North Pacific Fisheries Commission

NPFC-2023-SSC BFME04-IP08

Papers Consulted for the Scientific Basis of the US CMM proposal (Dec 2023)

Papers that document the occurrence of VME species

- Baco et al 2020 - This paper provides evidence of the occurrence of VME taxa including dense patches of octocorals, scleractinian reefs, and deep-sea sponges on all four of the surveyed NHR and ESC seamounts (Koko, Yurykau, Kammu and Colahan). In many areas these taxa occur in sufficient abundance and densities to constitute reproductively viable populations and to be acting as habitat for other species of invertebrates and fishes. Out of the surveyed sites, areas that would qualify for VME designation based on these criteria include, at a minimum, several locations on Koko, the southeast and northwest corners of Yuryaku, locations on Kammu, and the northwestern ridge of Colahan Seamount.

- The study by Dautova et al (2019) on the deep-sea ecosystems of the Emperor Chain seamounts in the northwestern Pacific Ocean unveils crucial insights into the biodiversity and biogeography of these VMEs. The research, primarily focusing on Octocorallia corals and Hexactinellida sponges, revealed significant variations in coral fauna across latitudes and identified a biogeographic boundary within the region. Key environmental factors such as substrate type, depth, temperature, and bottom hydrodynamics were found to influence the distribution of marine life significantly. The study highlighted the biogeographic importance of the Emperor Chain, suggesting a migration of boreal Pacific species southwards and tropical species northwards along the chain. Such findings are pivotal in informing future conservation strategies enhancing the understanding and management of these unique and sensitive marine habitats.

- The study by Galkin et al. (2020) provides key findings that support the conservation of Vulnerable Marine Ecosystems (VMEs) in the area of the Emperor Seamount Chain. It establishes a biogeographic boundary between coral faunas, which is believed to lie between 37° and 39° N, specifically around the Ōjin and Jingū guyots. This observation aligns with the previous work of Sirenko and Smirnov, which discussed the biogeographic boundaries between the boreal and Northwest Pacific regions based on echinoderm fauna analysis. Moreover, the study underscores the importance of delineating clear zoogeographic boundaries with specific reference to hexactinelid sponges and sea urchins.

- The study by Miyamoto and Kiyota (2017) focuses on identifying indicator taxa for VMEs in the Emperor Seamounts area of the North Pacific Ocean. It utilizes association analysis to evaluate the co-occurrence of benthic animals collected through scientific

surveys. The research identifies four clusters of benthic communities, each comprising sessile and mobile taxa. Gorgonians and Scleractinia were found to be effective VME indicators, co-occurring with various benthic taxa and representing key VME characteristics such as habitat provision, structural complexity, and sensitivity to disturbance. The study highlights the importance of these taxa in representing the broader characteristics of VMEs in the Emperor Seamounts.

- Baco et al (in press) summarizes knowledge of the extent of scleractinian reefs in the North Central Pacific through 2021.

Papers that indicate VMEs are likely to be widespread

- Reviewed in Baco et al (2020) - In addition to the documented observations, it can be inferred that VME taxa are or were present across broader areas of each of these seamounts in significant concentrations and in areas we did not explore from a number of lines of evidence. The most obvious is the precious coral fishery, which had some of the highest takes in the world in this region. A key target of this fishery was the "Milwaukee Banks" where a "huge bed of *Corallium* (now *Pleurocorallium*) *secundum* was discovered at 400m" in 1965. The take in this area was up to 200,000 kg of coralliids per year over the next 20 years. During this period 90% of global precious coral takes came from the NWHI/Emperor bend region [reviewed in Grigg 2002]. Both *Pleurocorallium secundum* and *Hemicorallium* (formerly *Corallium*) *laauense* were the target species at depths <600 m. The abundance and density of corals required to support such a large fishery for 2 decades imply a significant concentration of coralliid octocorals more than sufficient for a VME designation.

