THE SKIMMER ON MARINE ECOSYSTEMS AND MANAGEMENT

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Should we be conserving and managing marine ecosystems in 3D? The latest thinking on vertical zoning

Editor's note: Several new papers have examined the feasibility and advisability of applying different management and conservation measures at different depths of the water column (aka 'vertical zoning'). In this issue, with help from a couple of experts, The Skimmer takes a quick look at the history of vertical zoning and current thinking on where it can and should go next.

Why would we want to do vertical zoning? Isn't 2D[1] conservation and management complicated enough?

- As The Skimmer readers are well aware, the marine environment (temperature, pressure, salinity, light, nutrients, oxygen, currents, physical structures, etc.) and the species that inhabit it vary dramatically with depth. One just has to read the latest articles about fascinating new creatures discovered in the deep ocean to get a sense of this.

- This variability means that entirely different communities of organisms with different human uses, vulnerabilities, and conservation needs exist at different depths at the same latitude/longitude. This variability creates complexity for conservation and management but also opportunity. Most conservation and management actions essentially treat the ocean as 2D. Allowing different suites of human activities at different depths, however, could potentially reduce restrictions on human activities in the marine environment (potentially increasing public support for conservation and management activities) while affording the same level of ecosystem protection as vertically homogenous management. We catch up with the latest thinking on the soundness of this approach and our ability to implement it below.

So is anyone already doing vertical zoning?

- In short, yes. In fact, one type of vertical zoning – restricting activities (e.g., bottom trawling, mining, oil and gas extraction) on or near the seabed while allowing other activities (e.g., commercial and/or recreational fishing) at certain depths above – has been implemented in several countries. This scenario for vertical management arises because benthic ecosystems are generally viewed as more vulnerable than pelagic ecosystems due to:
  - High structural complexity (i.e., some benthic ecosystems such as coral and sponge reefs are easily damaged by fishing gear)
  - Long recovery times for many benthic structures and populations, and
  - Limited mobility of many benthic organisms.

- Examples of what existing vertical zoning schemes look like include:

  - The Tasmanian Seamounts Marine Reserve established by Australia in 1999 (and incorporated into the Huon Commonwealth Marine Reserve in 2007) created a Managed Resource Zone from the surface to 500 m depth where tuna longlining is permitted. Below that, a Highly Protected Zone from a depth of 500 m to 100 m under the seabed prohibits fishing and oil and mineral exploration, to protect the unique seamount ecosystems.

  - Benthic protection areas that exclude mobile fishing gear to protect the seabed have been created in Alaska and Florida. In Alaska, nearly 1.5 million km^2 of benthic habitat in federal and state waters have been protected since the mid-2000s. In Florida, the 520 km^2 Tortugas Ecological Reserve designated in 2001 protects benthic habitat adjacent to the Florida Keys National Marine Sanctuary.

  - In New Zealand, 32% of the seabed (1.2 million km^2) was placed in benthic protection areas (BPAs) in 2007. In New Zealand BPAs, fishing within 100 m of the seabed (including dredging and bottom trawling) is prohibited. Penalties are more severe (higher fines and possible vessel forfeiture) when fishing gear comes within 50 m of the seabed than when it comes within 100-50 m above the seabed, effectively creating a buffer zone around the actual seabed. (Trawlers are required to be outfitted with electronic net monitoring systems to monitor compliance.)

  - Mexico designated the Mexican Caribbean and Deep Mexican Pacific Biosphere Reserves in 2016. The Caribbean reserve includes a multiple-use zone which allows fishing in the upper 100 m of the water column while prohibiting it in core "no-take zones" below that. The Pacific reserve has "no-take core zones" from 800 m depth to the seafloor. Waters above 800 m are not part of the marine protected area (MPA) and are multi-use. It is doubtful that these areas would have ever become fully protected MPAs because the area in the Pacific has commercial fisheries and the area in the Caribbean has international shipping lanes. Designating the deep-sea areas as reserves enabled their protection from fishing and mining.

