

Cobalt crusts and the diversity and distribution patterns of seamount faunas



Workshop background and objectives

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Outline of talk

- **Scientific framework for managing mining of cobalt crusts**
- **Outcomes of the September 2004 ISA workshop on polymetallic sulphides and cobalt crusts**
 - Baseline data requirements
 - Environmental impact assessment of test mining
- **Knowledge gaps**
- **Current workshop objectives, addressing key gaps**



The crust environment

Hard substrates

- Seamounts & ridges
- Enhanced currents
 - Winnow away sediments
 - Association with abrupt seafloor topography

800 - 2200 m depth for thickest crusts

- Association with O₂ minimum (Hein 2002)

Equatorial Pacific

- Mid-Pacific Mts, Micronesia, Marshall Islands, Kiribati, Hawaii and Johnston Island

Existing seamount sampling

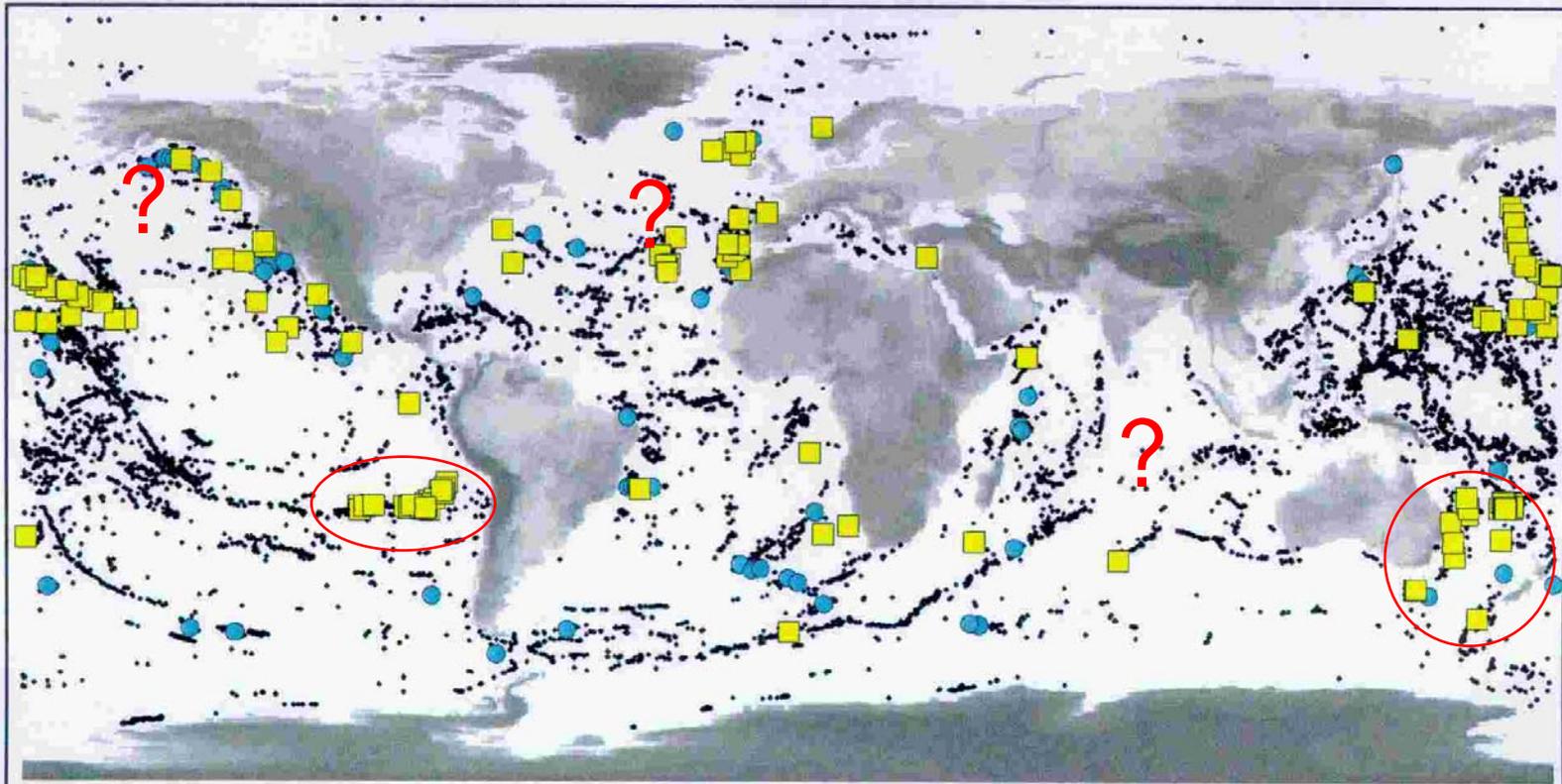


Figure 1. Existing Seamount Sampling. Yellow squares indicate 163 seamounts for which biological data are available in SeamountsOnline (seamounts.sdsc.edu; Stocks 2003) – many of these