Proceedings of
Pew Workshop on

Design of Marine Protected Areas for Seamounts and the Abyssal Nodule Province in Pacific High Seas

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Primary goals of Workshop:

1) Make specific (or generic) recommendations to the International Seabed Authority (but also UN, etc.) on the design of Marine Protected Areas to safeguard biodiversity and ecosystem function on Pacific seamounts and in the abyssal Pacific nodule region in international waters.

2) Outline research needs to allow better design of deep-sea MPA’s in international waters.

To Address these goals, the workshop will have three stages:

I. Overview (day 1)

   A) Learn about general principles of MPA design
   B) Elucidate general legal framework of environmental protection in the high seas
   C) Briefly review MPA activities in the high seas to date

II. Ecosystem Review – for Pacific Seamounts (days 1-2) and the Nodule Region (days 3-4) we will:

   A) Identify nature and distribution of anthropogenic threats (mining, fishing, etc.)
   B) Characterize key physical, ecological and biodiversity characteristics
   C) Summarize current knowledge of habitat distributions and biogeography

III. MPA Design – for Pacific Seamounts (day 3) and the Nodule Region (day 4) we will:

   A) Identify the goals of the MPAs
   B) Design specific (or generic) MPAs, applying the concepts of ecosystem based management and the precautionary principle, and considering stakeholder interests (where possible);
   C) Outline monitoring strategies and key research needs to allow better design of deep-sea MPA’s in international waters.
   D) Draft a workshop report to ISA (and a policy paper for Science?) with our rationales and recommendations (and also identifying our precendents)
   E) Please note: format for stage III. MPA Design is still to be determined, with input from MPA design experts (Gaines and Friedlander) and ecosystem experts.

The precautionary principle will guide our discussions in this workshop, as will the foundations of ecosystem-based management.

Definitions:

Ecosystem based management – An approach that “looks at all the links among living and nonliving resources, rather than considering single issues in isolation . . . Instead of developing a management plan for one issue . . . EBM focuses on the multiple activities occurring within specific areas that are defined by ecosystem, rather than political, boundaries.” — US Ocean Commission Report, 2004
The precautionary principle – “The principle that authorities should act cautiously to avoid damaging the environment or wellbeing of communities (in a way that cannot be reversed) in situations where the scientific evidence is not proven but the possible damage could be significant.” — The Highland Council

“This principle establishes that a lack of information does not justify the absence of management measures. On the contrary, management measures should be established in order to maintain the conservation of the resources.” — FAO

PART I: Design of Marine Protected Areas for Seamounts in the Pacific High Seas

Opening remarks from the International Seabed Authority concerning ISA’s mission, legal framework, and desired output from the workshop
Nii Odunton

The International Seabed Authority (ISA) was established by the United Nations Convention on the Law of the Sea (UNCLOS) and an implementation agreement relating to deep-sea bed mining which became active in 1994.¹ The ISA manages and administers the mineral resources in the international marine areas (int’l seabed). The organization of the ISA includes a general assembly, consisting of 154 member nations and the European Union for 155 total members; the U.S. is not a member since it has not ratified UNCLOS. A 36-member council represents the various interests of the member nations in the ISA and is grouped in chambers. Under the council, the Legal and Technical Commission (LTC) comprises various experts in a myriad of fields concerning the seabed. One of the LTC’s main concerns is the “equitable geographic distribution” of resources. The Finance Committee, composed of 9 members, also works under the council. For the purposes of this workshop, the Legal and Technical Commission is very important as they make recommendations to the Council.

During the UNCLOS conferences, polymetallic nodules were the main interest of potential mining activities. During the deliberation, land-based mining nations were concerned about perturbations to the international market represented by deep-sea bed mining activities. In the 1970s, consortiums formed in order to develop seabed mineral resources. Most of these various consortia were interested in the Clarion-Clipperton fracture zone.² A general framework was established under the ISA with broad provisions relating to protection and preservation of the marine environment. In UNCLOS, Articles 145 and 162 specifically address protection of marine resources.

- **Article 145** requires the ISA to take all necessary measures to protect the environment from 1) prospecting, 2) exploration and 3) mining.³

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² The consortia included groups from China, Japan; DORD; France; Russian Federation; Eastern European block [Poland, Bulgaria, Cuba]). These consortia were ‘pioneer investors’ in the Clarion-Clipperton area. An Indian consortium has explored an area in the Indian Ocean.
³ UNCLOS, Article 145, Protection of the marine environment. “Necessary measures shall be taken in accordance with this Convention with respect to activities in the Area to ensure effective protection for the marine environment from harmful effects which may arise from such activities. To this end the Authority shall adopt appropriate rules, regulations and procedures for inter alia: (a) the prevention, reduction and control of pollution and other hazards to the marine environment, including the coastline, and of interference with the ecological balance of the marine environment, particular attention being paid to the need for protection from harmful effects of such activities as drilling, dredging, excavation, disposal of waste, construction and operation or maintenance of installations, pipelines and other devices related to such activities; (b) the protection and conservation of the natural resources of the Area and the prevention of damage to the flora and fauna of the marine environment.”
**Discussion**

CSmith: *In the ISA rules, a “preservation reference area” (PRA) must be established. The PRA and IRA designation is analogous to an MPA designation, therefore it should be recognized as such.* Currently, the scales of PRAs are too small. Built into the ISA guidelines and UNCLOS are provisions allowing for MPA establishment. The whole concept of Impact Reference Areas (IRAs) and PRAs were established when there was very little known about the deep sea.

There are two basic classes of MPAs, including those established for: 1) population persistence, ecological consequences (discussed by Steve Gaines), and 2) those designated primarily for habitat preservation (discussed by Allan Friedlander). A review of 125 marine reserves in peer-reviewed

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**Footnotes:**

4. UNCLOS, Article 162, *Powers and functions.* “2. In addition, the Council shall: (w) issue emergency orders, which may include orders for the suspension or adjustment of operations, to prevent serious harm to the marine environment arising out of activities in the Area; (x) disapprove areas for exploitation by contractors or the Enterprise in cases where substantial evidence indicates the risk of serious harm to the marine environment.”
studies finds that less than 1% of the ocean is protected and less than 0.1% is preserved in “no-take” reserves. Most reserves are shallow, coastal and are primarily reserved against fishing threats. Marine reserves exhibit more biomass, more animals, larger animals, and more species; there is no geographic component to this response. In comparison to reserves, MPAs typically have a variety of rules (e.g. National Marine Sanctuary program allows extractive uses). Reserves, however, are “no-take,” and reserves do not allow fishing, which is generally the identifying factor for a reserve.

The response of species to protection is species-specific. Ecological interactions and bycatch are important processes and are highlighted in differences found between MPAs and reserve systems. Many MPAs and reserves are established as “restoration” efforts, rather than preservation. These protections are not setting aside ‘pristine’ areas; consequently establishing protections allows us to measure responses, as the system reacts to the rules. Reserves are still not big enough to protect species, as the biogeographic ranges of species are much larger than existing reserve systems. As a result, there is now a focus on the concept of networks of MPAs and reserves. Networks can be set up for habitats and for populations (esp. threatened populations). California, for example, has an explicit requirement to manage systems as a ‘network.’

A network is a collection of MPAs or reserves. The way the MPAs are connected alters the way they function. Networks allow us to foster ecological connections. There has been significant effort put into modeling studies of ecological connections through movement of adults and young. Adults are exposed to risk when they leave the reserve (esp. species that are targeted in fisheries). The question is whether larvae can make it to another reserve. This illustrates the concept of a persistence threshold. From modeling studies we know that the size of the MPA is the most important feature. The MPA size must be greater than the average scale of movement. Scales of distribution of species (adults and young) are different, but generally propagule dispersal is about 3X larger in the ocean than in terrestrial systems. The answer is that we need larger reserve systems if we are to ensure persistence, or better networks of MPAs in order to accomplish preservation/conservation goals.

MLPA Goals
- To protect the natural diversity and function of marine ecosystems
- To protect representative and unique marine life habitats
- To help sustain and restore marine life

A key criterion for network design is the spacing of MPAs, which must be less than the larval dispersal range. The final network design must consider movement of adults and larvae, and the size of the MPA must consider frequency distribution of adult movements. In California, for example, the preferred recommendation was that MPAs be at least 20 km² size and no more than 50 km apart in order for the network to achieve persistence thresholds.

An Ecological Network is a variety of entities connected a collection of MPAs. The function of the group changes depending on how they are connected. Ecological connections are defined through movement of both adults and young. For adults, leaving reserve is risky, problem when adults leave the MPA, they get fished! Leaving the protection of the reserve has few risks for larvae. Key question: can larvae get to another reserve? Protection must provide the ability to move from one reserve to the other.

Reserves & Species persistence: To promote sustainable populations: MPA size > scale of movement. This is a simple rule but poses a huge challenge because dispersal varies among species. For the young it is the exact same rule: MPA size> scale of movement. If the MPA is small relative to the dispersal, then it will not provide any benefits. Propagule dispersal of sedentary organisms: marine organisms move at larger scales, compared to terrestrial organisms. A good example is the Northwestern Hawaiian Islands (NWHI).

Dispersal between MPAs is just as beneficial as retention within the MPA if the larvae can make the jump. Spacing of MPA < larval dispersal. However, there are different dispersal abilities between the different organisms. There will always be winners and losers. Networks may maximize the

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5 16 U.S.C. § 1532(19). The definition of “take” in the Endangered Species Act (U.S.) is to “harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct”
number of species that benefit. Spacing can capture some of these species. For a network of MPAs the spacing guidelines: 10 km reserves (MPA Size); < 100 km apart, 20 km reserves, 50 km apart (preferred recommendation in CA). Thinking about the consequences of scale of movement.

    The design of MPAs for fisheries and biodiversity conservation must also consider habitat types, critical areas for inclusion (e.g. spawning or nursery sites), size, shape and configuration of individual sites within a network. In reconciling optimal reserve proportions and fisheries yields, the MSY is the governing fisheries concept. Egg production vs. adult “spillover” effect \(\rightarrow\) larger organisms provide exponentially greater egg production. **Marine reserves provide insurance against management mistakes, depending on size and the network.** Habitat is key criterion and must consider all the ecological linkages, life history of species and must seek to include critical habitat. We first need to understand distributions of species in order to know what areas to protect. Part of this effort requires us to build a library on species distributions and life histories in order to understand what areas are critical. In some species, there are linkages of habitats with ontogenetic shifts, therefore we need to be careful to ensure there are not breaks in the protections of habitats utilized.

**Design consideration for MPAs**

1) **Total Size of the Reserve or Reserve Network**: Marine reserves provide insurance against management mistakes depending on size. As we increase the proportion of area in protection, the catch increases.

2) **Habitat Types**: Importance of habitat. MPA greatest chance of including all species, several ages, etc.

3) **Critical Areas for Inclusion** (spawning and nursery \(\rightarrow\) Essential Fish Habitat): Ontogenic shifts in habitat utilization. Developing corridors to allow movement to other MPAs.

4) **Habitat Complexity, Size, Shape**: Biodiversity hotspots, areas vulnerable to fishing. Complex habitats focus points are spawning aggregations sites.

    In Hawai‘i, there are four major types of habitat types: colonized hard bottom, macroalgae, uncolonized hard bottom, and sandy bottom. We need to understand the complete linkage of habitat types utilized by animals in the system. For Hawai‘i suitable habitat for bottomfish is 100-400 m slope>20degrees, hard bottom habitat (Parke 2007). There is a correlation between habitat complexity (rugosity) and fish assemblages, habitat complexity is a good surrogate for species. We identify hotspots of observed vs. modeled diversity (in terms of rugosity).

Habitat complexity tends to be focal spots for biodiversity, and can be critical to ecosystem function. Measuring habitat complexity can be achieved through LIDAR (shallow water) or multibeam bathymetry. LIDAR-derived digital surface models for Hanauma Bay (Wedding et al. in press) were used to ascertain a measure of rugosity or habitat complexity. Multibeam bathymetry, back scatter, etc. can also be used to determine habitat rugosity and complexity. Subsequent characterization of the habitat complexity can be used for developing habitat suitability models for various species, and for MPAs. The key notion is to couple habitat with species assemblage structure to create a connectivity network for species. Then we can use probability of survival as a metric.

    Establishing MPAs first requires detailed benthic maps, then good ecological information on the biological resources. The next step is to get input from local stakeholders, then make recommendations for designation.\(^6\) In making the recommendations, the size and spacing of reserves need to be large enough to support adequate self-recruitment. There are general design principles for reserves, which include:

1) 20-50 % of the management area,

2) straight-line boundaries with clearly defined navigational references,

3) large enough to contain viable populations of species of interest,

4) inclusive of all habitats with an emphasis on special habitats and replicated, and,
5) Stakeholder involvement.

A biogeographic assessment of MPAs shows that habitat complexity explains a lot of the variation (25%); management regime accounted for another 10% of the variance. MPAs that are too small won’t have any positive effects on local fisheries (e.g. Main Hawaiian Islands). When designating reserves, a range of habitat complexities should be considered, with full protection from extractive uses and a variety of physical conditions (e.g. wave exposure). Depending on the goals of the reserve system, 20-50% of area needs to be protected. Networks should be divided up into individual reserves capable of supporting viable adult populations. Habitats should be protected in a replicated manner with a full representation of habitat types. Stakeholder input and support is a critical feature (not sure how this works in seamounts/deep sea). Ecosystem-based management assessments should be used to evaluate MPAs, and boundaries can be modified through time as an adaptive management approach.

Discussion

Fixing the MPA size based on patterns of adult movements and spacing requirements will work because larvae can make the jump from reserve to reserve. The probability that larvae lands in an MPA is higher with networks (esp. with spacing rules). The total area is important in order to preserve probability for larvae landing in a reserve. There is a concern about whether modeling preserves upstream/downstream effects. Larval distributions subjected to advective flow need larger MPAs, because larvae get pumped out of the MPA. In terms of spacing, there is a greater premium on larger MPA systems. In determining the portion of area protected the critical issue is the larvae, and we know much more about larvae in shallow systems than in the deep sea. This can be addressed via habitat continuity – a minimum size of MPAs is required in order to provide for larval success, which gets into metapopulation dynamics. The NWHI may be a good model system for modeling and studying metapopulation dynamics. The network is important, but each MPA must also be self-sufficient. One question is whether 20% placed into reserves is a good prediction for the deep sea.

Habitat complexity is another issue. The bathymetry of the high seas is very poorly defined in most cases. Perhaps we can develop probability of connection based on location. This is tricky because these are 3-d systems, where depth is very important and satellite information does not give a good scale. Typically the multi-beam information is the best in determining habitat complexity, but the data in this realm is not sufficient. ROV data only gets 1 or 2 sides of the seamount. Trawl data is usually from a flat area on the seamount, and plus there is nothing there after trawling. The vertical habitat on seamounts is different from the flatter, horizontal part of the habitat.

Who Owns (and Protects) the High Seas?
Alison Rieser

There are multiple zonation schemes in the ocean, and the geo-political zonation of the oceans was established under UNCLOS. The baseline determines where the ocean “starts,” from a jurisdictional perspective. Beyond the EEZ are the international high seas, where different rights apply. In the territorial sea, a maritime nation has full rights, except when it comes to innocent passage (also includes airspace). Within the EEZ nations do not have full sovereignty, but has sovereign rights for resources (living and non-living). The airspace is considered international. Under UNCLOS, nations are to manage living resources to promote “optimum utilization,” and UNCLOS language encourages utilization of the resources in the EEZ.

