Deep CCZ Biodiversity Synthesis Workshop

Friday Harbor, Washington, USA, 1-4 October 2019

SUMMARY OF SCIENTIFIC INFORMATION TO DESCRIBE PATTERNS OF BIODIVERSITY AND ECOSYSTEMS ALONG AND ACROSS THE CLARION CLIPPERTON ZONE

Note by the Secretariat

1. The Secretariat is circulating herewith a summary of scientific information in support of the Deep CCZ Biodiversity Synthesis Workshop to facilitate the description of biological and environmental patterns along and across the Clarion Clipperton Zone (CCZ), including biodiversity, community structure, species ranges, genetic connectivity, ecosystem function and habitat heterogeneity.

2. This summary was prepared by the Deep CCZ project topic leaders. It consists of scientific information submitted in the form of scientific articles or reports (references provided below), and original datasets as inputs to the workshop discussion. It should be noted that, in preparing this compilation, the Secretariat has not validated the scientific information, nor addressed the information gaps in the submissions. During the workshop, participants are expected to analyze and synthesize biodiversity and ecosystem patterns along and across the CCZ, building on the relevant scientific information contained in the present compilation.

SUMMARY OF SCIENTIFIC INFORMATION COMPILED TO SUPPORT THE WORKSHOP OBEJCTIVES

Physiographic, Resource, Sediment & Water Column, and Biogeographic Data - Dr. Travis Washburn & Dr. Craig R. Smith, University of Hawaii, USA

Environmental and biogeographic data were collected from various sources for the CCZ region to aid in analyses to understand biological patterns observed in the region for all topic groups. Data collected include physiographic data for the seafloor, polymetallic nodule resource data, environmental sediment data, environmental water-column data, flux data, and biogeographic data (Table 1).

Physiographic Data – Topographic and water depth data were obtained from the GEBCO and ETOPO1 databases. GEBCO data were created from a database of depth measurements and subsequent interpolation at 15 arc-second intervals (GEBCO, 2019) while ETOPO1 data were created from data acquired through several academic and government agencies and subsequent interpolation at 1 arc-minute intervals (Amante and Eakins, 2009). Seamount and knoll data were obtained from Dr. Malcolm Clark. Seamounts and knolls were identified by Yesson et al. (2011) using the Shuttle Radar Topography Mission bathymetry grid with 30 arc-second resolution with seamounts having an average height over 1000 m and knolls having a height between 200 – 1000 m. Seafloor slope data were obtained from Kirsty McQuaid. McQuaid (2019) calculated seafloor slope data using GEBCO bathymetry and the Benthic Terrain Modeler in ArcMap and were derived to a scale of 1 km^2.

Resource Data – Polymetallic Resource data, including nodule abundance and nickel, manganese, copper, and cobalt content, were obtained from Dr. Charles Morgan and are found in ISA Technical Report #6 (ISA, 2012). Nodule datasets included data from the ISA's Central Data Repository, Lockheed-Martin Corporation, the Republic of Korea, China Ocean Mineral Resources Research and Development Association, and Interoceanmetal Joint Organization. Empirical Bayesian Kriging was used to interpolate nodule data in the CCZ where nodule data were not available.

Sediment Data – Sediment type data were obtained from GeoMapApp. Dutkiewicz et al. (2015) used descriptions of over 14,000 surface sediment samples collected from the Index of Marine and Lacustrine Geological Samples to interpolate sediment types that compose more than 70% of the seafloor at a location using the International Ocean Discovery Program classification scheme and a support vector machine. Total organic carbon and sediment accumulation rate data at a 2 degree resolution were obtained from Jahnke (1996). Jahnke (1996) calculated sedimentation rates using oxygen isotope determinations with accumulation calculated by multiplying dry bulk density by sedimentation rate and concentration of various sedimentary components. Sediment thickness data were obtained from NOAA's National Centers for Environmental Information. Data at a 5 arc-minute resolution were interpolated by Straume et al. (2019). Calcite compensation depth data were obtained from Yool et al. (2013) who used nitrogen, silica, iron, chlorophyll, carbon, alkalinity, and dissolved oxygen data to determine the depths at which calcite concentrations fell below calcite saturation. Sediment calcium carbonate and biogenic silica concentrations were obtained from GeoMapApp. Archer (1999, 2003) estimated $CaCO_3$ and silica content in core top sediments using historical.

Water-Column Data – Bottom-water temperature, salinity, oxygen content, nitrate, phosphate, and silicate concentrations were obtained from the World Ocean Atlas 2018. Temperature (Locarnini et al., 2019) and salinity (Zweng et al., 2019) data were interpolated from a grid of data at ¼ degree scales and averaged across 2005 - 2017 while oxygen (Garcia et al., 2019), nitrate, phosphate, and silicate concentrations and oxygen utilization (Garcia et al., 2019) were interpolated from a grid of data at 1 degree scales and averaged across 1960 - 2017. The bottom depth where data was calculated for each location was used as bottom-water depth. Bottom-water pH was calculated with the program CO2SYS using inorganic CO2, alkalinity, temperature, salinity, and pressure from the Global Ocean Data Analysis Project and World Ocean Atlas, 2013 (Sweetman et al., 2017). Bottom-water particulate matter concentrations and nepheloid layer thickness were obtained from Gardner et al. (2018). Gardner et al. (2018) obtained bottom-water particulate matter concentrations at 10 m above bottom from nephelometer and transmissometer data from 1964 – 2016 and obtained nepheloid thickness by estimating the depth at which water had sediment concentrations > 20 μg/L.

