Proposed Definition of Habitat Management Zones of the CI seabed

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May 2023

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Runanga Takere Moana
COOK ISLANDS

Purpose and Notes

1. The Level 1 seabed habitat management zones* presented here would allow SBMA to:
   - Have a high level view of likely large scale habitats in the CI EEZ (plus ECS**);
   - Quantify seabed allocation within the context of Marae Moana and other legislation and policy.
2. Would be a contribution for the deep seabed component for marine spatial planning for Marae Moana
3. Is a sub-programme of a Strategic Environmental Assessment (SEA) being conducted for seabed minerals in the Cook Islands

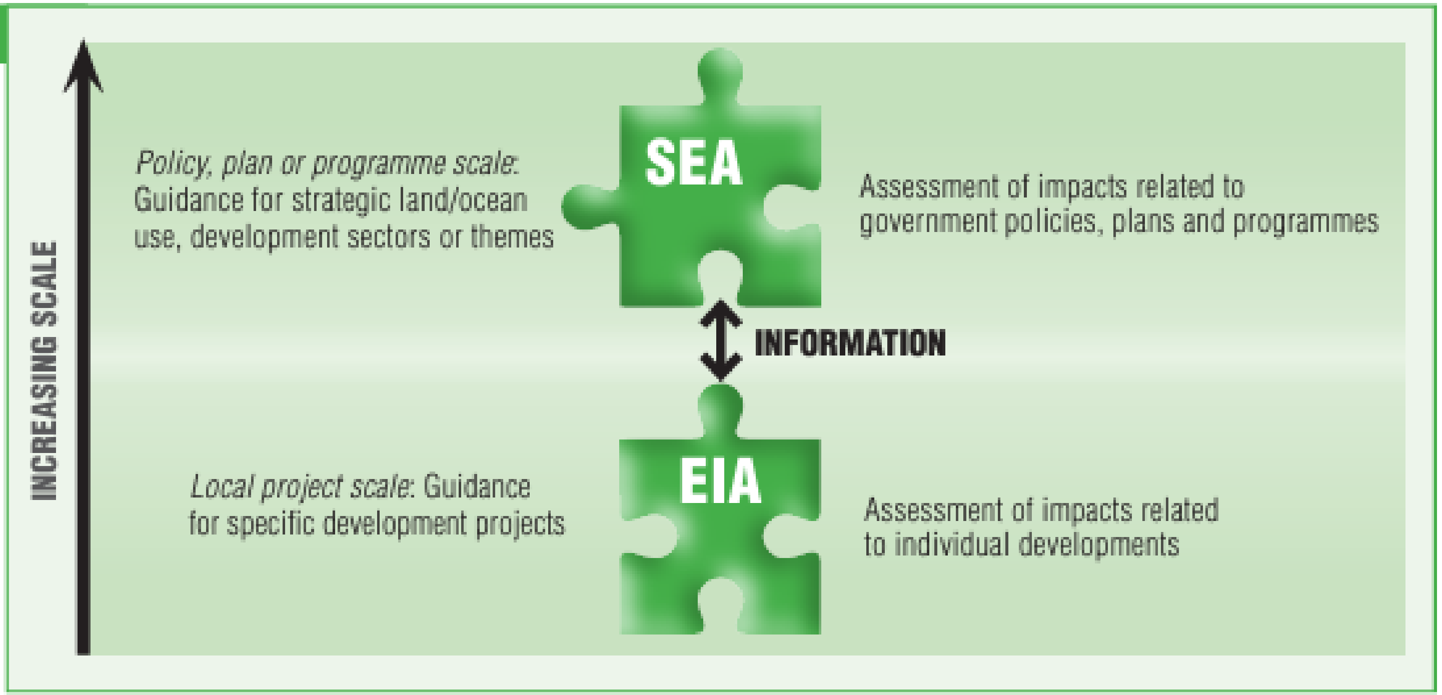
Noting that:

- Not included are areas above 200 m below sea-level (i.e. islands, atolls and immediate shelfs and slopes in the photic zone).
- Testing to date supports the assumptions behind the classifications made here but this should be reviewed again as material seabed information comes to hand.
- It is expected that ongoing detailed research will, in due course, allow for more detailed classifications (i.e. level 2 and maybe level 3).

*A *habitat management zone* will likely include ?slightly different *habitat types* (issue of scale). Then different habitat types and habitat management zones may use the same *1*.
**CI EEZ is Cook Islands Exclusive Economic Zone and ECS is extended continental shelf submission

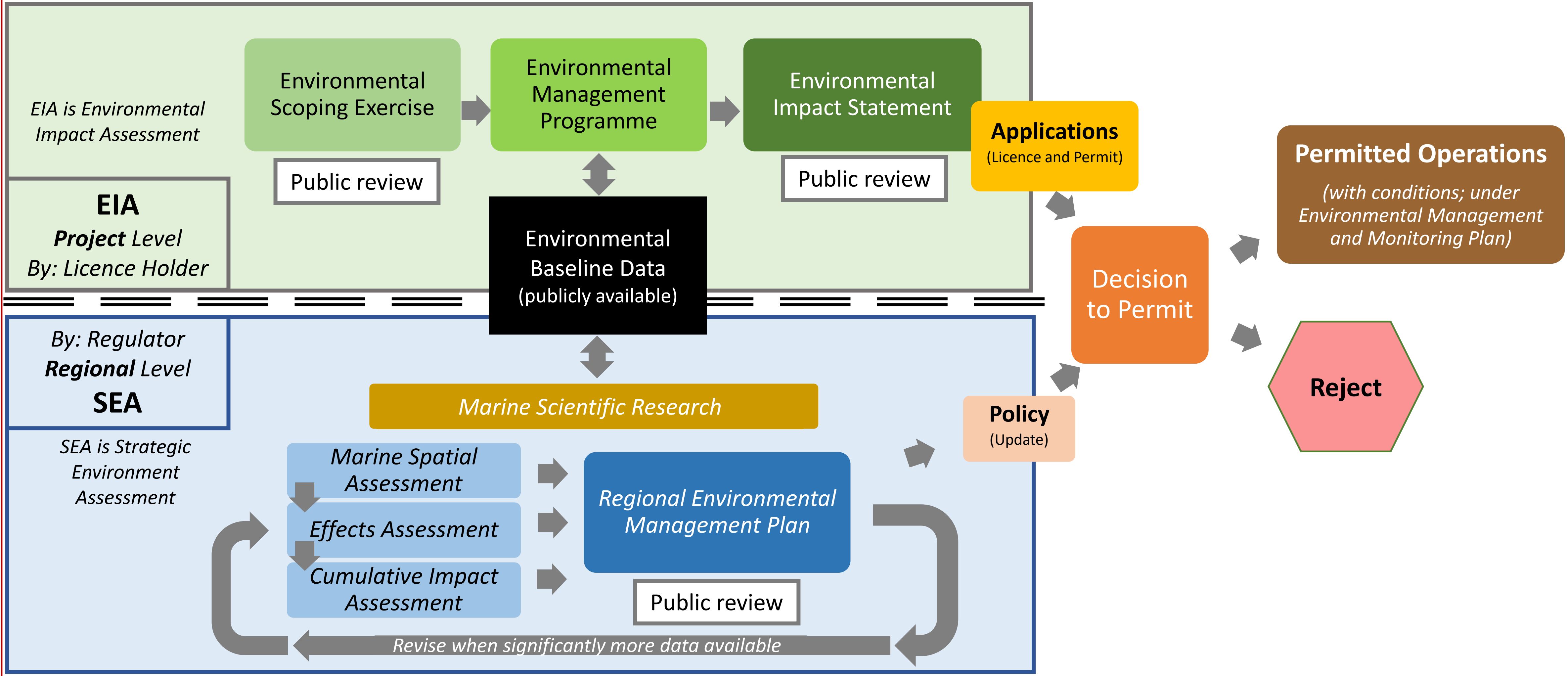
SEA versus EIA (SPREP, 2020)

FIGURE 2



SEA and EIA are applied at different scales and levels of detail with SEA best at considering multiple aspects and broader concepts while EIA is focused on single project; an SEA can guide EIA.

Parallel streams to ensure transparency and due environmental process

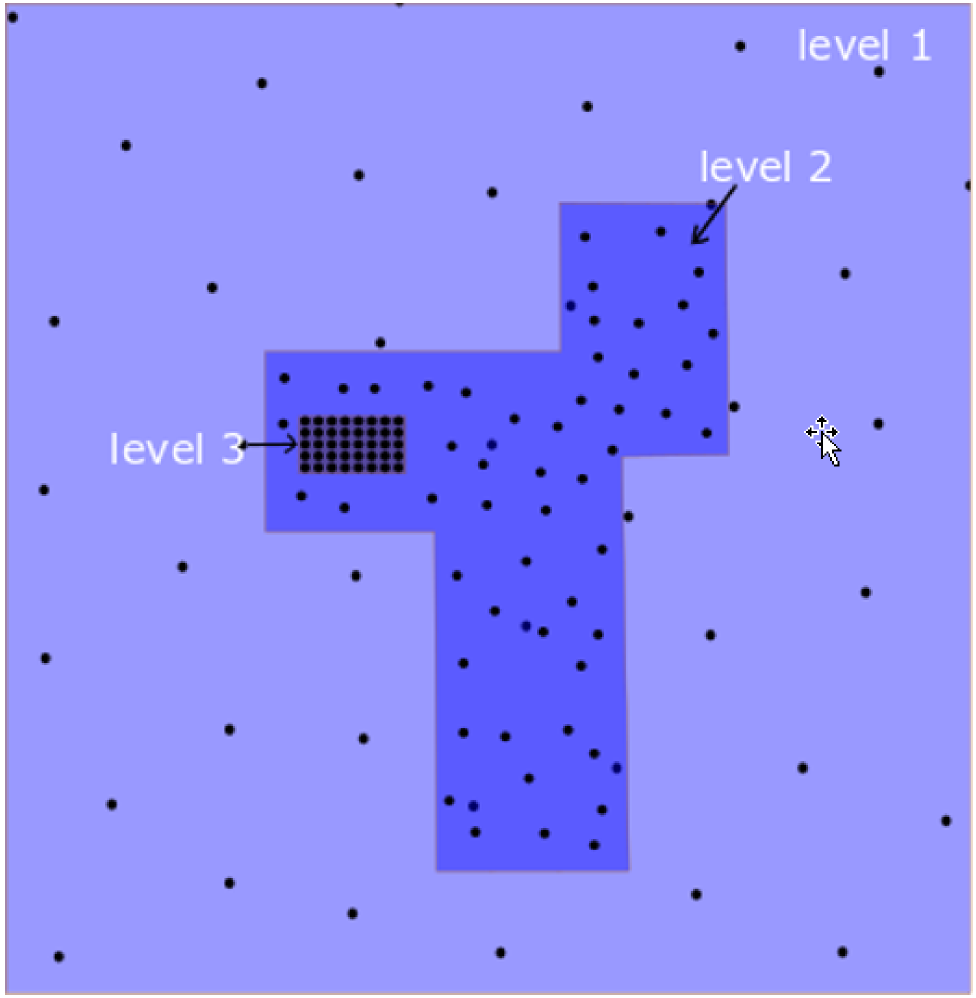


General Approach – Habitat Management Zones (HMZ)

1. Considered recent leading practice as applied in the Clarion Clipperton Zone
   i. Regional habitat classification per McQuaid *et al.* 2019
   ii. Regional and local geoform-habitat classifications in Fejer *et al.* 2021
2. Considered level of data available for the Cook Islands today and concluded only enough information for a regional "level 1" classification. Planned exploration work over the next five years should allow more detailed local classifications (so-called level 2 and 3).
3. Key data used: 1. classic seabed geomorphological interpretation and 2. net organic carbon export model to frame the classification.
4. A key assumption in using both datasets is that they materially influence biodiversity and makeup at the scale of the management zones
5. Tested both interpretation and model against alternative or complementary datasets.

Concept: Levels of HMZs and Habitats

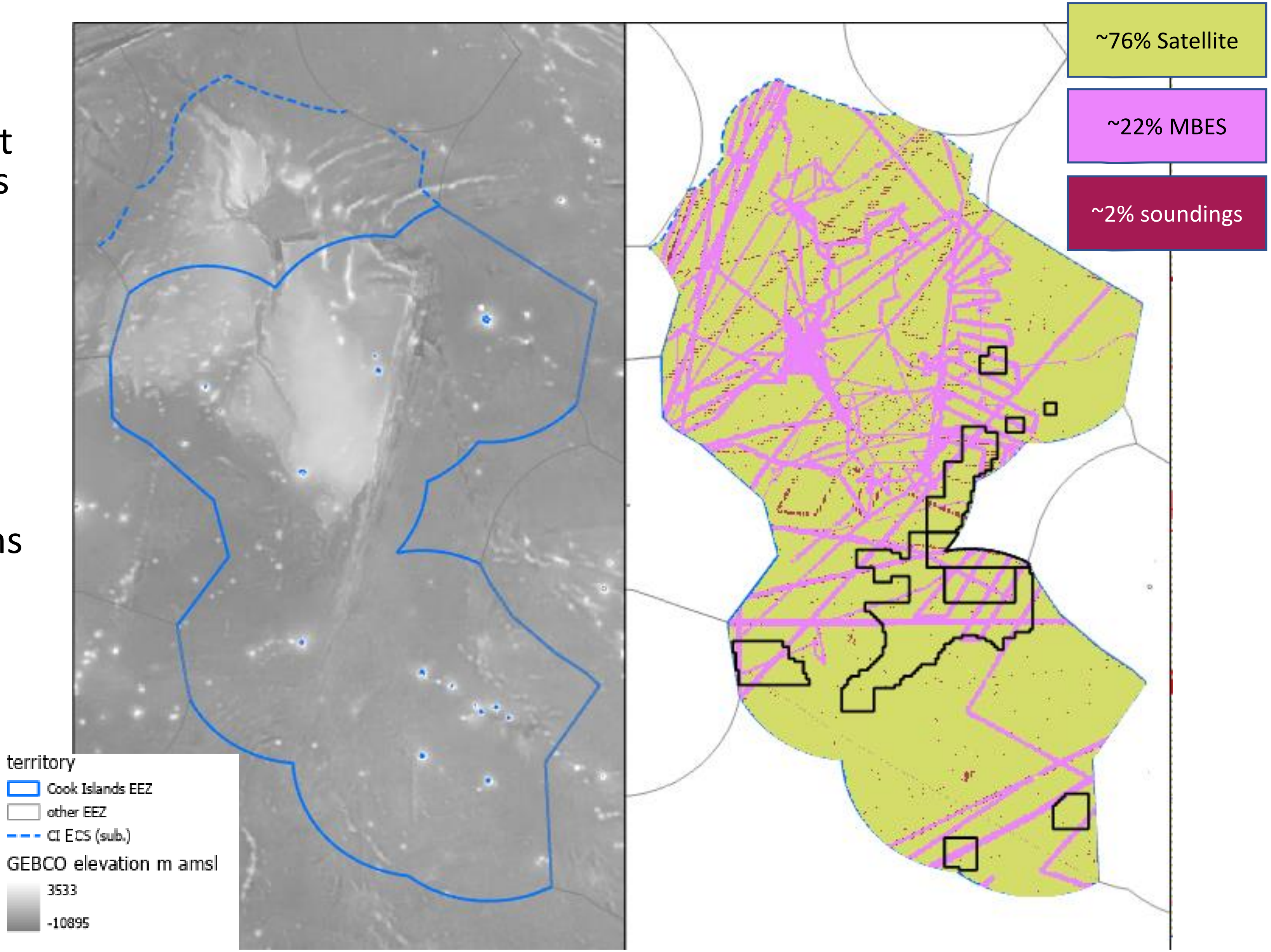
- Remains to be shown to be effective
- Other ?compatible schema:
  - JNCC (Joint Nature Conservation Committee) Marine Habitat Classification for Britain and Ireland
  - automated processing techniques of the substrate component (e.g. Geomorphons)



Level 1	Level 2	Level 3
Substrate: geomorphology from mostly satellite bathymetry	**Substrate:** geology and geomorphology from multibeam echosounder bathymetry (MBES) and backscatter	**Substrate:** detailed geology and geomorphology from MBES bathymetry and backscatter supported by systematic photo surveys
Ecosystem function: from net export model	**Biogeochemical and Chemical** characterisation by Habitat/HMZ	**Biogeochemical and Chemical** mapping
	Biological communities characterisation by Habitat/HMZ	**Biological communities** mapping and modelling
Application: entire EEZECS submission	**Application:** extents of MBES	**Application:** extents of planned development, anticipated impact and PRZs

GEBCO TID

- The type identifier from the GEBCO grid indicates the vast majority of the bathymetry is indirect measurements from sea-level as measure by satellite
- Thus the habitat mapping is really only possible at level 1 per Fejer et al 2021
- Higher levels should be possible once MBES programs are complete and seabed measurements made to characterize the difference types of seabed



Data used: GEBCO Grid

- GEBCO 2021 grid was contoured and carefully colour coded
- Reference was also made to magnetic data
- Then manually interpreted in terms of geomorphology

