Autonomous Ecological Surveying of the Abyss at the Porcupine Abyssal Plain

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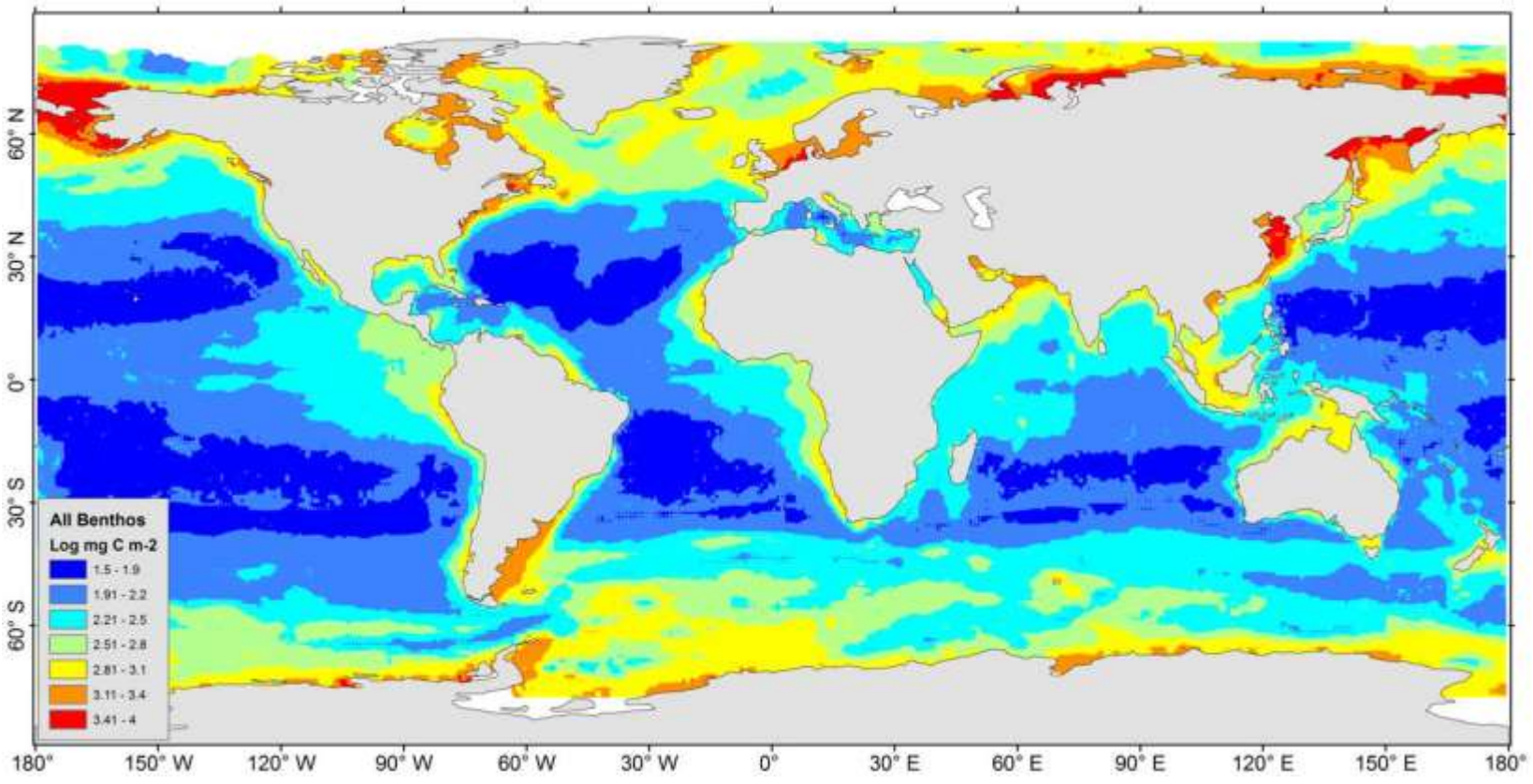
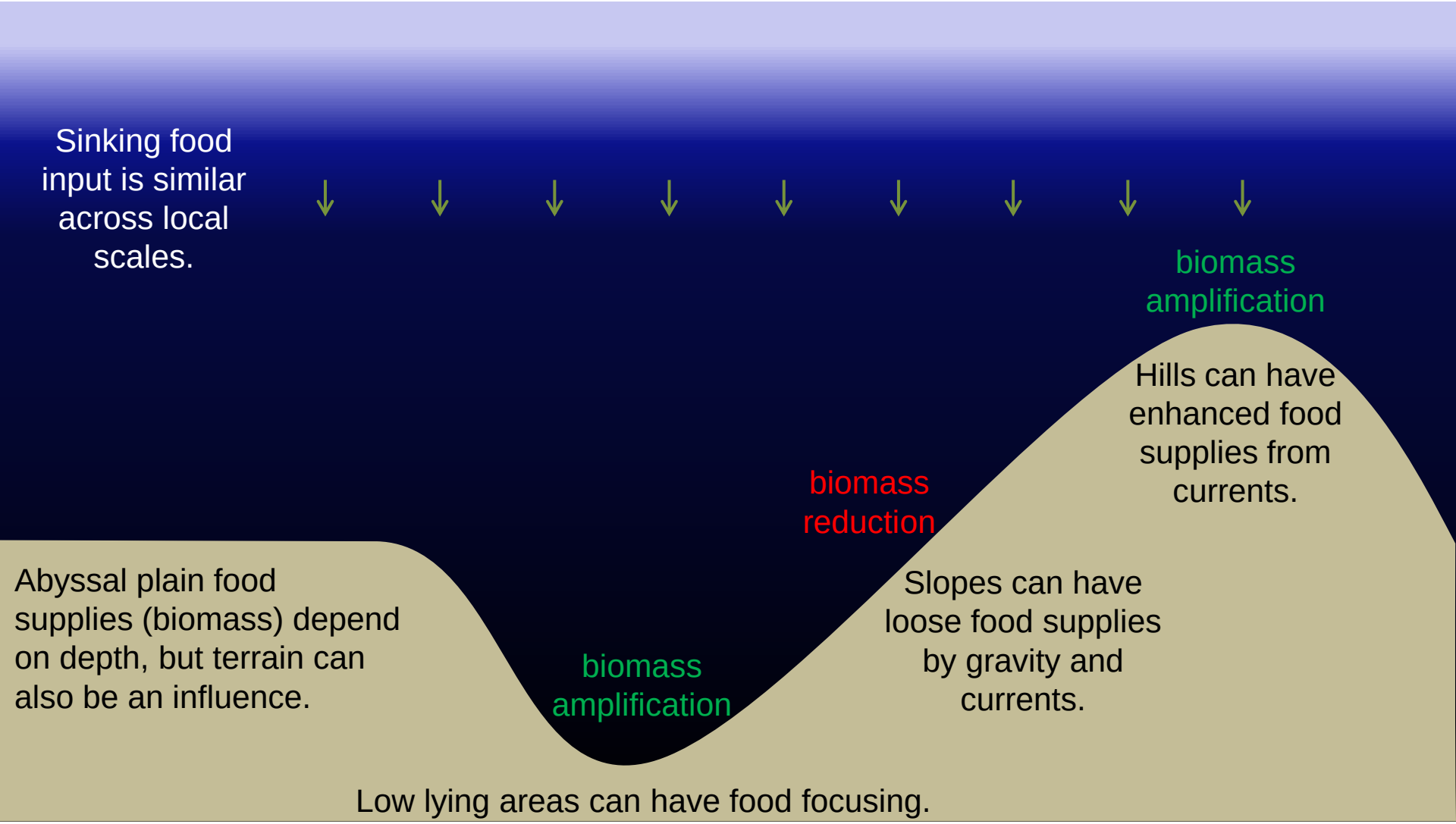
Global View of Seafloor Biomass