Flux and Biogeographic Data – Seafloor POC flux was calculated using the model from Lutz et al. (2007). Sweetman et al. (2017) obtained Level-3 chlorophyll-a concentrations and Level-4 VGPM primary productivity data for inputs in into the Lutz model and calculated export depth by subtracting water depth by euphotic zone depth. CCZ subregion blocks were obtained from Wedding et al. (2013) who divided the area both north-south and east-west due to strong productivity gradients. GOODS abyssal provinces (3500 – 6500 m) were obtained from Dr. Les Watling (Watling et al., 2013) while GOODS lower-bathyal (800 – 3500 m) and pelagic provinces were obtained from UNESCO (2009). Biogeographic boundaries were initially determined using ETOPO2 bathymetric data or oceanographic features and refined with temperature, salinity, dissolved oxygen, and particulate organic carbon flux data (UNESCO, 2009). Bathyal seamount classification data were obtained from Clark et al., (2011). Clark et al. (2011) combined lower-bathyal provinces (UNESCO, 2009) with seamount data (Yessen et al., 2011) and further divided seamounts using export productivity, summit depth, dissolved oxygen, and proximity. Water-column marine provinces were obtained from Longhurst (2006) who used physical forcing as a regulator of phytoplankton distributions.

Table 1. List of variables, units, original cell size and sources for environmental and biogeographic data.

Variable	**Units**	**Original cell size**	**Source**
Physiographic Variables			
Topography	m	0.004°	GEBCO14
Depth	m	0.016°	ETOPO1
Seamounts			Yessen et al. (2011)
Knolls			Yessen et al. (2011)
Seafloor Slope	Degrees	0.016°	McQuaid (2019)
Resource Data			
Nodule Abundance	Wet kg/m^2	0.5°	ISA (2012)
Nodule Nickel Content	Dry wgt. %	0.5°	ISA (2012)
Nodule Manganese Content	Dry wgt. %	0.5°	ISA (2012)
Nodule Copper Content	Dry wgt. %	0.5°	ISA (2012)
Nodule Cobalt Content	Dry wgt. %	0.5°	ISA (2012)

Sediment Data			
Sediment Type			Dutkiewicz et al. (2015)
Total Organic Carbon Content		2^o	Jahnke (1996)
Sediment Thickness	m	0.08^o	Straume et al. (2019)
Sediment Accumulation Rate	$g/cm^2/1000y$	2^o	Jahnke (1996)
Calcite Compensation Depth	km		Yool et al. (2013)
Calcium Carbonate Content	%	1^o	Archer (2003)
Biogenic Silica Content	%	1^o	Archer (1999)
Water-Column Data			
Bottom-Water Temperature	^oC	0.25^o	WOA18
Bottom-Water Salinity		0.25^o	WOA18
Bottom-Water Dissolved O_2	ml/L	1^o	WOA18
Bottom-Water AOU	ml/L	1^o	WOA18
Bottom-Water Nitrate	µmol/kg	1^o	WOA18
Bottom-Water Phosphate	µmol/kg	1^o	WOA18
Bottom-Water Silicate	µmol/kg	1^o	WOA18
Bottom-Water pH		1^o	Sweetman et al. (2017)
Bottom-Water Particulate Matter	µg/L	1^o	Gardner et al. (2018
Nepheloid-Layer Thickness	m	1^o	Gardner et al. (2018
Net Primary Production	mg $C/m^2/day$	0.1^o	Ocean Productivity
Flux			
Seafloor POC Flux	g $C/m^2/y$	0.25^o	Sweetman et al. (2017)
Biogeography			
CCZ Subregions			Wedding et al. (2013)
Abyssal Provinces			Watling et al. (2013)
Bathyal Seamount Classification			Clark et al. (2011)
Longhurst Marine Provinces			Longhurst (2006)

Lower-Bathyal Provinces			UNESCO (2009)
Pelagic Provinces			UNESCO (2009)

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Microbial Data – Dr. Matthew Church & Dr. Emma Wear, University of Montana, USA

The working group on microbes is focused on synthesizing datasets that characterize biodiversity of Bacteria and Archaea in the Clarion-Clipperton Zone (CCZ). As part of this effort, this working group has been actively collecting datasets derived from DNA sequencing approaches. In particular, sequences of marker genes (specifically 16S ribosomal RNA, or rRNA, genes) will be used as an indicator of taxonomic identity for microorganisms. Untargeted sequencing of genes that code for proteins and other functions (i.e., metagenomics) will also be used, when available, to provide information on metabolic capabilities among the microbial communities found in various CCZ habitats.