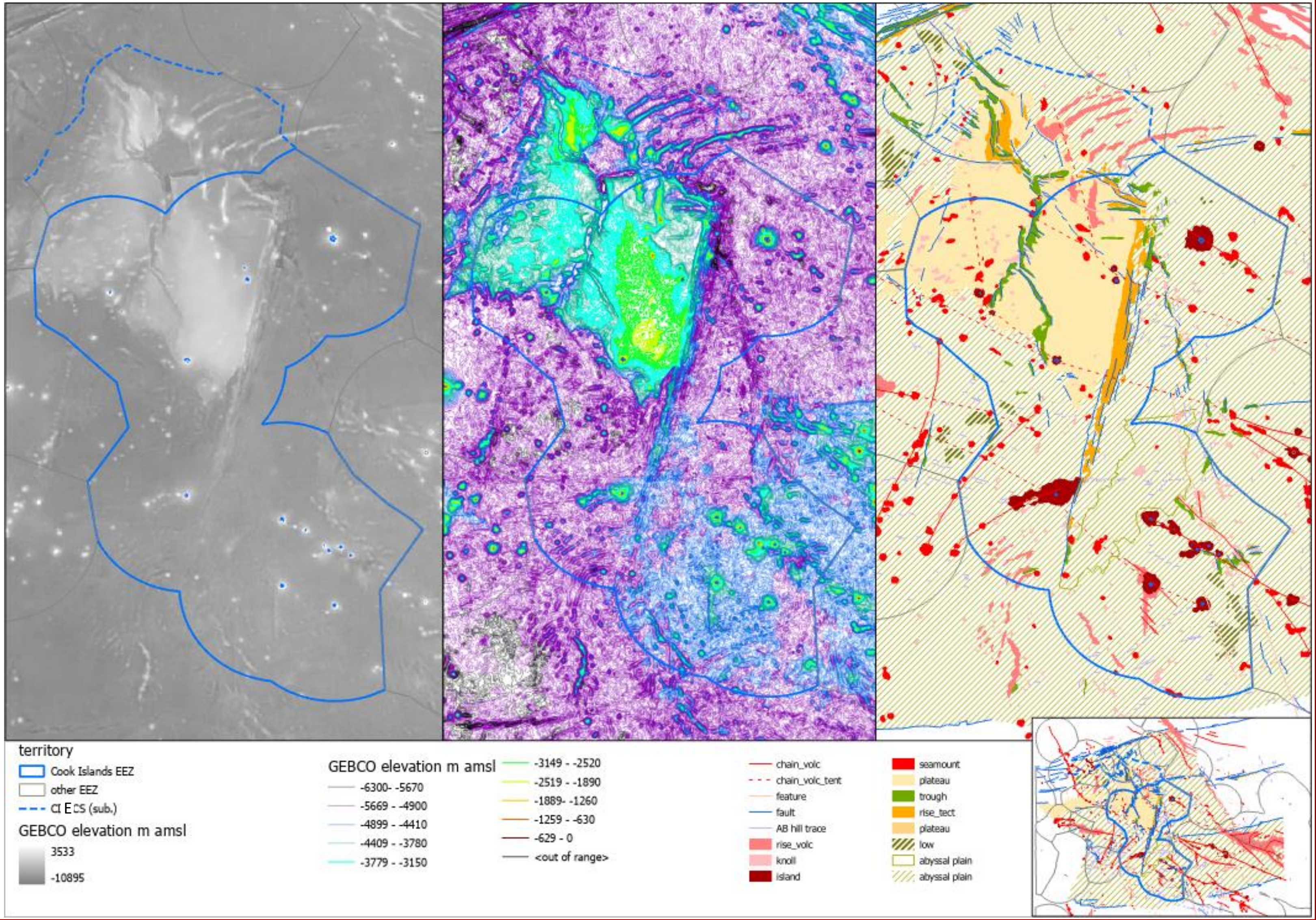

1. Abyssal plains and subtypes


2. Plateau and associated features


3. Knoll-Seamounts and derived chains

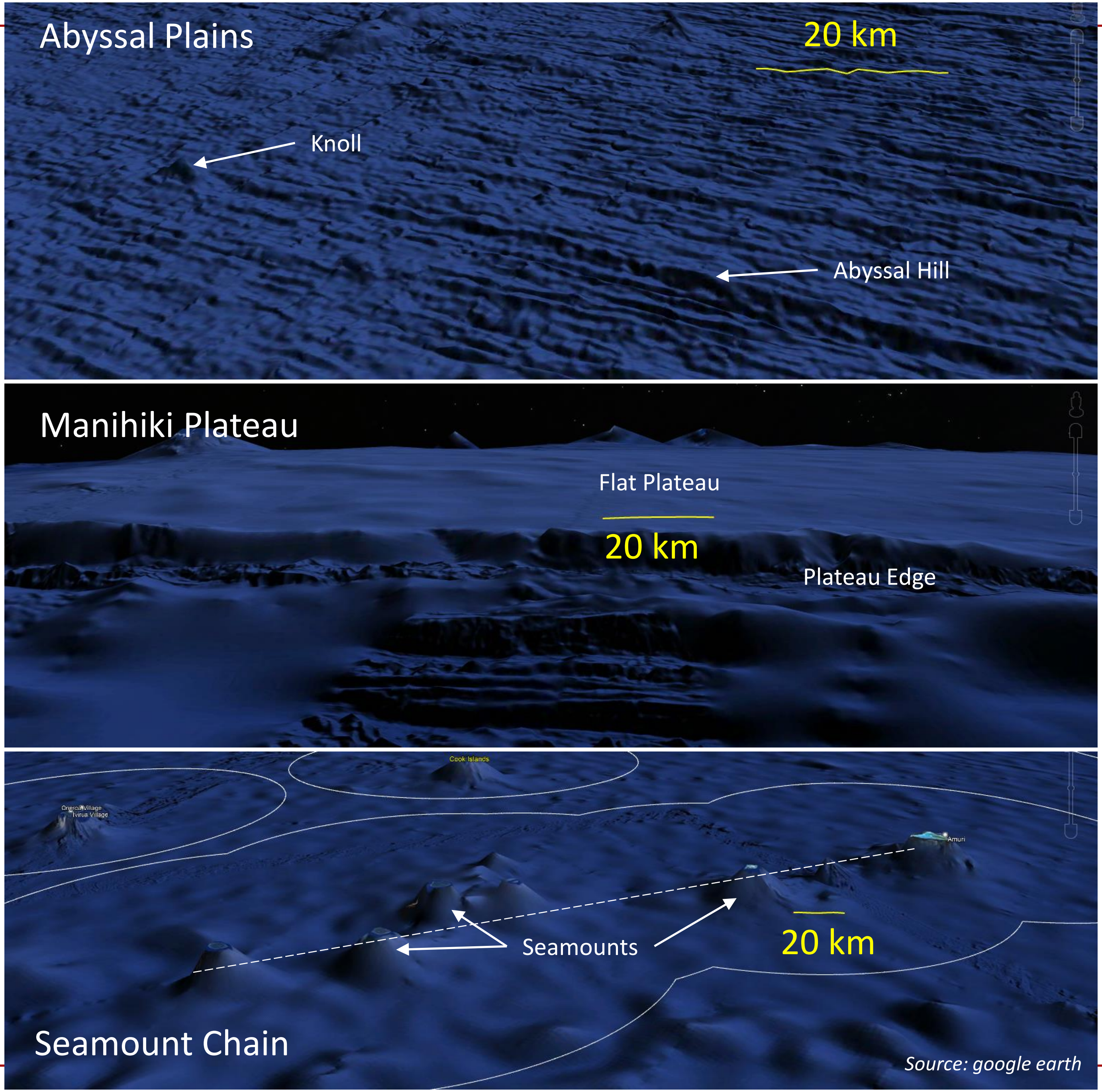

4. Other tectonic features

- Interpretation covered the region as many features extend beyond our EEZ



Types of landforms

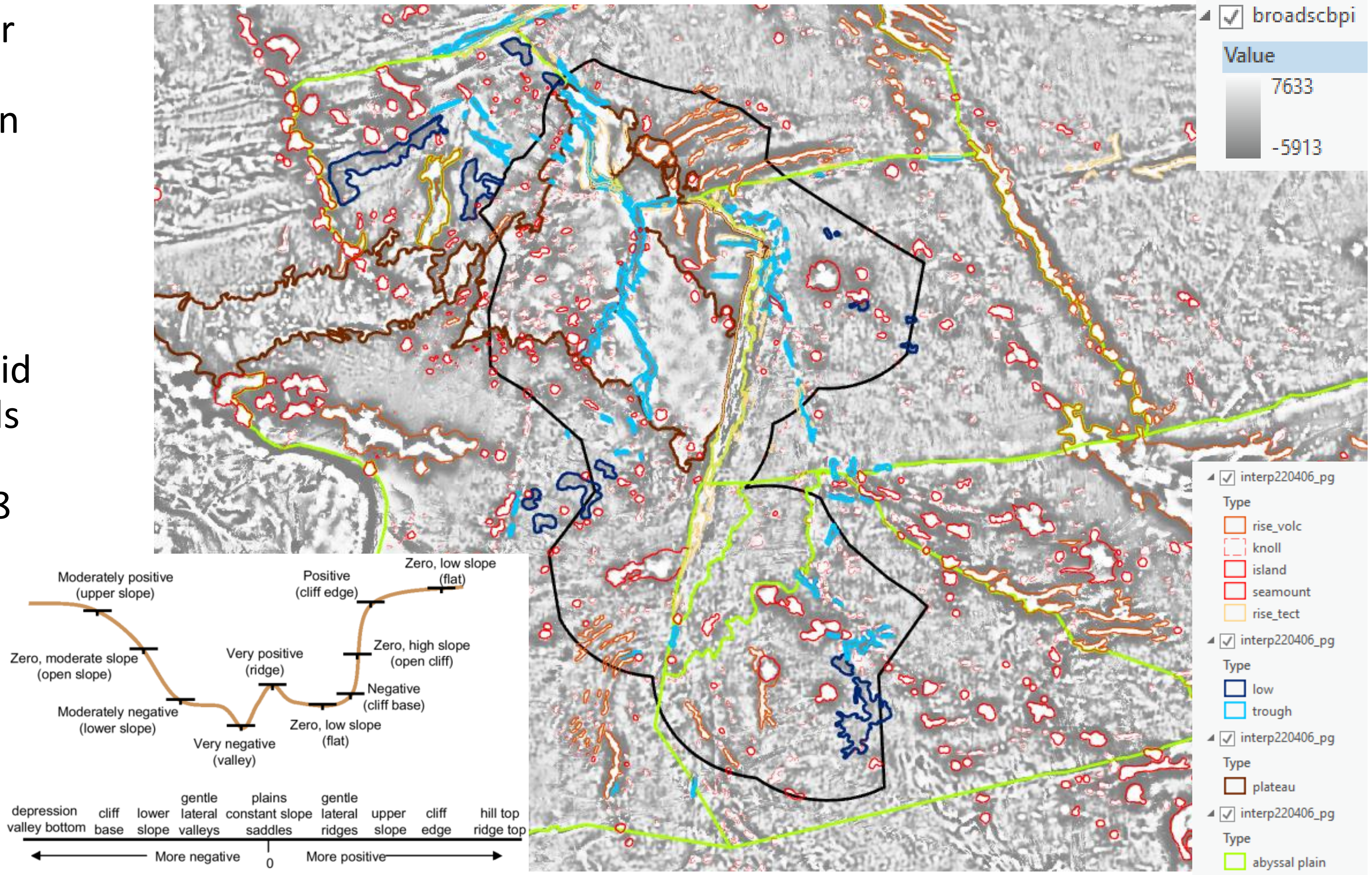
1. Abyssal plains and subtypes
   a. composed of long lines of hills and valleys formed by faulting
   b. includes some volcanic knolls (small round hills), isolated seamounts and troughs
2. Plateau and associated features
   a. Composed of higher flatter area (thick sediment cover)
   b. includes some tectonic rises, volcanic knolls and troughs
3. Volcanic Knoll-Seamounts and derived chains. Composed of discrete seamounts and continuous volcanic ridges.



Source: google earth

Comparison with bBPI (bathymetric position index broad scale)

- BPI (or TPI*) looks at relative position or depth based on scale factors that compare the position of a given position to its neighbours.
- Per McQuaid *et al.* 2019 for the broad scale BPI we used inner radius of 1 and outer radius 100 (scale factor 100 km) but we applied it to the GEBCO 2021 grid which has a resolution of 15 arc seconds (~463 m at the equator) or roughly 4 times the resolution of the GEBCO 2008 grid that they used
- Textural differences between the different map units suggests that even the GEBCO grid is reflecting seabed texture even if for example, individual abyssal hills cannot be seen

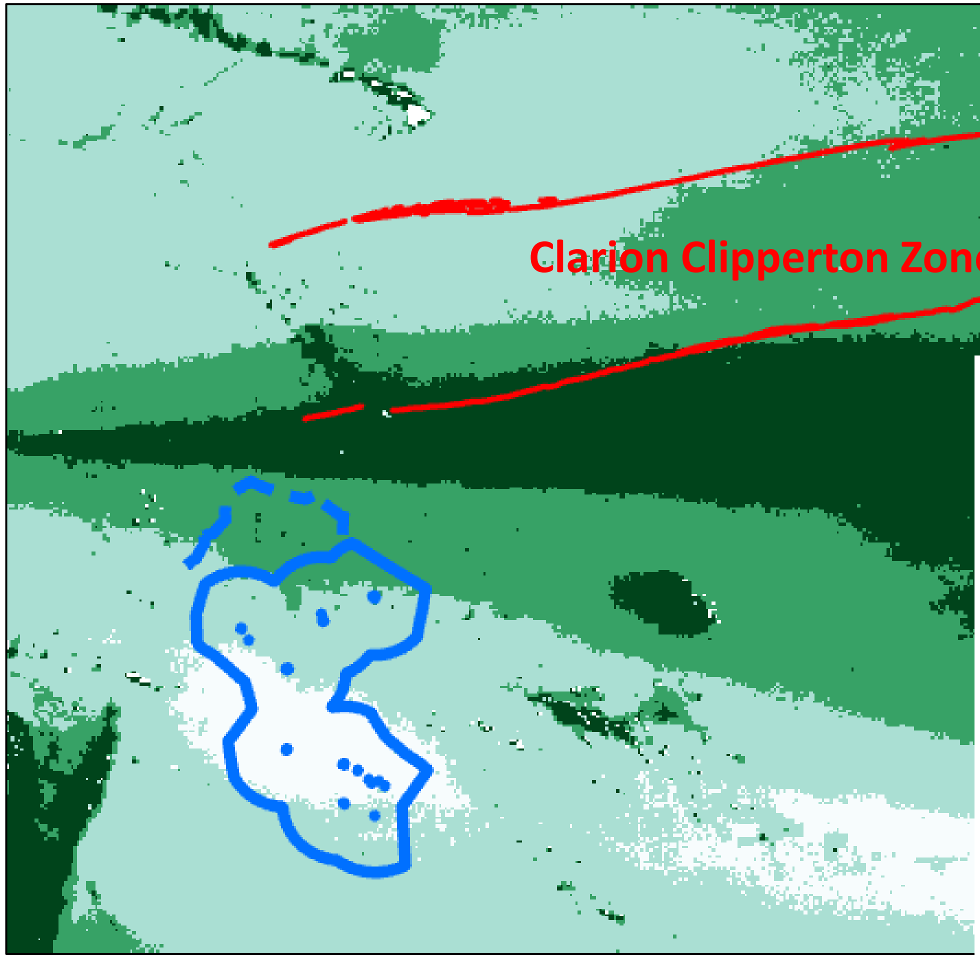


Wright, D. J., E. R. Lundblad, E. M. Larkin, R. W. Rinehart, J. Murphy, L. Cary-Kothera, and K. Draganov. 2005. ArcGIS Benthic Terrain Modeler, Corvallis, Oregon, Oregon State University, Davey Jones Locker Seafloor Mapping/Marine GIS Laboratory and NOAA Coastal Services Center. Accessible online at: http://www.csc.noaa.gov/products/btm/

*terrain position index

Data used: Net export organic carbon

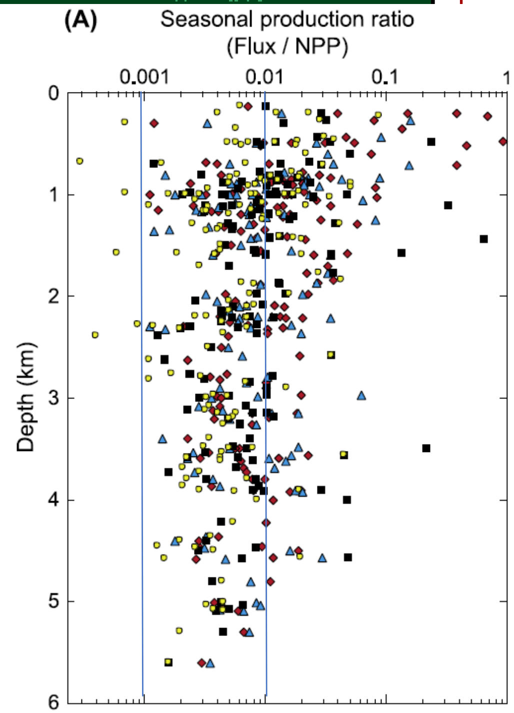
- Net export model of Lutz *et al.* 2007 as applied by McQuaid *et al.* 2019 to the CCZ.
- With one key change being addition of a very low class at ~half the upper threshold of McQuaid's lowest class.
- The South Pacific Gyre is more oligotrophic than the north, due perhaps to distance from land and influence from the Southern Ocean.



Lutz etal 2007 (g Corg/m2/yr)

- 0.046 - 0.67
- 0.671 - 1.355
- 1.356 - 1.81
- 1.811 - 220.05

adapted from McQuaid et al 2019 classification of the CCZ

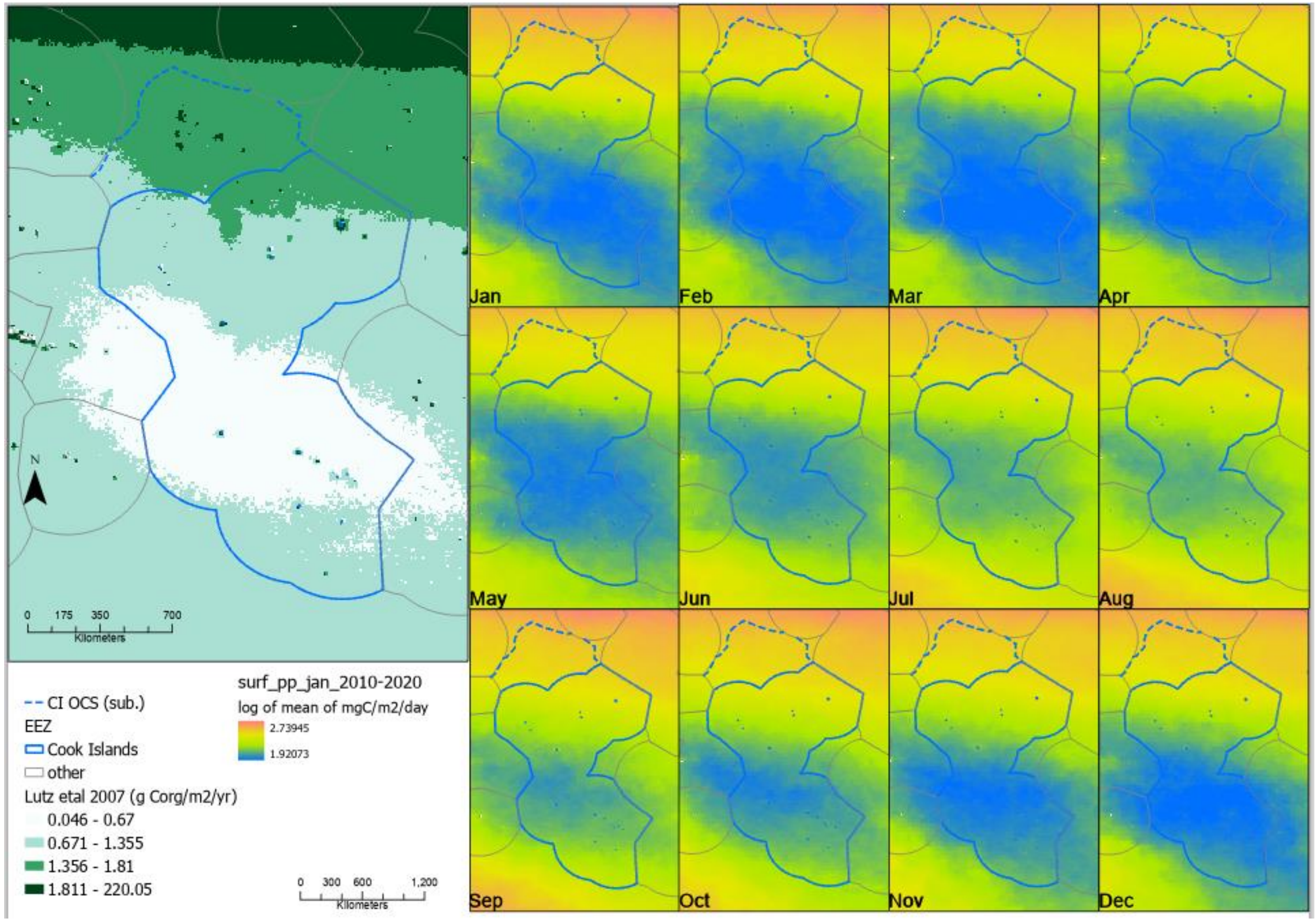


Lutz, M. J., K. Caldeira, R. B. Dunbar, and M. J. Behrenfeld (2007), Seasonal rhythms of net primary production and particulate organic carbon flux to depth describe the efficiency of biological pump in the global ocean, J. Geophys. Res., 112, C10011, doi:10.1029/2006JC003706.

