ZSL Institute of Zoology

LIVING CONSERVATION

Biogeography, Life Histories and Dispersal Patterns of Seamount Biota in International Waters

Dr Alex David Rogers,

Institute of Zoology,

Zoological Society of London,

Regent's Park,

London, NW1 4RY

Alex.Rogers@ioz.ac.uk

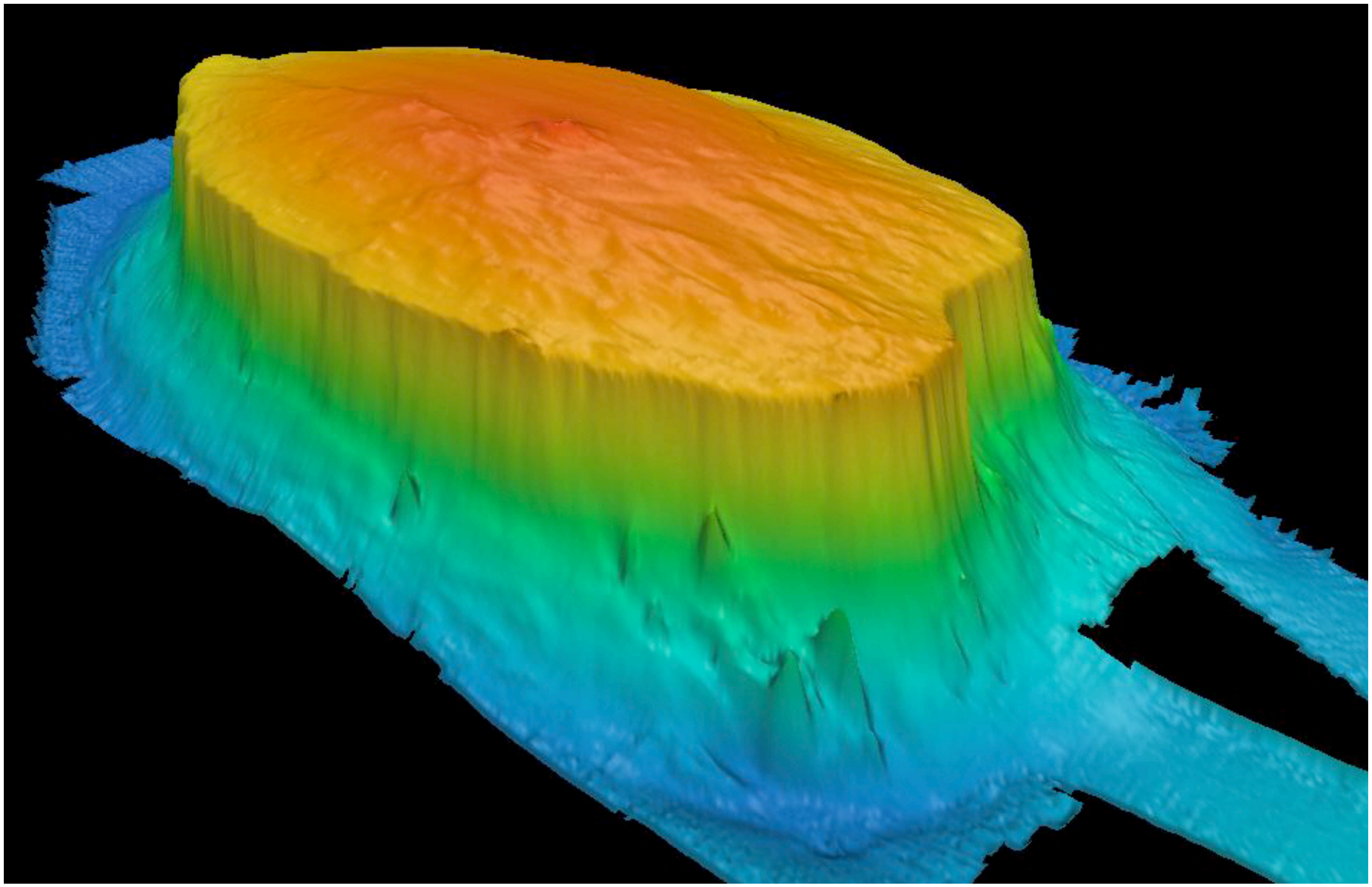
ZSL Institute of Zoology

LIVING CONSERVATION

The talk

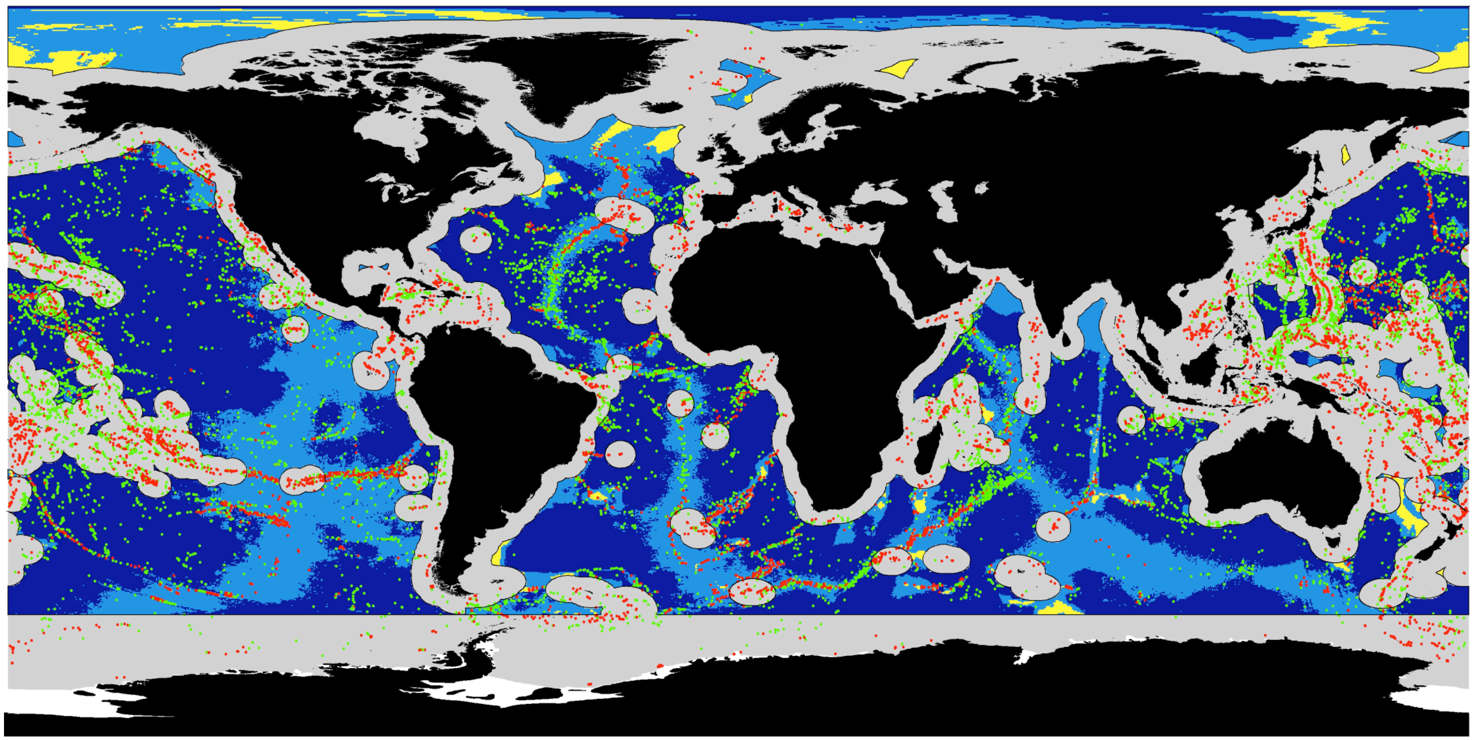
- **General patterns of community diversity**
  - **Endemism**
  - **Regional studies**
- **Habitat suitability - corals**

Seamounts



Anton Dohrn Seamount UK Dept. Trade & Industry SEA programme
c/o Colin Jacobs, NOCS

Distribution of seamounts
50,000-100,000 (1000m elevation)



EEZ

Seamounts
- < 2000m
- > 2000m

Depth (m)
- > 4000
- 2000-4000
- < 2000

Modeled seamounts = 14,287

Seamounts within EEZs = 7,276

Seamounts in High Seas = 7,011

Seamounts in High Seas (<2000m) = 1,876

Total area of High Seas = 277,000,000 km2

Area < 2000m = 9,000,000 km2

Area 2000 - 4000m = 92,000,000 km2

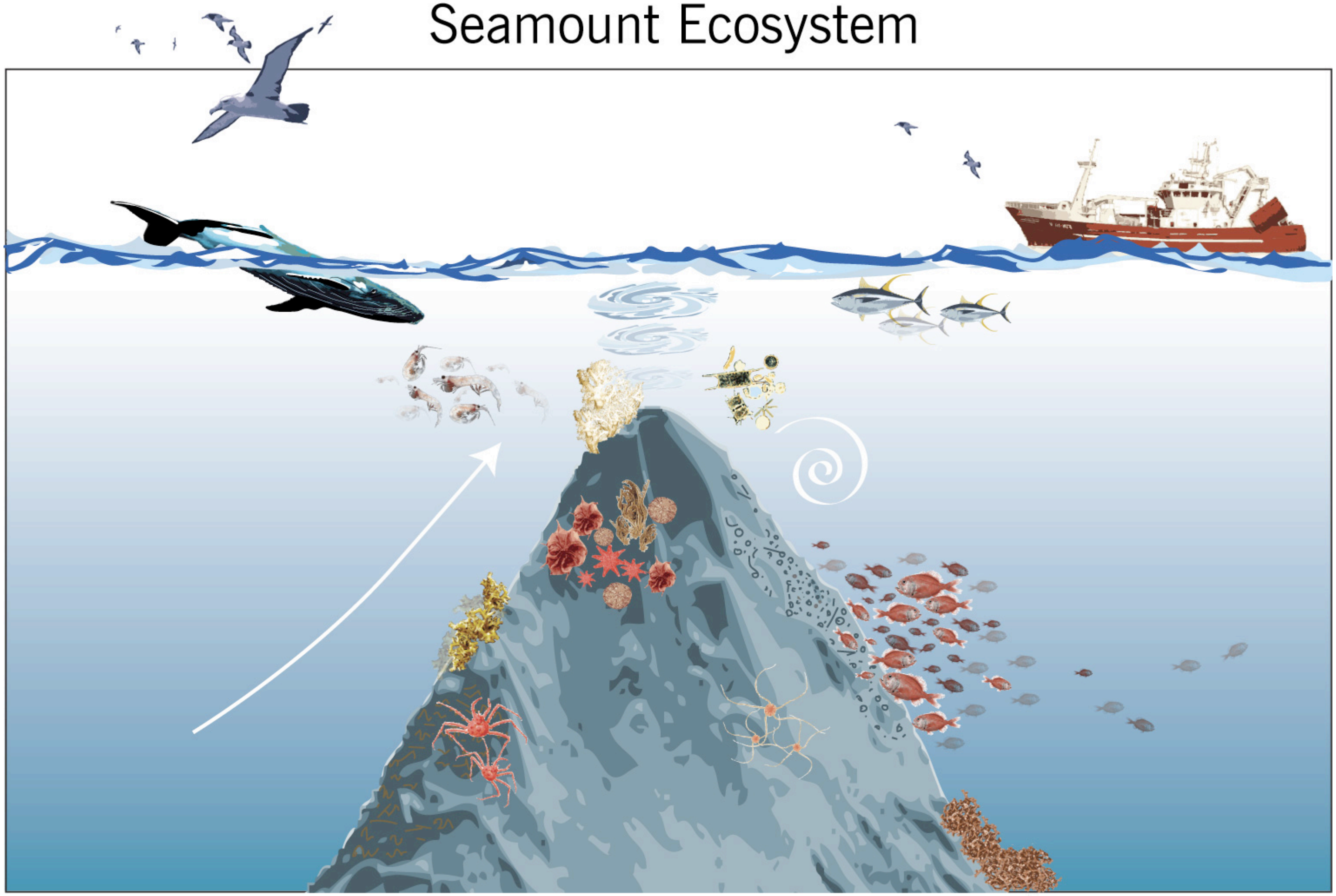
Area > 4000m = 176,000,000 km2

Note: The waters surrounding Antarctica (60-90 Degrees South Latitude) are disputed. High Seas area calculations exclude this area and seamounts found in these waters are not considered to be in the High Seas.

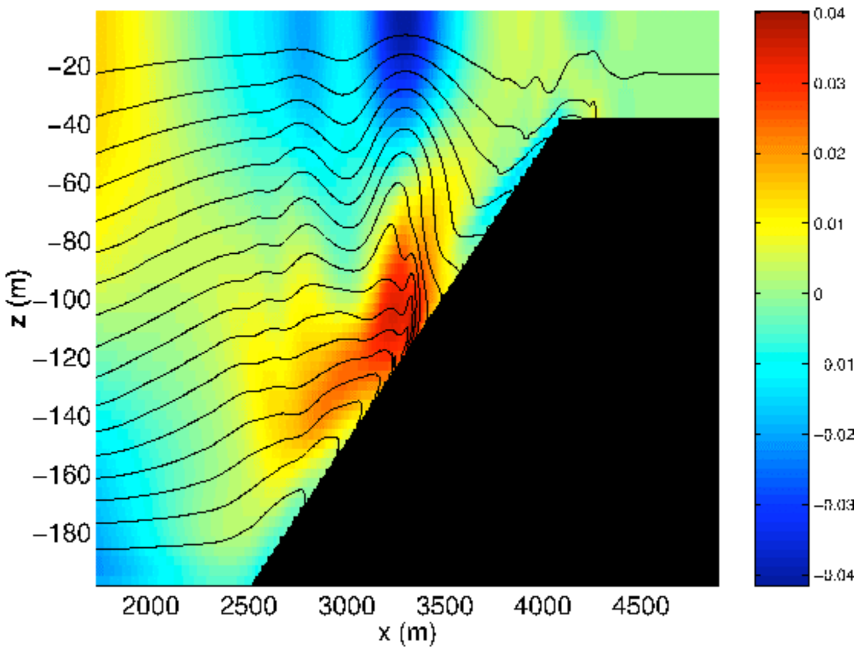
Map prepared by John Guinotte, MCBI

Importance of seamounts to the pelagic ecosystem

Seamount Ecosystem

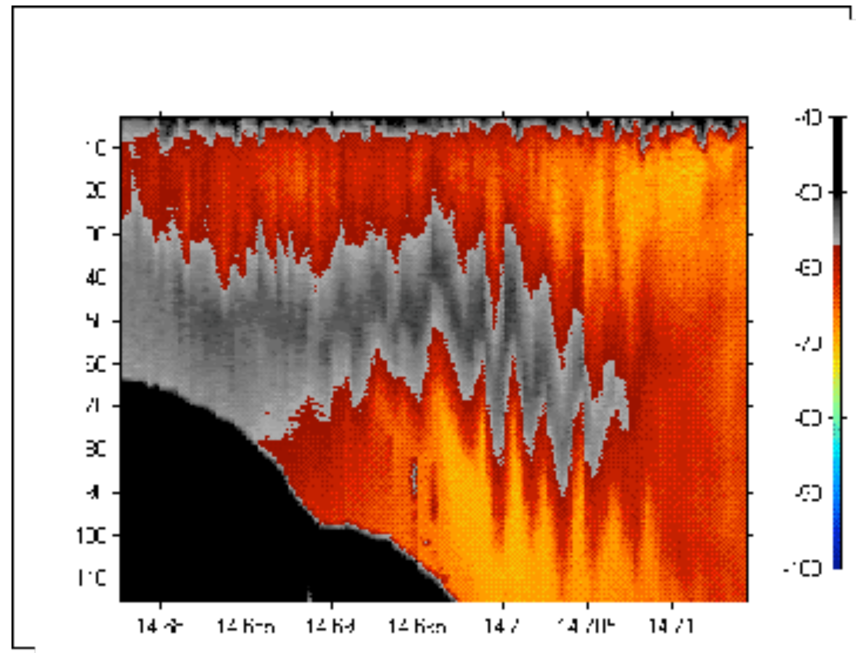


Internal waves



Modelled internal wave

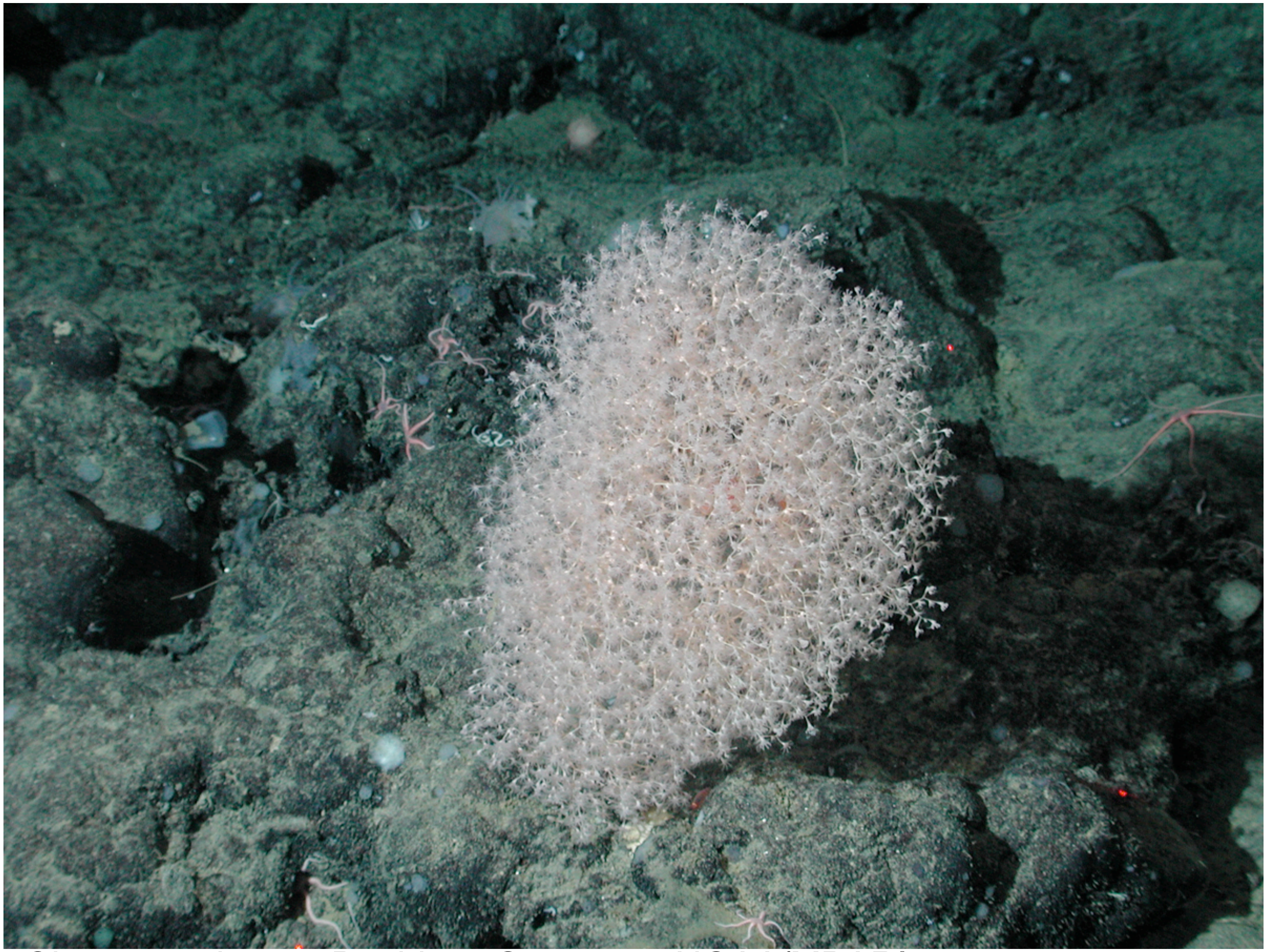
(MIT Climate modelling initiative)