To date, we have assembled 16S rRNA gene sequences from published works, public DNA sequence repositories, and as-yet unpublished datasets representing samples that were collected from the CCZ over approximately 20 years. These samples cover a broad spatial distribution across the CCZ, including contract areas licensed to the United Kingdom, Singapore, China, and Germany, as well as several APEIs. They encompass microbial habitats including polymetallic nodules, surrounding sediments, and the water column from just above the sediments up through the sunlit surface waters. We have also identified a small number of metagenomic samples from polymetallic nodules and surface waters in the CCZ.

Metagenomics is a newer technology, and one focus of our working group will be to discuss its utility as a monitoring tool for microbial biodiversity in the CCZ in the future.

Metazoan Meiofauna – Dr. Daniela Zeppilli, IFREMER, France

We will investigate patterns and variations in abundance, community structure, and biodiversity of benthic meiofauna associated with nodule fields from different mining claim areas in the Clarion-Clipperton Nodule Province. We will explore the presence/absence of rare meiofauna taxa comparing different nodule fields. Nematode and copepod diversity and composition will be analyzed at family/genus level. Selected abundant nematode and copepod genera will be investigated up to species level to explore species patterns and distribution all along the Clarion-Clipperton Nodule Province.

Sediment Macrofauna – Dr. Travis Washburn & Dr. Craig R. Smith, University of Hawaii at Manoa, USA

This group is compiling quantitative data for sediment macrofauna collected in the CCZ region using a standard sampling device for abyssal macrofaunal, the 0.25 m^2 box core. Our goal has been to assemble quantitative macrofaunal data (i.e., counts from known sample area) to evaluate patterns of abundance, community structure, diversity (richness and evenness) and species distributions along and across the CCZ. The abyssal macrofauna is generally defined as animals retained on 250 - 300 µm sieves. Nematodes, harpacticoid copepods, and ostracods are generally omitted from macrofauna counts because the vast majority of individuals from these taxa (>90%) pass through 250 and 300 µm sieves and are thus not quantitatively retained in these samples.

Through direct solicitation from scientists and contractors, sediment macrofaunal data (250 - 300 µm sieves) collected by box core have been obtained from a variety of research projects for areas in the central and eastern Clarion Clipperton Zone. Dr. Craig Smith from the University of Hawaii at Manoa provided data from 24 box cores in the UK-I exploration area from the ABYSSLINE project, with all taxa distinguished to species in the 12 cores collected in 2013, and polychaetes distinguished to species in the 12 cores collected in 2015 while remaining taxa were identified to phylum, class or order. Dr. Lenaick Menot and Dr. Magda Blazewicz provided data from approximately 30 box core samples collected in 2015 distributed among the IFREMER, GSR east, BGR, and Interoceanmetal exploration areas as well as APEI 3. These data are comprised of abundances of polychaetes and tanaids at the species level. Dr. Se-Jong Ju provided data from 57 box cores collected for the KIOST project, 36 cores collected in the Republic of Korea's exploration claim area from 2012 – 2014 and 21 cores from 2018 in Korea's exploration claim area as well as from APEI 6 and 9. These data were resolved to the species level for polychaetes, tanaids, and isopods, and to the phylum, class, or order level for other taxa. Dr. Ellen Pape provided data for 24 box cores collected in 2015 in GSR exploration areas with polychaetes and isopods mostly resolved to species and other taxa identified to phylum, class, or order. Dr. Koh Siang provided family-level data for polychaetes, tanaids, and isopods for 12 box cores collected from the ABYSSLINE project in 2015 in the OMS contractor area. Slava Melnik provided data from 214 box cores collected from 2010 – 2016 in the Yuzhmorgeologiya (Russian Federation) exploration area with all identifications to the phylum, class, or order level.

Data from peer-reviewed manuscripts have also been collected to supplement data acquired through solicitations from scientists. Species-level data for polychaetes have been compiled from several publications from several locations in and around the CCZ in Glover et al., (2002) and Neal et al. (2011). Species- and genera-level data for polychaetes, tanaids, and isopods have been compiled from samples collected in the COMRA and Cook Islands exploration areas during the 1980's from Wilson (2017). Species-level data for polychaetes and isopods, and phylum, class, or order-level data for other taxa have been obtained from 12 box cores collected in GSR areas from De Smet et al. (2017). Phylum-, class-, or order-level data have been obtained for 17 box cores from several locations in the west-central CCZ from Smith et al. (1997). Species and higher-level taxonomic data have also been obtained from 10 box cores in Hessler and Jumars (1974) collected 10 – 15 degrees north of the CCZ in the 1970s.

