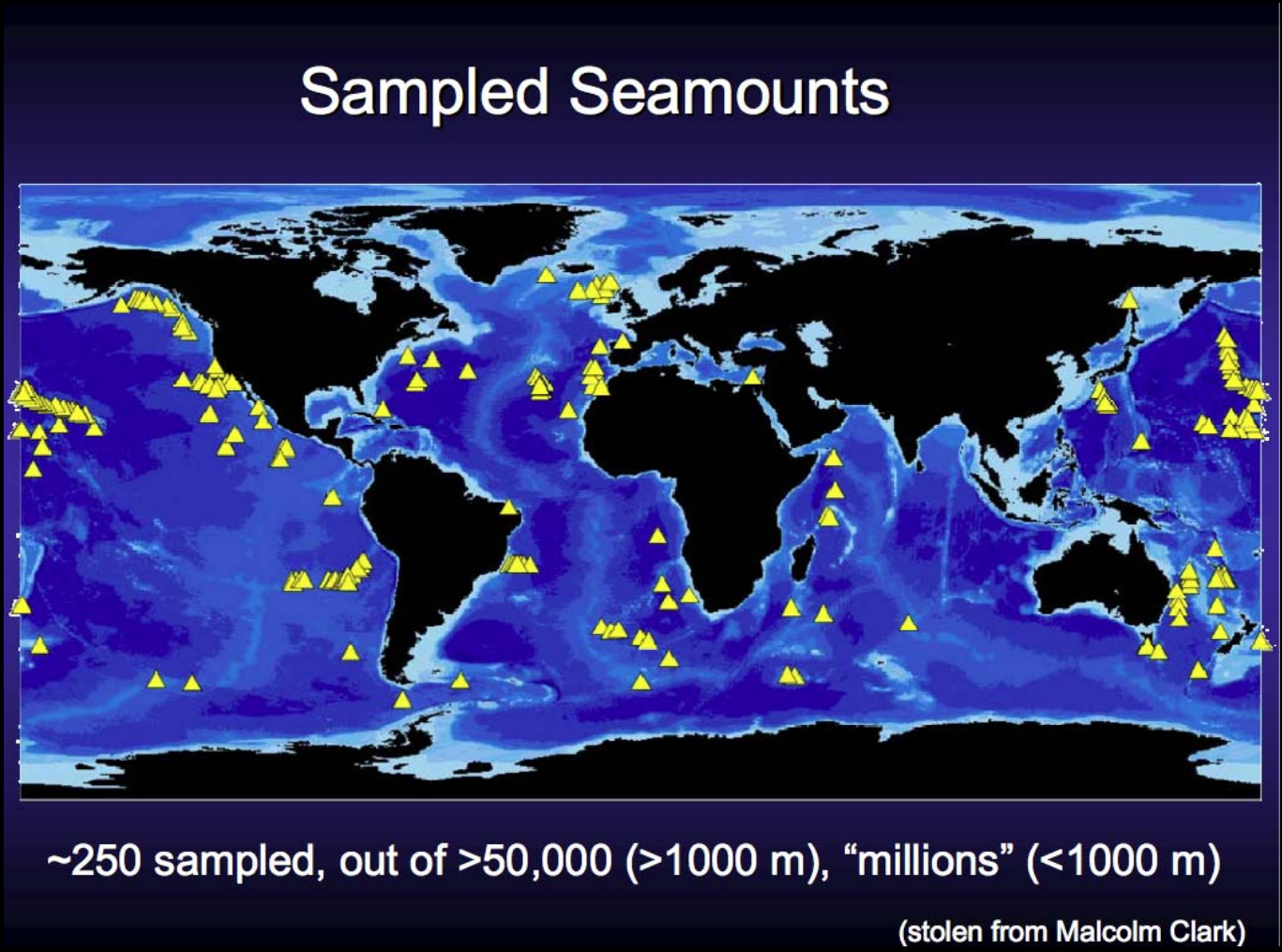


Very logical.
True in some places
And for some species
But….

Koslow ISA 2006

What is the scale of endemicity to deep sea hardgrounds?

