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
Map of most permissive area in global ocean

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

From Hein et al., 2009
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

A: octocoral *Paramuricea*
B: brittle star *Asteroschema*
C: scleractinian coral *Lophelia pertusa* & polychaete worm *Eunice*
D: octocoral *Parantipathes* & chirostylid crab
E: brittle star *Ophioplithaca* & *L. pertusa* & *Desmophyllum dianthus*

Shank ISA 2006
Corals

Scleractinia

Octocorallia

Antipatharia

NOAA Ocean explorers & IFREMER

Stylasterida
Deep sea corals grow slowly and live a long time

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

Hard corals can form reefs that grow slowly over many thousands of years.
Much of the crust fauna are very long lived

Table 1  Examples of age estimates of seamount invertebrate megabenthos

<table>
<thead>
<tr>
<th>Faunal group</th>
<th>Age (years)</th>
<th>Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass sponge</td>
<td>440</td>
<td>Ring count</td>
<td>Samadi et al. 2007</td>
</tr>
<tr>
<td>Stalked crinoid</td>
<td>340</td>
<td>$^{14}$C dating</td>
<td>Samadi et al. 2007</td>
</tr>
<tr>
<td>Zoanthid (Gerardia spp.)</td>
<td>400–900</td>
<td>$^{14}$C dating</td>
<td>Roark et al. 2006</td>
</tr>
<tr>
<td>Zoanthid (Gerardia spp.)</td>
<td>1800</td>
<td>$^{14}$C dating and ring count</td>
<td>Rogers et al. 2007</td>
</tr>
<tr>
<td>Gorgonian coral</td>
<td>67–2377</td>
<td>$^{14}$C dating</td>
<td>Roark et al. 2006</td>
</tr>
<tr>
<td>Bamboo coral</td>
<td>35–197</td>
<td>$^{14}$C and $^{209}$Pb dating</td>
<td>Rogers et al. 2007</td>
</tr>
<tr>
<td>Biogenic habitat (accumulated)</td>
<td>1000–50,000</td>
<td>U/Th dating</td>
<td>Rogers et al. 2007</td>
</tr>
</tbody>
</table>

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.

From Rex 2005
What is the scale of endemcity 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

Until recently it 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 endemicty to deep sea hardgrounds?

Poorly sampled
Especially here

~250 sampled, out of >50,000 (>1000 m), “millions” (<1000 m)

(stolen from Malcolm Clark)

Shank ISA 2006
What is the scale of endemicity to deep sea hardgrounds?

Almost no genetic information in 2006

Still need more

Sampled Seamounts

△ = published genetic studies
▲ = ongoing genetic studies

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 lauwense*) 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

Fisheries Centre, Aquatic Ecosystems Research Laboratory, University of British Columbia
Seamount fisheries: do they have a future?

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

Seamount Biogeosciences Network: SEAMOUNTS '09 Exploration, Biogeosciences and Fisheries
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.