A coastal state also has sovereign rights over the continental state for exploring the rights of the non-living seabed AND sedentary species. Claims can be made beyond 200 nautical miles (nm) as long as the state files with the UN within 10 years of becoming a party to the UN. Claims can be made out to 350 nm, including the continental slope (entire continental margin), and extended
continental shelf claims can be based on sedentary species as well as non-living resources (e.g. oil and gas).

In the high seas, the deep seabed is considered the “common heritage of mankind.” The seabed includes the entire seabed beyond the EEZ and/or continental shelf. UNCLOS established the ISA to manage this area. The high seas are associated with freedoms for fishing, navigation and overflight, marine research, installation of cables and pipelines, artificial islands, and other uses. Nations must give due regard to the interests of other nations in exercising high seas freedoms. In a UN Fish Stocks Agreement, all nations have a duty to cooperate to conserve fisheries and associated ecosystems. Nations are free to agree among themselves to limit their high seas freedoms (self limitation), but under UNCLOS all parties have an obligation to protect the marine environment. Under UNCLOS, there are several ways to protect seamounts and the abyssal plain. A coastal state can protect seamounts and abyssal plain within their EEZ and on its continental shelf and margin from fishing (sedentary species) and mining activities. A flag state can protect resources via regulation of their flagged vessels. Regional Fishery Management Organizations (RFMOs) can regulate fishing by member states’ flag vessels in its areas of high seas competence, but this requires the member state to adopt the measures as law. The International Seabed Authority has jurisdiction over the seabed beyond areas of national jurisdiction for mining. Regional Seas Programs also may protect areas within its area of competence (e.g., OSPAR). Lastly, fishing and mining companies can voluntarily protect wherever they operate.

Discussion

RFMO jurisdictions depend on the fisheries that the RFMO was created to manage. In considering sedentary species, does this include corals? Or other non-fished species? Could a coastal state use its continental shelf rights to protect a non-fish species? Yes, because they would be damaged by fishing activities. A coastal state would have jurisdiction to have exclusion areas for sedentary species. Measures must be taken to preserve or protect species – the ISA is subject to that authority (ISA is seabed and subsoil only, nothing above).

In the high seas, how is distinction between living and non-living resources articulated? Does this include DNA? The language of the convention defines resources of the deep seabed as mineral resources. There has been a running debate on the extremophiles, and whether or not these are related to mineral resources. This issue still needs resolution, and currently the only kind of living resources are those clearly associated with mineral deposits. All actions taken to protect hydrothermal vents, where there may be bioprospecting, have been adopted. The ISA believes the regional seas programs have no jurisdiction over high seas.

Update on Measures Being Considered or Adopted by RFMOs to Protect Deep-Sea Ecosystems
Lisa Speer

Unregulated bottom trawling on the high seas has been targeted by environmental groups for a moratorium. A UN Resolution issued on Dec. 2006 requires the identification of vulnerable marine ecosystems, including seamounts, hydrothermal vents and cold water corals are known to occur or are likely to occur (big step). This reverses the “burden of proof.” Currently, only four (4) existing RFMOs are able to regulate bottom fisheries, and have made bottom fisheries part of their

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7 UNCLOS, Article 136, Common heritage of mankind. “The [the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction] and its resources are the common heritage of mankind.”


jurisdiction. Some progress is being made in the RFMOs on the UN Resolution, and NAFO is an example (Georges Bank protections).

**Existing RFMOs with competence to regulate bottom fisheries**
- CCAMLR- Commission for the Conservation of Antarctic Marine
- GFCM- General Fisheries Commission for the Mediterranean
- NAFO-Northwest Atlantic Fisheries Organization
- SEAFO- Southeast Atlantic Fisheries Organization
- NEAFC-Northeast Atlantic

**High seas bottom fisheries are currently negotiation or awaiting entry into force.**
- Northwest Pacific
- South Indian Ocean
- South Pacific RFMO

New RFMOs are being developed, including one in the South Pacific RFMO. All trawl vessels are required to have 100% observer coverage and a vessel monitoring system (VMS). The FAO is negotiating an agreement for the northwest Pacific (FAO Area 61), which may expand to the entire North Pacific, much like the South Pacific RFMO. This document is very useful, and the criteria has been agreed to by an international body (FAO); currently the CBD has also defined some criteria for VMEs.

Human activities are increasing in the high seas. There is no assessment mechanism for human activities in the high seas and it is very important to consider how to mesh regulatory regimes currently in place and what regulatory regimes need to be implemented. For example, there are no regulations for iron fertilization, cable installation, and other human activities. Our existing regulatory structures currently inhibit protections for the high seas and environmental review for high seas activities.

**Discussion**

This workshop should get the definitions for VMEs from the CBD and FAO guidelines. Where are “significant adverse effects” defined? FAO guidelines have a definition: when ”harm is serious or irreversible…” see FAO guidelines for full definition. SGaines: When it takes several generations or decades to reverse the impact, impact with irreversible effect, after reading several definitions come to the conclusion that is a vague definition. **When no information is available you have to assume that damage will be irreversible (precautionary principle).** The definition of “productivity” entails all aspects of a population to maintain itself.

LWatling: If cold water corals are covered in the protections then all seamounts should be protected, because there are octocorals on all seamounts. The need for meshing regulatory regimes is very important. Marine ecosystems are connected, therefore human activities can change community structure (e.g. iron fertilization: affects seafloor communities). The RFMOs are limiting activities, but there are nations with global fishing fleets (e.g. Japan). How much fishing is actually regulated? **Nations that are not signatories to the agreements are not bound by the agreements (e.g. China, which has growing fleets), and these are key issues for RFMOs to consider.**

The vessel monitoring system (VMS) requirement is also important, so we know who is fishing and where the fishing occurs. There is a large meeting upcoming in the spring discussing fishing beyond national jurisdiction and regulation on the high seas. **Perhaps we need an implementing agreement under UNCLOS.** RFMOs are trying to manage countries with global fishing

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10 In the South Pacific RFMO, interim measures have been adopted, requiring nations to close areas that contain “vulnerable marine ecosystems” – see UN Resolution
11 Negotiations include Japan, Korea, Russia, U.S.
13 Definition not found (need sources)
boats (e.g. Japan). Japan involved is in RFMOs? We need to identify mechanisms to bring everybody in. Future meetings to focus on ad-hoc protecting marine areas beyond natural jurisdiction. Countries come together to talk about what can they do.

The identification of VMEs is important. The precautionary approach in the FAO guidelines does not mean protection, just means the RFMO has to consider protections for a specific seamounts. Some historical VMEs have been fished already. The interim measures: seamounts are de facto VMEs, unless you can demonstrate fishing will not have an adverse impact.

M Clark: What happened to the Northwest Pacific? Seamount vulnerable ecosystems, unless you show that fishing would not have an impact on them. When do you open them? Is it worth protecting a seamount that has already been trashed? If 30% of seamount is intact is not vulnerable marine ecosystem? How seabed authority communicates to the RFMO. There is no unit/organization that facilitates the connection/communication between these two entities.

Physical Oceanographic Context of Seamounts
Pierre Dutrieux

Seamounts are defined as greater than 1000 meters above seafloor with complex geometry, terraces, canyons, calderas, and craters. There are more than 30,000 seamounts in the Pacific alone. Seamounts can effect circulation and geochemical tracers as physical obstructions to circulation patterns, and can create eddy formation downstream. These anomalies are often characterized by their own “isolated dynamics” which in turn affect the physical habitat, geochemical signatures and biology. There are large scale flow interactions with seamounts that include current deflection, wakes, eddy formation in the lee, impacts on ocean circulation, and potential impact on global climate via air-sea interaction. The effects on circulation vary with depth. Is this reliable to help with transport distances of larvae between seamounts? Could we use this to infer optimal spacing of MPAs? Yes, this model is pretty reliable. We can use the model to look at advective processes to help infer MPA distribution that is optimal for larval transport.

Effects of seamount on circulation
- Taylor column
- Trapped waves (isolated physics, tracer isolation)

Sources of energy at intermediate depth in the ocean
- Large scale “wind driven” flows 1m/s at surface but 1-10 cm/sec at 1000m depth
- Mesoscale variability, eddies 1-10 cm/sec at 2000 m depth
- Tides- barotropic, baroclinic 10cm/sec
- Internal swell (wind generated internal waves) up to 10cm/sec

Seamount specific phenomena include the Taylor Column. This generates a weak flow, which creates a butterfly pattern that rotates anti-cyclonically (depending on hemisphere) around the seamount as a wave (unless friction prevents). A strong or steady flow can generate upwelling upstream, downwelling downstream. Cells are created above the seamounts, depending on characteristics of flow, creating upwelling/downwelling dynamics via periodic forcing.

Tides can also generate waves that travel down the topography of the seamount, resulting in strong up/down displacements and mixing along the relief of the seamount (angle of wave must be close to topography relief); this can generate strong displacement of isopycnals. This will happen regardless of surface currents because the tide acts as a shallow wave; the entire water column moves and the height of seamount is important but tides will create mixing along the seamount. We’ve used TOPEX data to determine internal tide mixing repartition. Internal swells can create the same mechanisms as tides, creating mixing along the flanks of seamounts. Mixing can also occur due to narrow topographic passages (bathymetric forcing – creates turbulence).

Take home message: seamounts have an impact on circulation & circulation has an impact on seamounts. CSmith: With regard to transport of larvae, optimal spacing → is it pretty reliable to
estimate larval transport at the mesoscale? **Simulations could be helpful to estimate larval transport.**

Mesoscale variability is also important. Mesoscale waves and eddies can be seen as storms for the deep ocean. Eddy energy decreases with depth, but there is still significant energy at 2000 meters. There are important implications for geochemical signatures and biology as upwelling increases nutrient concentrations. Water may become trapped above seamounts in areas with strong steady flows, but not for seamounts that exhibit weak flows. Trapped waves can occur (called the “Taylor Cap”) or oscillating flows and intermittent events can flush the area above the seamount. This has been supported with empirical data. The implications for sediments is that strong currents remove sediments on seamounts and enhanced turbulence increases potential down-slope turbidity currents. **For seamounts, the physical parameters of importance include height, diameter, steepness, degree of symmetry, smoothness of topography, stratification, mean current strength, oscillating current strength and frequency of oscillation, and direction of current.**

**Discussion**

CSmith: Can this model be used to determine currents at the sea floor? Not with this particular model - it would be weak. LWatling: Does the long term flow regime dictate the biology on the flanks of seamounts? Each of these models considers different types of energy (e.g. tides, mesoscale eddies). AFried: Have the different types of mixing mechanisms been amalgamated? It is a difficult process to add these different flows together, a lot of assumptions are built into the model. How much time would it take to determine this? Approximately 6 months to do a robust model. MClark: Some estimates can be made for seamounts, and with models available, can we predict likelihood of Taylor cap formation for seamounts? PDutr: if we know more about the seamount physical parameters and location, we can predict some physical flow parameters. The problem with tide is that we need a high resolution model. Adding all parameters is very difficult. LWatling: We need a general seamount model, but we also need detailed information.

**23 October 2007**

**Afternoon Session**

**Mining on Seamounts: Resource Distribution, Likely Technologies, and Likely Space and Time Scales of Mining Effort**

Charles Morgan

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Resource distribution of seamounts with deposit sites is worldwide. Cobalt-rich crusts exhibit high porosity, high surface area, and slow growth (1-6 mm growth/million years). Approximately 0.5% of the crusts are Cobalt, which drives the economics of extraction, so does platinum and potentially cerium. The bulk of deposits occur from 500m – 2 km, and are in the oxygen minimum zone. Guyots are the primary interest for mineral exploitation, rather than seamounts due to their conical shapes. An area west of Hawai‘i in the NW Pacific is the most likely area for mineral extraction of this nature. Guyots have more minable area, which is why they would be a target for a single conceptual mining operation. The likely technologies for a mining system include a pick-up system (extraction from seabed) and conveyance to surface; also need to consider that these minerals, when in place, are difficult to separate from substrate. This is all based on technology developed in 1990, but despite leaps in technology, extractive impact is probably the same today.

**Any operation or conglomeration of operations that exceeds 10% of current world production will disrupt world markets**, which then makes economic studies irrelevant. In this type of operation the dispersion of sediment associated with crust extraction is probably less of a concern

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14 This information comes from two sources: James R. Hein, “Seamounts and Cobalt-rich Ferromanganese Crusts;” and a programmatic EIS on proposed marine mineral lease sales: EEZ adjacent to HI and Johnston Atoll. Charles Morgan respectfully requests that the data presented not be used in any official correspondence or publication. James Hein is potentially going to publish this data, and some data may be used if requested and approved by the data owner.
than with nodules, but is still an issue. This type of mining will result in sediment dumping at multiple stages of the operation. The pick-up system is dependent on the viability of substrate removal, and has been tested in a mining simulation. Crust purity and efficiency of mineral extraction is difficult, given current methods of extraction and roughness of seafloor. Roughly, 1,500 km/E (E= mining efficiency) is required.

**Discussion**

CSmith: How many seamounts would 1,500 km represent? Probably just a few, depending on the thickness of the crust. LWatling: A Canadian company is mining sulfides in PNG – are they using the same technology? This operation will go commercial within 5 years, they use grinders to harvest a mass deposit, rather than a crust. CSmith: With regards to habitat complexity, is the harvesting mechanism is same as a rock dredge? A rock dredge picks up what “sticks” out. CSmith: we look for a flat habitat to sample, and we’ve found tremendous biodiversity in these spots. CMorgan: a rock dredge is not a good objective sampler, will sample acoustically flat areas, but gets complex habitats. CSmith: A rock dredge samples the same type of habitat, which can exhibit a high level of biodiversity. MClark: There is a high level of biodiversity. Morgan: Contractors are going for habitat that is not complex. LWatling: Areas with higher flow correlate with crust formation and high levels of biodiversity.

**Fishing on Seamounts: Resource Distribution, Technology and Local Impacts, Past and Future Exploitation**

Malcolm Clark

Global “deepwater” catches (< 200 m) have increased dramatically in recent years and decades, and constitute approx 4% of worldwide catch. From a global perspective, the catch is not very large and species included in “deepwater” are not restricted to those associated with deep-sea seamount habitat.

**Biological characteristics of “deepwater” fisheries (FAO 2007)**

- Slow growth rates
- High longevity
- Low fecundity
- Not annual spawning
- Low productivity

There is a need to better define deepwater seamount fishes and fisheries, based on biological characteristics, rather than simple physical parameters such as depth. Species of value in the deep sea include Orange Roughy, Oreos, Pelagic Armourhead, Alfonsino, Grenadier (mid-Atlantic), and Toothfish. The development of technology for deepwater fisheries (500-1500m) occurred in the 1980s – 90s: Deepwater fisheries follow a “boom and bust” cycle, and this is the norm, probably because seamounts are such unique environments. Some fisheries have experienced switches in the dominant fish type. Spawning may be somewhat unpredictable, but on average, these fish spawn every two years; it takes a long time for these organisms to grow.