  - In 2017 Canada designated the Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs MPA to protect globally unique, ancient glass sponge reefs. The MPA has three types of zones – Core Protection Zones (CPZs) containing the sponge reefs, seabed, subsoil to 20 m depth, and water column from the seabed to at least 40 m above each reef; Vertical Adaptive Management Zones (VAMZs) consisting of the water column from the CPZs to the sea surface; and Adaptive

Management Zones (AMZs) which surround the CPZs horizontally. All fishing is prohibited in the CPZs while some fishing is allowed in the VAMZs and AMZs. Conservation advocates felt that it would not have been possible to get the horizontal buffer AMZs if some commercial fishing had not been allowed in the VAMZs.

What about marine spatial planning - do any plans incorporate vertical zoning?

- Obviously, the vertical dimension (depth as well the air column above the sea surface) is critical for many aspects of marine spatial planning (MSP) as well as MPA planning. Human uses of the marine environment occur at the sea surface (e.g., shipping), seafloor (e.g., submarine cables), water column (e.g., fishing), and air column (e.g., air transportation) as well as over time. 2D maps may show conflicts when in fact uses can co-exist because they occur at different depths (or altitudes).

- Some MSP initiatives de facto take into account vertical differences in physical structure, marine communities, and human uses when determining the compatibility of human uses in the marine environment (e.g., shipping and submarine cables may be allowed at the same latitude and longitude.) Very few (if any), however, have discussed or created explicit vertical zoning schemes.

If vertical zoning can be implemented, why don't we do more of it?

- To a large degree, 3D conservation and management efforts face the same obstacles as 2D efforts (e.g., lack of political will, capacity, data). Currently only somewhere between 3 and 8 percent of the world's oceans are covered by MPAs, many of those ineffective. Vertical zoning is possible but is even more technically challenging than vertically-integrated management (e.g., more data are needed for decision making). And certainly, monitoring and enforcement of regulations is likely to be more difficult in an area that is vertically zoned, particularly for fishing, because some vessels in an area may be in compliance with regulations while others are not.

- For the most common type of vertical zoning that has been implemented to date (i.e., MPAs to protect benthic habitats and communities), the fundamental question is often one of advisability rather than feasibility, however. That is, to what degree does fishing for pelagic species (recreational or commercial) in the water column impact the benthic habitat and communities below? If there is little impact, vertical zoning (with some degree of pelagic fishing) could be compatible with protection of the benthic ecosystem and would avoid undue restriction of human activity. If pelagic fishing has a substantial impact on the benthic ecosystem because it disturbs critical linkages between ecological processes in the water column and the seabed, a benthic protection zone may not offer adequate protection for the benthic ecosystem.

- What do we know about benthic-pelagic linkages? Not as much as we would like to know, unfortunately. From a variety of sources – direct observation, tagging, diet analysis, stable isotope studies, and food web models – we know that there are indeed vertical linkages between the benthic and pelagic realms. The linkages occur through trophic interactions (e.g., predation), materials sinking (e.g., detritus and carcasses), vertical currents transporting organisms and nutrients, and the active vertical migrations of organisms (daily, seasonally, with developmental stage). What we are largely missing, however, is an understanding of how strong these linkages are, particularly for the deep sea. One exception to this, however, is that we do know that, except for some chemosynthesizing communities, deep sea communities are dependent on primary production in the photic zone for nutrients and strong positive relationships between primary production at the surface and species richness of deep-sea organisms have been observed.

A brief history of vertical zoning recommendations

- In 2005, a group of experts convened by the US NOAA National Marine Protected Areas Center offered preliminary recommendations for when vertical zoning is appropriate in MPAs. They based their recommendations on a conceptual model that benthic-pelagic linkages in shallower waters are relatively direct and strong (e.g., pelagic species are preying on benthic species and vice versa) and become weaker with increasing depth (i.e., there is relatively little interaction between pelagic and benthic communities on the deep continental shelf and in the open ocean). They suggested that recreational pelagic fishing may not be compatible with benthic conservation in: 1) areas with depths less than 50-100 m, 2) areas with topographically complex habitats (e.g., reefs and kelp forests), prominent topographic features (e.g., canyons and seamounts), and/or oceanographic features (e.g., upwelling, gradients) that attract pelagic predators, and 3) spawning areas. They concluded that vertical zonation might be appropriate in deeper waters (>100 m) because of weaker benthic-pelagic linkages at these depths.

