The impacts of deep-sea fisheries: their effects on the megabenthos and lessons for sustainability

Malcolm Clark

and Thomas Schlacher[1], Alan Williams[2], Ashley Rowden, Franzis Althaus[2] and David Bowden

1: USC
2: CSIRO

ICES Symposium: Effects of fishing on benthic fauna, habitat, and ecosystem function. Tromso, Norway. June 2014

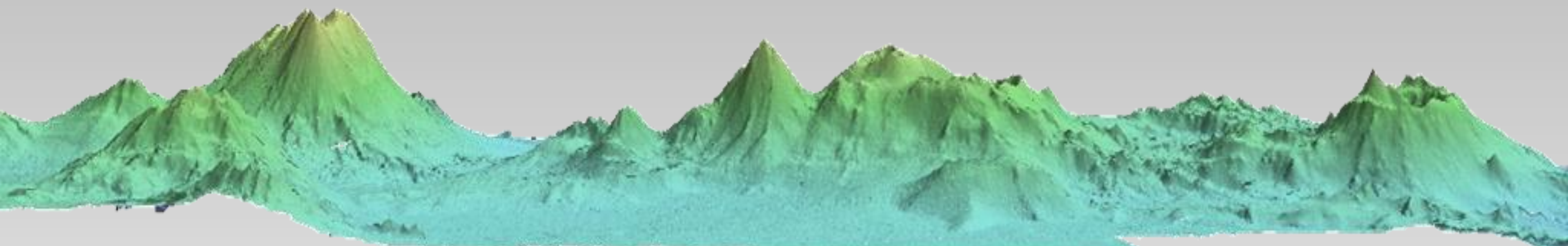
Presentation Outline

- **Deep-sea fish and fisheries**
  - Deep-sea species
  - Deep-sea fisheries
- **Deep-sea ecosystem**
  - Habitats
  - Faunal communities
- **Fisheries Impacts**
  - Nature and extent of impacts
  - Sensitivity of deep-sea habitats and communities
  - **Recovery potential**
- **Management implications**



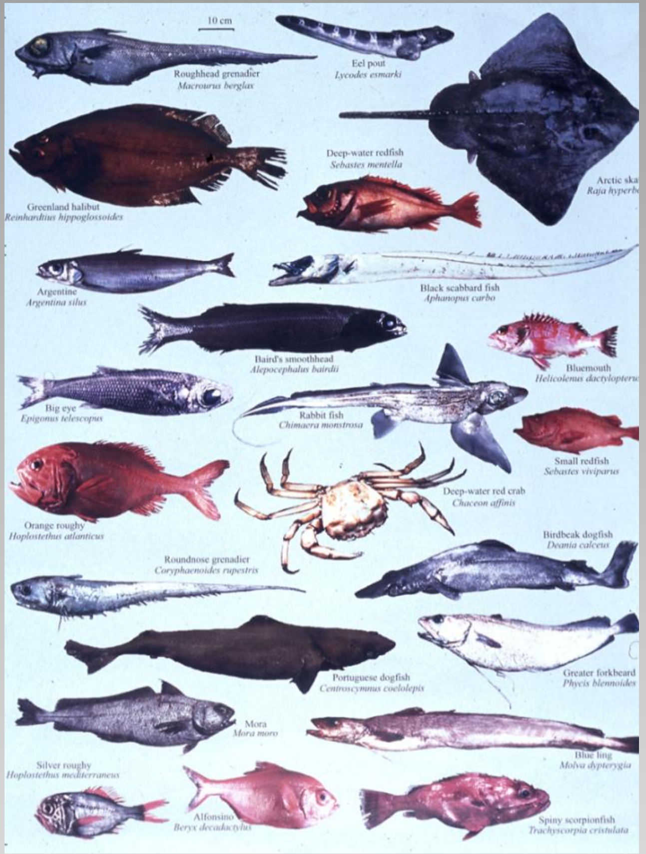

A piece of the jigsaw puzzle

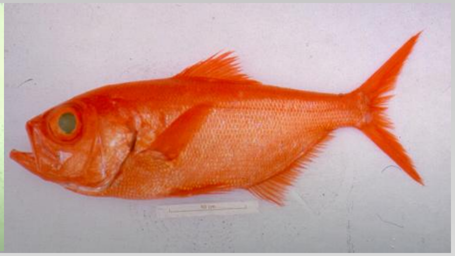
- A variety of “keynote” talks
  - General biodiversity and EBM
  - Shelf ecosystems-mixed sediments
  - fishing gear impact, soft sediments
  - effects on soft sediment biota
  - Mitigation options
- Deep-sea hard substrate
  - Focus on what (if anything) is different in the deep-sea



Deep-sea commercial fisheries

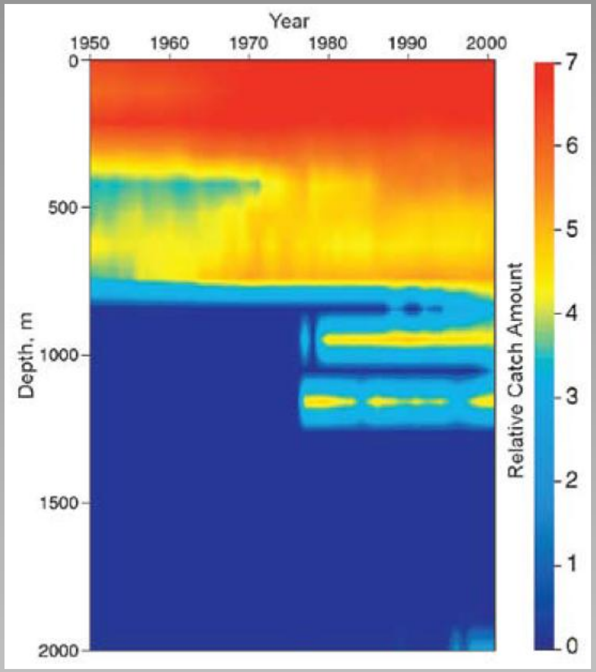
- Defined in various ways
- **Depth**
  - >200m (northern hemisphere)
  - >500m (southern hemisphere)
- **Productivity**
  - Low (FAO definition)
- **Habit**
  - Demersal (few deep pelagics)
- Species lists variable (<30 spp)





Deep-sea fisheries

- Trend in recent decades to fish deeper
- History of boom & bust
- Small on global-scale
- Current catches globally
  - 100,000-150,000 t
  - similar over last 5 years
- Still important locally
- New Zealand
  - 25,400 t (about 5% of total finfish catch)
  - value US$90million (about 10% of total finfish $)

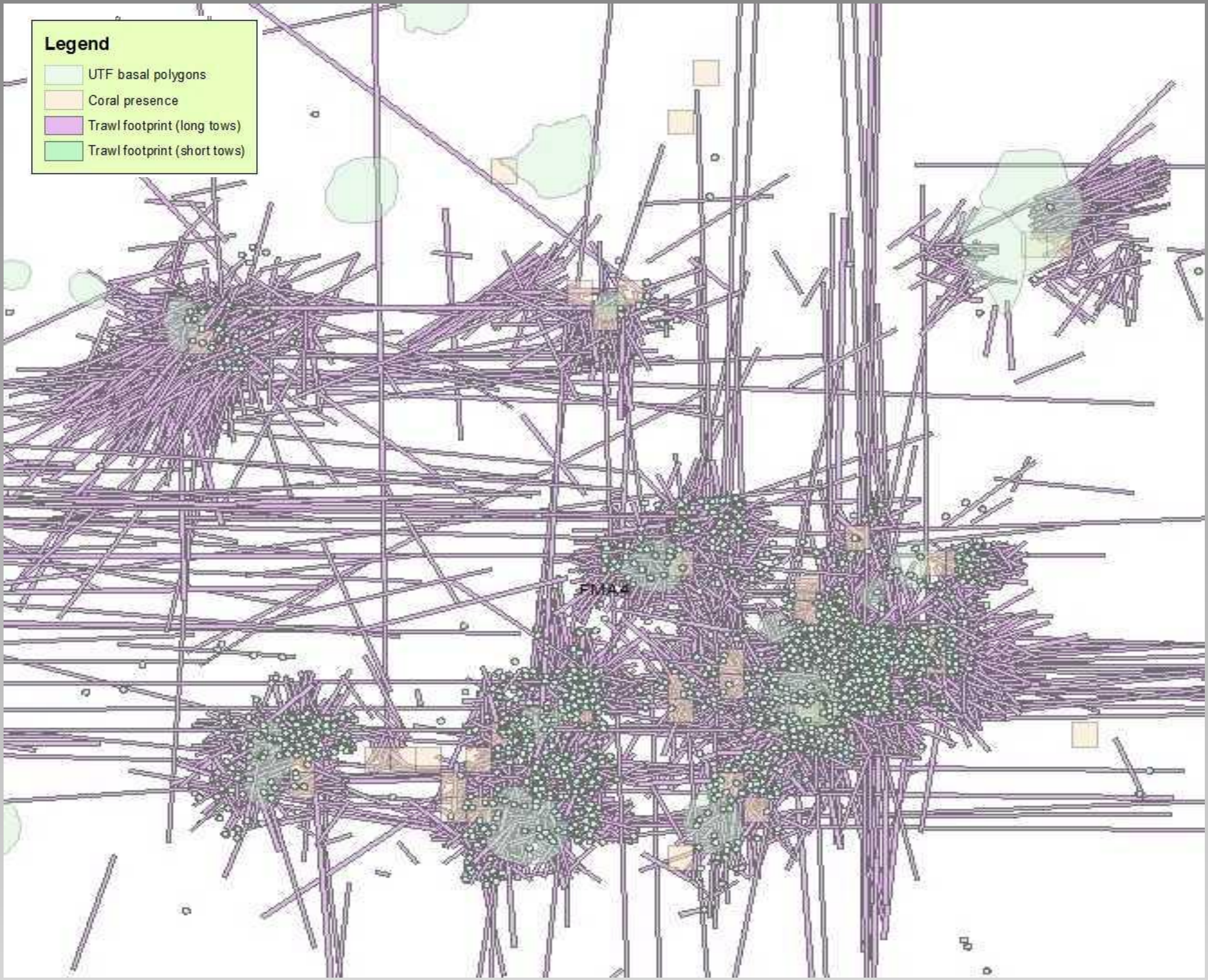


Pitcher et al. 2010

Deep-sea fisheries footprint

- Small on a global scale of “deep-sea”
- Locally significant at depth band to 1500m
- North Atlantic (OSPAR) >200m = 30,000 km^2
- New Zealand >200m = 180,000 km^2
  - Uneven distribution by depth (0-400m = 44% of fishable area; 800-1200m = 12%)
- Heavy in some habitats
  - New Zealand seamounts where up to 50% of ORH effort & catch came off seamounts in some years
  - 80% seamounts where summit depths between 800-1200m have been fished

Seamount "footprint"