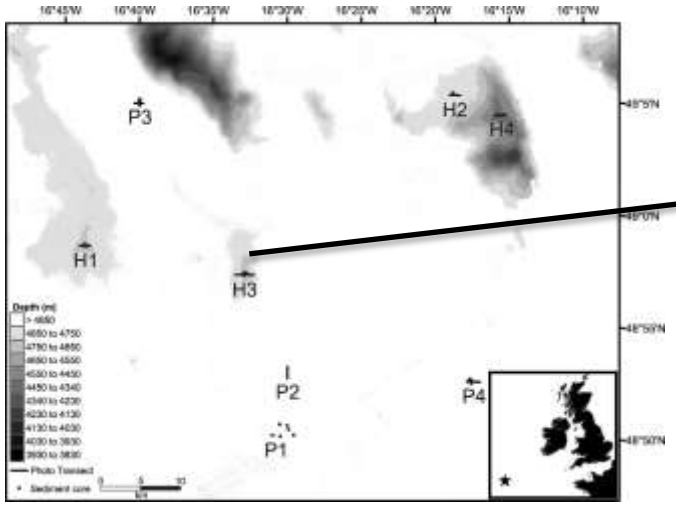
Wei et al. 2010

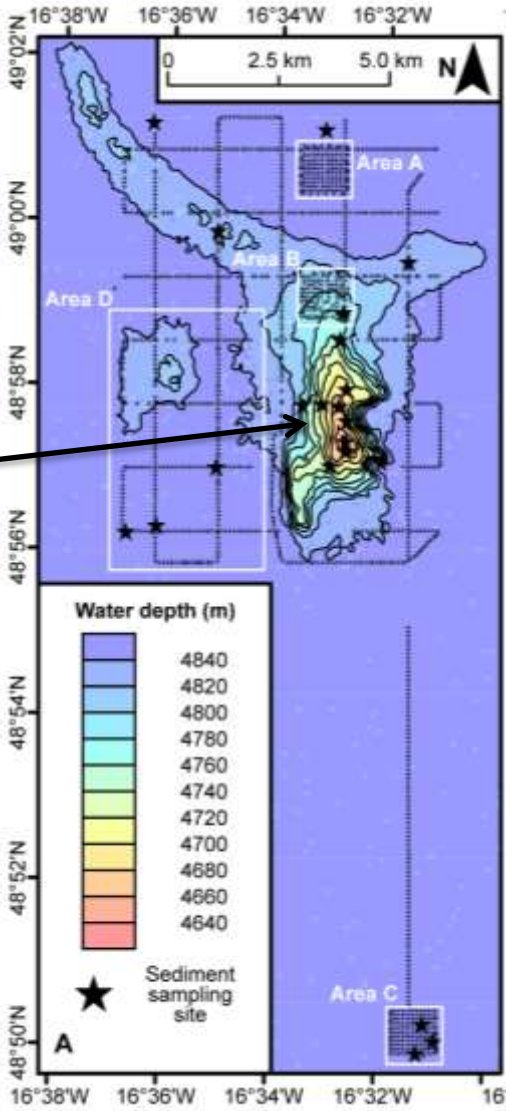
~Homogenous food supply → Heterogeneous biomass



e.g. Genin et al. 1986, Glud et al. 2013, Turnewitsch et al. 2013, Durden et al. 2014 , Ichino et al. 2014