Net export organic carbon compared with surface primary productivity (carbon)

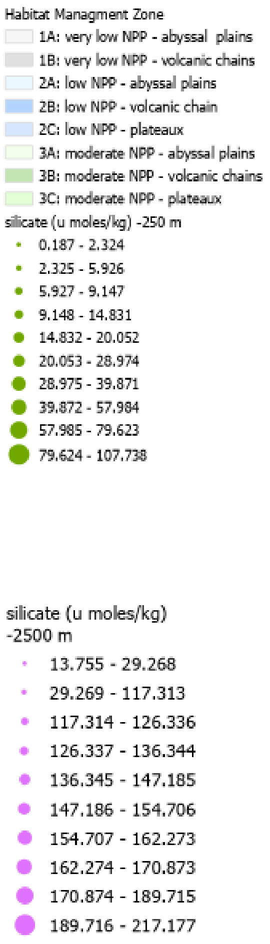
- Net export model of Lutz *et al.* 2007 is known to be imperfect when compared with seabed measurements related to carbon take-up (e.g. Sweetman *et al.* 2019).
- Lutz et al did consider seasonal variability and this is supported that the 'local scale'

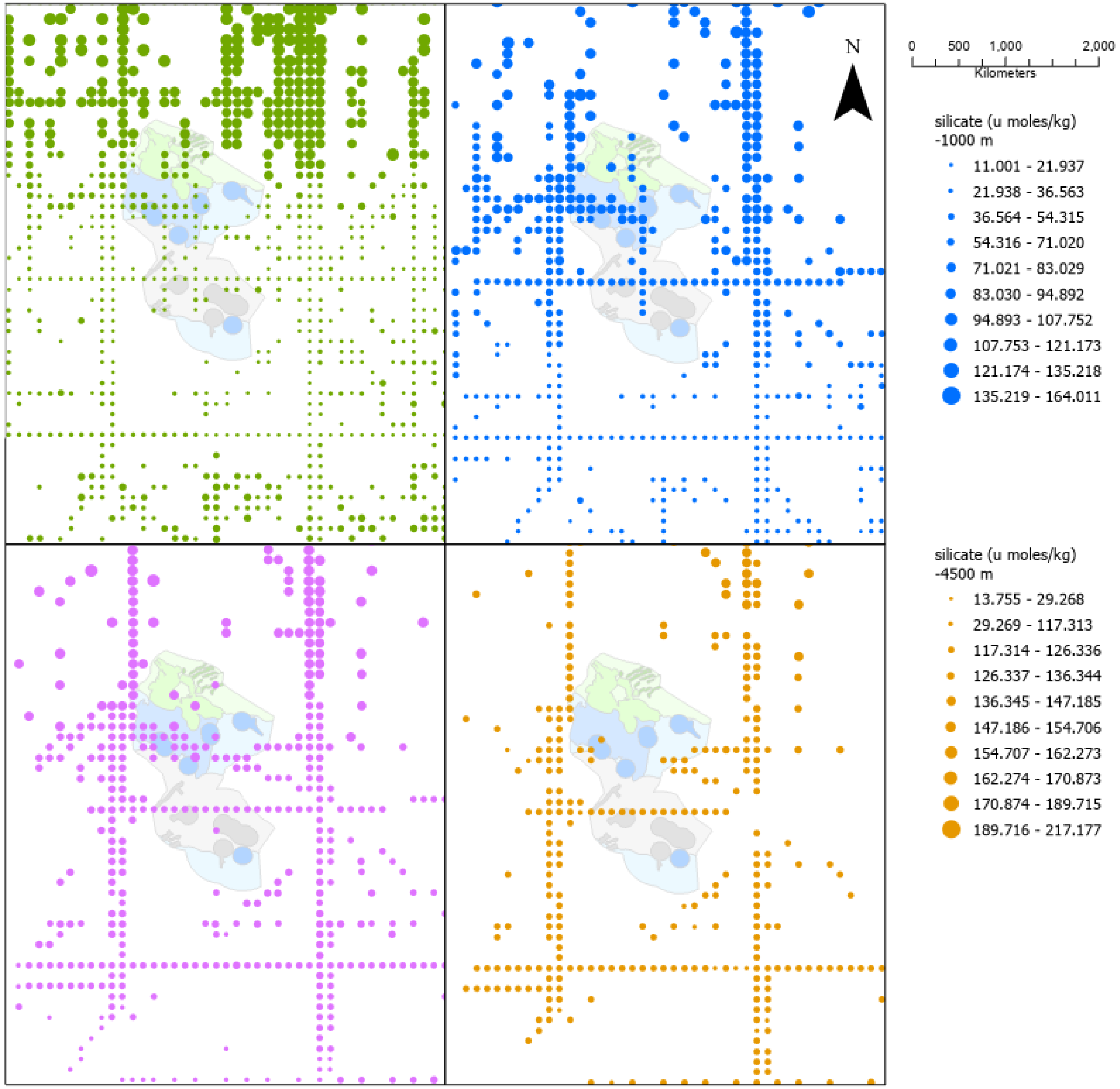
a comparison with monthly (at right) and annual surface primary productivity measurements (backup slides) both show a solid support (i.e. opposing conditions are never seen at the surface) .



Marine silicate

- Data is patchy
- More detailed depth levels generally support N->S decrease in silicate levels
- Near surface reflects surface C_{org}
- Silicates increase with depth to mid water then are more constant





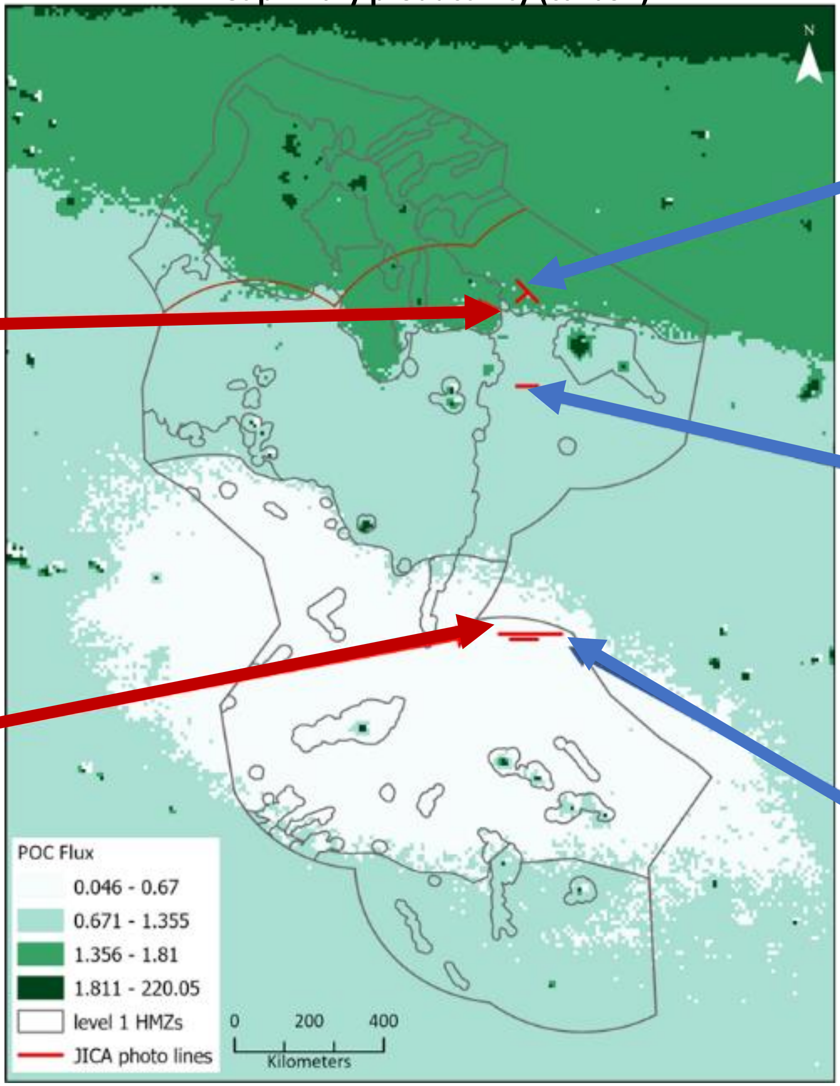
source: https://www.ncei.noaa.gov/products/world-ocean-atlas

Seabed Images – need more data

North Penrhyn Basin

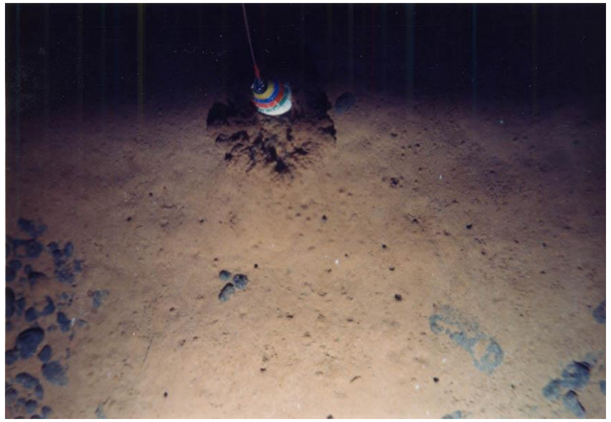
South Penrhyn Basin

Net primary productivity (carbon)