Internal wave: Georges Bank

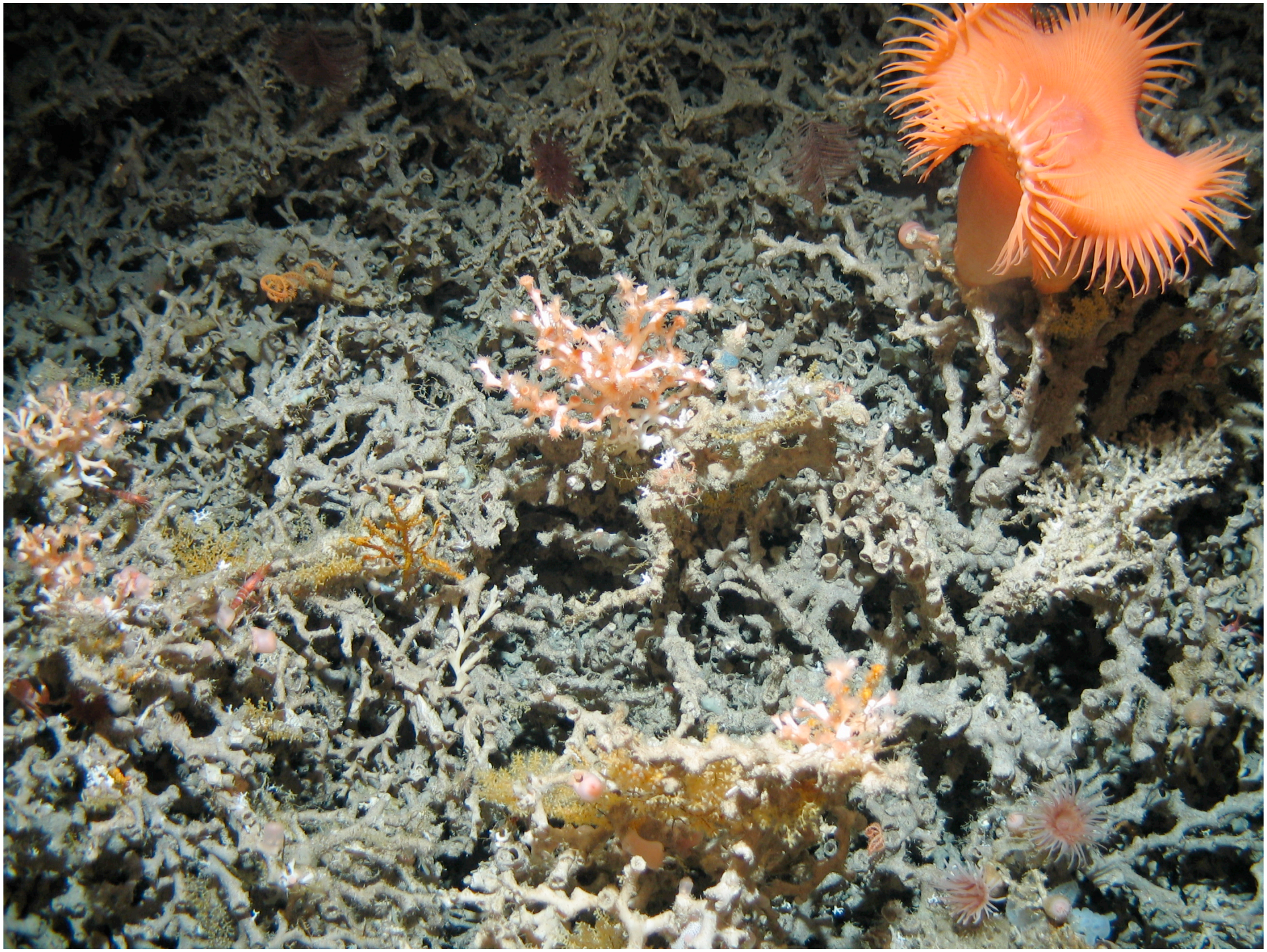
(GLOBEC)

Hard substrata



Chrysogorgia spp. Davidson Seamount NOAA/MBARI

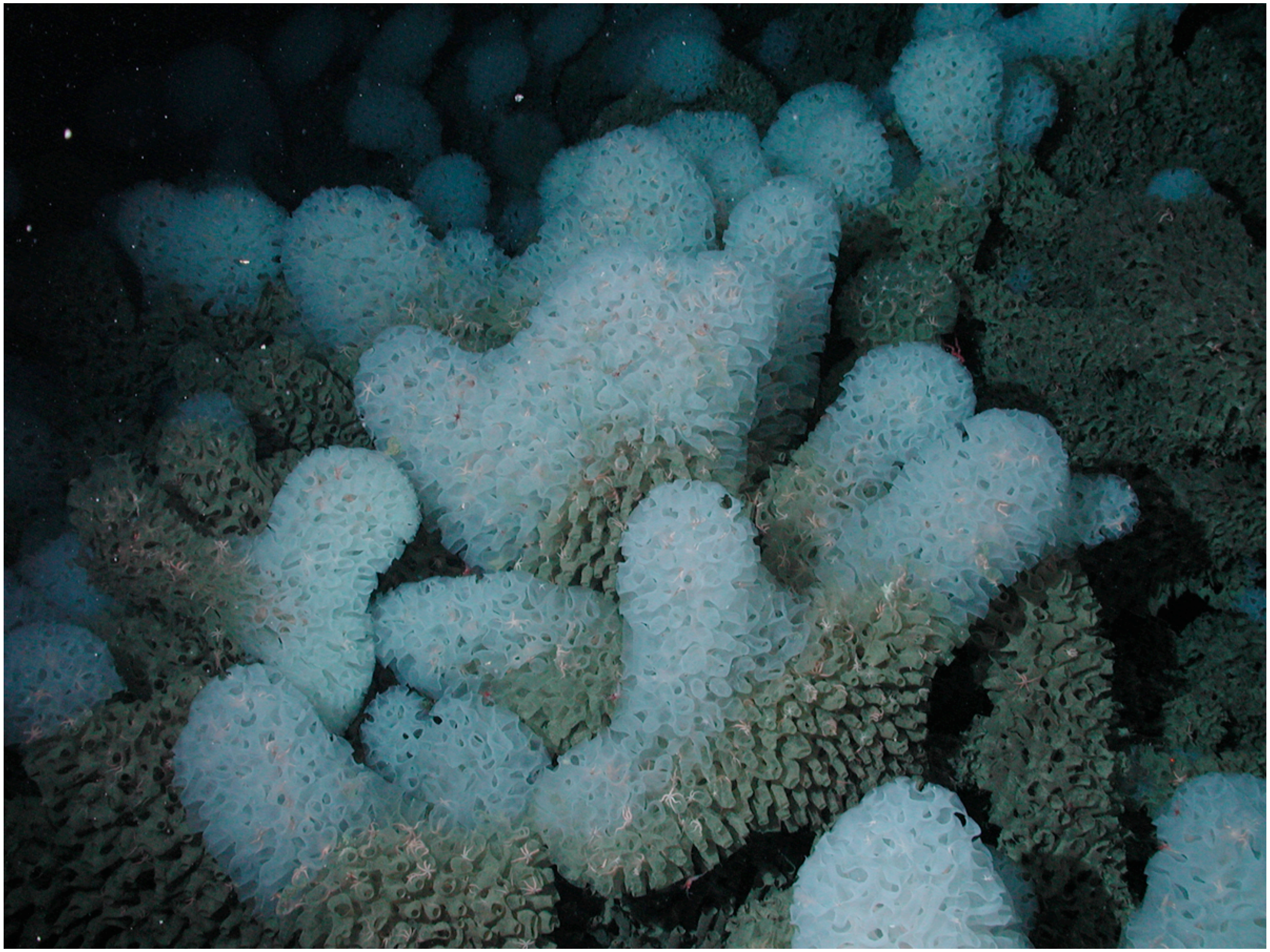
Scleractinian frameworks (cold-water coral reefs)



Lophelia pertusa reef, Hatton Bank, NE Atlantic DTi SEA programme

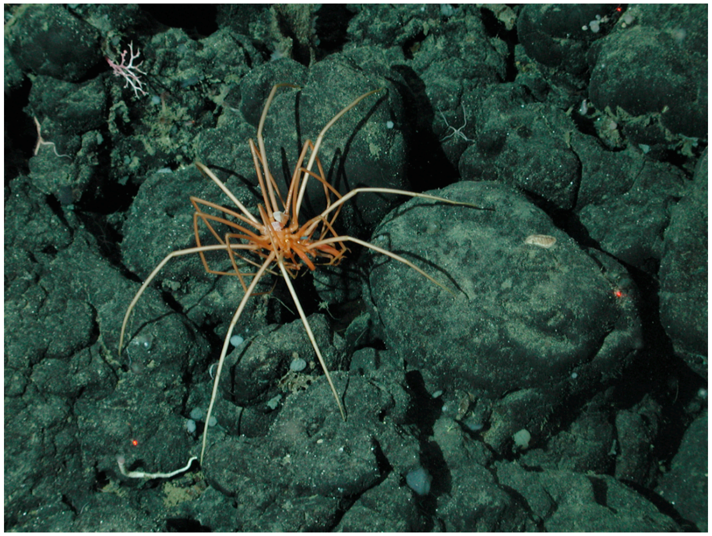
Octocoral gardens

Sponge communities

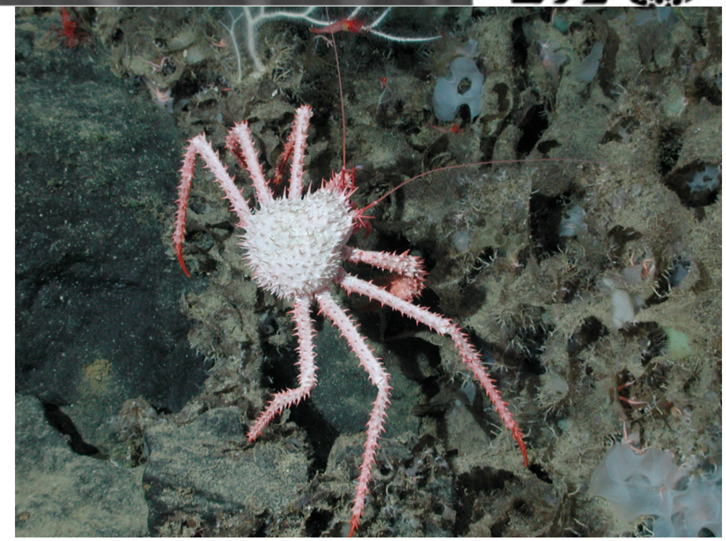


Farrea sp. on Davidson Seamount (NOAA/MBARI)

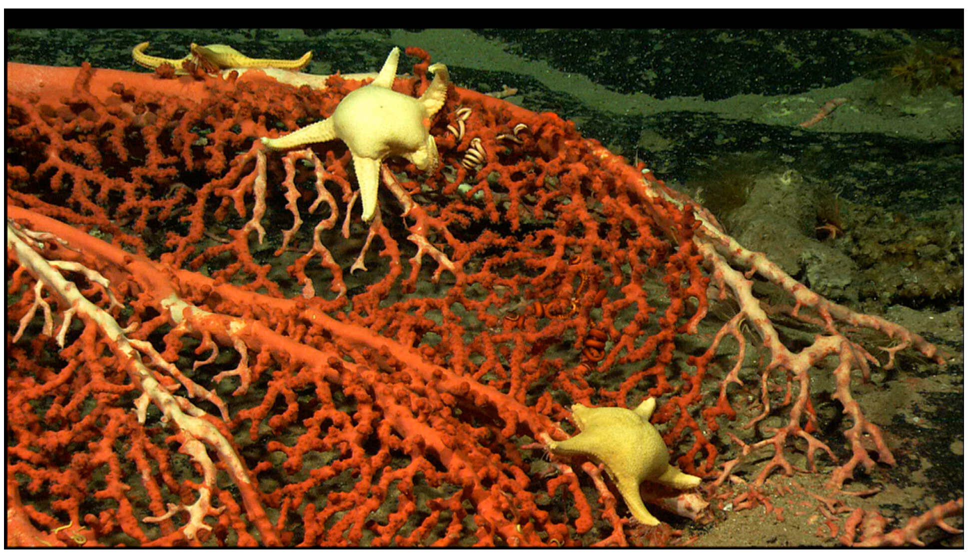
Mobile predators



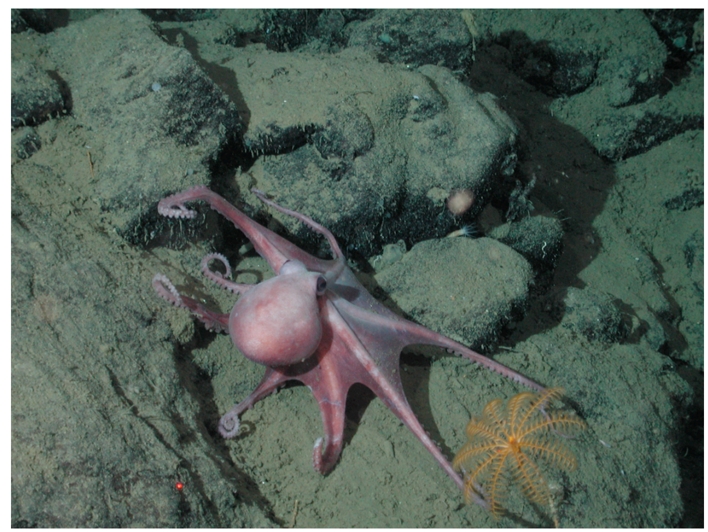
Davidson Seamount (Pycnogonid) NOAA/MBARI



Davidson seamount (*Neolithodes*) NOAA/MBARI



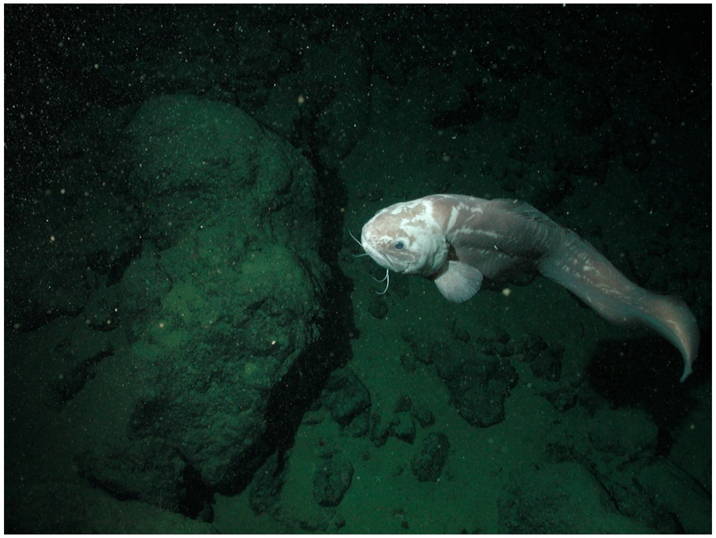
New England Seamounts (Asteroids eating octocoral) NOAA



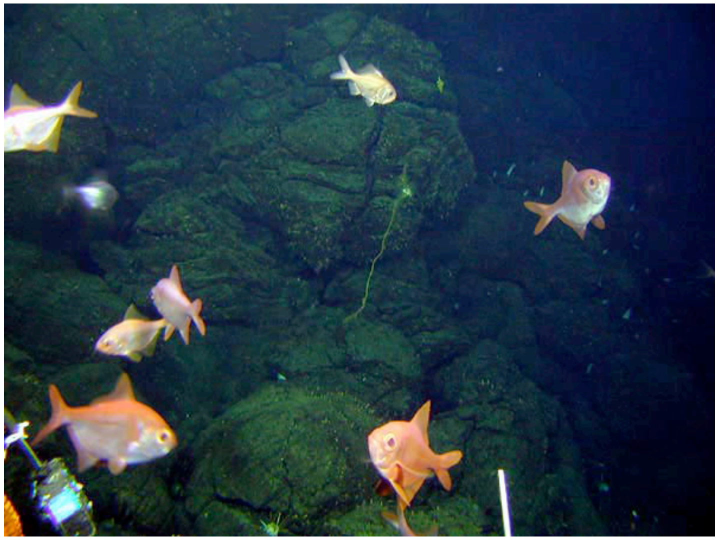
Davidson Seamount (*Benthoctopus*) NOAA/MBARI

Demersal / bentho-pelagic fish

Chimaera – Hatton Bank (DTi SEA Prog.)



Spectrunculus – Davidson (NOAA/MBARI)



Alfonsino (NOAA)

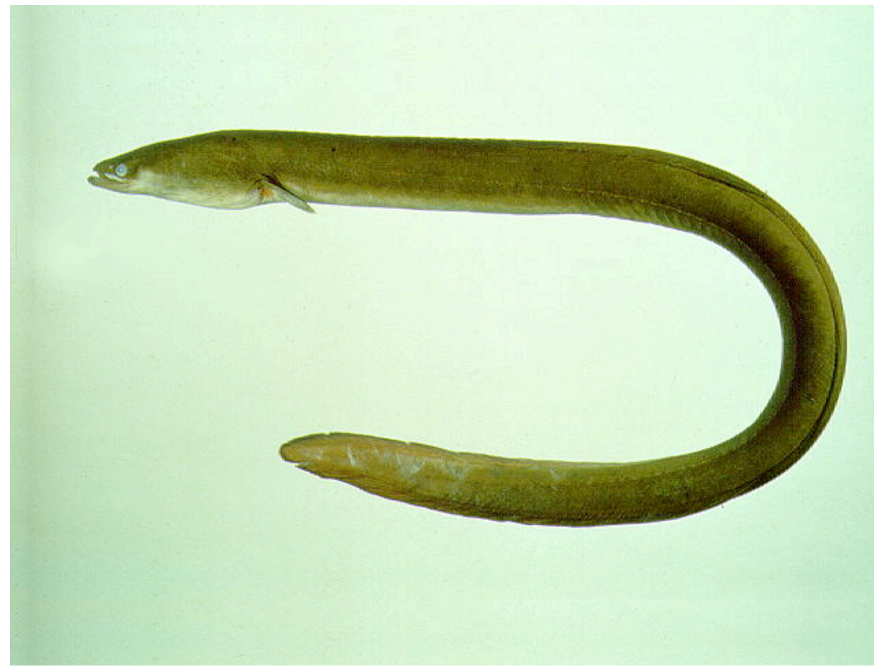
Oreo (NOAA)

Hydrothermal vents

Brothers Seamount, Kermadec Ridge (NOAA)

