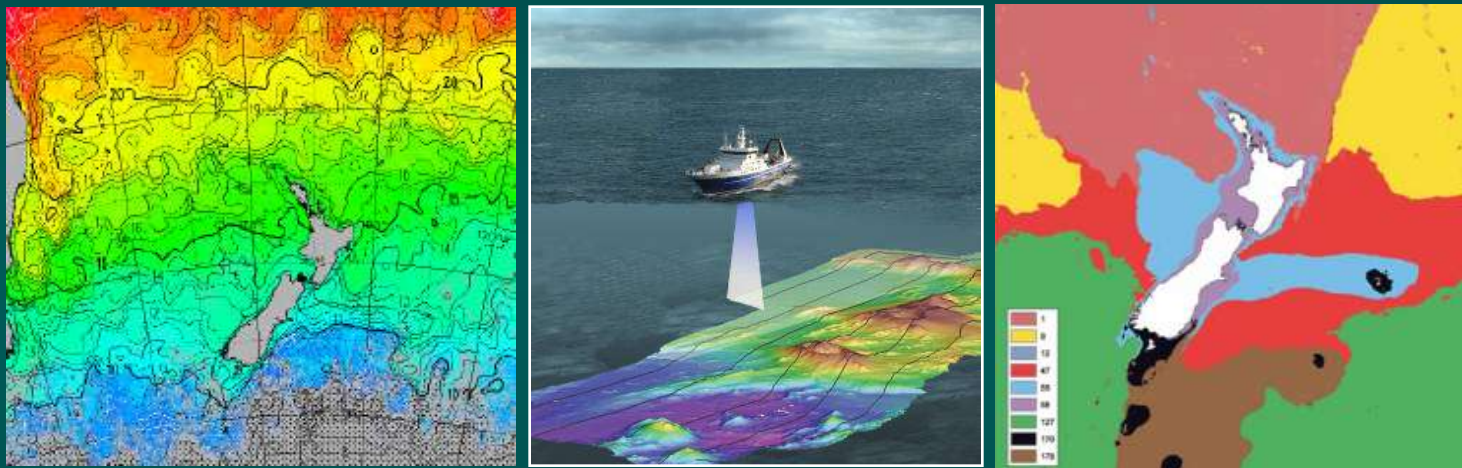


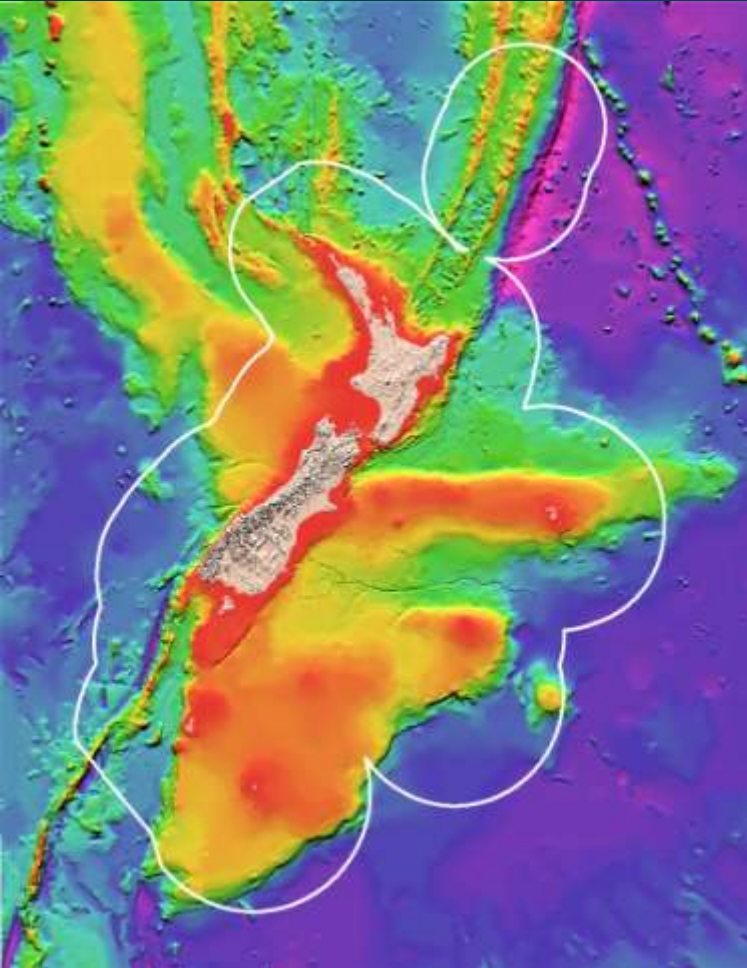
Broad scale biodiversity mapping and environmental classification of the deep-sea around New Zealand



David Bowden, Scott Nodder, John Leathwick,
Judi Hewitt, Ashley Rowden, Geoffroy Lamarche