7° S

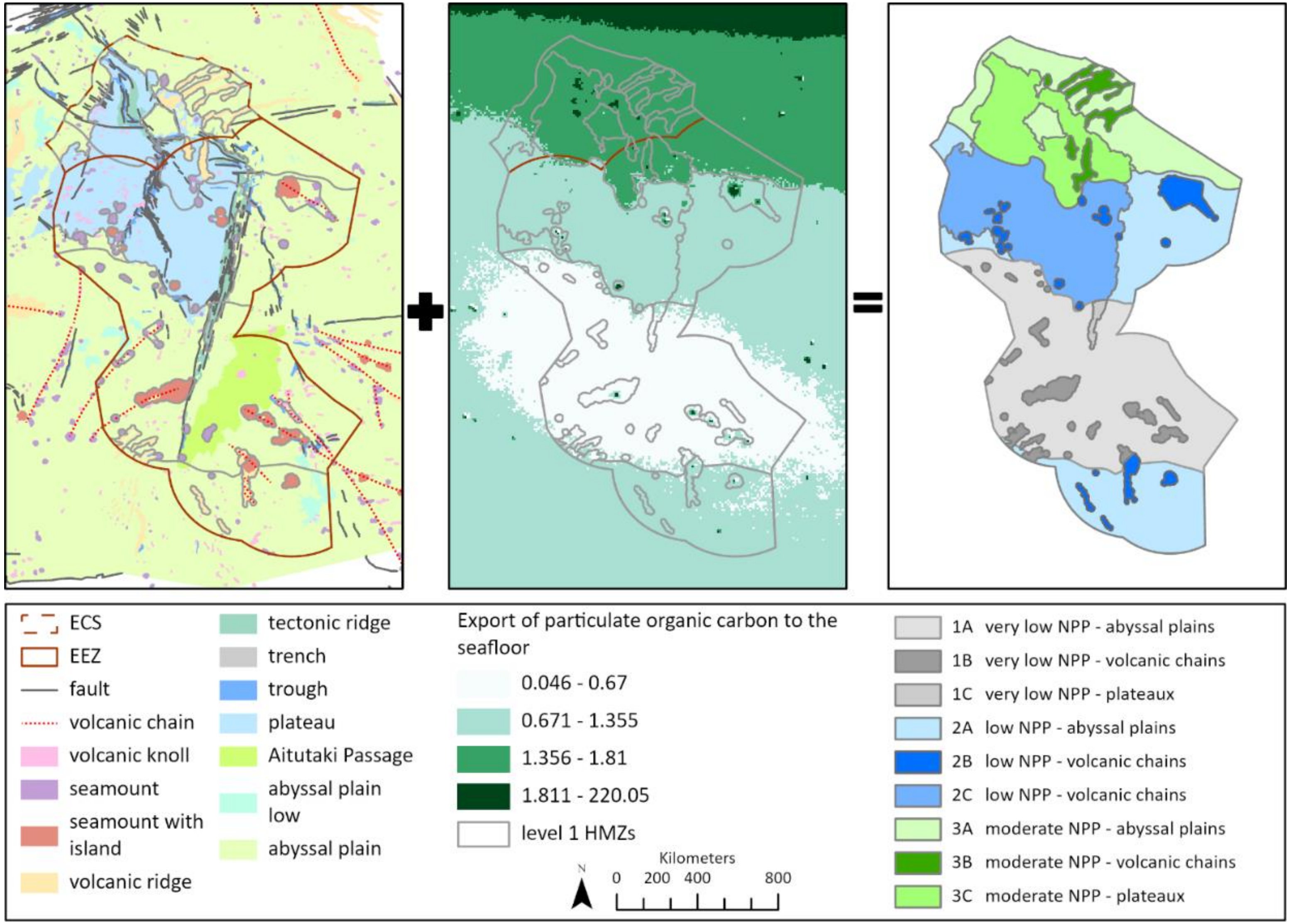
10° S



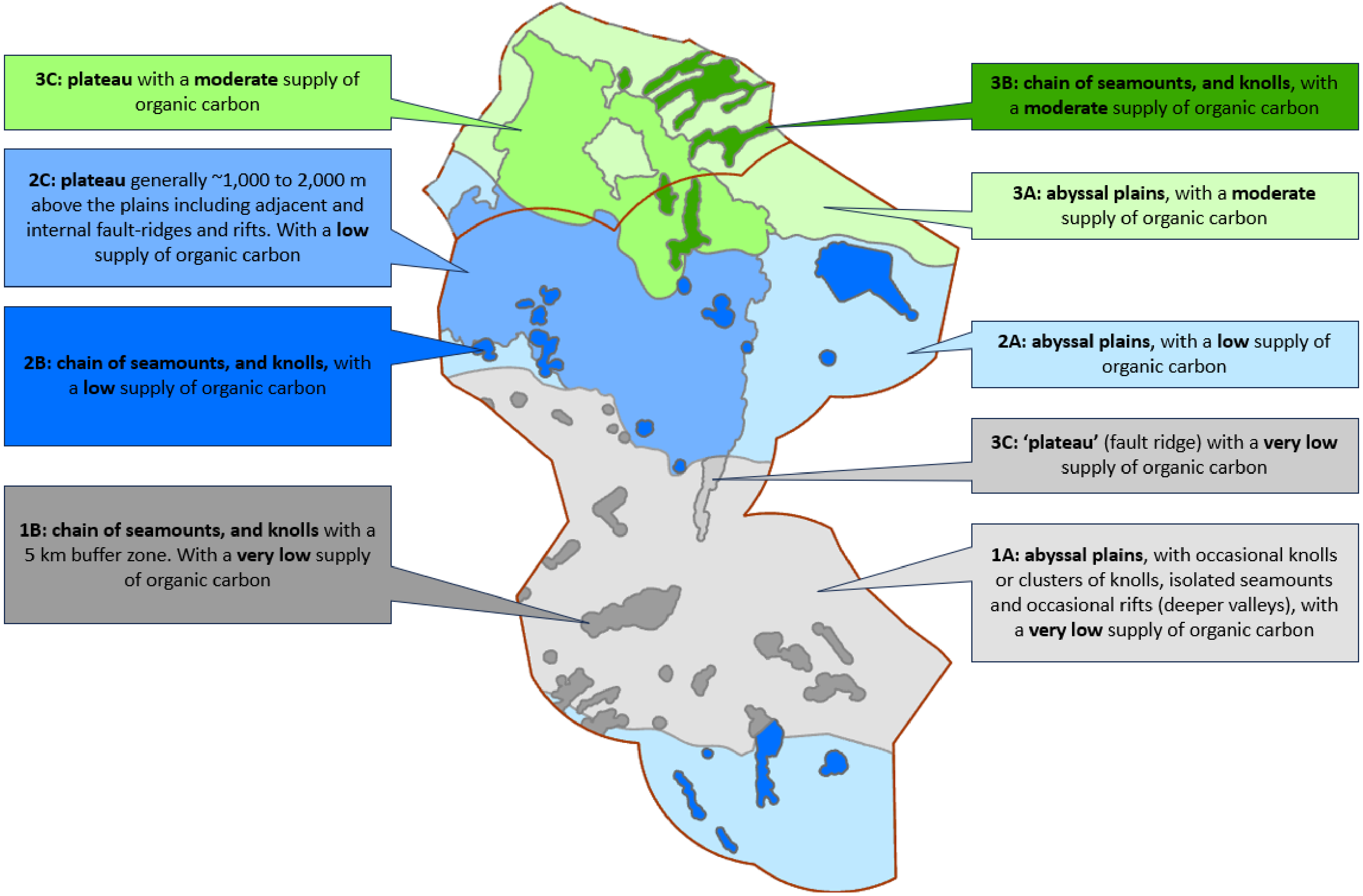
16° S

Images collected by JICA in 1985 and 1986

Specific Process for the HMZs



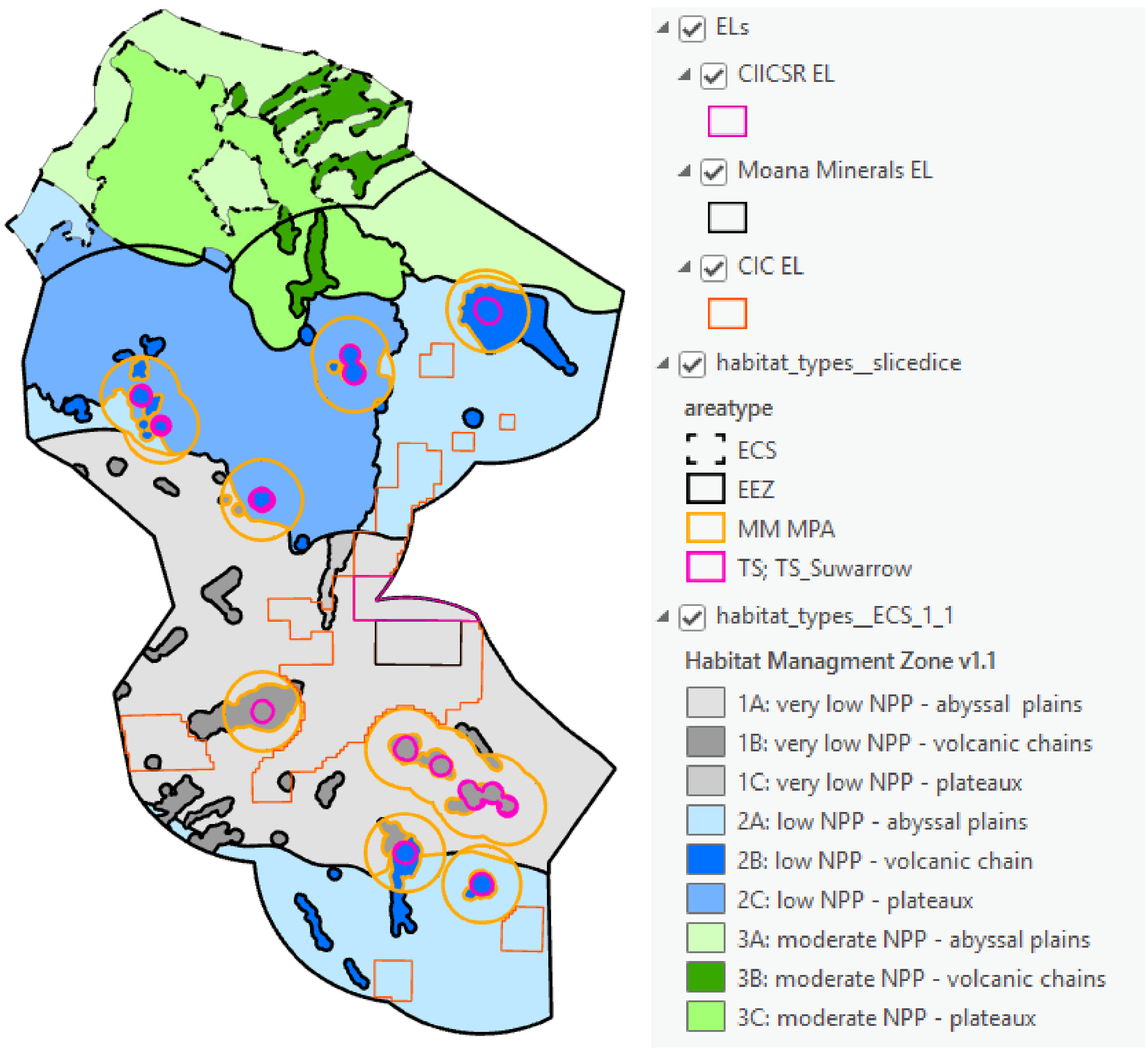
What are the Habitat Management Zones



Results

- Other questions in backup

		Abyssal Plains etc	Seamounts etc	Plateaux etc
Codes	Very low net POC	1A	1B	1C
	Low	2A	2B	2C
	Moderate	3A	3B	3C
	High	Not present in CI EEZ+ECS		
% of each HMZ in the EEZ+ECS	Very low	30%	3.6%	0.39%
	Low	22%	3.3%	17%
	Moderate	11%	2.4%	10%
% each HMZ under EL	Very low	27%	3.1%	17%
	Low	10%	0%	0.0047%
	Moderate	0%	0%	0%



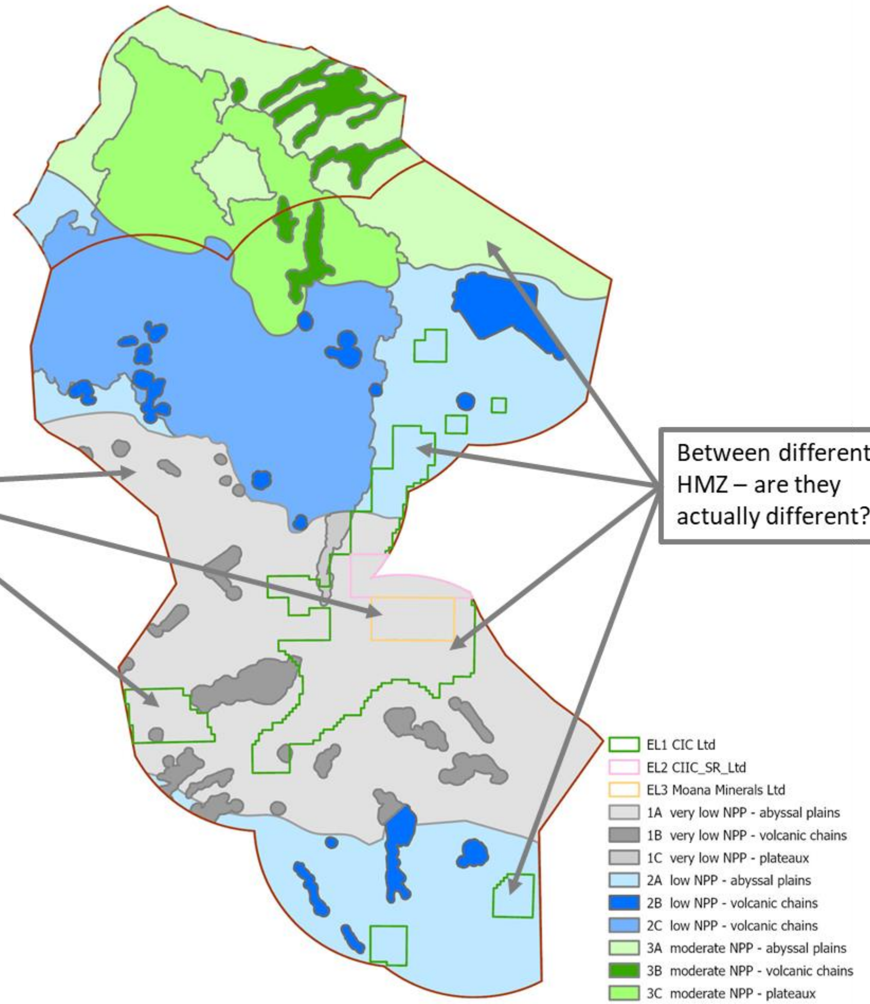
Testing?

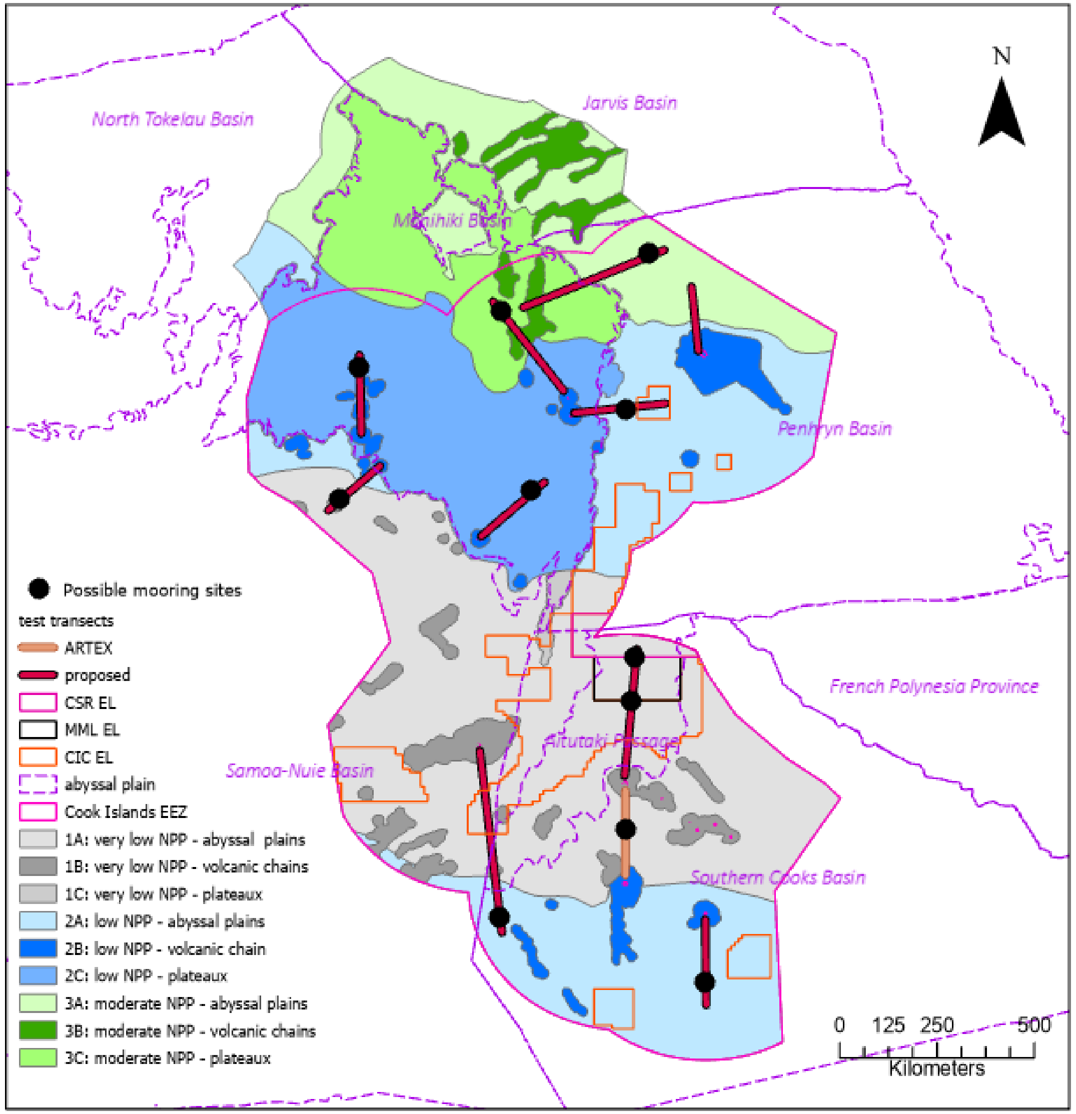
Two key questions
Example for A type morphologies

Between parts of a defined HMZ – are they truly the same?

Between different HMZ – are they actually different?

Note: B type morphologies have the greatest range in depths. The plateau also has <1 km depth variation (see backup)





Possible seabed programs to validate/invalidate habitats

14.4.2. Benthic habitat structure and function

Component	Specifications
Acoustic surveys	Mosaicked multibeam bathymetry and gain normalised backscatter at a resolution of 50 m or finer, georeferenced to industry standard. Geospatial techniques to classify benthic terrain to describe geoforms. Geospatial techniques, linked with groundtruthing below, to classify substrates.
Imaging surveys	Stable, low-altitude planar still imaging surveys to achieve image quality equal to or better than that reported in Simon-Lledó et al. (2020). Oblique video concurrent with planar stills with independent lighting systems. Georeferencing of camera platform to industry standard. Image based techniques to sample/mosaic imagery, segment and classify substrate types including nodule abundance-type classes, non-nodule sediment classes (e.g. bioturbation, substrate colour/texture properties), rock classes. Imagery to support groundtruthing of acoustic backscatter interpretation of substrates and also feed into megafauna biological community assessment.
Seafloor sampling	Box core sampling to determine nodule distribution, type and abundance using techniques that support image-based classification routines. Box core sampling to determine sediment physicochemical properties, nominally: • Trace metals – total and pore waters. • Nutrients – total and pore water. • Chlorophyll-a, phaeophytin. • Carbon and Nitrogen – Total carbon, TOC, TIC, total nitrogen. • Organics. • Grain size and moisture. • Mineralogy. Multicore sampling to determine sediment biogeochemical properties, nominally: • Particulate organic matter composition. • Sediment oxygen profiles, redox state, sulfur reduction. • Respiration rates of sediment infauna/epifauna.

14.4.5. Benthic ecosystem

Component	Specifications
Megafauna and benthic ecology imaging surveys	Imagery from 14.4.2, processed to analyse megafauna taxon abundance and distribution. Linked with 14.4.2, image-based techniques identify bioturbation, tracks and traces, and other biotic ecological features.
Seafloor sampling	Box core sampling to sample nodule-attached mega/macrofauna. Morphological and genetic techniques, trophodynamics, samples for ecotoxicology. Box core sampling to determine sediment macrofauna diversity, community composition, and distribution. Genetic and morphological techniques. Multicore sampling to determine meiofauna diversity, community composition, and distribution. Genetic and morphological techniques. Multicore sampling to determine microfauna diversity, community composition, and distribution. Genetic techniques. Multicore sampling to investigate sediment bioturbation, should imagery surveys indicate ecosystem importance. Consideration should be given to core CT scaning and geochemical indicators of bioturbation (e.g. ^{210}Pb).

The concept around the truthing of zonation is a hierarchical or phased approach:

1. Zones based on surface production and geoform – ie per this proposal

2. Truthing of zones from a physical substrates perspective – 14.4.2 Imaging surveys at left

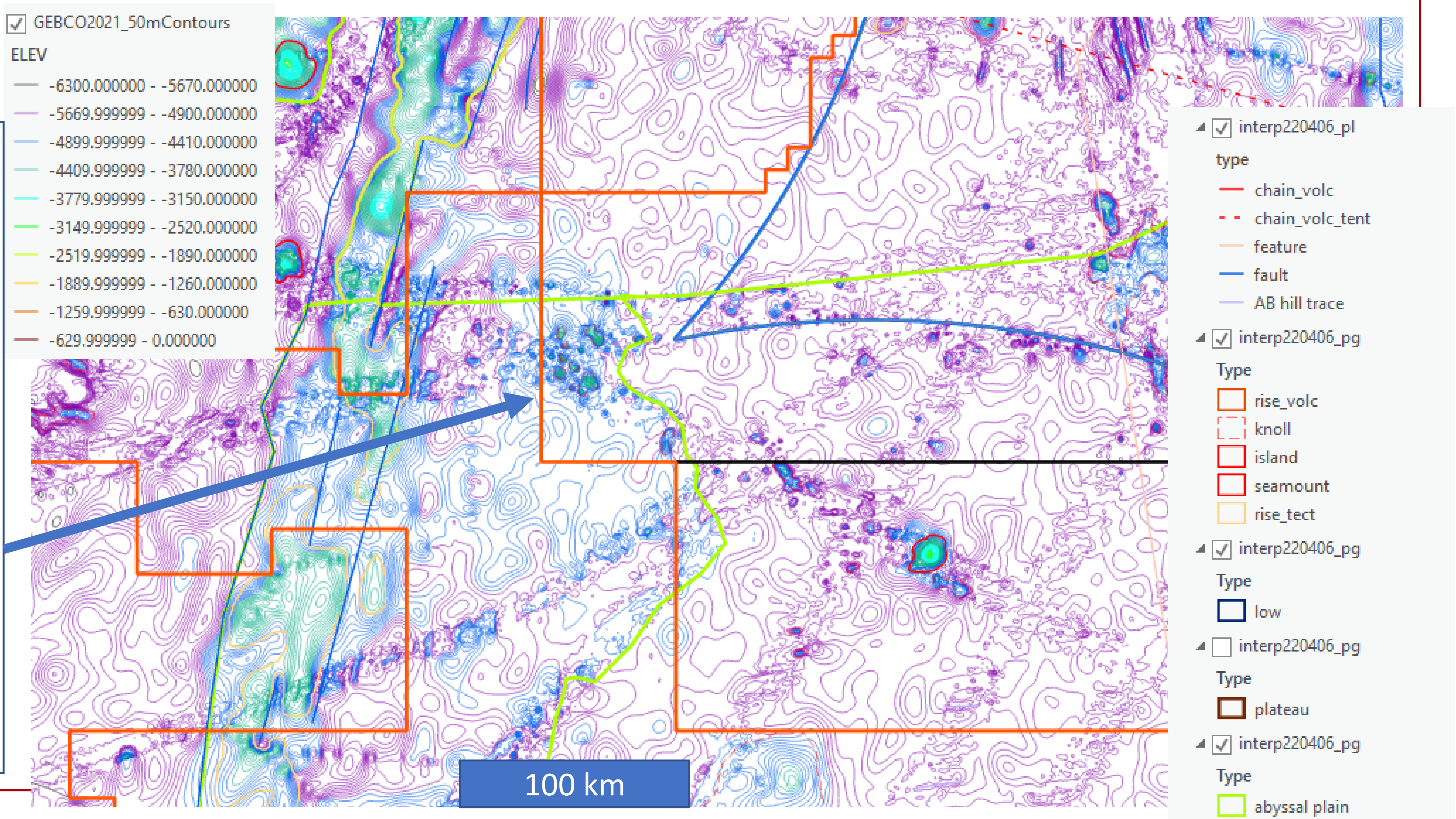
3. Truthing of zones from a biogeochemical and chemistry perspective – 14.4.2 Seafloor sampling at left

4. Truthing of zones from a biological communities perspective – 14.4.5 above.

Source: Moana Minerals ESIA 2022

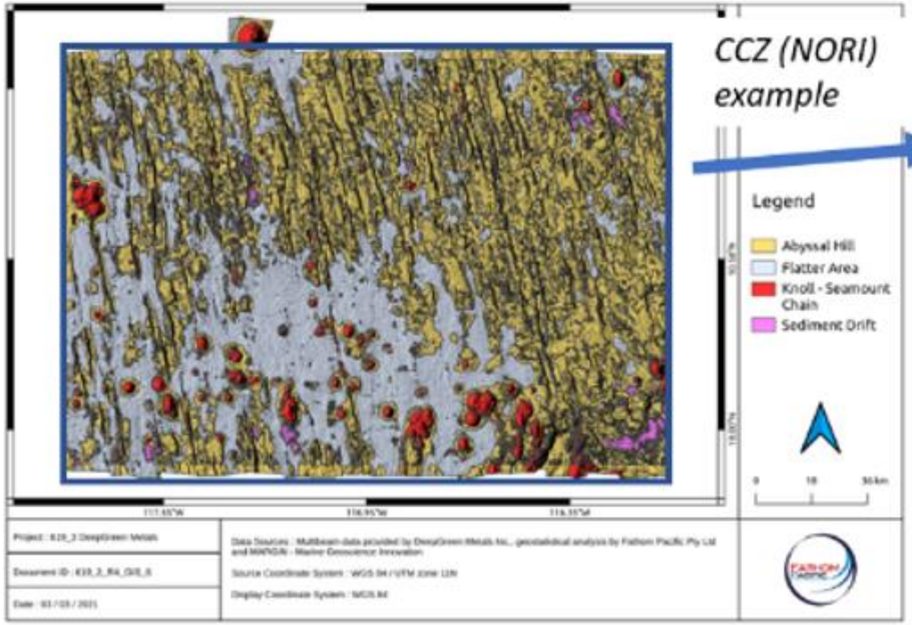
View towards a level 2 classification

Areas with MBES coverage show some areas with abundant knolls to seamounts and other area with classic abyssal hills
Full MBES coverage is needed to spatially define habitats that include these features.
All habitats need to be ground tested regarding ecosystem function.