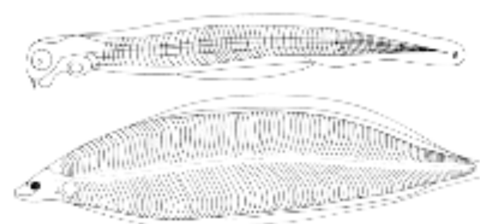
Japanese eel

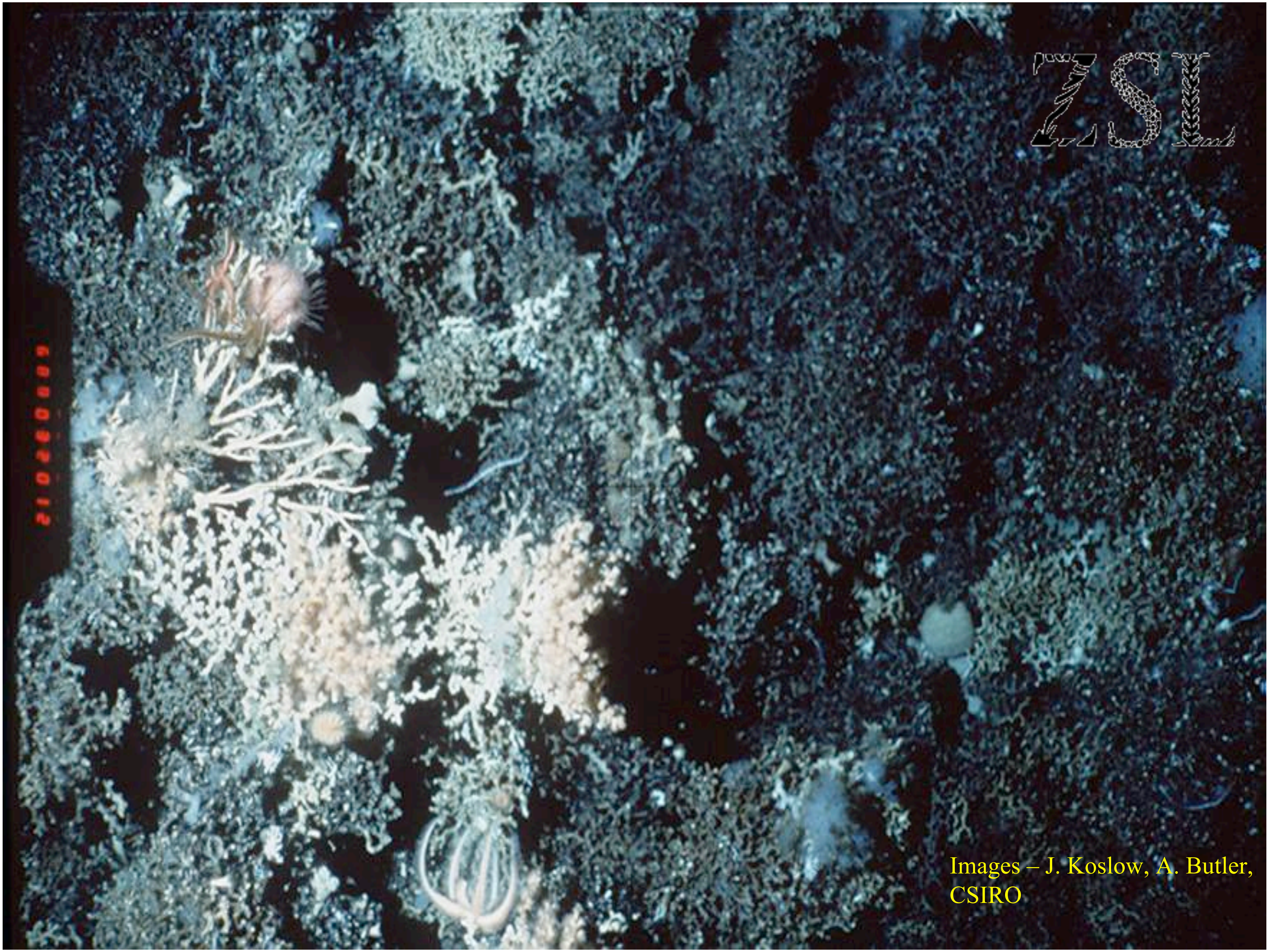
Japanese eel – *Anguilla japonica*



Spawns around 3 seamounts in the near the Marianas Islands

2,000 – 3,000km from freshwater habitats of adults





Images – J. Koslow, A. Butler, CSIRO

Seamounts harbour distinct communities with a high diversity

Tasmanian Seamounts

297 species of animals on 14 seamounts

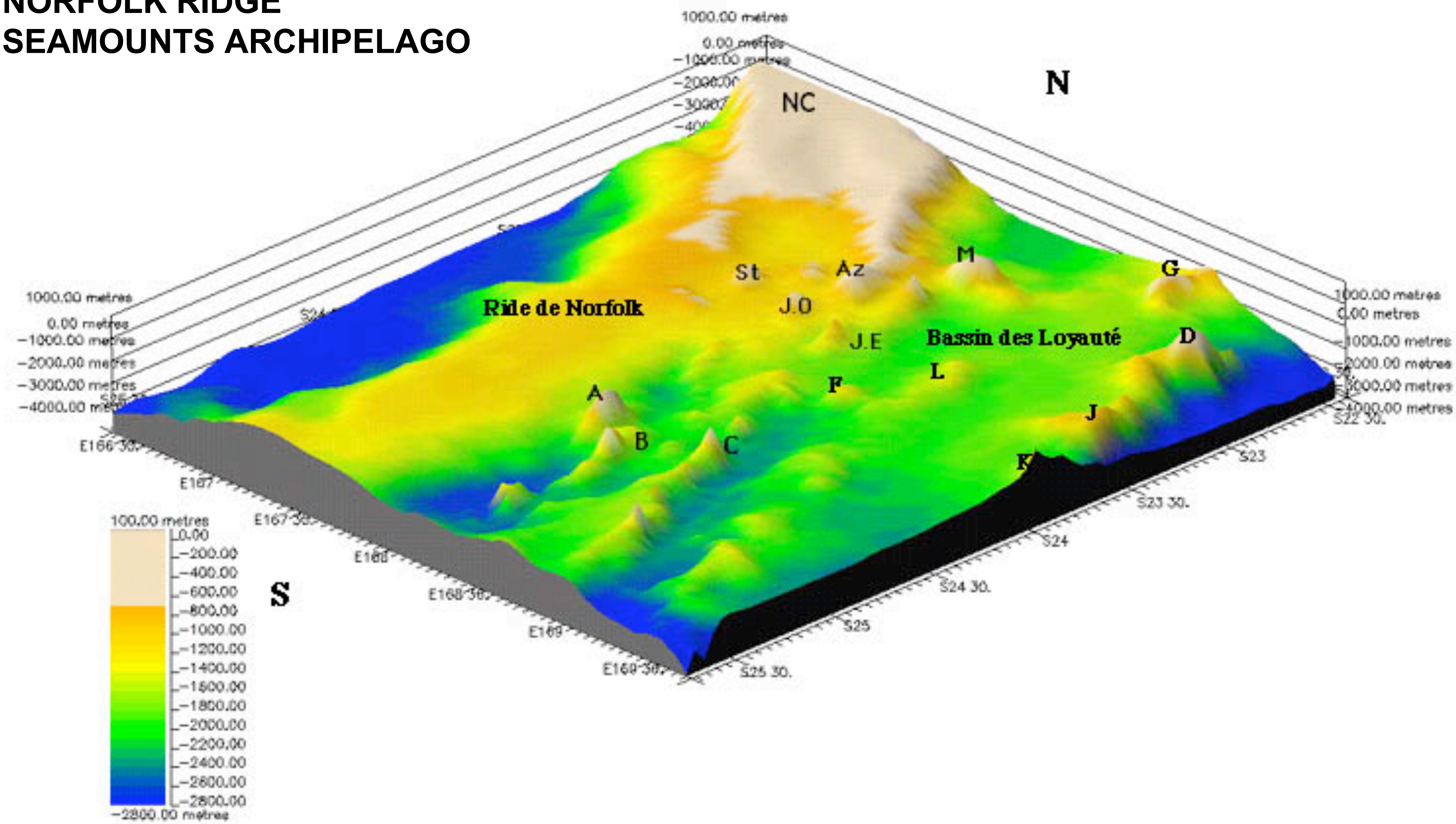
16 - 33% are new to science

Low overlap in species present on different seamounts

Even lower co-occurrence of species on different chains

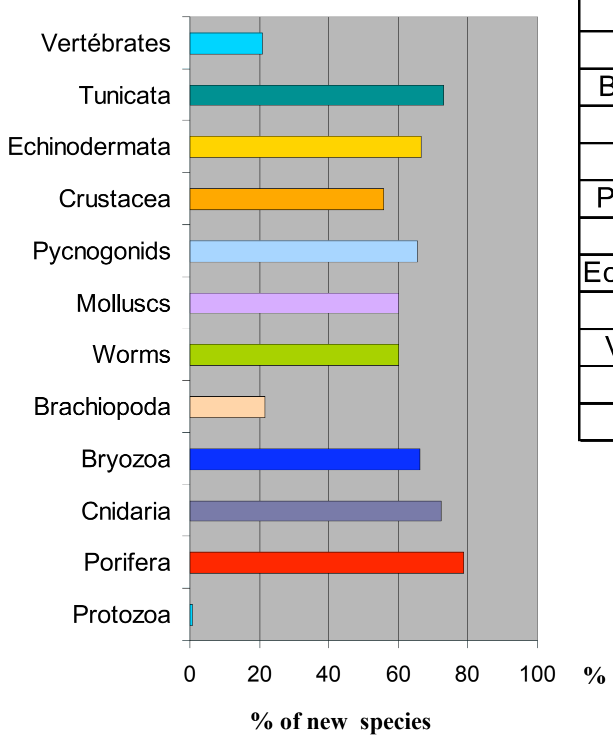
Seamount on the Norfolk Ridge, SW Pacific

NORFOLK RIDGE
SEAMOUNTS ARCHIPELAGO



Seamounts in the New Caledonia EEZ: Species diversity

THE NEW SPECIES



GROUPS	FAMILIES	GENERA	SPECIES	NEW SPECIES	% NEW OF SPECIES
Protozoa	29	83	124	1	0.8
Porifera	54	111	170	134	78.8
Cnidaria	8	18	72	52	72.2
Bryozoa	60	123	201	133	66.1
Brachiopoda	13	18	23	5	21.7
Worms	6	13	20	12	60
Molluscs	73	200	619	371	59.9
Pycnogonids	8	22	61	40	65.5
Crustacea	94	295	633	354	55.9
Echinodermata	14	27	33	22	66.7
Tunicata	13	37	63	46	73
Vertebrates	68	143	240	50	20.8
TOTAL	**440**	**1090**	**2259**	**1220**	**54**

The deep-sea fauna of New Caledonia is very rich (> 2000 species records so far…and growing...). Up to 50% of the species are new to science.

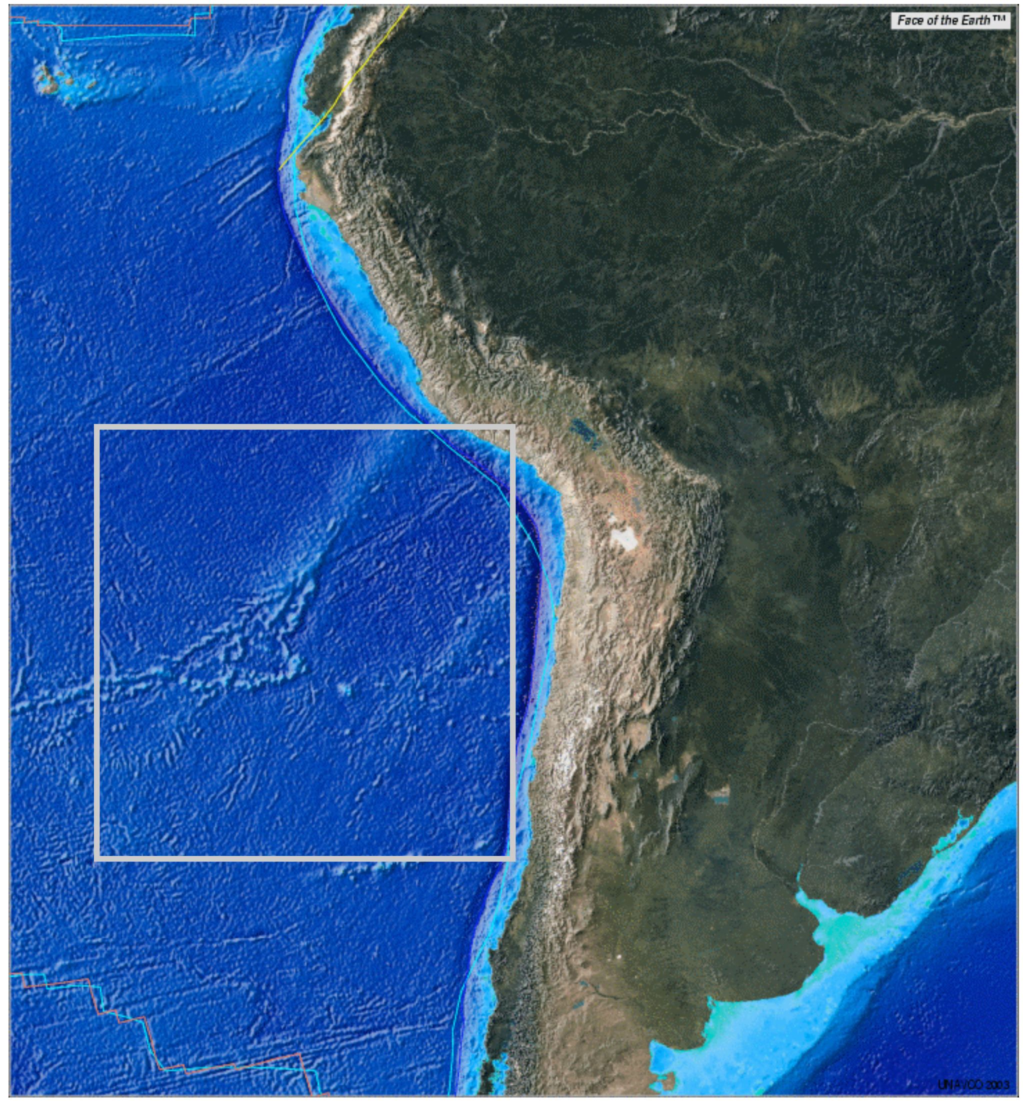
They include living fossils such as stalked crinoids and Crustacea.

Seamounts of the Nasca and Sala Y Gomez Ridges, SE Pacific

Invertebrates – 52% endemic species

Fish – 44% endemism

But – many of these areas are poorly explored so levels of endemism are difficult to estimate



Are Seamounts Different?
Data collection, North-East Atlantic

ZSL

Grasshoff (1972, 1973, 1977, 1981a, 1981b, 1981c, 1985a, 1985b, 1986, 1989), Zibrowius (1980), Keller (1985), Pasternack (1985), Tendal (1992), Howson and Picton (1997), Rogers (1999), Opresku (2001), Brito and Ocana (2004), Schröder-Ritzrau et al. (2005), Tyler and Zibrowius (1992), and Molotsova (in press).

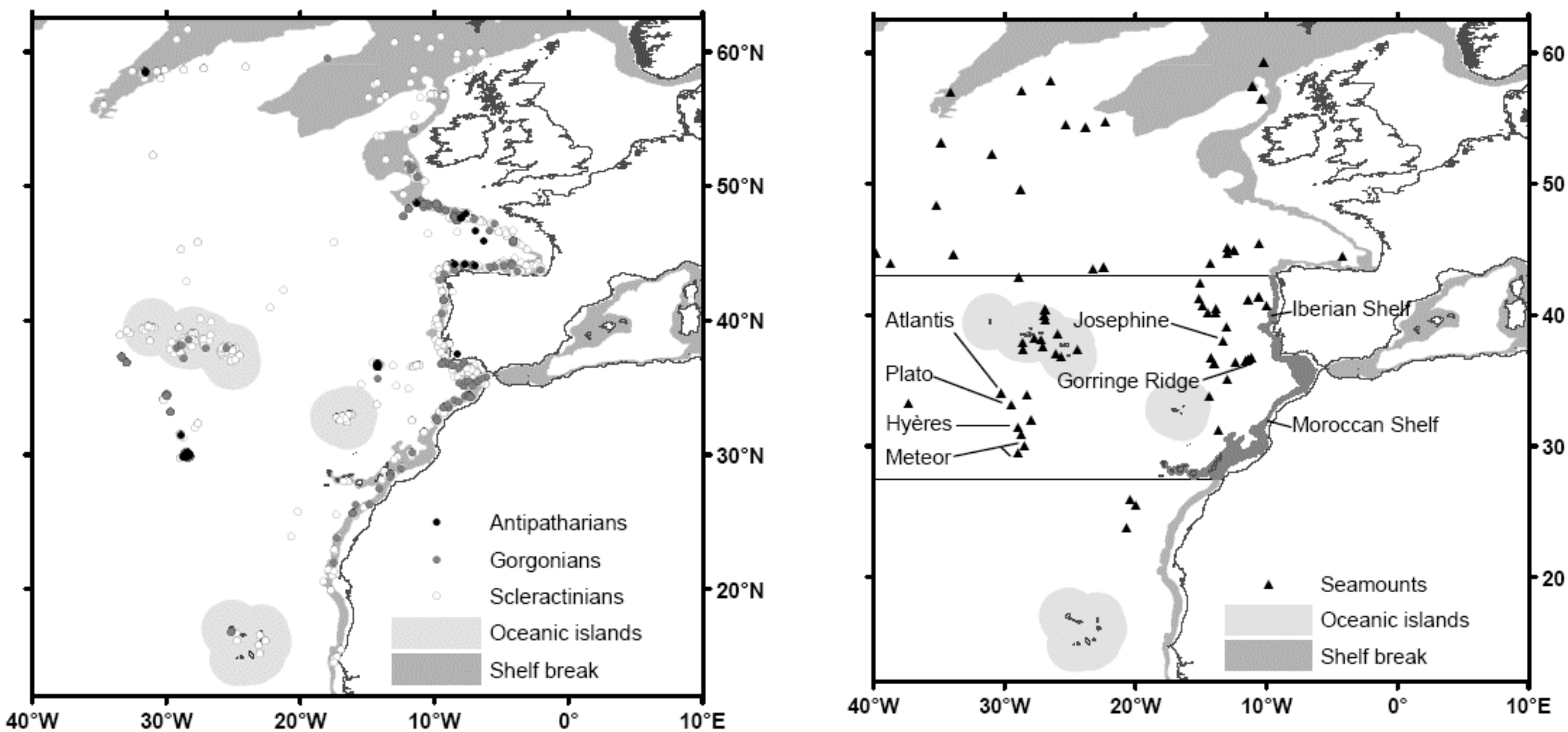
Taxon, position, depth, date collected, cruise details and other notes

Stylasterids excluded (not enough data)

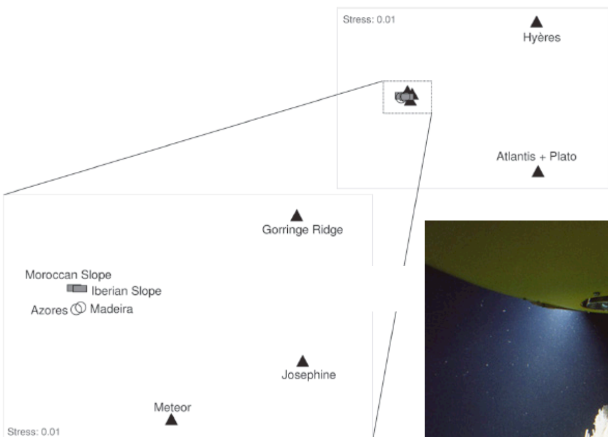
Coral records used (>2100 records)