- In 2012, the IUCN came out strongly against vertical zoning in MPAs, stating that "It often does not make ecological sense, as how benthic and pelagic systems and species interact is not yet fully known, and surface or mid-water fisheries may in fact impact on the benthic communities below… Furthermore, enforcing vertical zoning is extremely difficult if not legally impossible." (The view that vertical zoning is unsound is maintained in IUCN's 2018 guidance on applying its global conservation standards to MPAs.) It is important to note, however, that the 2012 IUCN guidance is supportive of recognizing the 3D nature of the marine environment by allowing/disallowing different activities in the pelagic and benthic realms **within a single zone**. They cite the example of the Habitat Protection Zones in the Great Barrier Reef Marine Park in Australia which protect sensitive benthic habitats from trawling but allow other types of fishing in the waters above.

- Most recently, a 2018 study by O'Leary and Roberts reviewed the literature on vertical linkages within the water column and between the water column and the seabed to evaluate if vertically-stratified management is ecologically justifiable. They found increasing evidence for strong linkages between ecological communities and processes in the water column and seabed (although still relatively little documentation of impacts from pelagic fishing in the open ocean on deep sea and seabed habitats). From this, they concluded that substantial pelagic fishing is *likely* to have significant impacts on the deep sea and that a precautionary approach to maintaining ecosystem health warrants fully-protected open ocean MPAs.

Are there any developments to help us better understand the 3D nature of the oceans for conservation and management purposes?

- Some progress is being made at enabling more widespread understanding and consideration of the 3D aspects of the marine environment in conservation and management, particularly in the area of classifying 3D ecosystems to facilitate systematic conservation planning.

- In 2005, in an effort to classify ecosystems in the pelagic environment for planning and management purposes, Australia identified 25 3D water masses in its offshelf waters using physical variables and satellite data. This same approach was used for the Southern Ocean in 2006. In 2009, UNESCO released a 3D biogeographic classification (30 pelagic provinces, 38 benthic provinces, and 10 hydrothermal vent provinces) of the world's oceans and seafloor for scientific research, conservation, and management purposes.

- Most recently, the geospatial information company Esri in collaboration with others released a classification of the global oceans into 37 Ecological Map Units (EMUs). EMUs are volumetric units defined by temperature, salinity, dissolved oxygen, nitrate, phosphate, and silicate (e.g., an EMU might be a "warm, low-saline, low-oxygen, high-nitrate, low-silicate, high-phosphate" unit). This work was based on 52 million data points collected over 50 years and compiled in NOAA's World Ocean Atlas. Analysis tools associated with the EMUs are also provided to help practitioners with 3D ocean visualization. [*Editor's note: Visit the web app and/or view a webinar on the EMUs hosted by the EBM Tools Network to learn more.*]

- While the EMUs are a huge advance in 3D mapping of the oceans, they do not yet fully represent all of the factors critical to defining ecosystems. EMU developers are currently working to add data on particulate organic carbon (POC), carbonate contents, ocean current patterns, surface ocean color, seafloor physiographic regions and features, temporal climatologies, and species records.

- 3D conservation planning is also coming onto the horizon. In a 2018 paper, Levin et al. cite an increasing need for 3D planning and management as human activities such as oil drilling, mining, and fishing expand into deeper areas and existing deep sea activities such as fishing increase in extent. (For example, the average depth of trawling increased by 50-100 m a decade in recent decades, and 40% of fish are now caught deeper than 200 m.) They review the state of 3D marine planning and propose a framework for incorporating depth into marine conservation planning. Steps and recommendations from the study include:
  - Using 3D planning elements such as cubes rather than 2D units such as squares or hexagons.
  - Characterizing the 3D aspects of marine systems, including vertical processes and connectivity of species and habitats (e.g., related to upwelling, currents, and gyres)
  - Determining biodiversity goals for different levels of the water column, including features that cross multiple levels
  - Determining threats to biodiversity at different levels in the water column
  - Determining costs for management, conservation, and restoration at different levels in the water column
  - Prioritizing and selecting vertical zones for conservation and management.

