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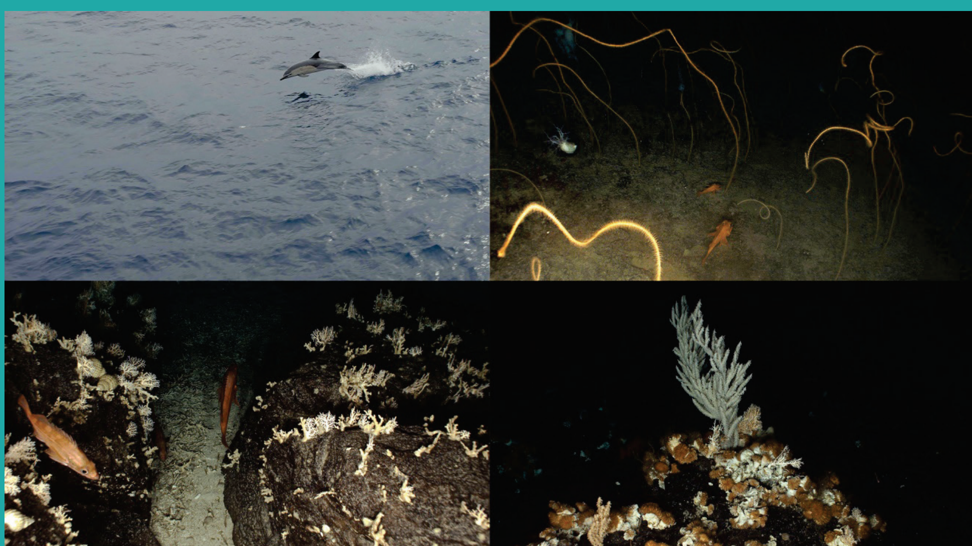

Report of Working Group 47 on Ecology of Seamounts

NORTH PACIFIC MARINE SCIENCE ORGANIZATION

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Report of Working Group 47 on Ecology of Seamounts

edited by
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Front cover:
Seamount taxa along the Cobb-Eickelberg seamount chain in the Northeast Pacific Ocean. The dolphin photo is by NOAA Fisheries/Paul Hillman and the three photos with corals are by Fisheries and Oceans Canada/NOAA Fisheries.

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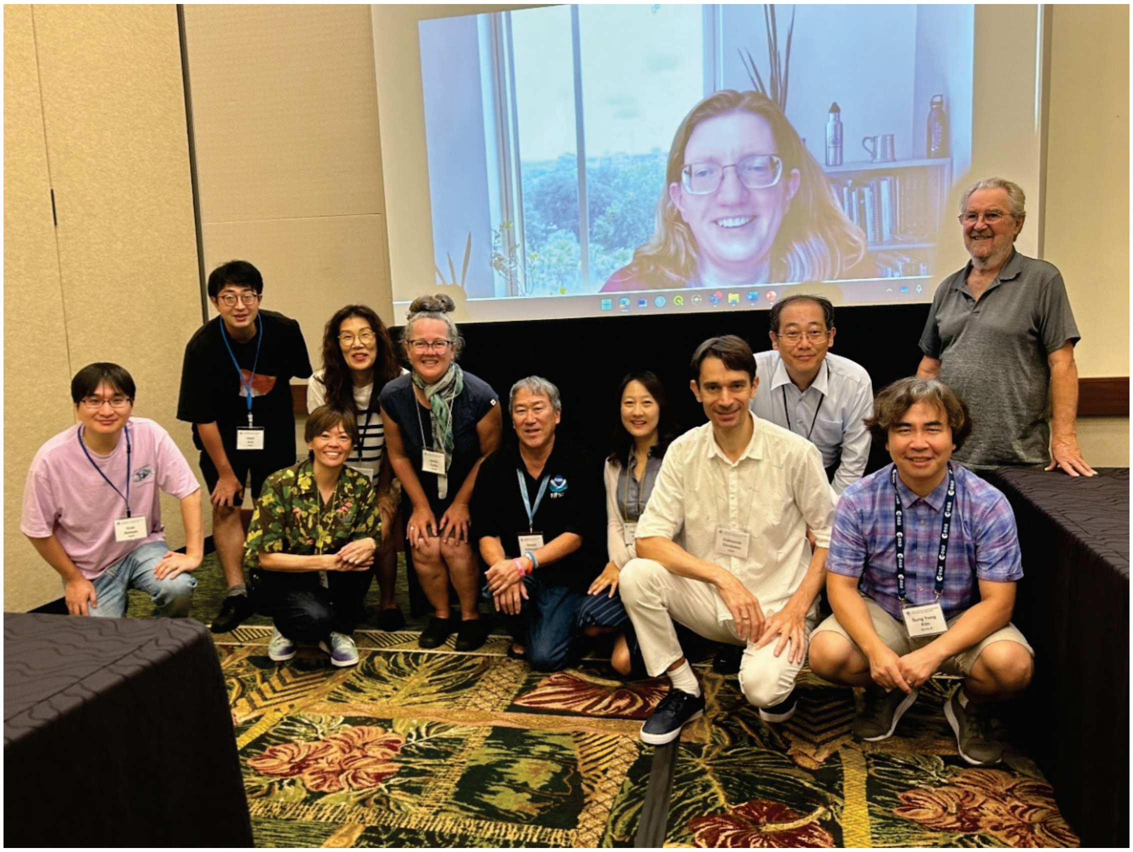

Participants and observers of the final WG 47 hybrid business meeting on October 31, 2024. On the screen (virtual participant) is Amy Baco-Taylor. From left to right in person: Kota Sawada, Satoi Arai, Mai Miyamoto, Seonock Woo, Janelle Curtis, Don Kobayashi (observer), Hye-Won Moon, Alex Zavolokin (observer), Hiroe Yutaka (observer), Sung Yong Kim, and Les Watling.

Acknowledgements

Many thanks go to the PICES Secretariat for their ongoing support of WG 47 from 2020–2024. The Secretariat helped convene a virtual Annual Meeting during the COVID-19 pandemic (2021), virtual inter-sessional meetings from 2022–2024, and facilitated hybrid meetings in Busan, Korea (2022), Seattle, USA (2023), and Honolulu, USA (2024). The Science Board and WG 47's parent committee, the Biological Oceanography (BIO) Committee, provided thoughtful guidance.

Thank you to Mai Miyamoto for ably co-chairing WG 47. Participants of WG 47 are gratefully acknowledged for their contributions to meetings and the research to address WG's terms of reference. All participants, observers, and invited speakers shared their knowledge of seamounts and associated biological communities during the business meetings, workshop (PICES-2022), and topic session (PICES-2023). This was especially true of WG 47's invited speakers, Telmo Morato and Ashley Rowden, who contributed to the success of the workshop and topic session, respectively. Approximately half of WG 47's participants participated in scientific meetings of the North Pacific Fisheries Commission (NPFC) and had particular interests in the identification and conservation of vulnerable marine ecosystems (VMEs). NPFC also co-sponsored the workshop and topic session convened by WG 47 during the PICES Annual Meetings.

Janelle Curtis
Co-Chair, Working Group 47

Executive Summary

There are approximately 100,000 seamounts worldwide and their abundance is greatest in the North Pacific Ocean. Most seamounts are deep, remote, and difficult to study. This means the ecology of seamounts is poorly understood as are the habitats of the pelagic, demersal, and benthic species they support.

The PICES Working Group on *Ecology of Seamounts* (WG 47) was established in 2020 and was extended by one year to 2024 due to COVID-19 restrictions that slowed the group's work. Janelle Curtis (Canada) and Mai Miyamoto (Japan) were the co-chairs.

Annual virtual business meetings from 2021–2024 focused on introductions of national representatives and observers, discussions of WG 47's terms of reference (TOR), and the exchange of information and ideas about participants' seamount research activities. Hybrid business meetings were also held at the PICES Annual Meeting (PICES-2022) in Busan, Korea, PICES-2023 in Seattle, USA, and PICES-2024 in Honolulu, USA. Hybrid meetings were attended by colleagues from the PICES FUTURE Scientific Steering Committee (FUTURE-SSC), the PICES Section on *Marine Birds and Mammals* (S-MBM), and the North Pacific Fisheries Commission (NPFC).

Many WG 47 members shared an interest in the spatial ecology of benthic organisms and had also supported the research activities of PICES WG 32 on *Biodiversity of Biogenic Habitats*. They also shared an interest in the identification of vulnerable marine ecosystems (VMEs) in the NPFC's Convention Area. Some of the key research activities of WG 47 members included:

- Gathering data on species associated with seamounts and submitting these to publicly accessible biodiversity databases, including Canada's Open Government Portal, the National Oceanic and Atmospheric Administration's (NOAA) Deep Sea Coral Portal, and GenBank (TOR 1, Year 1);
- Using an underwater stereo camera system to visually survey randomly-placed transects to about 850 m in depth on seamounts in the Cobb-Eickelberg seamount chain and collect environmental data hypothesized to influence the distribution and diversity of seamount taxa (TOR 2, Year 1);
- Convening a 2-day workshop on "*Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions*" during PICES-2022 in Busan, Korea (TOR 3, Year 1);
- Using visual and environmental data to identify VMEs on Cobb Seamount and predict the distribution of likely VMEs throughout the Cobb-Eickelberg seamount chain (TOR 1 and 2, Year 2 and TOR 1, Year 3);
- Convening a topic session on the pelagic, demersal, and benthic species associated with seamounts at PICES-2023 in Seattle, USA (TOR 4, Year 2) undertaking genomic assessment of deep-sea corals on seamounts in the Western Pacific Ocean (TOR 1, Year 3);
- Evaluating the use of e-DNA as a potential tool for learning about splendid alfonsino and North Pacific armorhead on the Emperor Seamount Chain (TOR 1, Year 3);

- Analyzing the genetics and abundances of coral taxa on fished and unfished seamounts in the Emperor Seamount Chain and North Hawaiian Ridge (TOR 1, Year 3);
- Evaluating the biogeography of North Pacific seamount communities to inform on the location of marine protected areas (TOR 2, Year 3);
- Preparing a final PICES Scientific Report and disseminating results (TOR 3, Year 3).

Although WG 47 members recognized the importance and value of TOR 3 in Year 2, specifically to *Use available data to predict climate induced changes in the distributions of seamount fauna*, there were be insufficient resources or capacity to complete this TOR. Also, several of the TOR called on members to focus on pelagic, demersal, and benthic taxa, but most research by WG 47 members centered primarily on benthic species. Thus some TOR were only partially addressed. Such information could be useful for guiding the next steps for PICES work on seamounts. WG 47 contributions to the TOR are described in section 4.

Potential next steps for PICES include the establishment of working groups to focus on (1) using available data to predict climate-induced changes in the distributions of seamount fauna, (2) identifying VMEs and/or assessing the relative risk of significant adverse impacts to those VMEs in the NPFC's Convention Area, and (3) clarifying the life history of seamount taxa, with an emphasis on reproduction, connectivity and a better integration of biology and physics.

1 Introduction

In their final report, members of the PICES Working Group on *Biodiversity of Biogenic Habitats* (WG 32; 2015–2020) recommended the establishment of a Working Group on *Ecology of Seamounts*, with a focus on understanding the diversity and distribution of benthic, demersal, and pelagic species that are associated with seamounts. Since its formation at PICES-2020, the Working Group on *Ecology of Seamounts* (WG 47) has built on the contributions of WG 32 by mapping the distribution of seamount fauna and expanding research into some of the unique and abundant ecosystems of the North Pacific Ocean.

There are approximately 100,000 seamounts worldwide and their abundance is greatest in the North Pacific Ocean. The ecology of only a few has been studied, in part because of how deep and remote most seamounts are. The difficulty in studying the ecology of seamounts means that they are poorly understood habitats in terms of the benthic, demersal, and pelagic species that they support.

Seamounts are unique habitats for deep-sea organisms and are biodiversity hotspots with relatively high rates of endemism (in some cases as high as 50%). Marine biodiversity is important for maintaining ecosystem structure and function, which in turn supports numerous ecosystem goods and services, including sustainable fisheries. Seamounts can host diverse communities of benthic filter feeders, including corals and sponges. The biodiversity of fishes is also high; almost 800 species of fish have been recorded from seamounts, representing half of the orders of fishes. As such, seamounts can be important sources of food. Indeed, the North Pacific Fisheries Commission (NPFC) manages commercial fisheries in international waters for several bottom fish associated with seamounts in its Convention Area, including sablefish (*Anoplopoma fimbria)*, North Pacific armorhead (*Pentaceros wheeleri*) and splendid alfonsino (*Beryx splendens*).

Interspecific interactions can also influence seamount biodiversity. Biogenic habitats can affect the communities of fish and other organisms that are distributed on seamounts. For instance, fish have been notably absent at sites without soft coral sea whips in some parts of the North Pacific Ocean. There may be a direct link between the abundance and diversity of commercial fish species and the presence of biogenic organisms. WG 47 members reported on a significant relationship between the density of deep sea corals and sponges and the number of species associated with them (see section 2.5.1).

Oceanographic variables and other physical factors, including depth, steepness, substratum, currents, isolation, and the upwelling of nutrient-rich water may also influence the life histories and diversity of taxa on seamounts. Invertebrates and fishes associated with seamounts generally tend to be K-selected (*i.e.*, they are long-lived, slow-growing, have late age at maturity, and low reproductive potential), in part as a consequence of the limited food supply on seamounts. Many pelagic taxa associated with seamounts, including cephalopods, are relatively short-lived, fast-growing, and semelparous. Another group of species, including many marine mammals, sharks, and turtles use seamount areas as foraging posts or migration stops.

The following section summarizes science products developed by WG 47*,* including (1) predictive modelling in the unique and abundant seamount ecosystems in the North Pacific Ocean to produce maps of the known and potential distributions of seamount taxa, (2) integration of data to better understand factors that influence trends in the distribution of seamount taxa, and (3) identification of potential indicators to monitor changes in the diversity of seamount taxa.

2 Working Group 47 Achievements with Respect to General Terms of Reference

This section includes summaries of some of the contributions to the WG 47 terms of reference (TOR) by this expert group's members (Appendix 2). All of WG 47's TOR (Appendix 1) were addressed, at least in part, with the exception of using available data to predict changes to the distributions of seamount fauna caused by climate change (TOR 3 in Year 2). Although WG 47 members had considerable interest in this topic, there was insufficient time, expertise, and required resources for members to address it.

Members also recognized that the first TOR in Year 1, the first, second, and fourth TOR of Year 2, and the first TOR of Year 3 specify a focus on pelagic, demersal, *and* benthic taxa. Because most research and contributions by members focused on benthic (and in some cases demersal) taxa, WG 47's contributions were mainly on benthic species, including deep-sea corals and sponges.

WG 47 contributions are outlined in the table that follows:

TOR	Contributions to the TOR
Year 1	
Section 2.1: Gather data on the distribution and life history of pelagic, demersal, and benthic taxa, including fish and invertebrate assemblages associated with seamounts in the North Pacific Ocean and facilitate their submission to appropriate biodiversity databases, *e.g.*, Ocean Biogeographic Information System (OBIS).	***This TOR has been partially completed***. Janelle Curtis submitted benthic data collected using an autonomous underwater vehicle (or AUV) and a remotely operated vehicle (or ROV) on Cobb Seamount in 2012 to Canada's Open Government Portal and to the Ocean Biogeographic Information System (OBIS). (See Cobb Seamount Visual Survey 2012 (ROV) - Open Government Portal and Cobb Seamount Visual Survey 2012 (AUV) - Open Government Portal). Chris Rooper submitted benthic data collected with a stereo camera system along the Cobb-Eickelberg seamount chain in 2022 to the NOAA Deep Sea Coral Portal at https://www.ncei.noaa.gov/maps/deep-sea-corals-portal/. Seonock Woo shared deep-sea coral bioinformatics data in GenBank that are shared as open data, and Les Watling is anticipating submitting data on benthic taxa from the Emperor Seamounts to OBIS.
Section 2.2: Gather data on key environmental variables (*e.g.*, temperature, depth, steepness, substratum, current velocity, isolation, ocean acidification) hypothesized to influence the distribution and diversity of species associated with seamounts.	***This TOR has been completed***. The World Ocean Atlas data that were compiled for use by PICES Working Group (WG 32) on the *Biodiversity of Biogenic Habitats* a decade ago was updated by Samuel Georgian and was made available to WG 47 members. Chris Rooper also collected oceanographic data along the Cobb-Eickelberg seamount chain in 2022 and 2024.

TOR	Contributions to the TOR
Section 2.3: Convene a 2-day workshop on "*Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions*".	***This TOR was completed during PICES-2022.*** For more details, see the PICES Press article about this workshop *"PICES-2022 W1: Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions"* in Appendix 4 and Summary of Scientific Sessions and Workshops at PICES-2022 in Appendix 3.
Year 2	
Section 2.4: Identify environmental and ecological predictors of patterns in the distribution and biodiversity of pelagic, demersal, and benthic taxa associated with seamounts in the North Pacific Ocean.	***This TOR has been partially completed*** by a team led by Janelle Curtis for benthic seamount taxa along the Cobb-Eickelberg seamount chain in the Northeast Pacific Ocean.
Section 2.5: Apply one or more modeling approaches (*e.g.*, MaxEnt, Boosted Regression Trees, or high-resolution bathymetry-based models) to predict the distribution of pelagic, demersal, and benthic biodiversity associated with seamounts in the North Pacific Ocean.	***This TOR has been partially completed*** by WG 47 members, including a team led by Janelle Curtis for benthic seamount taxa in the Northeast Pacific Ocean. Specifically, they used MaxEnt in 2021 and ensemble models in 2022 to predict the distribution of vulnerable marine ecosystem (VME) indicator taxa along the Cobb-Eickelberg seamount chain in the Northeast Pacific Ocean. The ensemble model coupled a Random Forest (RF), generalized additive model (GAM), and a Boosted Regression Tree (BRT) model. In 2023, a GAM model predicted the distribution of potential VMEs in the same area. Chris Rooper noted that guidelines and code for developing predictive habitat models, including RF, GAM, Generalized Linear Models (GLM) and BRT are available through ICES.
Section 2.6: Use available data to predict climate-induced changes in the distributions of seamount fauna.	***This TOR was not addressed*** because of insufficient capacity, time, and resources within WG 47.
Section 2.7: Convene a topic session on the pelagic, demersal, and benthic species associated with seamounts at the PICES Annual Meeting.	***This TOR was completed during PICES-2023***: see Topic Session 14 in Appendix 3 under Summary of Scientific Sessions and Workshops at PICES-2023.

TOR	Contributions to the TOR
Year 3	
Section 2.8: Identify potential indicators for assessing and monitoring the biodiversity of pelagic, demersal, and benthic taxa associated with seamounts.	***This TOR has been partially completed*** by a few WG 47 members. Kota Sawada noted that indicators, including e-DNA, that have been applied to other areas might also be applicable to seamounts. A team led by Janelle Curtis estimated an indicator for benthic seamount taxa in the Northeast Pacific Ocean. Specifically, a density of 0.6 VME indicator taxa (stony corals, black corals, gorgonian and non-gorgonian soft corals, glass sponges, and demosponges) per m^2 are indicative of the presence of VMEs in the North Pacific Fisheries Commission (NPFC) Convention Area. This density is associated with higher species richness of non-VME indicator taxa. Amy Baco-Taylor noted that precious corals may be indicators of the effects of disturbance. Other members noted that different suites of indicators may be appropriate for different seamounts (*e.g.*, shallow *vs* deep) and the size distribution of seamount taxa may indicate recruitment dynamics.
Section 2.9: Use cluster analysis and/or association analysis to review and document ecological interactions among seamount taxa.	***This TOR has been partially completed.*** Janelle Curtis and Devon Warawa undertook an analysis of species richness associated with structurally complex habitats and showed that species richness of benthic and demersal seamount taxa is associated with higher densities of VME taxa. Chris Rooper collected data for association analysis with visual survey data from the Cobb-Eickelberg seamount chain in 2022 and suggested that it would be interesting to compare similar analyses on Cobb Seamount and in the Emperor Seamounts. Les Watling described his research defining large-scale biogeographic patterns and contributed to multivariate analyses over broad scales of benthic organisms.
Section 2.10: Prepare scientific reports for dissemination of results.	***This TOR has been completed.*** Canada published a series of working papers about seamount taxa in the Northeast Pacific Ocean to the North Pacific Fisheries Commission (NPFC) in 2021, 2022, and 2023. Most WG 47 members described primary papers or reports that address this TOR. See Related Publications Authored/Co-authored by WG 47 Members in section 4.

2.1 *Gather data on the distribution and life history of pelagic, demersal,[1] and benthic taxa, including fish and invertebrate assemblages associated with seamounts in the North Pacific Ocean and facilitate their submission to appropriate biodiversity databases, e.g., Ocean Biogeographic Information System (OBIS)*

WG 47 members made data available through the Government of Canada Open Data Portal, Ocean Biodiversity Information System (OBIS, https://obis.org/), the NOAA Deep Sea Coral Portal, GenBank, and through data in the supplemental sections of primary papers.

Mai Miyamoto (Japan) also collaborated on a study to investigate the distributional properties of some of the North Pacific Fisheries Commission's vulnerable marine ecosystem (VME) indicator taxa, including specimens from three orders of corals (Antipatharia, Scleractinia, and gorgonians) as well as Porifera (sponges).

2.1.1 Submission of seamount data in the Northeast Pacific Ocean to Canada's Open Government Portal

Janelle Curtis and Devon Warawa submitted benthic data collected using a remotely operated vehicle (or ROV) and an autonomous underwater vehicle (or AUV) on Cobb Seamount in 2012 to Canada's Open Government Portal. The ROV dataset (Cobb Seamount Visual Survey 2012 (ROV) - Open Government Portal) contains observations of species occurrences from seafloor imagery collected by the ROV during the 2012 Expedition to Cobb Seamount. The ROV operated by Fisheries and Oceans Canada was a customized Deep Ocean Engineering Phantom HD2+2 which collected photographic images from 12 transects ranging from 35 to 211 m in depth. The AUV dataset (Cobb Seamount Visual Survey 2012 (AUV) - Open Government Portal) contains observations of species occurrences from seafloor imagery collected by the AUV during the 2012 Expedition to Cobb Seamount. The National Oceanographic and Atmospheric Administration-operated SeaBED-class AUV collected photographic images from four transects ranging from 436 to 1154 m in depth. More details about this dataset can be found in: Curtis, J.M.R., Du Preez, C., Davies, S.C., Pegg, J., Clarke, M.E., Fruh, E.L., Morgan, K., Gauthier, S., Gatien, G. and Carolsfeld, W. 2015. 2012 Expedition to Cobb Seamount: Survey methods, data collections, and species observations. Can. Tech. Rep. Fish. Aquat. Sci. 3124: xii + 145 p.

[1] Although the term of reference includes demersal taxa, the majority of the data gathered by WG members was on benthic taxa.

2.1.2 Submission of seamount data in the Northeast Pacific Ocean to NOAA's Deep Sea Coral Portal

Chris Rooper submitted benthic data collected with a stereo camera system along the Cobb-Eickelberg seamount chain during surveys in 2022 to the National Oceanographic and Atmospheric Administration (NOAA) Deep Sea Coral Portal at https://www.ncei.noaa.gov/maps/deep-sea-corals-portal/.

2.1.3 GenBank data submission

Seonock Woo shared deep sea coral bioinformatics data in GenBank that are shared as open data. The deep-sea octocorals *Calyptrophora lyra* and *Chrysogorgia stellata* were collected in a survey of the West Pacific seamounts area and the transcriptomic reads have been deposited in GenBank under BioProject IDs PRJNA750563 and PRJNA750568. The transcriptome shotgun assemblies for the two corals have been deposited in the FASTA format at DDBJ/EMBL/GenBank under accession numbers: GJII00000000 (https://www.ncbi.nlm.nih.gov/sra/?term=srr15421486) and GJIJ00000000 (https://www.ncbi.nlm.nih.gov/sra/?term=srr15421489).

2.1.4 Bathymetric segregation among demersal benthos and its contributions to the differences in the bycatches on bottom fisheries in the Emperor Seamounts area, Northwestern Pacific Ocean

What follows is a summary of a published paper by Osawa, Y., Okuda, T. and Miyamoto, M. 2023. Bathymetric segregation among demersal benthos and its contributions to the differences in the bycatches on bottom fisheries in the Emperor Seamounts area, Northwestern Pacific Ocean. *Regional Studies in Marine Science* **68**: 103261. doi:10.1016/j.rsma.2023.103261.

Background

Seamounts have attracted both commercial and research attention since the earliest ages of ocean exploration. As a consequence of their geographical and hydrological properties, seamounts induce unique local currents, leading this geographically ubiquitous landform to be one of the most enriched maritime ecosystems. The need for the management of commercially targeted species and surrounding ecosystems has become more apparent in conjunction with the thriving commercial exploration of open seas. Despite the growing global interest in how fishing activity impacts seamount ecosystems, data regarding the fishing impacts of bottom contact fishing gears are still scarce. The aim of this study was to reveal the potential effects of fishing operations and to investigate the distributional properties of demersal benthic species using data collected during fishing activities.

Research summary

Among the data provided by scientific observers onboard vessels of the Japanese commercial bottom fisheries (five of the bottom trawlers and one of the gillnetter) operating in the southern Emperor Seamounts area, data of the operations-caught benthic bycatches during the fishing seasons (January to October) from 2009 to 2020 were used in this study. We mainly focused on the bycatches of four taxonomic benthic groups, including three orders of corals (Antipatharia, Scleractinia, and "gorgonian"

Alcyonacea, excluding soft coral) and Porifera that are designated as “Vulnerable marine ecosystem (VME) indicator taxa” in the Convention Area of The North Pacific Fisheries Commission (NPFC).

Regarding the spatial segregation of fishing vessels, our principal components analysis (PCA) analysis indicated that the operational tactics of vessels using the two fishing gears were slightly different: trawlers mainly operated in shallower areas at higher longitudes and gillnetters operated in deeper areas at relatively higher latitudes. Despite these substantial differences, our quantitative comparative studies revealed that the bycatch trends were highly variable among vessels, even within vessels using the same fishing gear (Fig. 2.1.4.1). This may indicate that variations in fishing tactics, particularly the positions/fishing depth, are the major factors affecting the occurrence of benthic bycatches, rather than the features of the gears *per se*. Our study also indicates the contribution of water depth to the individual sizes and the morphological variations of VME indicator taxa. The fishing operational features shifted, especially in the gillnetter, between early (2009–2014) and later (2015–2020) fishing periods toward deeper and higher latitude. Consequently, the species composition of coral bycatches differed significantly between the two fishing periods (Fig. 2.1.4.2). Overall, our study revealed that (1) the distributions of the VME indicator taxa and their individual sizes seem to vary among bathymetric ranges and local topographies, and (2) operational features, such as geographic positions and depth, may strongly affect the bycatches of demersal benthos.