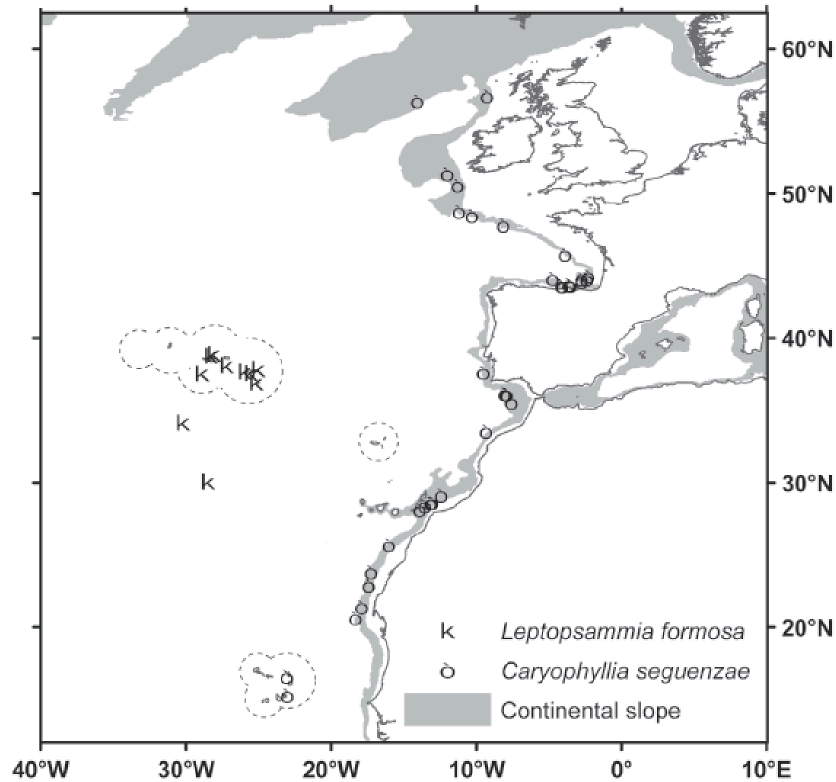
Expeditions	Date	Antipatharians	Gorgonians	Scleractinians
RV Josephine	1869	0	2 (1)	19 (8)
RV Porcupine	1869-1870	0	0	40 (38)
Prince of Monaco	1869-1911	0	55 (11)	153 (98)
RV Challenger	1873	0	1 (1)	31 (21)
RV Travailleur	1881-1883	0	21 (18)	19 (18)
RV Talisman	1883	0	50 (45)	51 (44)
RV Calypso	1958-1959	0	0	38 (21)
RV Sarsia	1958-1974	0	0	54 (43)
RV Jean Charcot	1966-1976	11 (4)	92 (38)	325 (189)
RV Meteor	1967-1970	11 (6)	117 (81)	105 (97)
RV Thalassa	1967-1973	2 (2)	39 (36)	158 (142)
RV Bartlett	1975	0	20 (16)	19 (16)
RV Cryos	1984	0	36 (36)	0
Others	1868-1983	52 (11)	196 (70)	409 (289)
Totals		76	629	1421

(a) Records of deep-water corals for the NE Atlantic compiled from (>200m depth) pre-1985 cruise and literature reports showing the oceanic island and shelf slope areas considered (200-2000 m)
(b) Seamounts in region



Continental margins vs oceanic habitats





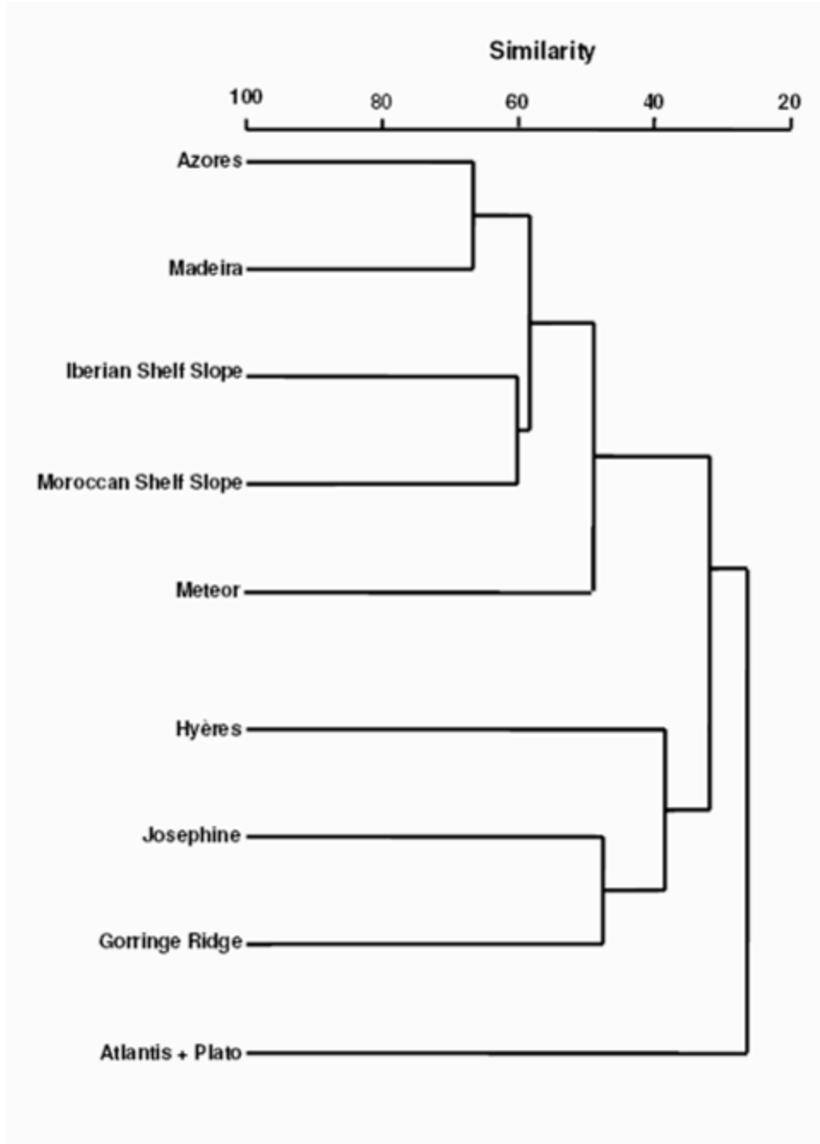
Hall-Spencer et al. (In press) Bull. Mar. Sci.

Similarity of slope, islands and seamounts

Group-averaged cluster plot of coral assemblages from 200-2000m depth in the NE Atlantic (Bray-Curtis similarity values calculated from species presence/absence

Islands 64% similar to continental slope sites

Seamounts are 26-49% similar to continental slope sites



Reasons for differentiation between seamount & non-seamount habitat

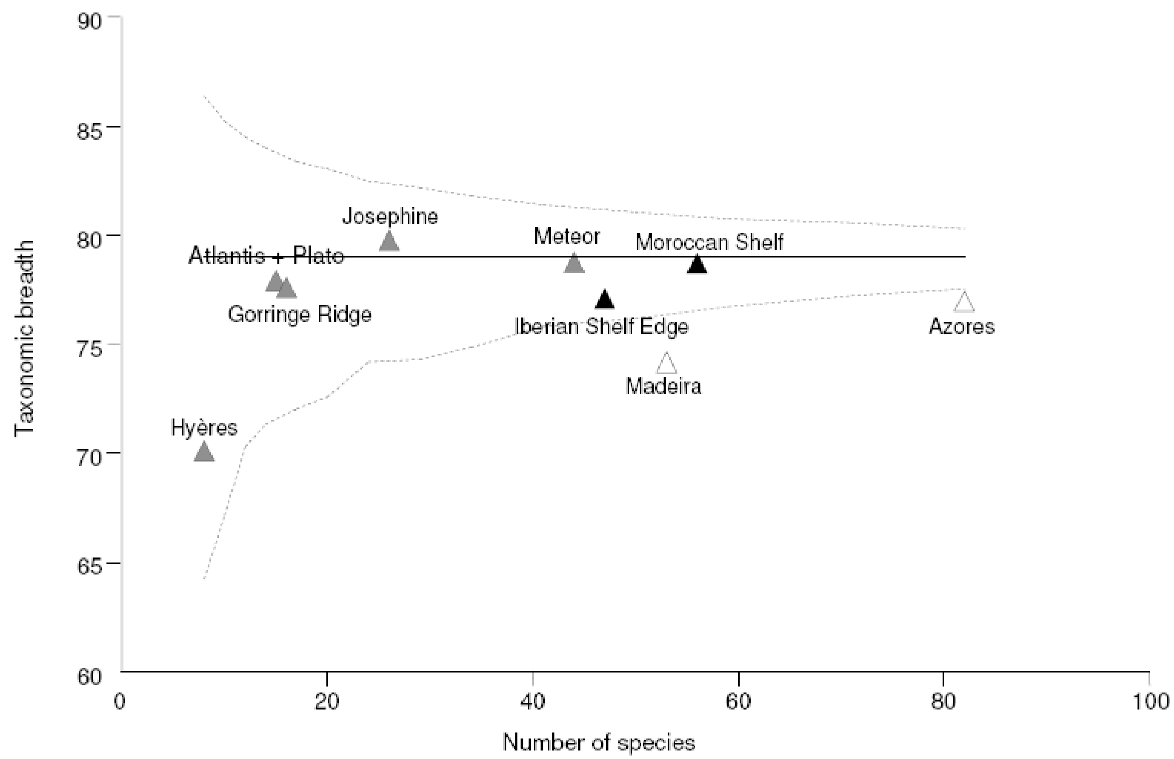
Some species only on seamounts; examples are: *Dentomuricea meteor* (Grasshoff, 1977) and *Tubigorgia cylindrica* (Pasternack, 1985) only found on Great Meteor. However, endemism to seamounts here is only <4%.

A suite of scleractinian species are only found in oceanic conditions (e.g. *Caryophyllia alberti* Zibrowius 1980*, Caryophyllia foresti* Zibrowius 1980*, Leptopsammia formosa* Gravier, 1915*, Paracyathus arcuatus* Lindström, 1877).

Also for antipatharians:*Antipathes erinaceus* (Roule, 1905), *Distichopathes* sp., *Phanopathes* sp. and *Stauropathes punctata* (Roule, 1905) (Molodstova in press).

Taxonomic breadth

Funnel plot of taxonomic breadth for deep-water coral assemblages. Dotted lines indicate the 95% confidence intervals for taxonomic breadth at any given level of species richness (x-axis); sites lying outside these bounds have lower or higher taxonomic breadth than expected at their richness level given the taxonomic composition of the pool of species from which they are drawn.



Taxonomic distinctness

For islands there is lower high-level (e.g. families, orders) taxonomic variation, or more low-level (species) taxonomic variation than expected.

This low taxonomic breadth in the island sites suggests proliferation of taxa in a few genera, whilst other genera from different higher families or orders remain relatively species poor.

Seamounts emerge as impoverished in species richness compared to islands although taxonomic distinctness is within confidence levels predicted for the region.

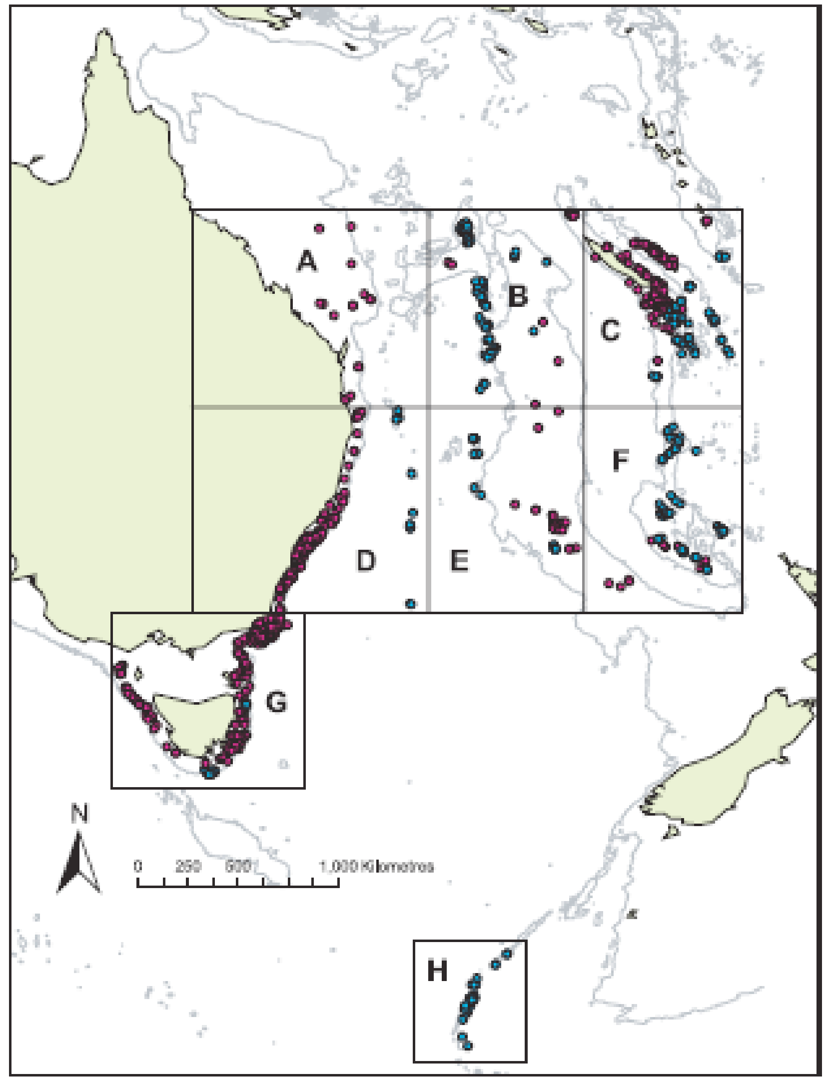
Great Meteor is the possible exception to this as it has a richness similar to continental slope sites (extremely large seamount)

Ophiuroids on seamounts

Tasman and coral seas:

Blue = seamount
Purple = non-seamount

O'Hara (2007) Global
Ecol Biogeogr.
DOI: 10.1111/j.1466-8238.2007.00329.



Global 1-way Anosim

Significant results for:

Latitude
Longitude
Minimum depth
Mean depth

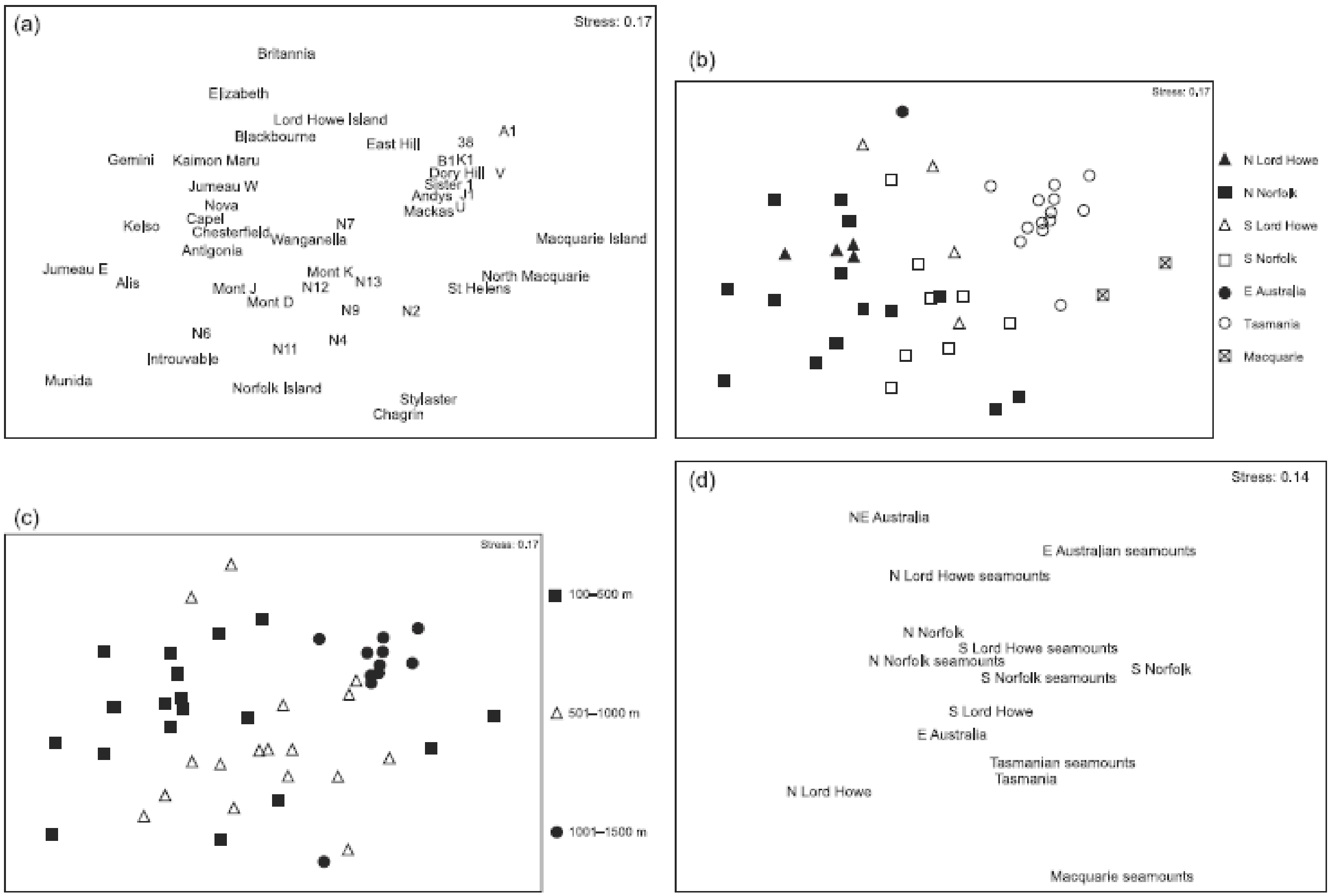
	1-way ANOSIM		2-way crossed ANOSIM averaged across latitude groups	
	Global *R*	*P*	Global *R*	*P*
Seamount				
Latitude	0.574	0.000*		
Longitude	0.417	0.000*	−0.051	0.638
Mean depth	0.342	0.000*	0.413	0.000*
Min. depth	0.174	0.000*	0.147	0.087
Emergence	0.071	0.188	−0.073	0.635
Region				
Latitude	0.387	0.007*		
Longitude	0.024	0.397	−0.049	0.591
Mean depth	−0.044	0.599	0.794	0.013*
Min. depth	0.236	0.090	0.548	0.040*
Habitat	−0.022	0.568	−0.143	0.790

*Significant result ($P < 0.05$).