- To demonstrate how this can be done, a 2017 study by Venegas-Li et al. used data from the Mediterranean and the conservation planning tool Marxan modified with 3D planning units to conduct a novel conservation prioritization study of the Mediterranean. For this study, researchers quantified biodiversity features and human activities in the Mediterranean both horizontally and vertically. They then used the modified version of Marxan to identify priority conservation areas, including some priority areas only at specific depth layers. The authors compared this to an analogous 2D planning study and found that the approaches yielded considerably different results, with the results from the 3D approach being more cost-efficient (e.g., less restriction of human use for a given level of protection). This is because, with 3D approaches, marine conservation and marine spatial planners can "target specific threats to specific conservation features, at specific depths in the ocean."

- So can this methodology be applied elsewhere? The Skimmer asked this question to the lead author from the study Rubén Venegas-Li, a doctoral student in the School of Biological Sciences at the University of Queensland. According to Venegas-Li, since the team followed well-established spatial conservation prioritization methods using tools that follow the core concepts of systematic conservation planning, the approach can indeed already be used in any area. "As with any planning methodology, however," he adds, "this methodology needs further testing in real case scenarios to fully understand its limitations and applicability."

- When asked what advances are still needed for doing more widespread 3D conservation and management, Venegas-Li replied that "the most pressing is better understanding how ecological processes and human actions interact across different depth zones in the ocean. This will allow us to understand how a specific human activity at a certain depth can affect conservation features at other depths. Despite advances, the science on linkages along the water column and between benthic and pelagic ecosystems is still in its infancy."

- As for the pros and cons of 3D marine conservation and management, Venegas-Li agreed that no-take reserves are the most effective biodiversity conservation measures and that 3D management would likely mean some level of compromise to protected area effectiveness as well as the need for greater knowledge and data requirements. He believes 3D conservation and management still have their place, however. According to Venegas-Li, "even if we know that no-take areas are the best recipe to protect biodiversity, more often than not planners need to balance the protection of biodiversity with the needs and interests of multiple users of the ocean. 3D management can be used to protect critical places for biodiversity, while minimizing losses (economic, cultural, etc.) to the different stakeholders in an area."

- A few other developments are also important to note in this discussion of 3D conservation and management. While not new, technologies such as electronic net monitoring systems that can monitor and transmit the depth of fishing gear are advancing and can provide relatively low-operational-cost means of monitoring 3D conservation and management schemes. And modeling benthic-pelagic linkages for regions where vertical zoning is proposed can help planners and managers determine the advisability of vertical zoning schemes. A number of 3D marine ecosystem models, such as the Atlantis ecosystem model, exist. Planners for the Mexican Caribbean and Deep Mexican Pacific Biosphere Reserves used modeling results for the carbon 'detrital flux' (movement of carbon nutrients vertically in the water column) to estimate the degree of benthic-pelagic linkages in the proposed MPAs prior to establishing vertical zoning in these areas.

Are we going to use vertical zoning on the high seas?

Areas beyond national jurisdiction (ABNJ) make up 64% of the oceans' surface. To provide for the conservation and sustainable use of biodiversity in these areas, the UN General Assembly is currently convening an intergovernmental conference to create a legally binding instrument under the United Nations Convention on the Law of Sea (UNCLOS). The conference held its first session in late 2018 and will have two additional sessions in 2019 and a final one in 2020.

UNCLOS currently has one level of stratification for ABNJ – the deep seabed which is governed by the concept of being "the common heritage of mankind" (with mineral extraction from the seabed governed by the International Seabed Authority) and the water column which is governed by the principle of "freedom of the seas" – which until now has allowed states freedoms of navigation, fishing, and scientific research with responsibilities in how those freedoms are exercised. Currently, areas with vulnerable marine ecosystems can be closed to bottom fishing while fishing is permitted in the water column above.

To learn more about what role vertical zoning may be playing in ABNJ negotiations, The Skimmer contacted Aria Finkelstein. Finkelstein is a Ph.D. candidate at MIT's Department of Urban Studies and Planning and a guest student at the Woods Hole Oceanographic Institute's Marine Policy Center and is researching efforts to implement MSP on the high seas.

According to Finkelstein, "To put it simply, vertical zoning is not currently playing a role in ABNJ negotiations." She added, "So far, while the negotiations emphasize spatial management under the umbrella of area-based management tools (ABMTs), they have not explicitly addressed the importance of vertical striations within the high seas water column."