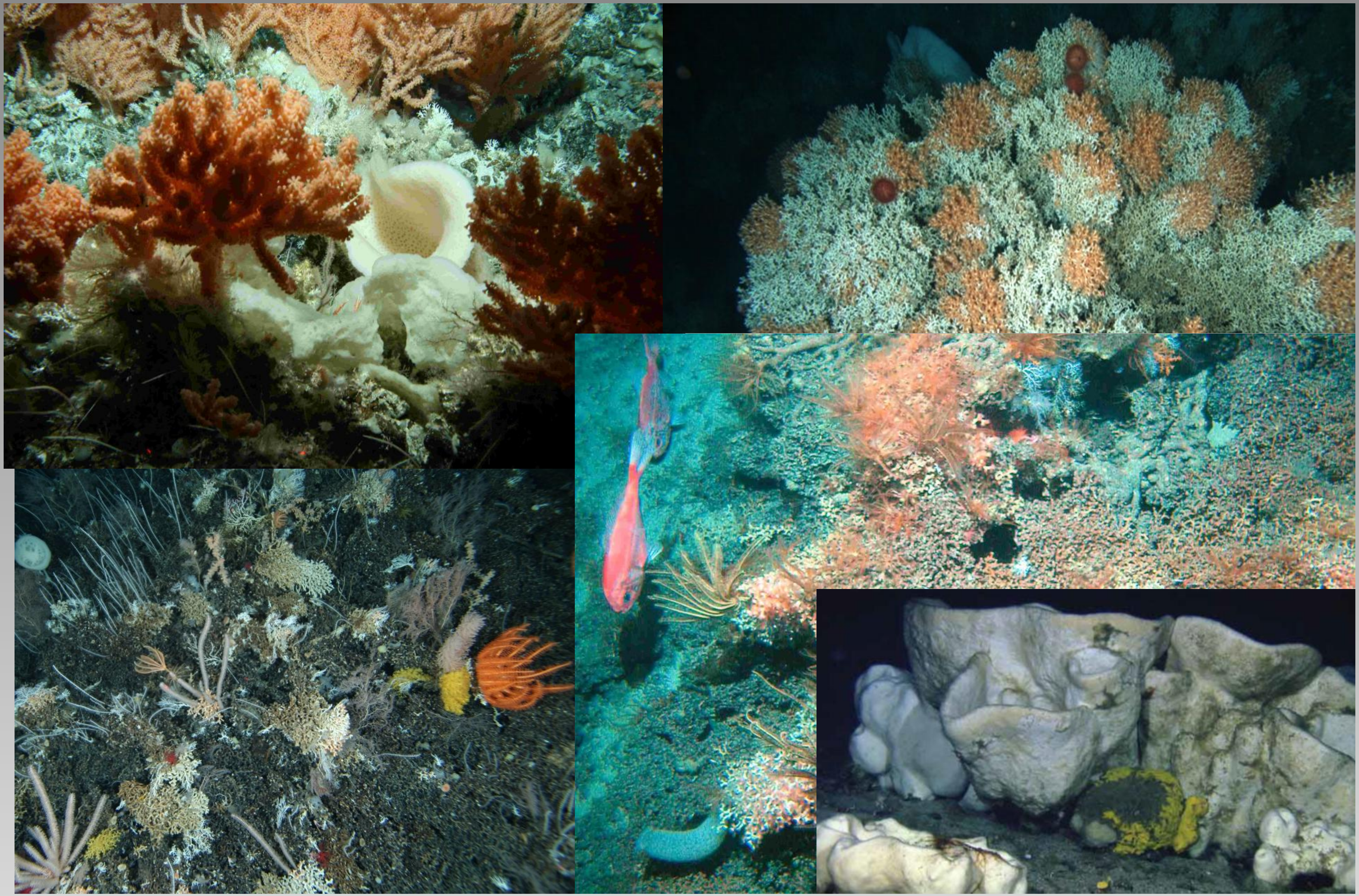
Trawling gear

- Commonly steel bobbin rig or rockhopper trawls
- Hard seafloor on ridges and seamounts is rough
- So the trawl gear itself is very robust, and heavy
- Typically 3-4 t in water on the bottom

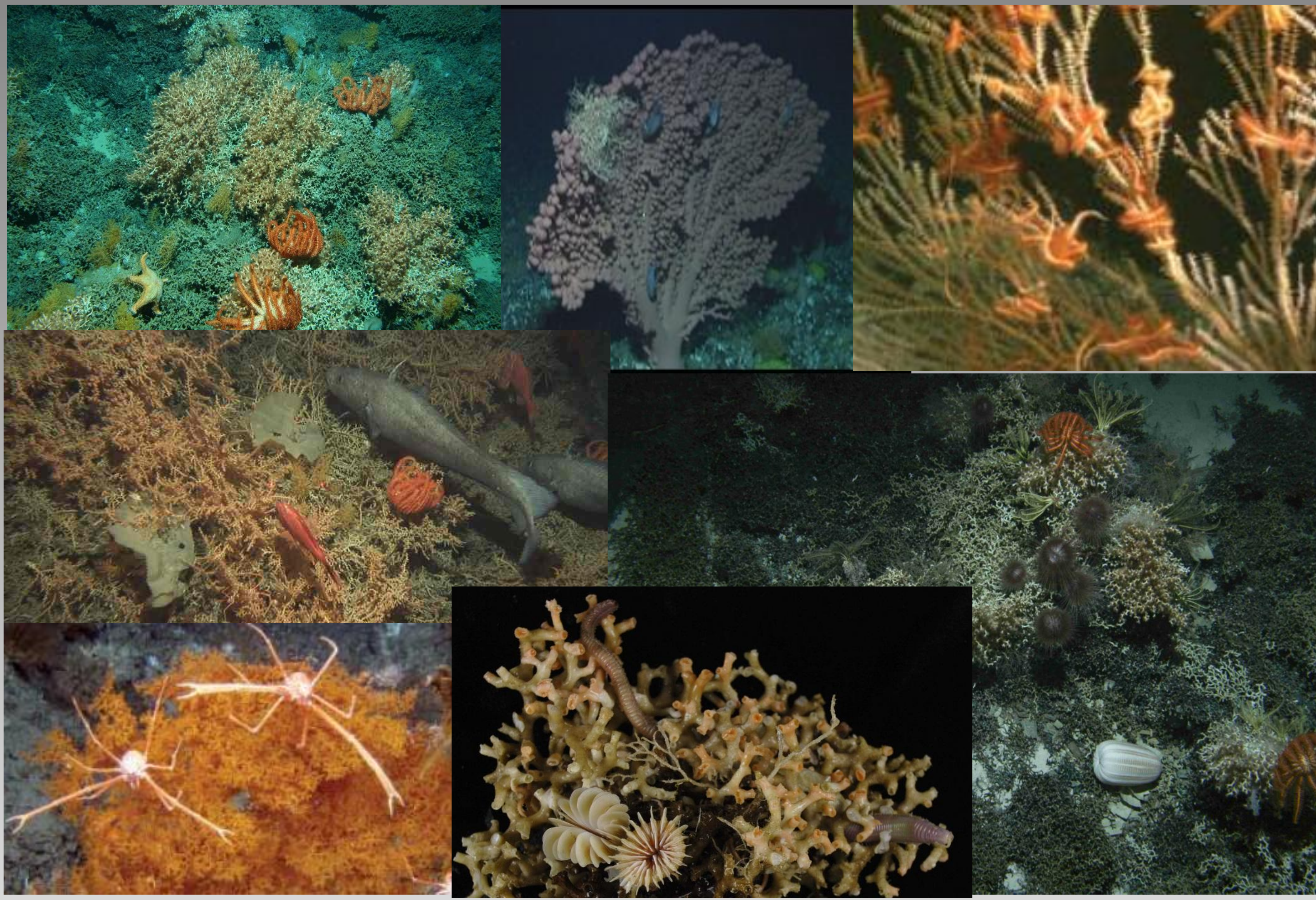
The deep-sea environment

- What is different?
- Minimal surface-driven impact (weather <100m)
- Bathyal depths cold and dark, in general less direct food, lower benthic productivity
- Faunal composition differs
  - Both fish and invertebrate changes, often 500-800m
  - Many high longevity and slow growth rate species
- Highly diverse habitats-most is soft sediment, but much of the fishery effort is focussed on hard substrate habitat
  - Seamounts, ridges, canyons
  - Biogenic habitat-the cold-water coral reefs, sponge gardens, bryozoan beds etc.

Deep-sea coral-sponge habitats

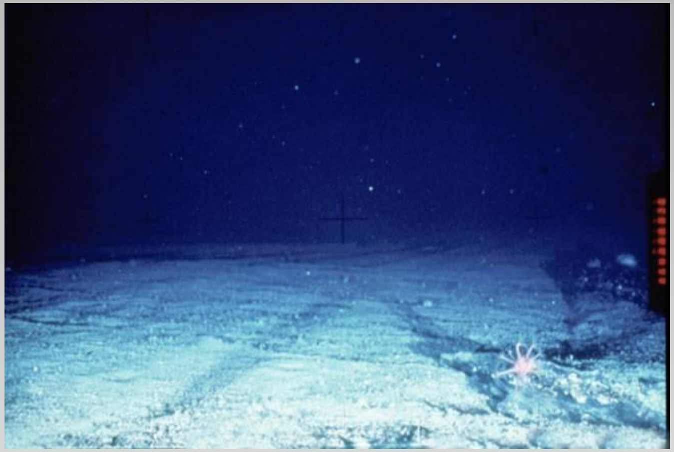


Associated communities



Trawling impact

- Types of impact generally similar to shelf depths (diversity, abundance etc)
- But although similar in nature, the extent may differ because of the concentrations of some taxa on localised hard substrate
- Reductions in the density/biomass of sponges and corals in seamount and bank environments has been well documented



Reduced abundance

- Tasmanian seamounts
  - *Solenosmilia* reefs
  - e.g., Koslow et al. 2001

	Heavily fished (n = 11)	Lightly fished (n = 11)	PA (n = 12)
Biomass (kg)	1.1 ±3.4	7.0 ±5.8	6.1 ±3.8
No. of species	8.7 ±6.3	20.1 ±3.6	22.2 ±4.6

- Gulf of Alaska slope
  - Sponge gardens
  - e.g., Freese et al. 1999

Group	Mean density (no. 100m^{-2}) Trawl	Reference	p
Sessile groups			
Finger sponges	71.4	119.1	0.3125
Anthozoans	5.7	13.2	0.0156*
Morel sponges	0.1	1.1	0.0156*
Vase sponges	1.0	3.7	0.0078*
Motile groups			
Asteroids and ophiuroids	17.1	20.0	0.7422
Holothurians	3.3	3.6	0.3672
Arthropods	2.4	1.3	0.0781
Molluscs	1.6	0.6	0.0547
Echinoids	9.5	18.7	0.0391

- Norwegian slope
  - *Lophelia* reefs
  - e.g., Buhl-Mortenson et al. 2014

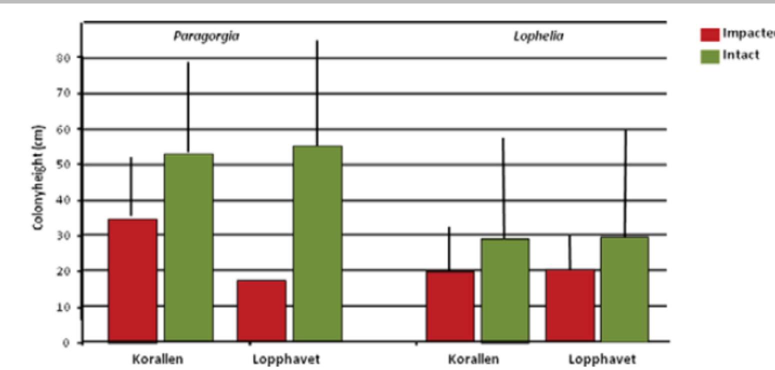
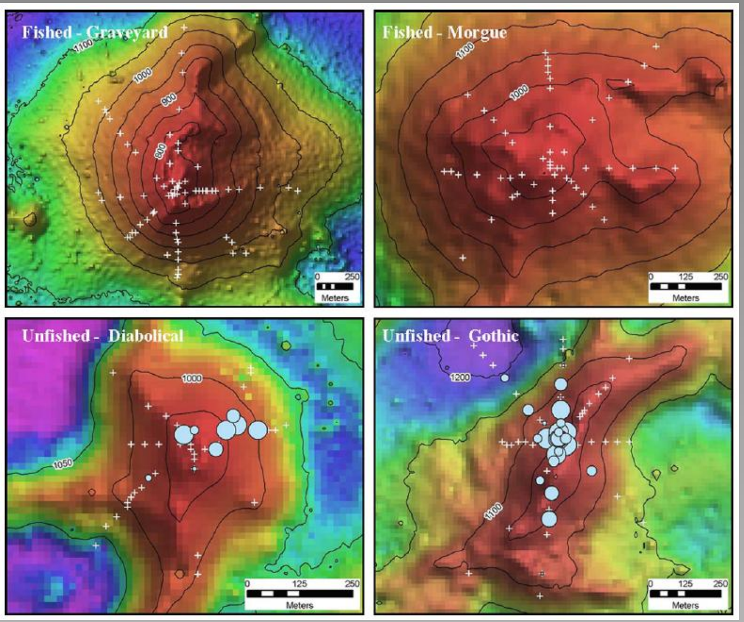


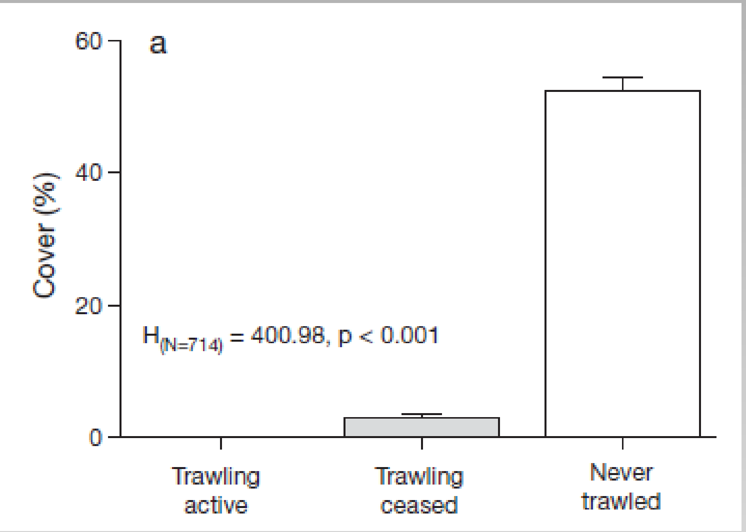
Figure 6.10. Height of coral colonies at affected and intact coral locations at Korallen and Lopphavet. The vertical error bars indicate the standard deviations.