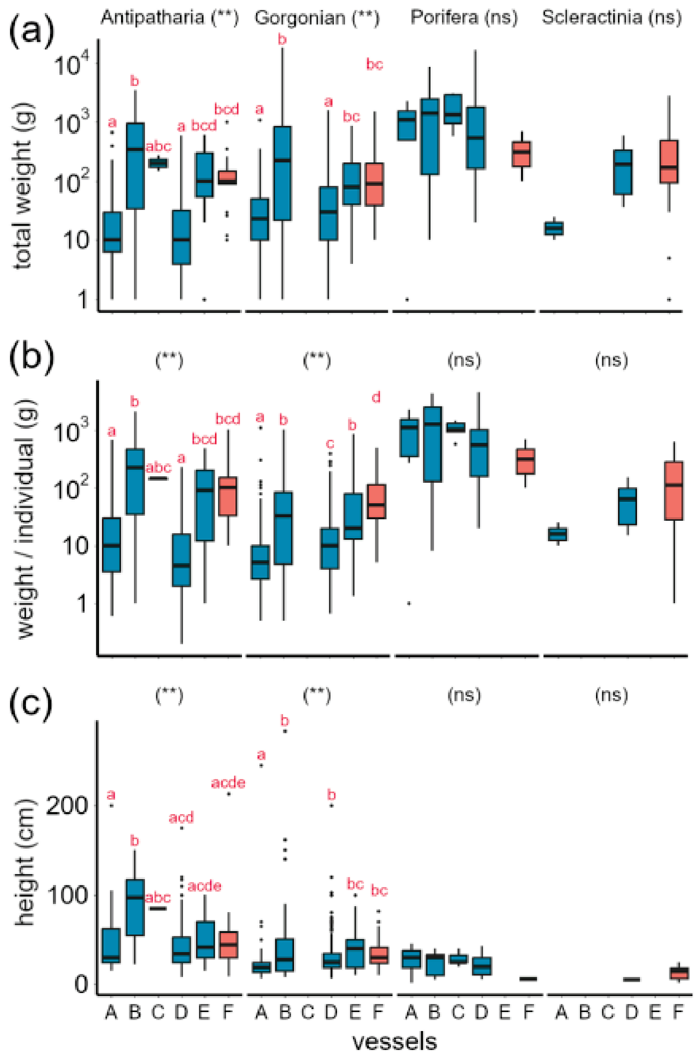

Fig. 2.1.4.1 Boxplots of (a) total catch weight, (b) individual weights and (c) individual height of bycatches (Antipatharia, gorgonian, Porifera, Scleractinia) per vessel (trawls in blue and gillnet in orange). Boxes show the 75%, median and 25% interval and upper and lower whiskers show the greatest and least values excluding outliers. Outliers, black solid circles over or below the whiskers, were plotted if the values were less than 1.5 times the upper and lower quartiles. Symbols in parenthesis are the results of statistical analysis using Kruskal–Wallis rank sum test (** – $p < 0.01$; * – $p < 0.05$; ns – no significant difference), and the results of the post-hoc comparisons (Holm adjusted pairwise comparisons using t-tests with pooled SD) are shown above boxes in red alphabets (a–e).[2]

[2] Reprinted from *Regional Studies in Marine Science*, **68**, Osawa, Y., Okuda, T. and Miyamoto, M., Bathymetric segregation among demersal benthos and its contributions to the differences in the bycatches on bottom fisheries in the Emperor Seamounts area, Northwestern Pacific Ocean. Copyright (2017), with permission from Elsevier.

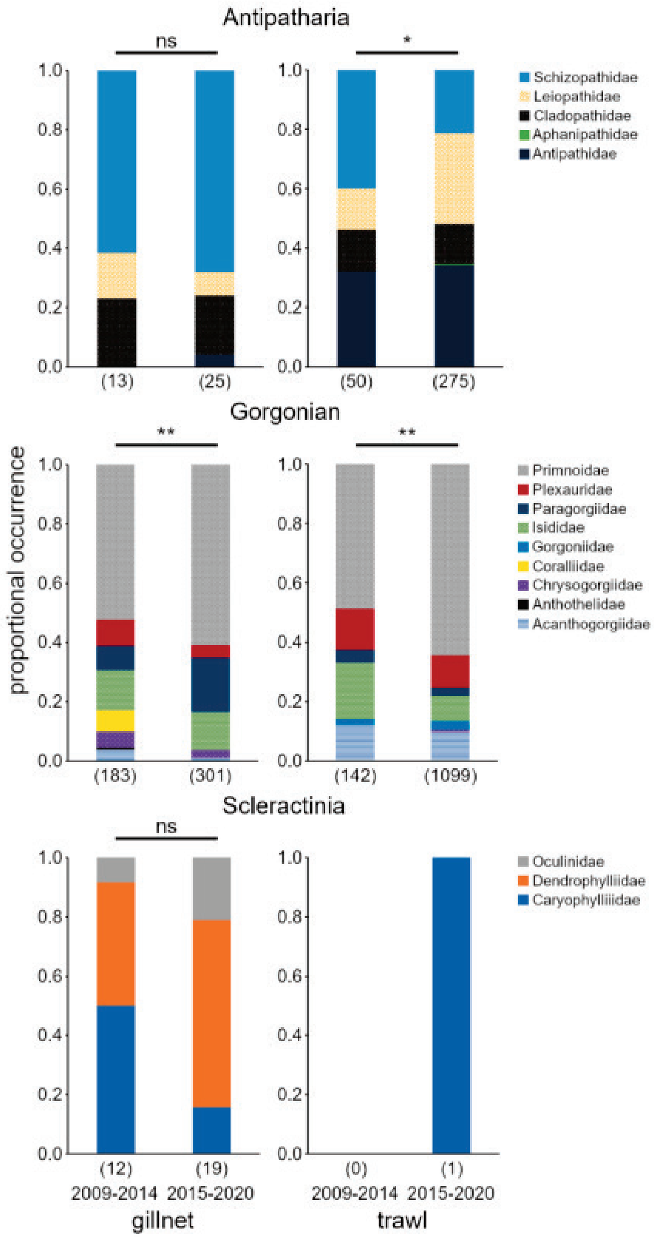

Fig. 2.1.4.2 Differences in the proportional occurrence of antipatharian, gorgonian, and scleractinian families collected in 2009–2014 (left) and 2015–2020 (right) by gillnets and trawls. Statistical differences in proportional compositions between two fishing periods are shown above bars (** – $p < 0.01$; * – $p < 0.05$; ns – no significant difference with Fisher's exact test for count data).[3]

[3] Reprinted from *Regional Studies in Marine Science*, **68**, Osawa, Y., Okuda, T. and Miyamoto, M., Bathymetric segregation among demersal benthos and its contributions to the differences in the bycatches on bottom fisheries in the Emperor Seamounts area, Northwestern Pacific Ocean. Copyright (2017), with permission from Elsevier.

2.2 Gather data on key environmental variables (e.g., temperature, depth, steepness, substratum, current velocity, isolation, ocean acidification) hypothesized to influence the distribution and diversity of species associated with seamounts

The World Ocean Atlas data that were compiled for use by PICES WG 32 on the *Biodiversity of Biogenic Habitats* a few years ago was updated by Samuel Georgian and was made available to WG 47 members. These members recognize that potential environmental and ecological predictors of the distribution and biodiversity of seamount taxa in the Pacific Ocean may be used to develop one or more species distribution models for seamount taxa. Those data may also be used to predict climate-induced changes in the distribution of seamount taxa during the coming years. Chris Rooper also collected oceanographic data along the Cobb-Eickelberg seamount chain in 2022 and 2024. See the following report.

2.2.1 Joint Canada–USA International Seamount Surveys – 2022 and 2024

Chris Rooper[1], Christina Conrath[2], Pam Goddard[2]

[1] Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo British Columbia, Canada
[2] AFSC-RACE, National Marine Fisheries Service, Seattle, Washington, USA

Acknowledgement

The authors wish to thank Paul Hillman (NOAA Fisheries) for his work on editing the images that appear in this section of the report, including on the cover. Paul also prepared blogs on the NOAA/DFO cruise in 2022 (see Joint Canada-U.S. Deep-Sea Coral Seamount Survey Post #1 | NOAA Fisheries; Joint Canada-US Deep-Sea Coral Seamount Survey Post #2 | NOAA Fisheries; Joint Canada-US Deep-Sea Coral Seamount Survey Post #3 | NOAA Fisheries; Joint Canada-US Deep-Sea Coral Seamount Survey Post #4 | NOAA Fisheries; Joint Canada-US Deep-Sea Coral Seamount Survey Post #5 | NOAA Fisheries).

Background and objectives

The Joint Canada–USA International Seamount Survey (JCUISS) was designed to study deep-sea coral and sponge communities on seamounts in international waters. Deep-sea coral and sponge distributions outside of the US and Canada exclusive economic zones (EEZs) are relatively under explored, with the exception of a handful of studies conducted at the Cobb Seamount complex off southern British Columbia. Historically (1970s–1990s) many of these offshore seamounts were fished by both domestic (Canada and USA) and foreign (Russia, Korea and Japan) fishing fleets. Currently, there is limited fishing by the Canadian Sablefish longline trap fleet at seamounts in international waters. The intersection between deep-sea coral and sponge distribution and fisheries is an ongoing concern of the North Pacific Fisheries Commission (NPFC), the Regional Fisheries Management Organization for international waters of the North Pacific Ocean (www.npfc.int). The NPFC manages fisheries and vulnerable marine ecosystems (VMEs) to monitor potential significant and adverse impacts on deep sea corals and sponges.

In 2022 and 2024, two two-week surveys using an underwater stereo camera were undertaken at 5 seamounts in the Cobb-Eickelberg seamount chain using a depth stratified-random survey design. Data were collected at 78 transects in 2022 and 56 transects in 2024. Preliminary analyses of these data have shown that deep-sea corals are widespread at relatively low densities across all the seamounts examined and especially at depths below 400 m where the majority of the sampling occurred. Preliminary species distribution models have been developed for coral and sponge taxonomic groups based on these data, but data from these international seamounts are limited.

The objectives of this study were to map and model the distribution of deep-sea coral and sponge in the seamount chain, determine important species associations with these communities and collect data on the oceanography of the seamounts and observations of marine mammals and birds over the seamount chain.

Approach

The main tool used in this work was the underwater stereo camera system developed during the Alaska Coral and Sponge Initiative in 2012–2015. The stereo camera survey followed a standard protocol outlined in Rooper *et al*. (2016), with a target of 15 minutes of on-bottom time for each transect. Images were processed to determine substrate type, density and size of structure-forming invertebrates and density and size of fish species using Sebastes software (Williams *et al*., 2015). The visual survey was designed in a robust statistically sound method so that inferences about the deep-sea coral and sponge communities on seamounts can be made. An estimate of the total abundance of deep-sea coral and sponge (and associated fishes) will be generated using the sampling for each of the seamounts and the seamount chain. Further species distribution modeling will also be conducted to predict hotspots of abundance and diversity in the seamounts that may warrant protection as VMEs (FAO, 2009).

In addition to the visual survey, we collected temperature data and water samples with adjoining images that can contribute to ongoing eDNA studies and taxonomic studies at each transect. Acoustic data from scientific echosounders were also collected during nighttime benthic mapping. A series of benthic grabs were collected to document the sediment at selected locations on Cobb Seamount.

Substrate data were collected at each survey transect, as well as temperature and depth profiles (including steepness). Profiles of current velocity and direction were collected continuously throughout the cruise as well as surface temperature and salinity. Additionally, temperature, oxygen, chlorophyll and zooplankton were collected at oceanographic stations on each seamount and between seamounts along the vessel path.

Significant results to date

In total 78 stations were occupied in 2022. In 2024, 56 of the 86 stations were occupied on Brown Bear and Cobb seamounts (Fig. 2.2.1.1).

Preliminary image analysis showed that gorgonian corals were present at 71% of the transects occupied. Most of the corals occurred at depths below 400 m and corals were present at most transects on all seamounts below this depth (Fig. 2.2.1.2). Coral taxa appeared to consist of Primnoidae, Isididae and other octocorallians and antipatharians at deeper depths. Hexactinellid sponges had a similar distribution to the corals, although they occurred in only 46% of the transects. Hydrocorals were common at shallow depths on Cobb and Corn seamounts, while sea whips (alcyonaceans) and sea pens (pennatulaceans) in part were not common, but found at most depths. Reef-building scleractinians were observed at 8 transects across both years. Figure 2.2.1.3 shows the density for VME indicator taxa and Figure 2.2.1.4 shows the height of VME indicator taxa measured with the stereo camera system.

Discarded longline gear was observed at ~10% of transects and a single furrow believed to be indicative of bottom trawl gear was observed. Most of the fishing gear occurred on Cobb Seamount.

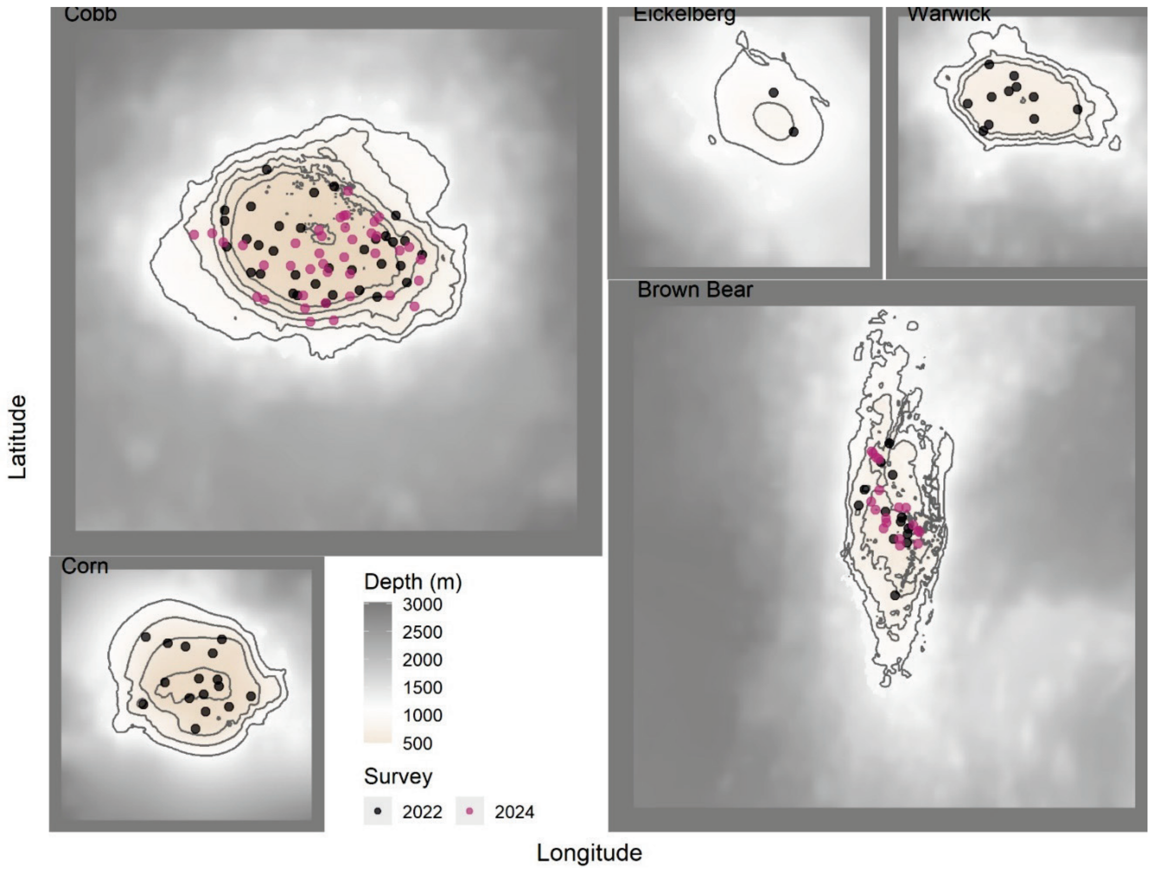

Fig. 2.2.1.1 Map showing distribution of randomly sampled transects in 2022 and 2024 at the five seamounts surveyed on the cruise in bold text (Cobb, Corn, Warwick, Eickelberg and Brown Bear seamounts).

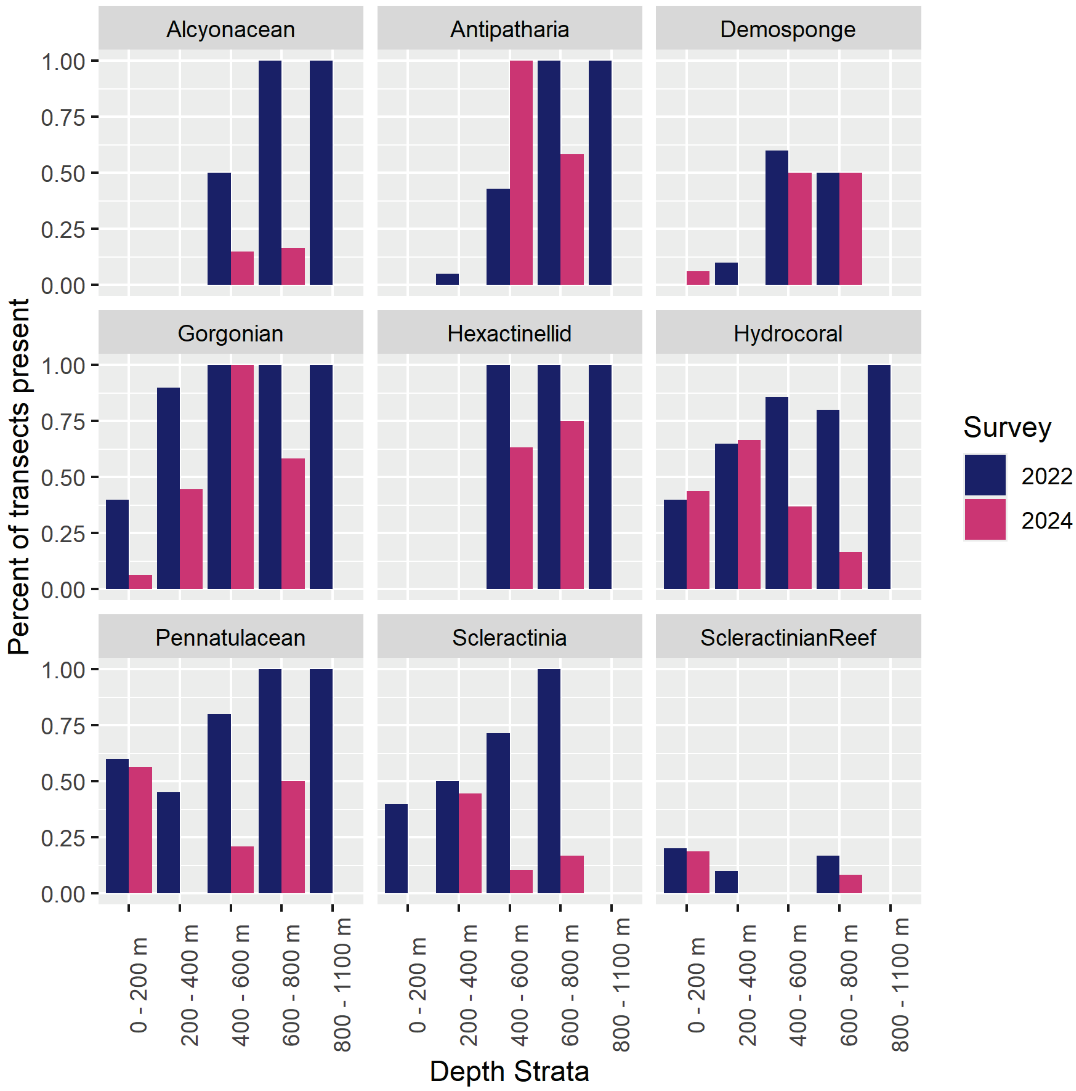

Fig. 2.2.1.2 Percentages present for the most common structure-forming invertebrates at the five seamounts observed during the Joint Canada–USA International Seamount Survey in 2022 and 2024.

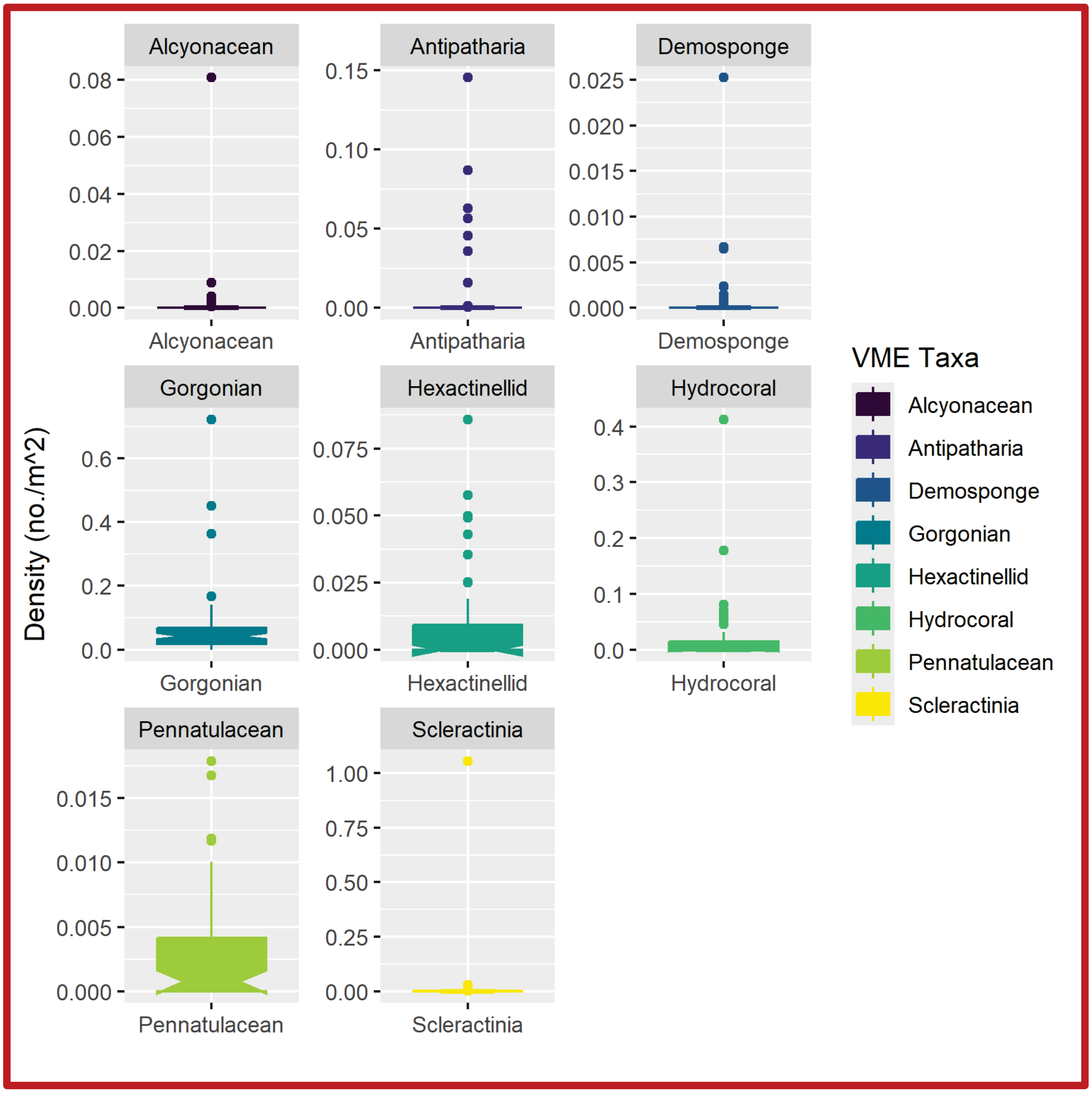

Fig. 2.2.1.3 Densities of the most common structure-forming invertebrates occurring at the five seamounts observed during the Joint Canada–USA International Seamount Survey in 2022 and 2024.

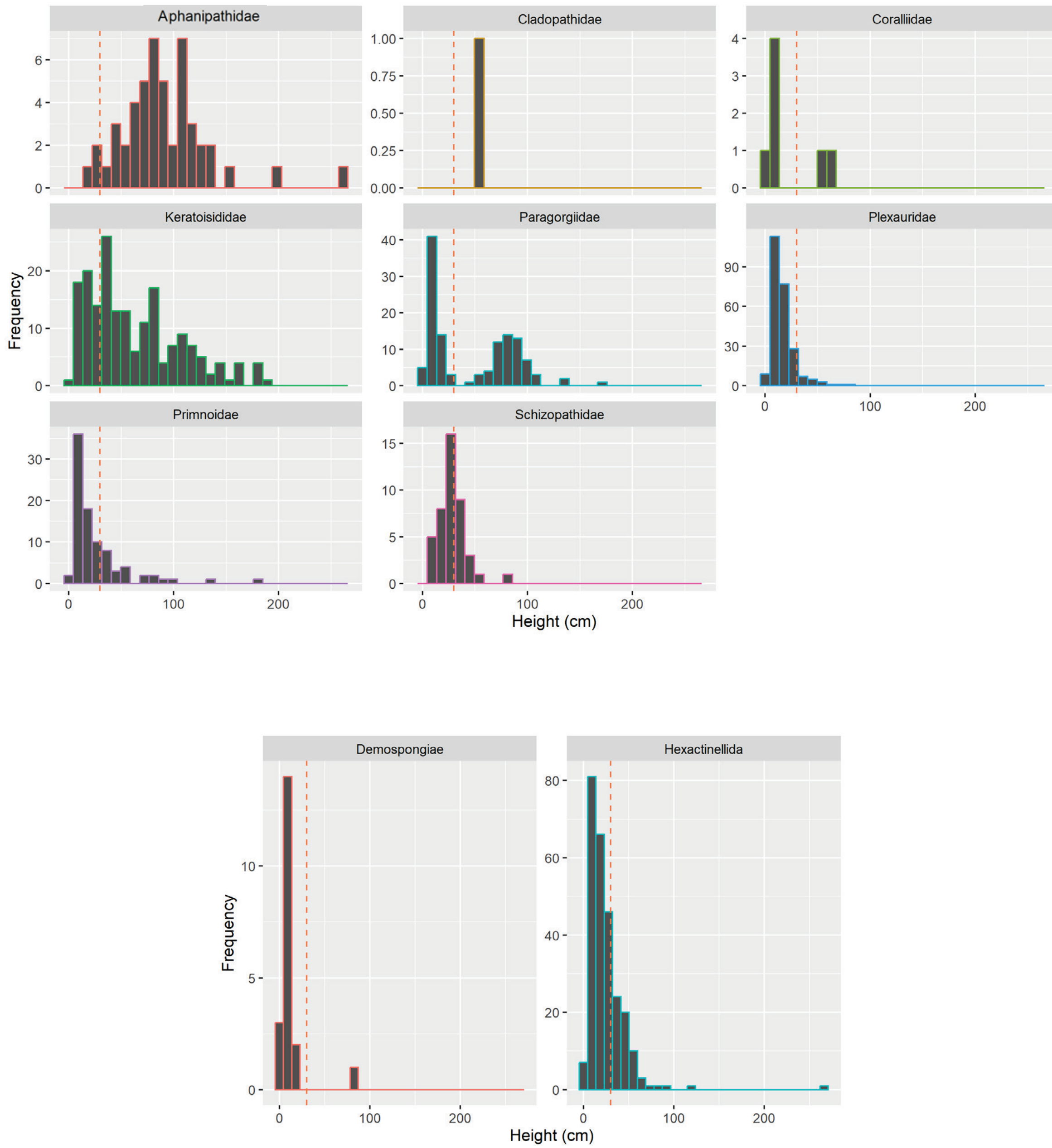

Fig. 2.2.1.4 Height distributions of common families of corals (top three rows) and classes of sponges (bottom row) observed at seamounts in international waters. Vertical dashed lines correspond to 30 cm in height.

2.3 Convene a 2-day workshop on "Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions

WG 47's 2-day workshop on "*Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions*" was convened from September 24–25, 2022, during PICES-2022 in Busan, Korea. The workshop was co-chaired by Janelle Curtis, Mai Miyamoto, Akash Sastri, Chris Rooper, and Samuel Georgian. Workshop participants identified and discussed environmental and ecological predictors of species associated with seamounts. Some of the highlights of the workshop included discussions about the importance of considering bentho-pelagic coupling when predicting distributions of benthic taxa, including deep-sea corals and sponges. There was also considerable discussion of methods to identify VMEs, and how best to model climate-induced changes in the distribution of seamount taxa. See the Vol. 31, No. 1 (Winter 2023) PICES Press article about this workshop in Appendix 4; also PICES-Press-2023-Vol31No1.pdf.

2.4 Identify environmental and ecological predictors of patterns in the distribution and biodiversity of pelagic, demersal,[4] and benthic taxa associated with seamounts in the North Pacific Ocean

This TOR has been partially addressed by a team led by Janelle Curtis for benthic seamount taxa along the Cobb-Eickelberg seamount chain in the Northeast Pacific Ocean. This team identified environmental predictors of patterns of the distribution of stony corals (Scleractinia), black corals (Antipatharia), gorgonian corals and non-gorgonian corals. The top predictors of the distribution of these corals included oxygen, photosynthetically-active radiation (PAR), roughness, and chlorophyll-a.

2.4.1 Predictive habitat models and visual surveys to identify vulnerable marine ecosystems on seamounts in the North Pacific Fisheries Commission Convention Area

What follows are excerpts of text relevant to this TOR from:

Warawa, D.R., Chu, J.W.F., Rooper, C.N., Georgian, S., Nephin,, J., Dudas, S., Knudby, A. and Curtis, J.M.R.. 2021. Predictive Habitat Models and Visual Surveys to Identify Vulnerable Marine Ecosystems on Seamounts in the North Pacific Fisheries Commission Convention Area. North Pacific Fisheries Commission NPFC-2021-BFME02-WP05, 44 pp.

[4] See footnote 1.