Poorly sampled
Especially here

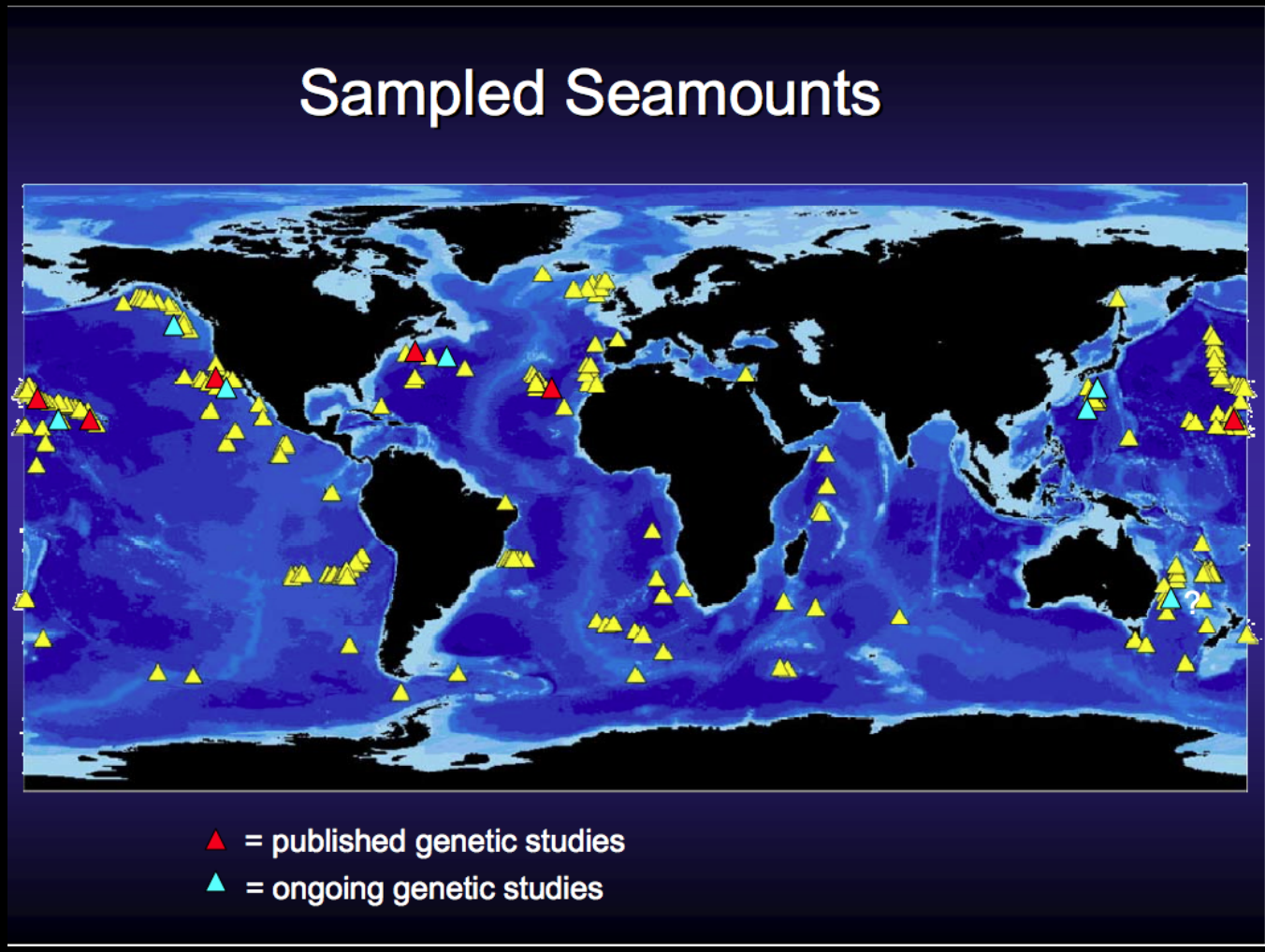


Shank ISA 2006

What is the scale of endemicity to deep sea hardgrounds?

Almost no genetic information in 2006

Still need more



Shank ISA 2006

What is the scale of endemicity to deep sea hardgrounds?

Current thought

(from recent articles and reviews including Clark et al., 2012 and Clark et al., 2010)

It is not well understood and generalizations should be used with caution.

Most data is still based on “shared species” which does not provide adequate information on current levels of connections among populations

It will vary between places, types of animals, and species.

More study is need to understand the general patterns

And

especially endemicity within a specific region

What is the scale of endemicity to deep sea hardgrounds?

Current thought

(from recent articles and reviews including Clark et al., 2012 and Clark et al., 2010)

It is not well understood and generalizations should be used with caution.

Many seamount species are widely distributed (within their preferred depth range).

Some have near global distribution, including many of the corals.

Many of the seamount species are also found on oceanic islands and continental slopes.

However, there is good data of significant differences in the structure of seamount communities compared to slope communities associated with the same corals.