The high value of deepwater fisheries generates interest from fishers, and ease of capture is also an attractive feature of the fishery. There is a lack of knowledge about recruitment patterns for deep sea fishes, and it appears as though there are long term periods between successful recruitment events. Cohort analysis is difficult because the age class approach is difficult with these species. Most deepwater fishes are feeding on mesopelagic fishes and zooplankton. These fish stay close to the benthos, waiting for the food to come to them as the migration of zooplankton comes to below the scattering layer. To illustrate the longevity of these fish, Orange Roughy become demersal at age 1 (~ 2-3 cm length), and become sexually mature at age 25 – 30 years.

Trawl gear design has developed dramatically, especially after GPS was used by the industry (since 1990); other electronic development (echo-sounders, net monitoring, and catch monitoring & bathymetric
mapping) has been added. In New Zealand, fisheries catch has increased substantially since the 1990s. The catch history shows a trend with decreasing catches over time. Frequent occurrence of fisheries with early large catches, followed by very low catches; often catches are irregular or sporadic.

**Factors affecting sustainability of deepwater fisheries**

1) Fishery characteristics inherent factors we can’t change, but need to be aware of:
   a. Low productivity,
   b. Ease of capture,
   c. High value
2) Lack of information
3) Assessment techniques
4) Elements of management

The young fish are developing in the pelagic somewhere, but where is unknown. Young are demersal from day one. Examples of fish with constant recruitment. There is a huge geographic separation of adults, and they are not recruiting at high and regular rates. *Juvenile fish are not observed on submersible dives*; the only juvenile fish observed in 40 dives seamounts was 3-4 cm size. A low food environment may be limiting recruitment (there is no proof for this). *Deepwater species do not grow very fast, perhaps due to food limitation, or other characteristics.* This is also observed at hydrothermal vents, where the temperature and pressure is high and most organisms are growing quickly. Unanswered questions: Why do fish grow slowly? Do they also live longer? What about corals in seamount? Feeding spawning strategies have been observed. One year old fish are not associated to the nursery area (seamount), what is the spawning patterns, how do young get back, if they come back or arriving to a seamount at age of 25 then what happens? Aggregations that come to the seamounts, could have come from other regions. There may be a downstream effect. Highly variable recruitment “advective law”, once every 20 years currents change and there is a big recruitment event.

**In order to developing seamount fishery management we need an adaptive approach, individually transferable quotas (ITQs), feature limits, and seasonal time/area closures.**

Environmental considerations that we need to include are essential fish habitat (preservation) and a need to protect biodiversity. Trawling intensity on seamounts can be quite high, the median is 130 km of trawls for 1 km² seamount area; trawl gear has a 100 m breadth. It is believed that for orange roughy the microscale habitat features are not important, only the feature itself (the seamount). Seamounts can recover after closure, we have observed a re-colonization of stylasterids on a New Zealand seamount.

**Seamount closures work best with a mixed management plan, including the closure of some to preserve biodiversity, reserving others for restoration, and leaving some open for fishing.** In managing seamounts, we should predict the distribution of cold-water corals to identify potential sites for preservation via reserves (VMEs). The two types of fisheries that are likely to impact seamount habitats the most are the orange roughy and alfonsino fisheries (low volume, high value fisheries). We can use a model to predict which seamounts will have scleractinian corals and then plot overlays with fisheries (habitats that have already been fished) to prioritize habitats for protection. This requires a balanced approach for comprehensive management of seamount ecosystems with open and closed areas.

**Discussion**

SGaines: Is there any pattern for recruitment for deep sea fishes. MClark: everything I’ve seen says there is a lot of variability. Recruitment is not at high or regular rates. LWatling: In all the dives (~40 dives), we only observed adult fish, even when we used high definition filming equipment. The same pattern with Patagonian toothfish has been observed. CSmith: So what is limiting reproduction or recruitment? There is no indication of production limitation with adults and we also don’t know what limits growth. Is it pressure or temperature? It could be a life history of the species, or could be food limitation. There are dense aggregations around seamounts, which is probably due to food availability. Everything on seamounts grows very slowly, and lives for very long time. LWatling: There may be a metapopulation dynamic; where are these dense aggregations
coming from? There is probably some source in the basin. CSmith: In the spawning aggregations that have been observed, is there the same brooding fecundity - is reproduction effort constant each year? Yes, this is what we have observed.

Ecology and Diversity of Seamount Biotas (Nature of Habitat, Factors Regulating Community Structure, Local to Global Diversity Patterns)
Malcolm Clark

Seamounts are biologically different, and can be regarded as “islands” of shallow seafloor that provide animals with a variety of depth ranges. These features exhibit steep slopes, currents, different substrate (rock surfaces), and substrate heterogeneity. Very little known about seamount fauna, and there is only good information available on only a few seamounts. There are major gaps in sampling; some future sampling has been planned.

- Seamounts with slow currents → sandy muddy substrate with deposit feeders.
- Seamounts with faster currents → hard surfaces more suspension feeders (i.e. corals).

For a global review see Wilson and Kaufmann (1987).\(^\text{15}\) Rich and varied fauna have been found, and generally the current speed determines fauna assemblages. In studies of seamount biodiversity over 3000 taxa have been observed on over 250 seamounts. Sampling gear is often selective, therefore we have a poor understanding of numbers of species on seamounts. Seamounts are hotspots for biodiversity, with variable substrate types and depth ranges; some animals (e.g. Lophelia) create additional habitat, with coral associated biogeography (asteroids, crinoids, sponges).

**Seamount productivity is variable.** Species richness can be variable, with a high biomass of fish and planktivores, not due to increased planktonic productivity. Trophic enrichment does occur, but is probably caused by processes such as entrapment of vertical migrators and enhanced horizontal fluxes of suspended food. There is a **seamount isolation theory**.

**Seamount Isolation Theory**

- Close seamounts can have very different faunal communities.
- Stepping Stone hypothesis
- Mode of recruitment? (local populations or wider area)
- Genetic mixing (large fish migrate between them)
- How much “self recruitment”

Seamounts together have different faunal communities, and the mode of recruitment unclear. There is some migration of larger species fish and mammals. Highly variable levels in endemism have been observed – most estimates are around 4-20%. **Endemism is likely higher for invertebrates than fish. Endemism levels may increase as cryptic species are described and taxonomic issues are resolved.** In a New Zealand study on macro-invertebrates, no “location” effect was found, though results differ depending on group. In this study, a cluster analysis with biologically “useful” physical parameters differentiated 12 groupings, some with geographic scale, some with environmental. **No depth pattern on levels of endemism is apparent.** Data sets are available with amalgamations of data for worldwide distributions but big holes exist. Habitat suitability maps have been built from predictive models for stony corals.

The **human effects on seamounts are serious.** Seamounts are highly vulnerable, effect of human impacts may be serious on endemic populations. The direct effects of fishing are obvious, other less obvious effects include sedimentation, change in community composition via selective removal, interactions between benthic-pelagic components. **Recovery of seamount ecosystems may be slow.** Management is needed to balance exploitation and conservation, and management can be informed by good scientific data, predictive studies, and known physical parameters.

**Discussion**

AFried: In addressing the endemism issue, specifically taxonomic endemism, we need quantitative data, which is tough with presence/absence data like we have on seamounts. Endemics can be overrepresented because of evolutionary mechanisms that have allowed them to persist in these habitats. E.g. Hawai‘i – 20-25% of species counted are endemic, but 50% of all animals were endemic. Endemics are differentially more abundant. MClark: Seamounts may be evolutionarily more constant over time because of the character of these environments. SGaines: are endemics rare? CSmith: This is the pattern in the deep sea, but could be artefact of sampling effort. Hard to determine without quantitative data. CSmith: Any comparison with slope versus seamount fauna, or any comparison with islands – e.g. HI ridge (cont scale slope), not associated with a continent, but associated with islands (HI). A complex archipelago. Could use existing data sets to perhaps investigate this (HURL data) – or add to existing data.

Biogeography, Life Histories and Dispersal Patterns of Seamount Biota in International Waters (Especially in the Pacific)
Alex Rogers

Seamounts are unique ecosystems. Benthic habitats are very diverse, and support a variety of reef-building species. Mobile predators are also present as are demersal bentho-pelagic fish. There is low overlap in species present on different seamounts, and low co-occurrence. One question we addressed is whether seamounts are different. Data for NE Atlantic analyzed for slope seamounts and for the flanks of islands. We compared continental slope versus oceanic habitats, and found that islands clustered with continental slopes. Seamounts were distinct (this is presence/absence data). Endemism was low (~4% of species), but this could be artefact of sampling protocol. Seamounts emerge as impoverished in species richness compared to islands. In terms of taxonomic levels, islands were actually higher in numbers of species.

The best regional analysis of biogeography of seamounts so far showed significance of latitude, longitude, and depth (min and max) in species distributions (O'Hara 2007). Most seamount specialists (endemics) are limited to 1 degree of latitude (narrow latitudinal ranges). This could be a sampling artefact or could be particularly rare species, it is hard to determine.

The take home message is:

1. seamounts do provide unique habitat,
2. high endemism is not supported with data to date,
3. there is possibly high local species richness, but may represent high regional species diversity,
4. species richness in some cases seems low (e.g. Great Meteor Seamount megafauna);
5. island biogeography and
6. Depth, latitude, oceanographic setting is important.

Our understanding of coral distribution on seamounts is hampered by an equatorial data gap in sampling of deep sea corals. The mean depth distribution of corals seem to be from 0 – 2000 m, with the highest diversity around 500 m, which is within the zone targeted by mining interests. Scleractinian corals mean depths 250-750 (1250) meters (important depth related to mining). Environmental Niche Factor Analysis (ENFA) was used to determine habitat suitability, which varies according to depth. Aragonite saturation and oxygen concentrations is very important for distribution of scleractinian corals. Octocorals: exhibit a different depth distribution than stony corals (corroborated Malcom’s presentation). ENFA has also been also used for Octocoral habitat suitability modeling. Factors affecting octocorals include slope (proxy for complex topography, hard substrata, and high current exposure), temperature, current, chlorophyll a concentrations, depth, and substrate. Scleractinian habitats tend to be concentrated in the southern hemisphere; octocorals tend

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17 See also: Davies et al. 2007. In press Deep Sea Research
to be concentrated in the northern hemisphere. Seamount depth and latitude are important determinants. There is some controversy regarding prediction of habitat suitability (Etnoyer & Morgan 2007).

**High seas protected areas should:**

1. consider seamounts with a range of depths and size,
2. be distributed across latitudes,
3. latitudinal distribution should not be by degree-bands but by water mass type (perhaps Longhurst biomes or LMEs), and
4. Consideration should include other existing or potential human impacts (fishing, pollution, research, climate change, other).

**Discussion**

LWatling: The lack of taxonomic consistency in databases is an issue. How has this been handled? We tried to use up-to-date data. We corrected taxonomy from earlier studies, updated those data from expeditions that we could, but probably still some problems. LWatling: A lot of the data from NE Atlantic is from 400 m samples. This makes it hard to compare between seamount depths, because communities are different. **Depth has a huge impact on the community structure and species present.**

CSmith: How much work has been done looking at micro-habitat distributions, especially with macrofaunal. Alex: Not much work on megafauna but not a lot has been done with habitat associations. This area is wide open. Amy: In one cruise in 2003 we looked at this. We have some data from the HI islands. LWatling: NW Atlantic cruises also looked at microtopography and substrate changes. Not sure where this data and analysis is, but should be available. Also some habitat classification schemes we published (book). Frank Parrish has a paper on habitat type and precious corals. CSmith: We need to look at this for Mn crusts and other crusts.
24 October 2007

Morning Session

**Genetic Studies on Seamounts and Implications for MPA Design**

Amy Baco-Taylor

Benthic seamount fauna are isolated. Benthic habitats in pelagic realms can be influenced by Taylor columns and there is some evidence for limited dispersal abilities, though only at one site. There is also some evidence for high levels of endemism. We tested seamount endemism using a genetic measure used to estimate migration or separation time in geographically structured populations. This measure focuses on changes in gene frequency cause by genetic drift. There are two gene flow models:

1. **Stepping-stone model** (expected for seamounts);
2. **Island Model** (expected to have long dispersal).

We conducted a literature review examining seamounts versus islands, slopes and other features. For seamounts, we looked at several studies and several different species.

The Patagonian toothfish is found around islands and seamounts. The Falkland Island toothfish population exhibits higher F$_{st}$, probably due to oceanographic fronts that separate the Falklands from other nearby seamount populations. Some speciation may be occurring on seamounts, and we need more data and better genetic markers to determine this. In summary, we found genetic structure with depth, there was no difference between island and seamounts in a group, oceanographic fronts/currents may constitute barriers and there is some evidence for speciation.

In a New Caledonia study, we compared slope to seamounts specimens from the same seamount were not closer genetically than different seamounts; there was no geographic pattern to most species. **Seamount endemism has been questioned**, and this argument says the data does not support seamount isolation. However, there are not enough samples from the slope (to compare to seamounts), and some sample sites are not “true” seamounts (> 1000 m). Sites also tend to be tightly clustered geographically, which follows patterns we’ve observed in other places. Tightly clustered sites have the same species. The end result is that seamount endemism has not been tested rigorously, and we are skeptical until there is better evidence.

Malcolm: how much does the depth of these sites matter? Are there differences ecologically? Amy: They are probably not that ecologically different. **Features on a ridge are not geographically separated** (Samadi et al. 2006). Seamounts on a ridge are not separated as much as oceanic seamounts on the abyssal plain. Seamounts could be species oases, especially for species with low dispersal. With regards to coral, cold and deep water scleractinian are more diverse than shallow species. Corals dominate in abundance and biomass on seamounts. Corals are found from 0-6000 m depth. In Hawai’i, precious corals include *Corallium luwense* (red), *C. secundum*, and *Gerardia* species. This is a profitable fishery, and there is only one refuge in the entire Hawai’i chain. We used gene flow models to study precious corals, and we expected a stepping-stone model. The refuge, however, is based on an island model. We sampled from the main Hawaiian Islands (MHI) and the northwestern Hawaiian Islands (NWHI), using DNA microsatellites because other markers are not variable in corals. Microsatellites are tandem repeats of DNA, are highly polymorphic and co-dominant; microsatellites are sensitive to small-scale genetic structure. We found within-population heterozygote deficiencies, which indicate a departure from Hardy-Weinberg expectations. This could evidence the occurrence of inbreeding occurring.

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18 Genetic Statistics include F$_{st}$, G$_{st}$, R$_{st}$, Ph$_{st}$, which exhibit a 0-1 value, and there are various assumptions to these statistical measures. The Rst value is more appropriate for microsatellite data.
20 Insert slide from Amy’s presentation?
The separation in islands might be attributed to vorticity or tidal motion, creating oceanographic blockages between populations. For *Corallium* species, there can be some genetic isolation, even in seamount chains. For some species there is clear structure including IBD patterns. The implications for MPAs: there are no generalizable patterns for seamount fauna, if seamounts are isolated, it is not likely to be across taxa. Oceanic islands can be considered as well. We need to consider oceanographic features in conjunction with life history characteristics in determining MPAs. We need studies across multiple taxa from same seamounts, and more studies of oceanic seamounts and islands, studies of seamounts in targeted areas, and funding and logistics support. The two species in HI are probably spawners, with an estimated dispersal distance of 405 km, which is much shorter than other corals.