Introduction

Predictive habitat models (PHMs), also referred to as species distribution models, can be used to predict areas of high habitat suitability for marine species of interest. In general, PHMs are statistical methods that relate known presences of a species to a set of environmental variables. Models can then be used to extrapolate where species are likely to occur within the extent of the environmental variables, including in areas where biological survey data are lacking (Franklin, 2010). Model outputs can also be used to generate hypotheses about the factors that influence species distributions, such as key environmental drivers, which can help identify priority areas for future data collection. Prediction maps generated from a standard PHM are usually presented as a logistic index with values ranging from 0 to 1. Depending on the model and data used, the logistic index is commonly interpreted as a probability of presence or as an index of habitat suitability, with predictions corresponding to low (0) and high (1) probability of presence or habitat suitability. We interpret the output of our four models as the probability that there is suitable habitat for the corresponding vulnerable marine ecosystem (VME) indicator taxon and we assume that the taxa can exist where there is suitable habitat.

PHM development requires a dataset of georeferenced species presences as well as gridded environmental data layers representing variables that potentially influence the distribution of the modeled species. In addition, data on species absences – areas where a species has been observed to not exist – can also be valuable. The environmental data should cover the entire extent of the area of interest, and the species presence/absence data should ideally be broadly distributed across the spatial and environmental gradients in the same area.

In this study, we use the Maximum Entropy model (MaxEnt) to develop PHMs for each of our four VME indicator taxa. MaxEnt is a machine learning, statistical method that originated in the fields of statistical mechanics and information theory (Phillips *et al*., 2006). MaxEnt has also been the most commonly applied PHM for examining distributions of cold-water corals and sponges when only presence data are available, which is most often the case for deep-sea taxa (Winship *et al*., 2020). By default, MaxEnt uses 'pseudo-absences' sampled from the surrounding background area to generalize the habitat conditions of an area; presence is unknown at the location of these background sampled locations. Although MaxEnt is known as a 'presence-only' model by default, absence data, instead of 'pseudo-absences', can be used with the MaxEnt algorithm. For our PHMs both presence and absence observations were sampled mostly within the adjacent exclusive economic zones of Canada and the United States of America. The availability of presence and absence observations of VME indicator taxa allows for the exploration of alternative models (*e.g*., Generalized Additive Models (GAM), Boosted Regression Trees, Random Forest models) in future iterations of PHM development.

Methods

We compiled a large dataset of georeferenced species records of the North Pacific Fisheries Commission's (NPFC's) VME indicator taxa in the Northeast Pacific Ocean. Records were queried as of September 2021 and come from scientific surveys data and museum records deposited in (1) the NOAA deep-sea coral data portal (https://deepseacoraldata.noaa.gov/), (2) standardized bottom trawl catch data from research surveys in the Gulf of Alaska, Aleutian Islands and eastern Bering Sea, (3) standardized bottom trawl catch data from DFO research surveys in British Columbia, Canada, and (4) standardized bottom trawl catch data from research surveys on the U.S. West Coast of Washington Oregon and California (Stauffer, 2004; Nottingham *et al*., 2018).

Records were identified to various levels of taxonomy and required up-to-date taxonomy verification with the World Register of Marine Species (WoRMS, Horton *et al*., 2021). After updated taxonomy was appended to the records, records with at least an order (black corals, stony corals) or family (gorgonian corals, non-gorgonian soft corals) level of identification were pooled for use as the presence data for each of their respective PHMs. Final sets of presence records used for PHM model development were also spatially restricted to those occurring within the four marine ecoregions of the world (MEOW) that characterize the oceanographic conditions from the Gulf of Alaska to the West Coast of North America (Spalding *et al*., 2007). No commercial bycatch records were included in the data used for PHMs.

Multiple depth-stratified research trawl surveys recorded the occurrence of all species captured over the latitudinal extent of our study area. We generated absence records from the fishing events that did not yield a species corresponding to our VME indicator taxa (*e.g*., Beazley *et al*., 2018; Chu *et al*., 2019). Because the trawl surveys occurred only on the continental shelf and slope, there is a sampling bias in location of the absence records relative to the presence records which include observations of VME indicator taxa at several offshore seamounts. With the exception of visual data from Cobb Seamount (Curtis *et al*., 2015), we prioritized keeping as many of these rare seamount observations in our models as possible and addressed this sampling bias by restricting the inclusion of offshore presence records to those occurring within the sampling depth range of the absence records which sampled a maximum depth of 1,600 m.

We used the gridded environmental data from Chu *et al*. (2019) developed by the North Pacific Marine Science Organization (PICES) Working Group 32 on *Biodiversity of Biogenic Habitats*, which were created for the development of PHMs for the North Pacific Ocean (Chu *et al*., 2019, 2020). This set of 30 environmental layers are gridded at a 1 km^2 resolution and include bathymetry-derived variables, physiochemical variables, and oceanographic properties that can be strong predictors of benthic species distributions. Davies and Guinotte (2011), Chu *et al*. (2019), and Georgian *et al*. (2021) provide general background on the data layers, original data sources, processing steps involved in their creation, and examples of their general use in PHM development for VME indicator taxa and identifying VMEs in the Pacific Ocean.

We followed the general MaxEnt model workflow described by Chu *et al*. (2019) and developed a PHM for each of the four VME indicator taxa. Species data were spatially thinned models, and to prevent general overfitting (*e.g*., Merow *et al*., 2013; ICES, 2021). Collinearity among predictors was addressed by examining variance inflation factors (VIF) and iteratively reducing the set of environmental data layers used for each model until the final subset of variables all had VIF < 10 (Table 2.4.1.1). Model performance was assessed using the area under the receiver operating characteristic curve (ROC) (Phillips *et al.*, 2006). Area under the curve (AUC) values of 1.0 indicate a model that can perfectly predict presence and absences and 0.5 indicates a model that performs no better than random. We tested a range of MaxEnt regularization coefficient values (to balance model overfitting, see Merow *et al*., 2013) and set the value to 1.0 which yielded models with the highest AUC. We used five-fold cross validation to assess how well each model performed. Occurrence (presence and absence) data were randomly sampled and split into five equal data partitions and models were trained on four partitions and tested with the remaining fold; this procedure was repeated five times with a unique partition used for testing in each iteration. Final models used the entire set of species presences and absences from each taxon to generate maps of presence probability.

Table 2.4.1.1 Summary of final MaxEnt model parameters. Training AUC (area under the curve) and the top three most important predictor variables based on their relative importance in each model are presented.

Vulnerable Marine Ecosystem group	Training AUC	1st ranked	2nd ranked	3rd ranked
Black corals	0.90	Oxygen (48%)	PAR (19%)	Regfl (7%)
Stony corals	0.90	Oxygen (48%)	Chl-A (13%)	SST (13%)
Gorgonian corals	0.85	PAR (37%)	Oxygen (16%)	BPI20000 (11%)
Non-gorgonian soft corals	0.92	Roughness (36%)	Oxygen (16%)	POC (8%)

Values are the mean among the 100 bootstrap resampling model runs that used the entire occurrence dataset. PAR – photosynthetically active radiation, POC – particulate organic carbon, BPI20000 – bathymetric position index at a 20,000 m scale, Regfl – Regional current velocity, SST – Sea Surface Temperature

Results

All MaxEnt models developed using presence–absence data performed well with AUC scores ranging from 0.85–0.92 among modelled taxa. The most important predictors varied slightly among models but all shared dissolved oxygen among their top two ranked predictors. Additional importance predictors included water column properties associated with surface water conditions (photosynthetically active radiation, particulate organic carbon, sea surface temperature, chlorophyll-A), seafloor characteristics (roughness), and broad scale currents (regional current velocity). The slight differences among the most important predictors also resulted in differences in the general footprint of areas predicted to have a high habitat suitability varied among models. However, shared areas of high habitat suitability among models were generally concentrated along the continental shelf in domestic waters and mostly at seamount areas within the international waters of the NPFC Convention Area. These results mirror those of Chu *et al*. (2019) who used a similar PHM approach but focused within a smaller study area inside Canadian domestic waters. The complementary findings reinforce the importance of the expansive oxygen minimum zone in the Northeast Pacific Ocean and its influence on the distribution of VME indicator taxa in this region.

2.5 Apply one or more modeling approaches (e.g., MaxEnt, Boosted Regression Trees, or high-resolution bathymetry-based models to predict the distribution of pelagic, demersal,[5] and benthic biodiversity associated with seamounts in the North Pacific Ocean

This TOR has been partially addressed by a team led by Janelle Curtis for benthic seamount taxa in the Northeast Pacific Ocean. Specifically, they used MaxEnt in 2021 and ensemble models in 2022 to predict the distribution of VME indicator taxa along the Cobb-Eickelberg seamount chain in the Northeast Pacific Ocean. The ensemble model coupled a Random Forest (RF), generalized additive model (GAM), and a Boosted Regression Tree (BRT) model. In 2023, a GAM model predicted the

[5] See footnote 1.

distribution of potential vulnerable marine ecosystems in the same area. Chris Rooper noted that guidelines and code for developing predictive habitat models, including RF, GAM, Generalized Linear Models (GLM) and BRT are available through ICES.

2.5.1 Vulnerable marine ecosystems (VMEs) in the Northeast part of the North Pacific Fisheries Commission Convention Area

What follows are excerpts of text relevant to this TOR from:

Warawa, D.R., Chu, J.W.F., Gasbarro, R., Rooper, C.N., Georgian, S., Nephin, J., Dudas, S., Knudby, A. and Curtis, J.M.R. 2022. Vulnerable Marine Ecosystems (VMEs) in the Northeast Part of the North Pacific Fisheries Commission Convention Area. North Pacific Fisheries Commission NPFC-2022-SSC BRME03-WP03. 23 pp.

Similar analyses are also published in the two publications:

Warawa, D.R., Nephin, J., Rooper, C.N., Chu, J.W.F., Dudas, S., Knudby, A., Georgian, S. and Curtis, J.M.R. 2023. Identifying potential VMEs on the Cobb-Eickelberg seamount chain based on predictive modelling. NPFC-2023-SSC BFME04-WP12

DFO. 2024. Identification of Vulnerable Marine Ecosystems on Seamounts in the North Pacific Fisheries Commission Convention Area using Visual Surveys and Distribution Models. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2024/038.

Introduction

This was an update to Canada's proposed quantitative approach to identifying vulnerable marine ecosystems (VMEs) described in Warawa *et al*. (2021). In this approach we used predictive habitat models to identify areas likely to be VMEs and visual data to identify VMEs, as outlined by the North Pacific Fisheries Commission (NPFC) framework for identifying data that can be used to identify VMEs in the Northwest and Northeast parts of the NPFC's Convention Area (NPFC, 2021). Our quantitative approach was based on work by Rowden *et al*. (2020) who identified thresholds related to the amount of VME indicator taxa in an area and how it contributed to an increase in associated species richness as a result of providing structural complexity. Canada's proposed approach to identifying VMEs shows an example of an extension of the Rowden *et al*. (2020) approach to presence–absence data and models. Our preliminary results from the Cobb-Eickelberg seamount chain study area detected a VME density threshold of 0.57 VME indicators taxa/m^2 and a VME occurrence threshold of 0.78. Applying these thresholds to visual data and predictive habitat models resulted in a total area of 750 m^2 identified as VMEs on Cobb Seamount and a total area of 1,542 km^2 identified as likely to be VMEs along the Cobb-Eickelberg seamount chain, respectively.

Methods

The main steps in our approach were to: (1) develop quantitative VME thresholds, (2) gather data on VME indicator taxa distribution, (3) apply the threshold to the data, and (4) identify VMEs or areas likely to be VMEs. The data and criteria differed for identifying VMEs and areas likely to be VMEs

(Figure 2.5.1.1). Identifying VMEs was based on applying a density VME threshold to visual data, and any areas with visual data showing VME indicator taxa equal to or greater than the threshold were considered VMEs. Identifying areas that are likely to be VMEs was based on applying an occurrence VME threshold to predictive habitat models. Areas where at least one VME indicator taxon has habitat suitability predictions equal to or above the threshold was considered likely to be a VME.

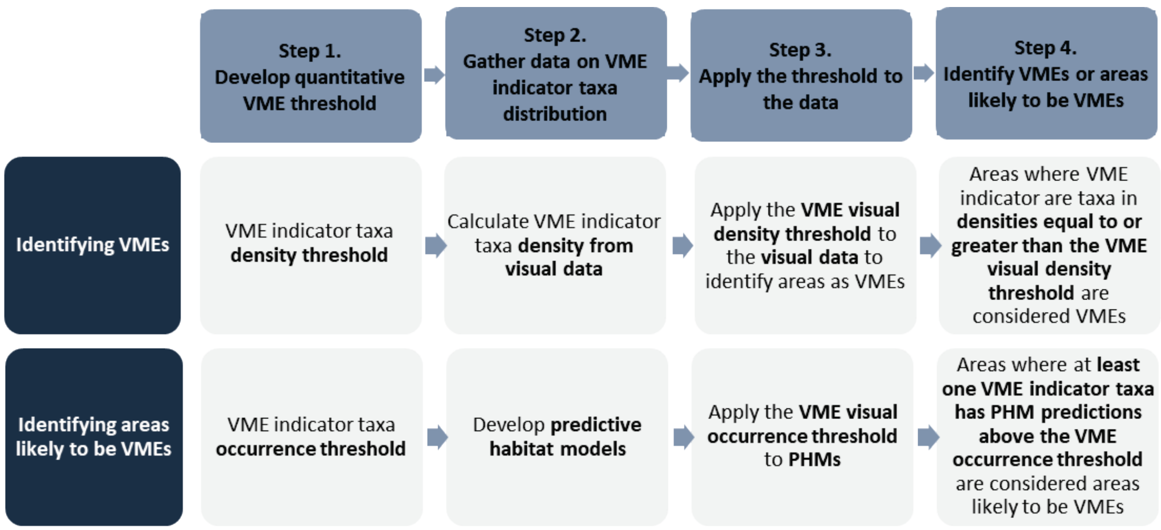

Fig. 2.5.1.1 Steps used to identify vulnerable marine ecosystems (VMEs) and areas likely to be VMEs. PHM – predictive habitat model.

In this update, we used a performance-weighted ensemble modeling approach instead of the MaxEnt approach used by Warawa *et al*. (2021). Ensemble modelling has been shown to improve model performance and interpretability (Araújo and New, 2007). Three modeling techniques were used that have successfully predicted the distribution of cold-water corals in other studies (*e.g*., Rooper *et al*., 2017; Morato *et al*., 2020; Georgian *et al*., 2021): Boosted Regression Tree (BRT), Generalized Additive Models (GAM), and Random Forest (RF). Each model outputs a habitat suitability score between 0 and 1, with 1 indicating more suitable predicted habitat. The outputs of individual model approaches (BRT, GAM, and RF) were combined using the area under the curve (AUC) weighted-average into a single ensemble model for each taxon. As each modelling approach relies on differing underlying structures and distinct statistical assumptions, they are therefore likely to produce dissimilar outputs and predictions (see Robert *et al*., 2016). Ensemble modelling can produce more robust predictions that are less reliant on model selection and parameterization (Araújo and New, 2007). BRT, GAM, and RF models were built and tested using a combination of 'biomod2' (Thuiller *et al*., 2016), 'gbm' (Ridgeway, 2004), 'dismo' (Hijmans *et al*., 2017), 'mgcv' (Wood, 2006), and 'randomForest' (Liaw and Wierner, 2002) in R (v3.6.1; R Core Team, 2019). BRT models were built using a minimum of 3,000 trees, an assumed Bernoulli distribution, and an interaction depth of 7 to prevent limiting interactions between terms. After testing a variety of model parameters during preliminary construction, GAMs were created using a binomial distribution and four degrees of freedom. RF models were constructed as classification models using 1001 trees and a node size of 5.

Results

BRT, GAM, and RF models developed using presence–absence data performed well with test AUC scores ranging from 0.795–0.898, kappa of 0.138–0.501, and TSS (true skill statistic) of 0.489–0.656 among all taxa. The most important predictors varied among taxa and modelling approaches, with dissolved oxygen, chlorophyll *a*, roughness, aspect, slope, TPI-20000, photosynthetically available radiation, and the saturation state of calcite generally contributing significantly to models. Model predictions varied both among taxa and modelling approach. However, shared areas of high habitat suitability in the final ensemble models were generally concentrated along the continental shelf in domestic waters and mostly at seamount areas within the international waters of the NPFC (Figs. 2.5.1.2–2.5.1.5). These results mirror those of Chu *et al*. (2019) who used a similar predictive habitat model (PHM) approach on a subset of the same presence and absence data. The complementary findings reinforce the importance of the expansive oxygen minimum zone in the Northeast Pacific Ocean and its influence on the distribution of VME indicator taxa in this region.

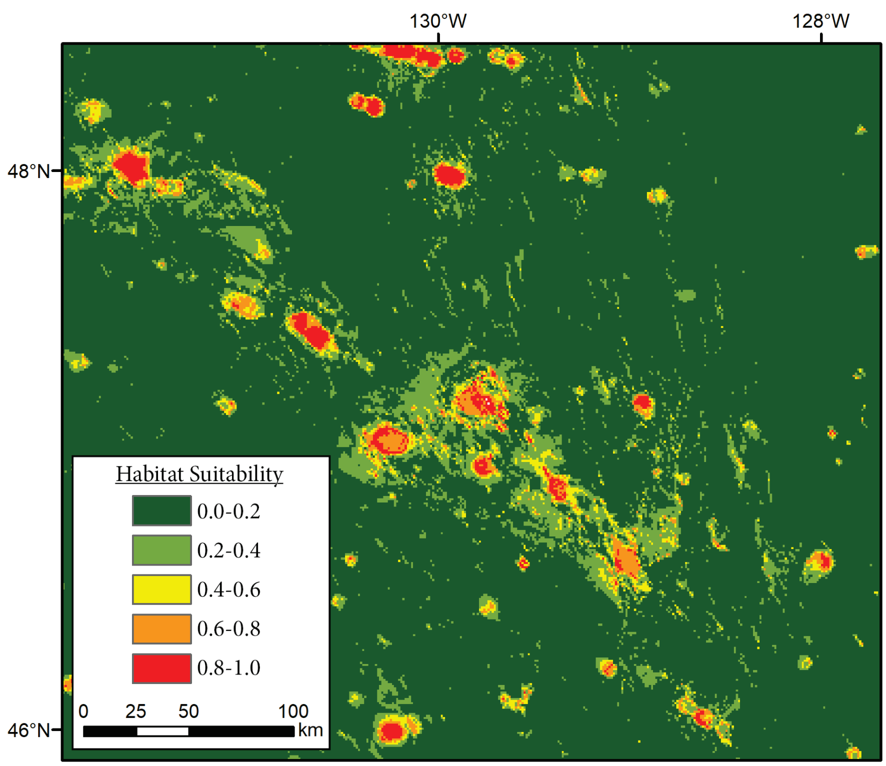

Fig. 2.5.1.2 Receiver operating characteristic (ROC) curve-weighted ensemble model for stony corals in the vicinity of Cobb Seamount.

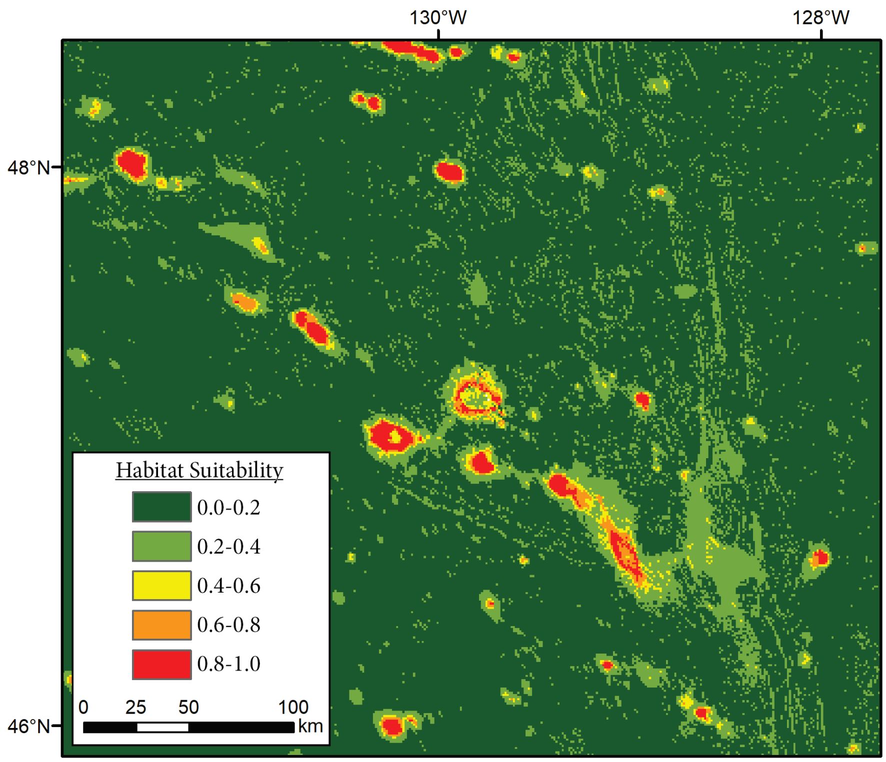

Fig. 2.5.1.3 ROC-weighted ensemble model for black corals in the vicinity of Cobb Seamount.

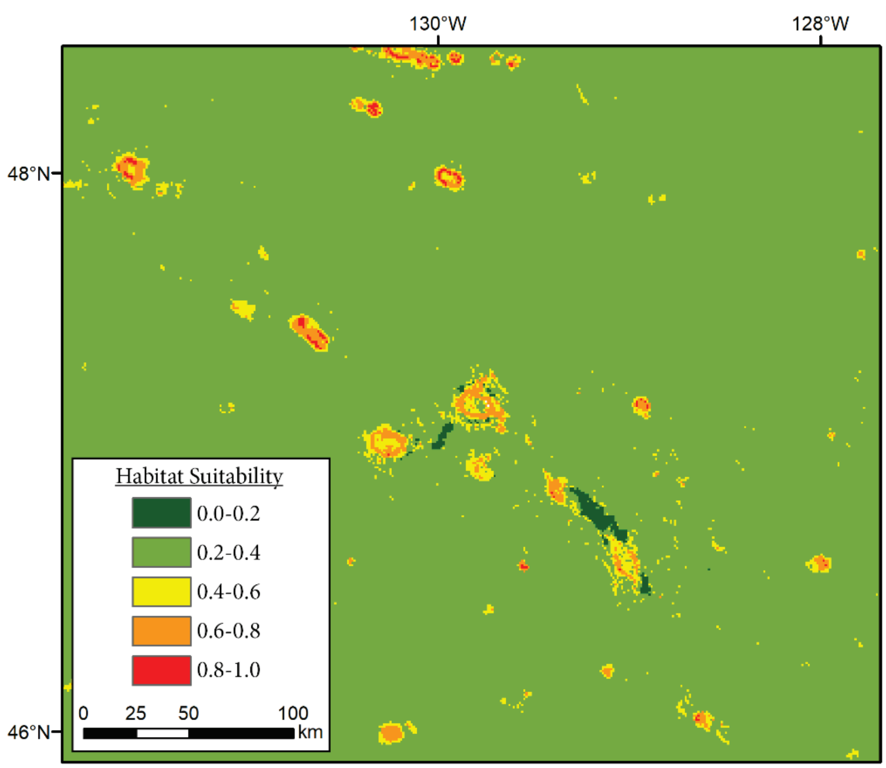

Fig. 2.5.1.4 ROC-weighted ensemble model for soft corals in the vicinity of Cobb Seamount.

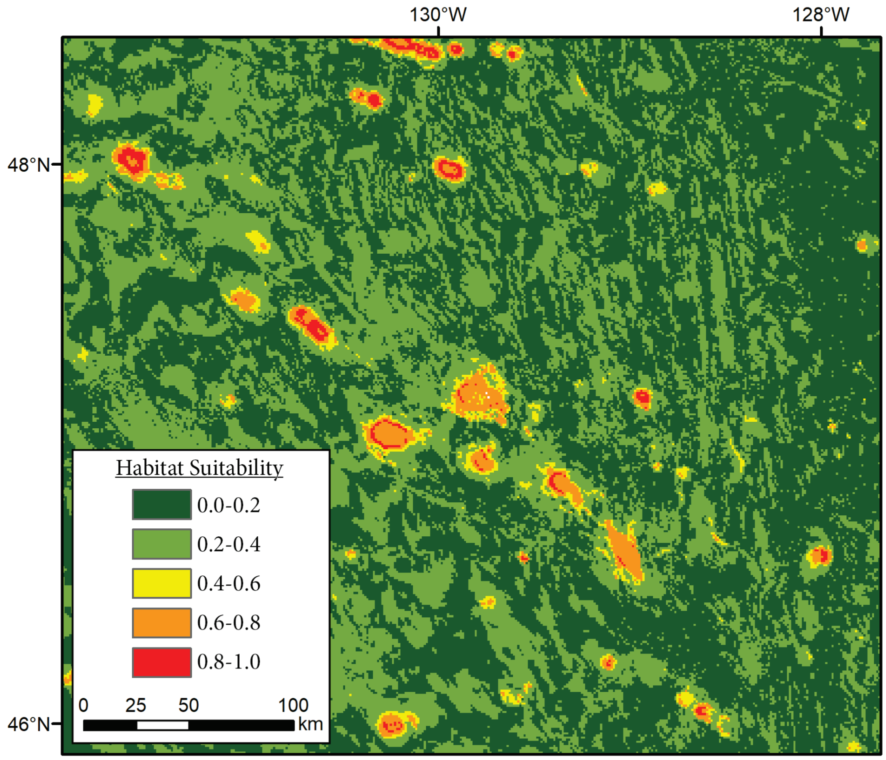

Fig. 2.5.1.5 ROC-weighted ensemble model for gorgonians in the vicinity of Cobb Seamount.

Identifying areas that are likely to be VMEs using PHMs will be strongly influenced by the taxa being modelled. Although our PHM models performed well, the NPFC's VME indicator taxa groups (black corals, stony corals, gorgonians and non-gorgonian soft corals) are taxonomically broad and capture a wider range of habitat conditions than what species-specific PHMs would resolve. Ideally, we would develop PHMs for taxa at lower taxonomic levels (*e.g.*, species or family) which could reduce the amount of species-specific habitat requirements being pooled into a single model. This could improve how well our PHMs predict the occurrence of VME indicator taxa on seamounts.

2.6 Use available data to predict climate induced changes in the distributions of seamount fauna

Although there was considerable interest among WG 47 members to predict climate-induced changes in the distribution of seamount taxa, all members agreed during their meetings at PICES-2023 and PICES-2024 that there were insufficient resources, capacity, and expertise to address this TOR before the end of WG 47's term in 2024.

2.7 Convene a topic session on the pelagic, demersal, and benthic species associated with seamounts at the PICES Annual Meeting

This TOR was completed during PICES-2023 in Seattle, USA. See Topic Session 14 in Appendix 3 under Summary of Scientific Sessions and Workshops. Presentations were given by or co-authored by WG 47 members, including Janelle Curtis, Mai Miyamoto, Chris Rooper, Kota Sawada, Les Watling, and Seanock Woo. Janelle Curtis' co-authored presentation was about the use of visual data and predictive models to identify vulnerable marine ecosystems (VMEs) in the Northeast Pacific Ocean. Mai Miyamoto presented her association analysis of seamount benthos for validation of VME indicator taxa in the North Pacific Fisheries Commission's Convention Area. Chris Rooper reported on his research on the distribution, abundance and size structure of deep-sea corals and sponge seamount communities in the Northeast Pacific Ocean. Kota Sawada's talk was about the biology and fisheries of North Pacific armorhead and splendid alfonsino in the Southern Emperor seamount chain and Northern Hawaiian Ridge. Les Watling discussed his work on the biogeography of seamounts in the North Pacific Ocean and co-authored a presentation on bathyal megafauna assemblages, and Seanock Woo spoke about coral biodiversity and genetic resources on Godin Guyot in the western North Pacific Ocean.

2.7.1 Biology and fisheries of North Pacific armorhead and splendid alfonsino in SE-NHR area – A review

What follows is a summary of the oral presentation during Topic Session 14 at PICES-2023 given by Kota Sawada and co-authors:

Kota Sawada[1], Kenji Taki[1], Takehiro Okuda[1] and Mai Miyamoto[2]

[1] Japan National Fisheries Research and Education Agency, Yokohama, Japan
[2] Japan NUS CO., LTD., Tokyo, Japan

North Pacific armorhead and splendid alfonsino are the most important targets for bottom fisheries in the Southern Emperor seamount chain and Northern Hawaiian Ridge (SE-NHR) area. We review original scientific literature and summarize current knowledge of biology and fisheries for the two species.