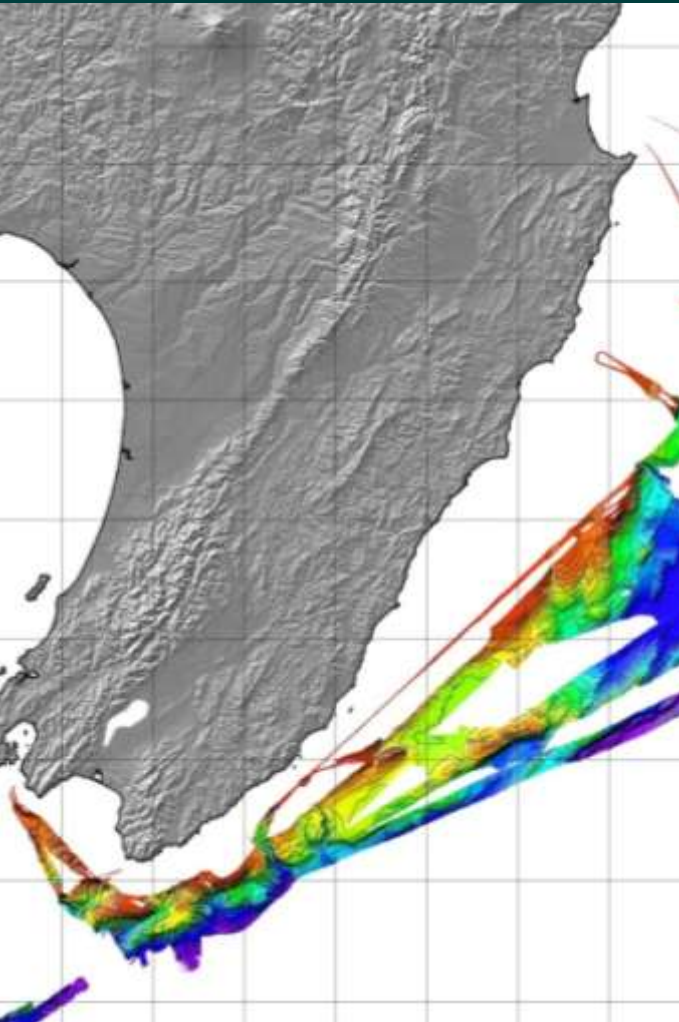
National Institute of Water & Atmospheric Research,
New Zealand

New Zealand's EEZ



- **Large**
 - UNCLOS continental shelf extension (CSE) pending
 - 4th largest (1.7 million km²)
- **Diverse**
 - subtropics to Southern Ocean (28-56° S)
 - shelf to hadal depths (Kermadec trench >10,000 m)
 - sediment plains, seamounts, canyons, cold water coral reefs, hydrothermal vents, cold seeps, volcanoes, subduction, faulting ...
- **Commercially important**
 - fisheries
 - Minerals
 - Oil and gas

Mapping

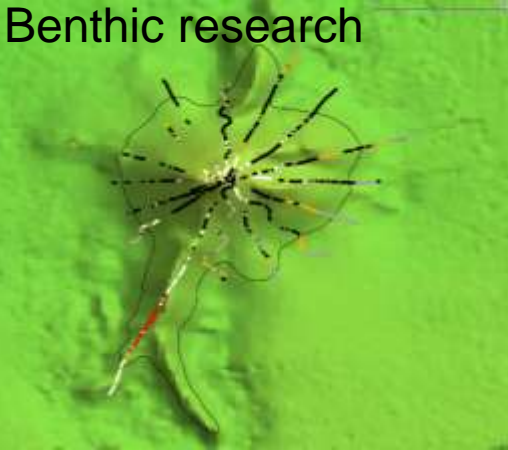
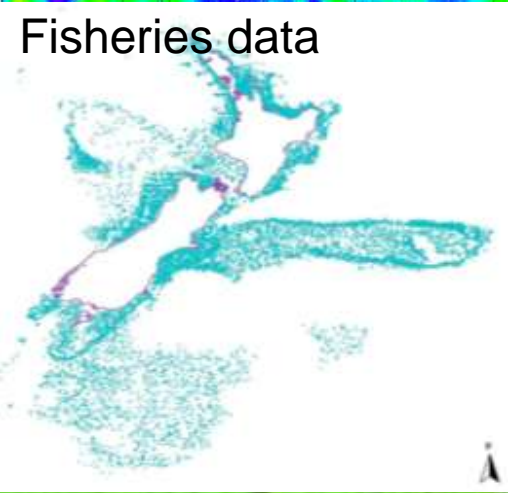
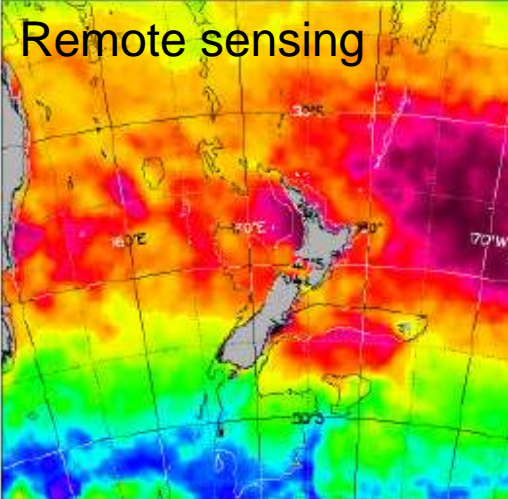


Large scale mapping needed to assess & manage:

- **Mineral (non-living) resources**
 - gas, oil, manganese, metal sulphides, gas hydrates ...
- **Biological resources (commercial)**
 - shelf and deepwater fisheries, demersal and pelagic, significant fraction of GDP
- **Biodiversity**
 - relatively unknown fauna
 - internationally agreed requirement to assess and maintain levels of marine biodiversity
- **Mapping at these scales is impracticable using ship-based methods (huge resources and time required)**
- **Needs a larger scale solution**

Questions

1. **What data are available?**
 - Without major investment in new surveys, what do we already know about the EEZ/CSE?
2. **Can we use these data to generate ecologically meaningful maps of the seabed across the EEZ?**
 - Are existing data sufficient to discriminate between biologically significant habitats/regions?
3. **How can we test the accuracy of these maps?**
 - If we make maps, we then need to know how well they represent reality on the seabed: ground-truthing
4. **How can we then improve their accuracy?**
 - Given that the first pass representation is unlikely to be definitive, our process needs to include an iterative feedback element in which new ground-truth data are used to refine the original model