have been only partially or opportunistically sampled. Blue circles indicate 90 seamounts for which data are not currently available in SeamountsOnline, but which have been sampled at varying levels. They do not include ~100 fisheries-related cruises in the Southern Indian Ocean by Ukrainian vessels for which data, including full sample location information, are unavailable. The small black dots indicate ~10,000 seamounts over 1000m high that have been located (courtesy of Adrian Kitchingman, Sea Around Us Project, Fisheries Centre, University of British Columbia, and Christopher Small, Lamont-Doherty Earth Observatory).



Seamount ecology in a state of flux

Wilson & Kaufmann (1987): 597 species reported

- 72% from only 5 seamounts
- 27 species from entire SW Pacific
- Endemism modest (avg 12 - 15%)

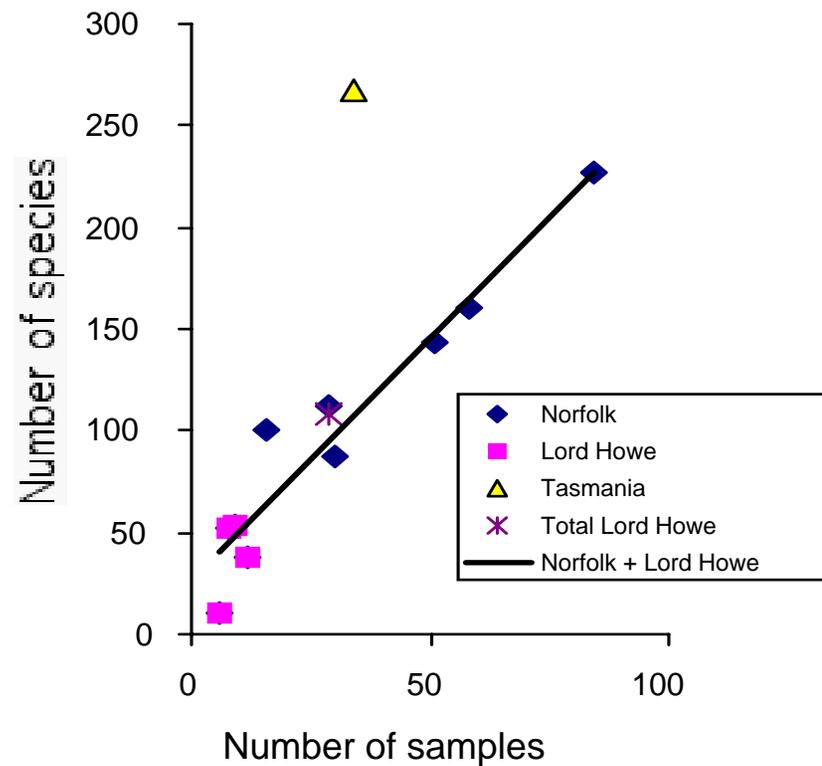
Parin et al (1997): 51% invertebrate endemism in E Pacific seamounts (Nazca & Sala y Gomez ridges)

Richer de Forges et al (2000):

- 850 macro- & megabenthic species from 24 seamounts in Tasman/Coral Seas
- 29-34% new to science/potential endemics