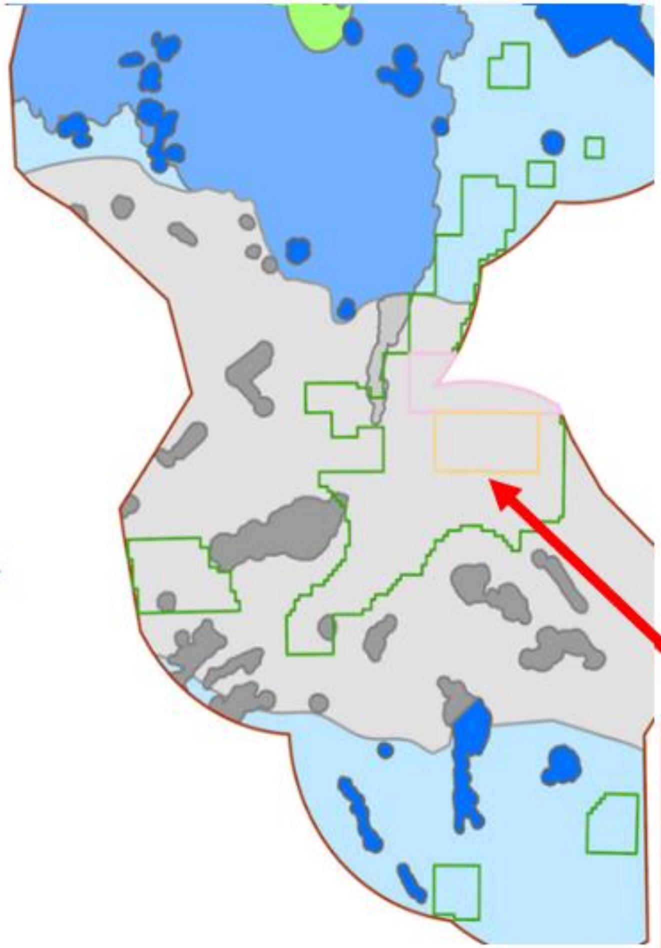


View towards a level 2 classification and towards IRZs and PRZs

- Impact Reference Zones (IRZs) and Preservation Reference Zones (PRZs) are not required under current regulations but are leading practice in the Area and have been proposed by a Licensee
- Level 2/3 classification would be part of the process of identifying any IRZs and PRZs

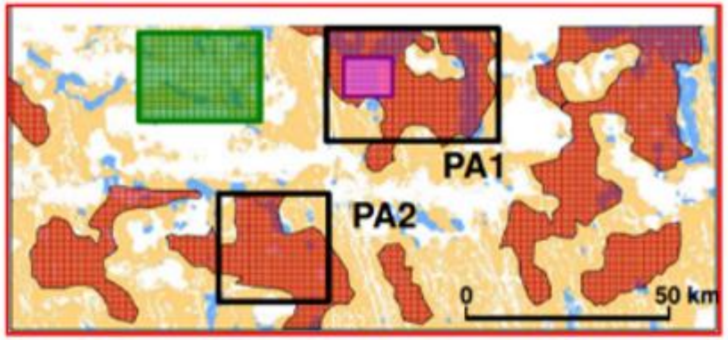


CCZ (NORI) example



- Impact Reference Zones (IRZs) are areas that have been harvested
- Preservation Reference Zones (PRZs) are ecologically representative areas that have not been harvested

CCZ (BGR) example



Backup

Other Questions

Proportion of areas

Comparison with other schema

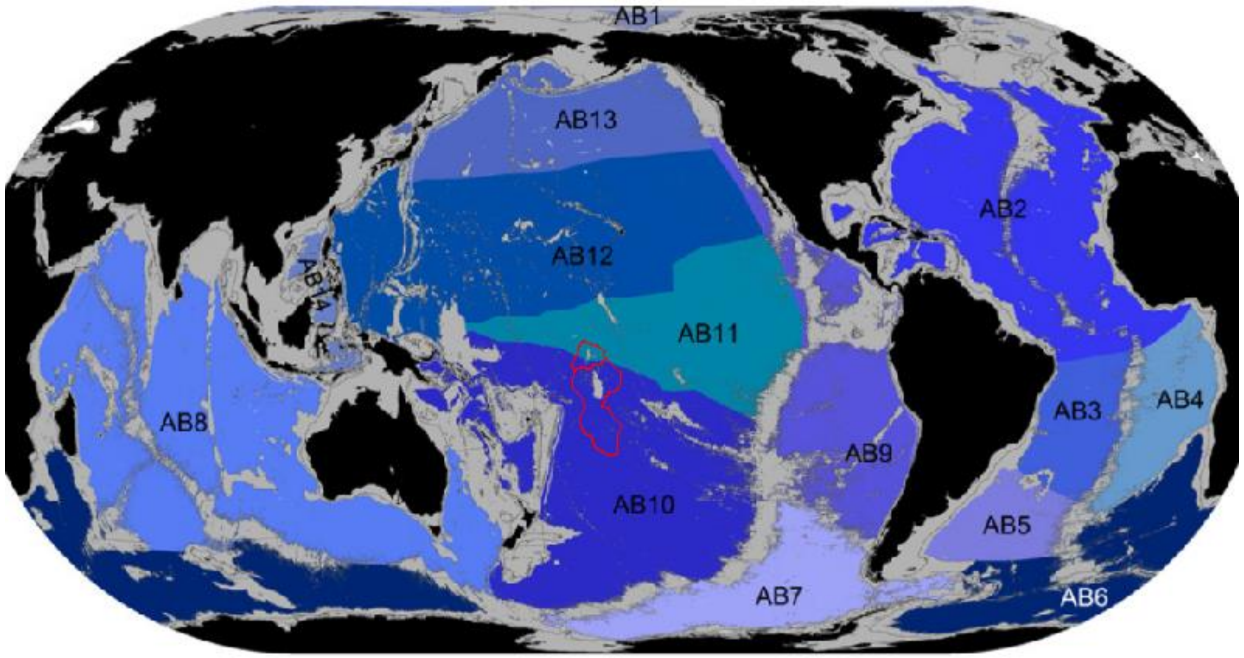
Geomorphological map

1. Bathymetry, datatypes and habitats
2. Check against BTM (fBPI etc.)

Organic Carbon Net Export

1. Check against annual surface PP

Example of level 1 -> 2 - >3 from CCZ

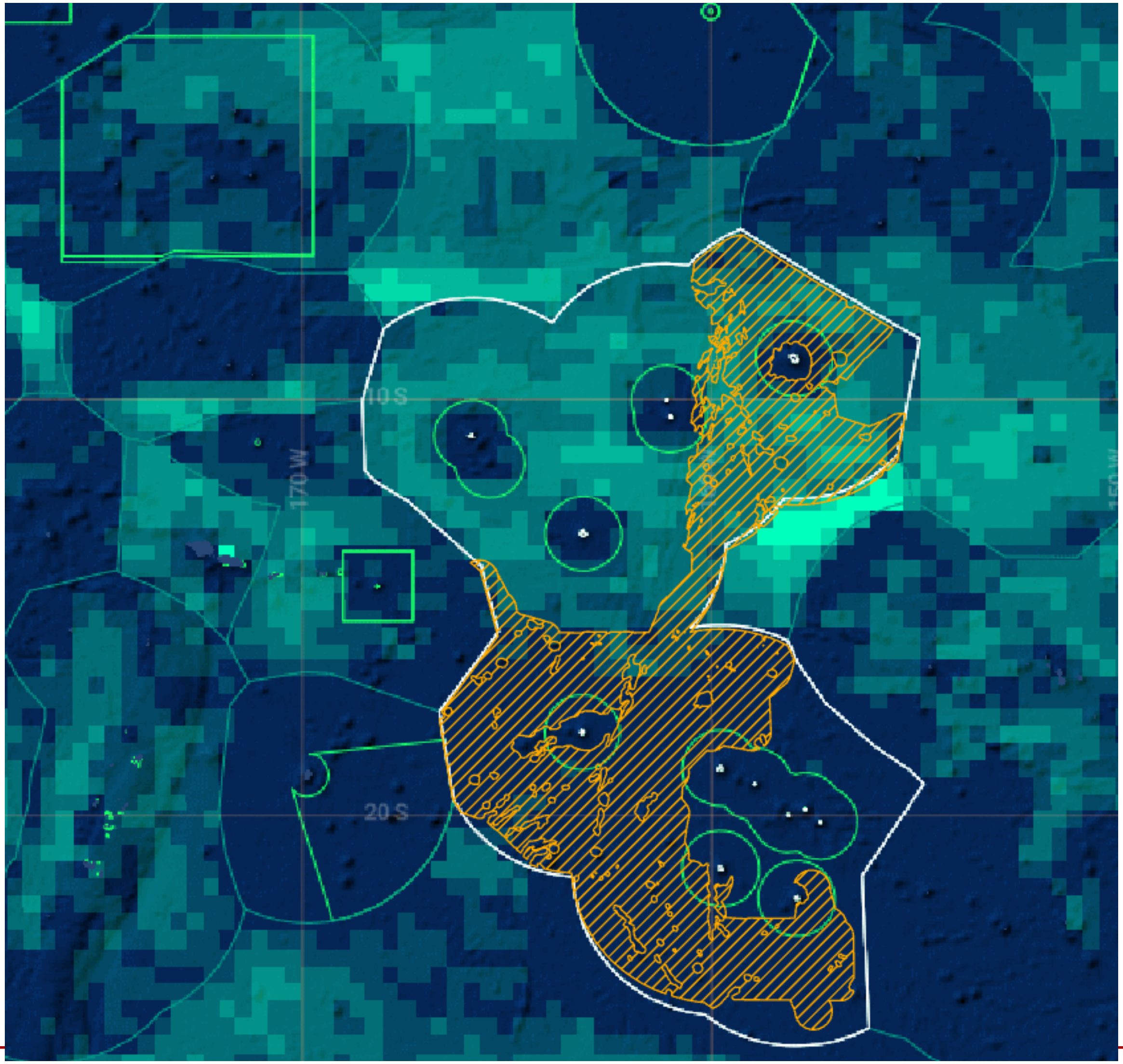


AB1: Arctic Basin
AB2:North Atlantic
AB3: Brazil Basin
AB4: Angola, Guinea, Sierra Leone Basins
AB5: Argentine Basin
AB6: Antarctica East
AB7: Antarctica West
AB8: Indian
AB9: Chile, Peru, Guatemala Basins
AB10: South Pacific
AB11: Equatorial Pacific
AB12: North Central Pacific
AB13: North Pacific
AB14: West Pacific Basins

Biogeographic zones of Watling *et al.* 2013

Seabed nodules versus fishing effort – mutually exclusive

- Nodule fields from RSC (2023)
- Fishing effort April/May 2023
- Other types of mineral occurrences found in slightly different places

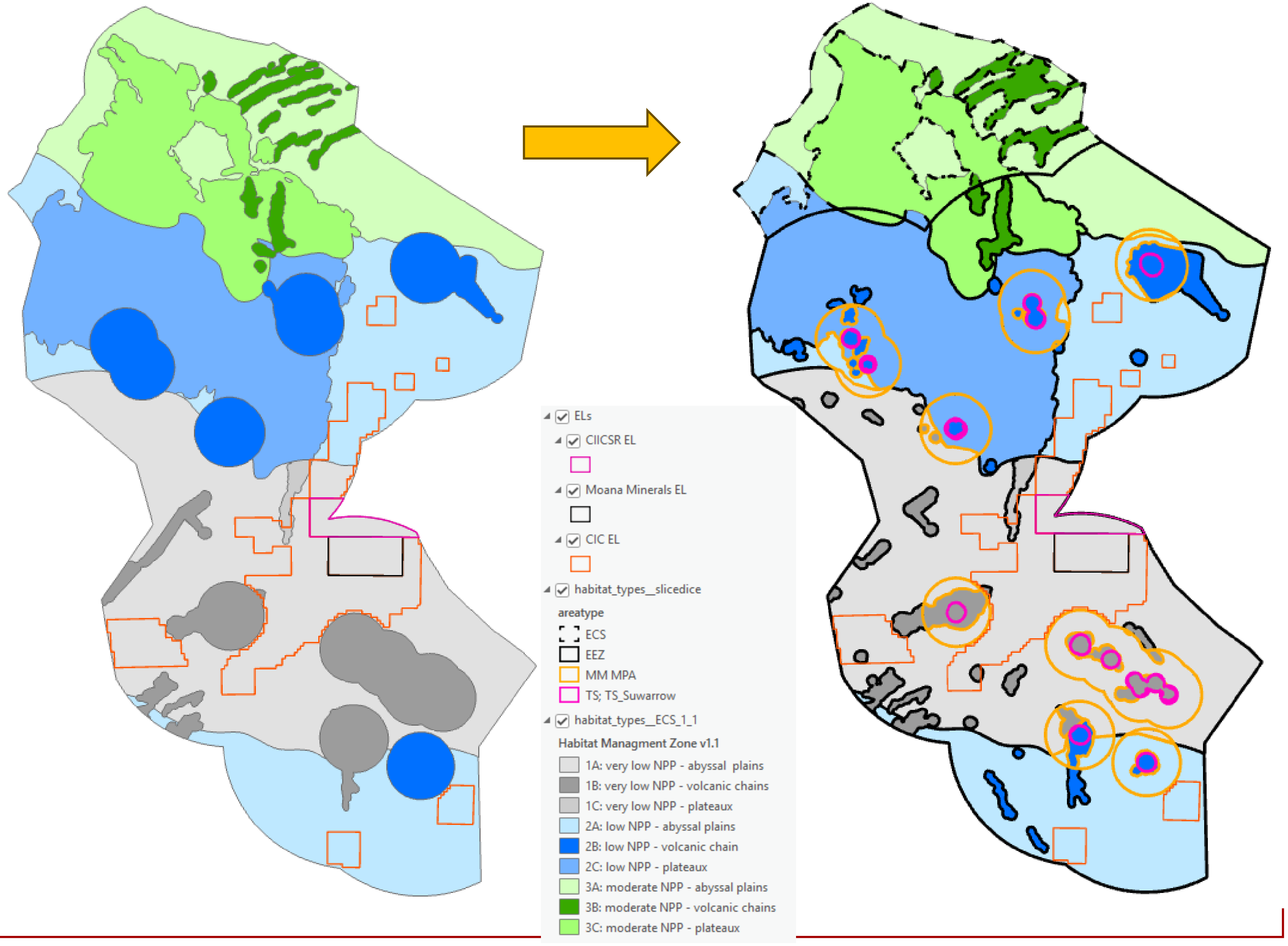


Revision of HMZs

No major changes

- MPAs taken out of the HMZs
- A few seamounts added to align more closely with SUMAs
- HMZs subclassified by “type” of sea ECS, EEZ, MPA, TS (helps to constrain National vs Island MSPs)
- Further subclassification by seabed minerals exploration licence

Note that the HMZs need to be tested via marine exploration



HMZs v1.1 allow for better spatial planning

- How much of each HMZ is present in the ECS+EEZ vs EEZ or ECS?

	plains	mounts	plateau
very low	1A	1B	1C
low NPP	2A	2B	2C
moderate	3A	3B	3C

	km2			of total area						area ranking in ECS+EEZ		
total (EEZ+ECS)	724,365	84,567	9,273	30%	3.6%	0.39%				1	6	9
2,381,635	512,591	79,104	402,084	22%	3.3%	17%				2	7	3
	271,240	56,787	241,624	11%	2.4%	10%				4	8	5
	km2			of total area			of HMZ concerned			area ranking in EEZ		
EEZ (incl MM MPA and TS)	724,365	84,567	9,273	30%	3.6%	0.39%	100%	100%	100%	1	5	9
1,969,867	492,093	79,104	385,369	21%	3.3%	16%	96%	100%	96%	2	7	3
	100,629	15,061	79,406	4.2%	0.6%	3.3%	37%	27%	33%	4	8	6
	km2			of total area			of HMZ concerned			area ranking in ECS		
ECS				0%	0%	0%	0%	0%	0%			
411,768	20,498		16,715	0.86%	0%	0.70%	4.0%	0%	4.2%	4		5
	170,611	41,726	162,218	7.2%	1.8%	6.8%	63%	73%	67%	1	3	2

How much of each seabed HMZ has been permitted?

- So far only exploration, and so far, only in line with MSR levels of activity
- Under exploration unlikely to have material impacts even for trial minerals harvesting
- 27% of 1A and 10% of 2A the likely beneficiaries of this research – we need to promote research in other zones
- Mineral harvesting licences, at least to begin with, likely to be much smaller

	km2			of total HMZ			of EEZ HMZ			area ranking in LH		
EL	196,726	2,592	1,599	27%	3%	17%	27%	3.1%	17%	1	3	4
254,649	53,713		19	10%	0%	0.0047%	11%	0%	0.0049%	2		5
				0%	0%	0%	0%	0%	0%			

	km2			of total HMZ			of EEZ HMZ			area ranking in LH		
ML				0%	0%	0%	0%	0%	0%			
0				0%	0%	0%	0%	0%	0%			
				0%	0%	0%	0%	0%	0%			

Note that 3 MLs each at 20,000 km2 all in 1A would equal about 8.3% of the 1A HMZ

If the goal is 30% seabed MPAs of similar type to the island MPAs?

- How much additional area is needed by seabed HMZ?
- Should the seabed MPAs extend into the ECS?
- HMZs are probably better than simple EEZ, but are they good enough?

	plains	mounts	plateau
very low	1A	1B	1C
low NPP	2A	2B	2C
moderate	3A	3B	3C

	km2			of total HMZ			of EEZ HMZ			to 30% of EEZ+ECS			to 30% of EEZ		
MM MPA ex TS except Suwarrow	107,845	26,095		15%	31%	0%	15%	31%	0%	109,465	-725	2,782	109,465	-725	2,782
294,693	49,857	33,295	75,591	9.7%	42%	19%	10%	42%	20%	103,920	-9,564	45,034	97,771	-9,564	40,020
	2,010			0.74%	0%	0%	2.0%	0%	0%	79,362	17,036	72,487	28,179	4,518	23,822
										extra (no reductions)		430,086	extra (no reductions)		306,556
											of existing	146%		of existing	104%

And how do the territorial seas compare?