The bottom fisheries of North Pacific armorhead in the SE-NHR area were first explored by the trawl fleet of the Soviet Union in 1967. The larvae are found in the surface waters over and adjacent to the SE-NHR area whereas juveniles and subadults live in the epipelagic layer of the subarctic water mass of the central and eastern North Pacific. Subadults settle to seamounts, where they mature and spawn in winter. After settlement, they cease growth and gradually lose body weight. North Pacific armorhead on seamounts are largely dependent on plankton and deep scattering layer organisms as prey resources rather than preying on locally produced benthic food.

The fisheries of splendid alfonsino began in the late 1970s as an alternative fishery when North Pacific armorhead showed poor catch. The genetic differentiation for splendid alfonsino has not been detected among the North Pacific populations. The spawning season in the SE-NHR area is likely to be summer. Splendid alfonsino shows an ontogenetic shift from planktivorous to micronektivorous diets in the SE-NHR area.

Given their commercial importance and concerns about their stock status, preparatory work for stock assessments of these species in the SE-NHR area is ongoing to guide a sustainable harvest. We discuss challenges in conducting the stock assessments, including a unique life history and insufficient biological information.

2.8 Identify potential indicators for assessing and monitoring the biodiversity of pelagic, demersal,[6] and benthic taxa associated with seamounts

This TOR has been partially addressed by a few WG 47 members. Kota Sawada noted that indicators, including e-DNA, that have been applied to other areas might also be applicable to seamounts. A team led by Janelle Curtis estimated an indicator for benthic seamount taxa in the Northeast Pacific Ocean. Specifically, a density of 0.6 vulnerable marine ecosystem (VME) indicator taxa (stony corals, black corals, gorgonian and non-gorgonian soft corals, glass sponges, and demosponges) per m^2 are indicative of the presence of VMEs in the North Pacific Fisheries Commission (NPFC) Convention Area. This density is associated with higher species richness of non-VME indicator taxa. Amy Baco-Taylor noted that precious corals may be indicators of the effects of disturbance. Other participants noted that different suites of indicators may be appropriate for different seamounts (*e.g.*, shallow *vs* deep) and the size distribution of seamount taxa may indicate recruitment dynamics.

2.8.1 Environmental DNA as a potential indicator of seamount biodiversity

Below is a summary of the following two oral presentations: the first was given at PICES-2023 in Seattle, USA, and the second was given at PICES-2024 in Honolulu, USA.

1. Environmental DNA as a potential tool for the understanding of demersal ichthyofauna in seamounts: a case study from the Emperor Seamounts area

Motoomi Yamaguchi[1], Kota Sawada[1], Yumiko Osawa[1], Mai Miyamoto[2], and Bungo Nishizawa[1]

[1] Fisheries Resources Institute, FRA, Japan
[2] Japan NUS

2. Testing the validity of environmental DNA analyses on the benthic fauna of pelagic seamounts

Motoomi Yamaguchi[1], Satoi Arai[1], Kota Sawada[1], Yumiko Osawa[1], Mai Miyamoto[2], Christopher Gardner Ayer[1] and Bungo Nishizawa[1]

[1] Fisheries Resources Institute, FRA, Japan
[2] Japan NUS

[6] See footnote 1.

Background

Environmental DNA (eDNA) can non-invasively detect organisms inhabiting environments where direct sampling or observation is difficult, such as the deep-sea floor. For elucidating the effectiveness of eDNA in studying the distribution of deep-sea benthic animals on oceanic seamounts, we conducted eDNA samplings in 2022 and 2023 along the Emperor Seamount chain, which is a prominent fishing ground in the high seas of the central North Pacific Ocean. To test the effectiveness of eDNA-based faunal research for different environments and fauna on the deep-sea floor, the first 2022 samplings were conducted on three relatively shallow southern seamounts, and in 2023, the sampling area was expanded to more northern and deeper seamounts, resulting in seven sampled in total. We primarily focused on fishes, because of the existence of established protocols and rich reference data, and the commercial importance of some species. In addition, we expanded our focus to include cold-water corals (octocorals), which are important but sometimes vulnerable organisms in seamount ecosystems. The eDNA analyses results were compared with the data from direct visual surveys of the seafloors in corresponding sites, and with species records from our previous fishery surveys and publications. We made presentations in PICES-2023 and PICES-2024 to report our findings and demonstrate the potential usefulness of eDNA surveys in the study of biodiversity of fishes and octocorals in challenging environmental conditions, such as the deep-sea, while illustrating some caveats.

Research summary

In this study, eDNA surveys for fishes were conducted in 2022 and 2023, and for octocorals were conducted in only 2023. After sequence analysis for the eDNA of fishes, those which had agreement > 98.5% with sequences in MitoFish database were chosen as candidates (Iwasaki *et al*., 2013). When multiple species had identical agreement, species with records in the Emperor Seamount chain were chosen. For the octocorals, it basically followed the fish method, and for primers and other processes, it followed Everett and Park (2018).

The results of eDNA analysis for fishes in 2022 are shown in the top half of Table 2.8.1.1. In the results three commercially important fishes (North Pacific Armorhead, Splendid Alfonsino and Oxeye Oreo) were detected in all three seamounts where the surveys were conducted, and the three fish species were observed by camera survey. On the other hand, eDNA detected the DNA fragments of a much greater number of nekton species than what was observed in visual surveys, suggesting that eDNA has better detection sensitivity. The results in 2023 for fishes are shown in the lower half of Table 2.8.1.1. The number of survey stations in 2023 is lower than in 2022, and likewise the number of operational taxonomic units (OTUs) detected is about 100 less than in 2022.

The results of eDNA analysis for octocorals are shown in Table 2.8.1.2. The table shows a list of 16 taxa/species (2 orders, at least 6 families). *Thouarella laxa* (highlighted) was the only species not recorded from the Emperor Seamount chain area.

These results show that eDNA can be a useful tool to assess and monitor biodiversity associated with seamounts. However, in the future, additional analysis of hexacorals, more reference data on fish and corals in the Emperor Seamount chain area, and denser sampling are needed to achieve even higher accuracy.

Table 2.8.1.1 Summary of sampling and results of eDNA analysis for fishes in 2022 and 2023.

	Seamount	Depth (m)	Stations	Copies	OTUs	Orders	Families	Spp.
2022 7/22~8/20	Koko	653~678	5	206,968	100	14	32	60
	Colahan	596~795	9	392,157	94	14	30	50
	Yuryaku (All)	475~645	8	401,214	142	14	34	71
	Yuryaku (Y40)	475	1	19,643	19	5	8	14
2023 6/27~7/21	Suiko	949	1	64,373	22	8	11	16
	Yomei	1,338	1	23,117	27	8	12	18
	Nintoku	1,040	1	51,215	32	10	16	23
	Jingu	877	1	28,602	32	8	14	21
	Ojin	1,071	1	28,218	25	8	9	15
	Yuryaku (Y40)	469	1	60,865	35	8	18	26

OTU – operational taxonomic unit

Table 2.8.1.2 Summary of sampling and results of eDNA analysis for octocorals in 2023.

Order	Family	Taxa/Species	Sampling Location						Records		
			Suiko	Yomei	Nintoku	Jingu	Ojin	Yuryaku	Emperor Seamounts	Hawaii	Central Pacific Ocean
Octocorallia *incertae sedis*	??	Octocorallian species	N	N	Y	N	Y	N	Y	Y	Y
		Pseudothesea sp.	N	N	N	N	N	Y	Y	Y	Y
Malacalcyonacea	??	Malacalcyonacean species	Y	N	N	N	N	Y	Y	Y	Y
	Acanthogorgiidae	*Acanthogorgia* spp.	N	N	N	Y	Y	Y	Y	Y	Y
		Anthomuricea tenuispina	N	N	N	N	Y	N	N	Y	Y
Scleralcyonacea	Keratoisididae	Keratoisididae spp.	Y	Y	Y	N	Y	Y	Y	Y	Y
	Chrysogorgiidae	*Chrysogorgia* spp.	N	N	N	Y	Y	N	Y	Y	Y
		Chrysogorgia geniculata	N	N	N	Y	Y	N	N	Y	Y
	Keratoisididae	*Isidella* sp.	N	N	N	N	Y	N	Y	Y	Y
	Primnoidae	Primnoidaen species	N	N	N	N	N	Y	Y	Y	Y
		Callogorgia spp.	N	N	N	N	N	Y	Y	Y	Y
		Calyptrophora spp.	N	N	N	N	N	Y	Y	Y	Y
		Paracalyptrophora hawaiinensis	N	N	N	N	N	Y	N	Y	Y
		Primnoa sp.	Y	N	N	N	N	N	Y	Y	Y
		Thouarella laxa	N	N	N	N	N	Y	N	N	N
	Sarcodictyonidae	*Telestula* spp.	N	N	Y	Y	N	N	Y	Y	Y

2.8.2 Identifying VMEs on Cobb Seamount using visual data and a VME indicator density threshold

What follows are excerpts from the North Pacific Fisheries (NPFC) working paper:

Warawa, D.R., Rooper, C.N., Nephin, J., Chu, J.W.F., Dudas, S., Knudby, A., Georgian, S. and Curtis, JM.R. 2023. Identifying VMEs on Cobb Seamount using visual data. North Pacific Fisheries Commission NPFC-2023-SSC BFME04-WP13, 8 pp.

Abstract

We identify vulnerable marine ecosystems (VMEs) on Cobb Seamount by applying a quantitative approach to assessing the Food and Agriculture Organization (FAO) criterion of structural complexity for identifying vulnerable marine ecosystems (VMEs) (FAO, 2009) developed by Rowden *et al*. (2020). VMEs are identified using visual data as outlined in the North Pacific Fisheries Commission's (NPFC's) framework for identifying data to identify VMEs (See Annex 2.3 in NPFC (2023a) and NPFC (2023b)). Using Rowden *et al*.'s (2020) approach, we calculated a VME density threshold of 0.6 VME indicator taxa colonies m^{-2}. Applying our threshold to visual data from autonomous underwater vehicle (AUV) transects on Cobb Seamount, we identify five areas as VMEs ranging in size from 50 to 200 m^2.

Introduction

Canada's quantitative and repeatable methodology for identifying VMEs in the NPFC's Convention Area (CA) (Warawa *et al*., 2022) was endorsed by the NPFC's Scientific Committee in December 2022 (NPFC-SC, 2022) and adopted by the NPFC Commission in March 2023 (NPFC, 2023c). This working paper applies the adopted methodology to Cobb Seamount in the eastern NPFC CA to identify VMEs where visual data is available.

Canada's method for identifying VMEs is an application of the quantitative approach developed by Rowden *et al*. (2020), which determines a density threshold of VME indicator taxa above which a VME is present, drawing on FAO's VME criterion of structural complexity (FAO, 2009). They identified VME density thresholds for *Solenosmilia variabilis*, a widespread VME indicator species in the South Pacific Regional Fisheries Management Organization (SPRFMO) CA, of 0.11, 0.14, and 0.85 coral heads m^{-2}, at spatial scales of 50 m^2, 25 m^2, and 2 m^2, respectively. They hypothesized that the thresholds used to identify VMEs would likely vary regionally. Hence, we applied their methodology to the Northeast NPFC CA using regional data and VME indicator taxa recognized by the NPFC. See Warawa *et al.* (2021) and Warawa *et al*. (2022) for NPFC working papers describing previous iterations of Canada's approach to identifying VMEs.

Data and data processing

Visual data were collected from Cobb Seamount in 2012 in a scientific survey to characterize the benthic community structure (Curtis *et al*., 2015). Photos were taken using a SeaBED-class autonomous underwater vehicle (AUV) deployed by the National Oceanic and Atmospheric Administration (NOAA), capable of diving to 1,400 m. We used the fully annotated dataset created by NOAA, which consisted of data extracted from 2,614 AUV photos. Photos were taken from four transects with an average length of 1805 m and ranging from 435–1154 m in depth. Discernable taxa, including corals, sponges, other invertebrates (but not brittle stars or snails), and fishes were identified and counted (Curtis *et al*., 2015).

To process the AUV data for analysis, transects were divided into area-standardized segments of 50 m^2 by grouping adjacent photos until a combined area of 50 m^2 was reached. Rowden *et al*. (2020) suggest that observations made at spatial scales between 25 m^2 and 50 m^2 result in more stable and reliable density estimates because they are more likely to capture whole coral reef patches. The area of each photo varied depending on the distance between the AUV and the seafloor when the photo was captured. We omitted transect segments from our analysis if they were 10% smaller or larger than our target area (50 m^2) to prevent a large variation in the actual final segment size. This resulted in the removal of 5.6% (13 out of a total of 234) of transect segments. Each 50 m transect segment group was composed of 5 to 12 AUV photos, depending on the area covered by each photo in the grouping.

Threshold estimation

Generalized additive models (GAMs) fitting associated taxa richness (dependent variable) to VME indicator density (independent variable) were used to estimate the VME thresholds after Rowden *et al*. (2020). Final model selection was based on the lowest Akaike's Information Criterion (AIC) score, while maintaining low standard error values. The GAMs were fit using a Gaussian distribution and an identity link function. Depth was included as predictor variable in order to account for any differences in taxonomic diversity related solely to the changes in depth (*e.g*., decreases in overall diversity at deeper depths as observed by other studies and meta-analysis (Davies and Guinotte, 2011; Georgian *et al*., 2014; Costello and Chaudhary, 2017). Transect was included as a random effect in the model to account for the potential dependence of observations taken from the same transect. The number of basis functions or inflection points in the smooth terms (k) was assessed to ensure dimension choices were adequate. Model accuracy was estimated using the adjusted R^2 values and model fit was compared using AIC score. The final model formula is shown below, where *bs* = "*re*" indicates the variable treated as a random effect and *s* indicates a cubic spline smoother:

Species richness ~ s(VME density) + s(depth) + s(transect, bs = "re").

We calculated the VME density threshold from the GAM using the same four methods outlined in Rowden *et al*. (2020) and used the average as the final threshold value as our estimate of the VME indicator density threshold. The methods include: (1) the point of intersection of linear regressions using the initial and final 5% of data, (2) the point of intersection between a linear regression using the initial 5% of data and the maximum cumulative species richness value, (3) the point on the curve that is closest to the top right corner (0,1), and (4) the point on the curve that maximizes the distance between the curve and the line between extreme points (Youden Index). See Figure S2 in Rowden *et al*. (2020) for a visual explanation of these methods using hypothetical curves.

Identifying VMEs

We identify areas as VMEs that meet the FAO VME criteria of structural complexity (FAO, 2009), where visual data report VME indicator taxa in densities equal to or greater than our regional VME density threshold.

Estimated VME density threshold

The density of VME indicator taxa was calculated for n = 221 50 m^2 segments of the AUV transects on Cobb Seamount. The number of associated species (richness) ranged from 2 to 16 per 50 m^2 transect segment, with a mean of 7.4 (SD = 2.5). The density of VME indicators ranged from 0 to 1.16 colonies m^{-2}, with a mean of 0.15 colonies m^{-2} (SD = 0.19).

Assessment of GAM fit showed the model performed well with an adjusted R^2 of 0.46T. The final average density threshold is 0.6 VME indicator taxa colonies m^{-2} (SD = 0.1, lower 95% CI = 0.5 and upper 95% CI = 0.7).

Identification of VMEs

Only 4.5% of the 50 m^2 transect segments (10 of 221) had VME density values above the threshold of 0.6 VME indicator colonies m^{-2}. This resulted in five VME areas identified as VMEs. VMEs ranged in size from 50 to 200 m^2 and ranged in depth from approximately 500 to 1150 m. VMEs were identified on two out of the four AUV transects on Cobb Seamount (Figure 2.8.2.1). The largest VME areas occurred in the deepest areas of transect AUV 4. VMEs on transect AUV 4 included colonies of gorgonian corals (290 colonies) with some black corals (45 colonies) and a few glass sponges (13 colonies), while the VME on transect AUV 2 consisted of mainly black corals (30 colonies) and only one gorgonian and one glass sponge. The total area assessed for VMEs in this study was 0.011 km^2 and the total area identified as VMEs was 0.0005 km^2, resulting in 4.5% of assessed area identified as a VME.

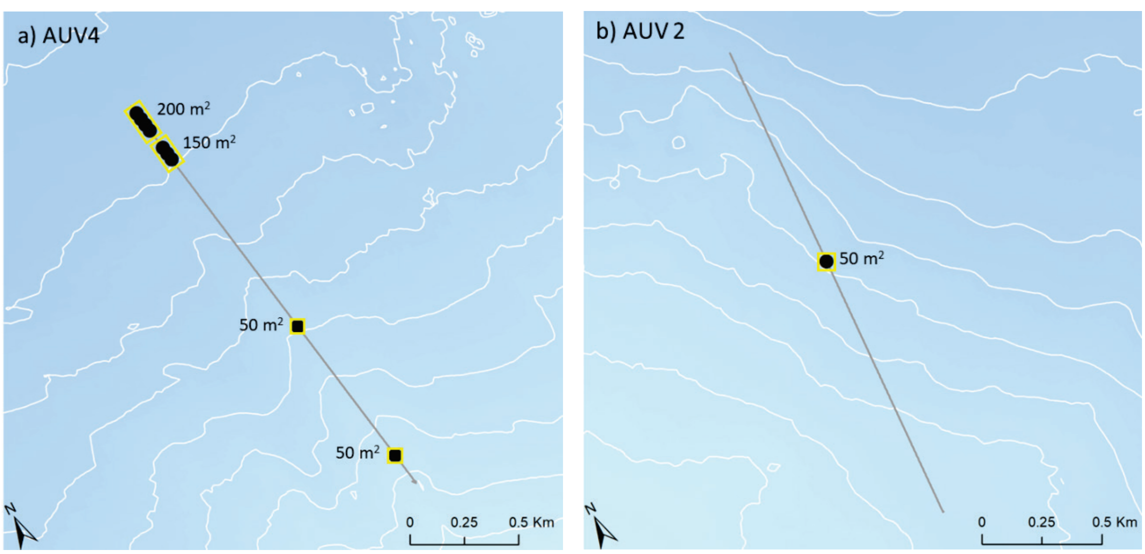

Fig. 2.8.2.1 VMEs identified on Cobb Seamount on transect AUV 4 (a) and AUV 2 (b). Yellow boxes surround spatially adjacent transect segments (black dots) grouped into VME areas ranging in size from 50 to 200 m^2. White lines are 100 m depth contour lines and grey lines are AUV transect lines (see Curtis *et al*., 2015).

2.9 *Use cluster analysis and/or association analysis to review and document ecological interactions among seamount taxa*

2.9.1 Biogeography of North Pacific bathyal seamount communities: Implications for locating marine protected areas

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Introduction

The first modern analysis of the bathyal biogeography of the Pacific Ocean was based primarily on hydrographic data due to the paucity of biological data (Watling *et al*., 2013). However, over the years since that paper was written, remotely operated vehicles (ROVs) with high-resolution cameras and frame grabbing capabilities have been used to explore seamounts and ridges in the Central Pacific and Emperor Seamount areas. In all, the NOAA ship *Okeanos Explorer* used the ROV *Deep Discoverer* to dive on 72 seamounts, 17 ridges, and 18 island slopes at lower bathyal depths (Kennedy *et al*., 2019). The Schmidt Ocean Institute ship R/V *Falkor* and ROV *Subastian* dove on 8 seamounts in the southern and central part of the Emperor Seamount Chain (Watling *et al*., 2024).

Detailed annotations of videos from the accumulated dives will be used to assess the relative similarity of the bathyal benthic megafaunal assemblages on the seamounts and ridges of the Central and part of the Northern Pacific Ocean. The data will be used to test the proposed biogeographic provinces of the region that were suggested on the basis of hydrography in Watling *et al*. (2013) and cnidarians in Watling and Lapointe (2022), and from sampling the Emperor Seamounts (Watling *et al*., 2024).

Method

For each ROV dive, video was annotated using the video annotation and reference (VAR) program from the Monterey Bay Aquarium Research Institute. Individuals and colonies were identified to the lowest possible taxonomic level and counted, with location and associated environmental data recorded.

Analysis of similarities of seamount dives at the province-wide scale was conducted using Infomap Bioregions Analysis (https://www.mapequation.org/bioregions/). This method finds networks of associated taxa by geographic grid cell. Preliminary filtering of taxa was based on the following reasons and resulted in many taxa being eliminated from the analysis: they were higher taxonomic categories that likely contained multiple species or genera, *e.g*., Keratoisidinae, Comatulida; the taxa represented highly mobile pelagic groups, *e.g*., mysids, Actinopterygii, shrimp; or the category was recorded once or a very few times. The remaining taxa were submitted with their abundance and the coordinates of their occurrence. The submitted records were then assembled into 1° squares, with the squares needing to have a minimum of 10 records to enter the network analysis. Each 1° square was then assigned to a network group based on the taxa present and their abundance. The network analysis used a cluster cost of 1 for maximum aggregation. The output of the analysis was in the form of shapefiles which were then plotted in ArcGIS 10. To determine which taxa are most characteristic of the network group, an

Indicator Index was computed. It is a ratio of the abundance of the taxon in the network group relative to all network groups.

Hierarchical cluster analysis was performed using the routines in Primer7. As with the network analysis, taxa were removed using similar criteria, but records were limited to those remaining taxa that were found more than seven times. Abundance counts of the remaining taxa were square-root transformed, the Bray-Curtis similarity measure was computed to create a resemblance matrix which was then used for cluster analysis based on the group average agglomerative algorithm, with a SIMPROF test applied to the clusters to determine the probability of their distinctness. The SIMPER routine was used to determine which taxa contributed the most to each distinct cluster.

Results

The Infomap Bioregions analysis produced four groups, two of which (Hess Rise and Northern Marianas) are each represented by only one 1° cell. The two remaining groups represent (1) the five 1° cells covering the seamounts north of the Main Gap in the Emperor Seamount Chain, and (2) the 81 1° cells from the central part of the North Pacific and the Emperor Seamounts south of the Main Gap. For each region the common total count and the scores for the indicator species are given in Table 2.9.1.1. The distribution of the bioregions is shown in Figure 2.9.1.1.

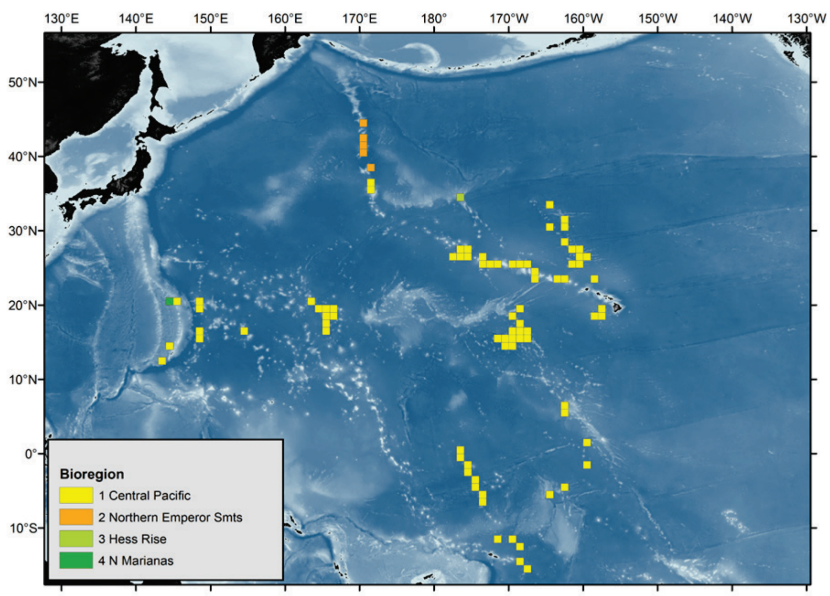

Fig. 2.9.1.1 Distribution of bioregions of the North and Central Pacific resulting from the InfoMap Bioregions analysis.

Table 2.9.1.1 Common and indicator species for the four bioregions defined by the Infomap Bioregions network analysis.

	Central Pacific (81 cells)			
Bioregion	Common Species	Common Species Count	Indicator Species	Indicator Species Score
1	Hemicorallium sp.	2574	Poliopogon sp.	1.04
1	Euryalidae	2258	Candidella gigantea	1.04
1	Poliopogon sp.	1784	Tretopleura sp.	1.04
1	Bathypathes sp.	1257	Stichopathes sp.	1.04
1	Candidella gigantea	1190	Calyptrophora sp.	1.04
1	Plexauridae	1135	Iridogorgia sp.	1.04
1	Chrysogorgia geniculata	1124	Victorgorgia alba	1.04
1	Pleurogorgia militaris	1086	Heteropathes sp.	1.04
1	Paragorgia sp.	1055	Calyptrophora angularis	1.04
1	Stauropathes sp.	915	Hyalonema (Corynonema) sp.	1.04
	Northern Emperor Seamounts (5 cells)			
Bioregion	Common Species	Common Species Count	Indicator Species	Indicator Species Score
2	Crypthelia sp.	362	Calyptrophora cf. clarki	7.42
2	Stylasteridae	293	Primnoa wingi	7.42
2	Lefroyella ceramensis	284	Thalassometra sp.	7.42
2	Walteria sp.	253	Farrea occa	7.42
2	Glyptometra cf. lateralis	222	Hemicorallium cf. niobe	7.42
2	Paragorgia arborea	183	Chaetarcturus cf. beddardi	7.42
2	Farrea nr. occa	182	Candelabridae	7.42
2	Calyptrophora cf. clarki	123	Sebastidae	7.42
2	Rossellidae	116	Paragorgia arborea	7.42
2	Pseudoanthomastus sp.	108	Hydractinia sp.	7.42
	Hess Rise (1 cell)			
Bioregion	Common Species	Common Species Count	Indicator Species	Indicator Species Score
3	Walteria sp.	21	Cetonurus sp.	127.86
3	Aspidodiadema cf. hawaiie	19	Tylaspis sp.	127.86
3	Farrea sp.	11	Trichometra vexator	127.86
3	Trissopathes sp.	11	Mastigoteuthidae	127.86
3	Euryalida	10	Bathygadus antrodes	127.86
3	Paragorgia sp.	9	Asteronyx sp.	79.91
3	Lefroyella ceramensis	9	Heteroptychus sp.	76.71
3	Thalassometridae	9	Euryalida	71.03
3	Paelopatides sp.	8	Radicipes sp.	71.03
3	Farrea nr. occa	8	Asteronychidae	63.93
	North Mariana (1 cell)			
Bioregion	Common Species	Common Species Count	Indicator Species	Indicator Species Score
4	Stylaster sp.	50	Alviniconcha hessleri	53.7
4	Synaphobranchus sp.	20	Conopora unifacialis	53.7
4	Halosauridae	8	Austinograea sp.	53.7
4	Stylasteridae	8	Stylaster sp.	53.7
4	Alviniconcha hessleri	8	Eumunida sp.	30.69
4	Conopora unifacialis	6	Lepidion sp.	26.85
4	Austinograea sp.	6	Neoscopelus macrolepidotus	26.85
4	Eumunida sp.	4	Calyptopora sp.	26.85
4	Lepidion sp.	3	Ventrifossa sp.	17.9
4	Homeryon asper	3	Lamprogrammus sp.	17.9

For the cluster analysis, 107 of the 187 CAPSTONE dives were in the range of the Lower Bathyal (700–3000 m). In addition, 11 Lower Bathyal dives were conducted at Hess Rise and along the Emperor Seamounts. The video annotation produced 536 taxa at various taxonomic levels. Filtering according to the noted criteria removed 297 taxon categories, leaving 239 taxa, most identified to genus, representing a total of 105,023 individuals or colonies at 118 dive locations.

Cluster analysis produced 21 distinct clusters, with several individual dives closely joining some of the distinct clusters. A few clusters, labeled *b*, *n*, *q*, *u*, *w*, *ac*, *af*, and *ag*, comprised 5 or more dives, with cluster *ac* made up of the most dives (13). Clusters *c*, *d*, and *e*, represent the 11 dives of the Emperor Seamounts and Hess Rise. Of the major clusters, *b*, *q*, *w*, and *ac* are the most widespread, while clusters *n*, *u*, *af*, and *ag* were restricted to a narrow range of longitudes in the central part of the North Pacific Ocean. Clusters *c*, *d*, and *e* represent dives along the Emperor Seamounts; those from *c*, and *d*, north of the Main Gap at shallower and deeper depths, respectively, and *e* south of the Main Gaps. See Figures 2.9.1.2, 2.9.1.3, and 2.9.1.4. See also Tables 2.9.1.2 to 2.9.1.12 for mean values of environmental and diversity variables associated with the clusters.