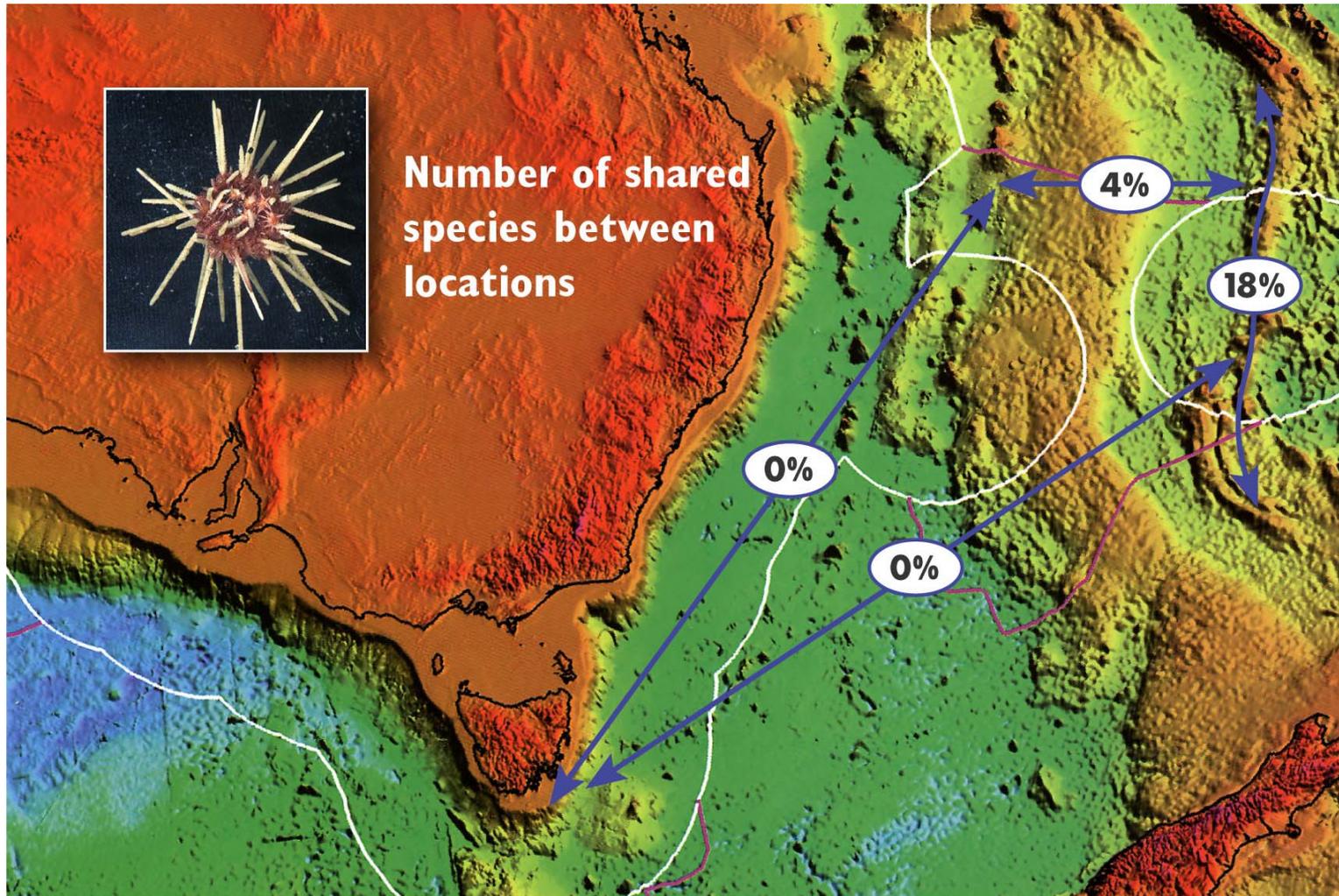


Seamount diversity high, but how high?



(Richer de Forges, Koslow & Poore (2000))

Localized distribution of seamount fauna



How robust is our analysis of endemism?

Is this pattern observed in other seamount regions?

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)





Conservation implications

- **Threat of extinction to localised heavily impacted species from widespread disturbance, eg fishing, mining**
- **Recolonization/recovery time long, due to isolation**



Cobalt crust seamount fauna

> 46 cruises since 1981 to study Co-rich crusts

No comprehensive benthic faunal surveys (!?)