Note that 80 - 90% of the many hundreds of macrofaunal species collected from the CCZ remain undescribed, and there has been limited intercalibration of "working species" collections across projects, so establishing ranges for particular species will not be possible for most of the morphologically distinguished species. In addition, box-core deployment and sample-washing protocols are not standardized across research programs which must be considered during quantitative comparisons; e.g., some sampling efforts may have downward biases (reduced abundances) resulting from box-core bow wave effects and lower retention efficiency of undamaged specimens on sieves.

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Invertebrate Megafauna – Dr. Dan Jones, Dr. Erik Simon-Lledo, & Dr. Jennifer Durden, National Oceanography Center, UK

Invertebrate megafauna will be assessed using data inferred from seabed image surveys conducted across the CCZ and nearby locations. As such, these were originally collected using a range of different methodologies (e.g. ROV, AUV, and towed-camera systems). The highest resolution datasets were re-analyzed in accordance to a CCZ standardized morphospecies catalogue. Available invertebrate megafaunal data (see Table) can be categorized as follows:

Quantitative quality-controlled data (QT/QC): These include imagery collected at 2-5 m above the seabed, with precisely quantified seabed area and (re)annotated using the standardized taxonomic catalogue. These enable density-based comparative analyses of faunal abundance, diversity metrics, and taxonomic composition. These include data from: UK-1 area (Amon et al, 2016); APEI-6 (Simon-Lledo et al, 2019); Tonga Offshore Mining Ltd. areas B, C, and D (Nautilus Minerals, Simon-Lledo et al, in prep); eastern Kiribati EEZ (Nautilus Minerals, Simon-Lledo et al, in review); and western CCZ APEIs 1, 4, and 7 (Deep CCZ, Durden et al, in prep). Additional data from the (non-CCZ) DISCOL area (Simon-Lledo et al, 2019) are also available, but likely not included in analyses.

Qualitative quality-controlled (QL/QC): These include imagery collected at 2-5 m above the seabed, with estimated seabed area, and (re)annotated using the standardized taxonomic catalogue. These enable presence/absence comparative analyses of faunal distribution, morphospecies richness metrics, and taxonomic composition. These include data from: APEI-3, BGR, and GSR (Vanreusel et al. 2016; Cuvelier, in review).

Other datasets: imagery collected either at above-seabed altitudes >5 m, or at lower image quality or lighting, or with imprecise measurements of the seabed area encompassed by sampling, and/or annotated using a non-standardized taxonomic catalogue. These datasets may be used to support discussion derived from main analyses and in additional evaluations of methodological aspects. These include data from: Korea Deep Ocean Study area (KODOS) and APEI-9 (KIOST, unpublished); GSR (Patania dives: GSR, unpublished); across CCZ (UKSR, McQuaid et al, in prep). Some of these datasets may be incorporated to higher category analyses (after the workshop) if consistently re-annotated.

Fishes and Scavengers – Dr. Jeffrey Drazen, University of Hawaii at Manoa, USA, et al.

Fishes and mobile scavengers will be evaluated using two types of data. First, baited cameras were employed across the CCZ and the Pacific at abyssal depths.Second, data for fishes were compiled from video or photo transecting methods in the CCZ and neighbouring regions.

Baited camera dataset: Data for scavenger diversity and relative abundance were compiled from baited camera deployments throughout the Pacific at depths below 3000 m. Data were gathered from the literature and by contribution of raw data by lead scientists of past studies. A total of 12 studies representing 157 deployments were compiled (see Table 2). Three studies representing 43 deployments were directly from the CCZ region: OMS and UK1 (Leitner et al 2017), APEIs 1,4, 6 and 7 (Leitner et al 2017; Leitner and Drazen, unpublished data) and BGR (Sweetman et al., unpublished data). The remainder ranged from New Zealand to California and south to the Peru Basin (DISCOL Site). This geographic coverage will enable evaluation of biogeographies of these very mobile animals. Data included camera viewing angle and area, duration of deployment and sampling interval to facilitate sample intercomparison. Only studies that presented the maximum number of animals visible during deployment (MaxN) were included. Many studies also presented the time of first arrival for each taxon. Both metrics have been used as indicators of relative abundance and enable estimation of diversity and community composition.

Transect dataset: Data for fish was also compiled from video or photo transecting methods (including ROV, AUV, and towed cameras) in the CCZ and neighbouring regions (see Jones et al summary Table for invertebrate megafauna). Data were collected from 2-5m above the seafloor with quantified (and occasionally estimated) seafloor area. Data were annotated with a standardized abyssal fish atlas for consistency. Fish abundance, diversity and community composition were then extracted. Data exists for 5 license areas: UK-1 area (Amon et al, 2016); Tonga Offshore Mining Ltd. areas B, C, and D (Nautilus Minerals, Simon-Lledo et al, in prep); eastern Kiribati EEZ (Nautilus Minerals, Simon-Lledo et al, in review); as well as 4 APEIs: western APEIs 1, 4, and 7 (Deep CCZ, Durden et al, in prep), eastern APEI 6 (Simon-Lledo et al, 2019).

Table 2. Summary of camera deployments compiled from the CCZ .