- Note TS areas include islands at this stage

	plains	mounts	plateau
very low	1A	1B	1C
low NPP	2A	2B	2C
moderate	3A	3B	3C

	km2			of total area						area ranking in ECS+EEZ		
total (EEZ+ECS)	724,365	84,567	9,273	30%	3.6%	0.39%				1	6	9
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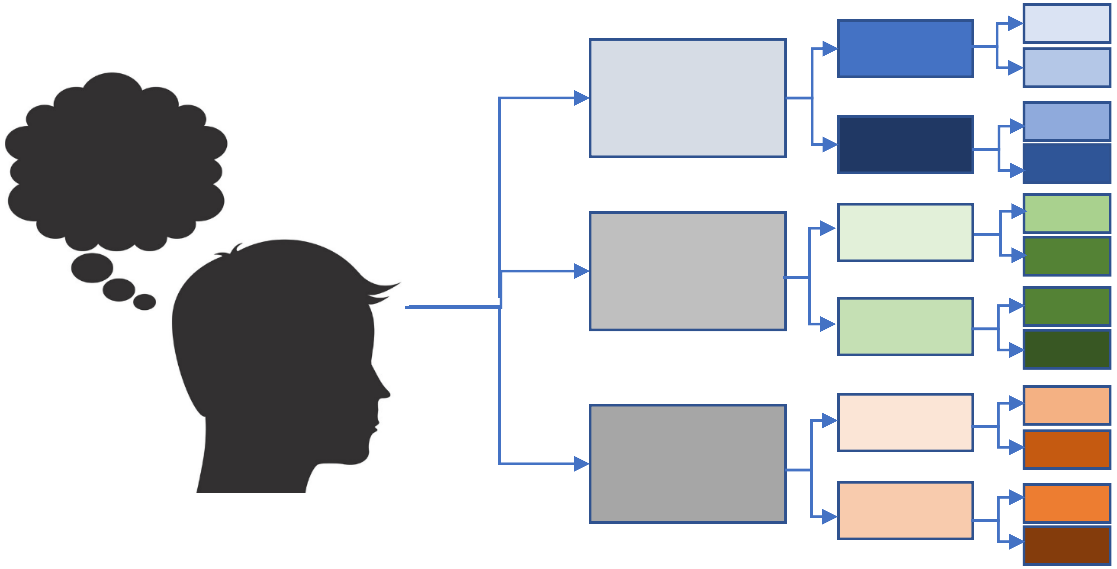
	100,629	15,061	79,406	4.2%	0.6%	3.3%	37%	27%	33%	4	8	6
	km2			of total HMZ			of EEZ HMZ			area ranking in TS		
TS except Suwarrow	1,038	12,703		0.14%	15%	0%	0.14%	15%	0%	4	2	
29,043		14,213	1,089	0%	18%	0.27%	0%	18%	0.28%		1	3
				0%	0%	0%	0%	0%	0%			

What is a Seabed Habitat Management Zone

It is an **area of seabed** that:

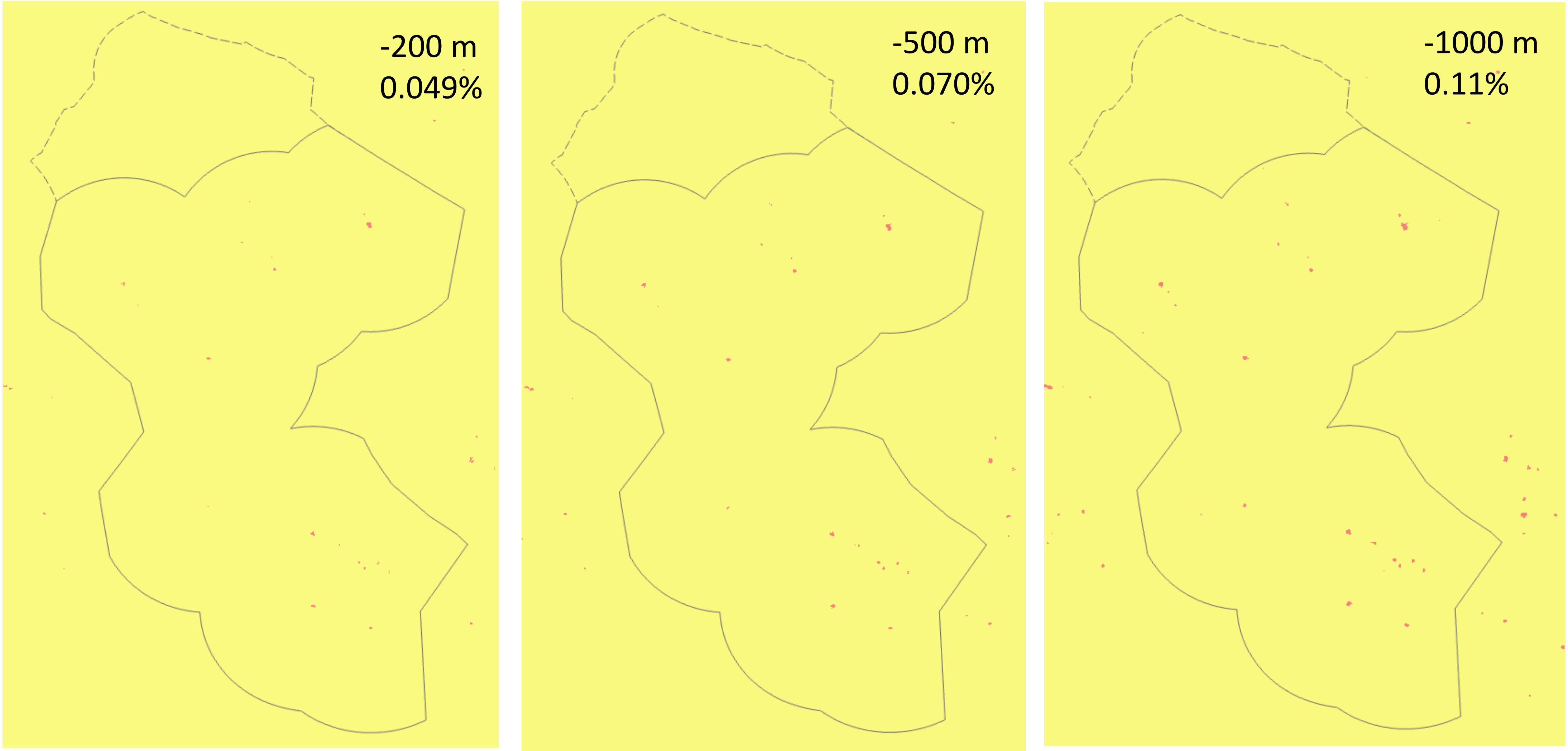
- contains broadly similar habitats
- can be considered **different** to other areas based on its setting (e.g. physiographic or biological features)
- can be **managed** effectively – not too large, not too small



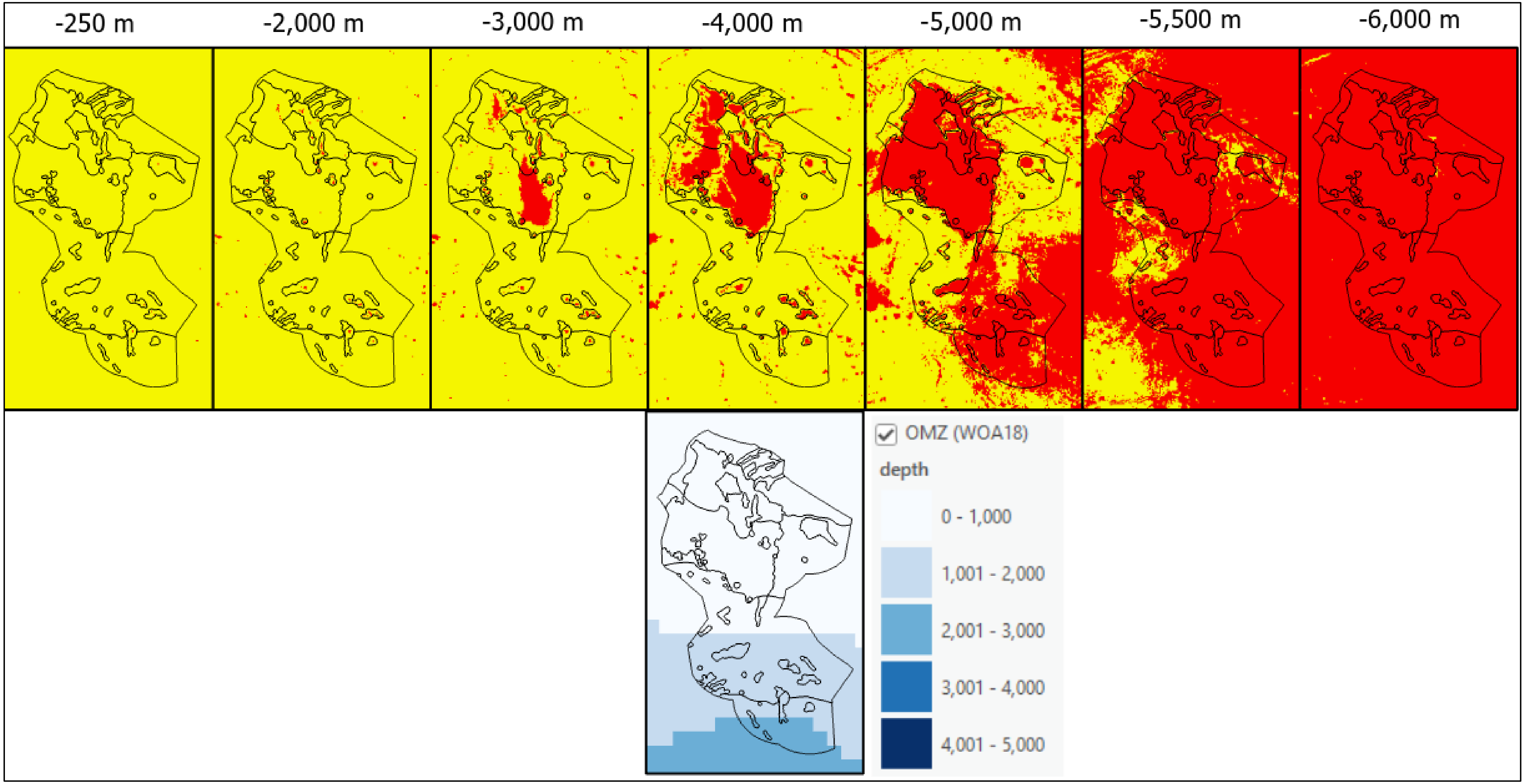
It is not:

- A single habitat, as these can vary widely in terms of size depending on what criteria are used (and what criteria might be important for conservation)
- Homogenous throughout, i.e. it can be hierarchical with levels of sub-zones and even sub-subzones

Proportion of area above a certain depth in EEZ+ECS



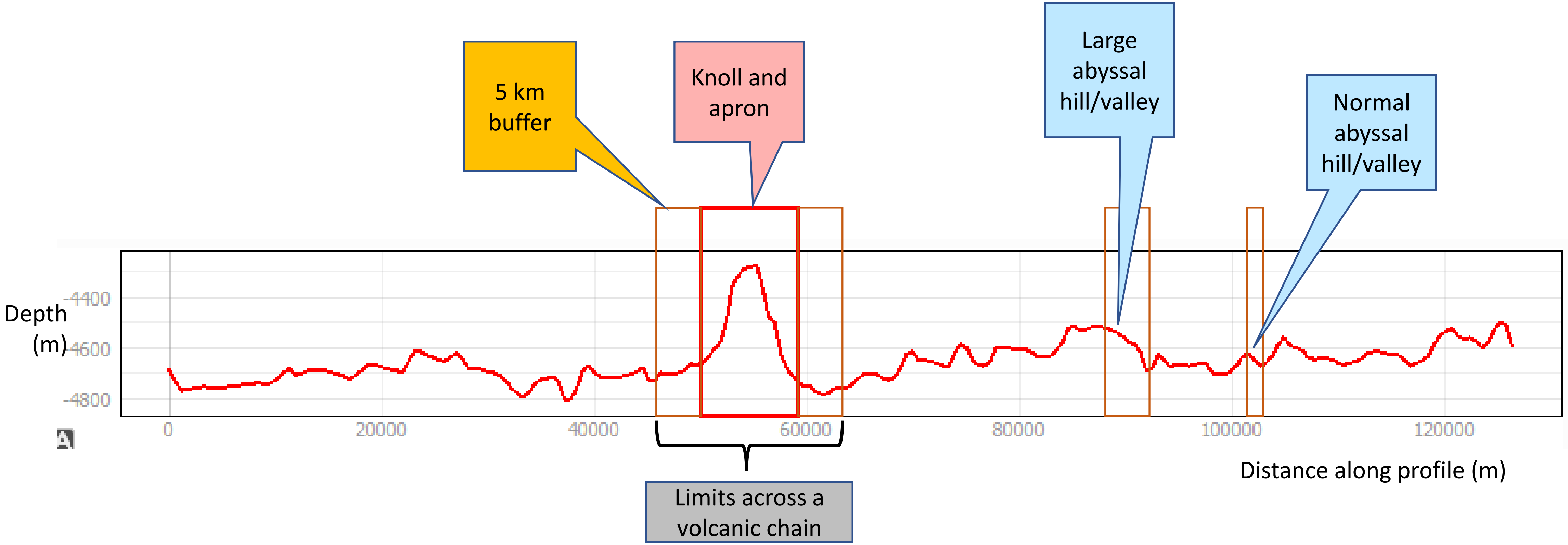
Proportion of area above a certain depth and OMZ



https://www.ncei.noaa.gov/access/world-ocean-atlas-2018/bin/woa18oxnu.pl?parameter=o

5 km buffer around volcanic chains

- Example 12 kHz MBES profile
- This might be revised once we have more extensive MBES data (including backscatter regarding sediment drifts around seamounts; typically <5 km in the CCZ).



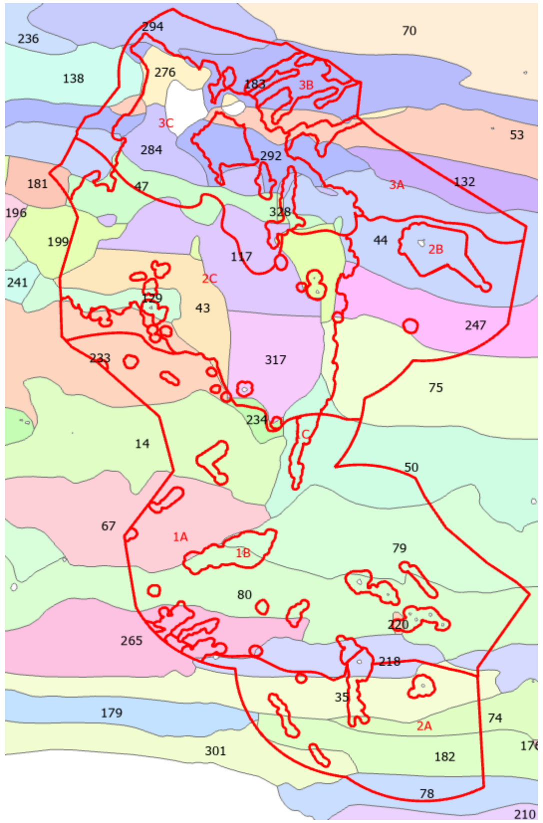
Comparison: MACBIO2018 SUMAs

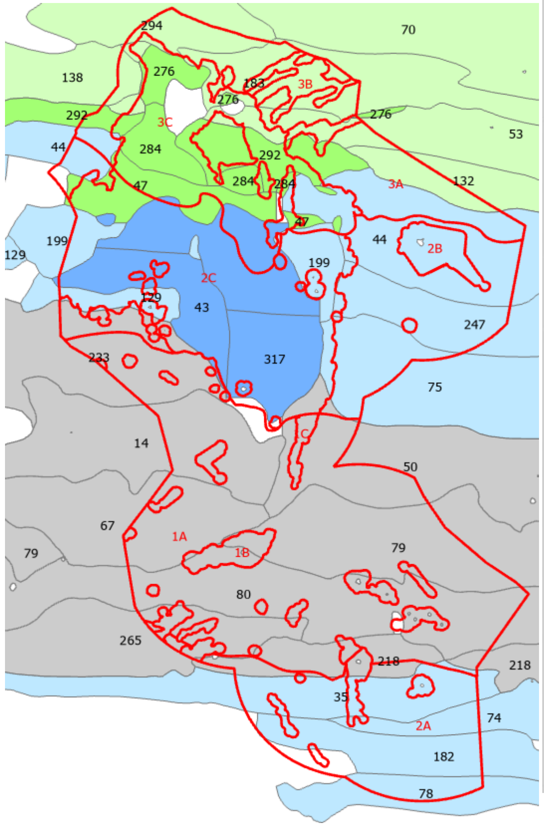
"Deepwater" for this analysis (MACBIO) was defined at the **200 m depth** or 20 km out whichever was the furthest from land.

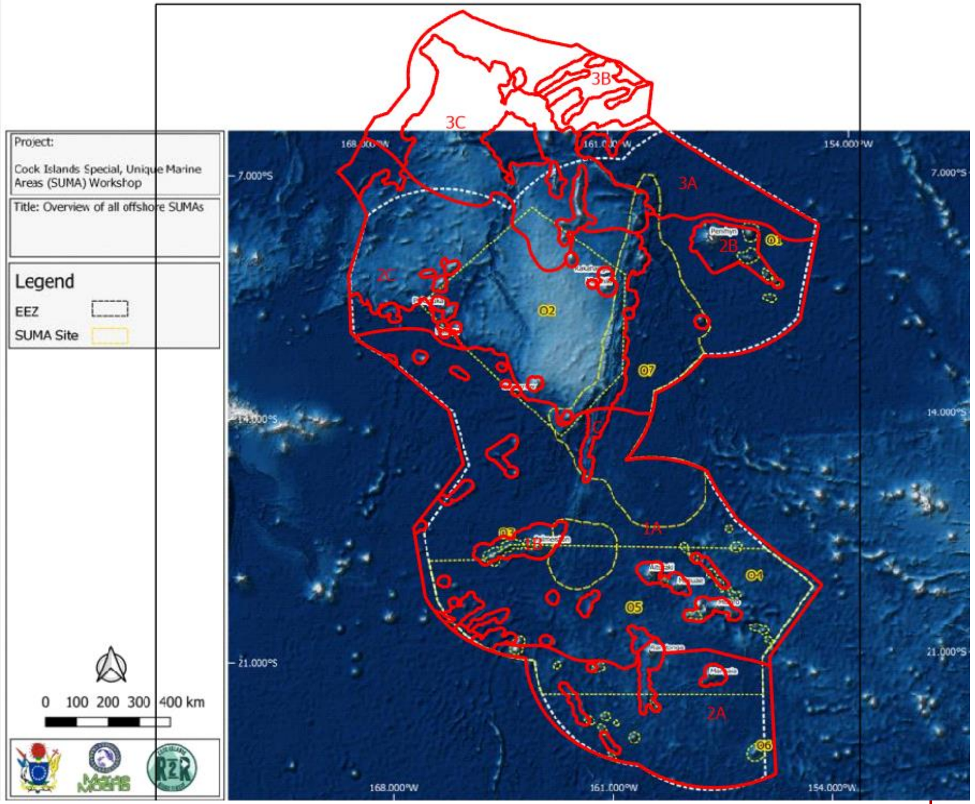
Based on cluster analysis of a range of surface and subsea data.
Most subsea data to 200 or 1000 m depth.
Bathymetry also highly influential.

Discriminating factors in each case currently unclear.

Review of these regions may be appropriate within the Cook Islands once additional material information comes to hand.