What is the scale of endemicity to deep sea hardgrounds?

Current thought

(from recent articles and reviews including Clark et al., 2012 and Clark et al., 2010)

It is not well understood and generalizations should be used with caution.

In general, commercially fished species and widespread and are not isolated populations, but are connected at large scales both among seamounts and to slope populations.

Some exceptions have been found with genetic differentiation (but not speciation) between seamount and non seamount populations

What is the scale of endemicity to deep sea hardgrounds?

Current thought

(from recent articles and reviews including Clark et al., 2012 and Clark et al., 2010)

It is not well understood and generalizations should be used with caution.

For other species the data suggests large differences between groups:

- A study of one family of coral found the metapopulations covered very large oceanic distances in the pacific.
- Another found genetic differentiation within precious corals (*Corallium lauuense*) on Hawaiian seamounts and islands suggesting largely local recruitment, with some long distance interconnections.
- A study of 9 seamounts and the slope of new Caledonia found a single metapopulation of each of 4 species of squat lobsters and that only one species of snail had significantly different populations among the seamounts.

What is the scale of endemicity to deep sea hardgrounds?

Current thought

(from recent articles and reviews including Clark et al., 2012 and Clark et al., 2010)

It is not well understood and generalizations should be used with caution.

Bottom line:

Older ideas that seamounts are each isolated “islands in the deep” with their own endemic species and populations are not correct.

Some species are widely distributed.

Some appear not to be.

However:

More study is need to understand the general patterns

And

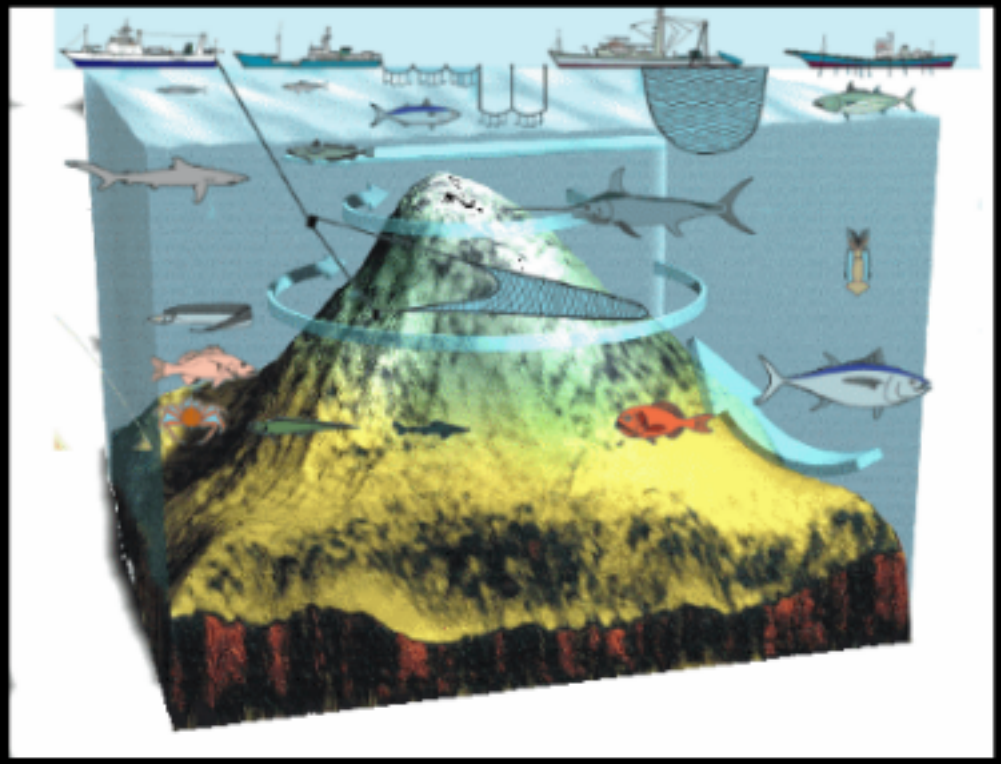
especially for a particular region

Is there a fauna unique to cobalt crusts?

- This is another critical question to evaluate the ecological/environmental impacts of mining cobalt crusts.
  - If some animals are only associated with high cobalt crusts, then these animals are at high risk and protection would require setting aside some high cobalt crust habitats.
  - If not, then perhaps can protect other similar depth hardgrounds to save species.
- Unfortunately, we do not know the answer to this question
  - Appropriately designed surveys have not been done
  - In general, it appears that the fauna is at least very similar
    - Good preliminary analysis for the megafauna, but not for small animals
  - One larval settlement study found differences
  - Another recent study also found some significant differences in established communities.