Habitat brief description	published paper	# camera deployments
BGR	Sweetman et al unpublished	10
OMS	Leitner et al 2017	6
UK1	Leitner et al 2017	6
western CCZ	Leitner et al 2017	2
APEI1	Leitner et al. unpublished	7
APEI4	Leitner et al. unpublished	7
APEI6	Leitner et al 2017	1
APEI7	Leitner et al. unpublished	4
CCZ total		**43**
California, Sta. F	Priede et al 1990	14
California, Sta. M	Priede et al 1994	11
Central California	Yeh and Drazen 2011	3
central North Pacific Gyre	Priede and Smith 1986	6
	Priede et al 1990	9
DISCOL	Drazen et al. 2019	6
Hawaiian Islands - Main	Leitner et al. unpublished	1
	Yeh and Drazen 2009	3
Hawaiian Islands - Northwestern	Yeh and Drazen 2009	4
	Drazen, unpublished	1
Kermadec	Jamieson et al 2009	1
	Jamieson et al 2011	4
	Linley et al 2017	28
Marianas	Jamieson et al 2009	2
	Linley et al 2017	10
New Hebrides	Linley et al 2017	7
South Fiji Basin	Linley et al 2017	4
Pacific wide total		**157**

Foraminifera – Dr. Andrew Gooday, National Oceanography Center, UK

Quantitative data, including abundance, species richness and diversity metrics, and taxonomic composition, of mainly meiofaunal (i.e. smaller) foraminifera come from 3 main sources. All data are derived from the 0-1 cm sediment layer, although different size (i.e. sieve-mesh) fractions were analyzed in each case, making comparison among the datasets difficult. I supervised and was directly involved in all these studies.

1) Megacores from the UK-1 and OMS areas collected during the ABYSSLINE project. These data are based on >150-µm sieve fractions, and for a subset of samples the >63 µm fractions. The results are mostly published (Goineau and Gooday, 2015, 2017, 2019; Gooday and Goineau, 2019).

2) Megacores from the IOM experimental disturbance area (impacted, resedimented, and control sites). Data are based on >250 µm fractions (M.Sc project in progress, University of Szczecin).

3) Megacore subcores from the Kaplan East and Central sites (Kaplan project) and the Japanese JET experimental site. The data come from the 32-63 µm and >63 µm fractions. These results are contained in unpublished theses by Japanese students based at JAMSTEC; the Kaplan East results are published in Nozawa et al. (2006).

Qualitative data on the occurrence (presence/absence) of macrofaunal and megafaunal foraminiferal species come from several sources. Most of the data concerns rarely-studied, largely undescribed groups such as the Komokiacea, xenophyophores etc.

1) Epibenthic sledge samples from the German, French, and Russian areas analyzed by Olga Kamenskaya (Moscow). I have not seen this material directly but Olga has provided photographs of every specimen.

2) Epibenthic sledge samples from the IOM, German and French areas, and APEI-3, collected during Sonne cruise SO239. I have worked on a subset of these samples with Brygida Wawrzyniak-Wydrowska in Szczecin

3) Species of megafaunal xenophyophores from UK-1, OMS, APEI-6 (ABYSSLINE cruises), and APEI 6 (JC120 and the Russian area (from Olga Kamenskaya)), collected mainly with box cores. Genetic data are available for some of the ABYSSLINE species. Much of this work is published (Kamenskaya et al., 2015, 2017; Gooday, 2017a-c; 2018a.b)

4) Additional xenophyophores collected using an ROV during the DeepCCZ project in APEIs 1,4,7 (western CCZ). Genetic data are available for some of these species.

5) Records for sessile foraminifera on nodules from the ABYSSLINE cruises (numerous ship-board photographs from UK-1, some published in Gooday et al., 2015). These will be compared with published photographs from western and eastern French areas of the CCZ (Veillette et al., 2007, supplementary material).

Published papers provide additional abyssal presence/absence records from the IOM (Radziejewska et al., 2005; Kamenskaya et al. (2012), Russian (Kamenskaya et al., 2013), and Kaplan Central (Ohkawara et al., 2009) areas. Other relevant studies on abyssal foraminifera (mainly hard-shelled, multichambered taxa) from areas of the Pacific outside the CCZ include, among others, Schultze (1907) and Tendal (1972, 1980) for xenophyophores; Walch (1978, M.Sc thesis available online), Enge et al. (2012), and Resig (1981) for the equatorial Pacific; Cushman (1910-1917) and Smith (1973) for the North Pacific; Ohkushi et al. (1999) and Szarek et al. (2007) for the NW Pacific; and Saidova (1975) for the Pacific generally.

Genetic Connectivity – Dr. Thomas Dahlgren, University of Gothenburg, Sweden; Dr. Adrian Glover & Dr. Guadalupe Bribiesca-Contreras, Natural History Museum, Great Britian

Genetic data based on DNA-sequences of selected CCZ taxa are available from work over the last ~10 years to support the proposed workshop goals. The data can be used to assess both species ranges (biogeography) and the degree of connectivity of populations (population genetics), both essential parameters in determining the potential placement of protected zones and the assessment of resilience to disturbance.