**Seamount Endemism Questioned.** Mitochondrial allele networks – specimens form the same seamount are not closer genetically than different seamounts. No geographic pattern is observed for most species. Current data does not support seamount isolation (still not clear).

**Problems**
- Seamount- any feature with >1000m relief?
- Too few slope samples
- Unique haplotypes (need to increase sample size)
- Tightly clustered seamounts and island < 225km distance
- Has not been tested rigorously

Is Genetic diversity greater on the summit? Seamounts vs. Islands, slopes and other seamounts. Deep sea Fish work= $F_{st}$ values not significant, in other areas significant. *In terms of MPA design:* No generalized pattern for seamount fauna; Oceanic islands can be considered for inclusion on seamount MPA plans.

**Gap Analysis** (Need to Study)
- Study across multiple taxa from same seamounts
- More studies of oceanic seamounts and islands
- Studies of seamount in targeted areas
- Funding and vessel logistics

**Take-home messages:**
1) Genetic Structure with Depth
2) No difference between island and seamounts in a group
3) Oceanographic fronts/current systems may affect genetic structure
4) Isolation/Speciation found in only one study

**Discussion**

LWatling: These distances are distances of a haplotype spread (405 km), which is the average distance of a mean dispersal distance in a probability distance distribution. This is based on microsatellite data. Is this a dispersal of a haplotype? LWatling: Some octocorals are found in all oceans, on every seamount. These species have probably been around for a long time. Have they spread slowly? Amy: some species were considered to be cosmopolitan, though upon genetic investigation have been found to be genetically distinct, different species. Are these the same species or different species? Alex: Depth is important in these systems. Deep species are probably using the conveyor belt for dispersal. There is genetic structure in populations shallower than 3000 m, which are probably different species.

Why are ones on the tops of the seamounts so heterogeneous? Alex: Relating heterozygosity to anything is difficult. Heterozygosity can be related to stress level of environment, also related to population size and other factors – so heterozygosity is problematic as a measure. CSmith: Patterns of distribution vary across taxa and size classes (same as abyssal). Endemism has been over-stated, but we don't have the data, should apply the precautionary principle and assume there is high endemism when we design MPAs. The abyssal plain also exhibits high endemism, which we have
always assumed is an artefact of sampling. But we must assume there is high endemism for MPA design - this is the burden of proof.

Endemism (Discussion). LWatling: What do we mean by endemism? I don’t see any evidence, but we need to define endemism, and what scales denote endemism. The sampling is sub-optimal, and I don’t see any evidence for it in the Atlantic. If something is restricted to the western side of the Atlantic is it endemic? Amy: Also we need to define a seamount? Does it have to be endemic to a feature? CSmith: It depends on the scale and the range of the species. I find it hard to believe any species would be constricted to such a small range. Amy: I have found a restricted species in HI. CSmith: What percentage of the habitat have we viewed though? LWatling: I’ve seen an original species, but you can’t see the whole site, can’t visit all the sites – of course it is somewhere else, we have a limited window to view. This is patchiness. We did 8-9 dives at same site and we found new species on the 9th dive when we thought we had this spot well characterized.

Csmith: In trying to understand endemism we need to apply models developed for better-studied ecosystems. In seamounts with long dispersal distances with lots of potential habitat, it is difficult to reconcile with local endemism. In the NWHI, some species that are ‘endemics’ are disproportionately more abundant, these are habitat specialists. Most examples of species for seamounts or abyssal plain are very rare species. There has been very little comparison of what we think is endemic in the deep sea versus other habitats. Species found at one location are typically species that are rare, which goes back to the sampling intensity issue. We can’t say this is a sampling artefact or endemism.

In being forced to design MPAs, we should assume there is a high level of endemism. The data are not strong enough to reject either hypothesis. SGaines: This has been looked at in terrestrial plants. Endemics do not tend to be in the tail of the range distribution. Rare species with small ranges would be an extinction event waiting to happen. CSmith: This happens, but it is rare and uncommon.

New idea: To compare rare species patterns by looking at other habitats/models where sampling has been more intensive.

Update on Work related to Biogeographic Criteria for the Classification of Open and Deep Ocean Areas (Mexico City Workshop)
Les Watling

Biogeographic classification systems are essential tools for integrated oceans management. Recent efforts have focused on determining biogeographic provinces in the deep sea, pelagic and benthic habitats. From a management perspective we need to know the biogeographic classification if we are to move towards integrated oceans management. Similar classifications of shallow water habitats have been proposed, but shallow water is well defined and the deep sea has very little assessment.

Our goals in the Mexico City workshop were to develop principles and frameworks for classification of the high seas. The Longhurst classification deals with productivity and not species distribution. There are well recognized depth zonations in the sea; we characterized three deep sea zones including the

1. bathyal (800-3500 m),
2. abyssal (3-6K m depth), and
3. hadal regions (> 6500 m).

These are still somewhat problematic because there are large areas where no one has really looked too much, and data is sparse – so how can we divide the ocean up?

First, we need a better way to plot the bathymetric data, to make a more visually compelling case. We used ArcGIS and topographic data. In the upper bathyal provinces there is a huge amount of fiction in the map based on our uncertainty. Abyssal province centers and hadal provinces exhibit some of the best data available, because of Russian sampling programs and constricted habitat. The biggest problem is that deep sea data are sparse. The solution is to map predicted patterns of deep

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Design

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more complicated abyssal provinces. bathyal areas, not abyssal (CSmith agrees). Isolation animals differences of 1 degree over 10,000 km CSmith: there may be vertical zonat so plotting density, sal water mass. GIS layers be combined in a water mass fashion. Oceanographic conditions For example, a large scale, across taxa. that has not new areas for sampling based on the biogeographic characterization. We could target a province parameters and environmental variability and then add in biological data. CSmith: We could target We are trying to develop proxies for developing re
discussions. We used an Eckert VI projection which better emphasizes ocean basins. We melded bathymetric data with hydrographic data (e.g. Temperature, O2, export of carbon to the benthos). We used data from Yool et al. 2007 in determining the export of carbon to the benthos because this data accounts for the F ratio (old v. new prod) and mixing.22 The caveat is that this breaks down at high latitudes because there is no permanent thermocline; as such, the Yool data may be over- estimating prod in the high latitudes. We used the average annual export because it is definitely a seasonal export process. We see distinct effects of upwelling zones on the abyssal habitat. We also need degradation curves, which don’t match up with sediment trap data. The Martin curve is from sediment curve data, but only from one basin; Pace curve tried to rectify, but there is still a big discrepancy, with a factor of 2 -3 between curve estimates and observed. The Rutgers model was much more complicated, with more potential error that the Yool et al. (2007) data. This data is annualized and is the export to the deep ocean. There is potential that we could break this data into seasons in order to account for export seasonality of food. There is variability in the annualized number.

But what about vertical zonation vs. water mass? Water mass makes sense for aragonite, etc. but for other parameters like temperature might not be so important? A 1º C change in temperature between Pacific and Atlantic might not be as important as the temperature change during vertical migration. We need to be careful not to overstate.

Take Home Message:
- There is no consensus still to understand the different regions in the ocean at different depths and map these regions with biological and physico/chemical characteristics.
- Global biogeography is necessary to understand benthic biology.
- We need a good understanding of the physical and biogeochemical processes with a geographic perspective (maps) at depth.
- Solutions- combine ArcGIS layers, follow water masses. Question: How well can we define the polygons?

Discussion

A Fried: Could we get a variance number and incorporate in order to account for seasons? We are trying to develop proxies for developing regions or zones in the oceans based on physical parameters and environmental variability and then add in biological data. CSmith: We could target new areas for sampling based on the biogeographic characterization. We could target a province that has not been sampled. Malcolm: Physical proxies are the only way to address this issue on such a large scale, across taxa. A critical element is combining the hydrographic variables into the model. For example, consider the Antarctic intermediate water, which drives big differences in the faunal distributions. Oceanographic conditions are key.

LWatling: One easy way might be to track and map water masses with polygons. Or let the GIS layers be combined in a water mass fashion. For example, in N. Atlantic you can peg things to the water mass. The problem with polygons is that the boundaries are fuzzy. The water masses mix, so plotting density, salinity, temperature, this might help differentiate between water masses. CSmith: there may be vertical zonation in the water mass as well. At abyssal depths, there are differences of 1 degree over 10,000 km – from a physiological perspective this is not much, plus some animals are migrating through. LWatling: The water mass effect is probably more important for bathyal areas, not abyssal (CSmith agrees). Isolation and productivity are more important for abyssal provinces. For the abyssal provinces, the Russians may have been right. The bathyal gets more complicated with ridges, potential for isolation along ridges and seamounts. The bathyal zone

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has potential for greater isolation. Another issue is how to add flow, which is a big part of the environment. The directional component of water movement might be hard to put into GIS. Flow also gets complicated around the ridges. Pierre: Usually the hydrographic parameters are used to track water masses.

Malcolm: how do we incorporate the depth? 800-3500 m is a huge change in depth, especially given the range distributions for fauna. We can’t even agree on depth slices within that range. The patterns differ in different parts of the world. LWatling: everything is in 500 m increments, in different bins. We picked 800-3500 based on Russian literature. You’re right- the problem is that species don’t transcend that whole range. Is there a mid-point line or should we look at multiple layers within a bathyal zone? It’s something we need to think about, but data is there so we can break it up any way we want. CSmith: one way to approach is to look at depth horizons for which there is a lot of surface area. This may not be monotonic – e.g. 1-2K meters there is a lot of habitat perhaps. LWatling: some areas are complicated (e.g. W Pacific) – there may not be ways to delineate such complicated areas. Alex: has a paper on the W. Pacific that might help.

Nii: Whatever is being protected – how does this directly related to what the ISA is doing? LWatling: we are trying to understand the biogeography of the deep sea – this is the issue. Is the nodule area represented by one biogeographic unit or two or three? CSmith: if there is a province boundary right in between the CCZ, you would design the mining operation differently that if it was just in one big province that is biogeographically similar. Alex: there is a gradient of production across the CCZ. CSmith: yes, from east-west and from north to south. Goal: Develop MPA recommendations to the ISA for the mining of seamount crusts (Mn)

Definition of Objectives for Establishing the MPAs for Seamounts in High Seas and Discussion of Design Strategies

Malcolm Clark

Goals & Objectives (w/ Discussion)
- Goals- what we want (general)
- Objectives- subset of goals (specific)

GOALS: (From MLPA goals)
- To protect the natural diversity and function of marine ecosystems
- To help sustain and restore marine life populations
- To improve recreational, educational and study opportunities in areas with minimal human disturbance
- To protect representative and unique marine life habitats
- Clear objectives, effective management, adequate enforcement
- Ensure the MPAs are designed and managed as a network

OBJECTIVES:
1. Preservation & Conservation of Marine Biodiversity
   - Protection given to rare species
   - Endemic species
   - Vulnerable species to human activities
   - Preserve genetic units of species (stock structures) and preserve genetic diversity

Discussion:
What is the definition of Biodiversity? Goals is to provide protection at a scale appropriate to biodiversity. AFried: the phrase biodiversity is ill-defined. Need to maintain and protect intact
ecosystems, in order to protect ecosystem integrity. At a minimum, should protect entire seamounts because they have all the elements of the ecosystem. This is an ecosystem approach. CBD definition of marine diversity should be used – from genetics to populations.24

2. Preservation & Conservation of Ecosystem Structure and Function (Ecosystem Integrity)
   - pelagic habitat
   - benthic habitat
   - structural complexity
   - critical habitat
   - maintain abundance and balance (not only biodiversity but also biomass)

Discussion: The scale of system considered is the Pacific (high seas zones in the Pacific). Both of these concepts are scale-dependent. We need to incorporate pelagic and benthic and links between these two systems. The structural complexity of benthic fauna needs to be considered. What is the best term for linkages, connectivity? Connectivity is the buzzword. Connections are scale dependent. Seamounts are not closed systems, they depend on productivity from elsewhere, and this is a connection. Open/Closed systems. At what scale do you need for a network of seamounts that can be considered a closed system? Also a temporal scale

Scale:
- minimum scale should be entire seamounts; maximum scales should be the Pacific High Seas
- need a network of seamounts

3. Integrated Management of Human Activities that Maintains the Sustainability, Integrity, and Health of the Ecosystem
   - Maintenance of Sustainable Fisheries: Essential fish habitat (EFH), spawning and nursery areas
   - Cable and Pipeline Installations
   - CO₂ sequestration and Fe Fertilization
   - Mining
   - Ecotourism Activities
   - Marine Research
   - Other human activities with a potential to affect the deep sea

Discussion:
A Fried: fishing will occur, so we need reserves where there is no extraction. There will be extraction, and that needs to be managed widely. LWatling: We should have a big MPA with zonations like the GBRMPA. Fishing is the most direct impact currently. This needs to be managed. SGaines: Fishing and mining are threats, and fishing activities are diverse (longlining, trawling). Should we propose different zonation schemes or consider these different types of fishing activities. This is part of the MPA planning process in CA MPAs. Alex: We have to specifically consider other activities such as cable laying, CO₂ sequestration. Include the full diversity of human uses.

Are these objectives or goals? Objectives might be more specific.
- Goal is integrated ocean management – from seafloor to ocean surface.
- Objective is more of an action item: e.g. “to identify and protect” - more actionable than a goal.

24 Convention on Biological Diversity. Article 2, Use of Terms. "Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Available at http://www.cbd.int/convention/convention.shtml
Malcolm: Objectives are a subset of goals. Goal: what needs to be achieved; Objective: How to achieve it. Don’t we just need to figure out the size and how many we need? Establishing goals and objectives is important, because it establishes guidelines for building a network.

4. Preservation of Unique and Representative Marine Habitats

- Geologic (Geophysical) and Geochemical Features
- Unique Marine Life Habitats
- Variety of depth strata?
- Must include geological features that are “well representative” of geological attributes/characteristics.

Discussion:

The setting of goals and objectives needs to be done by the stakeholders, not the science team. If you don’t get buy-in from stakeholders, the whole process is not good. **We need to translate these goals & objectives into scientific guidelines.** Who are the stakeholders? The stakeholders for seamount crust mining: the ISA, contractors, sponsoring states, supervisory council – this has all the stakeholders. Nii: What are the recommendations, considering the context: there will be only 1 or 2 operations. CSmith: In this scenario, an operation will mine 3-5 seamounts. Our guidelines: pick the ones that are not unique – and then target those. Nii: Regulations require an **Impact Reference Area (IRA)** and a **Preservation Impact Area (PRA).** Are we going too far with guidelines?

CSmith: Those are poorly designed concepts (PRA & IRA) that were done in 1984 by people who don’t know seamounts. This should replace the IRA and PRA. A context needs to be considered. The IRA and PRA are MPAs, and there is a mandate to have MPAs as part of the management plan for the mining – we can give better guidelines for this. Nii: Where is the balance – that is what will go through. Currently the ISA has only written code (guidelines) for exploration, and there is no code (guidelines) for exploitation. If this substitutes for the IRA/PRA, wonderful, but we have to consider this is the mechanism in place. This is too broad – the workshop is on nodule provinces, not on the entire abyssal Pacific. LWatling: We need a broad view because fishing and mining might be mutually supportive activities. Are crust-rich seamounts good for fishing? Need to know!