MDS – Species occurrence

Seamount name

Region



Mean depth

Regional groups

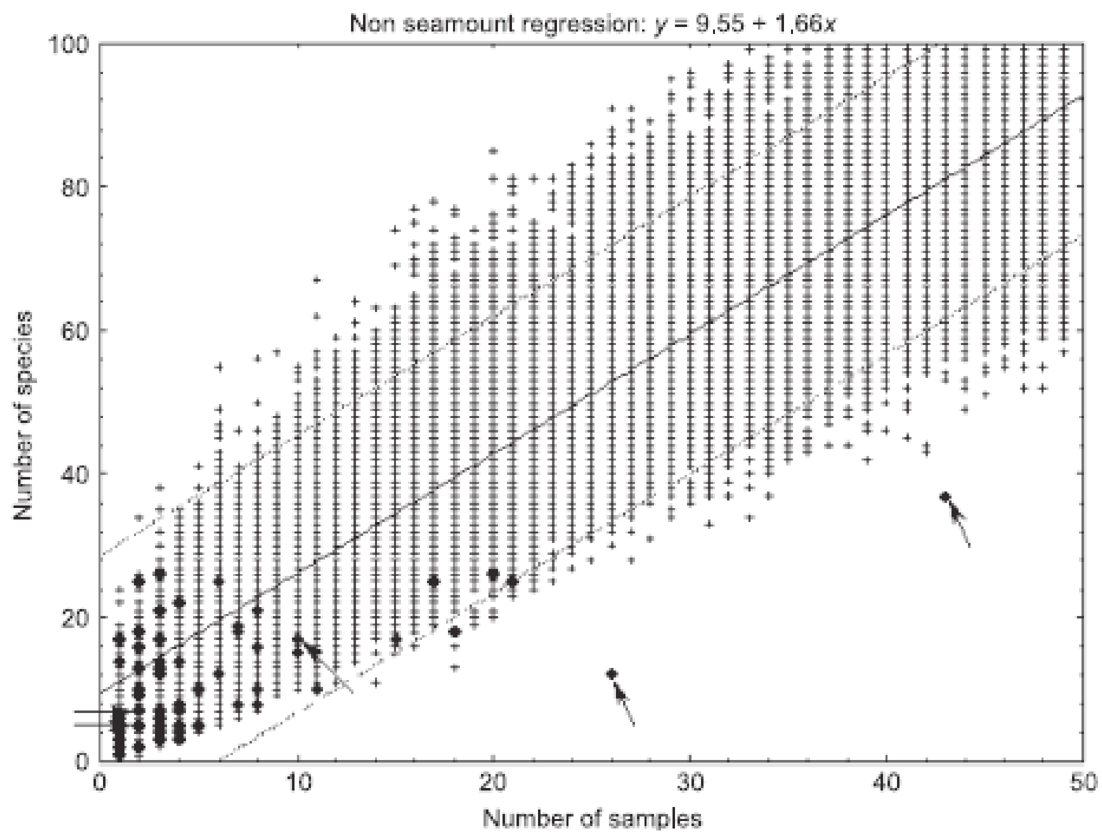
Seamounts in north to left, Tasmania and Macquarie R to right

Number of species vs number of samples

Seamounts = dots

Most seamounts fell within 95% confidence limits of the area

Few larger ones appear to have fewer species than non-seamount areas

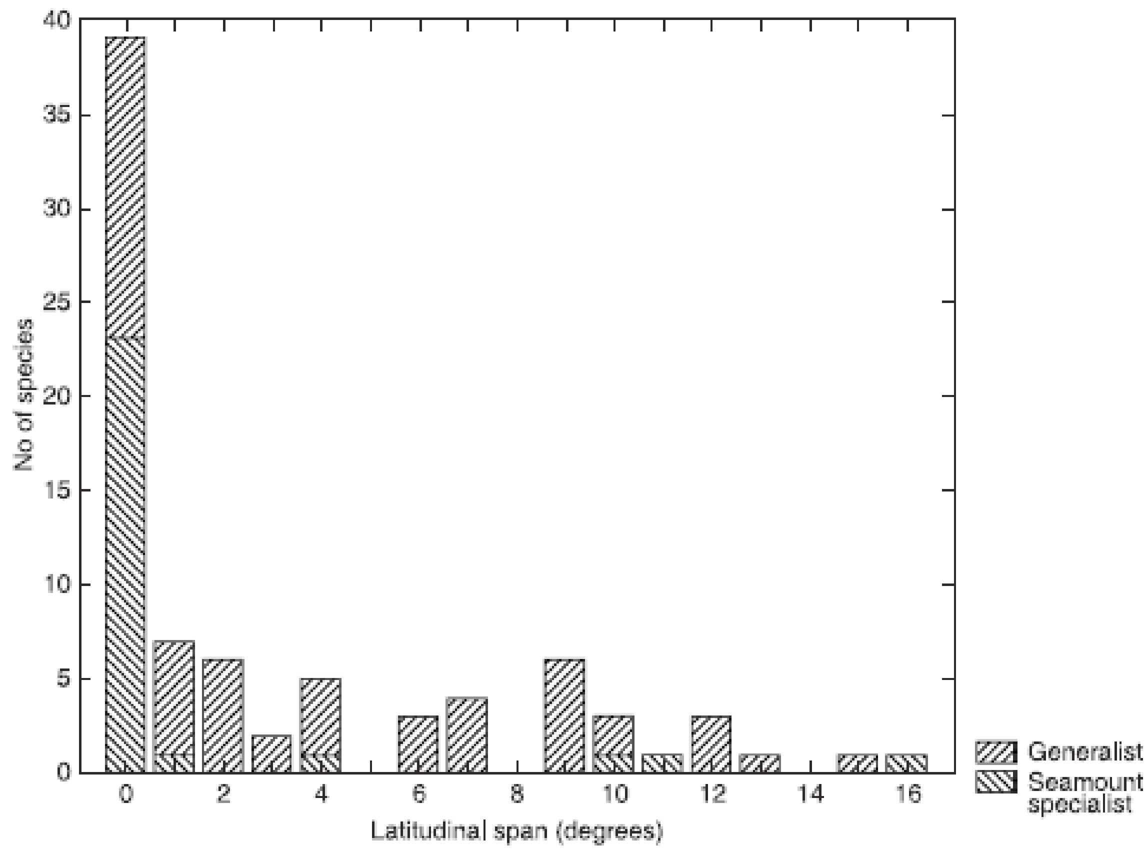


Endemism

82 endemic species
28 only found on seamounts (34%)
54 non-seamount or both (generalists)

Most seamount specialists limited to 1^{o} of latitude

15 species found on just one seamount



But……

When the number of narrow-range seamount specialists was compared to a null model that assumed the distribution of narrow range species was random with respect to geographical position (not shown), only one seamount fell outside the 95% prediction intervals of the model (number of species = 0.0563 + 0.0809 × number of samples). The exception was the Chesterfield Bank at the northern end of the Lord Howe Rise, which had fewer (n = 0) narrow-range species than predicted for the sampling intensity (43 samples) (O’Hara, 2007).

SW Pacific squat lobsters

Minimum-spanning haplotype networks

Squat lobster populations show high degree of mixing of populations

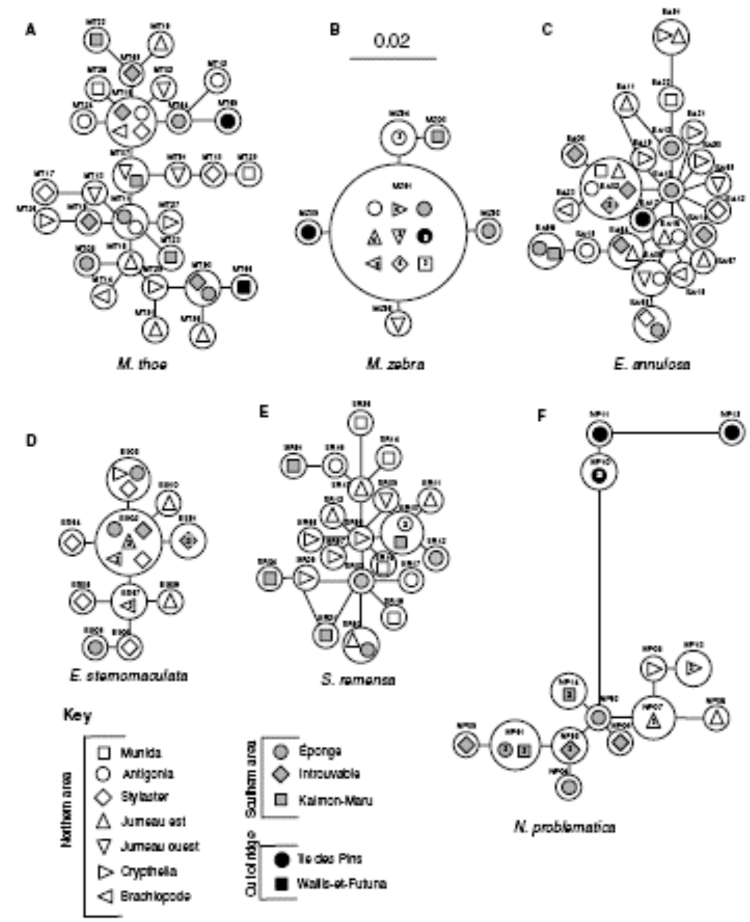


Table 1 Geographical distribution of species richness (number of species sampled) of Galatheidae genera and *Eumunida* (Chirostylidae) on Norfolk ridge seamounts

		Depth (m)			Number of stations sampled	Galatheidae				*Eumunida spp.*
		Min	Max	Mean		*Agononida spp.*	*Munida spp.*	*Paramunida spp.*	Other genera (pooled)	
"Isle des Pins" slope		100	1009	423	26	4	5	0	0	1
Northern seamounts	Antigonia	180	577	344	18	6	15	5	4	3
	Munida	86	590	357	11	4	10	5	3	3
	Jumeau Ouest	234	810	357	18	4	15	4	4	3
	Crypthelia	185	1190	394	20	2	15	1	1	3
	Brachiopode	276	762	401	14	2	12	2	4	4
	Stylaster	420	923	502	17	2	8	1	2	4
	Jumeau est	377	1434	538	25	4	9	1	3	4
	Refractaire	640	820	707	9	0	2	0	1	1
Southern seamounts	Kaimon Maru	227	896	335	19	2	18	2	5	2
	Eponge	500	1144	612	18	6	13	3	2	4
	Introuvable	555	1040	639	17	4	9	3	1	5
	Zorro	609	1100	762	8	2	5	0	0	1
	Trois mousquetaires	609	1150	804	9	3	3	0	0	2
Total number of species sampled on the two Norfolk cruises						11	36	8	9	5
Total number of species known in the Southwest Pacific						24	79	21	27	14

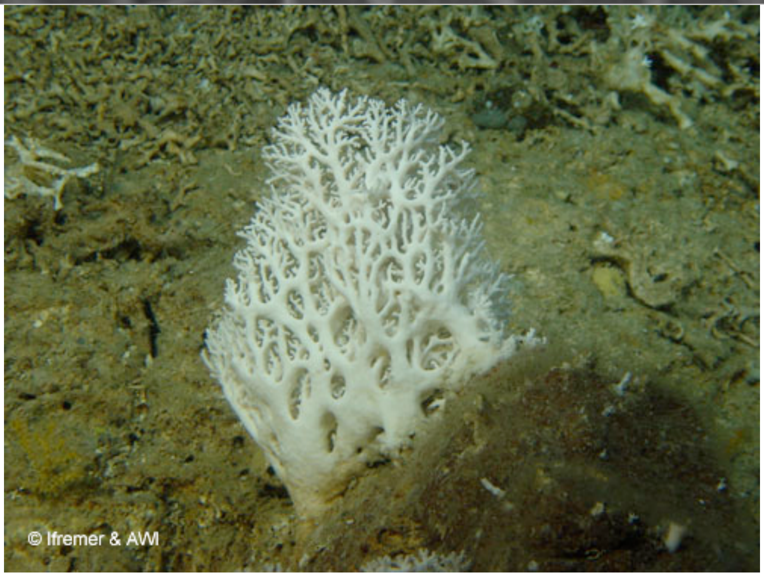
But seamounts had a high local species richness

Samadi et al., 2006 Mar Biol 149: 1463-1475

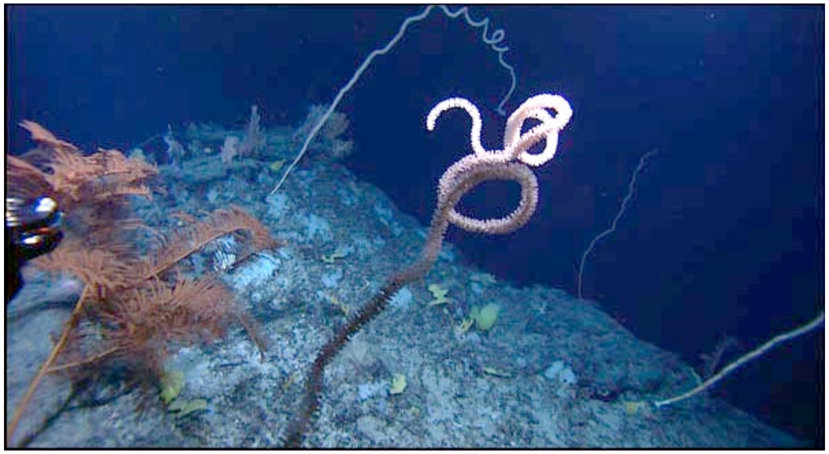
What does this indicate?

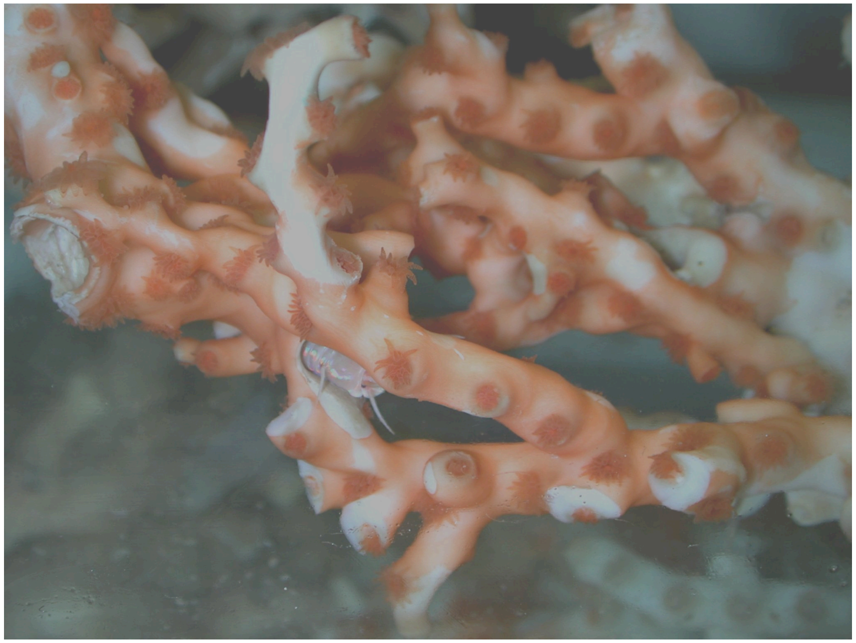
- Seamounts do seem to provide unique habitat
- High endemism is not proven
- Possibly high local richness but this reflects regional diversity
- In some cases species richness seems low (e.g. Great Meteor Seamount megafauna) – Island Biogeography
- Depth is important
- Latitude is important
- Oceanographic setting