6. *Gerardia* sp. and *Callogorgia gilberti* on dikes at 350-380 m depth on Cross Seamount.

Limited data from Cross Seamount (18° N) S of Hawaii (Grigg et al 1987, Grigg 2002)

Sparse (but potential for precious coral harvest), low diversity due to

weaker currents?

reduced surface productivity?

reduced O₂ or negative

interactions of biota with crusts?

relative isolation?

vertical zonation

Reduced impact from mining?

How representative is Cross?



Potential impacts of crust mining

Loss of epifauna on mined crusts

Enhanced sedimentation/release of metal species

- Impacts on benthic fauna on adjacent parts of the seamount
- Impacts on water column processes, eg primary productivity, grazers



Key issues

What is the risk of extinction to endemic seamount species?

What is the time scale for recovery, both for mined portions of the seamounts and adjacent areas affected by sedimentation?



Assessment issues (1)

Diversity and biogeography (distributional range) of the seamount fauna in potential mining region

How many seamounts will be mined, and what proportion (depth range) of each seamount?

- Additional local seamounts that will not be mined?
- How similar are the faunas of disturbed and undisturbed seamounts?
- Relationship between the faunas of disturbed and undisturbed portions of these seamounts: vertical and topographic zonation generally observed



Assessment issues (2)

- **Other sectors (eg fishing and coral harvesting) may also impact the region's seamount fauna**
 - May add to or mitigate mining impacts
- **Impacts of enhanced sedimentation/release of metals on benthic fauna adjacent to mining area**
- **Impacts of near-surface discharges on water column (phyto-, zooplankton): light, micronutrients, heavy metals**
- **Will local seamounts be set aside in a reserve? What proportion should be conserved to reduce the risk of extinction to 'acceptable' levels and how is this to be determined?**



Environmental baseline data requirements: I. physical & chemical data

Water-column sampling over exploration area to assess dominant patterns: T, S, O₂, pH, nutrients, heavy metals, particulates, etc

Set up/validate numerical circulation model to assess advection, eddy-diffusive dispersal

Sediment chemistry

Vertical particle flux & settling velocity of test-mining discharge particles

High resolution bathymetry

Archive pre-mining sediment cores



Environmental baseline data requirements: II. Biological data

Survey hard substrate communities in impact and preservation reference areas

- Imaging (video/photographic/submersible) transects
 - Quantitative (% cover), non-destructive, but low taxonomic resolution
 - Minimum: the 4 quadrants with transects covering surrounding open seafloor, base, slope & summit
 - Resolution: features > 1 cm diam
- Dredge/epibenthic sled sampling stratified by:
 - Seamount topography (e.g. summit, slope & base)
 - Hydrography & current regime, if appropriate
 - Predominant megafauna (e.g. corals)
 - Oxygen (if O₂ minimum present)
 - Depth
 - 5 samples per stratum recommended



Biological baseline sampling (cont)

Sample preservation: ethanol, formalin, frozen for genetic + taxonomic analysis

Taxonomy highly specialized: collaborative network of specialists for consistency & efficiency

- Critical to assess endemism between regions & contractors

Replicate box-core or multi-core samples of sediment habitats for macro- & meiofaunal abundance & diversity & bacterial biomass

Examine crust fauna (at least 10 samples/seamount)

Demersal fish fauna from trawling and/or photo/video/submersible/video transects

Trace metals monitored before & after mining operations from dominant fish & benthic species



Biological baseline sampling (cont)

Pelagic community

- Potentially distinct over and around seamounts
- Assess in the upper 1500 m based on depth-stratified sampling with at least 3 depth strata; sampling replicated day-night & temporally
- Surface water: standard sampling as per nodule impact assessment
 - phytoplankton composition, biomass & production, zooplankton biomass & composition and bacterial biomass & productivity
 - Seasonal & interannual variability to be monitored
 - Use remote sensing following calibration & validation
- Observations of marine mammals & other pelagic megafauna (often noted over seamounts)

Discharges below O₂ minimum zone

- Avoid impacts on primary producers & near-surface food web
- Avoid reduction of Mn oxide & sol'n of metals in minimum zone
- Need to assess depth of O₂ minimum & water properties at that depth (seasonal/interannual variability)