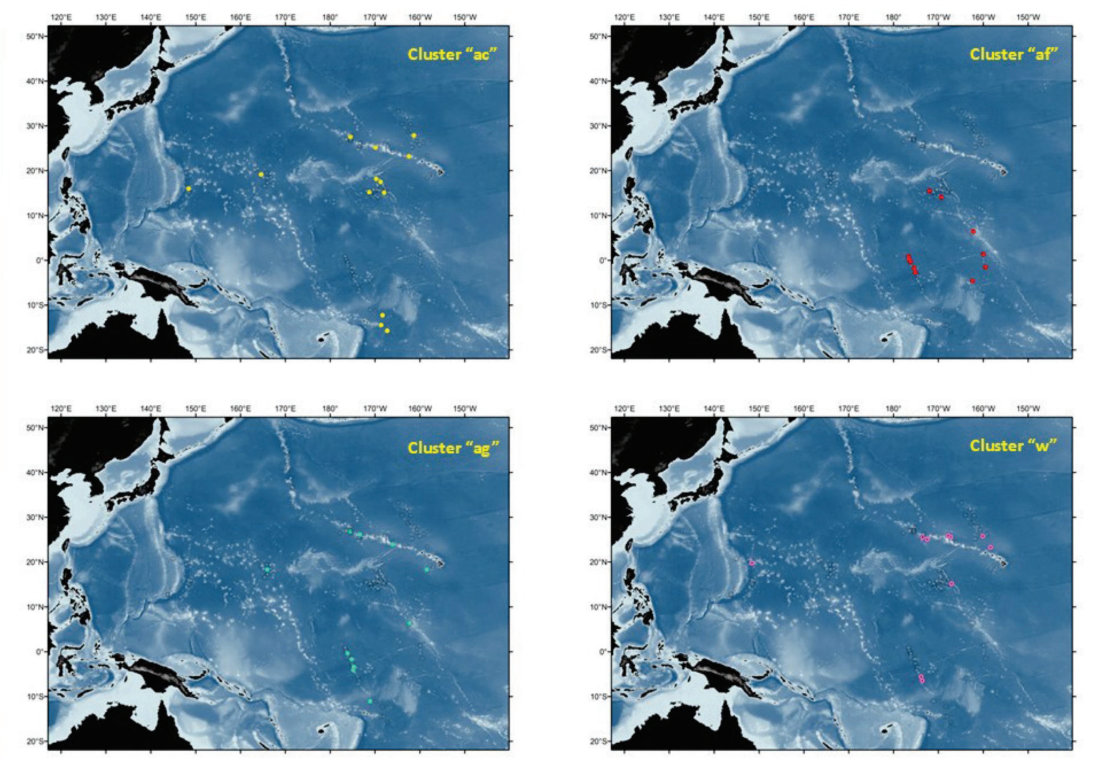

Fig. 2.9.1.2 Location of dives in clusters ***ac***, ***af***, ***ag***, and ***w***.

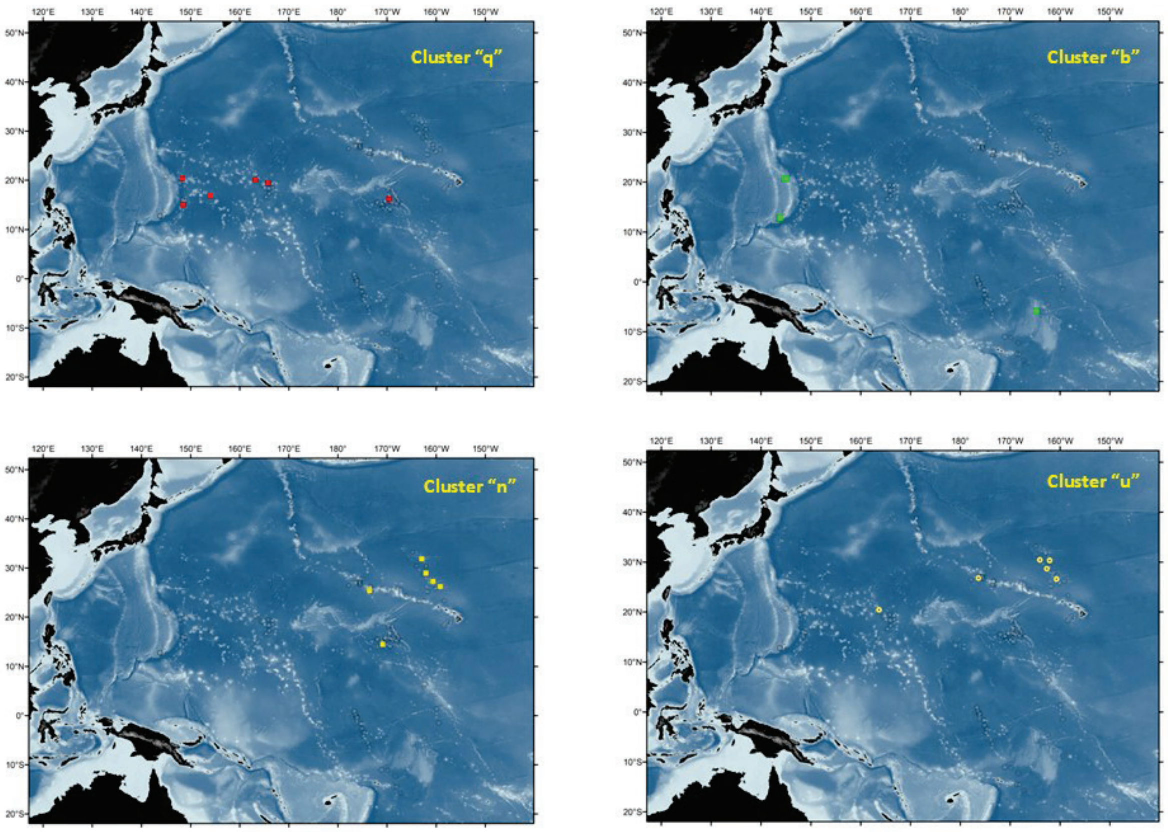

Fig. 2.9.1.3 Locations of dives in clusters ***q***, ***b***, ***n***, and ***u***.

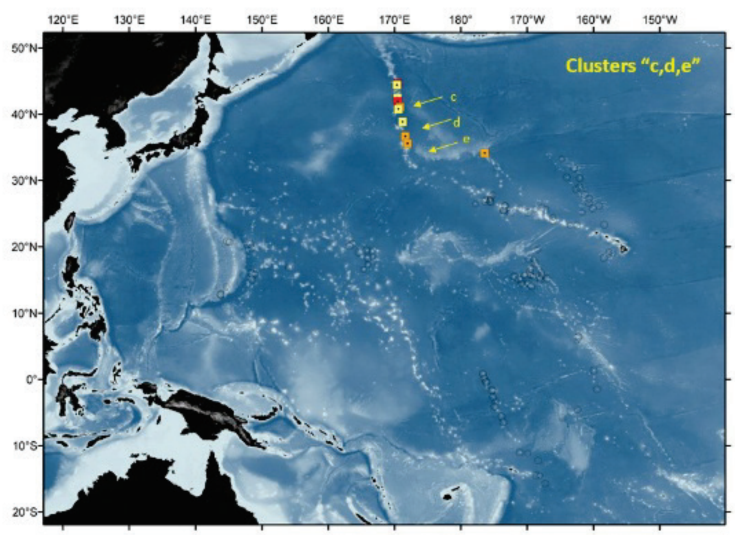

Fig. 2.9.1.4 Location of dives in clusters ***c***, ***d***, ***e***.

Table 2.9.1.2 Mean values of environmental and diversity variables associated with cluster *ag*.

		ag				
Mean Values			Species	Av.Abund	Contrib%	Cum.%
Depth	1165.80		Plexauridae	6.71	14.56	14.56
Temperature	3.75		Hemicorallium sp.	2.61	5.38	19.94
Oxygen Conc.(ml/l)	2.33		Chrysogorgia sp.	2.44	5.37	25.31
Salinity	34.53		Narella sp.	2.90	5.35	30.66
No. Species	39.55		Iridogorgia magnispiralis	2.06	4.44	35.10
Total Count	354.45		Victorgorgia alba	2.48	4.16	39.26
Evenness (Hill's Ratio)	0.55		Calyptrophora wyvillei	1.94	4.14	43.40
Diversity (J')	0.72		Paragorgia sp.	1.68	3.39	46.79
			Enallopsammia rostrata	3.06	3.29	50.08
			Acanthogorgia sp.	2.20	2.62	52.71
			Chrysogorgia geniculata	1.90	2.46	55.17
			Parazoanthidae	1.07	2.44	57.61
			Actinoscyphia sp.	1.44	2.40	60.01
			Anthomastus sp.	1.35	2.40	62.40
			Chirostylidae	0.88	2.02	64.43

Table 2.9.1.3 Mean values of environmental and diversity variables associated with cluster *af*.

		af				
Mean Values			Species	Av.Abund	Contrib%	Cum.%
Depth	1829.72		Paragorgia sp.	2.29	5.86	5.86
Temperature	2.55		Plexauridae	2.59	5.81	11.67
Oxygen Conc.(ml/l)	3.12		Ophioplinthaca sp.	1.36	5.51	17.18
Salinity	34.62		Chrysogorgia sp.	1.88	5.45	22.62
No. Species	38.00		Poecilasmatidae	1.74	4.43	27.05
Total Count	225.50		Metallogorgia melanotrichos	1.64	4.35	31.40
Evenness (Hill's Ratio)	0.58		Iridogorgia magnispiralis	1.69	4.33	35.73
Diversity (J')	0.79		Anthomastus sp.	1.79	4.28	40.01
			Hydroidolina	1.53	4.06	44.07
			Parazoanthidae	1.83	3.95	48.02
			Bathypathes sp.	1.24	3.76	51.78
			Brisingidae	1.18	3.69	55.48
			Hemicorallium sp.	1.10	2.64	58.11
			Bassozetus sp.	1.01	2.41	60.52
			Thalassometridae	0.96	2.24	62.76

Table 2.9.1.4 Mean values of environmental and diversity variables associated with cluster *e*.

		e				
Mean Values			Species	Av.Abund	Contrib%	Cum.%
Depth	1840.27		Farrea nr. occa	5.22	9.92	9.92
Temperature	2.16		Farrea sp.	3.85	7.83	17.74
Oxygen Conc.(ml/l)	2.13		Stylasteridae	8.84	7.68	25.42
Salinity	34.54		Anthomastus sp.	4.90	6.78	32.20
No. Species	55.80		Farreidae	2.91	4.89	37.09
Total Count	721.60		Lefroyella ceramensis	3.65	4.79	41.88
Evenness (Hill's Ratio)	0.57		Chrysogorgia sp.	5.77	4.45	46.33
Diversity (J')	0.77		Munidopsis sp.	1.99	3.81	50.13
			Poecilosclerida	2.40	2.71	52.84
			Paragorgia sp.	2.58	2.47	55.31
			Pseudoanthomastus sp.	5.49	2.35	57.66
			Hemicorallium sp.	2.29	2.15	59.81
			Antipatharia	1.31	2.07	61.88
			Aspidodiadema cf. hawaiiense	2.99	2.04	63.93
			Corbitellinae	2.17	1.92	65.85

Table 2.9.1.5 Mean values of environmental and diversity variables associated with cluster *u*.

		u				
Mean Values			Species	Av.Abund	Contrib%	Cum.%
Depth	1927.41		Chrysogorgia sp.	11.56	12.74	12.74
Temperature	2.03		Hemicorallium sp.	11.52	12.62	25.36
Oxygen Conc.(ml/l)	2.64		Narella sp.	8.56	8.14	33.50
Salinity	34.61		Candidella gigantea	5.49	5.46	38.95
No. Species	52.17		Acanthogorgia sp.	5.85	4.93	43.89
Total Count	1015.00		Paragorgia sp.	5.99	4.92	48.81
Evenness (Hill's Ratio)	0.60		Chrysogorgia geniculata	5.19	4.46	53.27
Diversity (J')	0.73		Paracalyptrophora sp.	3.45	3.11	56.39
			Jasonisis sp.	3.22	2.77	59.15
			Parazoanthidae	3.42	2.76	61.92
			Poliopogon sp.	2.45	2.12	64.03
			Anthomastus sp.	1.68	1.91	65.94
			Psathyrometra sp.	1.89	1.86	67.80
			Caulophacus sp.	2.20	1.58	69.38
			Munidopsis sp.	1.31	1.47	70.85

Table 2.9.1.6 Mean values of environmental and diversity variables associated with cluster *w*.

		w				
Mean Values			Species	Av.Abund	Contrib%	Cum.%
Depth	1927.76		Hemicorallium sp.	6.86	7.37	7.37
Temperature	2.14		Chrysogorgia sp.	6.97	7.02	14.40
Oxygen Conc.(ml/l)	3.04		Bathypathes sp.	5.59	5.18	19.57
Salinity	34.62		Paragorgia sp.	4.72	4.29	23.87
No. Species	58.30		Iridogorgia magnispiralis	3.81	4.08	27.94
Total Count	1028.20		Stauropathes sp.	4.54	3.85	31.79
Evenness (Hill's Ratio)	0.54		Pleurogorgia militaris	4.69	3.77	35.56
Diversity (J')	0.75		Poliopogon sp.	4.96	3.55	39.11
			Trissopathes sp.	4.13	3.38	42.49
			Anthomastus sp.	3.52	3.19	45.68
			Acanella weberi	5.36	3.17	48.85
			Psathyrometra sp.	2.80	3.03	51.88
			Chrysogorgia geniculata	3.39	2.91	54.79
			Umbellapathes sp.	3.38	2.91	57.70
			Parazoanthidae	3.53	2.89	60.58

Table 2.9.1.7 Mean values of environmental and diversity variables associated with cluster *q*.

		q				
Mean Values			Species	Av.Abund	Contrib%	Cum.%
Depth	2129.84		Narella sp.	5.64	9.98	9.98
Temperature	2.00		Tretopleura sp.	5.31	9.18	19.17
Oxygen Conc.(ml/l)	3.31		Poliopogon sp.	4.59	7.89	27.05
Salinity	34.63		Trissopathes sp.	4.65	6.98	34.03
No. Species	42.83		Bathypathes sp.	4.12	6.78	40.82
Total Count	403.00		Chrysogorgia sp.	4.22	6.41	47.22
Evenness (Hill's Ratio)	0.60		Candidella gigantea	3.87	5.91	53.13
Diversity (J')	0.79		Caulophacus sp.	2.62	5.80	58.93
			Antedonidae	1.26	2.78	61.70
			Farrea nr. occa erecta	1.63	2.29	63.99
			Bolosominae	2.05	2.25	66.24
			Actinostolidae	1.16	2.24	68.48
			Dictyaulus sp.	1.31	2.13	70.61

Table 2.9.1.8 Mean values of environmental and diversity variables associated with cluster *b.*

		b				
Mean Values			Species	Av.Abund	Contrib%	Cum.%
Depth	2260.44		Cladorhizidae	1.18	27.73	27.73
Temperature	2.27		Hydroidolina	0.90	14.54	42.27
Oxygen Conc.(ml/l)	3.51		Bathycrinidae	0.98	14.46	56.72
Salinity	34.61		Hyalonema sp.	1.44	9.99	66.71
No. Species	14.17		Bassozetus sp.	0.57	6.79	73.50
Total Count	51.50					
Evenness (Hill's Ratio)	0.63					
Diversity (J')	0.78					

Table 2.9.1.9 Mean values of environmental and diversity variables associated with cluster *n.*

		n				
Mean Values			Species	Av.Abund	Contrib%	Cum.%
Depth	2380.81		Chrysogorgia sp.	8.25	16.25	16.25
Temperature	1.75		Pleurogorgia militaris	6.28	10.30	26.55
Oxygen Conc.(ml/l)	3.23		Hemicorallium sp.	5.21	7.66	34.21
Salinity	34.64		Narella sp.	6.18	7.56	41.77
No. Species	39.50		Chrysogorgia geniculata	3.25	5.39	47.16
Total Count	575.17		Stauropathes sp.	4.30	4.20	51.36
Evenness (Hill's Ratio)	0.62		Bolosominae	2.57	4.10	55.45
Diversity (J')	0.73		Poliopogon sp.	3.12	3.98	59.44
			Trissopathes sp.	2.79	3.59	63.03
			Bathypathes sp.	3.42	3.41	66.44
			Anthomastus sp.	4.98	3.27	69.71
			Caulophacus sp.	1.83	2.99	72.70

Table 2.9.1.10 Mean values of environmental and diversity variables associated with cluster *ac.*

		ac				
Mean Values			Species	Av.Abund	Contrib%	Cum.%
Depth	2469.70		Chrysogorgia sp.	3.29	16.31	16.31
Temperature	1.83		Poliopogon sp.	4.13	14.48	30.79
Oxygen Conc.(ml/l)	3.66		Bolosoma sp.	2.79	7.35	38.14
Salinity	34.65		Narella sp.	2.37	7.06	45.20
No. Species	26.92		Caulophacus sp.	1.86	6.21	51.41
Total Count	184.62		Bolosominae	1.68	5.69	57.10
Evenness (Hill's Ratio)	0.64		Caulophacus (Caulodiscus) sp.	1.60	5.43	62.53
Diversity (J')	0.78		Pleurogorgia militaris	1.78	3.74	66.27
			Caulophacus (Oxydiscus) sp.	1.48	3.62	69.88
			Chrysogorgia geniculata	1.48	3.42	73.30

Table 2.9.1.11 Mean values of environmental and diversity variables associated with cluster *d.*

		d				
Mean Values			Species	Av.Abund	Contrib%	Cum.%
Depth	1414.82		Gracilechinus cf. multidentatus	22.39	10.35	10.35
Temperature	2.48		Stylasteridae	57.71	9.29	19.64
Oxygen Conc.(ml/l)	1.46		Antipatharia	15.99	8.26	27.90
Salinity	34.46		Paragorgia arborea	14.08	7.00	34.91
No. Species	52.00		Anthomastus sp.	7.21	6.87	41.78
Total Count	11858.25		Lefroyella ceramensis	9.73	6.82	48.60
Evenness (Hill's Ratio)	0.40		Farrea nr. occa	8.00	5.09	53.69
Diversity (J')	0.33		Glyptometra lateralis	6.72	4.76	58.46
			Tretodictyidae	3.70	3.38	61.83
			Parastenella gymnogaster	3.29	2.94	64.77
			Macroregonia macrochira	2.62	2.79	67.56
			Spongiactis sp.	2.64	2.23	69.79
			Stauropathes sp.	2.84	2.03	71.83

Table 2.9.1.12 Mean values of environmental and diversity variables associated with cluster ***c*.**

		c				
Mean Values			Species	Av.Abund	Contrib%	Cum.%
Depth	2012.93		Crypthelia sp.	64.89	33.85	33.85
Temperature	1.93		Umbellapathes sp.	5.1	6.7	40.55
Oxygen Conc.(ml/l)	2.70		Alcyoniidae	4.32	6.08	46.63
Salinity	34.59		Stauropathes sp.	5.19	3.98	50.62
No. Species	50.00		Corbitellinae	3.18	3.63	54.25
Total Count	7267.50		Macroregonia macrochira	2.34	3.63	57.88
Evenness (Hill's Ratio)	0.44		Poecilosclerida	4.55	3.63	61.52
Diversity (J')	0.31		Caryophylliidae	2.09	2.81	64.33
			Gorgonocephalidae	6.25	2.81	67.15
			Pseudoanthomastus sp.	4.14	2.81	69.96
			Caulophacus sp.	1.57	2.3	72.26

Discussion

The Infomap Bioregions analysis suggested that the whole of the Central Pacific is one large biogeographic unit at bathyal depths. That is partly due to the settings chosen for the analysis. Altering some settings, such as changing the cluster factor, produces a higher number of bioregions as the network is further subdivided. Using the new Infomap Bioregions 2, where the degree of aggregation of the cells is variable and can be controlled by the user, produces a mostly similar result (Fig. 2.9.1.5) to the output from version 1 with a cluster, including a low number of bioregions with a strong division at the Main Gap of the Emperor Seamounts and primarily one large bioregion encompassing nearly the whole of the Central Pacific. The uniqueness of the Hess Rise bioregion is also maintained.

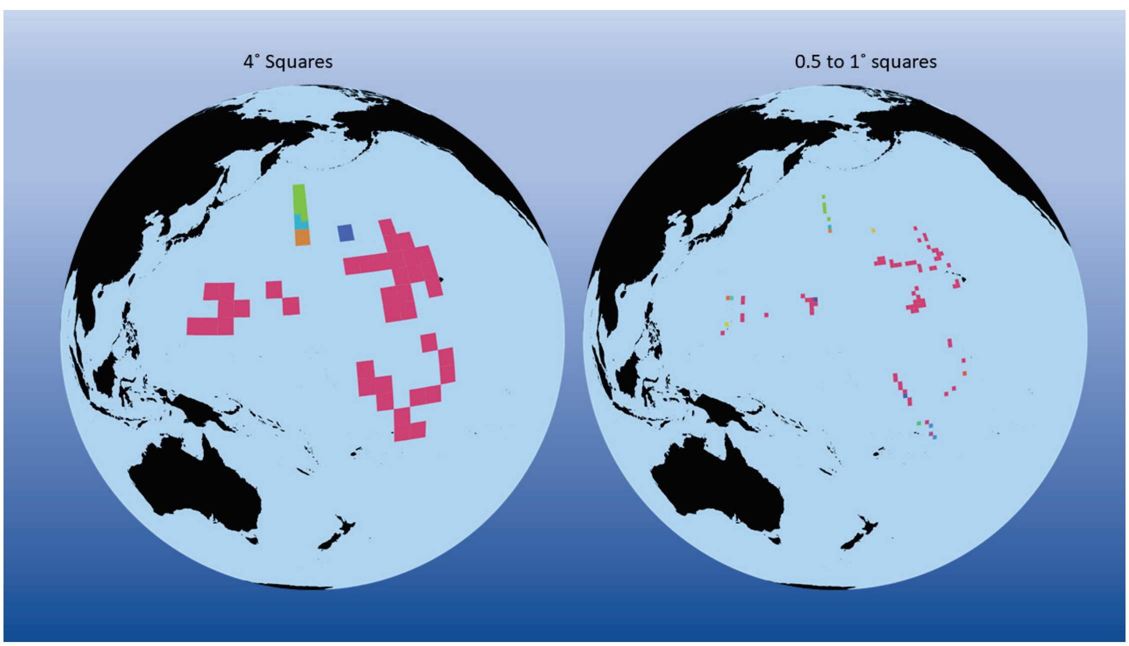

Fig. 2.9.1.5 Output from Infomap Bioregions ver. 2 of the CAPSTONE and Emperor edited bathyal records dataset. When the network results are aggregated into 4° squares, there are five bioregions, but when the results are aggregated at the level of 1° squares, the dive sites are assigned to 13 bioregions.

Hierarchical cluster analysis with the SIMPROF routine can be used to examine the subdivisions within the large Central Pacific cluster. Excluding clusters *c* and *d* which are north of the Main Gap and thus part of the North Pacific Province (Watling *et al*., 2024), and cluster *e*, which seems to represent a transitional area between the two major Pacific provinces, most of the other cluster units are widespread, although several are represented by only a few dives. A major caveat is that many of the "major" clusters are represented by 5 to 7 dives, sometimes with large distances between one of the dives and the others in the cluster. As a result, the dominance of several taxa seems to determine the membership in one cluster or another. That is, there is considerable patchiness that is captured by the dives, but there are not yet a sufficient number of dives to help understand what is the causal factor. On the other hand, the network analysis shows that when taking a large enough view, all those patches contribute to the overall characterization of the Central Pacific fauna.

Also seen in the cluster analysis is the effect of depth on the overall taxonomic resolution for some groups, especially the sponges, which are not as well studied to date as are the octocorals. Therefore, some of the cluster analysis and network analysis results might be biased by the low resolution of several of the taxonomic categories, *i.e*., those identified to the level of genus (larger unresolved categories were mostly removed from the analysis). Even so, it seems doubtful that the Central Pacific Province, at bathyal depths, will be subdivided with better taxonomic resolution. On the other hand, there does seem to be some evidence that the Central Pacific Province extends beyond the limits of sampling in the CAPSTONE program. Several new species that have been and are being described from the area of the South China Sea are identical genetically to those from the area of the Hawaiian Ridge (*e.g*., Wang *et al*., 2024; Xu *et al*., 2024).

2.10 Prepare scientific reports for dissemination of results

This TOR has been completed. Canada published a series of working papers about seamounts in the Northeast Pacific Ocean to the North Pacific Fisheries Commission (NPFC) in 2021, 2022, and 2023. Most WG 47 members published primary papers or reports that address this TOR. See Related Publications Authored/Co-authored by WG 47 Members in section 4 of this report.

3 Conclusions and Next Steps

The work of WG 47 has advanced our knowledge of the diversity, distribution, and associations of seamount taxa in the North Pacific Ocean, where seamounts are unique and abundant features yet relatively unknown. This working group gathered knowledge on seamount taxa with a particular focus on deep-sea corals, sponges, and fishes, and submitted some of their data to publicly accessible databases. The World Ocean Atlas data compiled by WG 32 on the *Biodiversity of Biogenic Habitats* was updated for use by members of WG 47 and the dataset was used to predict the distribution of benthic species on seamounts in the eastern part of the North Pacific Fisheries Commission's (NPFC) Convention Area. WG 47 convened a workshop on predicting the distributions of species associated with seamounts at PICES-2022 and a topic session on seamount biodiversity at PICES-2023. Several members used predictive habitat models to predict the distribution of benthic biodiversity. Indicators of seamount biodiversity included e-DNA and vulnerable marine ecosystems (VME) indicator density thresholds. Data have been collected for potential association analysis in the future, and large-scale biogeographic patterns were identified with cluster analyses. The working group produced maps of the distribution of seamount taxa and biodiversity indicators, including those of VMEs, that could be used to monitor change. Members also contributed to the co-authorship of more than 20 scientific publications (see Related Publications in section 4). Because most WG 47 members had an interest and expertise in the ecology of demersal or benthic fauna, most TOR were partially addressed with a focus on benthic and/or demersal taxa; therefore, the ecology of pelagic species associated with seamounts was not addressed. Also, WG 47 had insufficient time and capacity to address its TOR to "Use available data to predict climate-induced changes in the distribution of seamount fauna."

Enhancing our community's ability to better document and/or predict where diverse biogenic habitats occur is an important precursor to understanding how these habitats support other elements of the ecosystem, including commercially valuable species.

A focus on seamounts is a relatively new research avenue for PICES, with clear linkages to the activities of other PICES expert groups, including the BIO Committee and FIS Committee, and future PICES activities related to seamount research would support the PICES–NPFC Framework for Enhanced Scientific Collaboration in the North Pacific Ocean. At its PICES-2024 business meeting, WG 47 and some observers discussed the merits of establishing one or more PICES expert groups on the following topics:

- Use of available data to predict climate-induced changes in the distributions of seamount fauna.
- Identification of VMEs and areas likely to be VMEs in areas beyond national jurisdiction of the North Pacific Ocean and/or assessing the relative risk of significant adverse impacts to those VME areas.
- Improving our understanding of the life history of seamount taxa, with an emphasis on reproduction and connectivity, and a better integration of biology and physics.

4 Related Publications Authored/Co-authored by WG 47 Members

Dautova, T.N. 2025. Introduction to the Emperor Seamount Chain studies. *Deep Sea Research Part II* **222**: 105486, https://doi.org/10.1016/j.dsr2.2025.105486

DFO (Fisheries and Oceans Canada). 2024. Identification of Vulnerable Marine Ecosystems on Seamounts in the North Pacific Fisheries Commission Convention Area using Visual Surveys and Distribution Models. DFO Canadian Science Advisory Secretariat Science Response 2024/038.