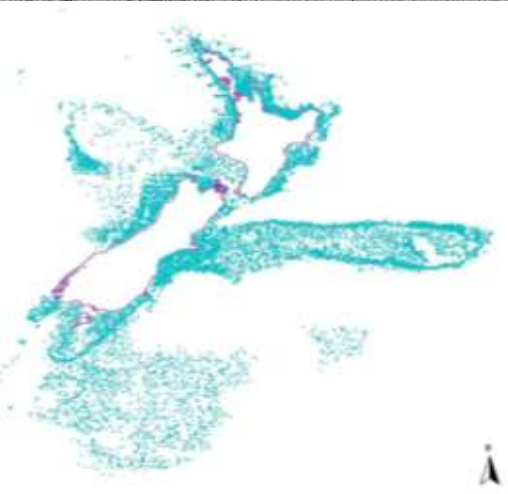
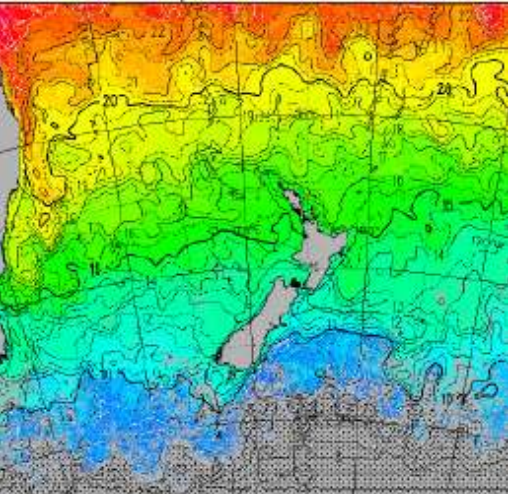


Available data

- **Available:**
 - continuous remote-sensed or modelled large scale physical oceanographic data: SST, depth, Chla, currents, topography (slope)
 - multi-year point data for demersal fish (fisheries)
 - benthic invertebrates (research)
 - benthic sediments (research)
- **mismatch of datasets:**
 - Ecologists and geologists (and fishers) focus sampling on specific areas of interest leading to clumped and patchy data
 - statisticians need evenly distributed sampling, preferably with replication
- **Only the broad scale oceanographic data and modelled data have full, consistent, coverage**

Using the available data

- **Multivariate classification as a tool to generate objective habitat maps from available data**
 - all grid cells are assigned to habitat classes based on multivariate similarity
 - classification methods have been available for a long time and continue to develop
 - no need to be dogmatic about which method is used; adopt new techniques as they are developed
 - Regardless of method (UPGMA, K-means, BRT, GDM etc), these techniques essentially do what we (especially ecologists) do intuitively with data; group it into sets of similar samples (e.g. Petersen-Thorson communities, JNCC Biotopes, Biomes) but they do it objectively

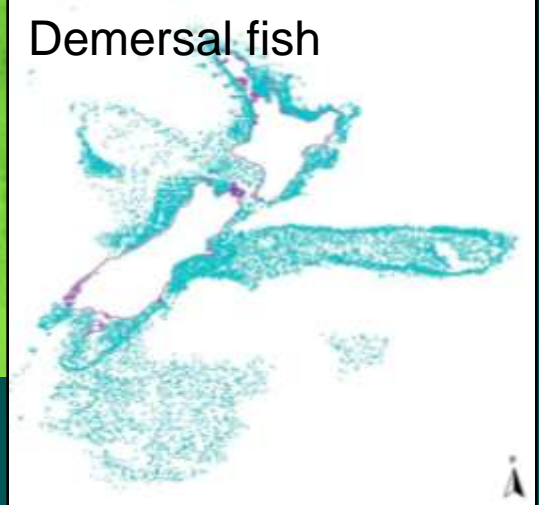


The New Zealand Marine Environment Classification (MEC)

- First attempt at NZ classification (Snelder et al 2004, 2006)
- Multivariate clustering (Gower metric, combined *K*-means and UPGMA) based on spatially continuous environmental data layers:
 - Depth
 - Solar radiation (summer, winter, annual mean)
 - Sea surface temperature (SST) (annual mean, winter mean, annual amplitude, summertime small-scale anomaly)
 - Orbital velocity (water velocity variation at seabed) (annual mean, annual extreme)
 - Tidal current
 - Seabed topography (curvature, slope, slope rate of change)
 - Freshwater fraction (from rainfall run-off model)

Chlorophyll a

Benthic inverts.



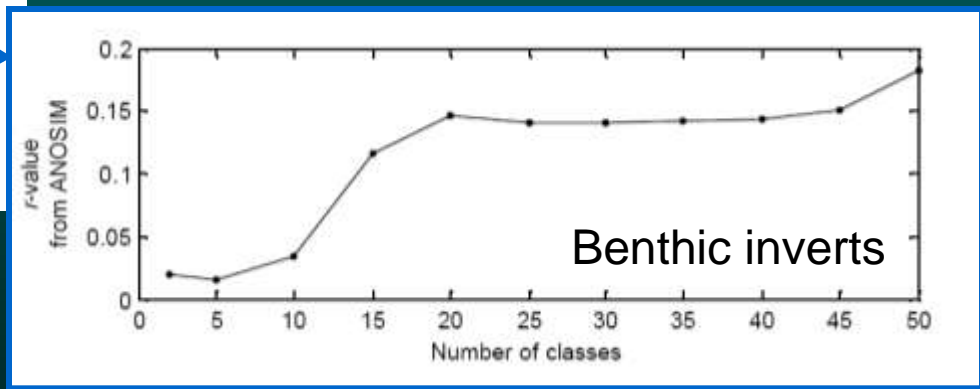
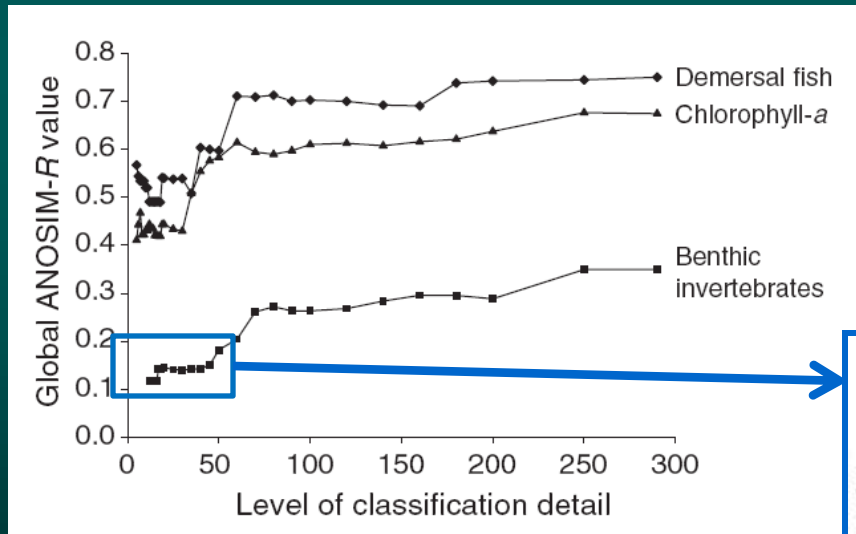
Tuning the classification