This critical question needs to be addressed with more research

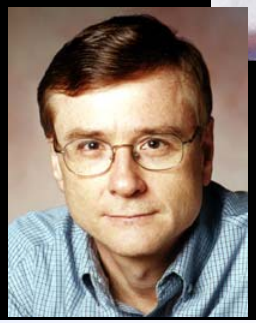
Seamounts as Fish Habitat



Currents and upwellings around seamounts concentrate plankton and increase productivity

Seamount fisheries: do they have a future?

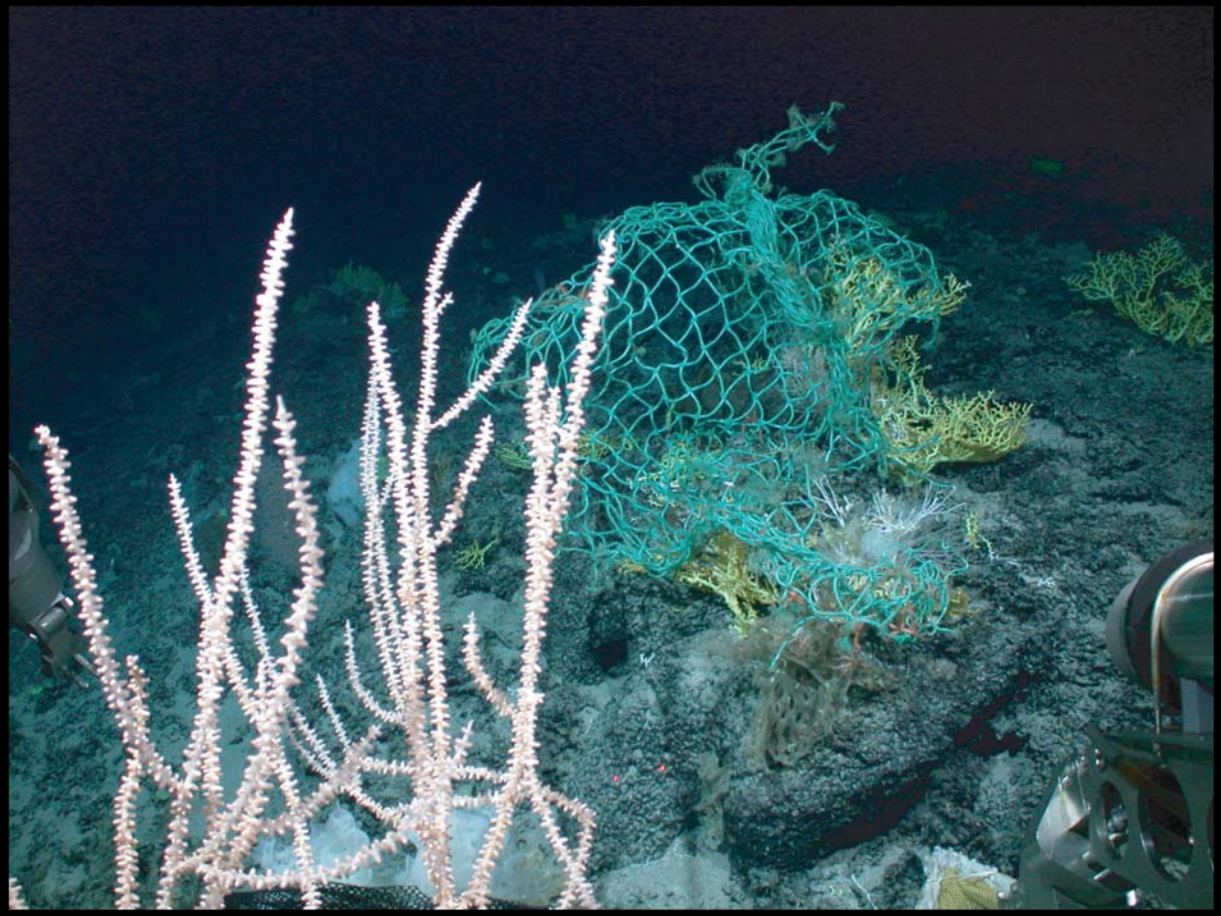
Tony Pitcher	UBC, Vancouver
Malcolm Clark	NIWA, Wellington
Telmo Morato	DOP, Azores
Reg Watson	SAU, Hobart