Du Preez, C., Swan, K.D. and Curtis, J.M.R. 2020. Cold water corals and other vulnerable biological structures on a North Pacific seamount after half a century of fishing. *Frontiers in Marine Science* **7**: 17, https://doi.org/10.3389/fmars.2020.00017

Egorova, E. and Dautova, T. 2025. Brachyuran and anomuran decapoda of the Emperor Seamounts. *Deep Sea Research Part II* **222**: 105501, https://doi.org/10.1016/j.dsr2.2025.105501

Hoshino, K., Kosaka, K., Sawada, K. and Kiyota, M. 2022. Identification of the commercially important oreosomatid fish (Zeiformes: Teleostei) of the Emperor Seamounts, with comments on diagnostic characters of the species. *Species Diversity* **27**: 1–13, doi:10.12782/specdiv.27.1

Korostelev, N.B., Baytalyuk, A.A., Maltsev, I.V. and Orlov, A.M. 2020. First data on the age and growth in Pacific flatnose *Antimora microlepis* (Moridae) from the waters of the underwater Emperor Mountain Range (Northwestern Pacific). *Journal of Ichthyology* **60**: 891–899, https://doi.org/10.1134/S0032945220060028

Korostelev, N.B., Maltsev, I.V. and Orlov A.M. 2023. First data on the age and growth of Schmidt's cod *Lepidion schmidti* (Moridae) from waters of the Emperor Seamounts (Northwestern Pacific). *Journal of Marine Science and Engineering* **11**: 1212. https://doi.org/10.3390/jmse11061212

Korostelev, N.B., Volvenko, I.V., Belyakov, V.V., Baytaliuk, A.A., Bush, A.G., Kanzeparova, A.N. and Orlov, A.M. 2023. "Firefly" of the submarine mountains: new data on *Physiculus cynodon* (Moridae, Teleostei) from Emperor Seamounts and Northwestern Hawaiian Ridge. *Journal of Marine Science and Engineering* **11**: 2355, https://doi.org/10.3390/jmse11122355

Korostelev, N.B., Volvenko, I.V., Maltsev, I.V. and Orlov, A.M. 2025. Brought to the surface from obscurity: the distribution and biology of *Coelorhinchus gilberti* (Macrouridae, Gadiformes, Teleostei) off the Emperor Seamounts (Northwestern Pacific). *Deep Sea Research Part II* **220**: 105461. https://doi.org/10.1016/j.dsr2.2025.105461

Lavery, M.A.K., Rooper, C.N., Sawada, K., Fenske, K., Kulik, V. and Kyum, J.P. 2022. Effects of oceanography on North Pacific armorhead recruitment in the Emperor Seamounts. *Fisheries Oceanography*. **2022**: 1–17, DOI: 10.1111/fog.12612

Nishida, K., Chiba, S.N., Sakuma, K., Higashi, R., Suzuki, N., Miyamoto, M., Yonezaki, S., Hoshino, K. and Sawada, K. 2022. Multiplex polymerase chain reaction method with species-specific primers for differentiation of two closely related fish species, *Beryx splendens* and *B. mollis* (Actinopterygii: Beryciformes). *Japan Agricultural Research Quarterly* **56**: 283–294, doi:10.6090/jarq.56.283

Orlov, A.M. and Tuponogov, V.N. 2025. Past and present ichthyological and fisheries research at the Emperor Seamounts: Lessons from the Soviet/Russian experience in the Central North Pacific. *Reviews in Fisheries Science and Aquaculture* **34**: 94–111, DOI: 10.1080/23308249.2025.2523058

Osawa, Y., Okuda, T. and Miyamoto, M. 2023. Bathymetric segregation among demersal benthos and its contributions to the differences in the bycatches on bottom fisheries in the Emperor Seamounts area, Northwestern Pacific Ocean. *Regional Studies in Marine Science* **68**: 103261, doi:10.1016/j.rsma.2023.103261

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Prokofiev, A.M., Emelianova, O.R., Saveleva, S.Y. and Orlov, A.M. 2026. Diversity and distribution of deep-sea fishes off the Emperor Seamounts, northwestern Pacific Ocean, with DNA barcodes, phylogenetic, and biogeographic considerations. *Journal of Marine Science and Engineering* **14**: 63, https://doi.org/10.3390/jmse14010063

Rodkina, S.A. and Dautova, T.N. 2025. Diet of deep-sea octocorals from the Emperor Seamount Chain inferred by fatty acid trophic markers. *Deep Sea Research Part II* **220**: 105462, https://doi.org/10.1016/j.dsr2.2025.10546

Rooper, C.N., Goddard, P., Wright, C., Conrath, C., Rand, K. and Lowe, V. 2023. Joint Canada-USA International Seamount Survey update for 2023. NPFC-2023-SSC BFME04-MIP02. Available at: https://www.npfc.int/joint-canada-usa-international-seamount-survey-update-2023

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Appendix 1

WG 47 Terms of Reference

Year 1

- Gather data on the distribution and life history of pelagic, demersal, and benthic taxa, including fish and invertebrate assemblages associated with seamounts in the North Pacific Ocean and facilitate their submission to appropriate biodiversity databases, *e.g.*, Ocean Biogeographic Information System (OBIS).
- Gather data on key environmental variables (*e.g.*, temperature, depth, steepness, substratum, current velocity, isolation, ocean acidification) hypothesized to influence the distribution and diversity of species associated with seamounts.
- Convene a 2-day workshop on "*Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions*".
- Annual WG business meeting, in association with the PICES Annual Meeting.

Year 2

- Identify environmental and ecological predictors of patterns in the distribution and biodiversity of pelagic, demersal, and benthic taxa associated with seamounts in the North Pacific Ocean.
- Apply one or more modeling approaches (*e.g.*, MaxEnt, Boosted Regression Trees, or high-resolution bathymetry-based models) to predict the distribution of pelagic, demersal, and benthic biodiversity associated with seamounts in the North Pacific Ocean.
- Use available data to predict climate induced changes in the distributions of seamount fauna.
- Convene a topic session on the pelagic, demersal, and benthic species associated with seamounts at the PICES Annual Meeting.
- Annual WG business meeting, in association with the PICES Annual Meeting.

Year 3

- Identify potential indicators for assessing and monitoring the biodiversity of pelagic, demersal, and benthic taxa associated with seamounts.
- Use cluster analysis and/or association analysis to review and document ecological interactions among seamount taxa.
- Prepare scientific reports for dissemination of results.
- Annual WG business meeting, in association with the PICES Annual Meeting.

Appendix 2

WG 47 Membership

WG 47 term: 2020–2023
Extended 1 year to 2024
Parent Committee: BIO

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Appendix 3

Workshop, Topic Session and Meeting Reports from Past Annual Meetings Related to WG 47

PICES-2021
Virtual Annual Meeting

2021 Report of Working Group 47 on *Ecology of Seamounts*

The Working Group on *Ecology of Seamounts* (WG 47) Co-Chairs, Dr. Janelle Curtis (Canada) and Dr. Mai Miyamoto (Japan), convened two virtual business meetings (via Zoom) that focused on introductions of national representatives and observers, discussions of WG 47's terms of reference and exchange of information and ideas about participants' seamount research activities.

An inter-sessional business meeting was held on June 15, 2021 from 22:00 to 24:00 (PDT, +UTC-7) and a business meeting associated with the PICES-2021 virtual Annual Meeting was held on September 20, 2021 from 17:00 to 20:00 (PST, +UTC-8). Both meetings had the same agenda (*WG 47 Endnote 1*). There were seven participants at the inter-sessional meeting (*WG 47 Endnote 2*) and 16 participants at the Annual Meeting (*WG 47 Endnote 3*). Participants at both meetings included WG 47 members, observers, the PICES Secretariat and expert group members.

AGENDA ITEM 3
Introductions and review of members' expertise and research interests

Members, observers, and the PICES Secretariat staff introduced themselves, their expertise and their research interests at both meetings and through email correspondence from July to October 2021. Many participants shared an interest in the work of regional fisheries management organizations (RFMOs) on the identification of vulnerable marine ecosystems (VMEs) on seamounts. Participants were also interested in the spatial ecology of benthic organisms, and many had also supported the research activities of WG 32 on *Biodiversity of Biogenic Habitats*. Some observers were actively engaged in research related to pelagic species associated with seamounts, notably marine birds and mammals, and expressed interest in collaborating with WG 47 members.

AGENDA ITEM 4
Review of WG 47 terms of reference

In Year 1, WG 47 proposed to: (1) gather data on the distribution and life history of species associated with seamounts in the North Pacific Ocean and facilitate their submission to appropriate biodiversity databases (*e.g.*, OBIS), (2) gather data on key environmental variables hypothesized to influence the distribution and diversity of species associated with seamounts, (3) convene a 2-day workshop on modelling the distributions of seamount taxa and (4) convene a business meeting.

(1) Some participants anticipate contributing to the submission of life history and distribution data to biodiversity databases, including the Ocean Biodiversity Information System (OBIS). Members from Canada and Japan specifically expressed their interest and ability to do so.

(2) Participants recognized the World Ocean Atlas data used by WG 32 have been updated and are available to WG 47, which will help members identify environmental and ecological predictors of

the distribution and biodiversity of seamount taxa in the Northeast Pacific Ocean and develop one or more species distribution models for seamount taxa. Those data may also be used to predict climate-induced changes in the distribution of seamount taxa during the coming years.

(3) The co-convenors of WG 47's 2-day workshop on "*Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions*" agreed to postpone the workshop because PICES-2021 was a virtual meeting. They resubmitted their proposal for PICES-2022 in Busan, Korea (*WG 47 Endnote 4*).

(4) As noted above, WG 47 held a business meeting associated with PICES-2021 on September 20, 2021.

Participants also discussed WG 47's terms of reference for Years 2 and 3.

AGENDA ITEM 5
Review of key scientific outputs

Participants discussed WG 47's anticipated scientific outputs and recognized that these would begin to take shape when the terms of reference in Years 1 and 2 were completed, although a scientific peer-reviewed paper will be prepared and submitted on the topic of the distribution of seamount taxa if WG 47's 2-day workshop proposal is accepted by PICES.

WG 47 Endnote 1

Agenda for WG 47's inter-sessional and annual meetings in 2021

1. Welcome and opening remarks
2. Adoption of agenda and appointment of rapporteur
3. Introductions and review of members' expertise and research interests
4. Review of WG 47 terms of reference (TOR)
5. Review of key scientific outputs (papers)
6. Other business

WG 47 Endnote 2

WG 47 inter-sessional meeting (June 15, 2021) participation list

Members

Janelle Curtis (Co-Chair, Canada)
Mai Miyamoto (Co-Chair, Japan)
Kenji Taki (Japan)

Members unable to attend

Canada: Cherisse Du Preez, Anders Knudby
China: Jinhui Wang, Zijun Xu
Japan: Nobuaki Suzuki
Korea: Hye-Won Moon, Seanock Woo
Russia: Tatiana Dautova, Alexei Orlov
USA: Amy Baco-Taylor, Les Watling

Observers

Chris Rooper (Fisheries and Oceans Canada)
Jackson Chu (Fisheries and Oceans Canada)
Samuel Georgian (Marine Conservation Institute)

PICES

Sonia Batten (Executive Secretary)

WG 47 Endnote 3

WG 47 Annual Meeting (September 20, 2021) participation list

Members

Janelle Curtis (Co-Chair, Canada)
Mai Miyamoto (Co-Chair, Japan)
Cherisse Du Preez (Canada)
Kenji Taki (Japan)
Hidetada Kiyofuji (Japan)
Sung Yong Kim (Korea)
Hye-Won Moon (Korea)
Samuel Georgian (USA)

Members unable to attend

Canada: Anders Knudby
China: Jinhui Wang, Zijun Xu
Korea: Seanock Woo
Russia: Tatiana Dautova, Alexei Orlov
USA: Amy Baco-Taylor, Les Watling

Observers

Ken Morgan (Canadian Wildlife Service)
Chris Rooper (Fisheries and Oceans Canada)
Jackson Chu (Fisheries and Oceans Canada)
Patrick O'Hara (Co-Chair, S-MBM)
Jennifer Boldt (FUTURE SSC liaison to WG 47)
Alex Zavolokin (NPFC)

PICES

Sanae Chiba (Deputy Executive Secretary)
Saeseul Kim (Intern)

WG 47 Endnote 4

Proposal for a Workshop on
"*Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions*" resubmitted for PICES-2022

Co-convenors: Janelle Curtis (Canada), Akash Sastri (Canada), Chris Rooper (Canada), Mai Miyamoto (Japan)

Potential Sponsorship: North Pacific Fisheries Commission

Invited speakers:
Telmo Morato (IMAR Azores & Marine and Environmental Research Centre, Portugal)
Russ Hopcroft (University of Alaska Fairbanks, USA)
Peter Miller (Plymouth Marine Laboratory, UK)

Changes in the marine environment influence distribution patterns of marine organisms in pelagic, demersal, and benthic ecosystems associated with seamounts. Biogenic habitats formed by some of these organisms support a range of biodiversity and provide critical habitats for some socioeconomically important fishes and invertebrates that attract commercial fishing and other anthropogenic activities.

This workshop aims to improve our understanding of factors influencing the diversity and distributions of species associated with seamounts in the North Pacific Ocean, identify and begin applying models to understand the ecology and distribution of species associated with seamounts, and predict how they are likely to respond to natural and anthropogenic forcing, including climate change. In preparation for the workshop, participants will build on the work of WG 32 by compiling new and existing data on pelagic, demersal, and benthic seamount species in the North Pacific Ocean as well as the marine environment to improve model predictions and interpretations based on a multi-model approach.

This workshop builds on quantitative approaches developed in a similar workshop convened by WG 32 in 2016. Applying habitat suitability models for the pelagic, demersal, and benthic biodiversity of seamounts in the North Pacific Ocean will be made for the collective biodiversity in these three ecosystems and for individual taxa, when plausible. Participants will be invited to discuss, compare, and evaluate the influence of predictor variable data, and different modelling approaches on results. This will help identify potential ecological and physiological mechanisms influencing seamount ecology and provide insight into the potential for changes in species distribution under different climate change scenarios. An anticipated novel outcome will be the first habitat predictions for seamount biodiversity at a basin-wide scale in the North Pacific Ocean. Workshop participants will synthesize lessons learned from the modelling exercise, future tasks to further improve predictive accuracy, and possible applications for supporting marine spatial planning processes.

Publication: a scientific peer-reviewed paper

PICES-2022
September 23–October 2, 2022, Busan, Korea

Excerpted from:

Summary of Scientific Sessions and Workshops at PICES-2022

W1: BIO Workshop

Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions

Convenors

Janelle Curtis, Mai Miyamoto, Akash Sastri, Chris Rooper, and Samuel Georgian

PICES' Working Group on *Ecology of Seamounts* (WG 47) convened a 2-day workshop from 24–25 September 2022 to explore questions around biodiversity associated with seamounts in the North Pacific Ocean and factors influencing their distributions. There are tens of thousands of seamounts worldwide and their abundance is greatest in the North Pacific Ocean. Few seamounts have been extensively studied due to their occurrence at deep depths of remote regions of the oceans and the resulting difficulty in accessing these habitats. Thus, the ecology of most seamounts is poorly understood in terms of the pelagic, demersal, and benthic species that they support. The primary aims of the workshop were to:

- Identify and understand factors influencing the diversity and distributions of species associated with seamounts in the North Pacific Ocean.
- Build capacity to develop predictive habitat models for seamount species.
- Consider how seamount species distributions are likely to respond to natural and anthropogenic forcing, including climate change.

Over the course of two days, we had participants from Canada, Japan, Korea, Portugal, and the USA join us in person, and another six participants from Canada and the USA join us remotely to present and discuss their work on seamount ecology. It was fortunate that the PICES Secretariat and the Korean Institute of Ocean Science and Technology (KIOST) were able to assist us in conducting this hybrid workshop as one of our co-conveners and three speakers were not able to join us in person. We were also grateful to Dr. Samuel Georgian for leading much of our discussion as an unofficial co-convenor.

The workshop was divided into three main topics: a series of oral and poster presentations on seamount ecology, case studies of particular topics on predictive modeling of seamount taxa and discussions of emerging issues that were inspired by the presentations and case studies. Our workshop began with an informative presentation by our invited expert, Telmo Morato, from the Okeanos Research Institute of the University of the Azores in Portugal: *Improved deep-sea biodiversity assessments inform sustainable management of seamount and other geomorphologic features in a changing planet: Lessons learned from the North Atlantic*. A number of speakers and participants have an interest in the identification of vulnerable marine ecosystems (VMEs), which often comprise populations of corals, sponges, and other benthic taxa. Telmo contributed significantly to our discussions and has undoubtedly inspired colleagues to explore seamounts and the intersect between seamount research and policy. Telmo's influential talk was followed by nine oral presentations:

1. *Oceanographic influences on biological production and energy transfer in seamount ecosystems.* **John Dower**
2. *Investigating seamount effects on zooplankton in the Northeast Pacific*. **Daniel Labbé**
3. *Seamount effects on micronekton at a subtropical central Pacific seamount*. **Réka Domokos**
4. *Can Gulf of Alaska seamounts be a spawning ground for sablefish recruiting to inshore nursery habitats?* **Georgina Gibson**
5. *Biology and fisheries of North Pacific armorhead and splendid alfonsino in the SE-NHR area.* **Kota Sawada**
6. *Species Distribution Modeling to Identify and Protect Vulnerable Marine Ecosystems: Case Studies from the South Pacific Ocean.* **Samuel Georgian**
7. *Using species distribution modeling to predict deep-sea coral and sponge communities, hotspots, diversity and indicators.* **Chris Rooper**
8. *Composition of cold-water corals and other deep-sea benthos in the Emperor Seamounts.* **Mai Miyamoto**
9. *Using predictive habitat models and visual surveys to identify vulnerable marine ecosystems (VMEs) on seamounts in the North Pacific Fisheries Commission's Convention Area.* **Janelle Curtis**

Three posters were also presented as part of this workshop:

1. *Features of spatial distribution of dominant groundfish species on the Koko Seamount (Emperor Seamounts) in 2019.* **Alexey Somov, Albina Kanzeparova, Svetlana Orlova, Denis Kurnosov, Vladimir Belyaev, and Alexei Orlov**
2. *Distribution of giant grenadier (Albatrossia pectoralis) at different stages of ontogenesis in the Bering Sea.* **Andrey Alferov**
3. *Genetic resources of deep-sea corals from seamounts in West Pacific by de novo RNA sequencing.* **Ye Jin Jo, Sung-Jin Hwang, and Seonock Woo**

Three oral presentations examined zooplankton productivity around seamounts in offshore regions. The work by Dr. John Dower showed that much of the productivity in seamount benthic systems arises in the pelagic zone through overwintering zooplankton in deep waters. Dr. Réka Domokos showed that micronekton communities (an important food source for tuna) can be more abundant near seamounts, using acoustic surveys. Interestingly, her work also documented both horizontal and vertical migrations of micronekton around the seamount flanks, potentially exposing them to predation by fishes at the tops of seamounts. Both of these studies documented the ways in which seamount zooplankton productivity can be aggregated at seamounts. Dr. Daniel Labbé added to the theme of seamounts as productive features of the ocean floor by showing that for three seamounts off the coast of Canada the assemblages of zooplankton can differ, both in species composition and in the relative abundance of each species. In part this may be influenced by how close the seamounts are to the continental shelf. The fish fauna of seamounts was also explored through a series of presentations and posters. The potential for large-scale oceanographic patterns to influence seamount fish fauna was shown by Dr. Kota Sawada who demonstrated that basin-scale oceanography had a weak but significant effect on recruitment patterns for North Pacific armorhead. However, recruitment for this species is difficult to predict and measure given the strange life history of the species where it essentially stops growing upon settlement to benthic habitat on seamounts. Dr. Georgina Gibson used models of large-scale circulation patterns to demonstrate the potential for connectivity between sablefish populations on the coastal shelf and those at seamounts. Her work also demonstrated that in years of high sablefish recruitment (*e.g*. 2016) the circulation patterns were much different than in years with average or low recruitment. Two poster presentations also examined the fish fauna of seamounts, with a description of the biology of giant grenadier in the Bering Sea (an important component of seamount fish fauna, Alferov *et al*.) and an examination of the fish fauna from Koko seamount using bottom trawl survey data (Somov *et al*.).

The final topic addressed by presentations was the distribution and abundance of vulnerable marine ecosystems (VMEs) on seamounts in the North Pacific Ocean. Managing VMEs is an important topic in seamount ecology due to the risks to VMEs imposed by fishing and climate change, as well as the interaction of these two pressures. Two presentations (Georgian *et al*. and Rooper *et al*.) focused on methods for modeling the distribution and abundance of VMEs using environmental covariates. A presentation by Dr. Mai Miyamoto examined the species composition of deep sea corals and sponges in the Emperor Seamounts in the Northwest Pacific Ocean, by examining fisheries bycatch and underwater images. Dr. Miyamoto found that the most important (measured by abundance) species in the Emperor Seamounts tended to be Alcyonacean corals, while sponges were generally not as important in these areas. This was in contrast to the presentations on the Northeast Pacific Ocean seamounts which tended to have fauna dominated by sponges. A poster presentation by Dr. Ye Jin Jo also demonstrated the potential for identifying and measuring biodiversity of corals using a combination of ROV collected specimens and DNA sequencing of function genes in deep-sea corals. Dr. Janelle Curtis finished up the oral presentations by demonstrating a method to identify VMEs using data on species presence or absence and its relationship to biodiversity. This is an important advance, as it allows for a quantitative definition of what a VME is, rather than using simply the presence of VME indicator taxa.

Following the presentations, the workshop moved to discussing key topics related to predicting the distribution of taxa associated with seamounts. We began with a discussion of environmental factors that influence the ecology of seamounts. Dr. Samuel Georgian then presented a case study of predicting the distribution of corals in the Northeast Pacific Ocean as a first step to identifying VMEs.

Key environmental factors that were highlighted as being important for both species distribution models (SDMs) and for spatial management based on those SDMs included bathymetry data and geomorphological structures. Participants also discussed the value of including surface variables, such as chlorophyll a, as predictors in SDMs and considering how these variables may be important for different taxa. Many surface variables, including temperature, salinity, oxygen, phosphate, silicate, and nitrate, are available from the World Ocean Atlas and from PICES' Working Group on the *Biodiversity of Biogenic Habitats* (WG 32). Discussions of spatial scale of both modeling and species distributions were a highlight of the workshop. It was noted during the discussions that productivity variables, such as chlorophyll a do not vary on the small spatial scales at which many seamount taxa, including corals are distributed, so this raised questions about the importance of including these variables in SDMs of seamount taxa. Participants noted that we are not usually observing the environment or developing predictive models at a scale that is relevant to animals: what we can observe and what we predict are at different spatial scales. Over finer scales, multibeam bathymetry data could be coupled with interpolated World Ocean Atlas data to model the distributions of suitable habitat for species. Participants also noted that scale matters both horizontally and vertically (as evidenced by the presentation from Dr. Réka Domokos); some predictor variables do not vary considerably at the 100 km scale, but what might be very important for benthic species is what the environment is within 10 m of the seafloor. This disconnect may be more important when modeling climate change to identify refugia for benthic species, habitats and ecosystems.

Participants discussed the importance of flow patterns, including Taylor cones, around seamounts and their effects on deep scattering layers and the availability of food, including overwintering copepods. Food availability is an important variable for predicting the distribution of corals, so including variables related to turbulence, current stability and speed, and POC flux would improve SDMs of corals. Oceanography has an important role in driving species distributions on seamounts; even though water column variables may be similar over large spatial scales, turbulence at the seafloor is where most seamount species live. Participants discussed the potential value of sediment traps to measure POC and export flux on seamounts.

The implications of bentho-pelagic coupling and species interactions for SDMs were discussed at length. Plankton can be included in SDMs for benthic taxa. All of the presentations on zooplankton at seamounts demonstrated the linkages between pelagic productivity and the benthos. Participants noted that it is important to include ecological interactions among species such as predation and competition when developing predictive models. The consequence of not including these interactions is that their omission may lead to models that predict species occurrence in suboptimal habitat where they may be outcompeted by other species.

Participants discussed the importance of clearly communicating the uncertainty associated with model predictions, especially given the broader scale of explanatory variables that are often used to predict the distributions of species that are distributed over smaller scales. One of the challenges noted was that SDMs developed for seamount taxa are often modelled at high levels of taxonomic resolution (*e.g.*, orders of corals). Species that are grouped at higher levels of taxonomic resolution vary in their niche space, which can potentially increase the uncertainty associated with corresponding model predictions and lead to overpredictions where the suitable habitat of a taxonomic group is likely to be found. Moreover, the remote location of most seamounts means that only a few have been sampled, and most have not been randomly sampled. Participants discussed the construction and use of relatively cheap drop camera systems that could be launched from small boats down to depths of 1000 m. Having such equipment on hand could improve our ability to collect visual data from remote seamounts and could improve our ability to use a design-based approach to surveying seamounts. Participants discussed the value of monitoring variability among seamounts by sampling across many seamounts and monitoring a few sites over time. Although surveys are costly, seamounts are remote and subject to seasonal, interannual, and climate change; moorings and a small fleet of autonomous underwater vehicles could help monitor changes in chlorophyll a, temperature, microscale turbulence and other variables during the course of one or more years.

The impacts of climate change on zooplankton and the seamount communities is generally unknown; however, workshop participants were able to draw some broad conclusions regarding potential impacts in the future. Long-lived species, such as many corals, may be affected by climate change over short time scales. The capacity of corals to adapt to change is slow and the most important variable is POC flux or availability of food. Some climate models predict changes to the size structure and lipid content of zooplankton as well as to their production and ontogentic migration, which will in turn affect predators. There is also some evidence of increasing productivity on seamounts in the North Atlantic Ocean. Corals with more food may be able to cope with sub-optimal conditions, but if food availability is lower, they are less likely to adapt. The oxygen minimum zone is more anoxic and the upper layer is shoaling. As this zone continues to shoal, species that live on seamounts will begin to run out of space to interact with other species and persist. Uncertainty in climate projections is important to include and models differ in their degree of optimism. Species adaptation, acclimation, or dispersal of species is often ignored when projecting changes in response to climate change. Physiological studies can help build an archetype that can predict what is anticipated to happen to a group of species. It can also be helpful to publish a range of projected scenarios that can then be communicated to managers and the public.

Finally, we considered next steps for PICES' Working Group on *Ecology of Seamounts* (WG 47). A key next step for WG 47 was to compile more data on variables that are important for predicting the distribution of seamount taxa and existing data on areas where those taxa are present or absent. Indeed, participants acknowledged the importance of validating model predictions with visual observations collected with remotely operated vehicles (ROVs), drop cameras, or other camera systems. And ideally, we would be in a position to collect data that allowed us to understand mechanisms that influence species distributions instead of relying on predictive models.

(photo: Workshop participants, co-convenors and one of the invited speakers at PICES-2022).

2022 Report of Working Group 47 on *Ecology of Seamounts*

Dr. Janelle Curtis and Dr. Mai Miyamoto, the Co-Chairs of Working Group on *Ecology of Seamounts* (WG 47) convened an in-person meeting at PICES-2022 in Busan, Korea. The business meeting focused on introductions of national representatives and observers, discussions of WG 47's terms of reference and exchange of information and ideas about participants' seamount research activities.

The meeting was held on September 28, 2022 from 9:00am to 12:30pm. The meeting had a similar agenda to the two business meetings in 2021 (*WG 47 Endnote 1*). Seven participants (*WG 47 Endnote 2*), including five WG 47 members, and two colleagues from other PICES expert groups attended the meeting. Unfortunately, this was not a hybrid meeting, but one member who was unable to participate in PICES-2022 circulated some thoughts on one of the agenda items before this year's meeting.

AGENDA ITEM 3
Update from the FUTURE SSC

Dr. Thomas Therriault, on behalf of FUTURE SSC liaison, Dr. Jennifer Boldt, provided updates from the SSC, which is the committee for the FUTURE integrative Scientific Program to understand how marine ecosystems in the North Pacific respond to climate change and human activities, to forecast ecosystem status based on a contemporary understanding of how nature functions, and to communicate new insights to its members, governments, stakeholders and the public. WG 47 falls within the Marine Ecosystem element of their integrative schematic: see Scientific-Programs - PICES - North Pacific Marine Science Organization.