- Validation of the initial classification against available biological data sets:

- demersal fish
- benthic invertebrates
- chlorophyll a

Invert data sparse & only two taxa; ophiuroids and asteroids

- matrix correlation tests to decide optimum combination and weighting of variables



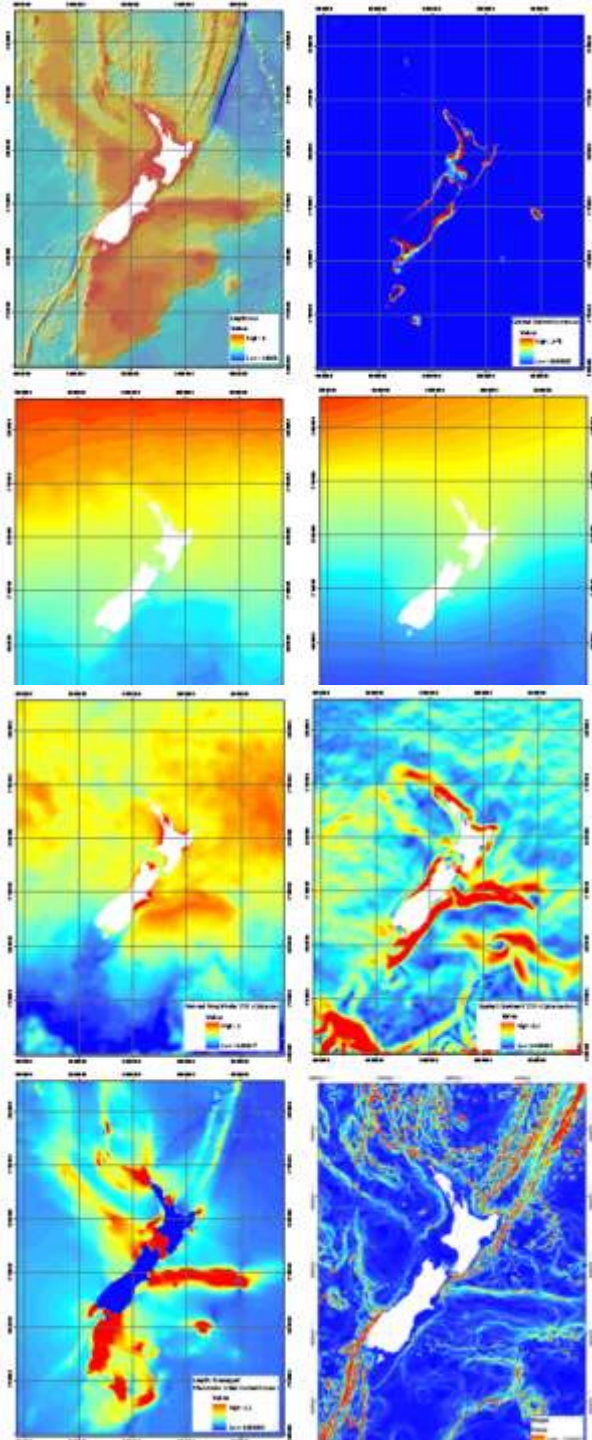
Tuning the classification

- Final combination of variables:

- Depth ($x^{0.5}$, weight x2)
- Wintertime SST
- Mean annual solar radiation
- Annual amplitude SST
- Spatial gradient of annual mean SST
- Mean orbital velocity ($\log_{10}x$)
- Tidal current ($x^{1/3}$)
- Slope (x^2)