When the code (ISA guidelines) for exploitation is being written, what is being considered at the workshop could be incorporated. This process could also help determine what kind of data is required of contractors – what criteria for habitat assessment are required. This has been done in the 2004 workshop where guidelines were formulated. SGaines: **an ambitious MPA network would lessen burden on the mining industry.** Therefore contractors should be advocates for this process because it relieves the mining industry of restraints, may even lessen their requirements of what they have to prove.

Amy: There are some seamounts with good thickness of Cobalt, maybe we need to predict some of those. There is no real resource assessment, so no one knows. Should we make a generic statement? Nii: **You need to show the LTC (ISA’s Legal & Technical Committee) that mining will result in species extinctions, then they will close those areas to mining.** The ISA is the only authority to close seared areas in the high seas. They are advised by the LTC, therefore the workshop should focus on a proposal to the LTC.

Is there any indication that crust-bearing seamounts have different biological communities? There is no data – THIS IS A GAP. MClark: Perhaps some data from New Caledonia, but there is nothing to indicate any differences. We have very few data on this. We don’t know enough of the Mn crust systems to make a definitive statement. Amy: some data in the HURL database on this, but the question is can the substrate type be delineated. Nii: Recommendations will go to the LTC, who recommends to the Council, who is the only authority to close areas. LWatling: How much of the seamounts above 2500 m are co-rich and are in the high seas? Quite a lot, but the guidelines will establish principles that nations can use within their EEZs. Csmith: Guidelines from ISA are being
used in PNG sulfide mining, for example. How can ISA integrate with RFMOs? To the extent that the two activities overlap they can integrate.

24 October 2007  

Afternoon Session

Recommendation of Strategy for Designing Seamount MPAs for High Seas  
Steve Gaines and Alan Friedlander

Discussion

There is no coherent management of the high seas, and this is a goal/priority of the Pew Charitable Trust. **Our targets for outputs include:** the ISA, UN General Assembly, FAO (does not have a regulatory role, but does have a code of conduct for sustainable fisheries), RFMOs. The RFMOs are voluntary, and not under the authority of the UN or FAO (or any other overarching authority; some RFMOs are associated with the UN FAO). The proposals for the South Pacific RFMO and Southern Indian Ocean RFMO are more PR moves (LWatling). Are these conservation efforts or PR moves? These have been an industry-driven process. There is some motivation in the RFMOs for industry to get exclusive rights to fish an area. In some areas, historical claims are used to establish fishing exclusivity, which is a property rights scheme.

**Lessons Learned**  
Steve Gaines

In creating guidelines for policy initiatives, we must be cognizant of who the audience is – this is very important. Structuring the game is also very important, because stakeholders will try to play the game to maximize their perceived benefit. The rules of the game are very important, especially in determining how science is implemented in the process.

- **Numerical (Quantitative) Guidelines are Critical.** Non-quantitative guidelines are useless and will result in science being relegated to a limited role)
- **An Overall Framework Simplifies the Process.** Without the framework a very effective strategy is to “just say no.” Scientific information can be too weak, so if someone vetoes a place, there must be another place that can be selected for protection. Guidelines are necessary so that if they say no in one place they could add another area instead. If you don’t have a framework, then the answer from the stakeholders will be negative. Replication will include whatever we have still not characterized.
- **Emphasize What We Know (and not what we don’t know).** Any emphasis on paucity of knowledge will be perceived as scientific weakness. We need to make a compelling arguments and recommendations in order to affect the process in a positive way. If we try to include every single step we will get nowhere → don’t be afraid to simplify.

**When building MPAs, larger size reserves benefit more species. We should make recommendations on suggested minimum size guidelines with quantitative, numerical size parameters.** If our only argument is “bigger is better,” then we won’t get too far in creating a productive decision-making process. The framework should also be constructed (e.g. reserves in network should not be more than 30-60 km apart). The audience needs to be constrained by the science.

In addressing the lack of data, connectivity is the main issue. **Even without data, we can still make recommendations.** This should be our focus. Decisions based on connectivity have to consider the different scales for different species. **Many orders of magnitude difference → different spacing of protected seamounts will have different results based on different species.**
Lessons Learned\textsuperscript{25}

Allan Friedlander

Each stakeholder will defend their own position, and we must consider socio-economics of the situation and cultural aspects, if any. Recognizing the target audience is critical at every step of the way, and the audience must be educated. We need to create an analytical framework for biogeographic assessment.\textsuperscript{26} Can we determine human impacts of fishing and where these impacts are concentrated? We should categorize seamounts by important variables, including depth, latitude, biogeographic provinces, type (guyot and conical), productivity, water mass type. We should build a nested, matrix design, with a suite of predicted faunal assemblages (e.g. by habitat suitability modeling). We need to determine metrics for proximity and isolation. Connectivity is a big issue and we need to know how to deal with this. What is geographic distribution of seamounts and can we categorize these? Determine clusters, isolates, archipelagoes, then we will have categories for spatial clustering.

Goals:

1) Representatives of the public set the goals, including all the stakeholders
2) Ecological & enforcement advisors clarify the goals and establish scientific guidelines

- Design criteria (incorporate local knowledge)
- Drafting alternatives (involve community alternatives)
- Selection of alternatives

Recommendations

Steve Gaines & Allan Friedlander

First Recommendation: Categorize the habitat and justify with a minimum number of replication.

SGaines: The easiest way to protect seamounts is to characterize the environment and then require a minimum number of replication in a geographical region. This alone with habitat types will get a justification, even without a lot of data. \textit{This is the core basis for a proposal}: We need a list of habitat types, seamount types (needs to be constrained to a tractable number – not in the 100s..). A list of habitat types that clearly alters the species present (LWatling has a paper on habitat types).

CSmith: We also need types of seamounts. Without a lot of data, we \textit{need a lot of replication in order to capture the under-represented biodiversity}. We need categories of habitats we would use – we don’t know enough about this. We could use a multiple regression to test this idea (AFried). This is preservation, not a restoration process – restoration is probably decades, maybe centuries in the deep sea.

Second Recommendation: Protection vs. Preservation vs. Restoration

What is the potential for seamounts once they are protected? The key is the likely recovery time. Putting in protections after seamounts are heavily fished may require decades or centuries to recover. \textit{We need to get information on seamounts that have not been fished – this is a Priority.}

MClark: Unfortunately the answer for this is no – we don’t know which seamounts have and haven’t been fished. SGaines: \textit{We need a larger replication in order to increase probability of preserving pristine habitats}. Since it is hard to know which seamounts have not been fished (Japan,

\textsuperscript{25} see Allan’s slide for this material: Slide title: Recommended Marine Reserve Designation Process
\textsuperscript{26} see Allan’s slide for this material: Slide title: Analytical Framework for Biogeographic Assessment
Korea, China, are not at the table – no idea where they have fished). There is a distribution of fleets Pacific-wide that fish seamounts.

LWatling: I would suspect that it is a small fraction – and maybe only a small proportion of a seamount may have been fished. CSmith: what proportion of seamounts have been so heavily fished that they aren’t worth protecting? Malcolm: The Japanese fleets are very efficient and they actively look for seamounts. Maybe 10% of seamounts are totally damaged in NZ. The 20-50% goals for protection – the logic behind these targets is not system-specific. What are the characteristics of a trawled seamount? How can you determine what seamounts could be more susceptible? We could engage in a quantitative exercise to expand the number of replicates to make sure unaffected sites are included in the MPAs. Some seamounts have been heavily trawled but are only damaged on the summit. In some cases the trawling damage goes all the way to 2700 m.

**Third Recommendation:** Conservation Benefits (% Populations Protected) vs. Reserve Size (%)

**Network Reserve Size**

We should focus on the Network Reserve Size, which focuses on persistence models. Persistence varies by species and different life history characteristics. We need 40-60% of the total area to guarantee persistence. **Reserve size is directly correlated to conservation benefits** – see Airame et al. (2002). We could use a meta-analysis of fisheries models (from Airame et al. 2002, NCEAS Marine Reserve Working Group). At small sizes, you cannot get big returns from the reserve because the benefits get diluted. With deep sea species, we need higher percentages because the species life history characteristics (late age maturity, slow growth). It could be a good exercise to look at adult movement patterns for fish, to see conservation benefits for deep sea species.

**In the face of uncertainty, the value must be in the 40-60% range to get conservation benefits and fisheries benefits.** AFried: Some fisheries will benefit, and some will not. It’s up to the managers to allocate the fish resources. For example, look at Georges Banks’ cod closure areas. Here 42% of the fish is caught within 1 km; 73% within 5 km. The catches for Haddock are coming right on the edges of the closure area, which is a huge benefit for fisheries.

We know *a priori* that Octocorals will be on all seamounts, and this is the same with some fish species. In some biogeographical provinces, we are going to make selections of 40% of the seamounts based on physical parameters that are predictive for habitat type (e.g. summit depth, etc.). Our first step is to take advantage of information we have that justifies preservation of specific seamounts that we know are in good condition. **We need to include the areas that have biological information on** with random selection of other seamount features in all of the bins established (above) representative of a broad range of biogeographic provinces.

**Extinction Potential:** Trawling could potentially cause species extinctions. Seamounts tend to have rare species. Comparisons of conservation/benefit curves are between shallow marine & terrestrial systems. Curves assume no contribution from outside the system. It is very powerful to combine fisheries benefits with conservation benefits. Not all fisheries will benefit but several of them will. There is density dependence prior to larval production: competition for food affects the fecundity of individuals. Reserves can help to diminish the selection pressure. *“Keep it simple, if we cannot explain it in simple words then nobody is going to listen.”*

*Presentation on Habitat Classification Scheme for Seamount Landscapes*
Les Watling & Craig Smith

**Seamount Habitats:**
1. Basalt (pavement, ridges, walls, ledges, tubes)
2. Fine-grained Sediment (flats, ripples, waves)

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Nodule or Mn crusts, which cover the basalt: Is there a difference between clean basalt and/or a Mn crust over basalt – esp. considering the biota. Could Mn nodules be considered as basal seamounts. Mn covers many basalt seamounts. The biological difference – macrofaunal differences in the substrate. AFried: What are the ecological parameters – this drives the taxonomic differences, but for management we need coarse feature descriptions. We need to differentiate if the seamount is primarily a hard substrate or a soft or cemented substrate. The age of seamount and location (in terms of productivity) determine habitat characterization of seamount. Sediment accumulation is primarily on top, so what proportion constitutes enough to alter community structure?

Ridge systems need to be defined; perhaps via sill/saddle depth (< 3000 m). Is there a difference? LWatling: Ridge systems could be different because animals that need ridge systems for dispersal. Those species that are not isolated by abyssal floor; bathyal organism propagules. Discussion on whether to use basal area, elevation, depth below the surface, and summit size to characterize seamounts. Minimum Area: use elevation as a proxy for size (don’t have size data, so use elevation from abyssal seafloor?). Use elevation and size of the seamounts that have been surveyed and get a probability distribution for elevation and size; this can determine if elevation is a good prediction for size. We could also just use elevation and use conservative replication parameters to account for different sizes; could use a variety of summit areas. How should we categorize oceanographic setting: should we use a LME strategy or a Longhurst style of strategy? Perhaps via overlying water mass (e.g. Subtropical, Convergence). Determining the biogeographic regions could be the first coarse filter for a seamount classification system. This could be done with a hierarchal approach. Replication is key.

Establishing quantitative amounts should follow the Precautionary Principle. Use a minimum of 40-60% for protection of seamount habitats. Rare and vulnerable habitats should be over-represented. Vulnerable habitat vs. Rare habitats: We still don’t know what are the rare habitats because we have not sampled enough.

Coral diversity is significant. Are corals extremely important for fish? There is no linkage between deep water fish and deep sea corals. Interesting, no linkage between the fish and the coral. In Alaska, it is possible that this is true but only because there is a lot of fish (some fish are habitat specialists and might relate with corals). Coral gardens and fish relationship → Not very clear. Is it habitat complexity rather than coral presence/abundance. Corals & Invertebrates: Corals could be very important for other invertebrates and this is a good reason to conserve corals. If they are gone, invertebrates will disappear as well.

Endemism: At what scale? If we have enough replication on isolated seamounts we could perhaps encompass most of the endemic species. Essential Fish Habitats. Fisheries, Precious coral beds, Spawning grounds, nursery areas, etc.

How do you define critical faunal habitat? If you replicate over a large scale, you could account for nursery area, spawning grounds, extreme vulnerable ecosystems, etc. We need 40% of the seamounts... but where? How can we distribute this area in a meaningful way? All the seamounts little replicates of each other in the Pacific. Different from Indian Ocean, 40% of the area means something different for different oceans. Key goal- to get ~40% of these seamounts that encompass all these categories identified above.

Can we use corals as a specific characteristic of a seamount? Every single seamount has a scleractinian or an octocoral. Some areas are very particular, but we don’t know if every other seamount would have the same biomass, diversity. Could every seamount be considered a VME? Then we have problems again...remember, be simple! How can we close areas based on rarity if we don’t know what rare is? You know seamounts are present, that’s it. So the next step could be a priori from previous evidence, then assume every seamount will have some type of octocoral/fish. Then, within this area we can pick up 40% of the seamounts and hopefully we will encompass all the biological characteristics (ecosystem drivers) that we are trying to protect. Example: Deep sea oyster reefs. What is unique? How many unique things will fall down from this classification in the short-term? Adaptive management?
Stratification system: Randomly select for protection. Make sure that the ones with rare evidence are included under the protection. Provide justification is that we have enough biological information. Our information will grow through time.

STEPS
1) Classification based on physical factors (within each province).
2) Bring in biological characteristics
3) Choose 40% of the seamounts, (include seamounts where info is available)

Gap Analysis (Future subjects we need to talk about)
- Connectivity
- Major current patterns relative to the chain
- Long ridge flow, linear distance, absolute number/value. What about breaks?
- Also, individual seamounts that are isolated. Solution: genetic data (but not in the short-term).
- How many of these long chains exist? Many?
- What about the spacing?
- Have better resolution maps for this discussion?
- Useful exercise to go in detail (topography) in a specific region.

25 October 2007

Drafting of Seamount Conservation Recommendations and Principles for the Design of Seamount MPAs
Malcolm Clark

Seamount Definition
Seamounts are defined as geologic features (generally of volcanic origin) extending from the seafloor with an elevation of more than 1000 meters above the abyssal seabed. The principles presented here can and should be applied to features that are geomorphologically distinct from, but ecologically similar to, seamounts. Such features may include:
1) knolls, (vertical elevation of 500-1000m from the seafloor),
2) banks
3) island slopes,
4) atolls,
5) continental slope-associated features (e.g. intraplate volcanoes and hills)

Seamount Classification System
Four key steps were identified in a process to identify and select potential Marine Protected Areas on seamounts (at the scale of an entire seamount as a minimum unit).
1. Define sets of physical characteristics to identify a range of habitat types
2. Determine the level of replication required in each category from (1)
3. Determine the reserve size (30–50% of management area)
4. The general principle involved here is the use of physical information as a proxy for grouping seamounts in a biologically meaningful way. For most oceanic areas, there are few biological data, but knowledge of physical characteristics is more available, and able to guide seamount classification as a first cut until more information is collected.