Reduced extent

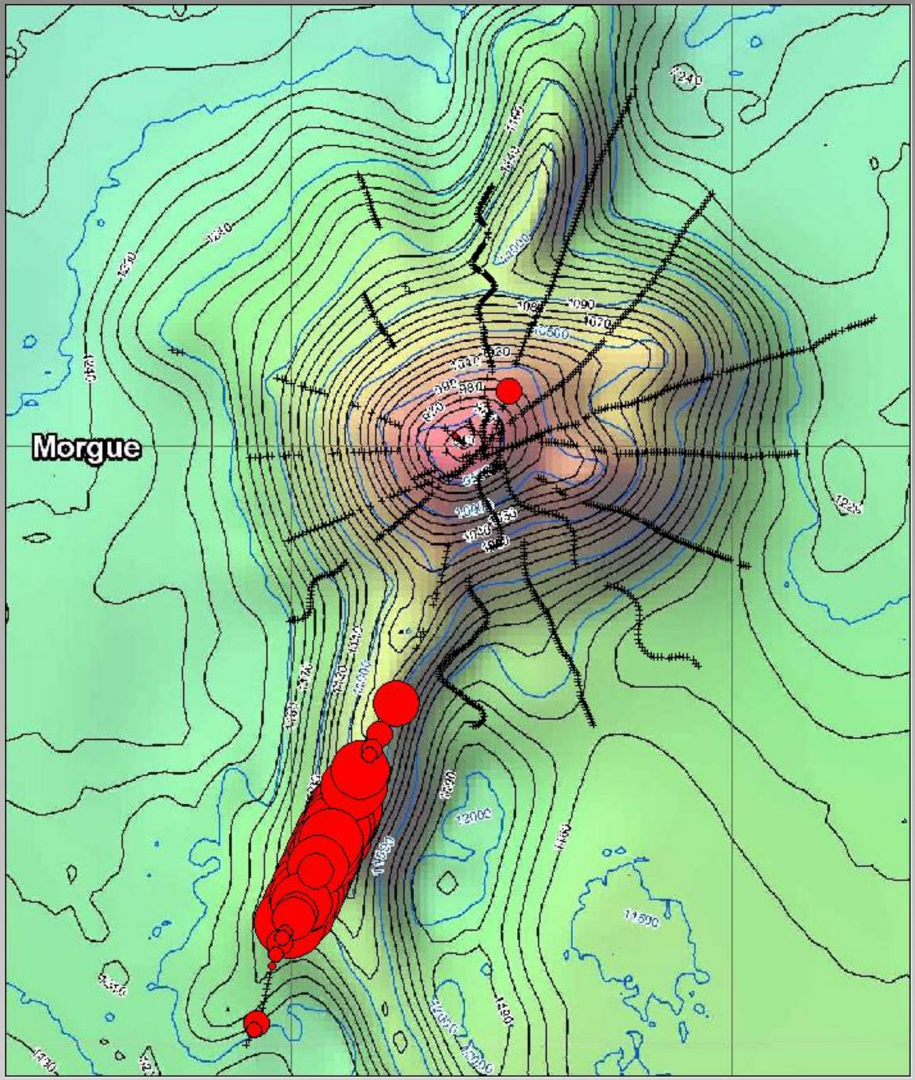
- New Zealand seamounts
  - Cover of *Solenosmilia*
  - e.g., Clark & Rowden 2009

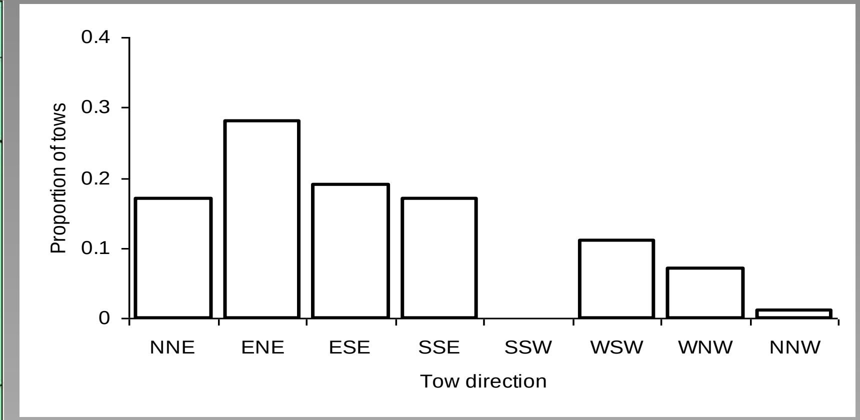


- Tasmanian seamounts
  - e.g., Althaus et al. 2009



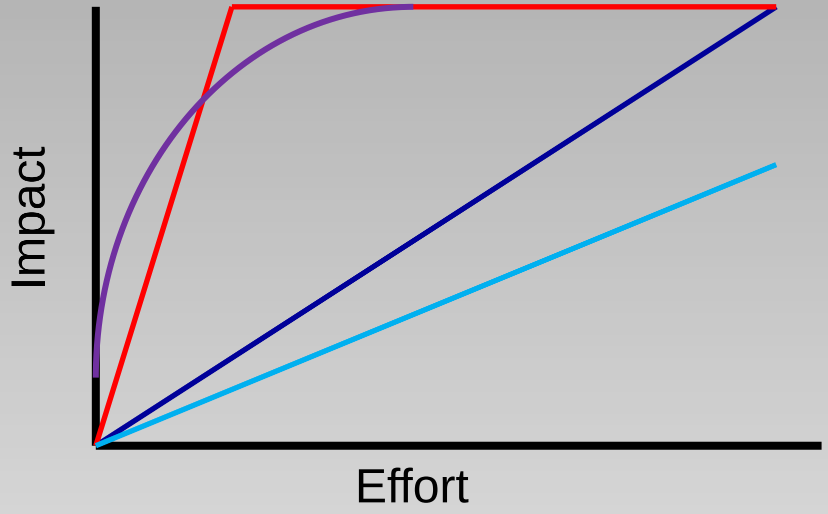
Strong association with trawling





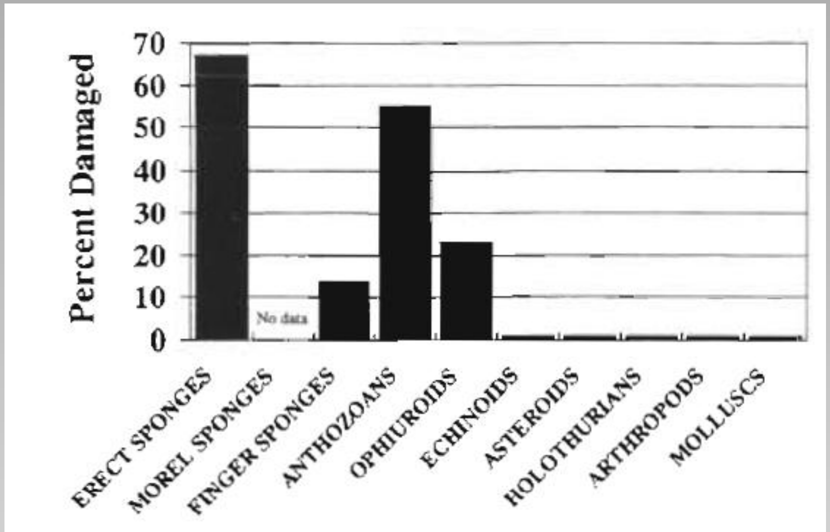
The extent of trawl damage??

- It is logical that heavily fished areas will be heavily impacted
- But damage is a gradient related to fishing effort- again logical that more effort, more damage
- The difficulty is to know the form of the relationship, and its absolute scale…

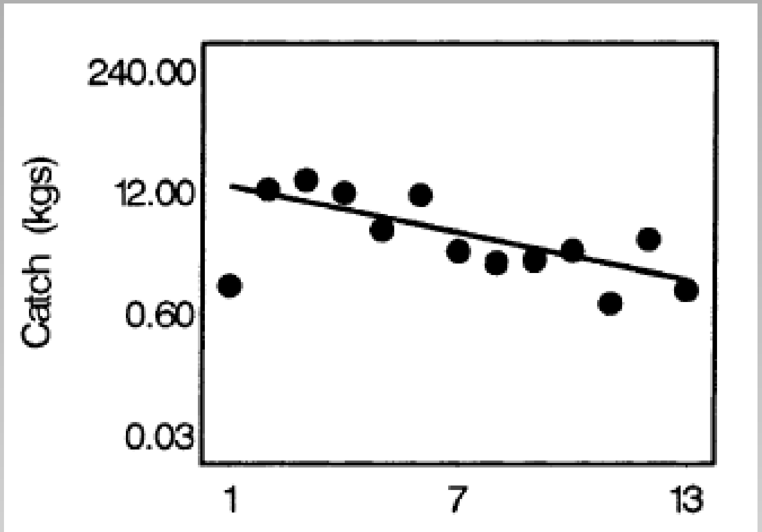


Specific trawl impacts

Location	Depth	Gear	Detail	Taxon	Damage	Reference
USA	20 m	Fish trawl	1 tow	Barrel sponge	32%	Van Dolah et al. 1987
Alaska	200-300m	Fish trawl	8 x 1 trawl	Sponges Gorgonian	67% 55%	Freese et al. 1999
NW Australia	50-200m	Fish trawl	1 trawl	Sponges	90%	Sainsbury et al. 1992
NE Australia	20-35m	Prawn trawl	6 x13 trawls	Sponge Gorgonian	80%	Burridge et al. 2003