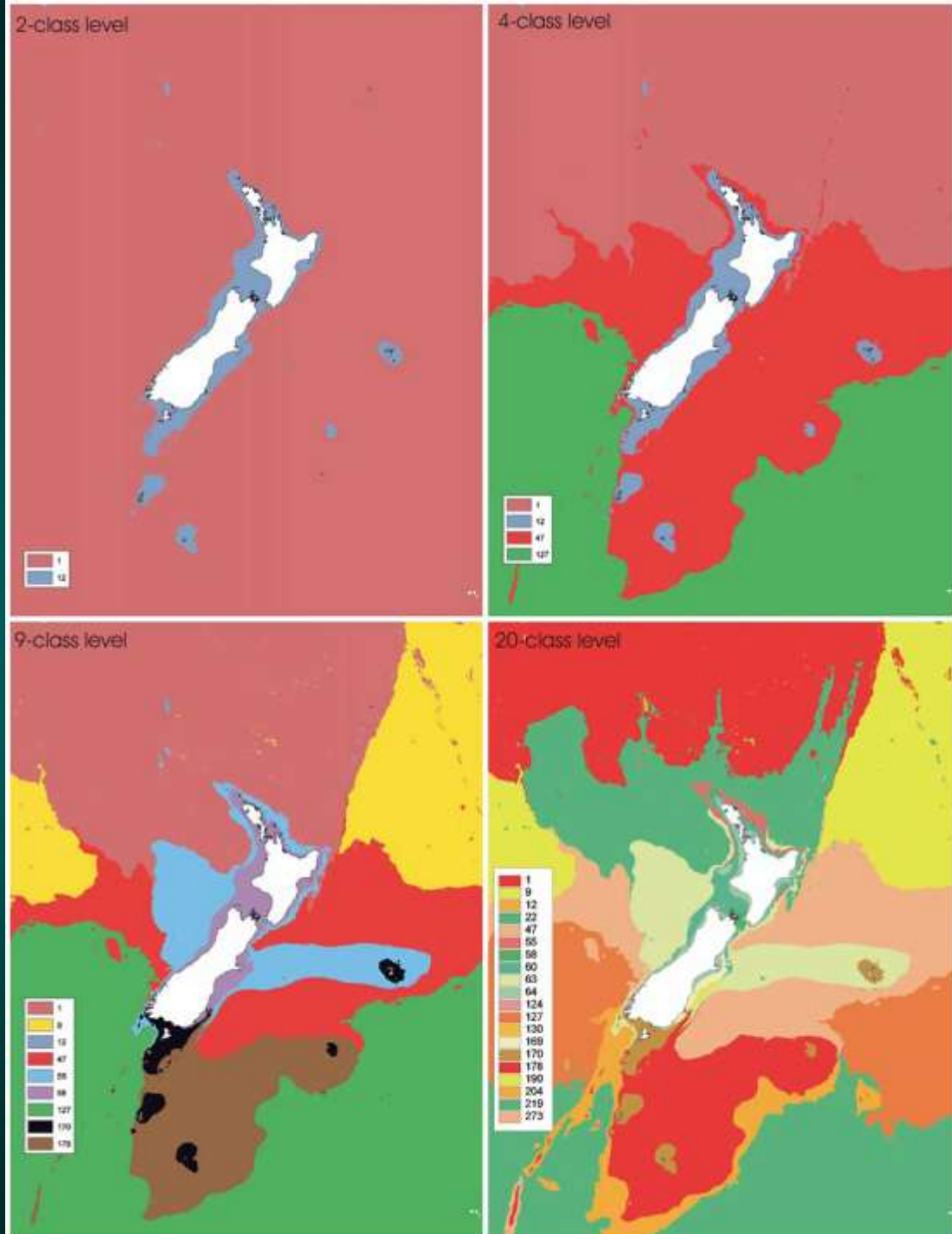
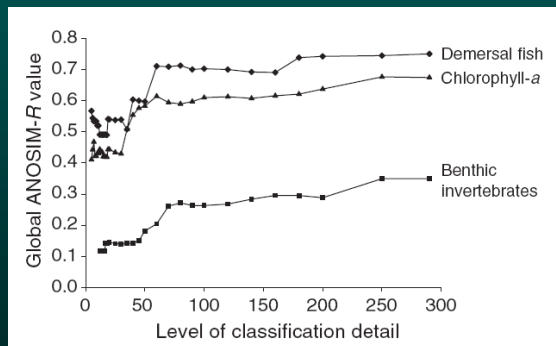
- Note

- none are biological
- none result from physical seabed sampling
- 2 main drivers of faunal distributions were left out:
 - sediment properties
 - primary production



MEC output

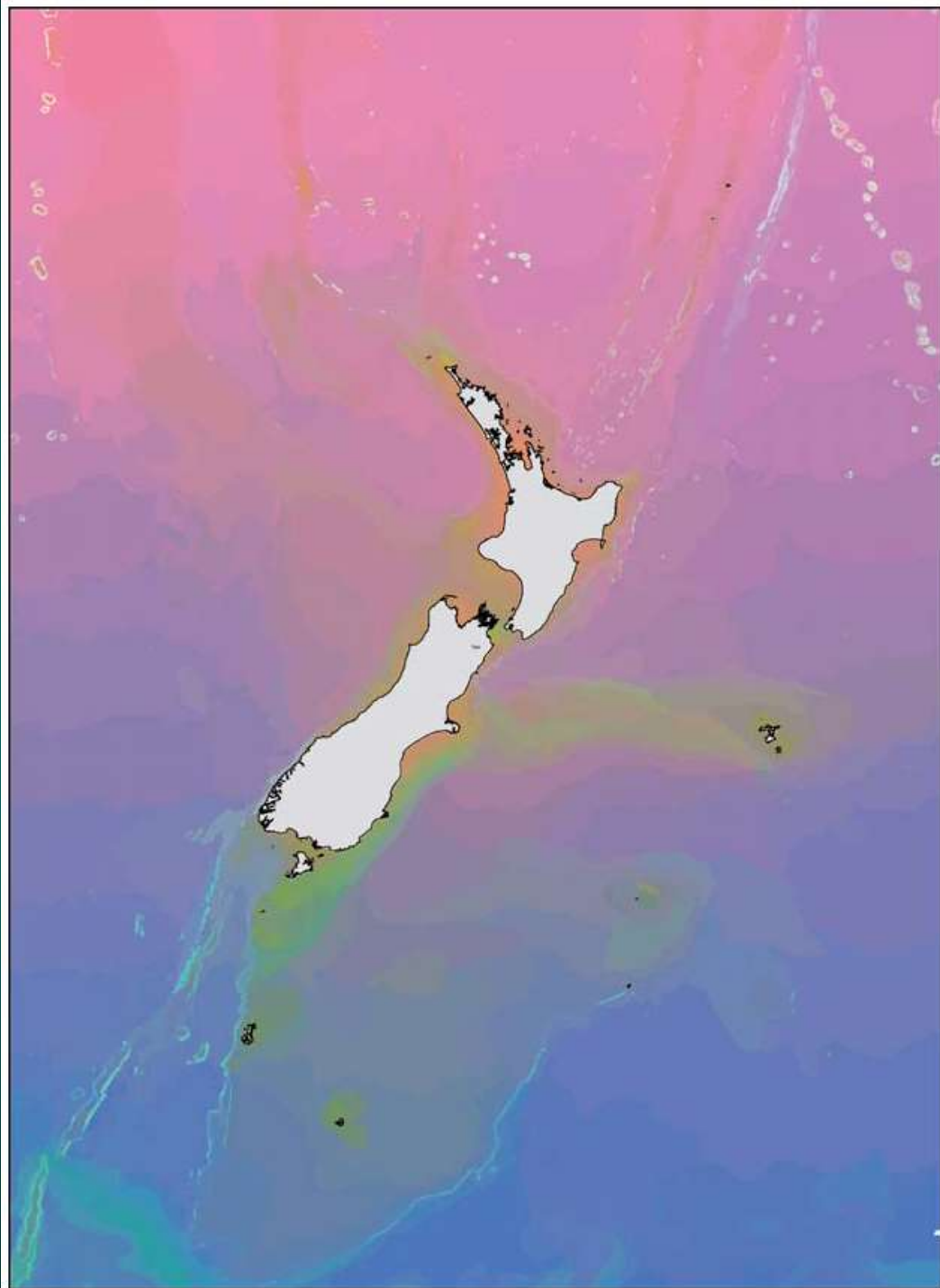
- Hierarchical clustering from 2 to 290 classes visualised as GIS layers
- At more than ~50 classes, remarkably good discrimination
- At the 20 class level adopted by managers, poor discrimination between areas known to be distinct