Data originate from 8 projects funded by both research organizations and contractors. These cover the entire CCZ, but the majority of the data is from the eastern part. Data are available from 4 APEIs and 8 contracted regions (Table 3). These include 109 taxa, 6872 samples (each sample being an individual specimen), and 1507 sequences (not all samples have been sequenced).

A request for data was made to 5 research/contractor groups in May 2019. Through this request for data, additional data was provided to this synthesis effort from the GSR samples (Pape et al, pers.comm.). Additional data has also been subsequently published (Jannsen et al 2019) from the BGR and IFREMER contracted regions, which are now available for synthesis.

The majority of information on biogeography (species ranges) is based on morphology (not discussed here), but there are now some data that support a much more rigorous assessment using DNA (for 29 taxa). Those taxa that have been suggested to have broader species ranges based on DNA assessment, have frequently been subsequently the target for more detailed population analyses (e.g Taboada et al 2017, 2018). This creates a currently unavoidable bias in that only those taxa which have broad species ranges are subsequently analyzed for population connectivity.

29 taxa that overlap across 2 or more ‘regions of interest,’ here defined as APEIs or contracted areas, have been identified. In addition, 29 taxa (coincidentally the same number, but not the same taxa) have been subjected to more detailed population-level analyses (Janssen et al 2019; Dahlgren et al in prep; Bribiesca-Contreras et al in prep).

Table 3 List of projects, regions of interest, taxa, samples, sequences and sources of data for CCZ fauna suited to analysis of DNA-based biogeography and population connectivity. The purpose is to give an overview of the general extent of the data, not the results themselves, which will be presented at the workshop.

Faunal component	Project	Area	No.taxa	No.sequences	Reference
Megafauna (Sediment)		UK1.A	2	13	Dahlgren et al. in prep
		UK1.B	2	6	
		OMS.1A	2	10	
	DeepCCZ	APEI.1	10	10	Bribiesca-Contreras et al. in prep
		APEI.4	15	17	
		APEI.7	18	19	
Megafauna (Nodules)	DeepCCZ	APEI.1	2	2	Bribiesca-Contreras et al. in prep
		APEI.4	2	3	
Macrofauna (mobile scavengers)	ABYSSLINE AB01	UK1.A	2	7	Bribiesca-Contreras et al. in prep

	DeepCCZ	APEI.1	11	51	
		APEI.4	7	48	
		APEI.7	10	51	
	MIDAS-JC120	APEI.6	9	37	
Macrofauna (Nodules)		GER	1	2	Dahlgren et al. in prep
		UK1.A	2	8	
		UK1.B	2	11	
		OMS.1A	1	22	
		IOM	1	3	
		BE	1	8	
	ABYSSLINE AB01	UK1.A	1	50	Taboada et al. (2018)
	ABYSSLINE AB02	UK1.B	1	41	Taboada et al. (2018)
		OMS.1A	1	39	
		APEI.6	1	38	
	DeepCCZ	APEI.4	5	7	Bribiesca-Contreras et al. in prep
Macrofauna (Sediment)		GER	4	66	Dahlgren et al. in prep
		FRA	3	15	
		UK1.A	5	36	
		UK1.B	6	55	
		OMS.1A	6	46	
		APEI.6	2	5	
		IOM	2	22	
		BE	3	21	
		DISCOL	1	10	
		ATLN	1	2	
		ATLS	1	1	

	BioNod 2012	GER	4	16	Janssen et al. (2015)
		FRA	5	13	
	DeepCCZ	APEI.1	4	4	Bribiesca-Contreras et al. in prep
		APEI.4	10	12	
		APEI.7	2	2	
	MANGAN 2010	GER	5	40	Janssen et al. (2015)
	MANGAN 2013	GER	10	358	Janssen et al. (2019)
	MANGAN 2014	GER	9	280	

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eDNA – Dr. Erica Goetze, University of Hawaii, USA

Environmental DNA (eDNA) biotic surveys were conducted in the western Clarion-Clipperton Zone as part of the DeepCCZ field program (https://oceanexplorer.noaa.gov/explorations/18ccz/welcome.html; C. R. Smith lead PI). Sediment, polymetallic nodules, and seawater samples were collected in APEIs 1, 4, and 7. Sampling targeted one seamount and the adjacent abyssal plain habitat within each APEI. Sampled seamounts had summit depths of 3100 m (APEI7), 3500 m (APEI4), and 3900m (APEI1). ROV Lu'ukai sampled sediments and nodules, with 3 dives in APEI7 (2 abyssal plain, 1 seamount), 3 dives in APEI4 (2 abyssal plain, 1 seamount), and 2 abyssal plain dives in APEI1, with 2-5 cores collected for eDNA on each ROV dive. Sediment samples were obtained by 7 cm diameter push cores and were subsampled for eDNA at 0-2 cm and 3-5 cm sediment horizons. Polymetallic nodules were either collected using push cores or by the manipulator arm of the ROV. Seawater samples were collected using conductivity-temperature-depth (CTD) casts with a 24 Niskin bottle (10L) rosette sampler (SBE 911plus/917plus, SeaBird oxygen sensor (SBE43), Seapoint fluorometer, Wetlabs C-Star transmissometer). A total of 12 CTD casts were conducted during the cruise with two over the abyssal plain and two over the seamount within each APEI.