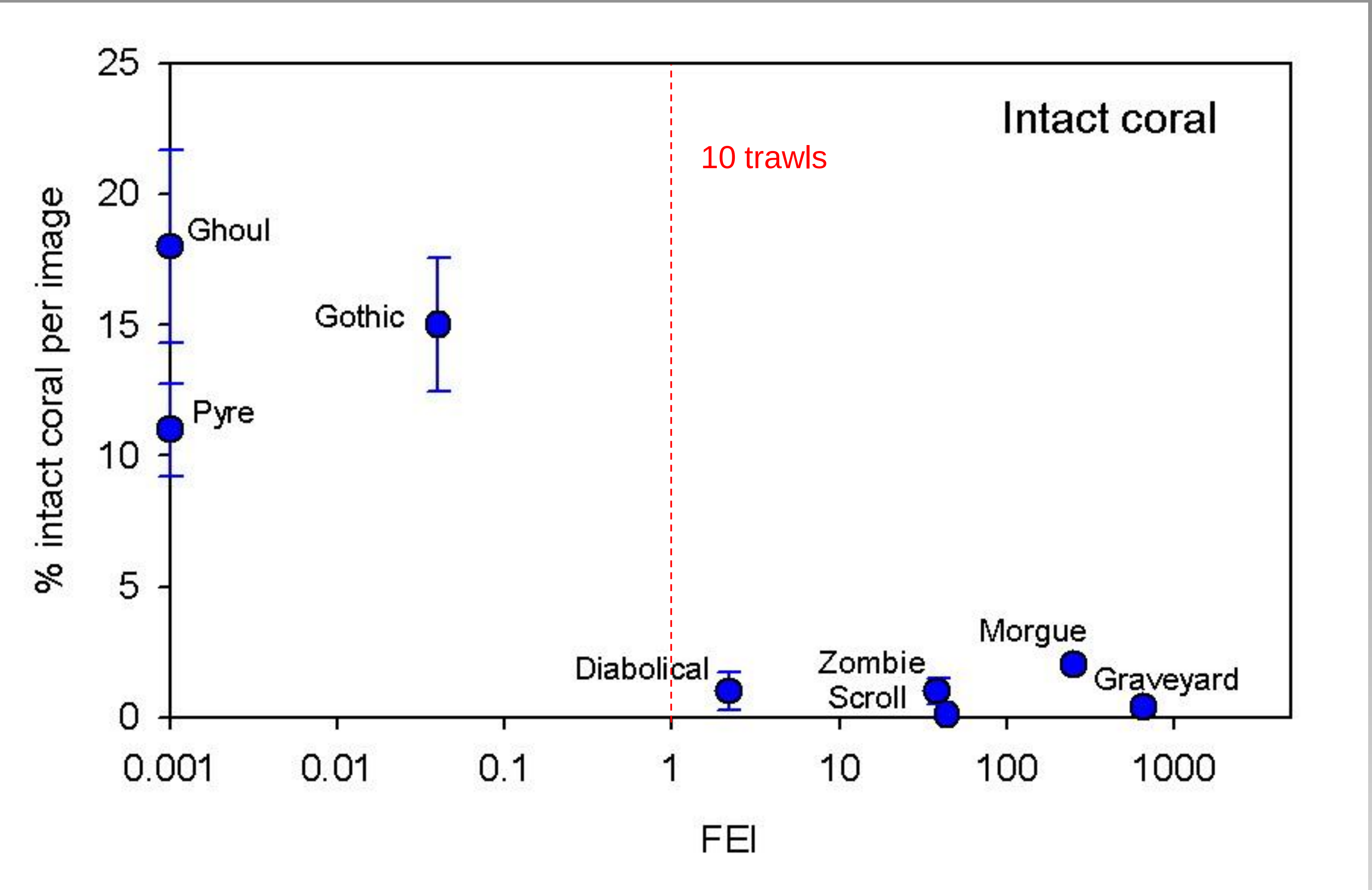


Freese et al. 1999



Burridge et al. 2003

Coral cover versus fishing effort



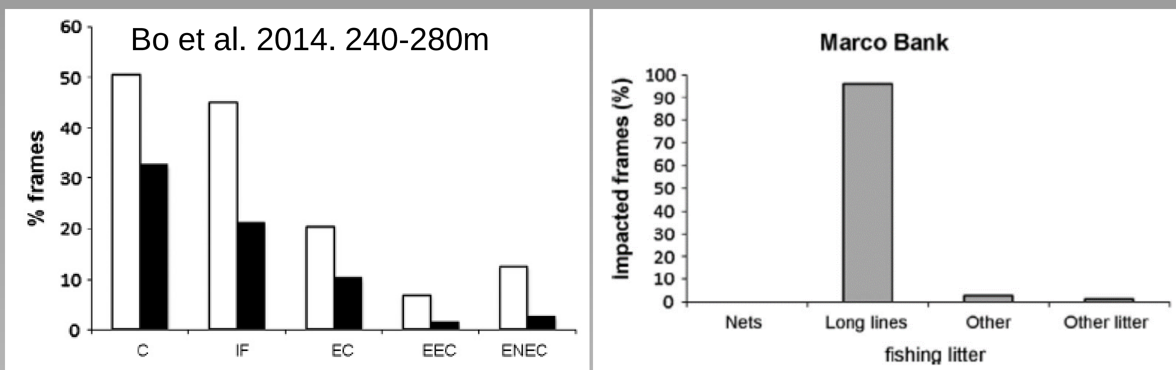
Clark et al.2010

Direct impact video

Longline fishery impacts

- Deep-sea longline fisheries also impact the seafloor
- Impact from bottom weights and lines

Heifetz et al. 2009



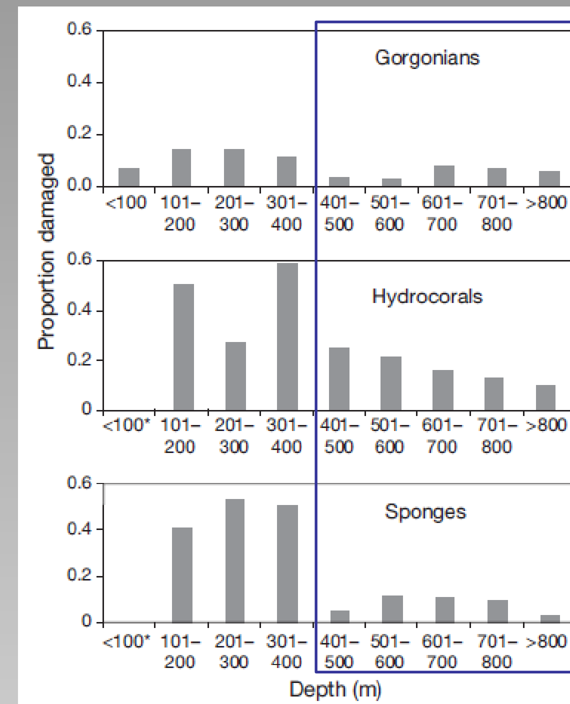
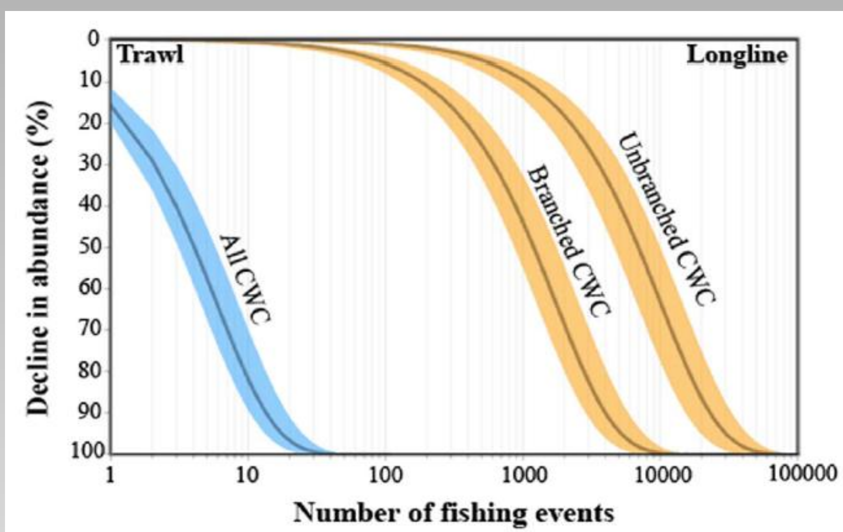


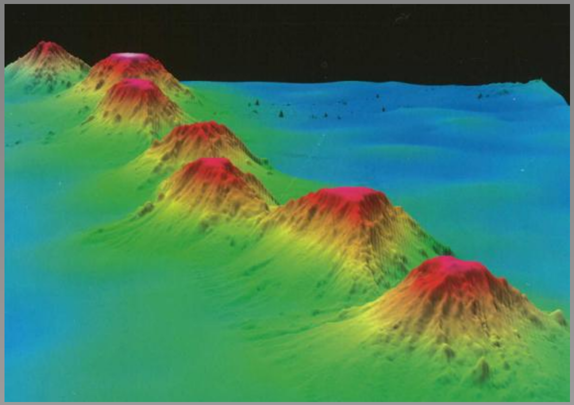
Fig. 3. Proportion of taxa with damage by depth in the central Aleutian Islands. Depths with no data for a particular taxa are denoted by an asterisk



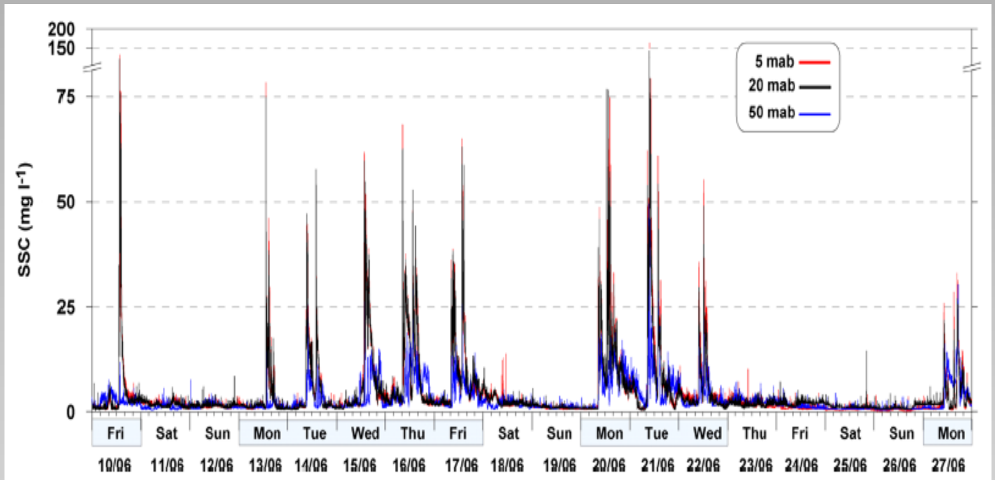
Pham et al. 2014

- **Overall, much less impact than trawls**

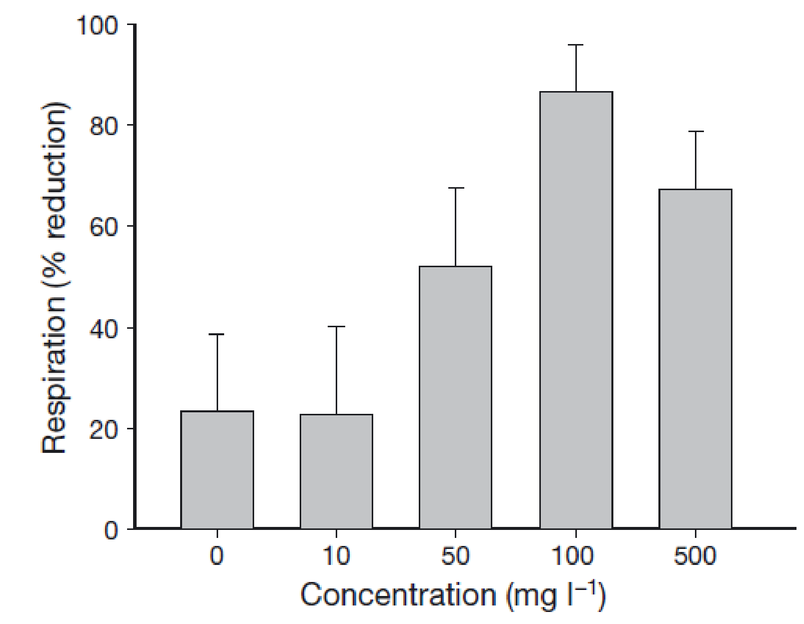
Indirect impacts



- Sedimentation issue
  - Largely slope and canyons
  - But seamounts/guyots also where mixed substrate (extensive areas of soft sediment amongst the hard)



Martin et al. 2014



Tjensvoll et al. 2013

Sediment plume video

Faunal sensitivity

Attribute	Traits	Response to disturbance
Feeding	Scavengers & predators	Positive; Provision of additional food source
	Suspension, deposit, grazers	Neutral; magnitude of positive or negative effects is likely to be dependent on location, disturbance regime and individual traits
Habit	Erect	Negative; Liable to breakage
	All others	Neutral; other habits are encompassed in the analysis by attributes related to living position
Mobility	**Sedentary**	**Strongly negative**; Unable to move away from approaching disturbance
	Limited	Negative; May be able to move away
	High	Neutral; Able to move away from (or bury below) approaching disturbance
Living position	**Sediment surface**	**Strongly negative**; Will be disturbed
	In top 2cm of sediment	Negative or neutral dependent on depth of disturbance;
	Deeper than 2 cm in sediment	Negative or neutral dependent on depth of disturbance;
Fragility	**Very fragile**	**Strongly negative**; Will be damaged/killed if disturbed
	Fragile	Negative; Will be damaged if disturbed
	Robust or not known	Neutral

Hewitt et al. (2011)

Seamount experience

- Some species appear resilient

Taxon	**Ecological traits and observations**
Hydrocorals: *Stylaster* sp. *Calyptopora reticulata, Lepidotheca fascicularis*	Small size (<~100 mm height); Tend to aggregate in rugged areas, under overhangs etc; Ubiquitous in survey areas.
Gold corals: *Chrysogorgia* spp.; Chrysogordidae n. gen.	Small size (<~200 mm height), compact (bottle-brush) shape. Flexible, whip-like, able to bend and recover form.