Snelder et al. (2006) Fig. 4

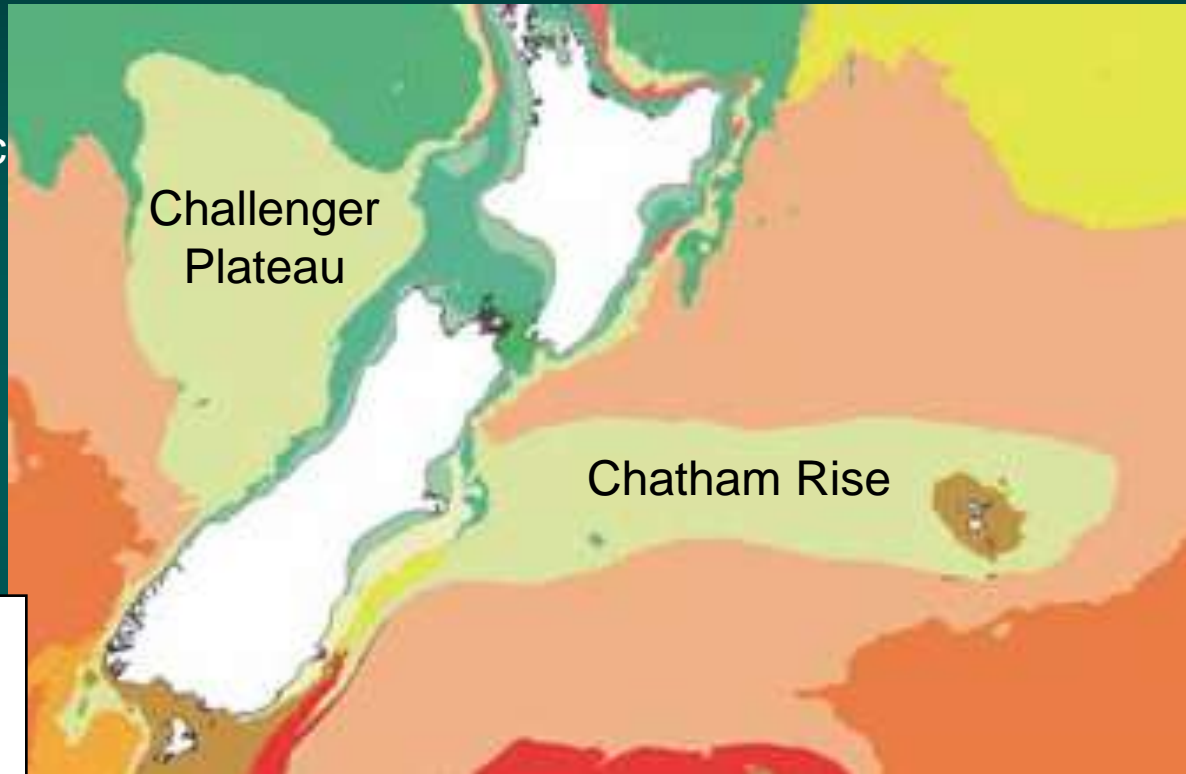
MEC output

- Full-resolution classification (290 classes) effectively shows gradients: much finer discriminations, more like reality ...
- Impractical for environmental management decisions?
- Valuable because it makes implicit predictions about what unsampled areas are like

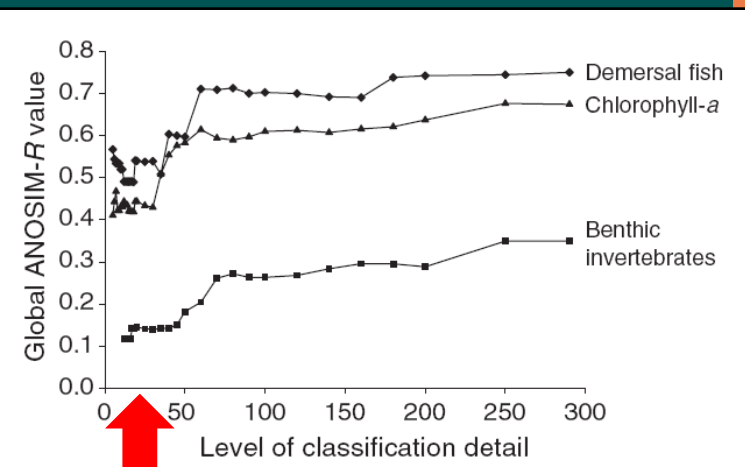


Regardless of the stats, does it work?