- Besides the coralliid octocorals, a high diversity of other octocorals, antipatharians, gold corals, stylasterids, and non-hermatypic scleractinians occur in significant concentrations to depths of at least 2000 m at a number of other Hawaiian Archipelago locations that have been explored [e.g. Grigg and Bayer 1976, Baco 2007, Parrish 2007, Parrish and Baco 2007, Long and Baco 2014, Schlacher et al 2014, Parrish et al 2017, Morgan et al 2015]. The species composition of these communities changes with depth and can vary within a single seamount [Long and Baco 2014, Schlacher et al 2014, Morgan et al 2015]. These taxa generally occur in hard substrate areas at densities that would qualify as VMEs. Observations of coral communities, as well as octocoral and gold coral stumps on multiple seamounts (documented in Baco et al 2020), support the expectation that these communities of VME taxa also occur(ed) widely on the ABNJ seamounts.

- Miyamoto et al. [2017] also confirmed the presence of many of these same VME taxa on ESC-NHR seamounts based on fisheries observers, beam trawls, and dredge samples.

- Besides octocorals and antipatharians, deep-sea scleractinian reefs were discovered at depths of 530–750 m on six ESC-NHR and US EEZ NWHI seamounts, including Koko, Yuryaku and Kammu [Baco et al 2017]. Colahan is added to that list of seamounts and had reef observed in sufficient density with visible faunal associations to be considered a VME. Additionally, rubble on Yuryaku, Kammu and Koko, with patches of live corals and recovering corals suggests these VMEs were once common on those seamounts as well.

- The study by Dautova et al. (2019) on the Emperor Chain seamounts provides substantial evidence suggesting that VMEs are indeed widespread in the Emperor Chain seamounts. The research documents a diverse range of habitats and species, including significant populations of Octocorallia corals and Hexactinellida sponges across various seamounts within the chain. This diversity, along with the detailed observations of different biotic complexes and environmental conditions, indicates a broad presence of VMEs in the region.

- The study by Galkin et al. (2020) provides indications that VMEs are likely to be widespread in the area of the Emperor Seamount Chain. The research identifies a biogeographic boundary between coral faunas, presumed to be located between 37° and 39° N. The identification of clear zoogeographic boundaries, particularly with regard to hexactinellid sponges and sea urchins, suggests a complex and potentially extensive distribution of these species. This implies the presence of diverse and widespread VMEs in the area, warranting further species identification and research

Habitat Suitability modeling papers indicate VMEs are likely to be widespread

Multiple habitat suitability modeling studies, corroborate the above evidence and suggest very high habitat suitability across most of the surface area of these seamounts for deep-sea corals in several taxonomic groups.

- Older papers with lower resolution global models, including Tittensor et al (2009) and Davies and Guinotte [2011] show very high to extremely high habitat suitability for structure forming scleractinians on several of the currently fished NHR and ESC seamounts near the bend, especially Koko and Kammu, but also Yuryaku and Colahan.
- Yesson et al. [2012] found extremely high habitat suitability for all 7 taxonomic groups of octocorals along the entire Hawaiian Ridge and Emperor Seamount Chain.
- In a higher resolution habitat suitability study, Miyamoto et al. [2017] found high habitat suitability for large octocorals in a broad depth band all the way around Colahan seamount, and in patches on Koko Seamount (the focal seamounts of their study).
- Yesson et al. [2017] found extremely high habitat suitability for antipatharians along the entire Hawaiian Ridge and Emperor Seamount Chain.

- Cordes et al (in press) using the highest resolution models to date, found very high habitat suitability for scleractinian reef forming species along the Hawaiian Ridge
- Silva et al (about to be submitted, not in dropbox), the first to incorporate scleractinian records from the Baco et al (2017) discovery of reefs, using 25m resolution data found extremely high habitat suitability for scleractinian reef forming species along the northwestern end of the Hawaiian Ridge and into the southern end of the Emperor Seamount Chain

-> Collectively these lines of evidence indicate an extremely high probability that deep-sea coral VMEs are likely to be widespread on all of the ESC-NHR seamounts.