Clark et al.2010



Recovery potential in the deep sea

- Reviews of fishing impacts including recovery elements by Collie et al.(2000), Kaiser et al (2006), Jones & Schmitz (2009), few deep-sea studies
- Age and growth of many deep-sea benthic invertebrates suggests long recovery times
- Several seamount studies have tried to address this…

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Contribution to the Theme Section 'Conservation and management of deep-sea corals and coral reefs'

OPEN ACCESS

Impacts of bottom trawling on deep-coral ecosystems of seamounts are long-lasting

F. Althaus[1], A. Williams[1,*], T. A. Schlacher[2], R. J. Kloser[1], M. A. Green[1], B. A. Barker[1], N. J. Bax[1], P. Brodie[1], M. A. Schlacher-Hoenlinger[2,3]

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ORIGINAL ARTICLE

Seamount megabenthic assemblages fail to recover from trawling impacts

Alan Williams[1], Thomas A. Schlacher[2], Ashley A. Rowden[3], Franziska Althaus[1], Malcolm R. Clark[3], David A. Bowden[3], Robert Stewart[3], Nicholas J. Bax[1], Mireille Consalvey[3] & Rudy J. Kloser[1]

1 CSIRO Wealth from Oceans Flagship, Marine Laboratories, Hobart, Tasmania, Australia
2 Faculty of Science, Health & Education, University of the Sunshine Coast, Maroochydore DC, Queensland, Australia
3 National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand

Age and growth of deep-sea taxa

Faunal group	**Age/ growth**	**Method**	**Author**
Glass sponge	440 yo	Ring count	in Samadi et al. 2007
Stalked crinoid	340 yo	^{14}C dating	in Samadi et al. 2007
Gorgonian corals	67-2377 yo	^{14}C dating	Roark et al. 2006
Bamboo corals	35-197 yo	^{14}C and ^{120}Pb dating	in Rogers et al. 2007
Biogenic habitat (accumulated)	1,000-50,000 yo	U/Th dating	in Rogers et al. 2007
Black coral (Leiopathes)	2320 yo	^{14}C dating	Careiro-Silva et al. 2013
Black coral (Leiopathes)	4000 yo	^{14}C dating	Roark et al. 2009
Zoanthid (Gerardia)	2700 yo	^{14}C dating	Roark et al. 2009
Black coral (Antipathes)	140 yo	^{14}C dating	Love et al. 2007
Bamboo corals (Lepidisis)	50 yo	^{210}Pb dating	Tracey et al. 2007
Stony corals (Solenosmilia)	120 yo (47,000)	^{14}C dating	Fallon et al. (2014)
Stony corals (Lophelia)	Various (9,000)		Hovland & Mortenson (1999)
Lophelia	1-35 mm/year(most <20)	Various	Various

Recovery criteria

Biological attribute	Rationale	Score 1	Score 0.5	Score 0
Generation time	Higher turnover enhances contribution to increased abundance	Short (years)	Intermediate	Long (>decades)
Larval output	Higher output increases the number of potential recruits available to the impacted area	Relatively high	Intermediate	Relatively low
Dispersal capability	Greater dispersal increases the likelihood of recruitment success	Broadcast spawner; long lived larvae. Dispersal is distant or wide.	Intermediate	Brooders; in situ egg laying; short-lived larvae. Dispersal is local or narrow.
Mobility	Higher mobility increases the ability to emigrate into impacted area	Mobile over distances of 100s m to km	Sedentary, or mobile over relatively short distances	Attached or sessile

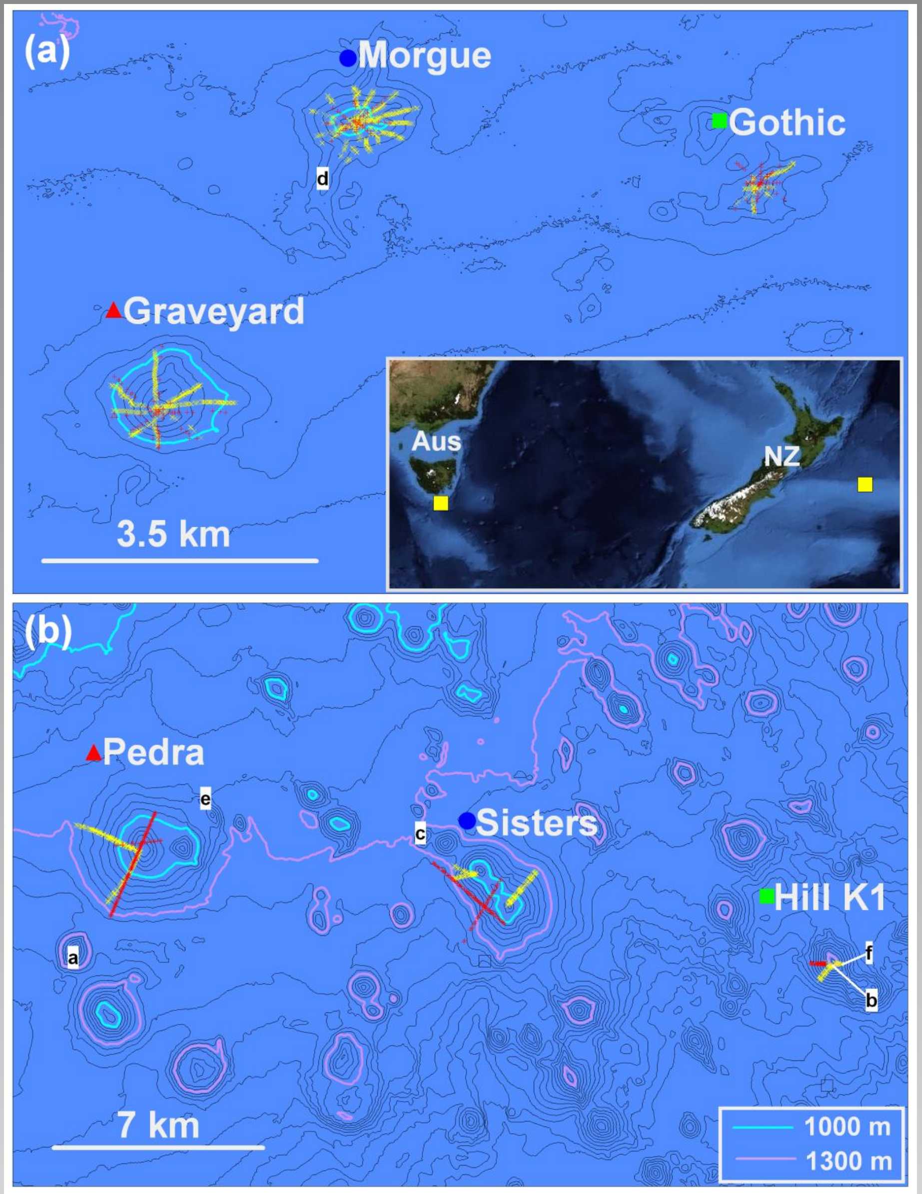
Williams et al. 2010

Relative recovery potential

Taxon	Score category	Score	Generation time	Larval output	Dispersal capability	Mobility	Confidence score
Crinoids (not stalked)	Low	1.5	0	0.5	0.5	0.5	2
Antipatharians	Low	1.5	0	1	0.5	0	2
Brisingids	Low	1.5	0	0.5	0.5	0.5	3
Paragorgia spp	Medium	2	0	1	1	0	2
Porifera	Medium	2	0.5	1	0.5	0	2
Solenosmilia variabilis	Medium	2	0	1	1	0	3
Echinoids	High	3	0.5	1	1	0.5	2
Stylasterids	High	2.5	1	0.5	1	0	2
Galatheids	High	2.5	0.5	0.5	1	0.5	2

Williams et al.2010

Compare & contrast studies



- In the deep, little opportunity for experimental manipulation, and always limited replication.
- Small seamount clusters off New Zealand and Australia gave an opportunity for treatment comparison
- Depths 800-1000m
- Fished (bottom trawling for orange roughy), unfished, and previously fished, closed for 5-10 years
- Photographic surveys done, quantifiable still images of benthic invertebrate fauna.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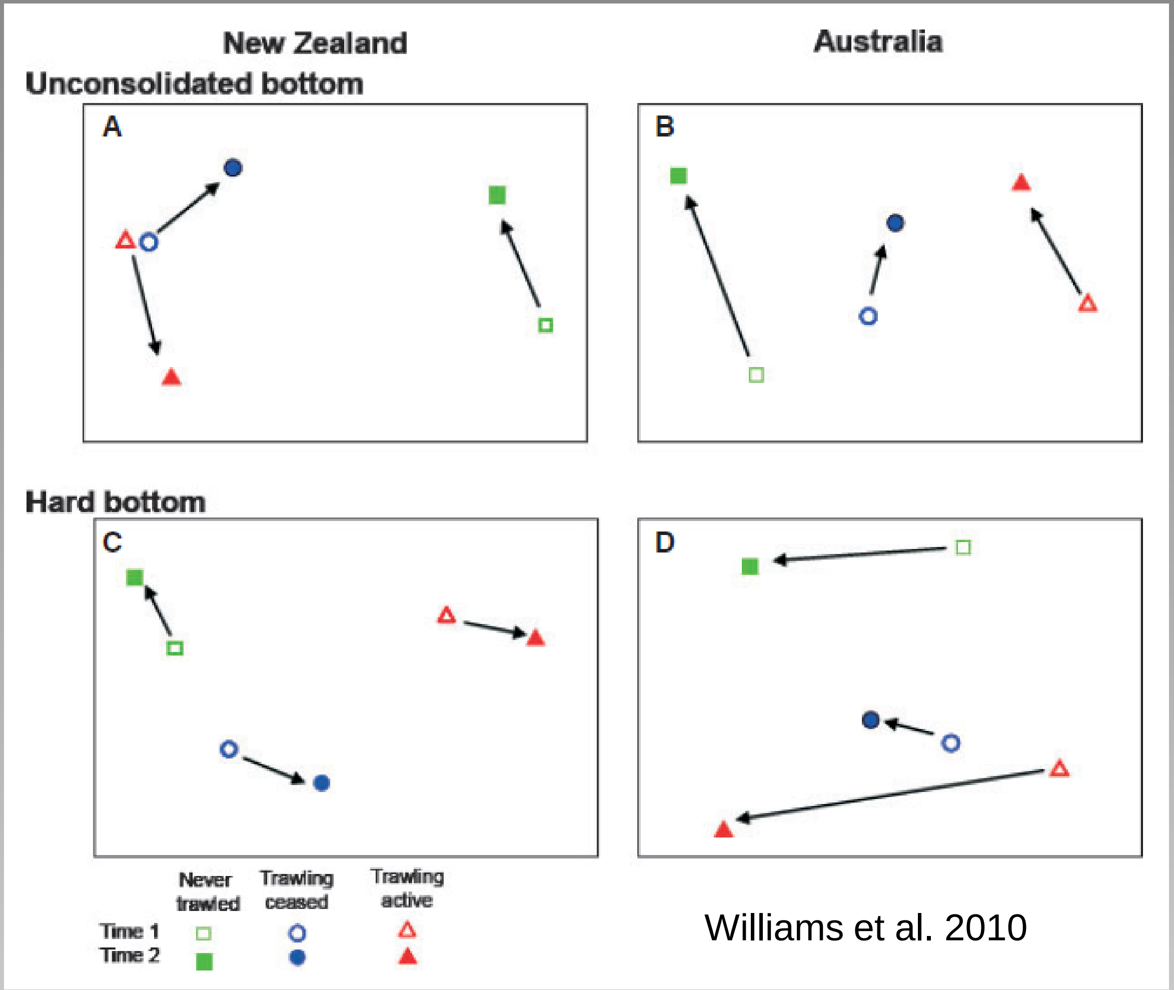
What changes do we expect