- Challenger Plateau
 - low productivity (low fishery catch, oligotrophic water column)
- Chatham Rise
 - high productivity (major demersal fisheries, overlain by subtropical front)



MEC 20 class level

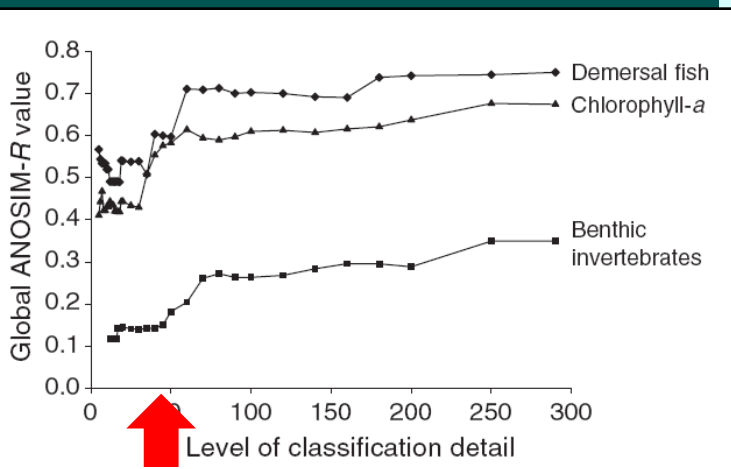


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MEC 40 class level

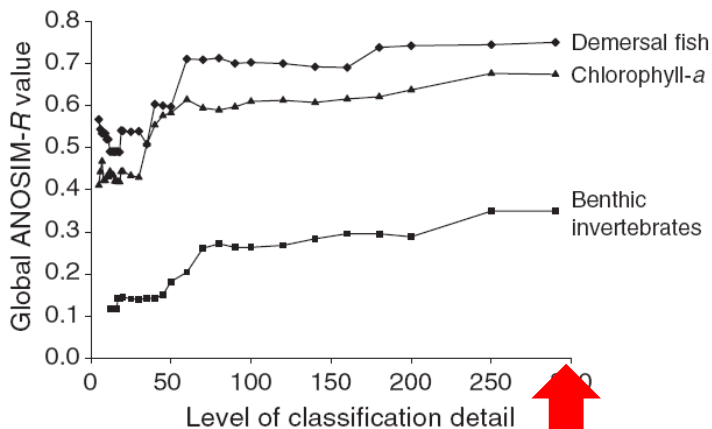


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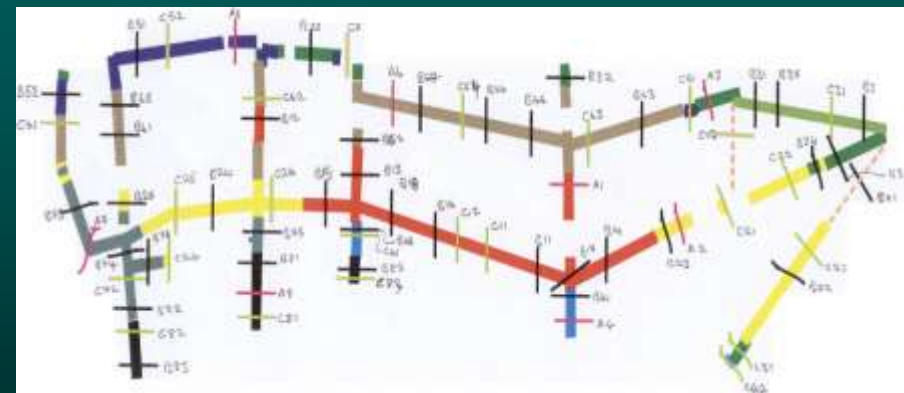
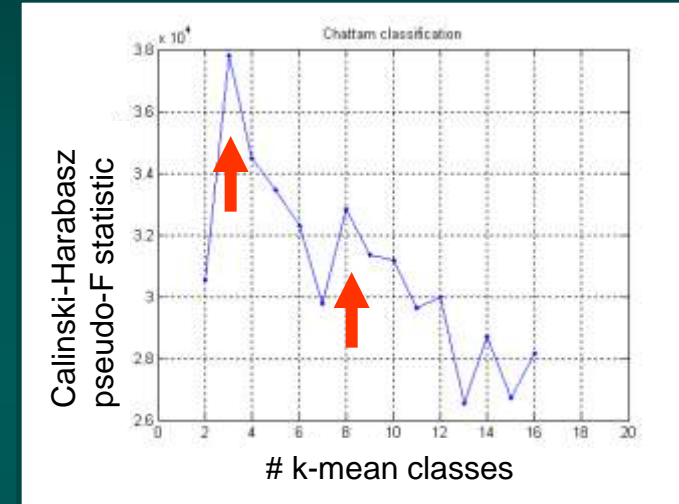