Coral distribution on seamounts

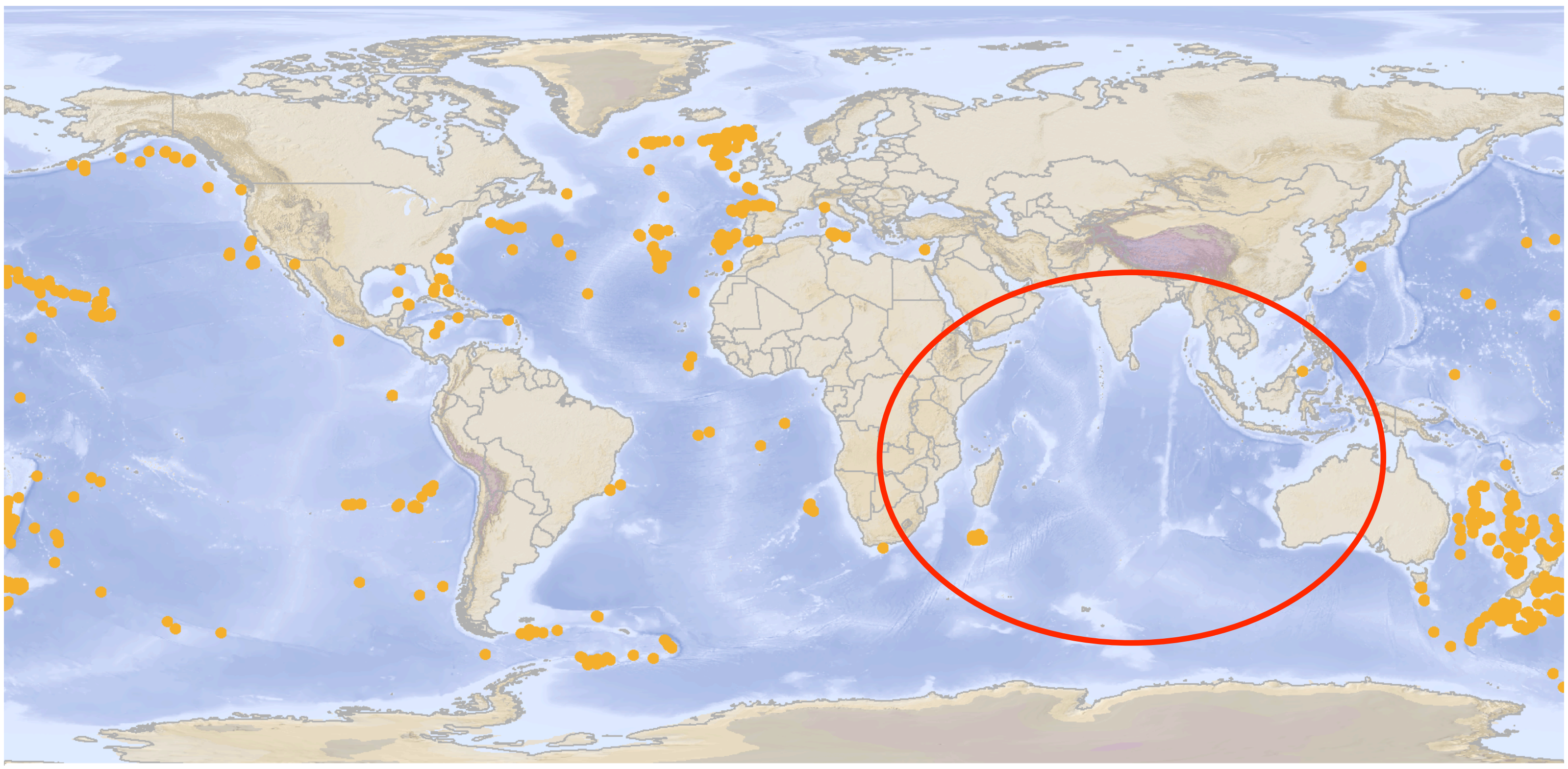


Paul Tyler, NOAA
Ocean Explorers, IFREMER



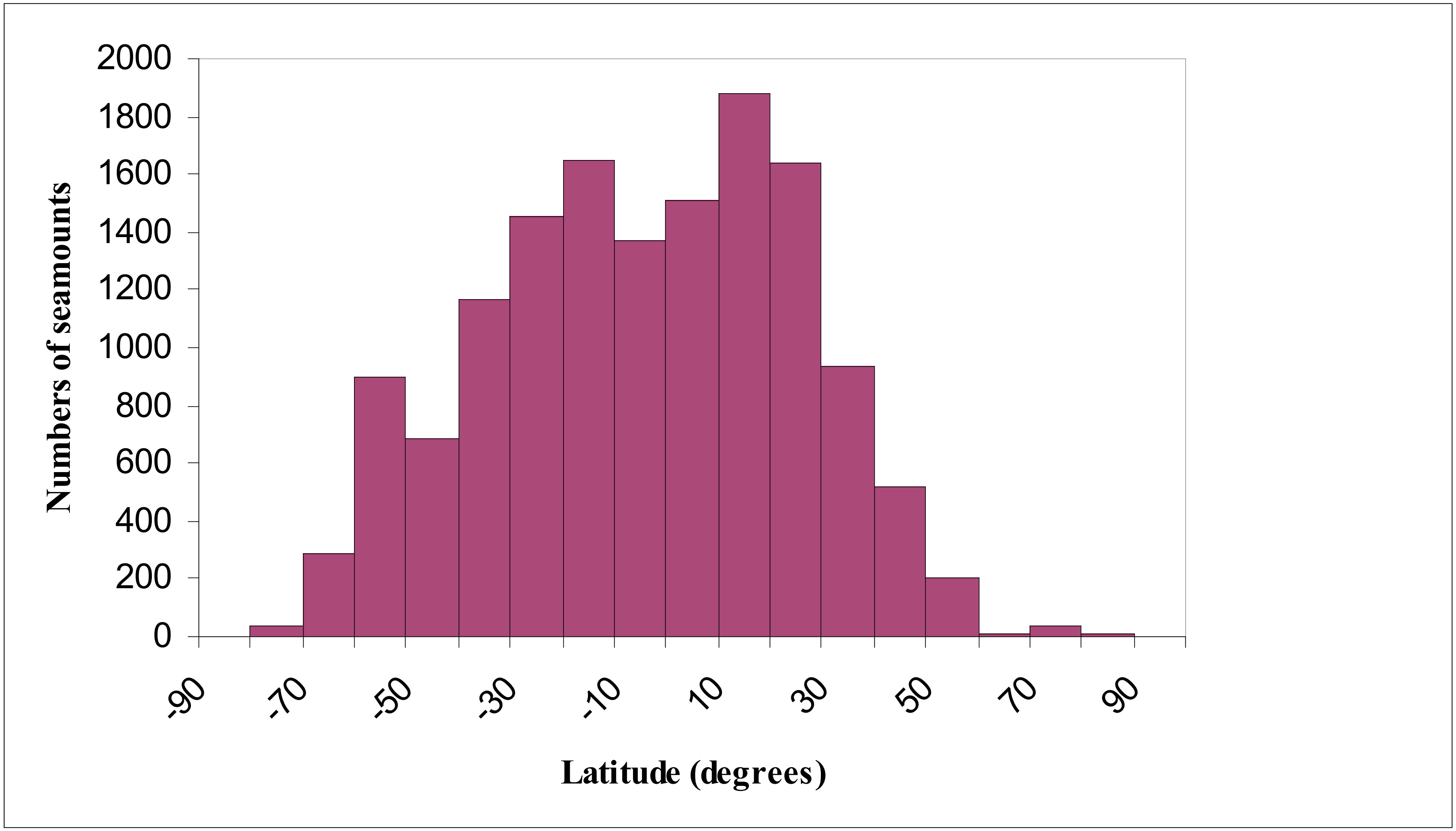


Database of all coral records on seamounts



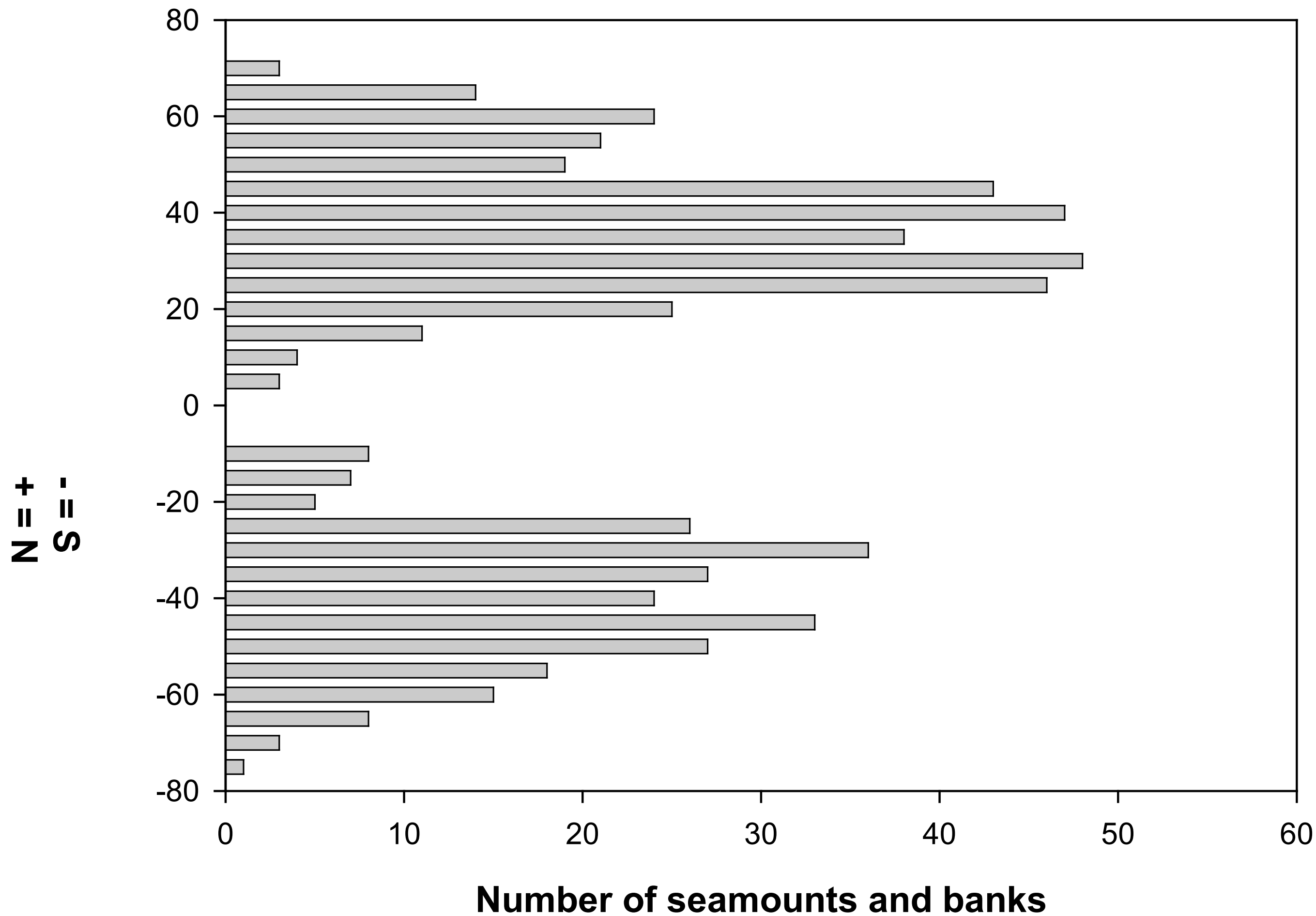
Rogers et al., In press; Clark et al. (2006) Seamounts, deep-sea corals and fisheries. UNEP WCMC, Cambridge UK 80pp

Distribution of seamounts by latitude



Clark et al., (2006)

Number of seamounts with coral records vs latitude



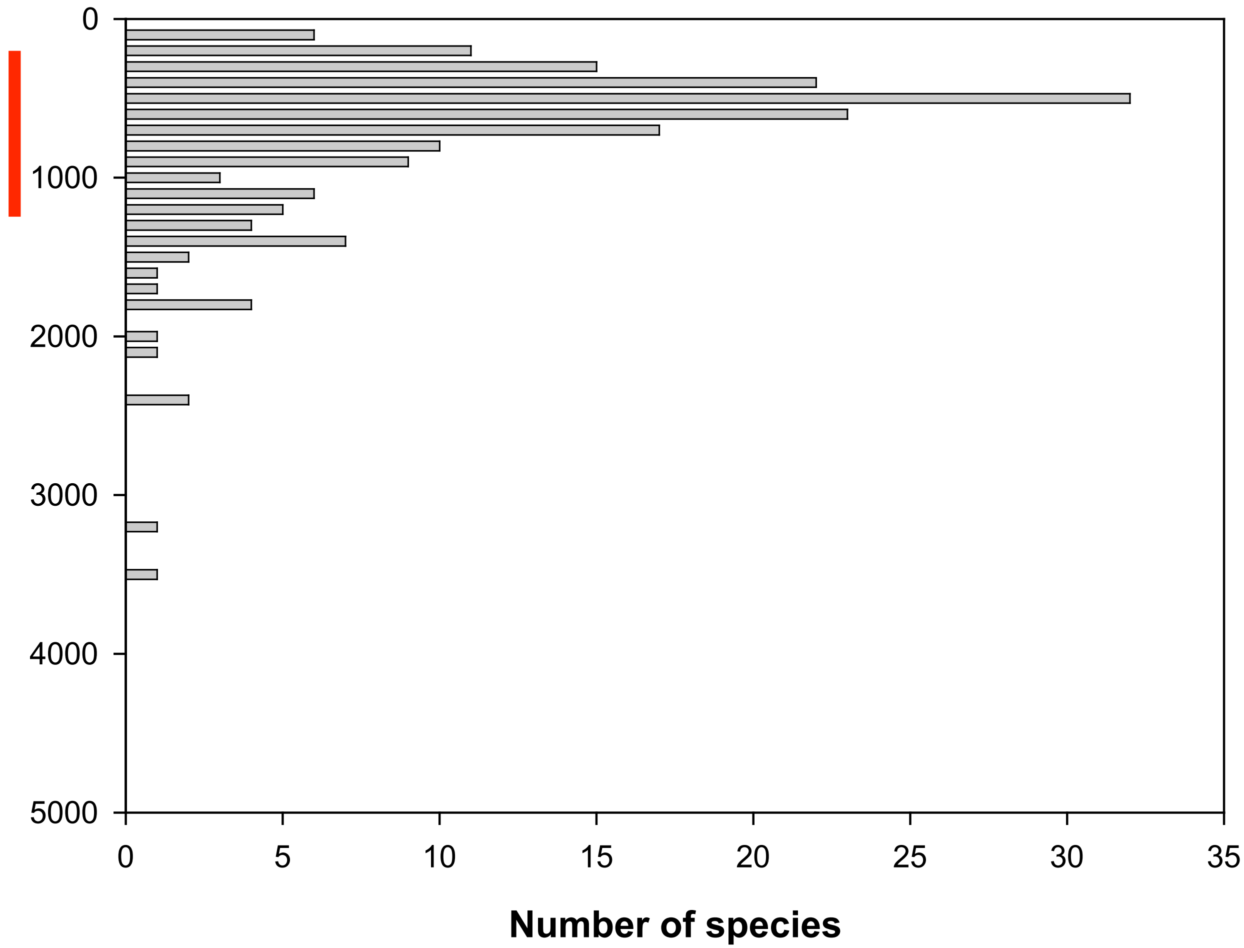
Rogers et al., In press

Mean depth of occurrence for deep-water Scleractinia (from seamounts)

ZSL

Scleractinia (Mean depth)

Depth of
CW coral reef
occurrence



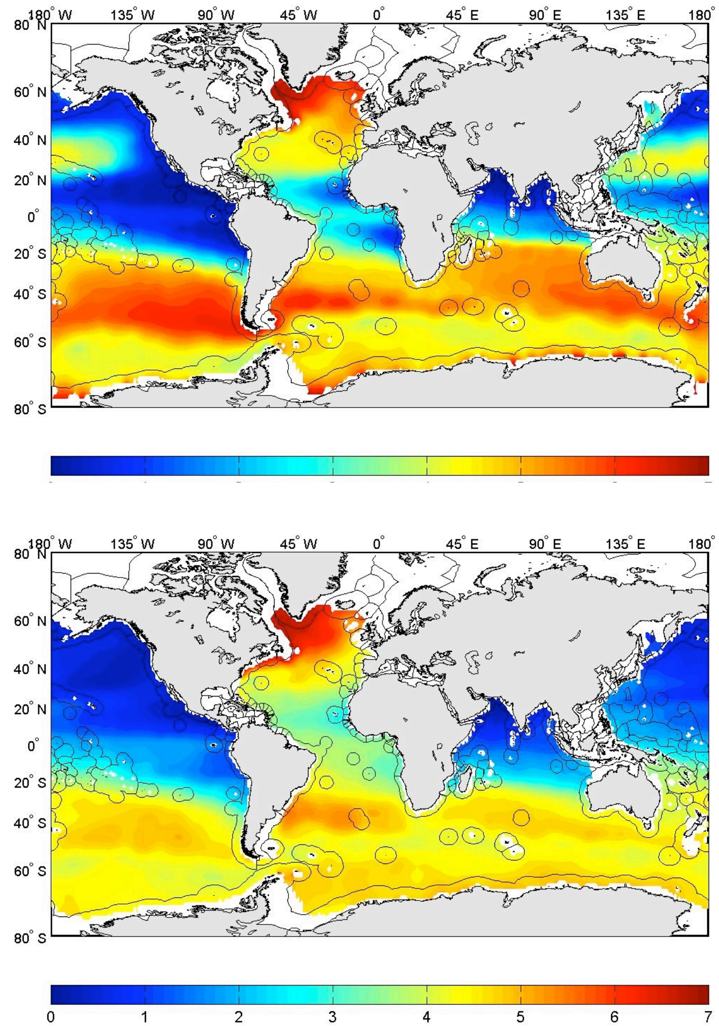
Modelling species distributions: Environmental Niche Factor Analysis (ENFA)

ENFA compares the observed distribution of a species, or group of species, to the Background distribution of environmental factors.

It assesses how different the environmental niche a taxonomic group occupies is relative to the mean background environment (its 'marginality'), and how narrow this niche is (its 'specialization').

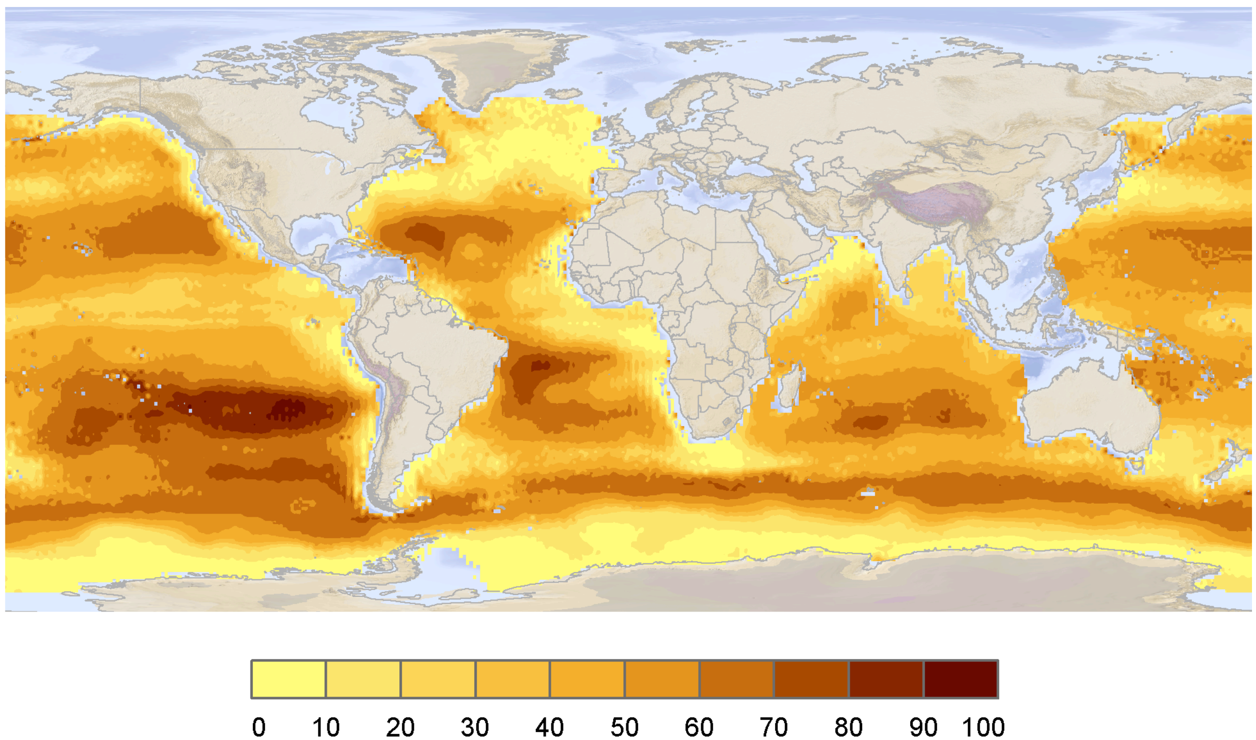
Why ENFA?

Because the coral database is a "presence only" dataset.



Aragonite µmol kg^{-1} at 500m & 1000m depth

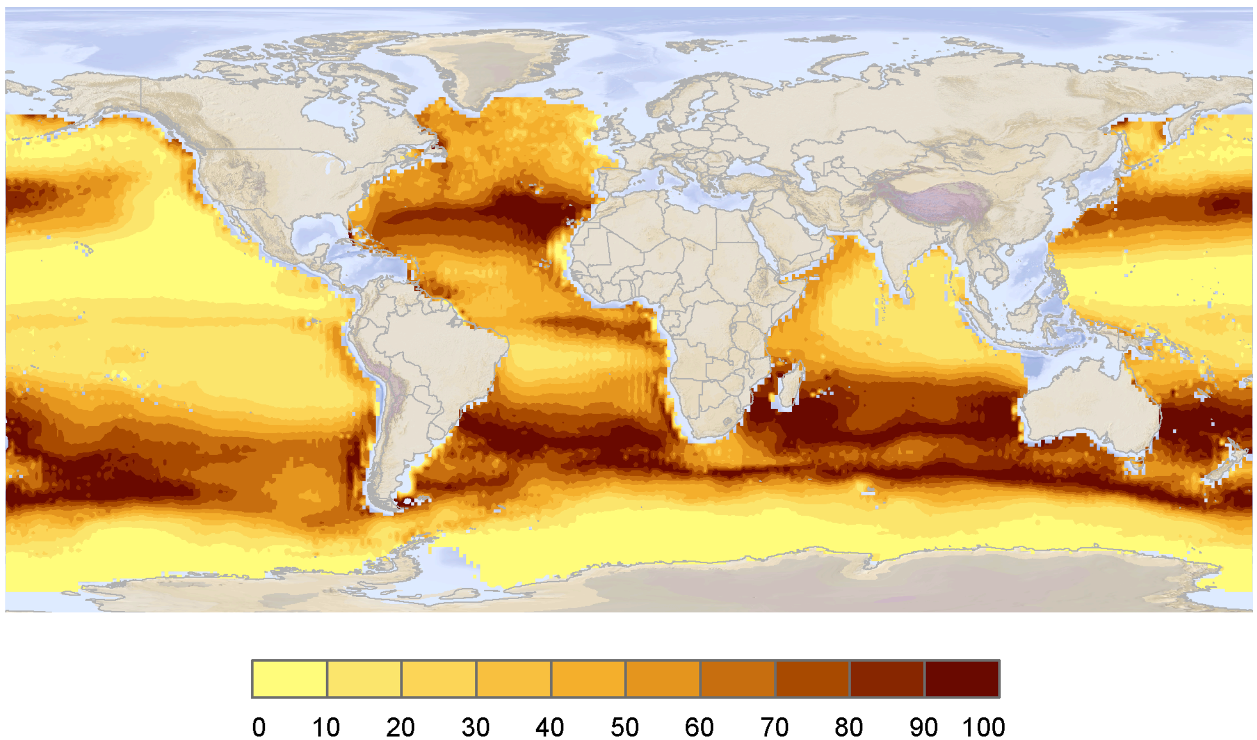
Habitat suitability 0-250m



Marginality = 0.918 (Habitat is different from background)
Specialisation = 1.396 (Coral occupy a narrow niche)