Seamount Habitat Type
Substrate Type: Sediment type will affect what fauna can occur (although acknowledged that most seamounts will have a wide range of substrate types)
- Predominantly hard substrate (basalt, rocky)
- Predominantly soft substrate (mud, sand)

**Seamount Shape:** this will in part determine the amount and depth of substrate (especially on summit)
- Guyot (flat-topped)
- Conical small summit area

**Connectivity Criteria:** distance between seamounts, and the relationship of seamount direction to current flow will affect the dispersal abilities of fauna
- Isolated seamount
- Seamount part of a cluster
- Seamount part of a linear chain (includes ridge peak system)

**Summit Depth**
Depth is a major determinant of species composition. As the seamounts by definition arise from abyssal depths (in most cases), elevation is also a relative measure of seamount size.
- 0–200 m
- 201–1000 m
- 1001–2000 m
- >2000 m

**Oxygen Concentration (OMZ)**
Oxygen levels can also be important for survival of certain groups of species
- 0–1 ml/l
- 1–3 ml/l
- >3 ml/l

**Biogeographic Zone**
This reflects oceanographic conditions (water mass). Various zonation systems could be applied (e.g., Longhurst, Large Marine Ecosystem, Mexico Workshop Zonation Scheme)
- Subtropical
- Tropical
- Subantarctic
- Antarctic
- Convergence/Frontal zone

**Volcanic Activity**
This identifies whether hydrothermal vent communities may exist, and also whether volcanic activity such as lava flows could impose significant natural change.
- Yes
- No

**Critical Ecological Habitat**
- Identifies the known presence of significant ecologically activity, such as the presence of *Vulnerable Marine Ecosystems* (VMEs), coral reefs, sponge gardens, spawning grounds, nursery areas. This is seen as a SECOND TIER criterion, where biological knowledge will be applied to the initial selection of seamount groups based on the above physical parameters.
• Critical Ecological Habitat: needs definition, and could include all the Essential Fish Habitat elements and definition of Vulnerable Marine Ecosystems from FAO.

HOW THE SYSTEM CAN WORK

• Use the above factors to create a number of groups of seamounts (e.g. hard substrate, summit depth <200 m, conical shape; hard substrate, summit depth 1001–2000m, guyot).

• Identify seamounts within the groups for which biological information is available that may indicate critical ecological habitat.

• Select 40% of the seamounts in each group (assuming entire seamount protected, based on number rather than size)

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28 16 U.S.C. § 1802, Magnuson-Stevens Fishery Conservation and Management Act (104-297), Section 3, (10) “The term ‘essential fish habitat’ means those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.”

## SEAMOUNT CLASSIFICATION SYSTEM

| Substrate Type | Hard substrate (basalt, rocky)  
|                | Soft substrate (mud, sand)      |
| Seamount Shape (within region) | Guyot (flat topped)  
|                                | Conical                      |
| Connectivity Criteria: Grouping | Chain (archipelago)  
|                                | Cluster                      
|                                | Isolated (>200 km from any other seamount of same class?) |
| Summit Depth (proxy of size)   | 0-200m: Photic zone  
|                                | 201-1000m: Depth scattering layer DSL  
|                                | 1001-2000m  
|                                | 2000m +                     |
| Oxygen Minimum Zone            | 0-1 mL/L                     
|                                | 1-3 mL/L                     
|                                | > 3 mL/L                    |
| Biogeographic Zone             | Various Zonations Schemes: Longhurst, Large Marine Ecosystem, Mexico Workshop Zonation Scheme  
|                                |   • Subtropical  
|                                |   • Tropical                   
|                                |   • Subantarctic                
|                                |   • Antarctic                   
|                                |   • Convergence/Frontal zone   |
| Volcanically active            | Yes/No                      |
| Ridge system                   | Yes: Saddle/Sill Depth ≤ 3,000m, >3000m  
|                                | No                           |
| Biological characteristics     | -Critical ecological habitat (Y/N)  
|                                | - Spawning grounds, nursery areas, etc. |

### Discussion

We need to define connectivity bins. For seamount ‘clusters’ use a nearest neighbor definition, perhaps based on larval dispersal distances. Of the 1500 seamounts, 700 are in EEZs. We need to establish guidelines that can be used within EEZs (as guidelines are used for sulfide mining in PNG). A critical issue is international coordination in the High Seas. There is no management structure in place to do this. For biological information, probably only use sites where there have been significant sampling efforts: Malcolm’s recommendation is to use sites that have been sampled > 40 (40 individual samples).

CSmith: do any of these indicate “critical ecological habitat?” MClark: It depends, different data are available. Are any of these in the mining provinces also targeted for fisheries? Yes, armourhead and alfonsino. CSmith: Some orange roughy in the N. Pacific. MClark: Orange roughy is a S. Pacific fishery primarily. Amy: It’s a different species in N. Pacific and there is some debate on this. LWatling: at 10 degrees S there is a big change in faunal difference. MClark: There is no orange roughy in New Caledonia, probably due to tropical convergence. So what information is available on spawning stocks? If we know of spawning stocks, these areas should be included in the 40% of those selected for reserves. This is great work – we could put together a theoretical model with not too much work. We need to define the connectivity bins. What is isolated? Should we use Amy’s 405 km number? Amy: I wouldn’t base anything on this. SGaines: But this is a good number to use for this type of system.

CSmith: We use dispersal numbers for shallow water systems, and now we need one for deep sea zones. Depth bins are to address different communities at different depth strata, perhaps some of these communities have different dispersal ranges, but we don’t know what they are. If a
seamount is isolated, it probably has a higher level of endemism. SGaines: Define “isolated.” Allan: there’s fewer isolated seamounts, so we probably want to replicate more of these. We should recommend that contractors mine a seamount in a cluster, where there is less probability of species extinction. LWatling: dispersal distances are probably larger than we think. In a study on vermetid snails there was no genetic differentiation in the main Hawaiian Islands, but a high level of differentiation in the northwestern Hawaiian Islands. They are dispersing somehow, despite the fact that they are direct development organisms. We also now know that Johnston Atoll is a stepping stone for Hawaii. It’s 500 km away, so dispersal is probably farther.

SGaines: We have to use an average dispersal distance, not the tails of the distribution. Some individuals might have an extraordinary range, but we must use an average. LWatling: But haplotype maps suggest a very far range for some organisms, and we have biological evidence for spreading the connectivity box to a larger scale. There are some distinct boundaries that show up and are related to current systems, but 25 km is totally unnecessary. The scale of movement is much larger. There is no evidence for shorter distances.

AFried: A scale in the low 100s of km is probably reasonable. LWatling: The fish are distributed basin-wide; and there is mixing of the populations. Alex: but is this efficient enough to change populations? There may be differences in the reproduction between these populations, so there is no evidence that these migrating individuals actually add to the population (reproductively). They aren’t breeding with other populations, the spawning cycles and reproductive timing is different. MCClark: Can we get rid of connectivity? And define a minimum spacing between seamounts selected as part of the 40% reserve? CSmith: We need to think on shorter scales.

AFried: Let’s play around with the model and see how it parses out. We can treat isolated seamounts differently (over-represent); clustered seamounts may fall out in a good way. We don’t want the protected seamounts strewn out everywhere because this is an enforcement nightmare. Protected seamounts should be spaced closer together if possible (and representative of habitat types) for logistical reasons. The high seas is the focus. For the purposes of establishing an MPA, the seamounts in the EEZs don’t exist. Could also could have a trans-boundary MPA – this could be done (MLodge). You would need buy-in from the coastal state, but there is no legal issue in doing so.

JKittinger: What about establishing within EEZ or trans-boundary MPAs in exchange for debt? (e.g. debt for reefs)? This could be potentially applied to deep sea areas as well. MLodge: Kiribati is doing this with Phoenix islands, but it is hard to economically value the islands to exchange debt for the reefs – there are some obstacles/difficulties to valuation. CSmith: I think we’ve come to a point when some people need to sit down with the data and come up with the theoretical model for an MPA. So what is the separation? Use a summit-to-summit distance – not basal distances. Existing data is summit-based – use this.
PART II: Design of Marine Protected Areas for the Abyssal Nodule Province in the Pacific High Seas

Nodule Mining on the Abyssal Seafloor: Resource Distribution (Local to Regional Scales), Likely Technologies and Exploitation Rates, Nature and Scales of Physical Impacts
Charles Morgan

The resource distribution is primarily in the Clarion-Clipperton Fracture Zone (CCZ), 110-160W; 0-20N (resource is 5-20° N). There are some publicly available data from sample stations (some is not published, but is available). Some data has come from the echo-sounder acoustic tool, which is not quite as accurate. This system uses an acoustic signature from nodules and has been empirically linked to abundance. This is not perfect, but it is the best system so far. There have been 15,000 samples in the CCZ for metals. We used a kriging analysis to converge on a resource estimate. Kriging always underestimates and averages over space. Kriging was developed for mining resource assessment and this is the method used.

**The highest grade nodules are bounded by 15N, 125W, 135W, 10N, and this may coincide with the Yool et al. export model.** It’s very interesting that export of carbon to the seafloor may be correlated with metal content. The abundance of metals is extremely patchy. A threshold level used to determine where contractors will mine is approximately 10 kg/m². The Chinese have said 5-7 kg/m²; there is no magic number because it depends on metal prices and technology. The Mn distribution is correlated with chlorophyll (a weak correlation for export). Cobalt and Mn are negatively correlated in the nodules. Ni and Cu are other metals of interest. *There are approximately 27 billion tonnes of Mn nodules.*

This is a huge resource for these metals and there will be a commercial pressure to exploit these, especially considering the world production on land of these metals. We used a geological model: goal is to extrapolate to where we don’t have data. The model shows a link between the surface biology and the deposits in place, and we have intriguing evidence for this. The biological data: the main trend is an east – west component. We observe a decrease in megafauna, with a similar trend from south to north in the CCZ. This is predictable based upon available food. We have been looking for proxy variables for export production: chlorophyll, CCD, distance from EPR (source of metals) have been considered. Fecal pellets and aggregated phytoplanктon detritus is deposited to seafloor, and picked up by benthic communities. This removes chelators and then metals are available for scavenging by Mn oxide surfaces. Mn surface sites are very efficient in scavenging reduced metals.

Depth is also important for carbonates – distance between deposit site and CCD. The module indicates that nodules form where the CCD hits the seafloor, or below the CCD. The seafloor above the CCD will accumulate carbonate sediments. The distance to the EPR was a linear input to the model. In running the model, we got about 20% prediction for metals, but the abundance prediction was terrible. In order to improve the model, we could import the Yool et al. export production data, and we are looking at some arbitrary land-based techniques (weight of evidence, logistic regression, etc.). The deposits do not seem to follow the bathymetry of the seafloor.

In the technology of nodule harvesting, the key issue is the collector, because this determines the efficiency and the environmental impact. The collector technology is still very inchoate in design. The plume size is an environmental concern for impacts. Direct impacts are at a 1 km² scale; 10-100 km disturbance for indirect impacts associated with mining impacts. One operation will impact 300 km². A 20 year operation is 600 km² mined. This results in a very large impact zone (100s of km²). The operation will also need a buffer for the material to lift it to the surface. Processing is probably 80% of the cost of the whole operation. Processing is the problem with the feasibility of this type of operation, but technology is improving all the time. If the processing can be done cheaply, then these operations become economically feasible. Collector, Buffer, Lift and Transport can be figured out; the processing of the ore will determine the economics of the nodule mining.

Patent information on the systems patented for offshore mining are available from ISA (1 gig size). This provides very interesting for background on how this industry has been explored from a
commercial standpoint. Mining will become an issue for nodules – probably not for seamounts, but mining of nodules will occur in the foreseeable future. Lift systems require a continual feed, so a buffer is required. The buffer provides a uniform feed for the lift. The collector cannot do this, so a buffer is used. The buffer and the collector are the sources of the pollution. The buffer is easier to isolate for low discharge, and can be placed at any point in the water column.

Environmental impacts include loss of hard substrate, direct disruption of surface, heavy local sedimentation, low level far field sedimentation, and surface discharge impacts. Determining the mining patterns will be key to mitigating environmental impacts to benthos. Approximately 300 km² per year will be directly disturbed, and potentially more for indirect impacts.

Ecology, Diversity and Biogeography of the Abyss and Clarion Clipperton Fracture Zone
Craig Smith

The abyssal benthic habitat comprises 54% of Earth’s surface (3-6,000 m depth surface). This habitat is mostly plains of sediments. The ecologically relevant structure is largely biogenic, and are fragile. Nodules provide a separate habitat and this is a distinct, but poorly studied fauna. Habitat heterogeneity exists on 1-100 km scales. This is a very food limited environment. Most organisms are feeding on a very dilute concentration of suspended food. Nodule fauna are largely suspension feeders. We have observed very high local species diversity, with 80-100 macrofaunal species per m²; 50 species per 100 individuals sampled (this is found in CCZ). More than 20 species of charismatic megafauna exist in this environment. The enigma is that rainforests and coral reefs have high habitat heterogeneity and complexity, yet the deep sea benthos has just as much species diversity – how can such a monotonous habitat provide for such diversity? A significant portion of the world’s global diversity (macrofaunal only) may be attributed to the deep sea. This has been attacked (perhaps rightfully) and continues to be a controversial issue in the scientific community. The abyssal fauna are very poorly sampled and described (see OBIS database).

There are likely severe ecological impacts that would be associated with nodule mining. There are 8 registered contractors with the ISA, 7 in CCZ, with 75,000 km² for each claim. MLodge: some areas have been reserved by the commercial arm of the ISA, but realistically the ISA will not mine these and one or more of the consortiums may apply for claims to these areas in the CCZ (see polymetallic nodule map in CCZ). Preservation Reference Areas are MPA structures provided for under UNCLOS III. The environmental impacts include direct impacts, such as “strip-mining” effects and sediment plume deposition. The “strip-mining effect” will directly impact nodule habitat, with attendant faunal populations, and could impact 300-600 km²/yr; ~10,000 km² per 15 year operation. Sediment plume deposition will entomb benthos, dilute deposit-feeder food, clog filter feeding, and could affect 50,000 km²/15 years, chronic plume effects not evaluated.31

Nodule mining will be patchy due to distribution of nodules, therefore plume area will impact much larger area than the footprint of the nodules themselves. Species extinctions occur as a function of habitat loss, based on species-area relationships. For species restricted to scales of mining claims, extinctions are likely. We need to quantify species ranges in order to estimate potential losses. The best experiment was the DISCOL experiment (Thiel et al. 2001).32 This study found dramatic declines in abundance and diversity of macrofauna and megafauna within 11 km² after 7 years. This was a low intensity disturbance compared to mining. Impacts persist for at least decades, and habitat alteration is probably permanent. One study found that geochemical fluxes are restored inside and outside of tracks of a collector, but the power for this study was very low.

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Add slide: CSmith’s ecological characteristics of abyssal seafloor
There are multiple conservation issues. Mining impacts will involve very large scales and long recovery times. **It is crucially important to set up MPAs prior to mining!** The primary MPA goals are: 1) protect representative and critical habitats, and 2) prevent species extinctions (NRC 1984).