AGENDA ITEM 4
Introductions and review of members' expertise and research interests

Members from WG 47 and other PICES expert groups introduced themselves, their expertise and their research interests. WG 47 had a few changes in membership in 2022. Mr. Tatsuki Oshima, representing Japan, is a newly appointed member who replaced Dr. Hidetada Kiyofuji. Dr. Chris Rooper, representing Canada, has replaced Dr. Cherisse DuPreez who stepped down. Some participants of WG 47 shared an interest in the work of regional fisheries management organizations (RFMOs) on the identification of vulnerable marine ecosystems (VMEs) on seamounts. Dr. Seonock Woo gave an overview of her research on genomic assessment of deep-sea corals on seamounts in the West Pacific. Mr. Tatsuki Oshima gave an overview of his research on demersal and pelagic fish ecology. Dr. Patrick O'Hara (S-MBM) is actively engaged in research related to birds and mammals associated with seamounts, and expressed interest in collaborating with WG 47 members. Other participants were also interested in the spatial ecology of benthic organisms.

AGENDA ITEM 5
Review of WG 47 terms of reference

There has been a bit of a COVID lull and relatively slow progress on WG 47's terms of reference the past couple of years. At its meeting during PICES-2022, WG participants discussed their research interests and anticipated contributions to WG 47's terms of reference.

In Year 1, WG 47 proposed to: (1) gather data on the distribution and life history of species associated with seamounts in the North Pacific Ocean and facilitate their submission to appropriate biodiversity databases (*e.g*., OBIS), (2) gather data on key environmental variables hypothesized to influence the distribution and diversity of species associated with seamounts, (3) convene a 2-day workshop on modelling the distributions of seamount taxa and (4) convene a business meeting.

(1) Some participants anticipate contributing to the submission of life history and distribution data to biodiversity databases, including the Ocean Biodiversity Information System (OBIS) during the coming years. Dr. Curtis (Canada) specifically expressed an interest and ability to do so with data from two seamounts in the Northeast Pacific Ocean.

(2) Participants recognized the World Ocean Atlas data used by WG 32 (*Biodiversity of Biogenic Habitats*) have been updated and are available to WG 47, which will help members identify environmental and ecological predictors of the distribution and biodiversity of seamount taxa in the North Pacific Ocean and develop one or more species distribution models for seamount taxa. Those data may also be used to predict climate-induced changes in the distribution of seamount taxa during the coming years.

(3) WG 47's 2-day workshop (W1) on "*Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions*" was convened from September 24–25, 2022 by Dr. Janelle Curtis, Dr. Mai Miyamoto, Dr. Akash Sastri, Dr. Chris Rooper, and Dr. Samuel Georgian (PICES-2022). Some of the highlights of that workshop included discussions about the importance of considering bentho-pelagic coupling when predicting distributions of benthic taxa, including deep-sea corals and sponges. There was also considerable discussion of methods to identify vulnerable marine ecosystems (VMEs), and how best to model climate-induced changes in the distribution of seamount taxa.

(4) WG 47 held a business meeting at PICES-2021 on September 20, 2021.

In Year 2, WG 47 proposed to (1) identify environmental and ecological predictors of species associated with seamounts, (2) apply one or more modelling approaches to predict seamount species distributions, (3) use available climate projections to describe anticipated changes in species distributions, (4) convene a topic session on pelagic, demersal, and benthic seamount species, and (5) hold a business meeting.

(1) WG 47's 2-day workshop (W1) on "*Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions*" which was convened in September 2022 identified and discussed environmental and ecological predictors of species associated with seamounts and…

(2) reviewed a few case studies of modelling approaches to predict seamount species distribution. Some of the highlights of that workshop included discussions about the importance of considering bentho-pelagic coupling when predicting distributions of benthic taxa, including deep-sea corals and sponges. There was also considerable discussion of methods to identify VMEs, and…

(3) how best to model climate-induced changes in the distribution of seamount taxa.

(4) WG 47 proposed to convene a 1-day topic session on "*Seamount biodiversity: pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean*" at PICES-2023 in Seattle, USA (*WG 47 Endnote 3*).

(5) WG 47 held its annual meeting associated with PICES-2022. Participants also discussed WG 47's terms of reference for year 3.

AGENDA ITEM 6
Review of key scientific outputs

Participants discussed WG 47's anticipated scientific outputs and recognized that these would begin to take shape when the terms of reference in Years 1, 2, and 3 were completed. Dr. Alexei Orlov communicated by email before PICES-2022 to share links to two recently published papers dealing with descriptions of new fish species from the Emperor Seamounts. https://www.mdpi.com/2077-1312/10/1/65 and https://link.springer.com/article/10.1134/S0032945222020151. Dr. Orlov suggested that one significant output of WG 47 regarding fish diversity might be publishing an ichthyofauna overview of the Emperor Seamount area based on published literature and unpublished data. Dr. Orlov also suggested the WG members share information about upcoming research cruises as well as opportunities for members to take part in these participations.

WG 47 Endnote 1

WG 47 participation list

Members

Janelle Curtis (Canada, Co-Chair)
Mai Miyamoto (Japan, Co-Chair)
Tatsuki Oshima (Japan)
Seanock Woo (Korea)
Samuel Georgian (USA)

Members unable to attend

Canada: Anders Knudby, Chris Rooper
China: Jinhui Wang, Zijun Xu
Japan Kenji Taki,
Korea: Hye-Won Moon, Sung Yong Kim
Russia: Tatiana Dautova, Alexei Orlov
USA: Amy Baco-Taylor, Les Watling

Observers

Patrick O'Hara (Co-Chair, S-MBM)
Thomas Therriault (Chair, AP-NIS)

WG 47 Endnote 2

WG 47 meeting agenda

1. Welcome and opening remarks
2. Adoption of agenda and appointment of rapporteur
3. Update from the FUTURE SSC
4. Introductions and review of members' expertise and research interests
5. Review of WG47 terms of reference
6. Review of key scientific outputs (papers)
7. Other business

WG 47 Endnote 3

Proposal for a Topic Session on
"*Seamount biodiversity: pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean*"
at PICES-2023

Co-Convenors: Janelle Curtis (Canada), Mai Miyamoto (Japan), Samuel Georgian (USA) Akash Sastri (Canada), Chris Rooper (Canada)

Suggested Co-sponsor: North Pacific Fisheries Commission

Duration: ½ day

There are approximately 100,000 seamounts worldwide and their abundance is greatest in the North Pacific Ocean. The ecology of only a few has been studied, in part because of how deep and remote most seamounts are. The difficulty in studying the ecology of seamounts means that they are poorly understood habitats in terms of the pelagic, demersal, and benthic species that they support. These are unique habitats for deep-sea organisms and many seamounts are biodiversity hotspots with relatively high rates of endemism. They can host diverse communities of benthic filter feeders, including corals and sponges. The biodiversity of fishes is also high; almost 800 species of fish have been recorded from seamounts, representing half of the orders of fishes. As such, seamounts are important sources of food. New and readily available data can be integrated to better understand factors that influence the distribution and trends in seamount biodiversity, including those related to oceanic fronts and eddies and to future climate-change scenarios. This proposed topic session will focus on improving our understanding of seamount biodiversity. As such, it will lay the foundation for WG 47's activities to identify potential indicators for assessing and monitoring the biodiversity of pelagic, demersal, and benthic taxa associated with seamounts.

PICES-2023
October 23–27, 2023, Seattle, USA

Excerpted from:

Summary of Scientific Sessions and Workshops at PICES-2023

Session 14: BIO Topic Session

Seamount biodiversity: vulnerable marine ecosystems (VMEs) and species associated with seamounts in the North Pacific Ocean

Convenors:
Janelle Curtis (Canada), Mai Miyamoto (Japan, ECOP), Devon Warawa (Canada, ECOP), Sam Georgian (USA, ECOP), Akash Sastri (Canada), Chris Rooper (Canada)

Background

There are tens of thousands of seamounts worldwide and their abundance is greatest in the North Pacific Ocean. The ecology of only a few has been studied, in part because of how deep and remote most seamounts are. The difficulty in studying the ecology of seamounts means that they are poorly understood habitats in terms of the pelagic, demersal, and benthic species that they support. These are unique habitats for deep-sea organisms and many seamounts are biodiversity hotspots with relatively high rates of endemism. They can host diverse communities of benthic filter feeders, including corals and sponges. Some dense communities of biogenic organisms on seamounts are recognized as vulnerable marine ecosystems (VMEs), in part because they can support high biodiversity and provide critical habitats for socioeconomically important fishes and invertebrates that attract commercial fishing and other anthropogenic activities. The biodiversity of fishes is high on seamounts; almost 800 species of fish have been recorded from seamounts, representing half of the orders of fishes. As such, seamounts are important sources of food. New and readily available data can be integrated to better understand factors that influence the distribution and trends in seamount biodiversity, including those related to oceanic fronts and eddies and to future climate change scenarios. This proposed topic session will focus on improving our understanding of seamount biodiversity and exchanging ideas on methods to identify VMEs and areas likely to be VMEs. As such, it will lay the foundation for WG 47's activities to identify potential indicators for assessing and monitoring the biodiversity of pelagic, demersal, and benthic taxa associated with seamounts.

List of papers

Oral presentation

1. (Invited) Methods and challenges for identifying VMEs and monitoring biodiversity on seamounts: A personal perspective from the South Pacific Ocean. Ashley Rowden.
2. Association analysis of Seamount benthos for identifying the validity of VME indicator taxa based on scientific sampling survey. Mai Miyamoto, Masashi Kiyota.
3. Using visual surveys and distribution models to identify vulnerable marine ecosystems on seamounts in the North Pacific Fisheries Commission Convention Area. Devon R. Warawa, Janelle M. R. Curtis, Chris N. Rooper, Samuel Georgian, Jessica Nephin, Jackson W. F. Chu, Sarah Dudas, Anders Knudby.

4. Patterns of deepsea coral and sponge monitoring groups on Northeast Pacific seamounts: Management Implications. Megan A. Davies, Cherisse Du Preez, Amanda E. Bates.
5. Distribution, abundance and size structure of deep-sea corals and sponge communities on seamounts in international waters of the NE Pacific Ocean. Christopher N. Rooper, Pamela Goddard, Christina Conrath, Cynthia Wright, Kim Rand, Vanessa Lowe.
6. Monitoring cold-water corals and sponges in changing ocean conditions: a case study in the Canadian Pacific. Lindsay Clark, Cherisse Du Preez, Amanda E. Bates.
7. Bathyal biogeography of North Pacific seamounts. Les Watling.
8. Bathyal megafaunal assemblages of the Musicians Seamounts. Caroline Edmonds, Les Watling.
9. Spatial distribution and community structure of benthic megafauna from two seamounts in the northwest Pacific. Chailinn Park, Yujin Kim, Se-Jong Ju.
10. Environmental DNA as a potential tool for the understanding of demersal ichthyofauna in seamounts: A case study from the Emperor Seamounts area. Motoomi Yamaguchi, Kota Sawada, Yumiko Osawa, Mai Miyamoto, Bungo Nishizawa.
11. Coral biodiversity and genetic resources of West Pacific seamount, Godin Guyot. Seonock Woo, Yejin Jo.
12. Application of environmental DNA metabarcoding approach to reveal biodiversity of seamounts in the northwestern Pacific Ocean. Eun-Bi Kim, Youngtak Ko, Yeon Jee Suh.
13. (Cancelled) Fish biodiversity monitoring in extreme environments: A case study of fish in the Southern Ocean. Yehui Wang, Chunlin Liu, Mi Duan, Wenchao Zhang, Shuyang Ma, Jianchao Li, Jianfeng He, Yongjun Tian.
14. Flow around seamounts and larval retention: Revisiting the Taylor cone. Tetjana Ross, Cherisse Du Preez, Debby Ianson.
15. Variability in zooplankton biomass and nutritional quality above Northeast Pacific seamounts, with application to marine conservation efforts. Daniel M. Labbé, Akash R. Sastri, Cherisse Du Preez, Julian A.C. Smith, John F. Dower.

Poster presentation

1. The Microbial communities associated with the deep sea stalked barnacle. Seonock Woo,Won Gi Min and Jae Kyu Lim.
2. Habitat mapping to understand deep sea benthic communities and ecosystem. Won-Gi Min, Min-Su Woo and Dongsung Kim.
3. The first report of deep-sea scallop *Propeamussium investigatoris* (E. A. Smith, 1906) from the seamount OSM 9-1 in the Western Pacific. Jong-Seop Shin, Ki-Seong Hyeong, Kwang-Sik Choi.

2023 Annual Report of Working Group 47 on Ecology of Seamounts

Janelle Curtis and Mai Miyamoto, the co-chairs of Working Group on *Ecology of Seamounts* (WG 47) convened a virtual business meeting as well as an in-person hybrid business meeting at the PICES 2023 Annual Meeting in Seattle, USA. The business meeting focused on introductions of national representatives and observers, discussions of WG 47's terms of reference, and exchange of information and ideas about participants' seamount research activities.

The virtual business meeting was held on 14 September 2023 from 17:00–18:00 PDT (*WG 47 Endnote 2*) and there were five participants (*WG 47 Endnote 1*). The in-person hybrid meeting was held on 25 October from 14:00–17:30 PDT (*WG 47 Endnote 3*) and there were 14 participants (*WG 47 Endnote 4*), including eight WG 47 members, two colleagues from PICES Section on *Marine Birds and Mammals* (S-MBM), and three observers with expertise in seamount biodiversity. The meetings had similar agendas to the business meeting in 2022. The PICES Secretariat arranged for the business meeting in Seattle to be a hybrid meeting and one WG 47 member joined the meeting remotely, as did one of the members of the S-MBM.

Meeting participants introduced themselves after WG 47 co-chairs welcomed everyone and shared their opening remarks. Meeting participants adopted the agenda and Devon Warawa served as the meeting rapporteur. A few group photos were taken (*WG 47 Endnote 5*).

WG 47 had a few changes in membership since PICES-2022. Dr. Kota Sawada (Japan) is a new member of the WG 47 replacing Tatsuki Oshima (also from Japan). Kuidong Xu (China) is a new member of WG 47. Jinhui Wang (China) resigned from WG 47.

Agenda item 4: Update from PICES Future SSC

Jennifer Boldt provided updates from PICES FUTURE SSC, which is an integrative Scientific Program to understand how marine ecosystems in the North Pacific respond to climate change and human activities, to forecast ecosystem status based on a contemporary understanding of how nature functions, and to communicate new insights to its members, governments, stakeholders, and the public. WG 47 falls within the Marine Ecosystem element of their integrative schematic: see Scientific-Programs - PICES - North Pacific Marine Science Organization.

Agenda item 6: Presentations by members about their expertise, research interests, and contributions to achieving WG 47's Terms of Reference (ToR)

Most meeting participants on 25 October shared presentations about their research and contributions to achieving WG 47's ToR. Presentations were made by Janelle Curtis, Kota Sawada, Les Watling, Hye-Won Moon, Jae Kyu Lim, Won-Gi Min, Seonock Woo, Patrick O'Hara, Chris Rooper, and Amy Baco-Taylor to describe their research interest, expertise, and contributions to WG 47's ToR. Based on participant presentations, questions, and ensuing discussions, most of WG 47's ToR have been or will be addressed.

These are outlined in the table that follows.

Term year	ToR	Contributions to the ToR
Year 1	Gather data on the distribution and life history of pelagic, demersal, and benthic taxa, including fish and invertebrate assemblages associated with seamounts in the North Pacific Ocean and facilitate their submission to appropriate biodiversity databases, *e.g.*, Ocean Biogeographic Information System (OBIS).	***This ToR has been partially addressed***. Canada is submitting benthic data collected using an autonomous underwater vehicle (or AUV) and a remotely operated vehicle (or ROV) on Cobb Seamount in 2012 to Canada's Open Government Portal and to Ocean Biogeographic Information System (OBIS). Canada is also submitting benthic data collected with a drop camera along the Cobb-Eickelberg seamount chain in 2022. Les Watling is anticipating submitting data on benthic taxa from the Emperor Seamounts. Seonock Woo described deep sea coral bioinformatics data in Genbank that are shared as open data.
Year 1	Gather data on key environmental variables (*e.g.*, temperature, depth, steepness, substratum, current velocity, isolation, ocean acidification) hypothesized to influence the distribution and diversity of species associated with seamounts.	***This ToR has been addressed***. The World Ocean Atlas data that were compiled for use by PICES WG 32 on the Biodiversity of Biogenic Habitats a few years ago was updated by Samuel Georgian and is available to WG 47 members. Canada also collected oceanographic data along the Cobb-Eickelberg seamount chain in 2022.
Year 1	Convene a 2-day workshop on "Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions".	***This ToR was completed during PICES-2022:*** see PICES 2022 Annual Meeting - Program - PICES
Year 2	Identify environmental and ecological predictors of patterns in the distribution and biodiversity of pelagic, demersal, and benthic taxa associated with seamounts in the North Pacific Ocean.	***This ToR has been partially addressed*** by Canada for benthic seamount taxa along the Cobb-Eickelberg seamount chain in the Northeast Pacific Ocean.
Year 2	Apply one or more modeling approaches (*e.g.*, MaxEnt, Boosted Regression Trees, or high-resolution bathymetry-based models) to predict the distribution of pelagic, demersal, and benthic biodiversity associated with seamounts in the North Pacific Ocean.	***This ToR has been partially addressed*** by Canada for benthic seamount taxa in the Northeast Pacific Ocean. Specifically, Canada used MaxEnt in 2021 and ensemble models in 2022 to predict the distribution of VME indicator taxa along the Cobb-Eickelberg seamount chain in the Northeast Pacific Ocean. The ensemble model coupled a random forest, generalized additive model (GAM), and a boosted regression tree model. In 2023, a GAM model predicted the distribution of potential VMEs in the same area. Chris Rooper noted that guidelines and code for developing predictive habitat models, including random Forest (RF), Generalized Additive Models (GAM), Generalized Linear Models (GLM) and Boosted Regression Trees (BRT) are available through ICES.

Year 2	Use available data to predict climate induced changes in the distributions of seamount fauna.	***This ToR is not anticipated to be addressed*** because of a lack of capacity within WG 47.
Year 2	Convene a topic session on the pelagic, demersal, and benthic species associated with seamounts at the PICES Annual Meeting.	***This ToR was completed during PICES-2023***: see PICES 2023 Annual Meeting - Program - PICES
Year 3	Identify potential indicators for assessing and monitoring the biodiversity of pelagic demersal, and benthic taxa associated with seamounts.	***This ToR has been addressed partially*** by Canada for benthic seamount taxa in the Northeast Pacific Ocean. Specifically, a density of 0.6 North Pacific Fisheries Commission (NPFC) vulnerable marine ecosystem (VME) indicator taxa (stony corals, black corals, gorgonian and non-gorgonian soft corals, glass sponges, and demosponges) per m^2 are indicative of the presence of VMEs. Kota Sawada also noted that indicators that have been applied to other areas might also be applicable to seamounts. Amy Baco-Taylor noted that precious corals may be indicators of the effects of disturbance. Other participants noted that different suites of indicators may be appropriate for different seamounts (*e.g.*, shallow *vs* deep) and the size distribution of seamount taxa may indicate recruitment dynamics.
Year 3	Use cluster analysis and/or association analysis to review and document ecological interactions among seamount taxa.	***This ToR has been addressed partially.*** Janelle Curtis and Devon Warawa undertook an analysis of species richness associated with structurally complex habitats. Chris Rooper is undertaking association analysis with 2022 data from the Cobb-Eickelberg seamount chain and he suggested that it would be interesting to compare similar analyses on Cobb Seamount and in the Emperor Seamounts. Les Watling described his research defining large-scale biogeographic patterns and suggested he could contribute to multivariate analyses over broad scales of benthic organisms. Hye-Won Moon suggested that an assessment of functional diversity could be applied to any seamount and could inform this ToR.
Year 3	Prepare scientific reports for dissemination of results.	***This ToR is in progress.*** Canada published a series of working papers about seamounts in the Northeast Pacific Ocean to the North Pacific Fisheries Commission (NPFC) in 2021, 2022, and 2023. Most WG 47 members described primary papers or reports that address this ToR.

WG 47 convened two virtual business meetings in 2021, an in-person business meeting during PICES-2022 in Busan, Korea, and a hybrid meeting during PICES-2023 in Seattle, USA. WG 47's term was extended by one year by Governing Council in 2023. Thus, WG 47 anticipates its last business meeting during PICES-2024 before it completes its final report for PICES-2025.

Agenda Item 7. Requests or recommendations about WG 47 terms of reference (ToR)

Because WG 47 has one more year (2024) to complete its work, and there are a few outstanding ToR to complete, meeting participants agreed to recommend that Science Board change its ToR.

The first recommendation from WG 47 was to omit one of the outstanding ToR from Year 2: *Use available data to predict climate induced changes in the distributions of seamount fauna*. There is considerable interest among WG 47 members to undertake such analyses, but no participants at the meeting anticipated having the capacity to address this ToR before the end of WG 47's term in 2024.

Participants also recognized that the first ToR in Year 1, the first, second, and fourth ToR of Year 2, and the first ToR of Year 3 specify a focus on pelagic, demersal, ***and*** benthic taxa. But because most research and contributions by members have focused solely on benthic (and in some cases demersal) taxa, meeting participants recommended that the focus of those ToR change to pelagic, demersal, ***or*** benthic taxa.

Although PICES Science Board (SB) recommended those changes to WG 47's ToR, PICES Governing Council (GC) suggested that it would be more transparent to include details in the final report indicating which ToR could not be achieved and identifying the reasons. That information would be useful in guiding next steps for PICES work on seamounts.

Agenda Item 8: Review of key scientific outputs (papers)

Participants discussed WG 47's anticipated scientific outputs. Many outputs have been published and/or submitted already. Meeting participants were very enthusiastic about Hye-Won Moon's proposal to lead the writing of a joint WG 47 paper on functional diversity.

Agenda Item 9: Discussion about WG 47's final report

WG 47 members agreed to submit chapters, text, and images for the final report within a few months of WG 47's final business meeting during PICES-2024. Meeting participants agreed that readers would benefit from a list of recommendations for future work.

WG 47 Endnote 1

WG 47 virtual meeting (14 September 2023) participation list

Members
Janelle Curtis (co-chair, Canada)
Mai Miyamoto (co-chair, Japan)
Chris Rooper (Canada)
Kota Sawada (Japan)
Amy Baco-Taylor (USA)

Members unable to attend
Canada: Anders Knudby
China: Kuidong Xu, Zijun Xu Japan: Kenji Taki
Korea: Seonock Woo, Hye-Won Moon, Sung Yong Kim
Russia: Alexei Orlov, Tatiana Dautova
USA: Samuel Georgian, Les Watling

WG 47 Endnote 2

Agenda for WG 47's virtual meeting on 14 September 2023, 17:00-18:00 PDT

1. Welcome and opening remarks
2. Review achievements of WG 47 against the Terms of Reference (WG 47 ToR)
3. Requests/proposals to the Biological Oceanography Committee and Science Board.

WG 47 Endnote 3

Agenda for WG 47's hybrid meeting on 25 October 2023

1. Welcome and opening remarks
2. Introductions
3. Group Photo
4. Update from Future SSC
5. Adoption of agenda and appointment of rapporteur
6. Presentations by members about their expertise, research interests, and contributions to achieving WG 47's Terms of Reference
7. Requests or Recommendations to SB about WG 47 terms of reference (ToR)
8. Review of key scientific outputs (papers)
9. Discussion of WG 47's Final Report
10. Other business

WG 47 Endnote 4

WG 47 hybrid meeting (25 October 2023) participation list

Members
Janelle Curtis (co-chair, Canada)
Mai Miyamoto (co-chair, Japan)
Chris Rooper (Canada)
Kota Sawada (Japan)
Seonock Woo (Korea)
Hye-Won Moon (Korea)
Amy Baco-Taylor (USA)
Les Watling (USA)

Members unable to attend
Canada: Anders Knudby
China: Kuidong , Zijun Xu Japan: Kenji Taki
Korea: Sung Yong Kim
Russia: Alexei Orlov, Tatiana Dautova
USA: Samuel Georgian

Observers
Jennifer Boldt (PICES Future-SSC)
Patrick O'Hara (PICES S-MBM)
Ken Morgan (PICES S-MBM)
Devon Warawa (NPFC)
Jae Kyu Lim (Korea)
Won-gi Min (Korea)

WG 47 Endnote 5

WG 47 hybrid meeting (25 October 2023) photo of participants. From left to right on the screen (virtual participants): Ken Morgan and Amy Baco-Taylor. From left to right (back row): Won-gi Min, Patrick O'Hara, Kota Sawada, Les Watling, and Hye-Won Moon. From left to right (bottom row): Jae Kyu Lim, Seanock Woo, Devon Warawa, Janelle Curtis, Chris Rooper, and Mai Miyamoto (photo by Jennifer Boldt).

WG 47 co-chairs, Janelle Curtis (left) and Mai Miyamoto (right), during BIO Topic Session 14: *Seamount biodiversity: vulnerable marine ecosystems (VMEs) and species associated with seamounts in the North Pacific Ocean* (photo by Kota Sawada).

PICES-2024
October 26–November 1, 2024, Honolulu, USA

2024 Report of Working Group on Ecology of Seamounts (WG 47)

Janelle Curtis and Mai Miyamoto, the Co-Chairs of Working Group on *Ecology of Seamounts* (WG 47) convened a virtual business meeting as well as an in-person hybrid business meeting at the PICES 2024 Annual Meeting in Honolulu, USA. The business meetings focused on introductions of national representatives and observers, discussions of WG 47's terms of reference, exchange of information and ideas about participants' seamount research activities, and preparation of WG 47's final report.

The virtual business meeting was chaired by Janelle Curtis, held on 23 September 2024 from 17:00-18:00pm PDT (*WG 47 Endnote 2*), and there were three participants (*WG 47 Endnote 1*). The in-person hybrid meeting was chaired by Janelle Curtis, held on 31 October from 8:50am–12:30pm HST (*WG 47 Endnote 2*) and there were 14 participants (*WG 47 Endnote 1*), including nine WG 47 members, one colleague from PICES FUTURE Program, one colleague from the PICES Secretariat, and two observers with expertise in the identification of vulnerable marine ecosystems (VMEs) on seamounts in the North Pacific Fisheries Commission's (NPFC) Convention Area. The meetings had similar agendas to the business meetings in 2022 and 2023, although there was also a focus on preparation of WG 47's final report in 2025. The PICES Secretariat arranged for the business meeting in Honolulu to be a hybrid meeting and one WG 47 member joined the meeting virtually.

During both meetings, participants introduced themselves after WG 47 co-chair(s) welcomed everyone and shared their opening remarks. Meeting participants adopted the agenda at both meetings. A group photo was taken during the hybrid meeting on 31 October 2024 (*WG 47 Endnote 3*).

Dr. Satoi Arai (Japan) is a new member of WG 47 since the 2023 PICES meeting in Seattle.

Virtual meeting on 23 September 2024

AGENDA ITEM 2
Review achievements of WG47 against the Terms of Reference (WG47 TOR: https://meetings.pices.int/members/working-groups/wg47)

Meeting participants reviewed primary papers and other working papers that could be cited as evidence that WG 47's TOR have been addressed.

AGENDA ITEM 3
Discuss any requests/proposals to the Biological Oceanography Committee and Science Board

No requests or proposals were identified during this meeting.

AGENDA ITEM 4
Identify relevant primary papers that have or will be completed, and if authors need financial support for open-access publications

Although Alexei Orlov was unable to participate in the meeting, he let participants know of his co-authoring of two primary papers that focus on the distribution and biology of *Coelorhinchus gilberti* (Macrouridae, Gadiformes, Teleostei) from longline catches off the Emperor Seamounts, and a review of Soviet/Russian fisheries off the Emperor Seamounts.

AGENDA ITEM 5
Other Business

Participants discussed the formatting and content of WG 47's final report and agreed to discuss this in more detail at the hybrid meeting during PICES-2024.

Hybrid meeting on 31 October 2024

AGENDA ITEM 2
Update on FUTURE (Jennifer Boldt)

Jennifer Boldt provided updates from PICES FUTURE SSC, which is an integrative Scientific Program to understand how marine ecosystems in the North Pacific respond to climate change and human activities, to forecast ecosystem status based on a contemporary understanding of how nature functions, and to communicate new insights to its members, governments, stakeholders, and the public.

AGENDA ITEM 3
Preparation of a PICES Fact Sheet for WG 47 (Devon Warawa)

Devon Warawa provided information about how WG 47 will prepare a Fact Sheet about its work. In response to questions from participants, Devon clarified that she would work with WG 47 to prepare a Fact Sheet before WG 47 submits its final report.