- **Never fished**
  - Climax communities (typically cold-water coral reef structures, coral and sponge dominants)
  - Little variability over time
- **Fishing continues**
  - Depends upon the state of modification
  - Reduction in large habitat-forming species (or few left)
  - Ongoing changes in species abundance and community composition (or stable with different species/densities)
- **Fishing stops**
  - Increase in “weedy” species-the fast colonisers and growing species
  - Over time, shift towards the stable unfished state
  - Changes will be slow

ANZ combination

New Zealand
5 years (2001-2006)

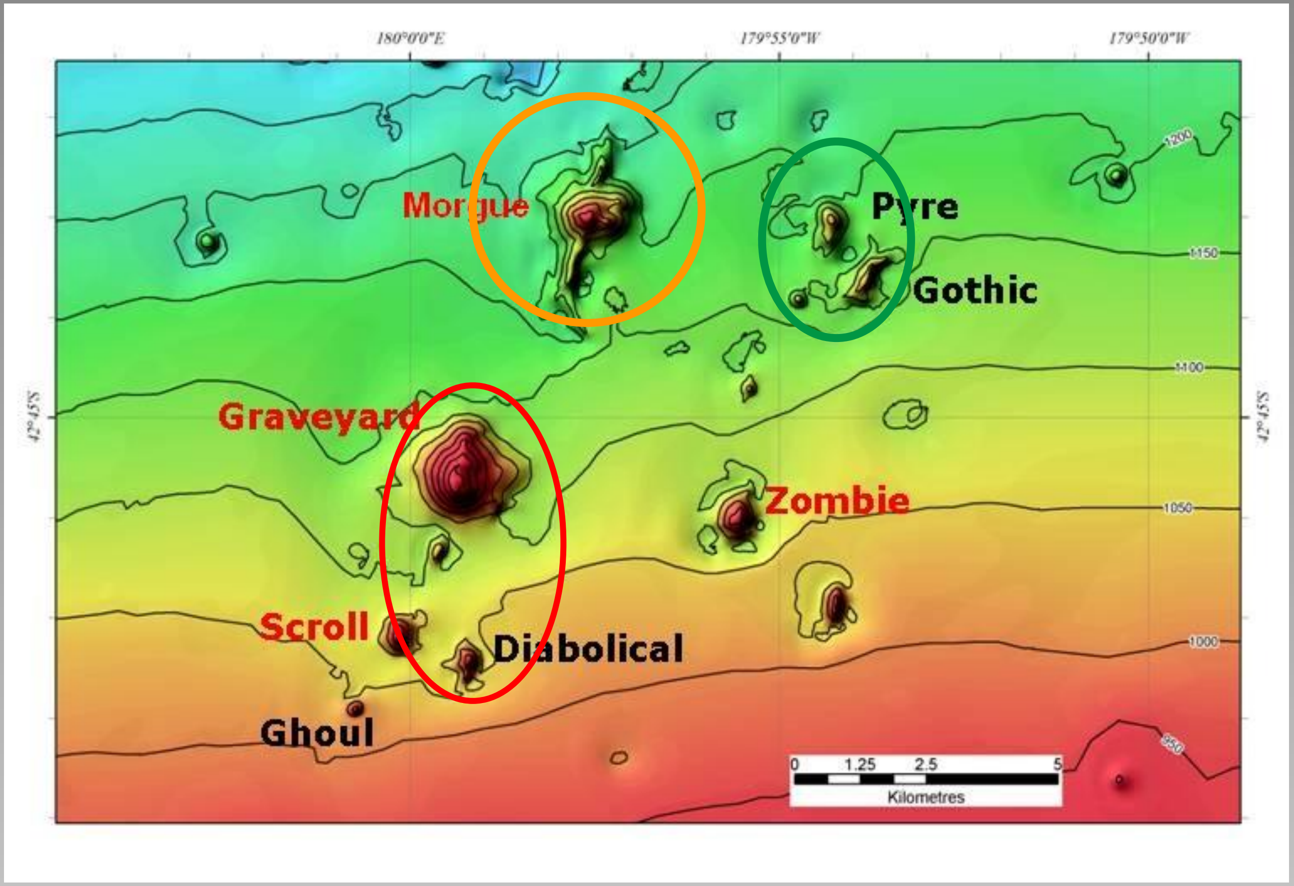
Australia
10 years (1997-2006)



NMDS ordinations of group centroids from redundancy analysis examining temporal and spatial patterns in community composition

No clear signal of community change over time consistent with recovery

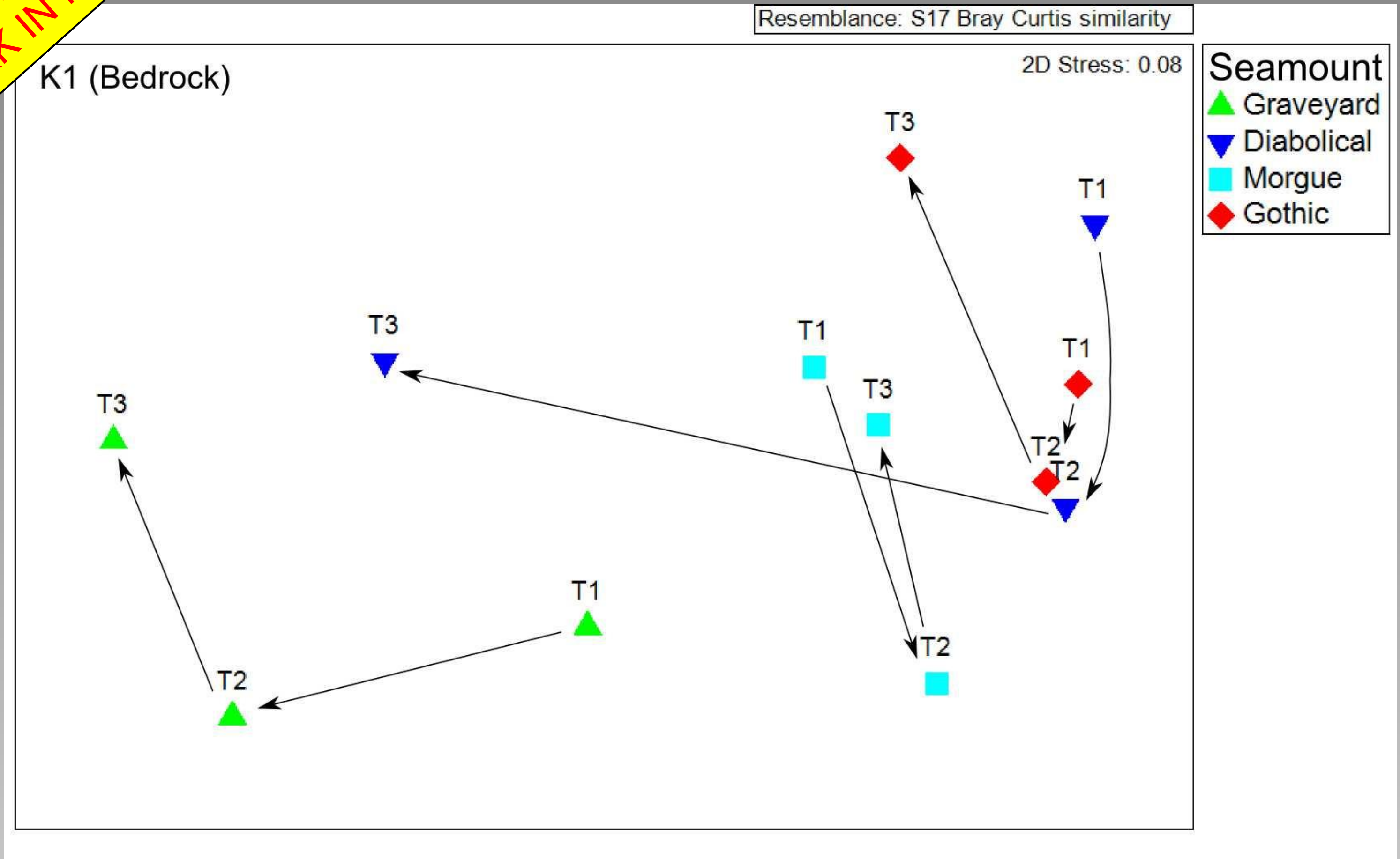
New Zealand seamounts



Fished (red) and unfished (black) seamounts, plus fishing gradient
In 2001 Morgue, Pyre & Gothic were protected
Time series of surveys: 2001
2006
2009 (planned survey in 2015)