Cobalt-rich crust habitat and fauna

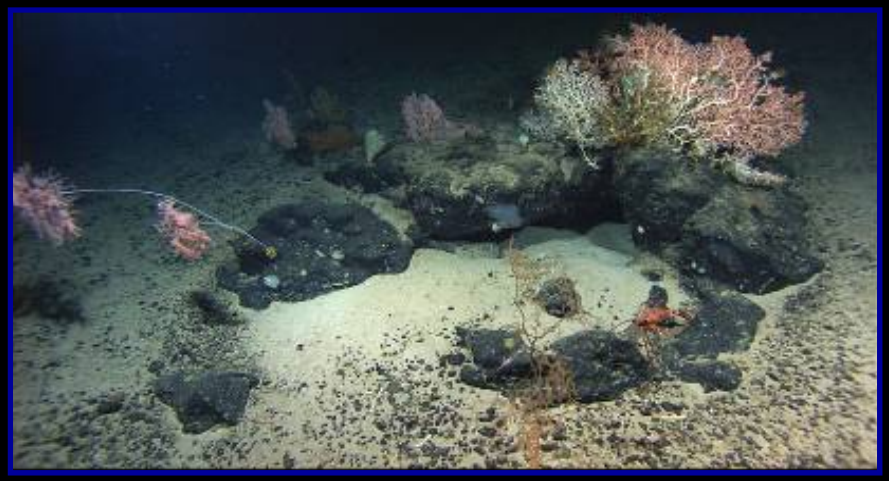
Seamounts can host commercially important fish aggregations. As a result, many are already heavily impacted by commercial fishing operations

However, there may be very little overlap between seamounts that could support abundant fisheries and ones with high cobalt crusts in the W. Pacific region (because of depth differences).
More on this from Malcolm Clark



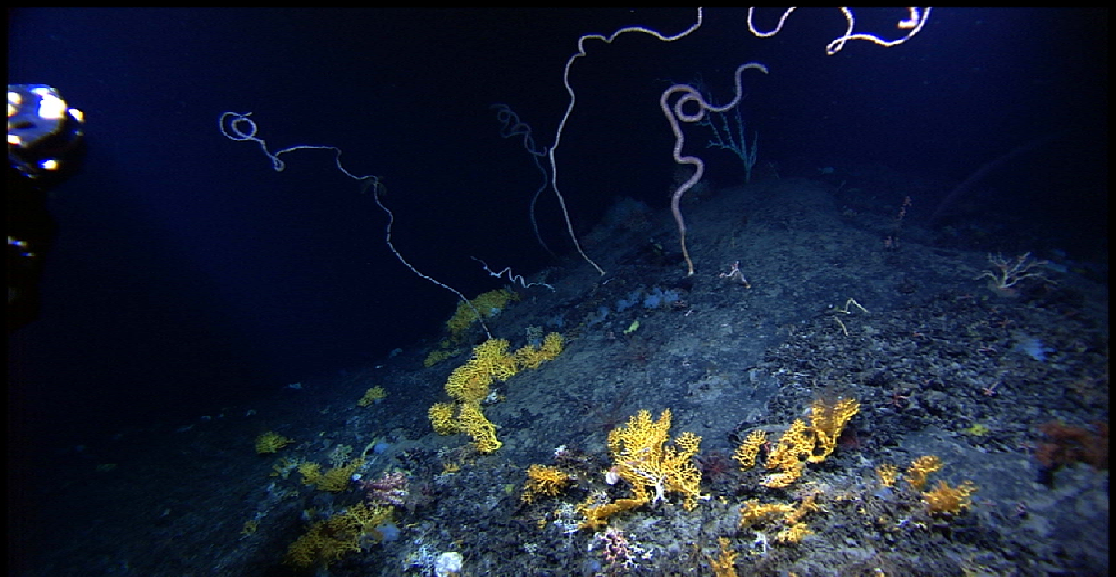
Cobalt-rich crust habitat and fauna

- Seamount communities can be high biomass, and support high levels of biodiversity
- Much more genetic work needs to be done to understand biodiversity
  - Cryptic speciation of megafauna is largely not constrained



Cobalt-rich crust habitat and fauna

- Although megafauna is rapidly becoming better known, most regions are grossly under sampled
  - Macro and meiofauna are very poorly known
- Hardground communities (like other communities) vary by depth within a region



Cobalt-rich crust habitat and fauna

- Many of the dominant and ecosystem structuring fauna is very long lived.
- Levels of endemism are likely to vary widely by species, by taxonomic group, and also by region
- More work is needed to determine if there is a fauna endemic to cobalt-rich crusts