Abyssal biogeography forcing processes include:

- Particulate Organic Carbon (POC) flux (probably the most important process);
- Flow regime (Holister and McCave 1984);
- Substrate type;
- Hydrostatic Pressure (upper and lower limits?);
- Flow and Topography interactions;
- Historical Processes;

There appears to be regional species diversity. Biogeographic species level patterns are related to body size and mobility, and to larval dispersal abilities. SGaines: larval dispersal ranges are being challenged for biogeographic patterns. Dispersal patterns don’t map onto range size.

CSmith: this might be different for deep sea. Bentho-pelagic fishes we probably don’t have to worry about. For invertebrate megafauna, most species are widely distributed, some endemism related to high POC flux; pelagic dispersal of lecithotrophic larvae. For macrofauna (e.g. isopods), species richness is high, abyssal radiation evident, local endemism appears to be common, though species are grossly under sampled.
Currents and Circulation in the Abyssal Pacific Nodule Province
Andreas Thurnherr

Main Points discussed:

- Abyssal dispersal on ecologically relevant timescales involves both advection & eddy diffusion;
- Circulation schemes do not generally provide useful information on the relevant time scales;
- Lagrangian data are required on all but the longest time scales (when eddy diffusion can be treated statistically);
- Many years of measurements are required to determine a statistically representative description of the flow field;
- Topography is very important and should be studied regionally.

In determining the currents and circulation in the abyssal Pacific nodule province, we want to answer two fundamental questions:

1. What is range in mean and maximum flow velocities likely to be in 1 m (or 10 m) above the seabed in the Pacific nodule province? (Easy to answer)
2. What is the maximum distance in each direction neutrally buoyant particle within 500 m from the bottom is likely to travel and the time scales involved (weeks, months, year?). That is much harder to answer. The data are not there yet.

There is very few data on deep circulation on deep Pacific Ocean, particularly in the nodule province. The deepest water mass in the region is ABBW (Antarctic Bottom Water). The pathways of ABBW are controlled by topography. The two published circulation schemes are largely inconsistent (very typical for the abyssal ocean – few data), with an exception for the South Brazilian Basin.

Circulation x CM data: The ISA current meter profiles (2 year survey): currents in small regions of the Nodule province show different direction patterns each year. There is no clear pattern of circulation emerging from these data. The possible reasons (discussed in Devidova et al, 1999) are: 1) biased current profiles by local bottom topography and 2) longer mean-circulation time scales compared to the current meter record lengths.

The question is really important to be addressed for sediment re-suspension (mining originated plumes). We need to know what the range in flow velocities is to tell whether sediment can be re-suspended or how much energy is there. Weekly to monthly averaged velocities plotted in a rosette graph show velocity that ranges from few centimeters per m². (Data from 100 m from seabed, but not substantially different from right above (~1 m) the seabed). Weekly averages primarily dominated in most regions of the ocean by mesoscale eddies (those seen in altimeter data, sea-surface satellite, chlorophyll, temperature data). These point in any direction, which is typically for regions of weak flows. For monthly time scales: the flow velocities decrease; year time scales: velocities smaller than 1 cm/m².

Abyssal Eulerian Mean Velocities: CM data can be used to answer 1st question (What is range in mean and maximum flow velocities likely to be 1m (or 10m) above the seabed in the abyssal Pacific nodule province over time scales of 1month to 1 year?). This question is important - e.g. for sediment re-suspension but not for dispersal on time scales of months or longer (because of spatial variability). On time scales of weeks to months, Eulerian mean velocities in abyssal ocean can typically be in any direction (with non-uniform distributions). Weekly averaged speeds are dominated by meso-scale eddies (Demidov: synoptic scale), several cm·s⁻¹ typical. Longer averages are characterized by smaller speeds; yearly-averaged velocities are often <1 cm·s⁻¹. One-year or longer record averages are often implicitly assumed to represent mean circulation.

Abyssal Dispersal in Practice: Current meter data indicate northward flow of 0.5 +/- 1.1 cm.s⁻¹ (i.e. indistinguishable from zero) on the western ridge flank. Coincident tracer measurements
Abundance, Biomass and Source-Sink Predictions, and Species Distributions in the Abyssal Pacific
Sarah Mincks

Nodule formation hypothesis: Metals from land and EPR are carried in suspended sediments → particulates consumed by plankton → fecal pellets produced → fecal pellets are metabolized by benthos and metals are released → reduced metals scavenged by Mn oxides.

Modeled Nodule Abundance: Based on Chl-a concentrations only and there is a poor fit to real data. This is because current Chl-a patterns are not related to historical patterns during nodule formation; surface Chl-a are not a good proxy of vertical export and metals are derived from alternative sources.

Available biological data: Data are available from different sampling programs: CLIMAX-II, HOT, Kaplan 1,2,3, JGOFS, DOMES, among others. Macro- and meiofauna were better sampled. Correlation analyses show some significant relationships: macrofauna abundance and latitude (likely the South-North productivity gradient). Some discrepancies between sampling programs are likely due to field methods (sieving and preservative methods).

Applying archived data to test the “Abyssal SINK” hypothesis: Pacific x Atlantic (Ratio of Shelf Area to Total Area): Roughly 2-3X lower in the Pacific (0.04). Atlantic is 0.1. Does that mean fewer colonists per unit area of abyssal seafloor in the Pacific basin? But benthic standing crop is roughly similar in both oceans!! Maybe faunal densities in the abyss are a function of distance to the slope?? A stepwise multiple regression for abundance of abyssal fauna: most of the variance in macrofauna abundance is related with chl-a concentrations; and it increases with increasing distance from slope. So do we have an “Abyssal SOURCE Hypothesis”??

Genetic Diversity of Abyssal Polychaetes (results from the KAPLAN project): The best data set of 18S r-RNA (Cirratulidae, Lumbrineridae, Sylidae, Spionidae, Paraonidae) tested with Bayesian analysis. Output from the phylogenetic trees: more species that previously thought.

Conclusions:
- The first molecular study for abyssal polychaetes (i.e. preliminary!!)
- Low PCR success rates with abyssal material possibly caused by warming during box-core recovery in tropical oceans;
- Use of nested PCR methods improved 18S results (70% success); still working on the other genes;
- Some evidence for cryptic speciation within putative ‘morphological species’, hence abyssal biodiversity is currently under-estimated;
- Some evidence for monophyly of abyssal clades?
- No shared genotypes have been found between sites C and W (possibly indicating low gene-flow) even using a conserved marker such as 18S rRNA—sampling artifact?

Main Points:
- Background: Modeling Mn-nodule abundance in the CCFZ
- Available biological data from the CCFZ
- Quality-control and relationship to environmental parameters
- Testing source-sink predictions
- Morphological and genetic diversity of the polychaetes across the CCFZ (data from the Kaplan project)
- Links to Antarctic fauna??

The Biodiversity and Ecology of Deep-sea Ecosystems: Abyssal diversity / Gene flow – Molecular Insights
Alex Rogers
Polymetallic nodule regulations 2000
Michael Lodge

Regulation is for exploration ONLY (essentially directed search for and evaluation of commercially-exploitable deposits). Review of 1) who is entitled to contracts, 2) how to get a contract, and 3) terms and conditions of contract (15 years; 150,000 km², reducing to 75,000 km²).

Contractors: Mainly States or State entities: COMRA (China), DORD (Japan), IFREMER (France), Korea, Yuzhmoregeologia (Russia), Interoceanmetal Joint Organization, BGR (Germany). The exploration areas are in

1. Clarion-Clipperton Zone;
2. India (Indian Ocean basin);

Environmental Requirements: The basic premise: little environmental impact from exploration (list of “no impact” activities from U.S. Deep Seabed Hard Mineral Resources Act remains valid).33 Contractor requirements in exploration phase aimed at:

- Collection of baseline data;
- Monitoring of environmental impact of exploration;
- Reporting on above to ISA;
- Supported by ISA guidelines on monitoring and evaluation of environmental impacts;

Test mining: Environmental regulation becomes more stringent at phase of “test mining.” Contractors’ obligation to set aside “impact reference zone (IRZs)” and “preservation reference zones (PRZs).” What is “test mining” This somewhat depends on technology development.

Questions and issues: What are criteria for IRZs and PRZs? Size and characteristics? Are these required of each contractor or shared zones? Political constraints: Contractors will not want to set aside best mining areas. Contractors will wish to delay implementation. Contractors will not want to spend money on monitoring and assessment.

Considerations: Should make use of opportunities for data collection during exploration phase. Should build on existing regulatory regime; consider incentives to contractors to cooperate with scientific community, e.g. potential for shared IRZs and PRZs and access to data and evaluation.

Discussion:
C. Smith: these guidelines were made by U.S. representatives (National Research Council – NRC, 1984). He points that PRAs should be established immediately. NOdunton: Environmental data generated by contractors MUST be available for the community (scientific and general public). CSmith: proposes a proactive relationship (scientific community and contractors) from the very beginning of the PRAs designing process.

26 October 2007
Morning Session

Definition of MPAs for Abyssal Nodule Provinces in the CCZ

- ISA only has jurisdiction for activities on the seabed – but the threats associated with the nodule province are primarily associated with mining, which will affect the water column
- Make recommendations on the pollution/sedimentation associated with sediment plumes in the water column

OBJECTIVES for setting up MPAs (specifically for mining activities)
Include preamble with overview about how management of the seabed needs to be joined with management of the overlying water column in a holistic strategy
(Alter objectives established for seamount systems; but couch this towards the ISA)

Objectives of MPA Design for Nodule Mining

1. Preserve and Conserve Marine Biodiversity
   • Protection given to rare species
   • Endemic species
   • Vulnerable species to human activities
   • Preserve genetic units of species (stock structures) and preserve genetic diversity

2. Preservation/Conservation of Marine Ecosystem Structure, Function, and Integrity
   • pelagic habitat
   • benthic habitat
   • structural complexity
   • critical ecological habitat
   • maintain abundance and balance

3. Manage Mining Activities to Maintain the Sustainability, Integrity, and Health of the Marine Ecosystem
   Seafloor Mining Activities include:
   • Direct and Indirect Effects of Mining at/near the Seafloor
   • Sediment Plume Discharge in the Water Column

4. Communicate the Need to Manage Human Activities to meet the goals of the MPA System
   Other human activities may include:
   • Maintenance of Sustainable Fisheries: Essential fish habitat (EFH), spawning and nursery areas
   • Cable and Pipeline Installations
   • \( \text{CO}_2 \) sequestration and Fe Fertilization
   • Mining
   • Ecotourism Activities
   • Marine Research
   • Other human activities with a potential to affect the deep sea

5. Preserve Unique and Representative Marine Habitats
   • Geologic(Geophysical) and Geochemical Features
   • Unique Marine Life Habitats

Discussion
Alex: impacts are not limited to the seabed and sediment plumes may drift. MLodge: The ISA’s interest is in the recommendations for establishing Preservation Reference Zones (PRAs). It is good to point out these objectives, but we need to be mindful of what the ISA needs. e.g. OSPAR – makes recommendations on protected areas and communicates this to NIAF – the regional fisheries authority, who can then enforce. We need to establish PRAs and then work to get these areas to be adopted by RFMOs. CSmith: need to get these PRAs established and need to reference other human activities. We must communicate the need to respect the PRAs.
Designing MPAs for Abyssal Nodule Provinces
Steve Gaines & Allan Friedlander

We should use straight line boundaries, because these are easier to enforce. We need to define major habitat types on the abyssal seafloor (e.g. density of nodules [low, medium, high]; overlying productivity [food availability – could change with changes in climate]; unique spawning aggregations). We should use replication. The stakeholders need to be involved; stakeholders must buy into the process. There are different issues than seamounts, which are discrete entities with potential isolation and perhaps a large fraction have been or will be affected by human activities. The CCZ claim map has changes in biota from east-west and from north to south. There are different assemblages along this gradient. The area is bounded to the north and south by fracture zones, and to the east and west boundaries by EEZs. We need to project a map of nodule abundance (from CMorgan) on to the CCZ claim map.

We have complete certainty that mined areas will have massive biological impacts with centuries for recovery. We could have MPAs associated with individual claims (tied to current regulations), or we could have a generic MPA for all claims. Setting aside all unclaimed areas in the CCZ would this satisfy all the objectives. An alternative way to think about this would be a claim-by-claim basis, which would probably get you to a similar conclusion. Meeting the goals would be served by setting aside the area outside the claims.

MLodge: This would be a tough sell. Because there are a number of areas from previous claims (US Consortium), which may again become active. There could be overlaps with the German claim. Other areas of potential interest that exist – we don’t see the council approving this, especially when this effectively doses all other areas in the CCZ for future claims. On the claim map, the areas in white: each claim is 150,000 km$^2$, which then gets paired down to 75,000 km$^2$. White areas should be 7 x 150,000 km$^2$ (1,050,000 km$^2$) and 7 x 75,000 km$^2$ (525,000 km$^2$). The total area claimed is ~1.5 million km$^2$. The total CCZ area is ~6.5 million km$^2$ (claimed area is approx 23% of CCZ total area).

MLodge: surely you would want to set aside an area that is bounded by defined area – why set aside the whole area? The first claims that were made resulted in a lot of overlap, so there was a long process of sorting out these overlaps. Claims with more detailed boundaries probably reflect more work on resource assessment than others. White sites probably represent similar habitat as the areas that will be mined. Half of the white areas will be relinquished. In the relinquishing process, after survey and exploration work is completed the contractor will discard those areas that are not good for mining. So the mining site is half of your original site.

All colored areas on the map are effectively “gone” because the half relinquished will be closed and will likely be impacted by mining activities (sediment plume). AFried and CSmith: divide CCZ into 3 x 3 grid to account for differences in productivity, which alters types of communities. Three lines from E-W and three from N-S. The preservation reference areas will fit within framework of established claims. We also need to consider seamounts on extreme E and W ends of CCZ, need to overlay map of seamounts and knolls. The unclaimed areas need to overlay map of nodule abundance. CSmith: Unclaimed areas probably contain the whole range of habitats found in unclaimed areas. Malcolm: This must include some areas in the white boxes, that way you will preserve some equivalent habitat to that which is being managed. Areas within the claims are not viable for MPAs because impacts of surrounding mining activities will likely make these areas moot. We could establish a zone of predicted impacts around existing claims; this would show habitat that would potentially remain untouched.

The language from NRC report states:

- “Preservation Reference Areas” (PRAs) are SRAs that are distance enough from seabed mining to be unaffected by mining activities, yet representative of the environments to be mined.”
“Impact Reference Areas” (IRAs) serve as “controls” for the study of mining impacts, and must be located close enough to mining to minimize inherent environmental differences so that statistically valid assessments of the impacts of mining can be made.”

“One IRA per mining site should be designated simultaneously with the issuance of each commercial recovery permit.”

We should focus on using language adopted in the legislation (MLodge). The contractor actually has the power in the legislation to establish the PRAs and IRAs – this is not an optimal arrangement and has not worked for other conservation schemes (SGaines). Establishing the PRAs now is accomplishable, and we can get them approved by the LTC and the Council, which will satisfy the contractor’s obligations, and will establish criteria for contractors. The size requirements are vague, and ‘environmental variability’ language may be impossible to fulfill. We have to view this as whether or not populations will persist outside of mining areas. The PRA/MPA has to be large enough that populations will not be affected by local variability. There must be an adequate buffer. MLodge: The legal framework allows for PRAs to be set up now.