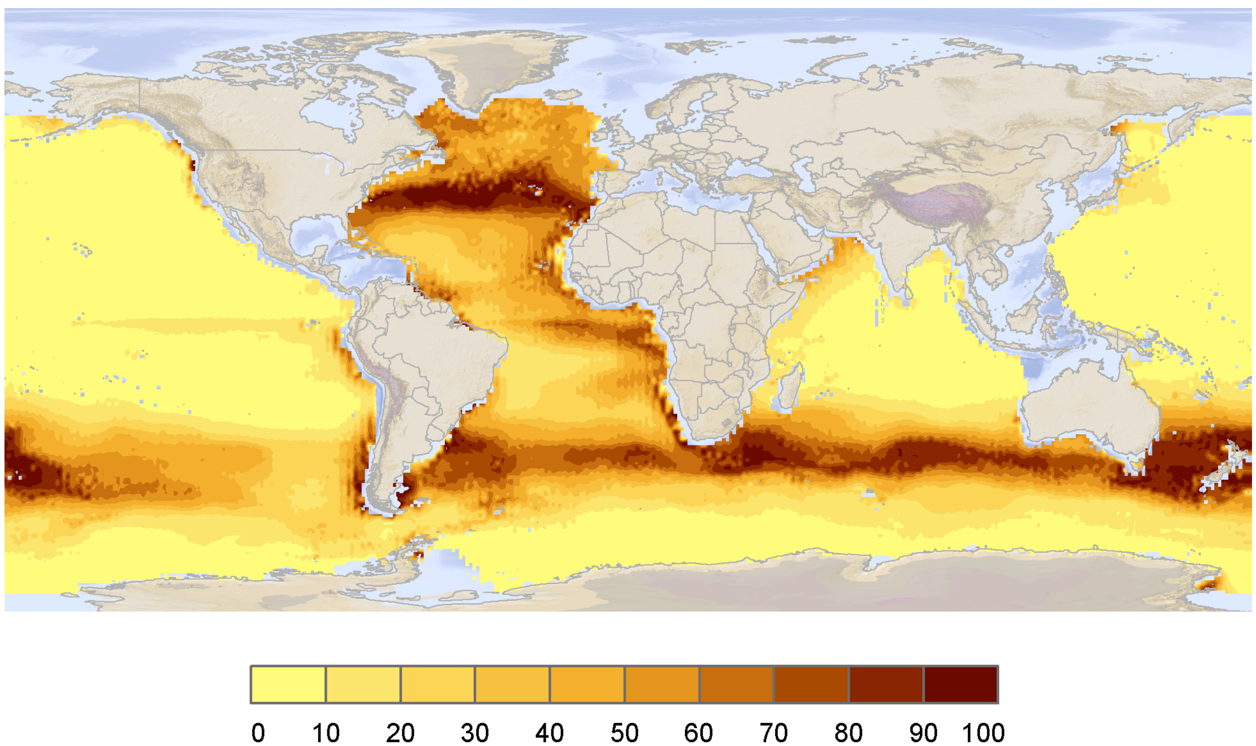
Habitat suitability 250-750m

ZSL

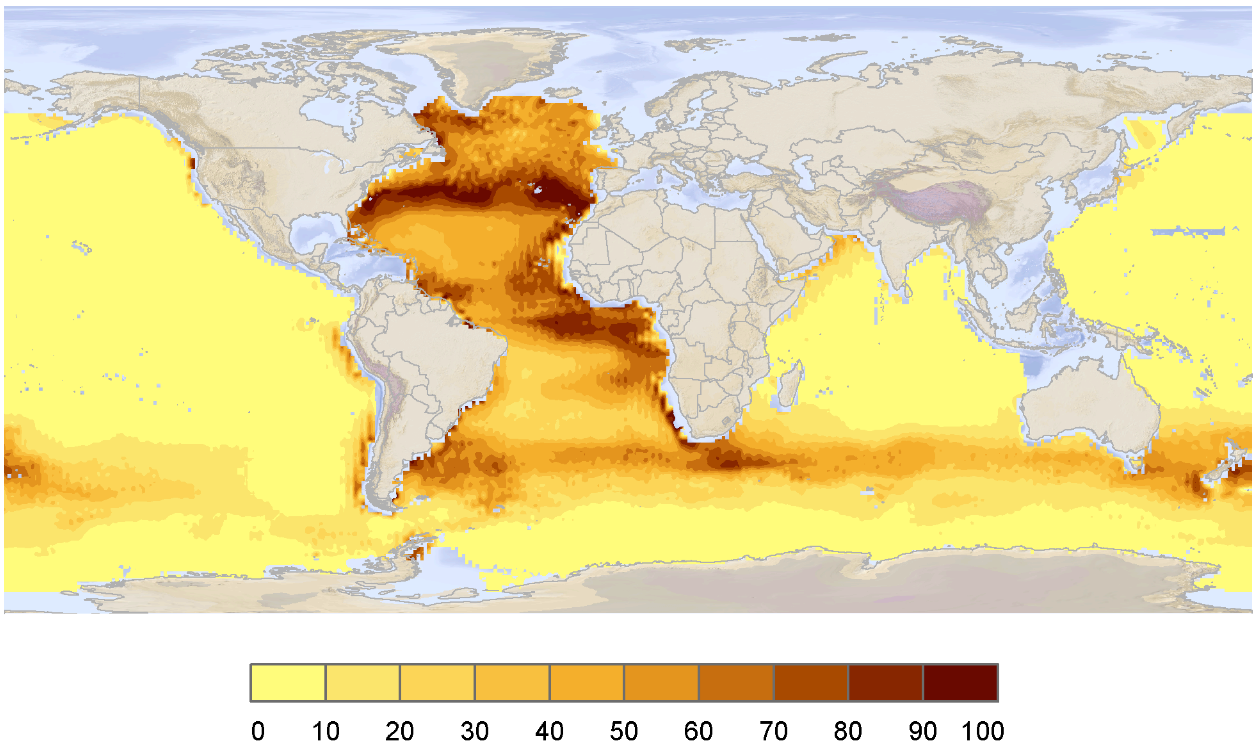


Habitat suitability 750-1250m

ZSL

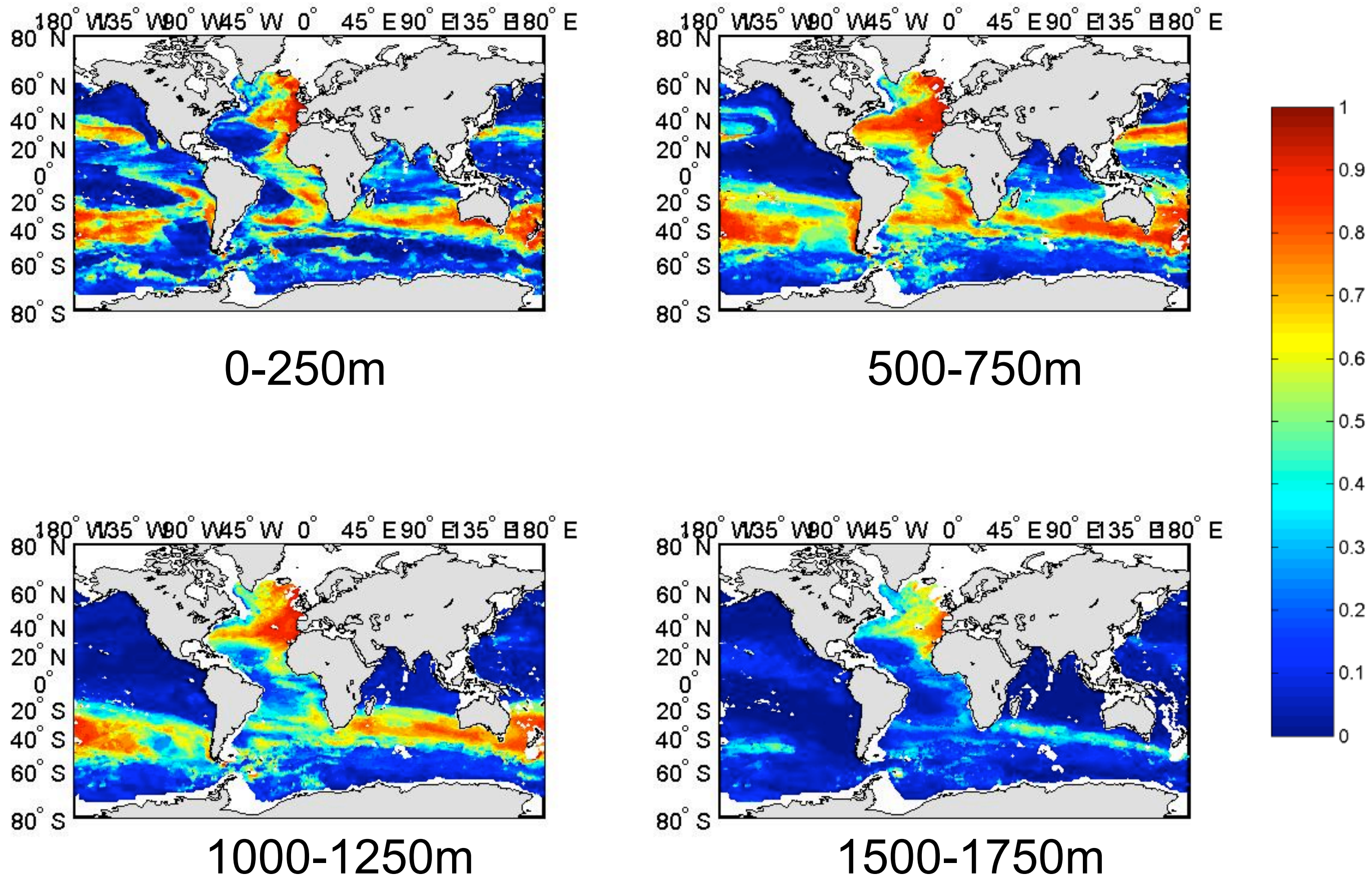


Habitat suitability 1250-1750m



Gradient in favourability of habitat, progressively more to the SW with depth

Habitat preferences of deep-water Scleractinia



Model of habitat suitability for Scleractinia on seamounts carried out using maximum entropy (Tittensor et al., in submission)

Factors influencing the geographic distribution of cold-water Scleractinia on seamounts

- Aragonite saturation
- Oxygen concentration and % saturation

    See paper by Dodds et al (2007) JEMBE 349: 205-214

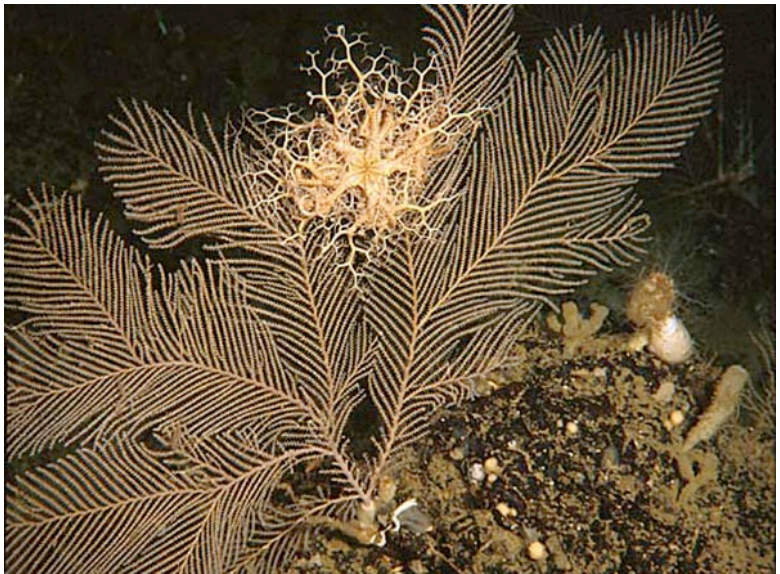
    Critical PO_2 about 3.26ml l^{-1} for *Lophelia pertusa*
- Temperature
- Low dissolved organic carbon, nitrates, phosphates and silicates

    High nutrient levels are known to impact rate of carbonate accretion in shallow zooxanthellate coral species e.g. Renegar

    & Riegl MEPS 293: 69-76

See also: Davies et al Deep-Sea Research In press.

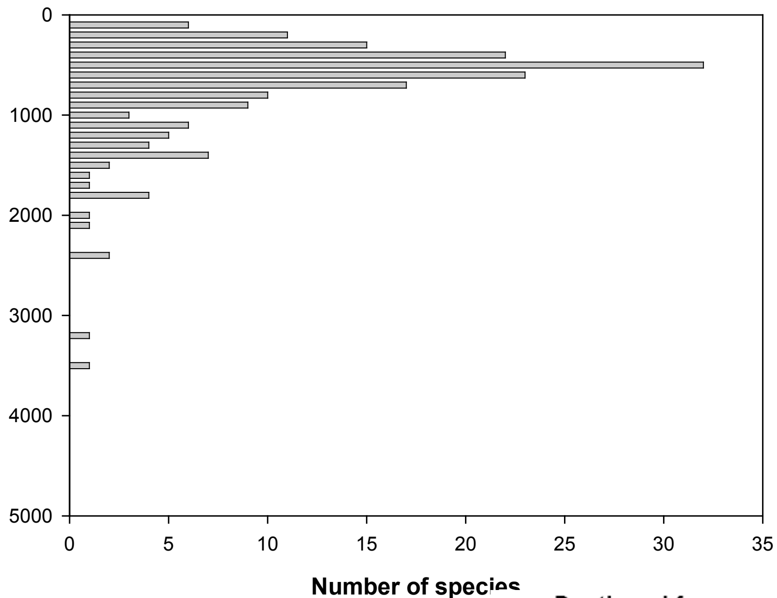
Octocorals



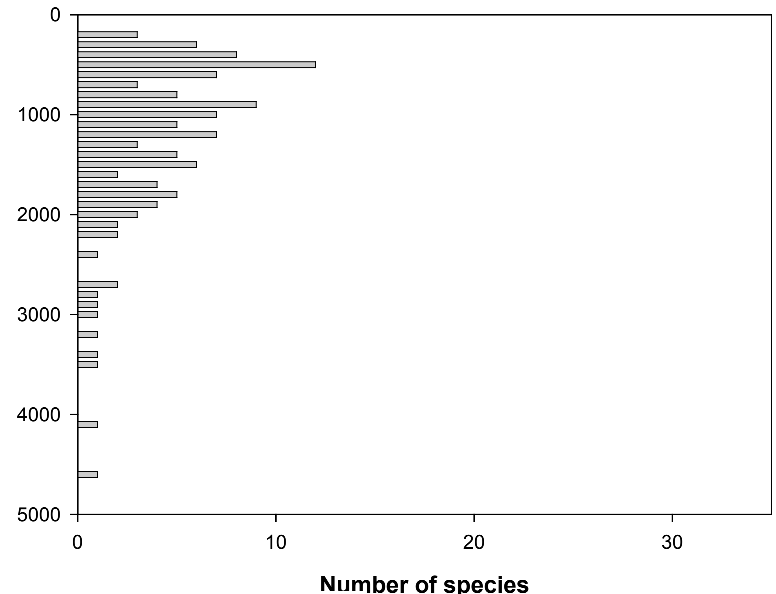
NOAA Ocean Explorers

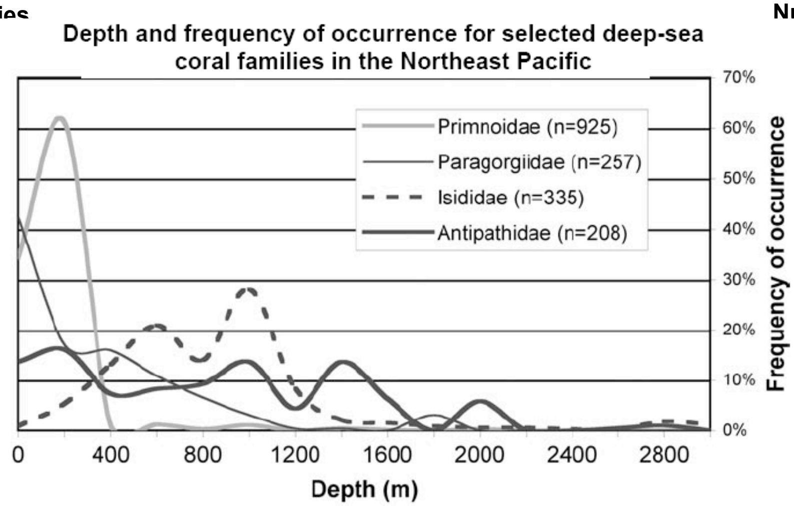
Differences in depth distribution of major coral groups

Scleractinia (Mean depth)



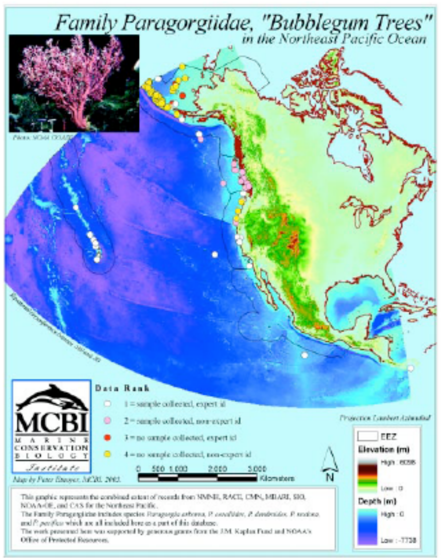
Octocorallia (Mean depth)

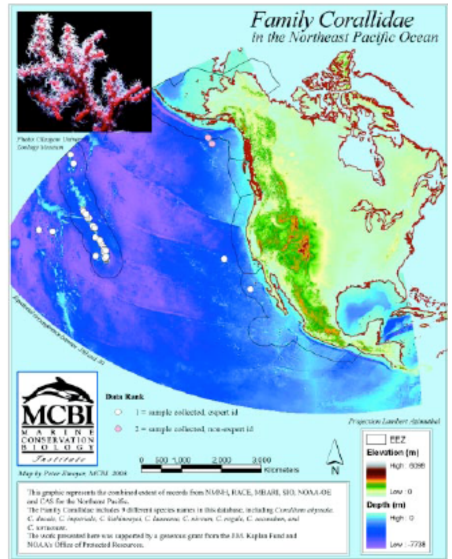


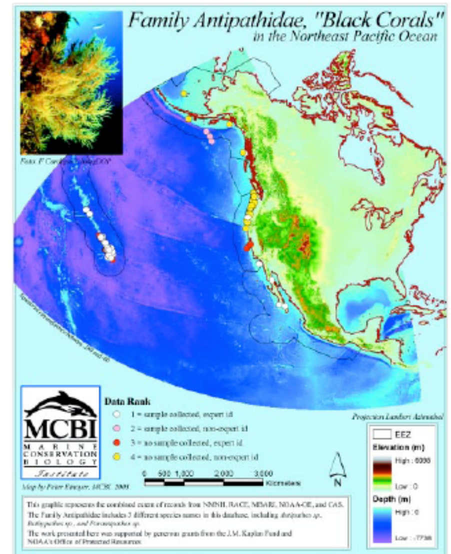


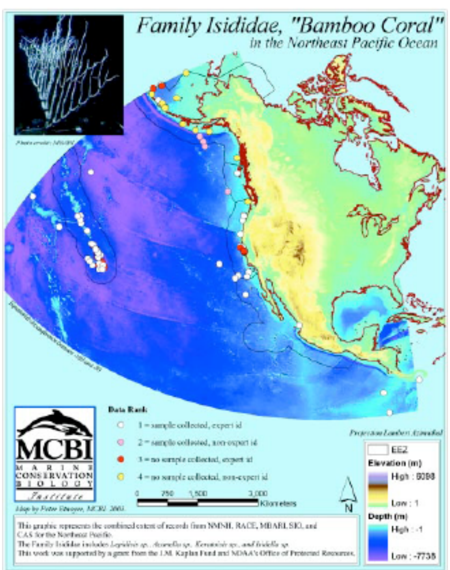
Rogers et al., 2007;
Etnoyer & Morgan, 2005

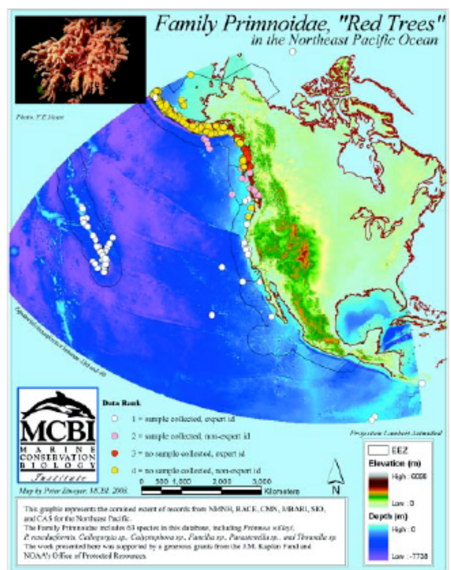
Octocorals, antipatharians & stylasterids, NE Pacific (Etnoyer & Morgan, 2003)