MEC 290 class level



Testing the MEC: ground truthing

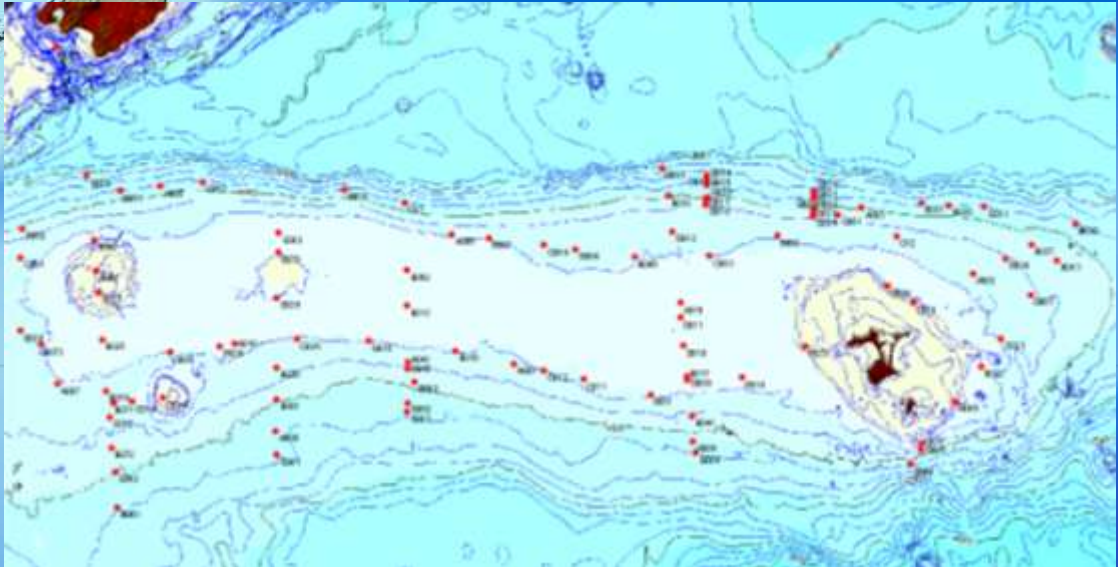
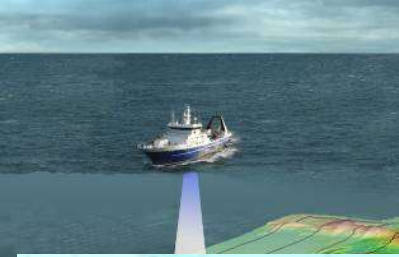
- Ocean Survey 20/20
 - 3 voyages to Chatham Rise & Challenger Plateau in 2006-7
 - Aim to generate a statistically robust, spatially extensive benthic dataset for these areas *independent* of the MEC: a test dataset
 - Multibeam grid transects first:
 - backscatter, bathymetry, btm, and oceanographic layers used to classify into sampling strata (*K*-means clustering)
 - Then randomised sampling with replication within classified strata



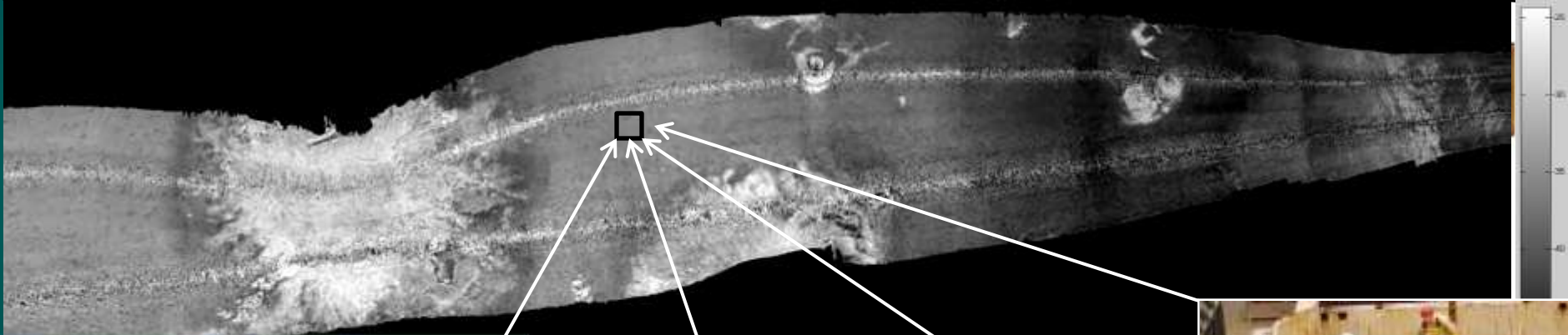
Chatham Rise : *K*-means classes & sample sites

Ground truthing

- 159 sampling sites
- 155 h seabed video
- 36,000 still images
- Sampling for
 - Sediments
 - Bacteria
 - Meiofauna
 - Macrofauna
 - Megafauna



- Goal to estimate habitat and faunal variability across scales:
 - from $<1 \text{ m}^2$ (within still image)
 - to 100 m^2 (within video transect)
 - to 100 km^2 within strata



Using the data to validate the map

- Data from OS 20/20 will be used:
 1. **As a test of the original MEC classification**
 - How well do sample data match MEC predictions at different class levels?
 2. **As additional data layers in the next iteration of the MEC**
 - How much improvement do we get by investing in this level of sampling effort?
 - How much information do we really need in order to reach a useful level of classification strength at different scales?
 - ... the less, the better

Conclusions: pros & cons of the MEC

- **Pro**

- Objective methods for:
 - evaluation and selection of environmental variables
 - use of available biological data to tune the classification
 - determination of optimal weighting and transformation of variable to best match known distributions
- It uses widely available data
- It makes testable predictions for the entire EEZ

- **Con**

- Too general: pelagic and benthic components unlikely to respond in the same way to environmental variables used
- Chl_a probably should have been included in the classification model, not used as a validating dataset
- Too broad: attempted to cover all depths from coast to abyss
- Some patterns, at some classification levels, are clearly wrong

Acknowledgements

This work is being funded through various stages from classification to sampling and analysis by Land Information New Zealand, the Ministry of Fisheries, the Department of Conservation, and NIWA. Too many people at NIWA have been involved to list all here but their efforts are greatly appreciated.