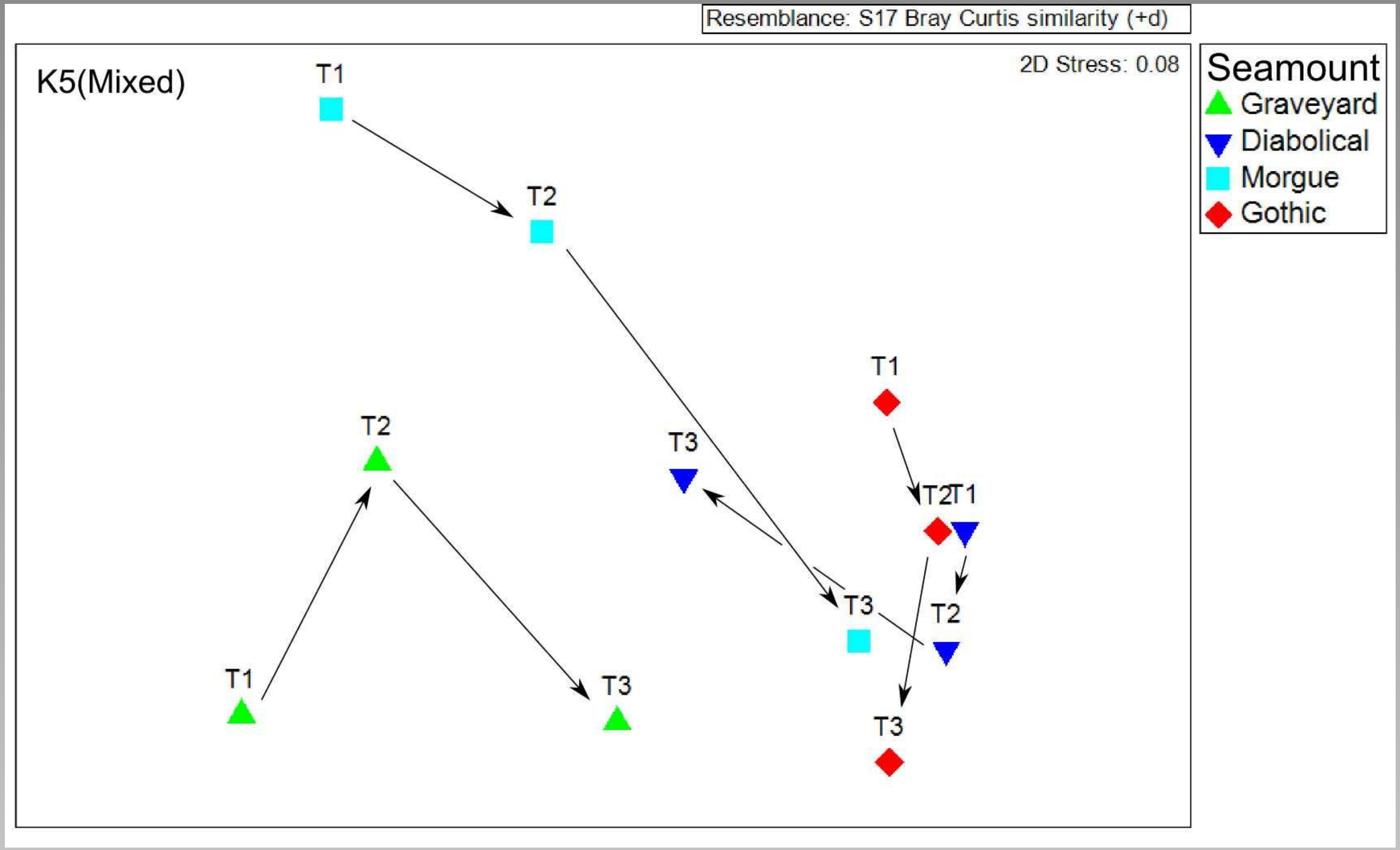
MDS plot 1-bedrock

Caution:
WORK IN PROGRESS



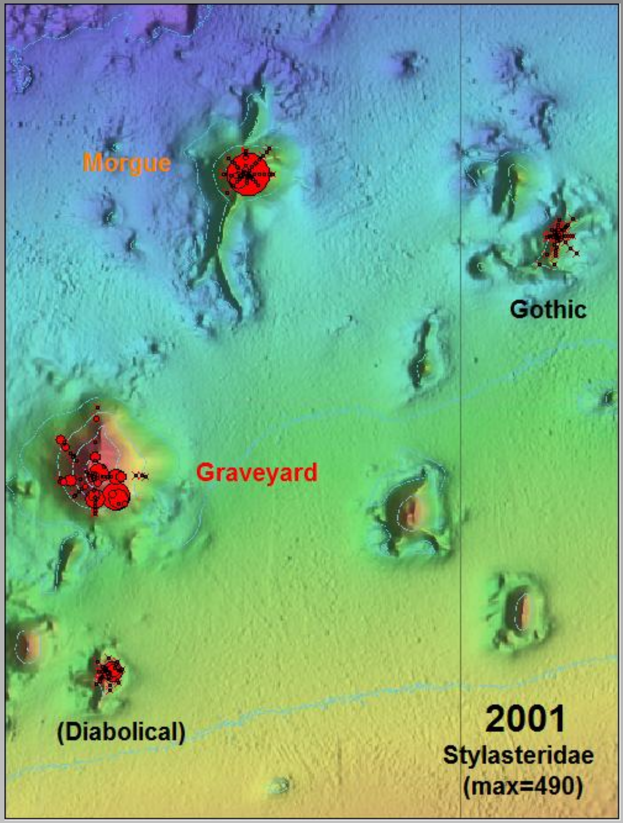
- GOTHIC similar “location” on RHS, GRAVEYARD also similar on LHS
- MORGUE is fairly consistent, in middle area but tending to RHS
- DIABOLICAL similar T1-T2, then large shift towards Graveyard

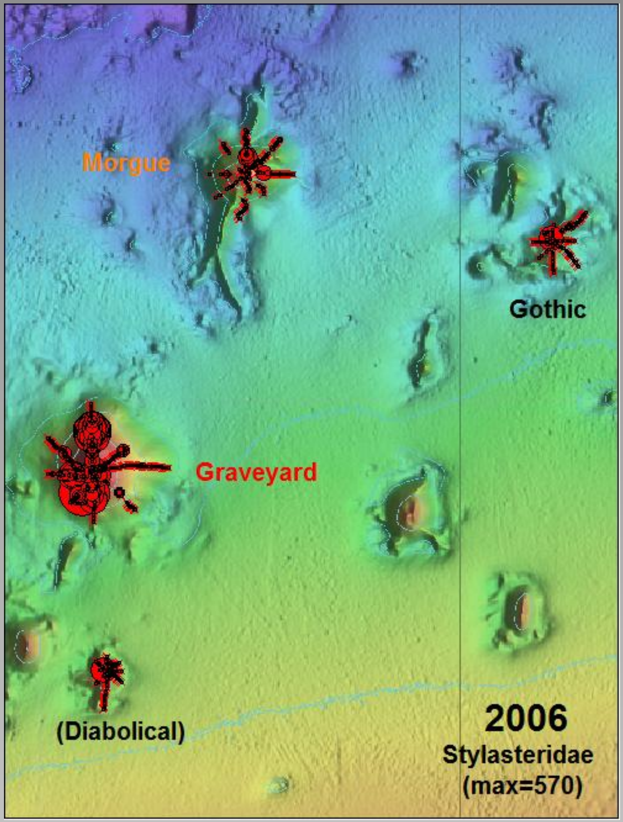
MDS plot 2: mixed substrate

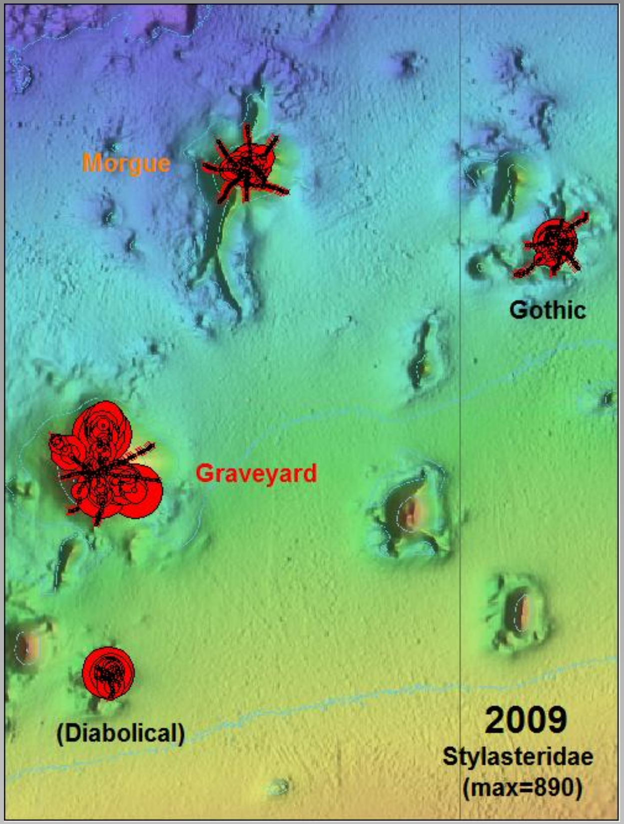


- GOTHIC, similar between surveys, on RHS
- GRAVEYARD similar between periods, on LHS but some variability
- MORGUE shows consistent trend towards Gothic space
- DIABOLICAL similar to Gothic in T1 and T2, shift towards Graveyard T3.

Temporal changes: Stylasteridae







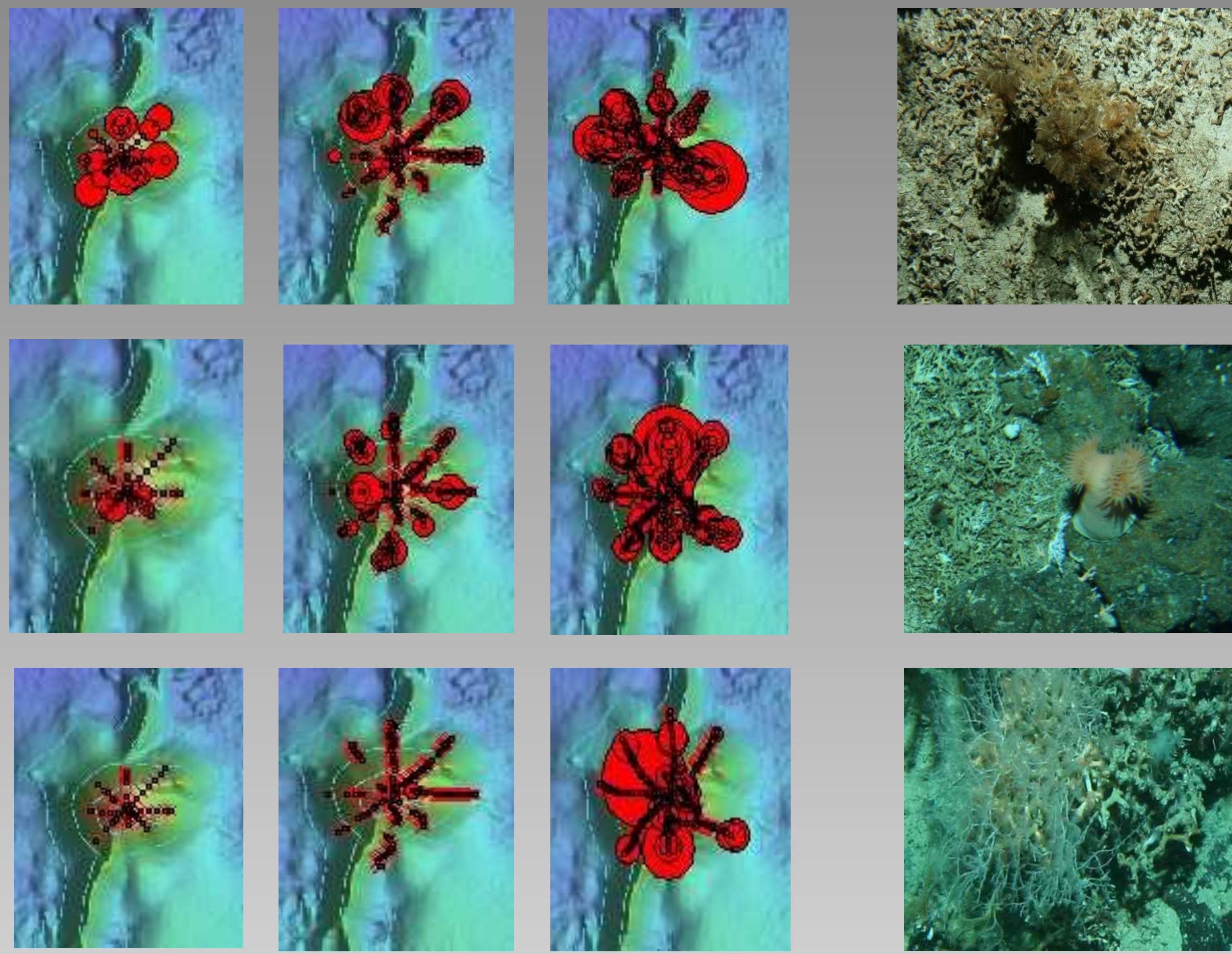
Hydrocorals
General increase in frequency and abundance on all seamounts, strong on Graveyard and Morgue