Papers that document the occurrence of SAIs

- Assuming that VMEs are widespread in hard substrate areas of these seamounts as supported by the evidence above, then many lines of evidence for significant adverse impacts are documented in Baco et al (2020) and in Baco et al. [2019] for the NHR and ESC seamounts that are actively fished. These include 1) Large areas of hard substrate on each of the four seamounts that were devoid of fauna (Baco et al (2020) Figs. 7a and 8a). 2) These same areas showed numerous scars from bottom contact gear, with 19–29% of AUV survey images showing evidence of scars (Table 1). 3) Patches of coral stumps, from both gold corals and octocorals were observed (Fig. 9e). 4) Expansive areas of coral rubble from scleractinian reefs were observed on all four seamounts (Figs. 5a and 7b,e, 8b, 9a, c, 10c). 5) Evidence of both fishing and SAIs is further supplied by presence of lost gear observed on every seamount, including many observations of coral rubble in or around the nets, lines, floats, etc entangled in corals or laying across the coral beds (Figs. 9 h, 10D, and [Baco et al 2019]).

- Baco et al (2020) argue that evidence of SAIs on these seamounts can also be inferred from the extremely low abundances of coralliid octocorals. To have supported the high levels of and duration of coralliid harvest in this region (1960–1980s), coralliids likely were present in comparable or greater abundances to other high-density coralliid beds in the Hawaiian Archipelago. Based on data from Parrish [2007], we can estimate densities of coralliids of 30–50 ind per 100 m2 in hard substrate areas on the Milwaukee Banks, with substantial abundances likely on the extensive hard substrate areas of most of the other NHR and ESC seamounts at depths <600 m as well. Kammu, the larger of the Milwaukee Banks, had only 1 coralliid observed on 6 sub dives and two 30-h AUV dives (>100 h total bottom time, and well over 100 km of linear distance surveyed). Coralliids were also rare on the other surveyed seamounts, with *Pleurocorallium* nearly absent from all 4 seamounts studied (1 individual on Yuryaku) and *H. laauense* only found as small colonies in protected pockets. A density and abundance of coralliid octocorals

which could support a documented fishery for over 2 decades clearly qualifies as a VME, and findings of few to no coralliids on those same seamounts 40 years after the peak of the fishery, cannot be defined as anything other than a significant adverse impact, across a significant spatial extent, to a VME taxon.

- Baco et al (2023) demonstrate that seamounts of the NWHR and ESC that have a history of trawling have lower abundances and smaller colony sizes of the coralliid octocorals *Hemicorallium laauense* and *Pleurocorallium secundum*. Both of these are VME indicator taxa and also former targets of fisheries in the region.

- Baco et al (2023) also demonstrate that some recovery is possible as outlined in the next section, however they note that "Kammu, one of the primary seamounts of the coral fishery, had only a single coralliid observed. The other primary coral fishery target, Yuryaku, had only a small number of coralliids in a steeply sloped area. These two actively Trawled seamounts do not appear to be able to recover under the current levels of fishing pressure."

-> Therefore, with the evidence that indicates an extremely high probability that VMEs were widespread on all of the ESC-NHR seamounts prior to the fisheries detailed above, the observations outlined here (as well as in numerous other studies in other seamount coral beds in other parts of the world (e.g. Waller et al 2007, Clark and Rowden 2009, Althaus et al 2009, Williams et al 2010) collectively indicate that bottom contact fisheries cause significant adverse impacts to VMEs on the NHR and ESC seamounts.