Eukaryotic communities were characterized by amplicon sequencing using two genetic markers, the V4 region of the 18S rRNA gene (approximately 450 base pairs [bp]) and a fragment (ca. 350 bp) of the mitochondrial COI gene. For 18S rRNA, the eukaryotic forward Uni18SF: 5′-AGG GCA AKY CTG GTG CCA GC-3′ and reverse primers Uni18SR: 5′-GRC GGT ATC TRA TCG YCT T-3′ primers (Zhan et al., 2013) were used; For COI, the universal metazoan primers mlCOIintF: 5′-GGW ACW GGW TGA ACW GTW TAY CCY CC-3′ and jgHCO2198: 5′-TAI ACY TCI GGR TGI CCR AAR AAY CA-3′ (Leray et al., 2013). Samples were sequenced on two MiSeq Illumina™ lanes using V3 chemistry and paired-end sequencing (2×300 bp). A total of 10,315,003 and 17,202,778 reads were generated for 18S and COI, respectively. These data have been processed through a Qiime2/DADA2 bioinformatic pipeline, including quality filtering, denoising, merging and chimera removal. These eDNA sequence data are available to inform this synthesis effort, and we aim to leverage the assembled data from conventional surveys to evaluate the utility and sampling completeness of the eDNA approach to surveying diversity in the abyssal CCZ.

During the course of the Workshop, we also aim to assemble metadata for ongoing eDNA programs that are currently collecting similar data in other regions of the CCZ. The aim is to create an overview of the unpublished eDNA data that exists in the research community, document the spatial scale and approximate locations of samples, sample types, organismal types (protists, metazoans), and markers (primer sets), in order to better understand how comparable these data will be once published.

Ecosystem Functions – Dr Andrew Sweetman & Marta Cecchetto, Heriot-Watt University, Scotland

Most of the data found on ecosystem function are extrapolated from the Equatorial Pacific (EqPac) Experiment in the 1990s (Honjo et al., 1995; Hammond et al., 1996; Berelson et al., 1997; Smith et al., 1997). These data sets offer insights on export production of particles (Honjo et al., 1995), biogenic budgets of particle rain, benthic remineralization, and sediment accumulation (Berelson et al., 1997), early diagenesis of organic material (Hammond et al., 1996), and latitudinal variations in benthic processes (Smith et al., 1997). These data are then used in more recent publications, i.e., Smith and Rabouille, (2002) and Lutz et al., (2007).

Khripounoff et al., (2006) offers insights on sediment composition, oxygen respiration rates, and nutrient concentrations (silicate, nitrate, and phosphate) on the eastern side of the CCZ in the NIXO zone. More recent data from the eastern side of the CCZ were published by Sweetman et al., (2019) on the role of bacteria in the short-term cycling of carbon. Here, we have more oxygen respiration rates data from the UK1 and Ocean Minerals of Singapore (OMS) claim areas to add to our list.

The study conducted by Kim et al., (2015) offers sediment composition data such as organic carbon, carbonate and lithogenic material insights at KOMO Station. More recently, Mewes et al., (2016) discussed total organic carbon (TOC), ammonia, nitrate, and dissolved oxygen composition into the sediment in the German license area "East". This study also discusses previously collected data by Mewes et al., (2014) and Mogollón, Mewes, and Kasten, (2016).

Volz et al., (2018) gives valuable insights on natural spatial variability of depositional conditions, biogeochemical processes and element fluxes in the sediments of the eastern CCZ, sampling APEI 3, BGR, GSR, IFREMER and IOM stations.

Further data on ecosystem function were collected from Glover et al., (2002), Shulse et al., (2017), and Wilson, (2017) mentioning turnover, respiration rates, and species diversity in the CCZ.

Finally, unpublished data on 3 APEIs (APEI 1, APEI 4, and APEI 7) on the western side of the CCZ will be included in the data summary for the workshop. These data include sediment community oxygen consumption (SCOC) rates, dissolved inorganic carbon (DIC) production rates, and nutrients analysis.

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Habitat Mapping and Environment Data – Dr. Kerry Howell & Kirsty McQuaid, University of Plymouth, UK

The habitat modelling team have collated available relevant GIS layers of environmental data for the CCZ. Some guiding principles for variable selection, from Ramos, Puente, and Juanes (2015), were:

- Spatial variability at the regional level in the study
- Proposed in other classifications of similar scales
- Related to the geographic distribution of the communities of interest
- Possibility of obtaining continuous quantitative and standardized data across the study area
- No mutual influence (i.e. correlation) between variables

Temperature and salinity data were obtained from the National Oceanic and Atmospheric Administration (NOAA) World Ocean Atlas (WOA) 2013 data series. Measurements of mean annual temperature and mean annual salinity were obtained for the period 2005-2012 at 1-degree resolution and various depths throughout the water column (0, 50, 100 m etc).