Morgue: temporal changes

Crinoids

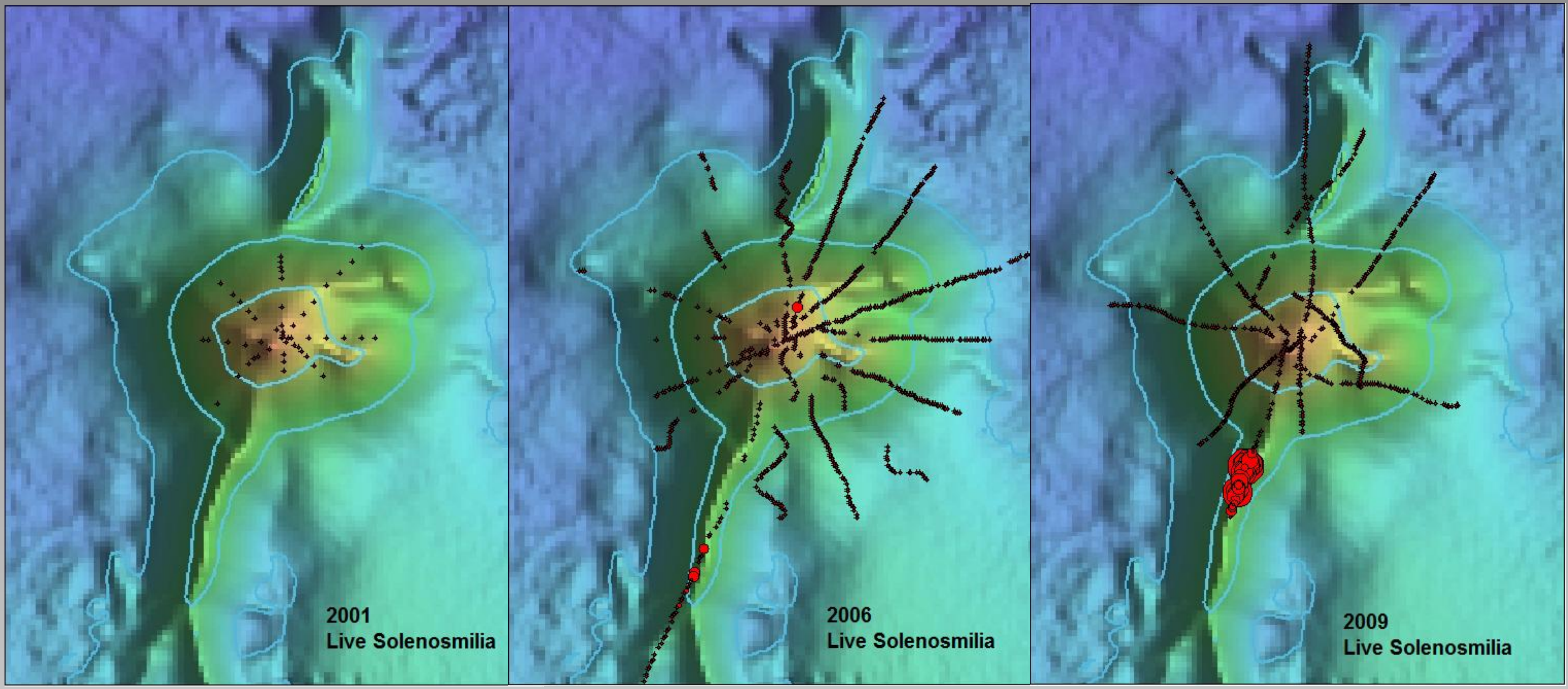
Anemones

Hydroids



2001 **2006** **2009**

And what about the corals?



MORGUE:
No indication of any quantity of live *Solenosmilia variabilis* except on the unfished SSW ridge (and tricky to survey)

Management implications

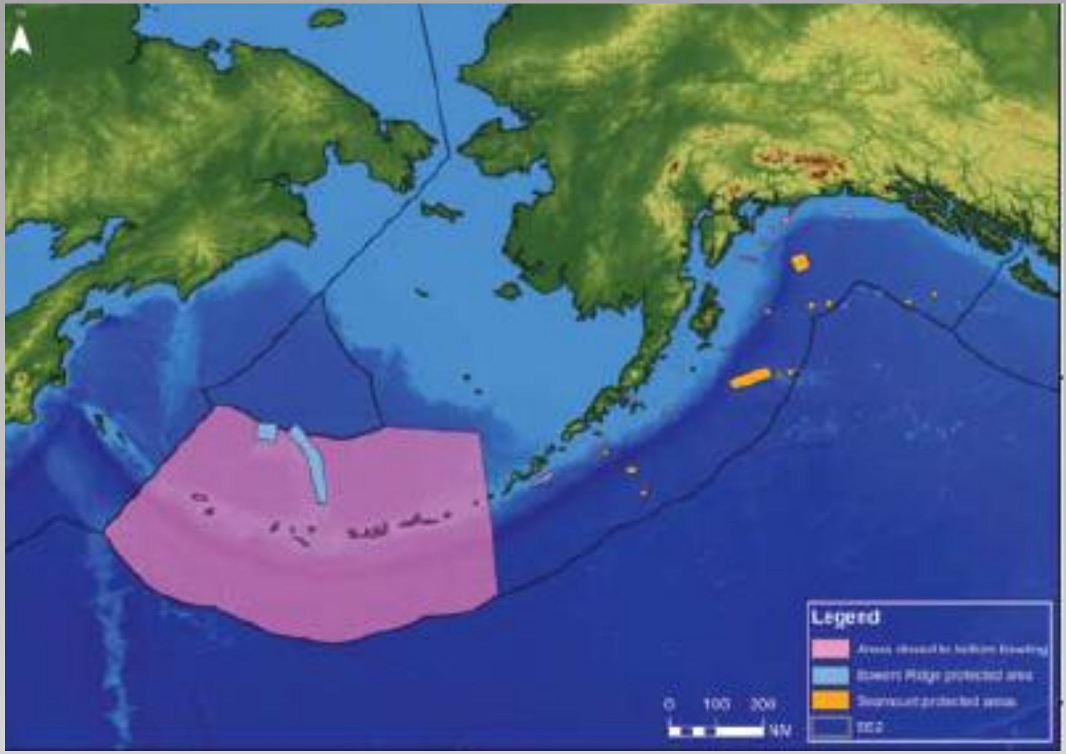
- Fishing impacts on deep-sea megabenthos can be severe, and occur with relatively low levels of effort.
- Reducing fishing effort will reduce impact, but the damage is rapid and substantial on hard-bottom communities
- Productivity of benthic species is wide-ranging, but many species are often long-lived and slow-growing. This affects recovery dynamics
- Changes in deep seamount benthic communities following impact can occur within years, and with some taxa are consistent with expectations of responses to fishing/closure
- No evidence of “Recovery” of stony corals. This is likely to be very slow-decadal time scales, possibly 100s years, if it can occur at all.

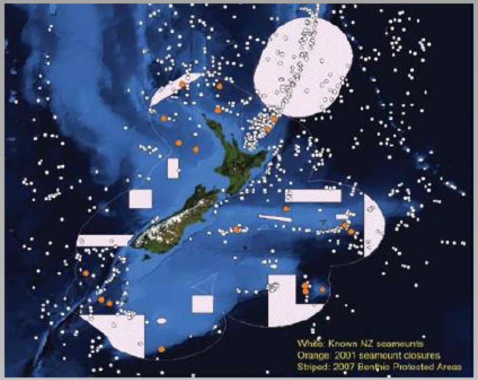
Management implications (2)

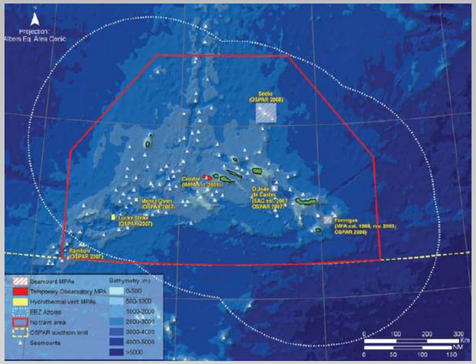
- Restoration in most deep-sea habitats is not a realistic "remedy" management option following heavy fishing.
  - Either unachievable in a reasonable time frame, or be very expensive (van Dover et al. 2013)
- Closures can be effective, but they need to occur BEFORE fishing
- Spatial management, a network of open and closed areas, is the most appropriate option
  - Complete closure of large areas or features that will include unfished and fished
  - Freezing the "footprint" and zoning areas
  - Consider also multiple uses (e.g., DSM) and ocean acidification (really important for cold-water corals)

Spatial management options

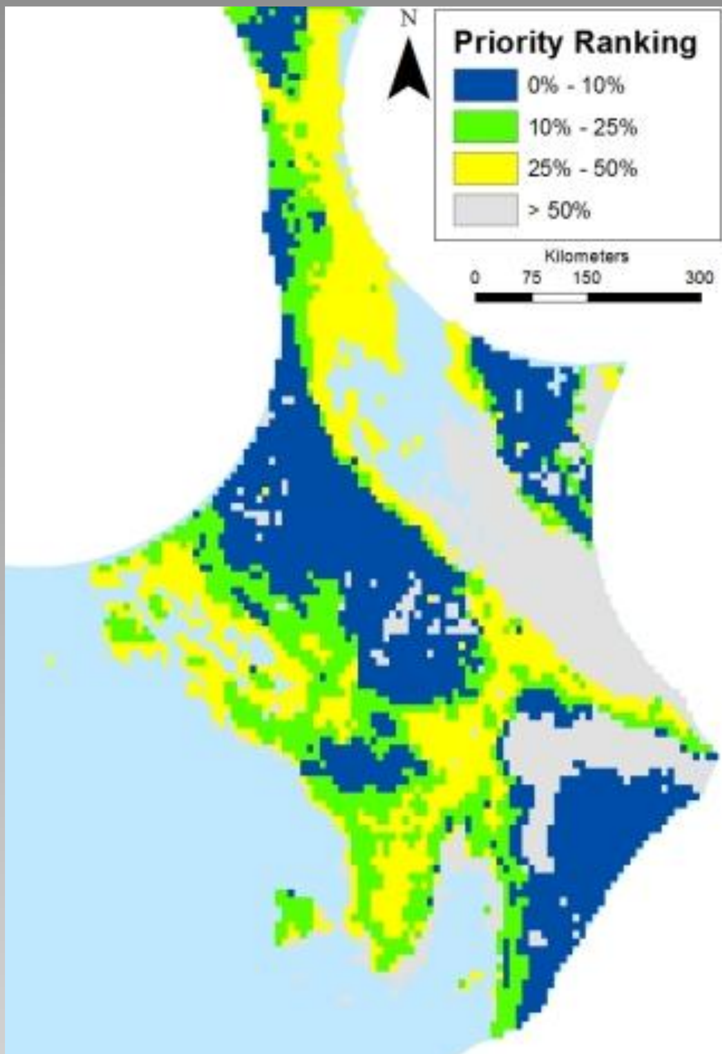
- Growing array of protection measures in the deep sea.
- Fishery closures, Benthic Protection Areas, offshore MPAs, habitats of conservation importance, Essential Fish Habitats
- CBD Ecological or Biologically Significant Areas (EBSAs)
- VMEs and associated move-on rules under UNGA



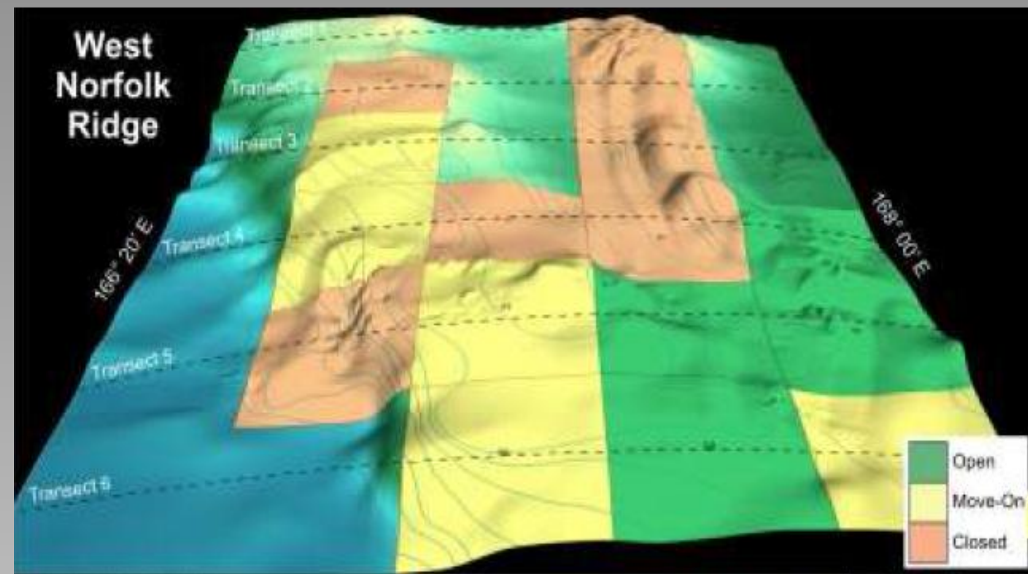




Spatial management options (2)



SPRFMO New Zealand fishing limitations



Status	Closed	Move-on	Open
No. tows	0	1-9	>9

"Zonation" spatial planning software run using distribution of VME taxa, fishing expense, aggregation rule and biogeography variables.

"I don't know why I don't care about the bottom of the ocean, but I don't."

New Yorker 1983

- Hopefully things have changed since the early 1980s….
- Science in the deep sea will always be a challenge, with limitations of money, equipment, survey design, getting enough quality data.
- But combining observations with the greater understanding of shallow system dynamics, there are ways forward that can balance exploitation and conservation

Tusen takk

Acknowledgements

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