Test mining

Impacts to be assessed through properly designed BACI (Before-After, Control-Impact) study

- Define impact reference & preservation reference areas with comparable faunas
- Sufficient replication to detect 50% change
- Assessment of benthic & pelagic impacts

Mining system characteristics to be assessed for impacts:

- Crust removal technique
- Transport to surface
- Mine ship processing & overflow discharge rate
- Crust recovery rate from seafloor & overall

Data required at least 2 yr before test mining

- Test site location & plans
- Transportation corridors in the Area
- Estimated characteristics of surface and benthic discharges



Test mining environmental monitoring

Benthic impact & faunal succession

- Standard sampling (samples + visual)
- At site & standard distances to assess impact of plume
- At time of mining & selected times after to examine succession

Water column impacts

- Plankton, including effects of trace metals
- Observations on pelagic megafauna (eg fish kills, altered behavior)
- Vertical light distribution from particle discharge
- Particle dispersion in midwater, settling velocity

Data issues

- Recommend that all environmental data made available within 2 yr
- Data to be archived with the ISA with full metadata



Recommended cooperative research

- **Taxonomic collaboration to identify major groups (fish, mollusks, decapods, corals, sponges, echinoderms) due to limited specialist knowledge and to assess distribution of fauna between sites**
- **Biology of seamount fauna**
 - growth, longevity, age of maturity, reproduction, dispersal, recruitment, genetic isolation, recolonization process
- **Modeling studies**
 - Risk evaluation (eg of extinction)
 - Management strategies (eg protected area design), impacts from other seamount activities (eg fishing, coral harvesting)
- **Standardized methods & reporting to allow for comparability & data analysis across contractors**



Key data gaps

- **Diversity, endemism, distributional range of seamount faunas**
- **Biology of key organisms, related to recovery of populations/communities:**
 - Growth rates, longevity, age of reproductive maturity, reproductive modes, dispersal capability, recruitment dynamics
 - Population genetics between seamounts, chains, basins (seamounts to seas)



Scientific workshop objectives

- review potential impacts of mining cobalt-enriched crusts on seamounts:
 - . distribution of potentially commercial deposits
 - . the fauna associated with cobalt-enriched crust
 - . mining methods and their potential impacts
- assess patterns of diversity, endemism and distribution of seamount faunas
- examine the factors that drive these patterns (e.g. seamount configuration, depth, overlying productivity, proximity to continents)
- assess critical knowledge gaps and propose research to meet those gaps
- identify and develop collaborative networks to carry forward research initiated at the workshop
- Consider how to apply workshop results to management of mining (& fishing), eg design of impact & reference areas, MPAs



Workshop structure

Focus on patterns of diversity, endemism and distribution

•Days 1 & 2: overview talks

- Available and new data sets
- Regional studies
- Faunal syntheses

•Days 3 – 4: Biogeographic working groups

- North Atlantic, North & East Pacific, SW Pacific
- Taxonomic groups? (eg corals, echinoderms?)

•Day 5: Evaluation of taxonomic issues

- Critical remaining knowledge & data gaps
- Possible collaborations to address gaps, continue biogeographic synthesis



Workshop methodology

- **Assess diversity by region**
- **Compare faunal similarity within & between seamount chains & regions at varying spatial scales**
- **Compare endemism (species' distribution ranges) by region**
- **Multivariate analysis of seamount communities at varying spatial scales**



Critical issues

- **Are the data adequate for the analyses?**
 - Methodology comparable/consistent between regions/studies?
 - Taxonomy adequate & comparable/consistent between regions/studies?
- **If not, can focussed short-term studies enable the analyses?**



Workshop outputs

• **Workshop report**

- Working Group Chair reports on outcomes
 - Basin-scale assessments of diversity, endemism, distributional ranges, spatial scale of faunal similarity

• **Review paper(s) in refereed journal**

- Regional/global seamount biogeography, patterns of diversity, endemism, distributional ranges (*Deep-Sea Research? Science or Nature?*)

• **Input analyses to a workshop to focus on management/MPA design**