AGENDA ITEM 4
Update on member research and activities related to WG 47 TOR

Some of the WG 47 members updated others on research activities related to WG 47's TOR and there were thoughtful comments and questions from meeting participants. As examples, Janelle Curtis updated participants on her program's work to use visual data to identify vulnerable marine ecosystems (or VMEs) on Cobb Seamount and predict the distribution of likely VMEs throughout the Cobb-Eickelberg Seamount Chain. Kota Sawada summarized his research with e-DNA and cameras on splendid alfonsino and North Pacific armorhead on the Emperor Seamount Chain. Mai Miyamoto described her research on sea-floor visual observation survey to determine the distribution of VME indicator species in the northern fishing area of Emperor Seamounts. And Amy Baco-Taylor described some of her research on the genetics and abundances of coral taxa on fished and unfished seamounts in the Emperor Seamount

Chain and North Hawaiian Ridge. Les Watling also presented some of his research. Although Chris Rooper wasn't able to participate in this meeting, he did let participants know that he spent a few weeks surveying seamounts with randomly placed drop camera transects down to about 850 m in depth on seamounts in the Cobb-Eickelberg Seamount Chain.

AGENDA ITEM 5
Report on Deep Ocean Stewardship Initiative (DOSI) Seamount Science Summit (Les Watling)

Les Watling provided an update on the Deep Ocean Stewardship Initiative's (DOSI) Seamount Science Summit that was convened in Honolulu just before PICES-2024 began. Four members of WG 47 (Les Watling, Amy Baco-Taylor, Chris Rooper and Janelle Curtis) participated in that seamount summit. Don Kobayashi, one of the observers during WG 47's business meeting, also participated in DOSI's Seamount Science Summit. Janelle Curtis was invited to the summit specifically to update DOSI members on the workplans of WG 47 and the North Pacific Fisheries Commission's (NPFC) Scientific Committee. There were also discussions about WG 47 including a proposal for a new working group to focus on VMEs and/or significant adverse impacts (SAI) on seamounts and the potential for merging a new PICES working group on seamounts with an NPFC scientific group.

AGENDA ITEM 6
Discussion of collaboration on primary papers

There was no discussion of collaboration on primary papers.

AGENDA ITEM 7
Discussion of preparation of WG47's final report, including recommendations for future research

WG 47 members discussed their contributions to achieving WG 47 TOR, including making data available through the Ocean Biodiversity Information System (OBIS https://obis.org/), the Government of Canada Open Data Portal (Cobb Seamount Visual Survey 2012 (AUV) - Open Government Portal, Cobb Seamount Visual Survey 2012 (ROV) - Open Government Portal), and data in the supplemental sections of primary papers. Members also identified potential publications to cite related to indicators for assessing seamount biodiversity and data that could potentially be used to document ecological interactions among seamount taxa.

Topics related to one or more proposals for a new PICES working group were explored again. Apart from a proposal for a new working group to focus on VMEs and/or significant adverse impacts (SAI) on seamounts, participants expressed an interest in a working group that was able to focus on life history of seamount taxa, with an emphasis on reproduction and connectivity, and a better integration of biology and physics. Another topic to explore was the improvement of science communication with stakeholders and the general public.

Members also agreed on a general timeline for preparing and submitting WG 47's final report in the spring of 2025.

WG 47 Endnote 1

WG 47 virtual meeting (23 September 2024) participation list

Members
Janelle Curtis (Co-Chair, Canada)
Kota Sawada (Japan)
Hye-Won Moon (Korea)

Members unable to attend
Canada: Anders Knudby, Chris Rooper
China: Kuidong Xu, Zijun Xu
Japan: Satoi Arai, Mai Miyamoto, Kenji Taki
Korea: Seonock Woo, Sung Yong Kim
Russia: Alexei Orlov, Tatiana Dautova
USA: Amy Baco-Taylor, Samuel Georgian, Les Watling

WG 47 hybrid meeting (31 October 2024) participation list

Members
Janelle Curtis (Co-Chair, Canada)
Mai Miyamoto (Co-Chair, Japan)
Satoi Arai (Japan)
Kota Sawada (Japan)
Sung Yong Kim (Korea)
Hye-Won Moon (Korea)
Seonock Woo (Korea)
Amy Baco-Taylor (USA)
Les Watling (USA)

Members unable to attend virtual and/or hybrid meetings
Canada: Anders Knudby, Chris Rooper
China: Kuidong Xu, Zijun Xu
Japan: Kenji Taki
Russia: Tatiana Dautova, Alexei Orlov
USA: Samuel Georgian

Observers
Don Kobayashi (USA)
Hiroe Yutaka (Japan)
Alex Zavolokin (NPFC)

PICES
Jennifer Boldt (FUTURE)
Devon Warawa (PICES Secretariat)

WG 47 Endnote 2

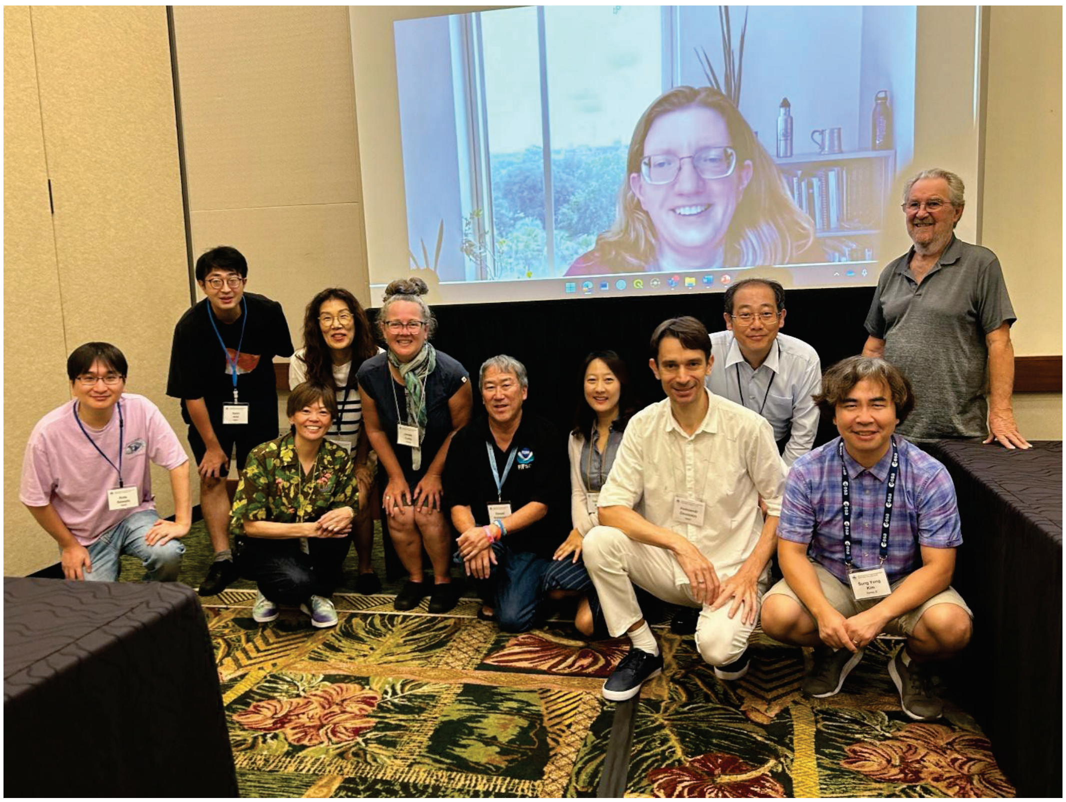
WG 47 meeting agenda (virtual meeting on 23 September 2024, 17:00-18:00 PDT)

1. Welcome and opening remarks
2. Review achievements of WG 47 against the Terms of Reference (WG47 TOR: working- groups - PICES - North Pacific Marine Science Organization)
3. Discuss any requests/proposals to the Biological Oceanography Committee and Science Board.
4. Identify relevant primary papers that have or will be completed, and if authors need financial support for open-access publication(s).
5. Other business.

WG 47 meeting agenda (hybrid meeting on 31 October 2024)

1. Round of introductions and group photo
2. Update on FUTURE (Jennifer Boldt)
3. Preparation of a PICES Fact Sheet for WG 47 (Devon Warawa)
4. Updates on member research and activities related to WG 47 TOR
5. Break – 10:15am to 10:50am
6. Report on Deep Ocean Stewardship Initiative (DOSI) Seamount Science Summit (Les Watling)
7. Discussion of collaboration on primary papers
8. Discussion of preparation of WG 47's final report, including recommendations for future research

WG 47 Endnote 3



WG 47 hybrid meeting (31 October 2024) photo of participants. On the screen (virtual participant): Amy Baco-Taylor. From left to right in person: Kota Sawada, Satoi Arai, Mai Miyamoto, Seonock Woo, Janelle Curtis, Don Kobayashi, Hye-Won Moon, Alex Zavolokin, Hiroe Yutaka, Sung Yong Kim, and Les Watling.

WG 47 Endnote 4

Working Group Achievement against TORs

* This information was submitted to SB-2024

List of TOR Items	How did you achieve the TOR items?
Year 1: Gather data on the distribution and life history of pelagic, demersal, and benthic taxa, including fish and invertebrate assemblages associated with seamounts in the North Pacific Ocean and facilitate their submission to appropriate biodiversity databases, *e.g*., Ocean Biogeographic Information System (OBIS)	Canada has autonomous underwater vehicle (AUV) and remotely operated vehicle (ROV) data from Cobb Seamount in international waters that were recently published on Canada's Open Government Portal. So those two datasets are now publicly available.
Year 1: Gather data on key environmental variables (*e.g*., temperature, depth, steepness, substratum, current velocity, isolation, ocean acidification) hypothesized to influence the distribution and diversity of species associated with seamounts.	Sam Georgian updates the World Ocean Atlas data that Working Group 32 on the *Biodiversity of Biogenic Habitats* used to predict the distributions of benthic taxa. These environmental data are now available throughout the North Pacific Ocean, and available for use in analyses or predictive models of seamount taxa.
Year 1: Convene a 2-day workshop on "Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions".	This 2-day workshop was convened during PICES-2022 in Busan, Korea.
Year 2: Identify environmental and ecological predictors of patterns in the distribution and biodiversity of pelagic, demersal, and benthic taxa associated with seamounts in the North Pacific Ocean.	Analyses suggest that dissolved oxygen, photosynthetically active radiation, Omega calcite, and particulate organic carbon were correlated with and potentially influence the predicted habitat suitability of black corals. Analyses also suggest that sea surface temperature, roughness, chlorophyll-A, and current velocity are correlated with the habitat suitability of stony corals. Slope, eastness, omega calcite and Chlorophyll-A are correlated with the habitat suitability of gorgonian corals, and the habitat suitability of other soft corals is correlated with roughness, chlorophyll-A, and topographic Position Index.
Year 2: Apply one or more modeling approaches (*e.g*., MaxEnt, Boosted Regression Trees, or high- resolution bathymetry-based models) to predict the distribution of pelagic, demersal, and benthic biodiversity associated with seamounts in the North Pacific Ocean.	WG 47 built MaxEnt models that did not include any true absence data. These have since been updated to include absence data from NOAA and DFO trawls surveys. Sam Georgian also constructed ensemble models using Random Forest, Boosted Regression Trees, and Generalized Additive Models (or GAMs) for black corals, stony corals, and gorgonian and non-gorgonian soft corals. Canada has also predicted the distribution of areas that are likely to be VMEs in the Cobb-Eickelberg Seamount Chain in the Northeast Pacific Ocean using a generalized additive model or a GAM.

Year 2: Use available data to predict climate induced changes in the distributions of seamount fauna.	This term of reference (TOR) will not be completed by WG 47 because of limited data, capacity and expertise within our group.
Year 2: Convene a topic session on the pelagic, demersal, and benthic species associated with seamounts at the PICES Annual Meeting	This topic session was held during PICES-2023 in Seattle.
Year 3: Identify potential indicators for assessing and monitoring the biodiversity of pelagic demersal, and benthic taxa associated with seamounts.	WG 47 members concluded that the density of North Pacific Fisheries Commission indicators (corals and sponges) can be used to identify vulnerable marine ecosystems (VMEs) on seamounts. Members also agreed that eDNA can also be used to assess and monitor seamount biodiversity.
Year 3: Use cluster analysis and/or association analysis to review and document ecological interactions among seamount taxa.	Canada undertook a cluster analysis of species associated with structurally complex habitats, or what was identified as VMEs based on the density of structure forming deep sea corals. Compared was the community of species that are associated with those structure-forming corals and the community of species not associated with those deep-sea corals. The two communities are significantly different from each other in terms of both the number and type of species.
Year 1–3: Annual WG business meetings, both virtual meetings and those in association with the PICES Annual Meeting	Annual business meetings were held virtually in 2021 and 2022, in person during PICES-2022 and 2023 and virtually on 23 September 2024.

Appendix 4

PICES Press Article Related to WG 47

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PICES-2022 W1: Distributions of pelagic, demersal, and benthic species associated with seamounts in the North Pacific Ocean and factors influencing their distributions.

Co-convenors: Janelle Curtis, Mai Miyamoto, Akash Sastri, Chris Rooper, and Samuel Georgian

W1 Convenors with their invited speaker. L-R: Akash Sastri, Janelle Curtis, Temlo Morato, Samuel Georgian, Mia Miamoto.

PICES' Working Group on Ecology of Seamounts (WG47) convened a 2-day workshop from 24-25 September 2022 to explore questions around biodiversity associated with seamounts in the North Pacific Ocean and factors influencing their distributions. There are tens of thousands of seamounts worldwide and their abundance is greatest in the North Pacific Ocean. Few seamounts have been extensively studied due to their occurrence at deep depths of remote regions of the oceans and the resulting difficulty in accessing these habitats. Thus, the ecology of most seamounts is poorly understood in terms of the pelagic, demersal, and benthic species that they support.

The primary aims of the workshop were to:

- Identify and understanding factors influencing the diversity and distributions of species associated with seamounts in the North Pacific Ocean.
- Build capacity to develop predictive habitat models for seamount species.
- Consider how seamount species distributions are likely to respond to natural and anthropogenic forcing, including climate change.

Over the course of two days, we had participants from Canada, Japan, Korea, Portugal, and the USA join us in person, and another six participants from Canada and the USA join us remotely to present and discuss their work on seamount ecology. It was fortunate that the PICES Secretariat and the Korean Institute of Ocean Science and Technology (KIOST) were able to assist us in conducting this hybrid workshop as one of our co-conveners and three speakers were not able to join us in person. We were also grateful to Dr. Samuel Georgian for leading much of our discussion as an unofficial co-convenor.

The workshop was divided into three main topics: a series of oral and poster presentations on seamount ecology, case studies of particular topics on predictive modeling of seamount taxa and discussions of emerging issues that were inspired by the presentations and case studies.

Our workshop began with an informative presentation by our invited expert, **Telmo Morato**, from the Okeanos Research Institute of the University of the Azores in Portugal: *Improved deep-sea biodiversity assessments inform sustainable management of seamount and other geomorphologic features in a changing planet: Lessons learned from the North Atlantic.* A number of speakers and participants have an interest in the identification of vulnerable marine ecosystems (VMEs), which often comprise populations of corals, sponges, and other benthic taxa. Telmo contributed significantly to our discussions and has undoubtedly inspired colleagues to explore seamounts and the intersection between seamount research and policy.

Telmo's influential talk was followed by 9 oral presentations:

- **John Dower:** *Oceanographic influences on biological production and energy transfer in seamount ecosystems.*
- **Daniel Labbé:** *Investigating seamount effects on zooplankton in the Northeast Pacific.*
- **Réka Domokos:** *Seamount effects on micronekton at a subtropical central Pacific seamount.*
- **Georgina Gibson:** *Can Gulf of Alaska seamounts be a spawning ground for sablefish recruiting to inshore nursery habitats?*
- **Kota Sawada:** *Biology and fisheries of North Pacific armorhead and splendid alfonsino in the SE-NHR area.*
- **Samuel Georgian:** *Species Distribution Modeling to Identify and Protect Vulnerable Marine Ecosystems: Case Studies from the South Pacific Ocean.*
- **Chris Rooper:** *Using species distribution modeling to predict deep-sea coral and sponge communities, hotspots, diversity and indicators.*
- **Mai Miyamoto:** *Composition of cold-water corals and other deep-sea benthos in the Emperor Seamounts.*
- **Janelle Curtis:** *Using predictive habitat models and visual surveys to identify vulnerable marine ecosystems (VMEs) on seamounts in the North Pacific Fisheries Commission's Convention Area.*

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3 posters were also presented as part of this workshop:

- **Alexey Somov, Albina Kanzeparova, Svetlana Orlova, Denis Kurnosov, Vladimir Belyaev, and Alexei Orlov:** *Features of spatial distribution of dominant groundfish species on the Koko Seamount (Emperor Seamounts) in 2019.*
- **Andrey Alferov:** *Distribution of giant grenadier (Albatrossia pectoralis) at different stages of ontogenesis in the Bering Sea.*
- **Yejon, Sung-jin Hwang, and Seonock Woo:** *Genetic resources of deep-sea corals from seamounts in West Pacific by de novo RNA sequencing.*

Three oral presentations examined zooplankton productivity around seamounts in offshore regions. The work by Dr. John Dower showed that much of the productivity in seamount benthic systems arises in the pelagic zone through overwintering zooplankton in deep waters. Dr. Réka Domokos showed that micronekton communities (an important food source for tuna) can be more abundant near seamounts using acoustic surveys. Interestingly, her work also documented both horizontal and vertical migrations of micronekton around the seamount flanks, potentially exposing them to predation by fishes at the tops of seamounts. Both of these studies documented the ways in which seamount zooplankton productivity can be aggregated at seamounts. Dr. Daniel Labbé added to the theme of seamounts as productive features of the ocean floor by showing that for three seamounts off the coast of Canada the assemblages of zooplankton can differ, both in species composition and in the relative abundance of each species. In part this may be influenced by how close the seamounts are to the continental shelf.

Photo: Fisheries and Oceans Canada

The fish fauna of seamounts was also explored through a series of presentations and posters. The potential for large scale oceanographic patterns to influence seamount fish fauna was shown by Dr. Kota Sawada who demonstrated that basin-scale oceanography had a weak but significant effect on recruitment patterns for North Pacific Armorhead. However, recruitment for this species is difficult to predict and measure given the strange life history of the species where it essentially stops growing upon settlement to benthic habitat on seamounts. Dr. Georgina Gibson used models of large scale circulation patterns to demonstrate the potential for connectivity between sablefish populations on the coastal shelf and those at seamounts. Her work also demonstrated that in years of high sablefish recruitment (e.g. 2016) the circulation patterns were much different than in years with average or low recruitment. Two poster presentations also examined the fish fauna of seamounts, with a description of the biology of giant grenadier in the Bering Sea (an important component of seamount fish fauna, Alferov et al.) and an examination of the fish fauna from Koko seamount using bottom trawl survey data (Somov et al.). The final topic addressed by presentations was the distribution and abundance of vulnerable marine ecosystems (VMEs) on seamounts in the North Pacific Ocean. Managing VMEs is an important topic in seamount ecology due to the risks to VMEs imposed by fishing and climate change, as well as the interaction of these two pressures. Two presentations (Georgian et al., and Rooper et al.) focused on methods for modeling the distribution and abundance of VMEs using environmental covariates. A presentation by Dr. Mai Miyamoto examined the species composition of deep sea corals and sponges in the Emperor Seamounts in the northwest Pacific Ocean, by examining fisheries bycatch and underwater images. Dr. Miyamoto found that the most important (measured by abundance) species in the Emperor seamounts tended to be Alcyonacean corals, while sponges were generally not as important in these areas. This was in contrast to the presentations on the northeast Pacific Ocean seamounts which tended to have fauna dominated by sponges. A poster presentation by Dr. Ye Jin Jo also demonstrated the potential for identifying and measuring biodiversity of corals using a combination of ROV collected specimens and DNA sequencing of function genes in deep-sea corals. Dr. Janelle Curtis finished up the oral presentations by demonstrating a method to identify VMEs using data on species presence or absence and its relationship to biodiversity. This is an important advance, as it allows for a quantitative definition of what a VME is, rather than using simply the presence of a VME indicator taxa.

Following the presentations, the workshop moved to discussing key topics related to predicting the distribution of taxa associated with seamounts. We began with a discussion of environmental factors that influence the ecology of seamounts. Dr. Samuel Georgian then presented a case study of predicting the distribution of corals in the northeast Pacific Ocean as a first step to identifying VMEs.

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Key environmental factors that were highlighted as being important for both species distribution models (SDMs) and for spatial management based on those SDMs included bathymetry data and geomorphological structures. Participants also discussed the value of including surface variables, such as chlorophyll-a, as predictors in SDMs and considering how these variables may be important for different taxa. Many surface variables, including temperature, salinity, oxygen, phosphate, silicate, and nitrate, are available from the World Ocean Atlas and from PICES' Working Group on the Biodiversity of Biogenic Habitats (WG32).

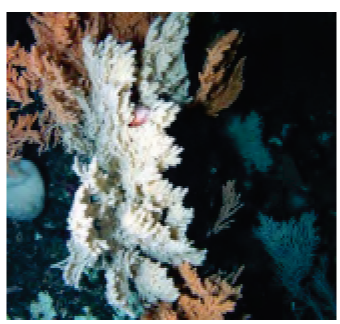
Discussions of spatial scale of both modeling and species distributions were a highlight of the workshop. It was noted during the discussions that productivity variables, such as chlorophyll a do not vary on the small spatial scales at which many seamount taxa, including corals are distributed, so this raised questions about the importance of including these variables in SDMs of seamount taxa. Participants noted that we are not usually observing the environment or developing predictive models at a scale that is relevant to animals: what we can observe and what we predict are at different spatial scales. Over finer scales, multibeam bathymetry data could be coupled with interpolated World Ocean Atlas data to model the distributions of suitable habitat for species. Participants also noted that scale matters both horizontally and vertically (as evidenced by the presentation from Dr. Réka Domokos); some predictor variables do not vary considerably at the 100 km scale, but what might be very important for benthic species is what the environment is within 10 m of the seafloor. This disconnect may be more important when modeling climate change to identify refugia for benthic species, habitats and ecosystems.

Participants discussed the importance of flow patterns, including Taylor cones, around seamounts and their effects on deep scattering layers and the availability of food, including overwintering copepods. Food availability is an important variable for predicting the distribution of corals, so including variables related to turbulence, current stability and speed, and POC flux would improve SDMs of corals. Oceanography has an important role in driving species distributions on seamounts; even though water column variables may be similar over large spatial scales, turbulence at the seafloor is where most seamount species live. Participants discussed the potential value of sediment traps to measure POC and export flux on seamounts.

The implications of bentho-pelagic coupling and species interactions for SDMs were discussed at length. Plankton can be included in SDMs for benthic taxa. All of the presentations on zooplankton at seamounts demonstrated the linkages between pelagic productivity and the benthos. Participants noted that it is important to include ecological interactions among species such as predation and competition when developing predictive models. The consequence of not including these interactions is that their omission may lead to models that predict species occurrence in sub-optimal habitat where they may be outcompeted by other species.

Participants discussed the importance of clearly communicating the uncertainty associated with model predictions, especially given the broader scale of explanatory variables that are often used to predict the distributions of species that are distributed over smaller scales. One of the challenges noted was that SDMs developed for seamount taxa are often modelled at high levels of taxonomic resolution (e.g. orders of corals). Species that are grouped at higher levels of taxonomic resolution vary in their niche space, which can potentially increase the uncertainty associated with corresponding model predictions and lead to overpredictions where the suitable habitat of a taxonomic group is likely to be found. Moreover, the remote location of most seamounts means that only a few have been sampled, and most have not been randomly sampled. Participants discussed the construction and use of relatively cheap drop camera systems that could be launched from small boats down to depths of 1000 m. Having such equipment on hand could improve our ability to collect visual data from remote seamounts and could improve our ability to use a design-based approach to surveying seamounts. Participants discussed the value of monitoring variability among seamounts by sampling across many seamounts and monitoring a few sites over time. Although surveys are costly, seamounts are remote and subject to seasonal, interannual, and climate change, moorings and a small fleet of autonomous underwater vehicles could help monitor changes in chlorophyll a, temperature, microscale turbulence and other variables during the course of one or more years.

The impacts of climate change on zooplankton and the seamount communities is generally unknown, however workshop participants were able to draw some broad conclusions regarding potential impacts in the future.



Long-lived species, such as many corals, may be affected by climate change over short time scales. The capacity of corals to adapt to change is slow and the most important variable is POC flux or availability of food. Some climate

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models predict changes to the size structure and lipid content of zooplankton as well as to their production and ontogentic migration, which will in turn affect predators. There is also some evidence of increasing productivity on seamounts in the North Atlantic Ocean. Corals with more food may be able to cope with sub-optimal conditions, but if food availability is lower, they are less likely to adapt. The oxygen minimum zone is more anoxic and the upper layer is shoaling. As this zone continues to shoal, species that live on seamounts will begin to run out of space to interact with other species and persist. Uncertainty in climate projections is important to include and models differ in their degree of optimism. Species adaptation, acclimation, or dispersal of species is often ignored when projecting changes in response to climate change. Physiological studies can help build an archetype that can predict what is anticipated to happen to a group of species. It can also be helpful to publish a range of projected scenarios that can then be communicated to managers and the public.

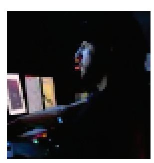
Finally, we considered next steps for PICES' Working Group on Ecology of Seamounts (WG47). A key next step for WG47 was to compile more data on variables that are important for predicting the distribution of seamount taxa and existing data on areas where those taxa are present or absent. Indeed, participants acknowledged the importance of validating model predictions with visual observations collected with remotely operated vehicles (ROVs), drop cameras, or other camera systems. And ideally, we would be in a position to collect data that allowed us to understand mechanisms that influence species distributions instead of relying on predictive models.

Janelle Curtis is a research scientist in ecological modelling at Fisheries and Oceans Canada's Pacific Biological Station. Her research focuses on identifying vulnerable marine ecosystems (VMEs) on seamounts and assessing the relative risk of significant adverse impacts (SAIs) on VMEs in the northeast part of the North Pacific Fisheries Commission's (NPFC) Convention Area. She is currently chair the NPFC's Scientific Committee and Co-Chair PICES' Working Group on Ecology of Seamounts (WG47). When she's not undertaking research on seamounts, she edits two publications by the Alpine Club of Canada's Vancouver Island Section, which has a special interest in landmounts.

Dr. Akash Sastri is a Research Scientist with Fisheries and Oceans Canada at the Institute of Ocean Sciences in Sidney, BC, where he leads the Plankton Ecology program. He has a background in biological oceanography with a focus on the roles of marine plankton communities in changing environments. His Ph.D. thesis at the University of Victoria focused on the development and application of novel ways to measure zooplankton productivity routinely at sea. In PICES he is the Chair of the Biological Oceanography Committee (BIO), a member of Working Group on Towards best practices using Imaging Systems for Monitoring Plankton (WG48) and the Advisory Panel on North Pacific Coastal Ocean Observing Systems (AP-NPCOOS).

Mai Miyamoto is an environmental consultant working on marine environment and fisheries issues. Her research focuses on deep-sea coral species identification, analysis of the spatial distribution of VMEs, and SAI assessment of fishing grounds in the Emperor Seamounts of the northwest part of NPFC Convention Area. She received her PhD in Marine Science from Tokyo University of Marine Science and Technology in 2017. In PICES, she is currently the Co-Chair of the Working Group on the Ecology of Seamounts (WG47). She enjoys SCUBA diving on her days off.

Dr. Chris Rooper is a Research Scientist with Fisheries and Oceans Canada in the Stock Assessment and Research Division at the Pacific Biological Station in Nanaimo, British Columbia. His research interests are in the function of habitats for fishes, particularly rockfishes and deep-sea corals and sponges, using a combination of in situ studies with underwater cameras and regional scale modeling. In PICES, he is a member of the Working Group (WG47) on Ecology of Seamounts, the PICES-ICES Joint Working Group on Small Pelagic Fish (WG43) and the FIS Committee.



Samuel Georgian is a spatial ecologist working at Marine Conservation Institute, a non-profit organization dedicated to securing permanent, strong protection for the ocean's most important places. He received his Ph.D. in Biology in 2016 from Temple University studying the distribution and ecophysiology of deep-sea corals. His current research focuses on using ecological models to better understand and manage vulnerable marine ecosystems, with a special focus on deep-sea and seamount habitats. When he's not modeling, he enjoys climbing, mountaineering, and skiing.