She said:

"For example, one area that is hugely important and sorely understudied is the mesopelagic zone, or the twilight zone between 200 and 1,000 meters depth. The organisms that populate this low-light layer are so dense they were originally thought to be the bottom of the sea because they registered in soundings. These organisms constitute an enormous store of biomass and play a large role in global carbon cycles, actively sequestering carbon from surface waters via fecal pellet fall or mortality at depth.

These organisms have been notoriously difficult to harvest, but technologies to exploit them, especially for aquaculture feed and nutraceuticals, are developing quickly. Fully fledged mesopelagic fisheries are probably still a way in the future, but neglecting to provide a framework for regulating them now could spell a serious failure in preventing the erosion of our biological climate change regulation systems. So there is no question that 3D thinking is necessary for effective high seas management."

She suggested that even if the ABNJ biodiversity negotiations do not address the desirability of or options for vertical zoning of high seas MPAs head-on, simply establishing a legal framework for high seas MPAs may "allow for case-by-case consideration of whether vertical zoning is appropriate or not." If it does, she said, "there's no doubt the requirements for doing so need to call for great caution, for example, by explicitly limiting it to systems in which benthic-pelagic linkages are demonstrably weak and ruling it out where these systems are more strongly connected or their relationship is still uncertain or unknown."

At the moment, with our current, very limited understanding of deep sea dynamics and very limited ability to effectively monitor human activities and ecosystem status in the deep sea, Finkelstein concluded, "the importance of benthic-pelagic linkages for the health of marine ecosystems and global carbon cycles as a whole is a compelling reason to avoid vertical zoning, as it may fail to account for these relationships."

And, finally, do we need to extend our thinking about 3D management?

- Yes, probably. In addition to considerations from the seabed on up, the advent of directional drilling for mining and oil and gas extraction means that someMPAs may be subject to mining impacts that occur beneath, but not within, them. For this reason, some MPAs such as the Great Barrier Reef Marine Park extend to the subsoil (down 1000 m) beneath the parks (to a depth of 1000 m below the seabed in the case of the Great Barrier Reef Marine Park).
- And with the increasing prevalence of drones (in addition to existing aircraft traffic from planes, helicopters, and technically hovercraft), 3D management is becoming increasingly important in the air space above the ocean surface as well as below it. The presence of drones can disturb marine mammals as well as birds. Many jurisdictions have or are developing regulations concerning drone usage – a number of national marine sanctuaries on the US West Coast require that motorized aircraft including drones maintain minimum altitudes above specified areas.

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[1] In this article, the acronym 3D is used for "three dimensional", and the acronym 2D is used for "two dimensional".

Photo credits:

#1 - Diagram showing the divisions of the worlds oceans. Chris huh. Used under CC BY-SA 3.0.

#2 - The Effect of Trawling the Seafloor for Groundfish. (A) The coral community and seabed on an untrawled seamount. (B) The exposed bedrock of a trawled seamount. Both are 1,000–2,000 meters (1094–2188 yards) below the surface. Source: Gewin V: *Troubled Waters: The Future of Global Fisheries.* PLoS Biol 2/4/2004: e113. https://dx.doi.org/10.1371/journal.pbio.0020113. Wikimedia Commons. Used under CC BY 2.5.

#3 - A Bolosoma stalked glass sponge beginning near the summit at a depth of ~2,500 meters. Image courtesy of the NOAA Office of Ocean Exploration and Research, 2017 American Samoa. NOAA Ocean Exploration and Research. Used under CC BY-SA 2.0.

#4 - Crowded Open Space: A 3D View. BOEM.

#5 - Figure from *Vertical Zoning in Marine Protected Areas: Ecological Considerations for Balancing Pelagic Fishing with Conservation of Benthic Communities.*

#6 - Screenshot from webinar on EMUs hosted by EBM Tools. 2017.

#7 - A chimaera seen during the 2016 Deepwater Exploration of the Marianas expedition. NOAA Ocean Exploration and Research. Used under CC BY-SA 2.0.

#8 - Drone is hovering above the Pacific Ocean, over Half Moon bay. Tomwsulcer. Used under CC0 1.0 Universal.