Papers that indicate Recovery is possible

- Baco et al (2019) provide evidence for recovery following protection of NWHI seamounts including colonization of corals over areas with visible gear scars, coralliid and reef-forming scleractinians regrowing from fragments among the coral rubble surrounding and spilling out of lost nets, and counts of megafauna from replicated, quantitative AUV image tracks that show higher levels of megafauna overall and higher levels of corals, on recovering seamounts in the US EEZ when compared the sites which are still trawled on the NHR and ESC.

- Baco et al (2020) provides additional images of remnant and/or recovering VME populations on all four currently fished seamounts. Koko and Colahan have the best developed coral communities with pockets of significant concentrations of VME taxa remaining. Kammu and Yuryaku are more heavily impacted, but have patches that suggest recovery is possible if protections are put into place. Observations included larger more mature octocoral colonies in areas with lost lines, gear and gear scars (Fig. 5f and g, 7c,), observations of dense stands of remnant or recovering populations of

octocorals on Koko Seamount; rare but observed images of young *Thouarella* (a primnoid octocoral) on Kammu; pockets of corals on Yuryaku; and pockets of healthy reefs on Colahan.

- Baco et al (2023) demonstrate that a portion of the individuals of *Hemicorallium laauense* on Koko Seamount, and a portion of the population of *Pluerocorallium secundum* on Bank 11 (a formerly trawled seamount now protected in the US EEZ), are likely to be newly recruited individuals.

- The study by Miyamoto and Kiyota (2017) discusses the concept of recovery in the context of Vulnerable Marine Ecosystems (VMEs), specifically relating to the fragility and slow recovery of certain taxa from physical damage. The study notes that gorgonians and Scleractinia, which are effective VME indicators, represent VME characteristics such as structural complexity and fragility, and they have a slow recovery from physical damage. Furthermore, the study mentions that due to their slow growth, long lifespans, and slow recovery from physical damage, cold-water corals are considered important components of VMEs. This indicates an understanding that these ecosystems, while fragile and slow to recover, have the potential for recovery if managed appropriately.

->Collectively these observations provide evidence that recovery of deep-sea coral VME taxa may be possible if protections are put into place. Also, pockets of remnant VME populations exist on the currently impacted seamounts that may help to speed the recovery process at those sites. As trawling continues any remnant populations will be further damaged, reducing recovery rates and overall recovery potential.

Additional Considerations

- Baco et al (2016) reviewed available studies of population genetics and connectivity of deep sea species across habitats and found that the mean dispersal distance was about 33km, which is smaller than the distance between most of the seamounts of the ES-NHR, suggesting limited connectivity among seamount populations.

- Morgan et al (2023) examined the genetic connectivity of *Hemicorallium laauense*, an octocoral that is presumed to be one of the dominant members of the baseline VME communities of the ES-NHR seamounts based on fisheries takes. They found that at unfished sites in the Hawaiian Archipelago this species has moderate levels of inbreeding and significant genetic structure among populations. Additionally this species showed moderate genetic structuring among populations *within a single seamount* for populations separated by as little as 3 km. Consistent with the previous bullet, this study

also suggests that this key species has low levels of genetic connectivity which will lead to protracted recovery times in the absence of remnant populations.

- Watling and Auster (2017) argue that all seamounts should be considered VMEs.

- In a global analysis of corals on seamounts, Rogers et al (2007) concluded that the Hawaiian Archipelago is a biodiversity hotspot for deep sea corals (alpha diversity).

- Seamounts of the Hawaiian Archipelago show extremely high levels of beta diversity for benthic invertebrate megafauna across small depth ranges and among sides of the same seamount (Long and Baco 2014, Schlacher et al 2014, Parrish et al 2017, Morgan et al 2015)

- Similar to studies of benthic invertebrates, studies of fishes in the NWHI also indicate high levels of beta diversity among sides of a single seamount and that one side of a seamount may have a more similar fish community to a different seamount than to another side of the same seamount (Mejia-Mercado et al 2019, Mejia-Mercado and Baco 2022, 2023).