Fauna inside the 75,000 km² claim area is likely to be represented outside of a claim area. Within 9 different productivity zones, with a single MPA in each you have no replication. We have to have at least one MPA in each “bioregion” (productivity region). You would want these to be sufficiently large, or replicate. It is not clear you can fit one of sufficient size within the current CCZ claim map. You have to have a 100 km buffer on each side of the MPA as a buffer. If it was mined on all sides then you would have only a small fraction inside the area that wouldn’t be impacted. The minimum area should be 100 km on each side of a claim area to buffer, and this should be the minimum MPA size. We should take claim areas and map a buffer zone around them to see what is left over. This would establish a 100 km “Mining Impact Zone.”

Establish 500 x 500 km PRAs and overlay on to CCZ claim map. MLodge: Why does PRA need to be 75,000? CSmith: This is the minimum scale of range of habitat variability. The fish are the most mobile species. They move 100s to 1000s of km. As species they have biogeographic ranges larger than the entire CCZ. There are other species persistence issues – whether species are mobile enough to move out of the impacted areas is the key. Holothurians would be good species to use because they aren’t as mobile and can’t escape effects of mining. CSmith: We need a habitat classification system, and what we need to have represented. Create a diagram with different types of habitat and sediment; also a range of elevation features. Are non-exempt areas going to be representative of all these types of habitats?

There are different ranges of nodule density on small scales (100 km) and you can capture the full range of habitat variability. SGaines: We need the scale for habitat variability. Seamounts will also get hammered by the mid-water plumes and sedimentation. What is the scale below which we can consider it flat? 100 m? Abyssal hills undulate on the scales of 1-2 km, at 20 m height. We need to determine the scale of impacts, particularly the sedimentation. How long will it take to settle, and at what range will it be distributed? We need also to know how much sediment is sufficient to choke filter feeders and other ranges of effects predicted for species. Relief features will accelerate flow and therefore you’ll get different types of fauna.

**Abyssal Nodule Province: Habitat Types**

**Habitat Types:**
1. **Abyssal Plain:** use French system of Nodule Facies (CSmith slide)
   - Nodule abundance- different community structure (proportions of species are different), all the environmental variability/habitat heterogeneity will be captured on a 100 km scale
     - Low
     - Medium
     - High

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34 Reference S. Gaines’ Persistence Criteria
Zero

Scarp

2. **Topographic Features**: None of these features are known on the scale required. Can ID seamounts, and we know the differences in productivity from E-W and N-S. Have to use features that we can identify

- Knolls (500 – 1000 m)
- Seamounts (> 1000 m): use definition created in workshop
- Fracture zones (and associated hard substrate faunal communities)

3. **POC flux within the CCZ** (or biomass – some data available) use Yool et al. data for POC export (LWatling has this)

- 3 latitudinal strata
- 3 longitudinal strata

**Discussion on MPA Parameters for Abyssal Nodule Province**

Is there any hydrographic variability across this region? Some topography, but no major ridges. Southern border does get shallower, and to the east there is the EPR. Eastern end is within the OMZ. We need enough replication of seamounts at different depths. Ships will avoid seamounts because of currents and danger associated. Are these concerns built into current claims? No vent communities in the CCZ (that we know of). Fracture zones probably aren’t seeps, but may have hard substrate associated with knolls. We need to overlay claim areas on the seamount layer and nodule abundance, POC export and predicted impacts of mining.

How can we capture minimum viable population sizes? Minimum population size can be mathematically determined by population growth rates (need to understand life history). Using species/area curve approach is challenging without enough data. Include enough area to approach the asymptote of the species preserved. We could review literature of macrofaunal distributions (post-workshop activity?). There may be reproductive/mate-finding strategies that we don’t understand. We could also use known information for shallow-water systems. We need dispersal distances, and information from reproductive biology → genetic approaches to appropriate minimum viable population size: this would be very difficult. The diversity of marine populations is influenced by many factors, especially given the variability in life histories and reproductive strategies. Genetic information doesn’t give you any behavior information, but might be able to give you some information on distances of distributed genes – these will fall outside the CCZ, so it’s probably not much good.

SGaines: In absence of this information, you’re better setting aside a percentage of area (50%) to capture patchiness of the habitats. Using small parcels wouldn’t work with this, because there isn’t a true network approach. This is for maintaining viable populations within MPA. (**are networks primarily for protecting species of commercial interest, e.g. fisheries?**). The 50% rationale comes from looking at models of persistence of species when habitats become fragmented. See SGaines’ slide “Network Reserve Size” – reserve size (%) v. Conservation Benefits 35(% population protected). We need to protect a fraction sufficient to preserve species with different life histories. This is based on empirical studies of reserves. The benefit of these MPAs being sufficiently large is that you bound larval dispersal; (~200km) you get a sizeable fraction of offspring settling within the MPA, ensuring persistence.

How feasible is this design for the ISA? Area: **2,250,000 km² proposed for MPA. 6.5 million km² total CCZ area** - MPA would be ~33% of entire CCZ. We need to go through an appropriate

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analysis of the buffer required. The critical size is 200 x 200 km square. Entire MPA would be 400 x 400 km. 1.44 million km$^2$ over 6.5 km$^2$ total area = 22% of total CCZ. We don’t need a 100 km boundary to the north or south, but this might be some leeway in the design. Stakeholders need to be involved in the placement and informed by the guidelines we establish here.

The dispersal of larvae is non-normal, with exponentially decays. Task: acquire current meter data from the region. Andreas will calculate a dispersal scale of larvae. What temporal scale – 1 year or monthly? Maybe this is pointless – because the length of larval immersion is sufficiently long for large scale dispersal. We will use the 200 km scale for larval dispersal.

How would ISA respond? MClark: there is no reason to give in if our conservative approach is based on sound ecological principles. SGaines: Stakeholders have flexibility in determining siting. Do we need MPAs in non-productive areas? These areas are not of mining interest – so perhaps we should not include these (will bring % area of MPAs down). The US and Italy have claims (not on map) over the most dense assemblages of nodules. We need some robust scientific rationale for siting of MPAs in order to thwart a claim from US and/or Italy.

**Preservation Reference Area Goals:** PRAs should be sufficiently large to ensure continual persistence of representative characteristic fauna of the deep sea environment. The PRA must be 1) far enough removed to remain unaffected by mining activities, and 2) representative of habitats in areas impacted by mining.
- Minimum Size of an individual PRA: 200 km per side
- Total target area (as % of each bioregion or “productivity/food availability zone”)

**Framework (Quantitative Goals) for MPA/PRA System:**
1. Size: 200 x 200 km side
2. Buffer Zone: 100 km on each boundary of the MPA preserve (200 x 200) = 400 x 400 km area
3. Strata: Bioregion/”Productivity Area” 9 strata – based on Yool data or macrofaunal biomass
4. Number and type of Seamount Features preserved (will get wiped out by sediment plumes)

**Remaining Steps to Establish PRA/MPA System in the CCZ**
- Need to overlay the claim map with the abundance of nodules
- Need to overlap the export production map over CCZ
- Overlay Macrofaunal biomass/abundance – apply a Martin curve. Below 2000 m, the curve gets linear
- Add in US and Italy claims

**The Next Step:** Put a proposal together and attend the LTC meeting and pitch the project.

**Discussion**
The ISA has the information to act as the environmental steward. The better way to sell the MPAs: set the quantitative parameters, and let them decide where. The presentation goes to the LTC (LTC has 24 members, elected from among the member sites). The LTC formulates a recommendation that goes to the Council after consultation with stakeholders. Ideally, the Council would then adopt the decision and it becomes binding. Include mechanisms to make this an adaptive management plan so there is flexibility to change as new information becomes available. Kriging data is approx. 10 km on a side. Habitat variability is finer than this (CSmith), as are the nodule patches (CMorgan).

**Key Selling Point:** This allows the ISA to satisfy the UN Millennium Development Goals & CBD Targets:
- UN Goals: 10% of total area reserved now, 30% total of ocean reserved (long term)
- CBD Target: a global network of MPAs by 2012

This will make the ISA the only international institution to achieve these goals.
- Overlaying maps\(^{36}\) (parameters) to establish the best configurations of MPA’s for the CCZ nodule province (A. Friedlander and C. Morgan work together with ArcGIS to put the seamount layer together with claim areas, nodule abundance, claim areas, etc)
- output of 9 areas of 400 Km X 400 km (total 160,000 Km\(^2\) including a buffer zone of 100 km)

Rationales for Seamount MPA Network Design
Malcolm Clark

The physical and ecological classification of seamounts was agreed to upon previous discussion, but the biogeographic provinces should be worked in more detail/accuracy. The issue of distance needs to be resolved: define connectivity, isolation. Dispersal distance: agreed upon in the order of 200 km. CSmith: It was put in discussion earlier that if it should be considered different dispersion scales for the different seamount depth strata (0-200; 200-1000;...1000-2500 m). Andreas: The data available up to 1000 m is good enough (3000 floats spread in all ocean basins) but below that depth is guesswork. If a lot of effort is put on data acquisition and analysis is likely to be possible to derive dispersion scales for the deeper layers of the Pacific. But that would be a paper and a lot of work requiring funding, etc.

CSmith: We would require a quick and pragmatic rationalization. Summarize the outputs of the rationales and the proposed design of MPAs into a few publications on the peer reviewed journals. Where to publish? Ecological Applications?; Marine Policy? Depending on the target public to be informed (Policy makers, scientific community, etc). A couple of discrete papers and one regarding Marine Policy. Publications would be a good input for ISA to use environmentally sound principles in this process. Perhaps we can pursue some funding (CenSeam??, Cedamar: $5,000?, mini-grants) for the publication efforts can be put available. This would supplement investigators’ time doing analyses.

Comments from Craig Smith:
I had an extensive discussion with Nii Odunton after the final dinner of the workshop about the best strategy for bringing our recommendations for PRA design and setup to the ISA. Nii felt quite strongly that this should be two-step process:
(1) We sell the Legal and Technical Commission and the rest of the ISA on the concept, i.e., that it makes sense to set up PRAs now (or soon) under the design principles we have developed, with contractors sharing PRAs and not needing to develop their own conservation framework.
(2) We work with the LTC to identify specific PRAs in the management area, consistent with our design criteria and with active involvement of the stakeholders. This process would take at least two years, but would include more active participation by the stakeholders and would still be timely with respect to nodule mining. This approach seems reasonable to me, however, I do think we should have a hypothetical set of PRA’s designated to give the contractors and ISA a sense of what these would look like. Please let me know your thoughts.

Task List for Design of Clipperton-Clarion Zone MPAs (or PRAs) for the Abyssal Pacific Nodule Province

1) Complete/improve the current GIS product
   - Nodule claim areas (including existing USA, Italy, German claims)
   - Nodule abundance\(^{37}\)

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\(^{36}\) Lamont website: has a database of worldwide distribution of seamounts (Chris Small – Lamont) [http://www.ldeo.columbia.edu/~small/Seamounts.html](http://www.ldeo.columbia.edu/~small/Seamounts.html)
Macrofaunal abundance
Seamounts in depth zones (0-200 m, 200-1000 m, 1000-2000 m, >2000 m); Seamounts distribution from altimeter TOPO data
Bathymetry
Yool et al. export production
rigorous geo-referencing of the claim areas;
bathymetry

**Tasks:**
- *People responsible: Friedlander (overall GIS), Morgan (nodule abundance), Mincks (macrofaunal abundance), Watling (Yool et al. export production).* MLodge: will contact Marcos at ISA for shape files of claims (International and US claims); C. Morgan will send to A. Friedlander a Geo-referenced raster file of the nodule abundance; LWatling: Provide Yool et al. data on net productivity/export flux; SMincks: provide macrofaunal abundance/biomass. Use proportional bubbles and not use any Kriging method to not overestimate the data; CMorgan and AFriedlander (+ L. Watling) are assigned for this task with a deadline of end of November.

**Time Frame: completed by Nov 30**

2) **Fine-tune the recommended positioning of the PRAs** - *indicate flexibility of siting*

- generate 5 or 6 different scenarios (to bargain upon contractors interests and our (scientific) interests);
- generate the total area (km$^2$) of the claims and the proposed MPA network
- starting point: do not step any box in the current claim areas

**Tasks:**
- *People responsible: Smith, Friedlander, Gaines, Watling, Morgan.* This task is dependable on the accomplishment of task no I (complement GIS layering). A. Friedlander, S. Gaines and L. Watling are responsible for this task. This task can be done in a few days, or a week.

**Time Frame: completed by Dec 15**

C. Morgan raises the question about the US claims (Should we put the PRA’s on areas that eventually would be claimed by US?). Craig points out, and C. Morgan agrees/confirms, that even if ISA has promised some areas for US, none of those areas have been claimed by the US yet in terms of legal structure.

3) **Generate/write a preamble:** Rationales for the proposed MPA network design for the CCZ Nodule province.

- 200 x 200 km square to maintain viable populations and ecosystem function, and incorporate range of habitat variability (including seamounts)(help from Gaines and Thurnherr) as a minimum/acceptable size to maintain minimum viable population size (think about the right terminology to be in agreement with other studies. S. Gaines will help with that). A. Thurnherr will provide help on that, using/providing his graphics
- 100 km buffer zone to avoid impacts of plume dispersal (help from Thurnherr). As a 100 Km buffer zone. C. Smith and A. Thurnherr need to do some literature work to come up with a more rigorous rationale
- Stratification of CCZ management area into 9 strata or cells – 3 east-west levels, and 3 north-south levels (help from Mincks, Morgan and Watling)
- The adaptive nature PRA management (if claim areas change, and as knowledge advances, the location of PRAs can be adjusted).

**Tasks:**

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37 Craig Smith: Copyright of all presentations contents will be respected. All participants must agree that if someone is willing to use any figure or data from other person’s presentations must to ask for consent in advance.
People responsible: Smith, with help from Gaines, Thurnherr, Mincks, Morgan and Watling
Time frame: draft completed by Nov 25

4) Put together a written document or presentation to go to LTC of the ISA

   Include all the experts as co-authors in the document. But M. Lodge, C. Morgan and N. Oduntun as observers. (No timeframe was selected for this particular task). MClark: The range of habitat types that should be included in the 200 x 200 km PRA areas should be highlighted in the document.

Tasks:
   Craig Smith, with help from others
Time frame: written document by Feb 1, 2008; presentation in May 2008

Task List for Design of Seamount MPAs

This is a very general summary of what needs to be done. I need some specific input from Malcolm Clark and Tony Koslow especially on particular tasks and people to spearhead them.

1) Summarize our generic conclusions about the design of seamount MPAs including (a) our hierarchical classification approach based on physical properties (biogeographical province, seamount shape, summit depth, connectivity or isolation, oxygen concentration, volcanism, etc.), (b) presence of critical ecological habitat, and (c) level of replication (40-50% of seamounts protected within each stratum protected).
   People responsible: Clark, Koslow, Watling, Rogers, Baco?
   Time frame: 15 December 2007?

2) Apply hierarchical approach to several example seamount systems: North Atlantic (Watling and Rogers?), South Pacific Co-rich area (Clark and Koslow?), Indian Ocean (Rogers, Clark and Koslow?).

   People responsible: Clark, Koslow, Watling, Rogers?
   Time frame: 30 Jan 2008?