The CCZ is an abyssal plain region with water depths of up to 5,500 m, and the NOAA WOA 2013 data do not extend all the way to the seafloor in some parts of this area. A Random Forest spatial model (latitude*longitude*depth) was used to predict measures of salinity and temperature at the seafloor. The model was then trained on the General Bathymetric Chart of the Oceans (GEBCO) bathymetry layer (at 1 km2 resolution) to obtain a grid of values of the variable (salinity or temperature) at the seabed in each GEBCO cell. The model was built with 500 trees and explained 99.24% of the variance.

Topographic variables were derived from the GEBCO bathymetry layer. All variables were generated in ArcMap 10.4 using the Benthic Terrain Modeler extension (Wright et al., 2005). Slope is determined as the largest change in elevation between a cell and its 8 nearest neighbors. Bathymetric position indices (BPI) was derived at both broad and fine scale, to capture topographic features at different scales across the region. Broad-scale BPI (BBPI) was derived with an inner radius of 1 and an outer radius of 100, with a scale factor of 100 km. This broad scale layer identified large geomorphological units, such as abyssal plains, steps and troughs. This choice of scale draws from the US Federal Geographic Data Committee's Coastal and Marine Ecological Classification Standard (CMECS) (FGDC, 2012). Fine-scale BPI (FBPI) was derived with an inner radius of 1 and an outer radius of 10, with a scale factor of 10 km. This finer scale layer identified smaller megahabitats or features on the scale of kilometers to tens of kilometers, as defined in Greene et al. (1999). These features include seamounts, abyssal hills, canyons, plateau, large banks, and terraces.

Estimates for POC in the CCZ were obtained from a global model produced by Lutz et al. (2007). Lutz et al. (2007) modelled flux of POC to the seafloor based on water depth and seasonal variability in remote-sensed net primary productivity between 19 August 1997 and 24 June 2004. These estimates were interpolated to a 1-km^2 resolution in the CCZ using kriging.

Modelled estimates of nodule abundance across the CCZ region were obtained from *ISA Technical Study No. 6: A Geological Model of Polymetallic Nodule Deposits in the Clarion Clipperton Fracture Zone* (ISA, 2010).

All above variables were interpolated to 1 km^2 and converted into rasters in WGS 1984 PDC Mercator projection, an equal-area projection suitable for use in the Pacific Ocean. An equal-area projection was used so that estimates of the area of each habitat identified through the classification can be calculated.

Additional oceanographic variables were obtained from the WOA2008 at 1 degree resolution.

Variable	Units	Manipulation	Original cell size	Source	Obtained
Oceanographic variables					
Bottom temperature	°C	Rescaled to 1kmx1km using random forest modelling	1°	WOA2013	Y
Bottom salinity	ppt	Rescaled to 1kmx1km using random forest modelling	1°	WOA2013	Y
Bottom dissolved oxygen conc	ml/l		1°	WOA2009	Y
Bottom oxygen saturation rate	mmol/l		1°	WOA2009	Y
Bottom phosphate	mmol/l		1°	WOA2009	Y
Bottom nitrate	mmol/l		1°	WOA2009	Y
Bottom silicate	mmol/l		1°	WOA2009	N
Topographic variables					

Depth	m	None	0.016°	GEBCO2008	Y
Slope	°	Created using ArcGIS Spatial Analyst Extension	0.016°	GEBCO2008	Y
Bathymetric position index – broad scale	-	Created using ArcGIS Benthic Terrain Modeler extension (Wright et al., 2005). Inner radius 1, outer radius 100, scale factor is 100km	0.016°	GEBCO2008	Y
Bathymetric position index – broad scale	-	Created using ArcGIS Benthic Terrain Modeler extension (Wright et al., 2005). Inner radius 1, outer radius 10, scale factor is 10km	0.016°	GEBCO2008	Y
Curvature	-	Created using ArcGIS Spatial Analyst Extension	0.016°	GEBCO2008	Y
Plan curvature	-	Created using ArcGIS Spatial Analyst Extension	0.016°	GEBCO2008	Y
Profile curvature	-	Created using ArcGIS Spatial Analyst Extension	0.016°	GEBCO2008	Y
Terrain ruggedness	-	Created using ArcGIS Benthic Terrain Modeler extension (Wright et al., 2005).	0.016°	GEBCO2008	Y
Other variables					
Particulate organic carbon flux to seabed	$Mg/m^2/year$	Interpolated to 1kmx1km	7x7km	Derived from Lutz et al. (2007)	Y
Nodule abundance	kg/m^2	Interpolated to 1kmx1km	0.25°	ISA, 2010	Y