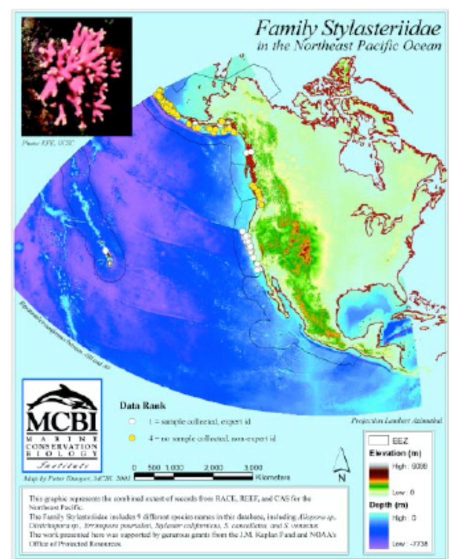




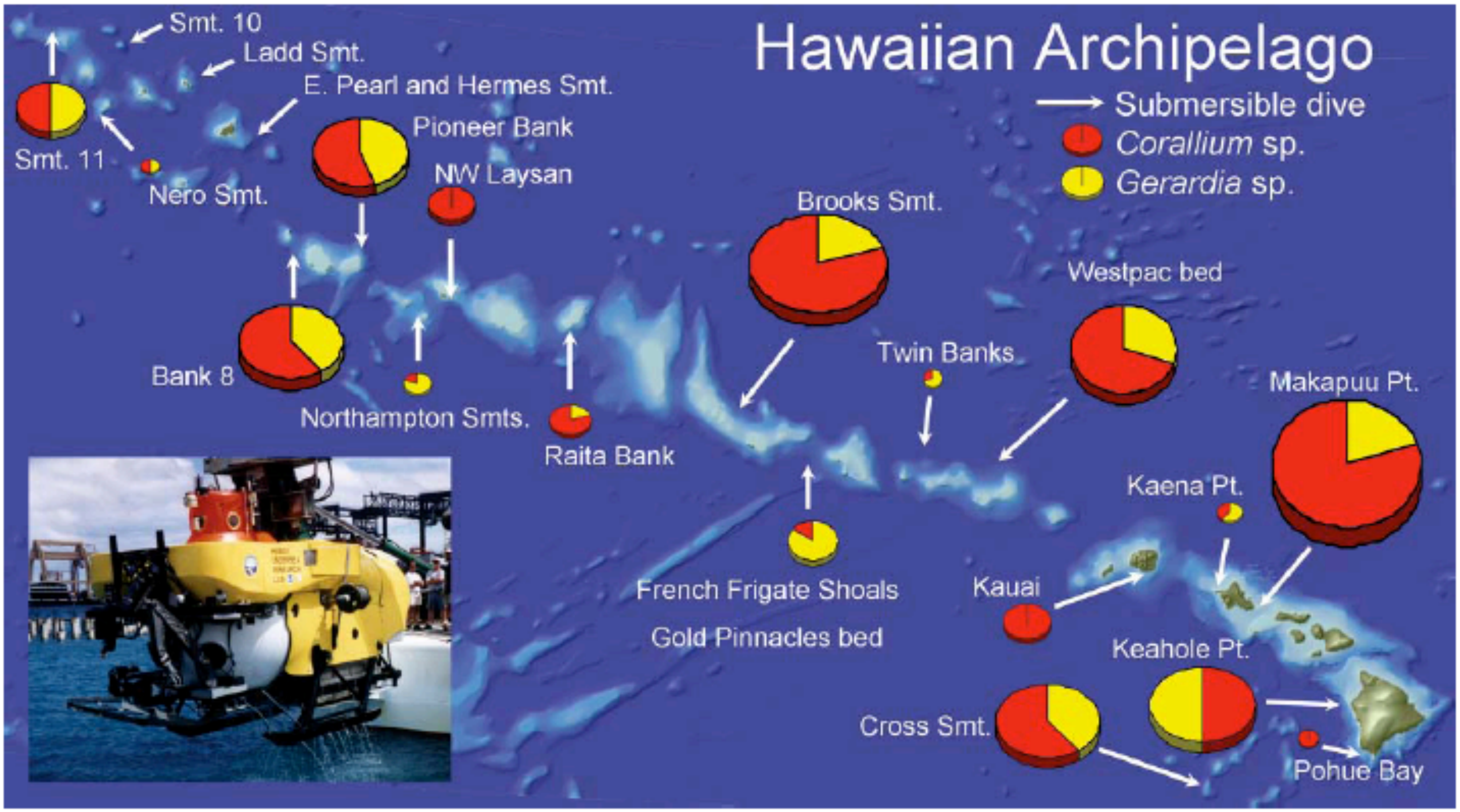








Distribution of octocorals (*Corallium* sp. & *Gerardia* sp.) Hawaiian region

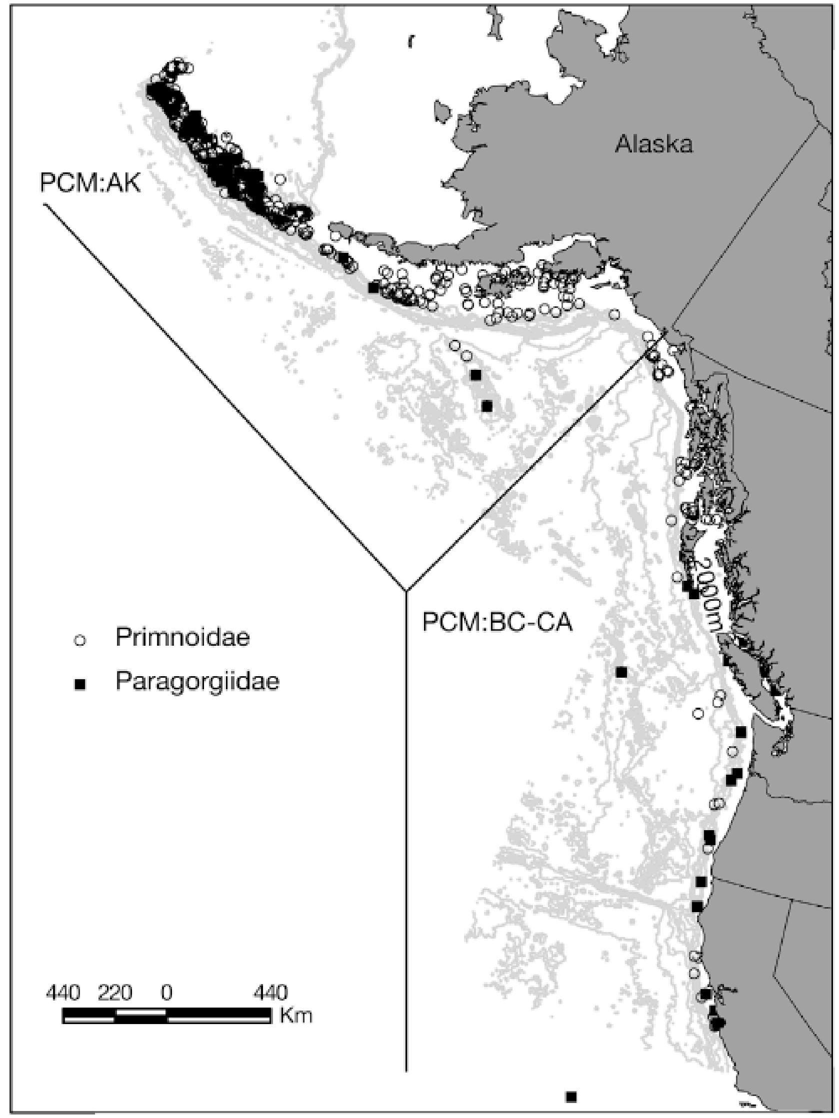


Parrish & Baco, 2007

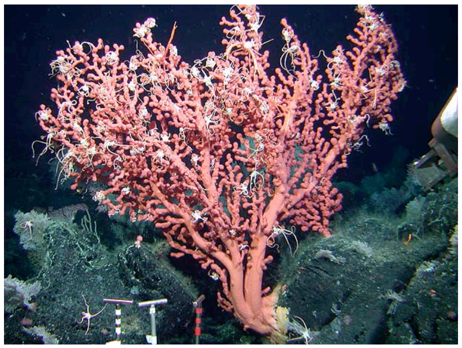
Habitat suitability modelling - octocorals

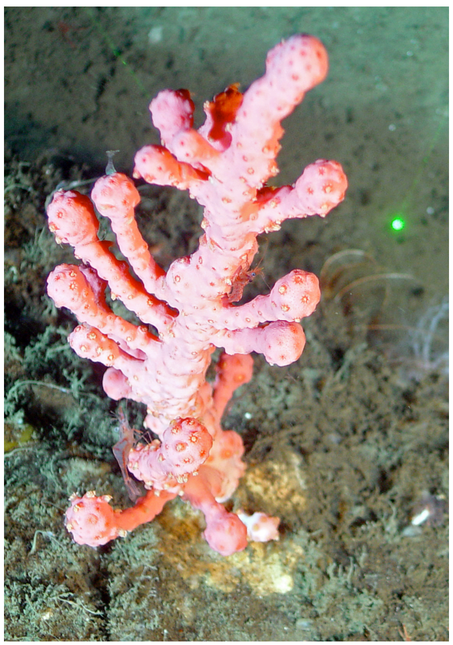
ENFA for octocoral data in the NE Pacific.

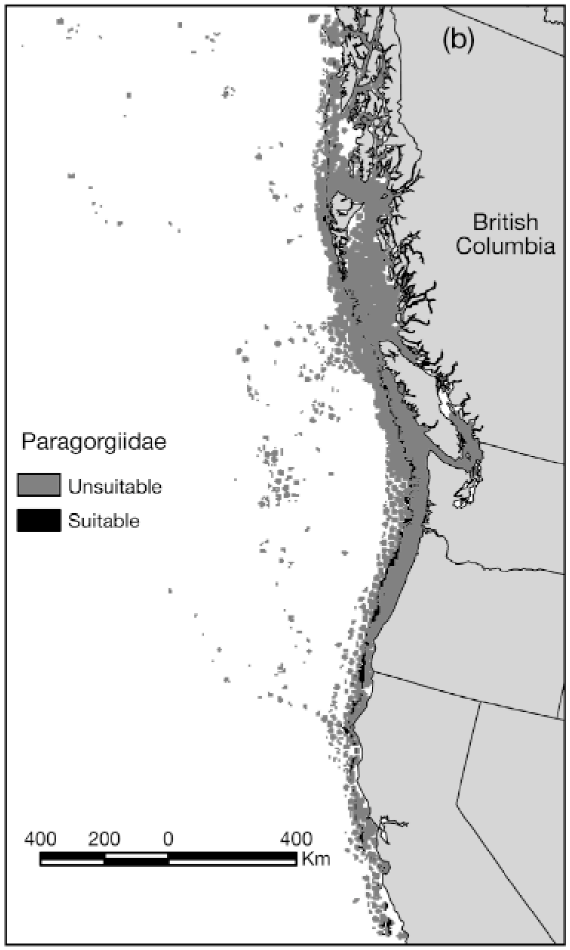
Data restricted to the Primnoidae and Paragorgiidae

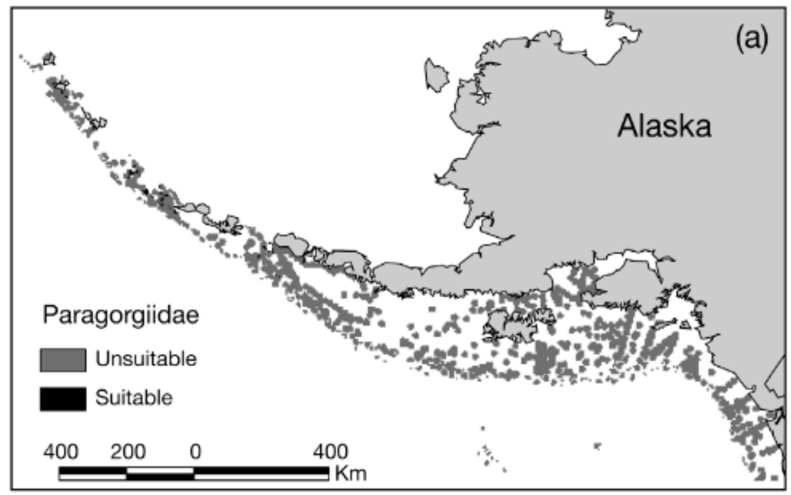


ENFA-Paragorgiidae



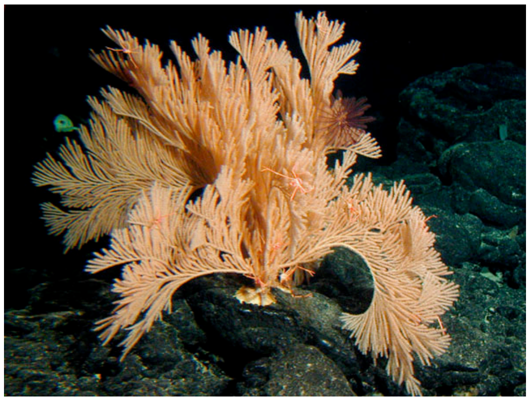


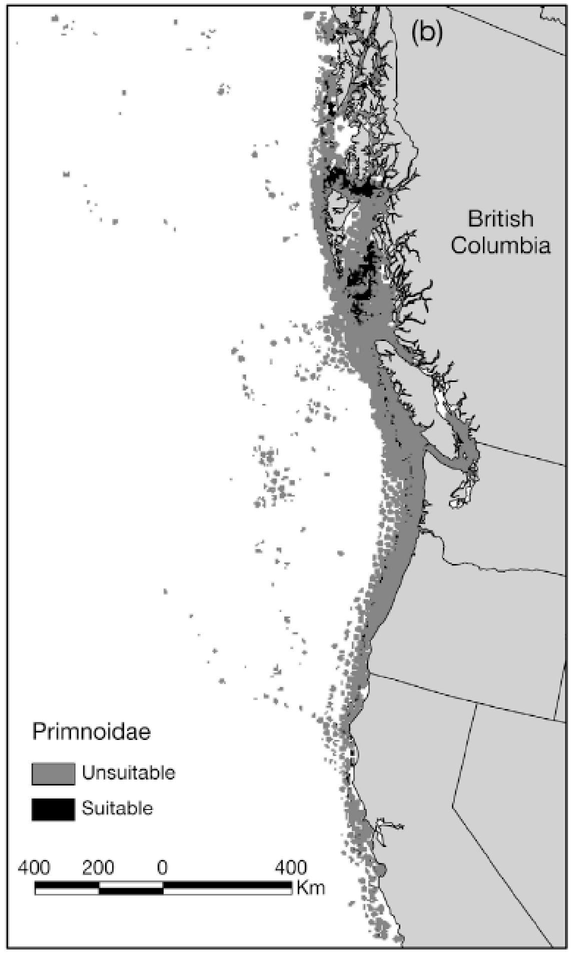


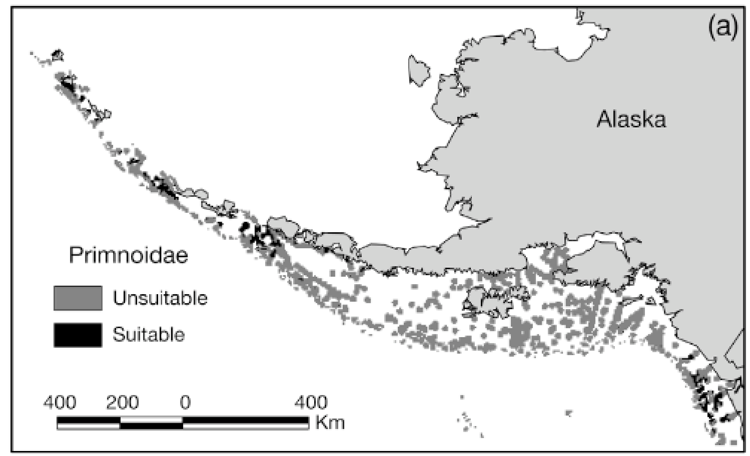


Bryan & Metaxas, 2007 MEPS 330: 113-126
See also Leverette & Metaxas, 2005Freiwald A, Roberts JM (eds), 2005,
Cold-water Corals and Ecosystems. Springer-Verlag Berlin Heidelberg, pp 467-479

ENFA-Primnoidae







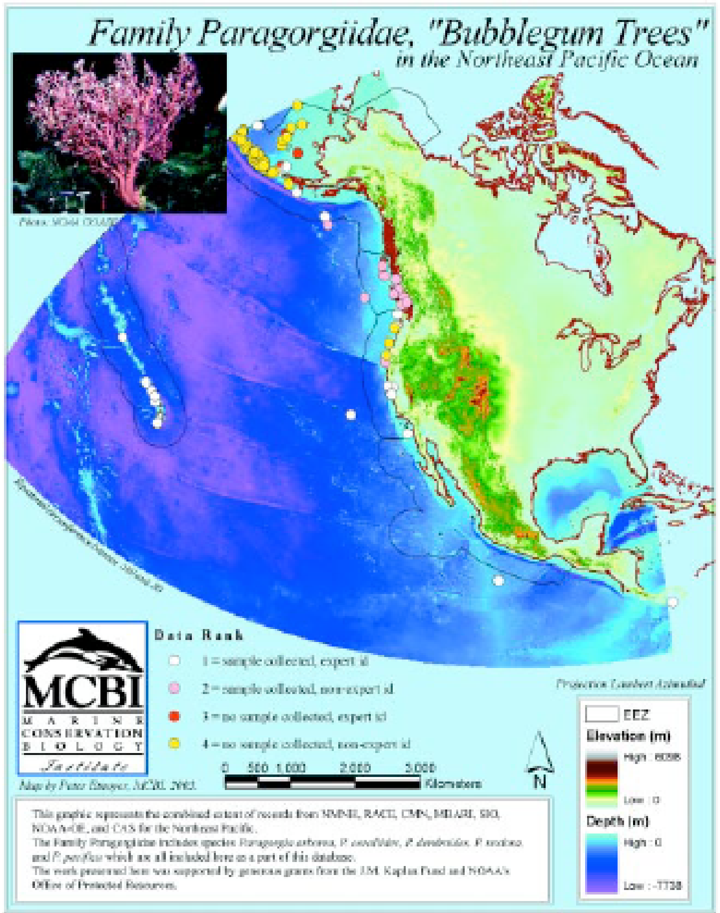
Bryan & Metaxas, 2007 MEPS 330: 113-126
See also Leverette & Metaxas, 2005Freiwald A, Roberts JM (eds), 2005,
Cold-water Corals and Ecosystems. Springer-Verlag Berlin Heidelberg, pp 467-479

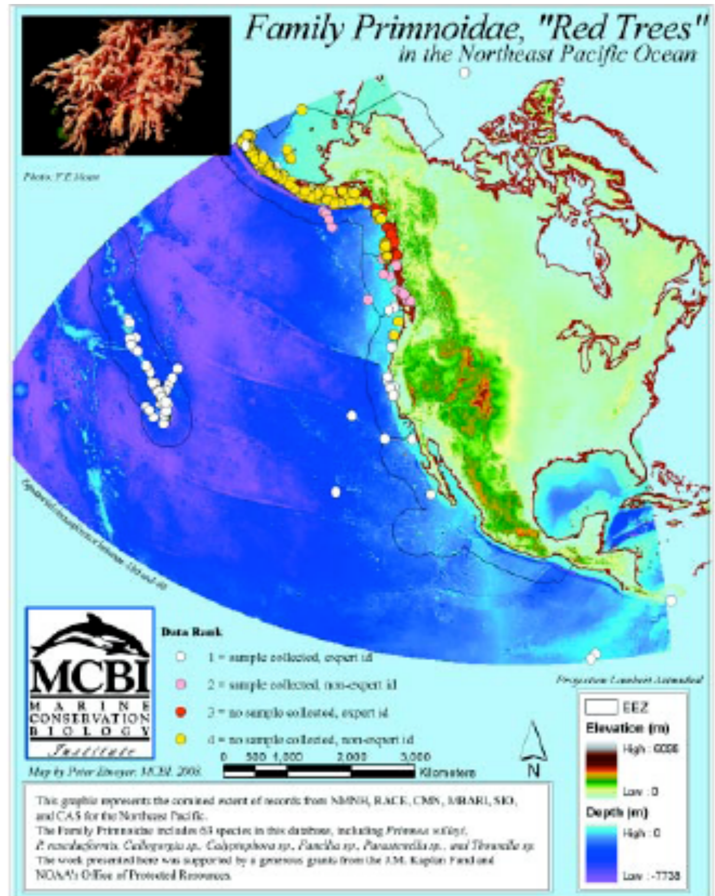
Factors influencing the geographic distribution of deep-water octocorals

ZSL

- Temperature
- Slope (proxy for complex topography, hard substrata, high current exposure).
- Current
- Chlorophyll *a* concentrations (low – nutrients?)
- Depth
- Substrata

Some controversy….





Etnoyer & Morgan 2007, MEPS 339:311-312

What can we learn for conservation in the Pacific

- Still major knowledge gaps for large areas of the Pacific, especially in equatorial regions

- Scleractinian habitats tend to be in Southern hemisphere
- Octocoral habitats dominant in the North Pacific
- Seamount depth is important
- Latitude is important
- Biogeochemistry (water masses) are important as they influence productivity, nutrient levels, temperature etc.

High seas protected areas

- Should represent seamounts with a range of depths and size
- Should be distributed across latitudes
- Latitudinal distribution should not be by degree-bands but by water mass type (perhaps Longhurst biomes or LMEs)
- Consideration should include other existing or potential human impacts (fishing, pollution, research, climate change)