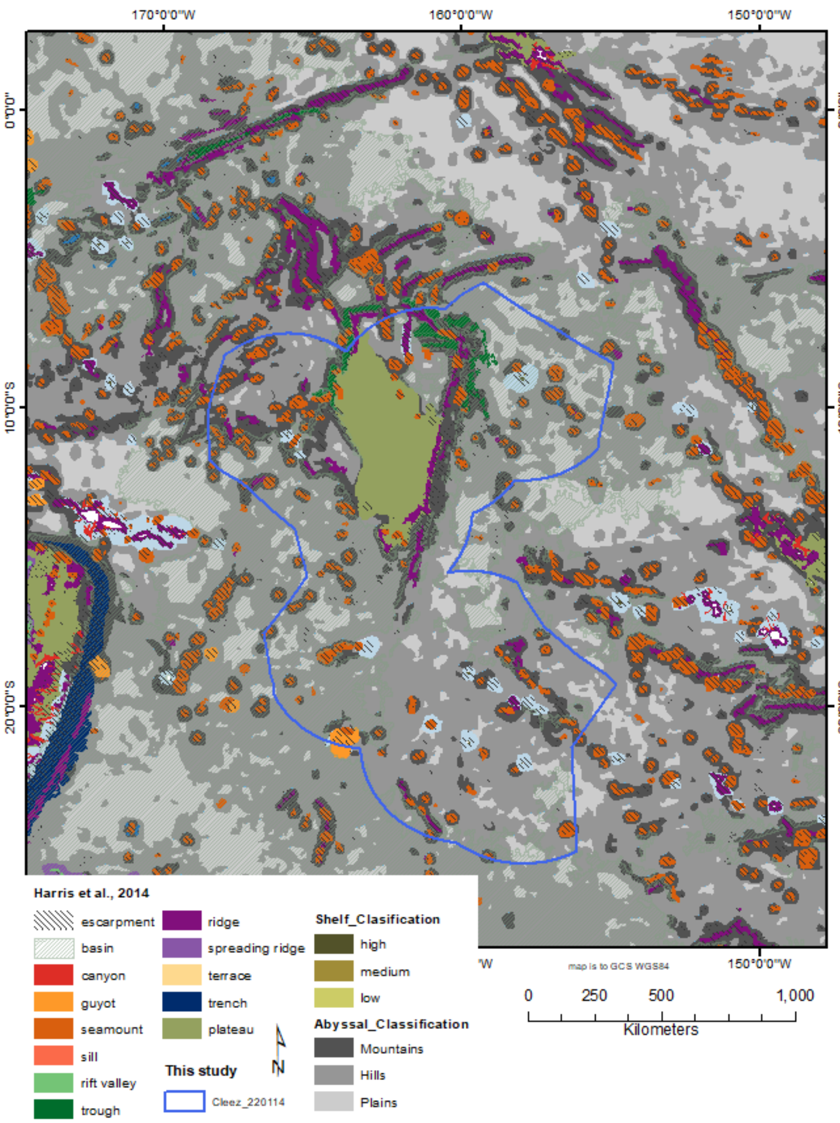


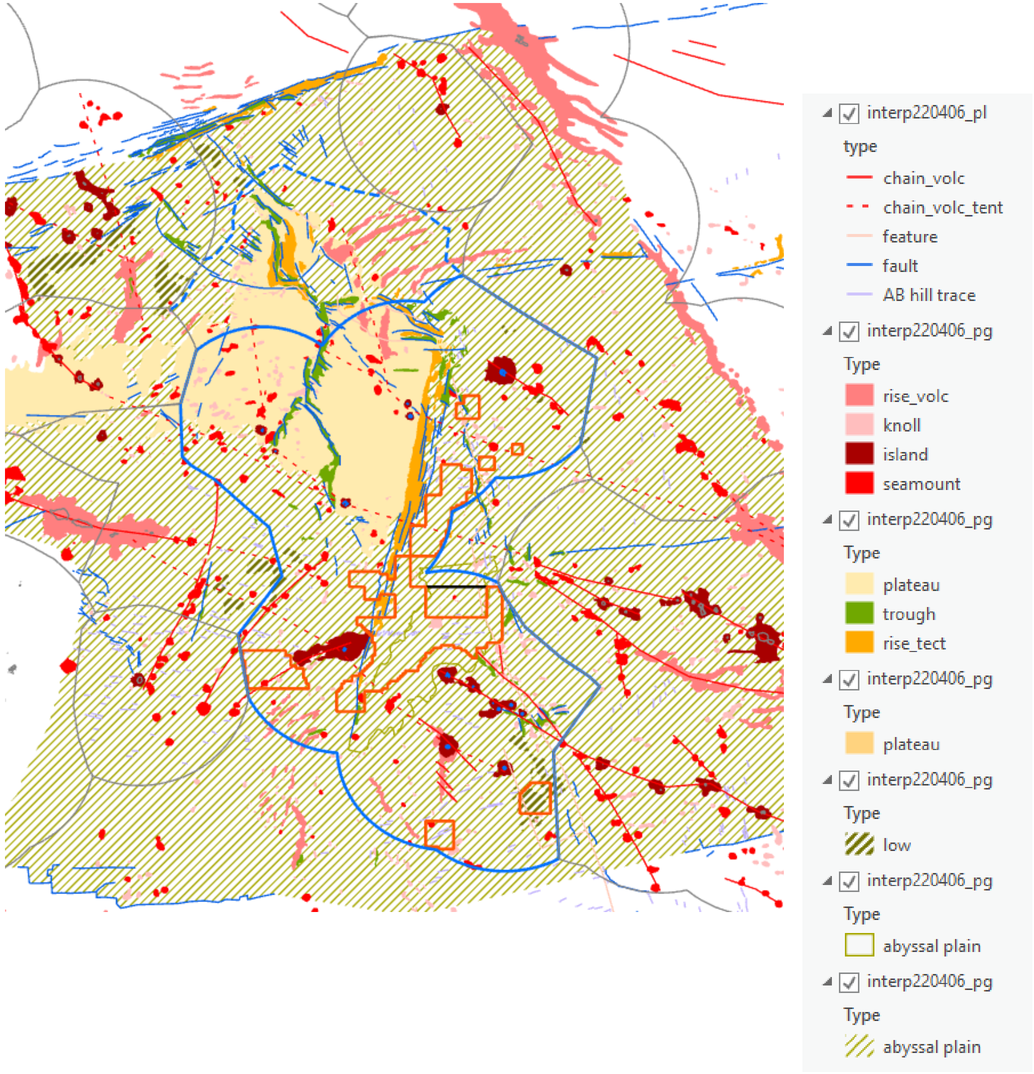


Wendt, H., M. Beger, J. Sullivan, J. LeGrand, K. Davey, N. Yakub, S. Kirmani, H. Grice, C. Mason, J. Raubani, A. Lewis, S. Jupiter, and L. Fernandes. 2018. Draft marine bioregions in the Southwest Pacific. MACBIO (GIZ, IUCN, SPREP), Suva.

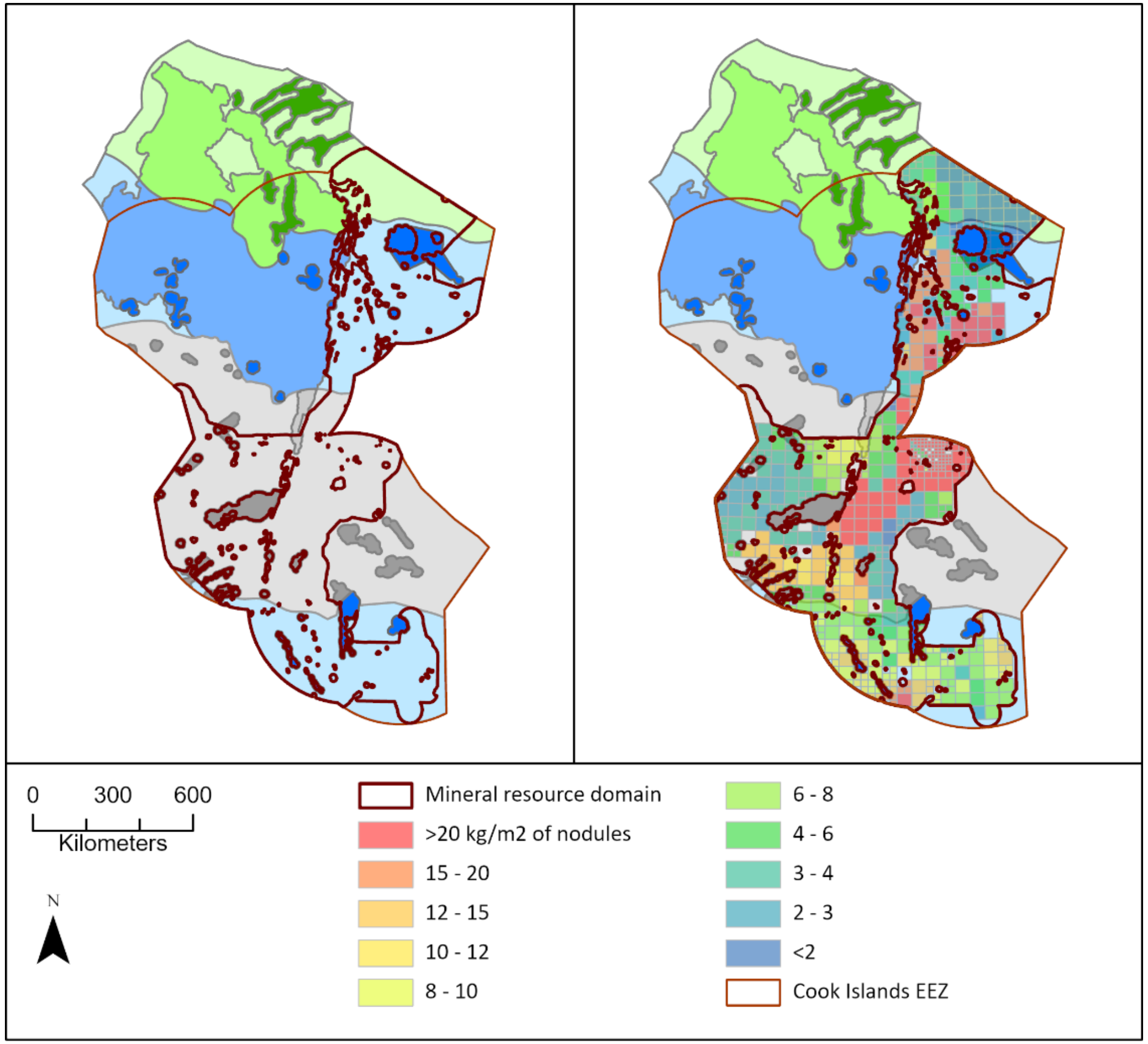
http://macbio-pacific.info/wp-content/uploads/2018/03/MACBIO-Bioregions-Report_Digital.pdf

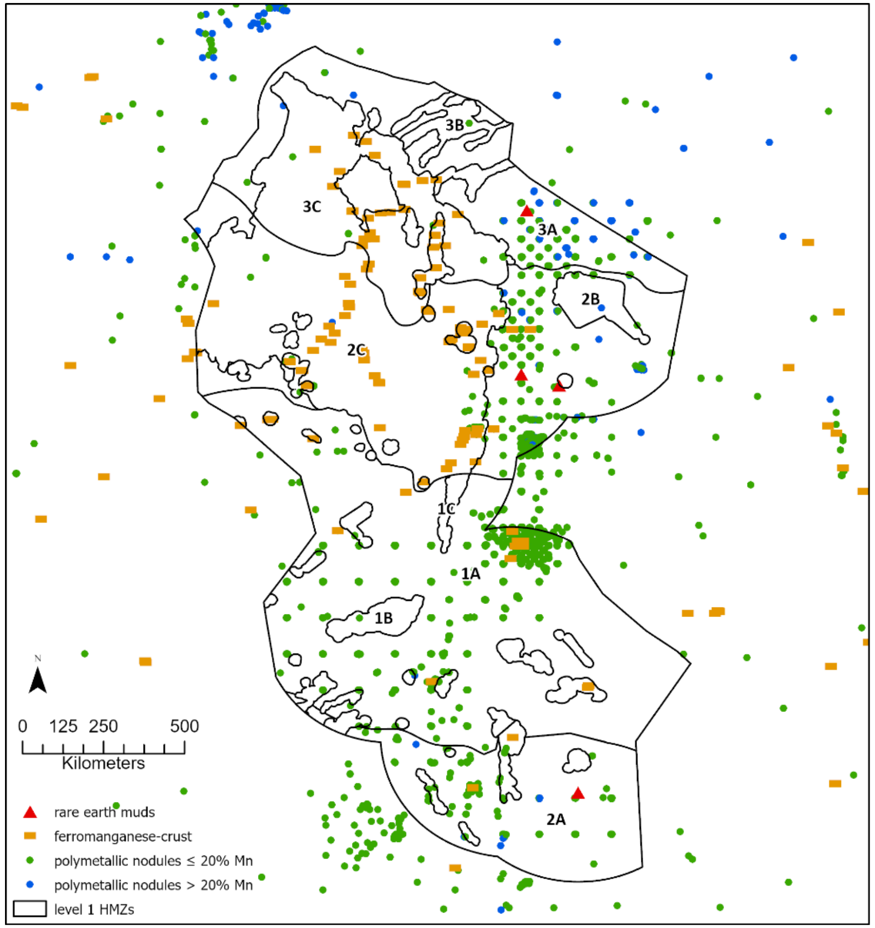
Comparison with Harris (2014) global geomorphology





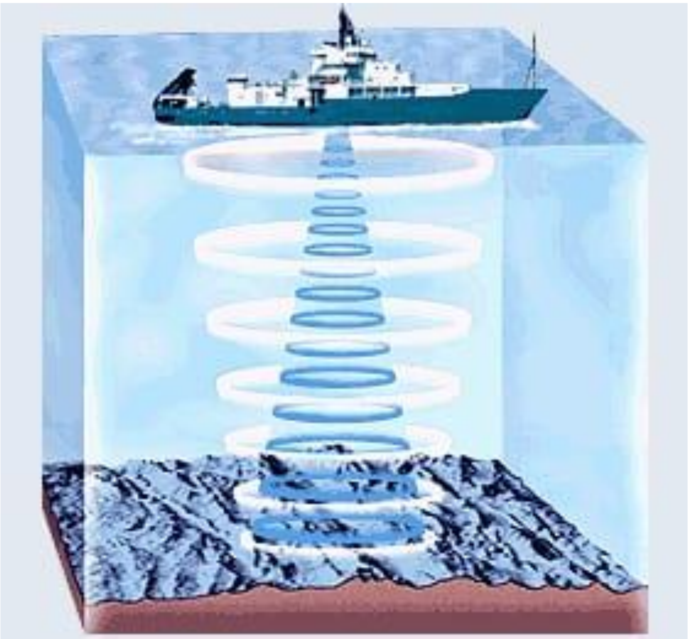
Mineral resource and Occurrences and the HMZs





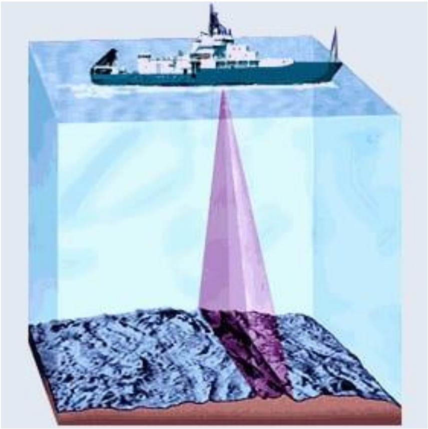
Theory of key data sources

Single beam echo sounder



https://www.whoi.edu/know-your-ocean/ocean-topics/tools-technology/acoustics/sonar-single-beam/

Multi beam



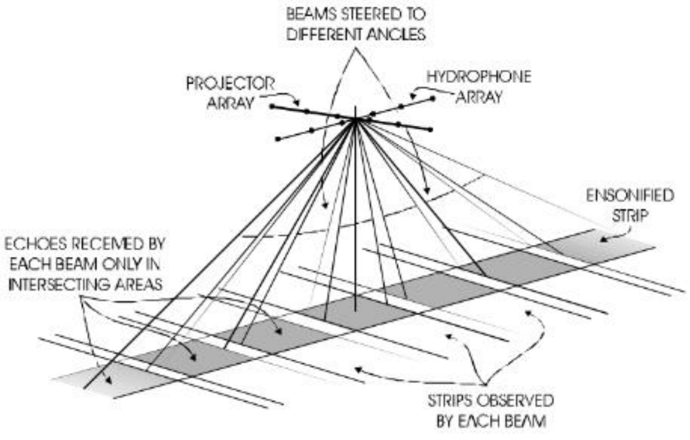
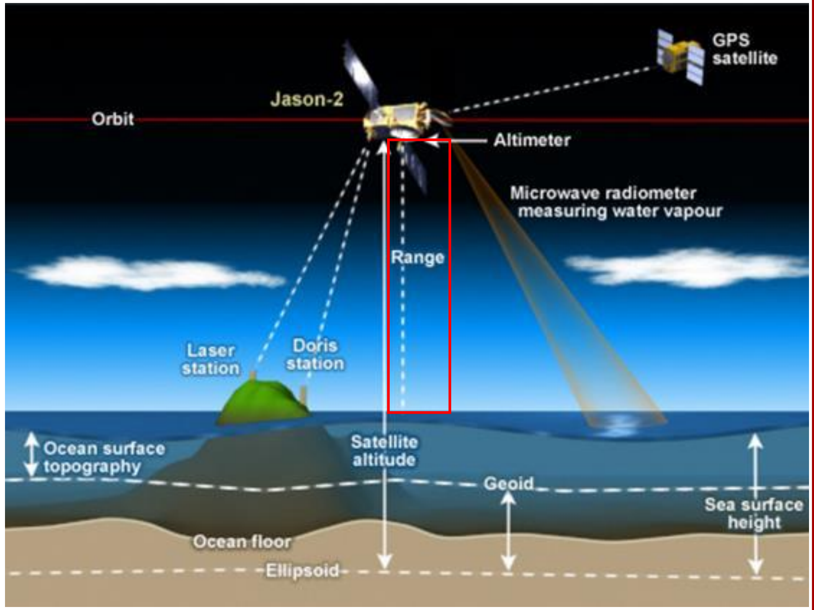
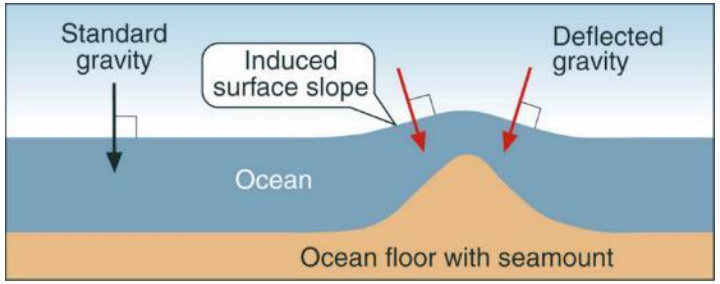


Figure Chapter 3 - -21: Mills Cross with Multiple Steered Beams

https://www.whoi.edu/know-your-ocean/ocean-topics/tools-technology/acoustics/sonar-single-beam/
https://www3.mbari.org/data/mbsystem/sonarfunction/SeaBeamMultibeamTheoryOperation.pdf

Satellite





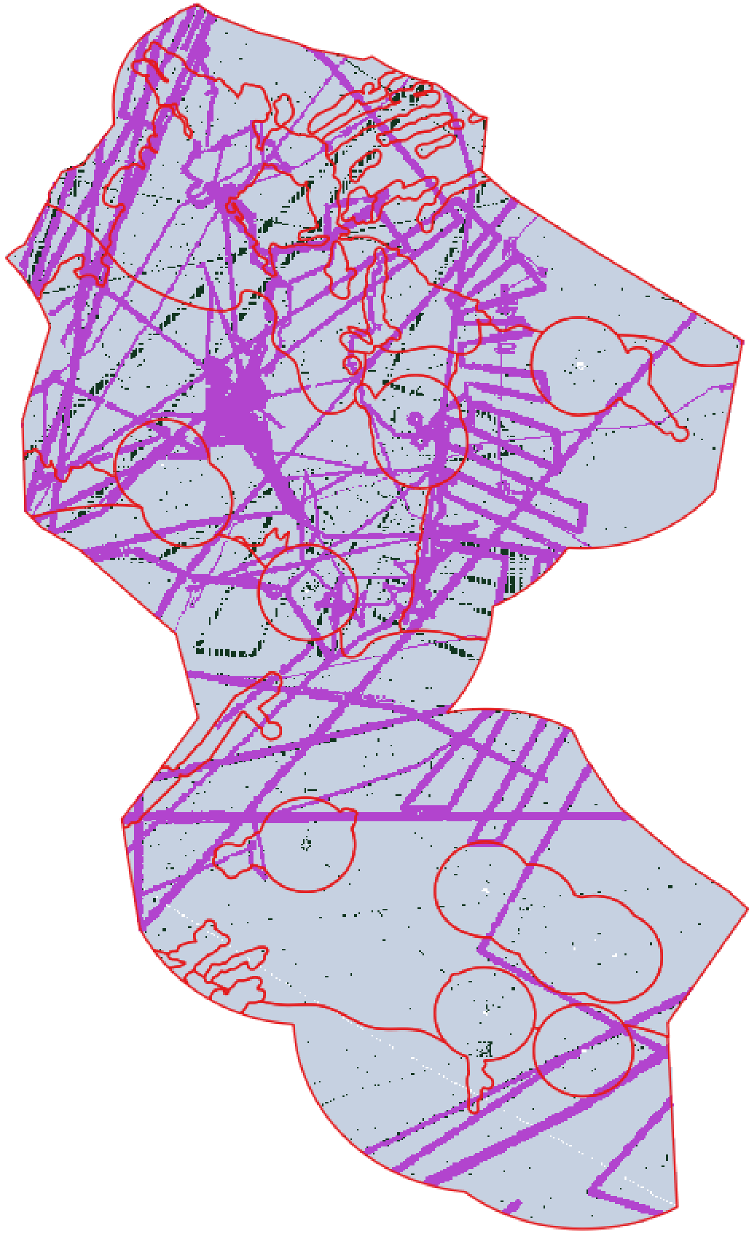
https://www.star.nesdis.noaa.gov/socd/lsa/AltBathy/

GEBCO 2021 TID by HMZs

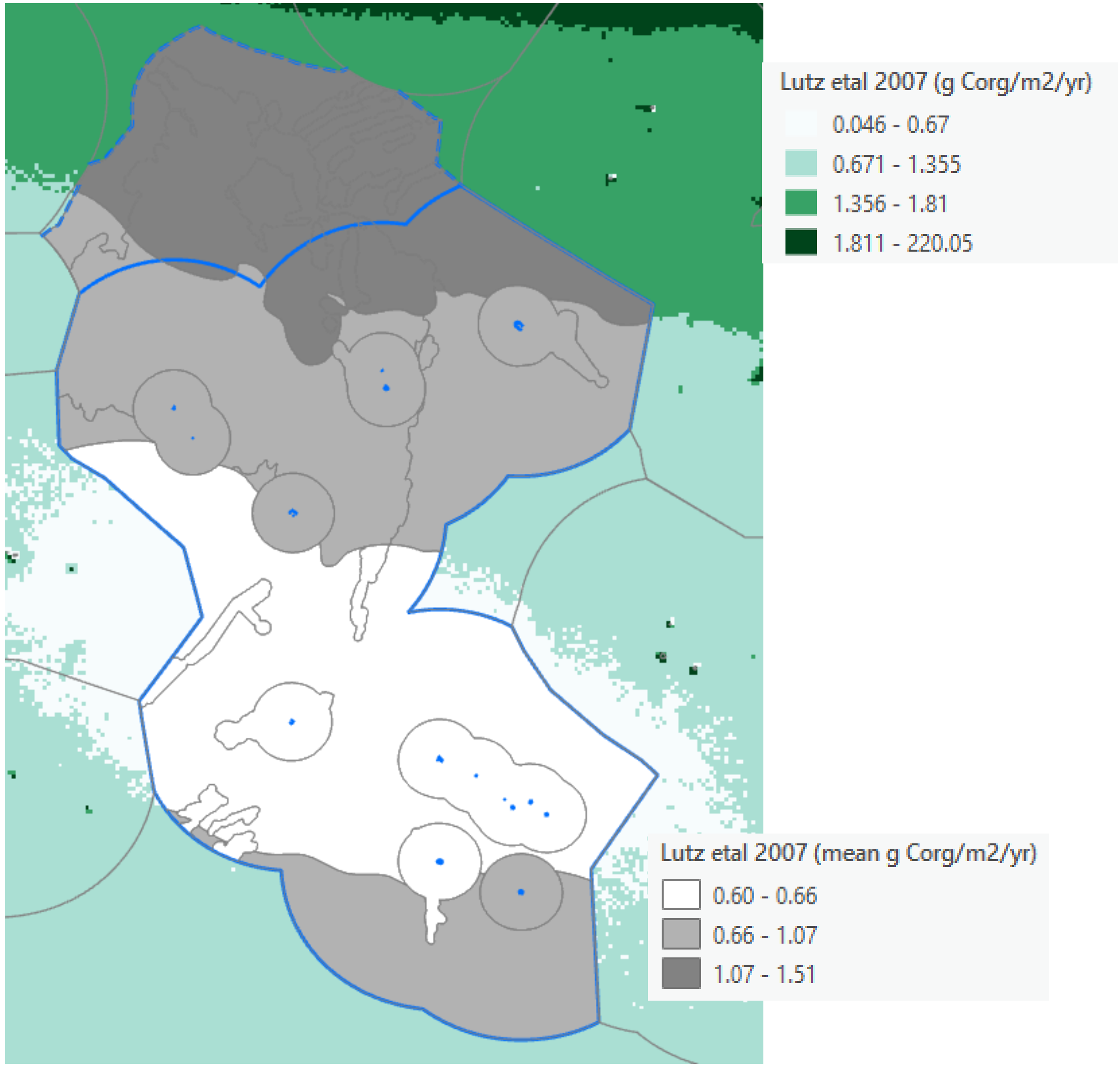
satellite	Abyssal Plains etc	Volcanic Chains etc	Plateaux etc
Very low	81%	90%	N/A
Low	76%	72%	65%
Moderate	74%	74%	71%

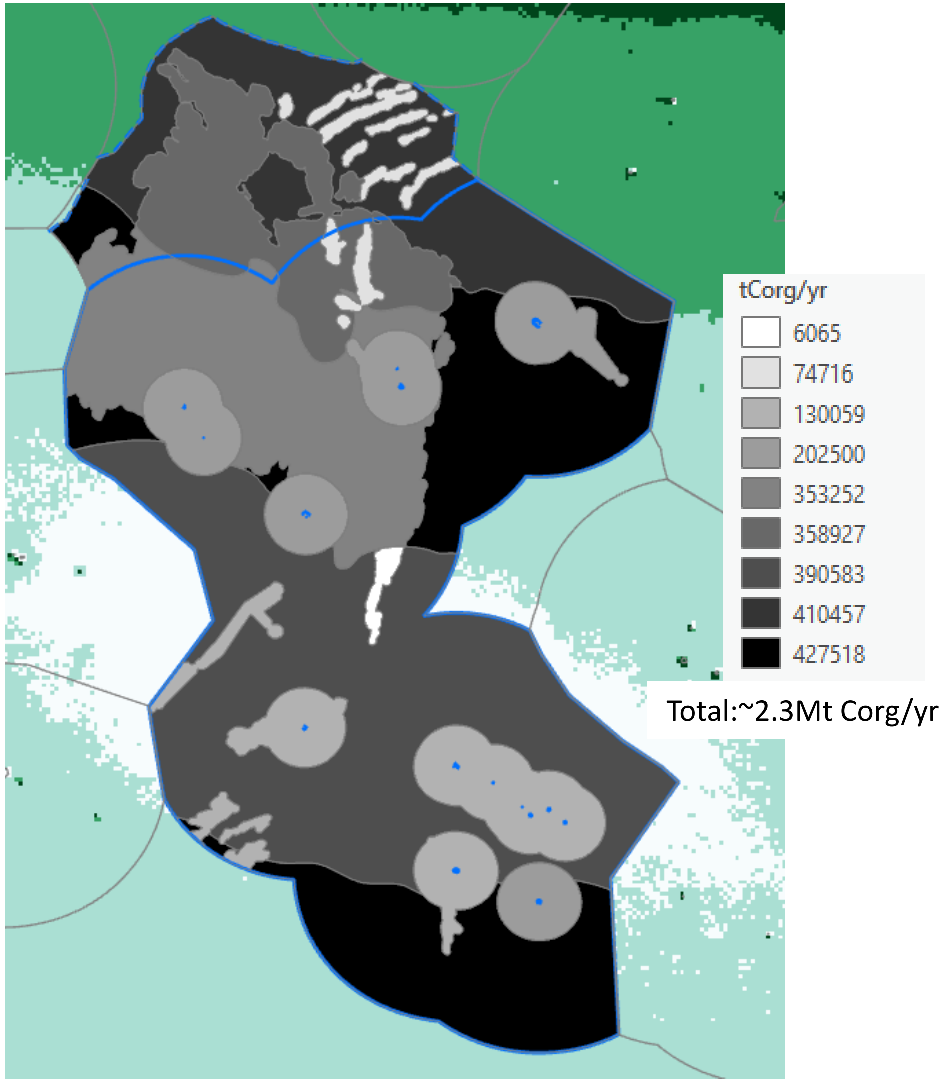
MBES	Abyssal Plains etc	Volcanic Chains etc	Plateaux etc
Very low	**17%**	**8.3%**	**N/A**
Low	**23%**	**25%**	**32%**
Moderate	**23%**	**22%**	**27%**

sounding	Abyssal Plains etc	Volcanic Chains etc	Plateaux etc
Very low	1.2%	1.0%	N/A
Low	1.5%	2.5%	2.9%
Moderate	2.7%	4.6%	2.3%



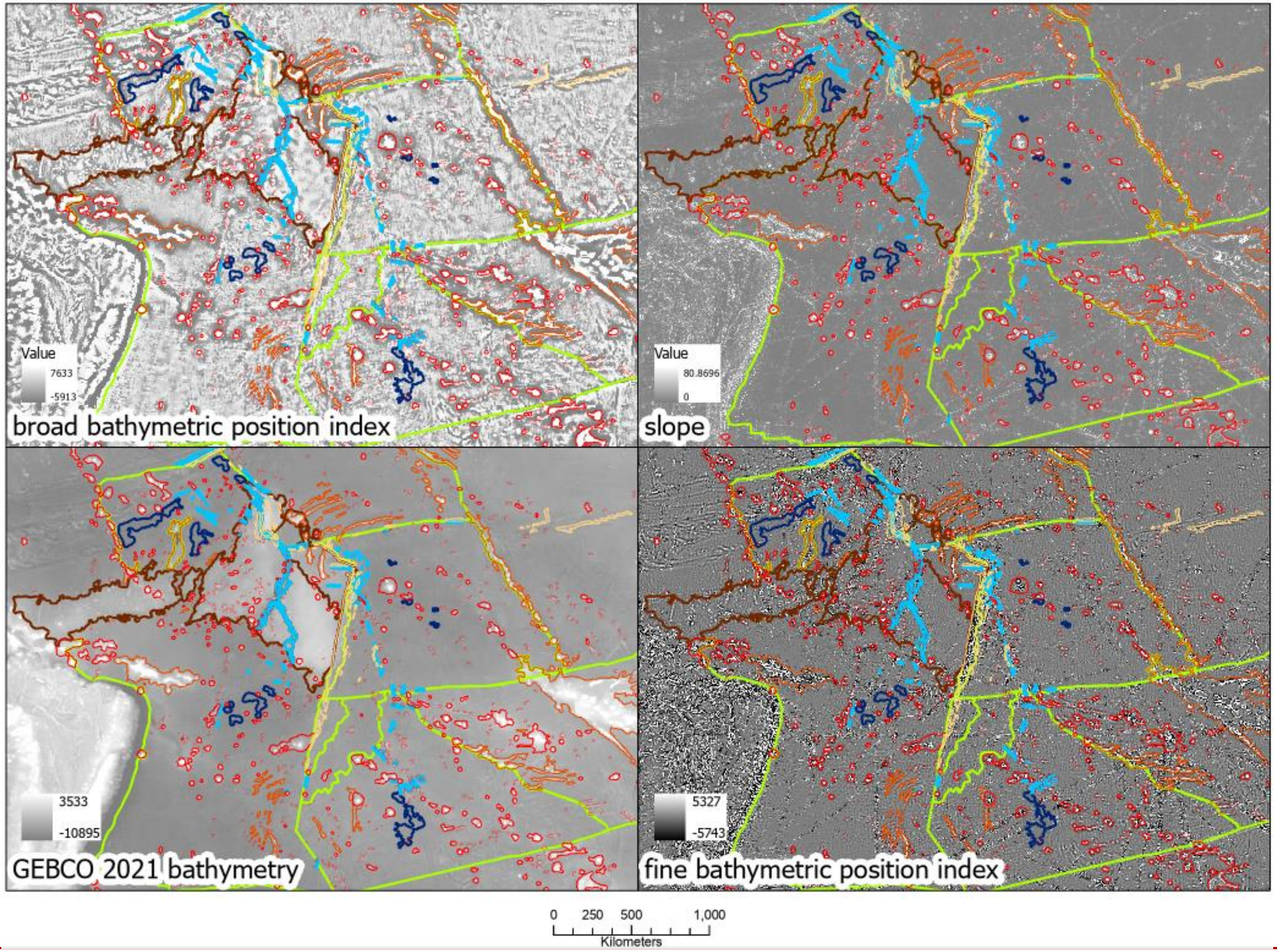
Net export (≈sequestration) by area based on Lutz et al 2007 model





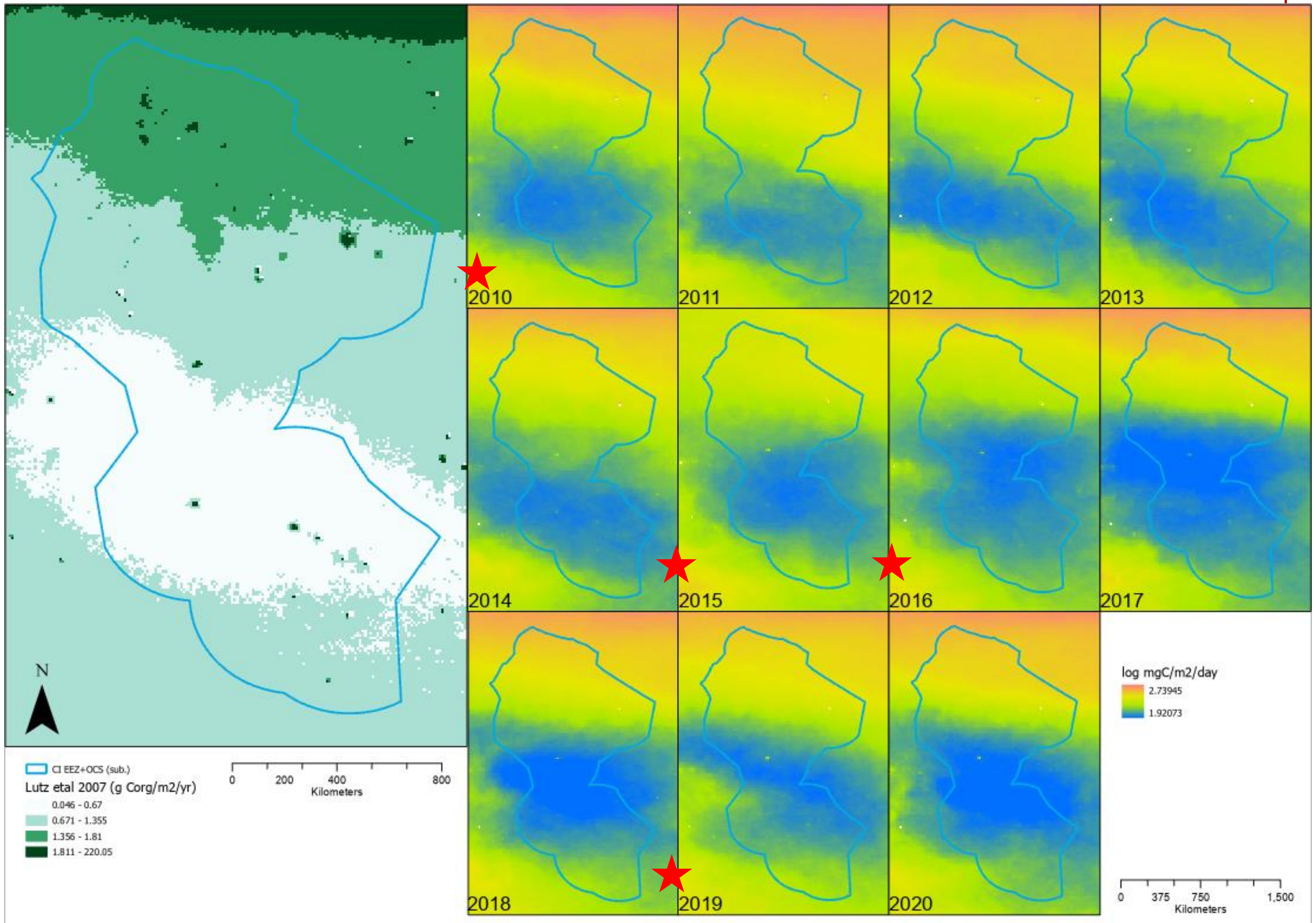
Comparison with BTM products

- Bathymetry and bBPI products support each other
- Insufficient data at this scale for fBPI and slope

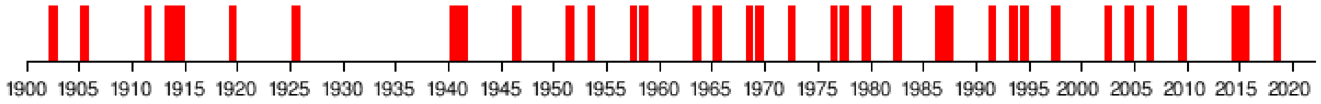


Net export organic carbon compared with annual surface primary productivity

- Annual averages of PP broadly support the very low NPP zone.
- El Nino conditions are usually most manifest between October and March, so these calendar year averages are probably not ideal
- Inter-year variations are fairly minor but La Nina years may result in the lower surface primary productivity zone being located slightly further south



Periods of El Nino



https://en.wikipedia.org/wiki/El_Ni%C3%B1o

NORI D levels by Fejer et al