Landscape Scale





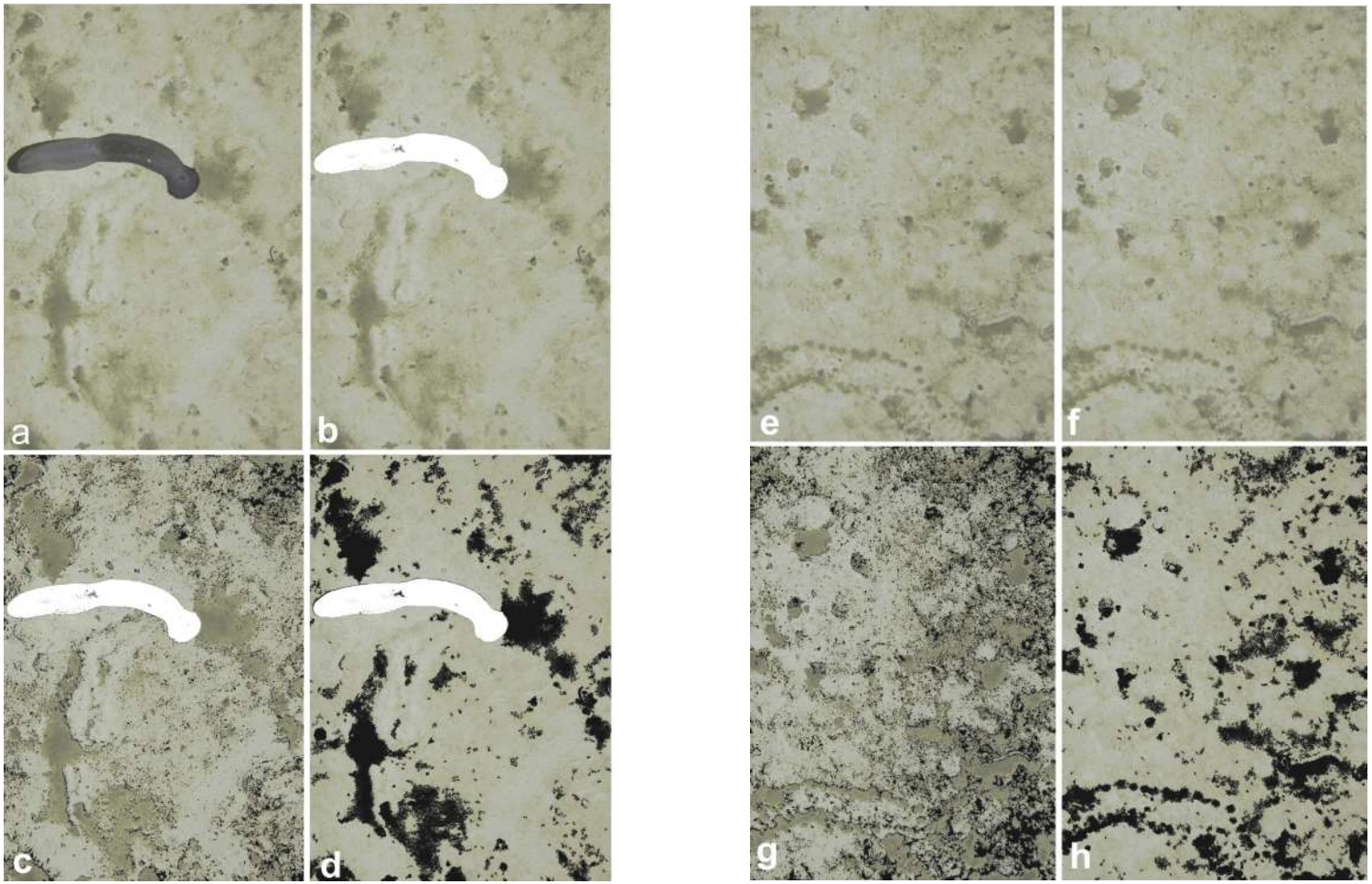
Human Annotation of Images - Biomass

- Biomass determined by annotating the type, size and location of individuals.
- Taxon-specific length scale conversions to biomass were applied.
- Invertebrate megafauna assemblage composition and biomass from 64,690 vertical images.
- Fish densities from 71,035 oblique and 180,715 vertical camera images.

Wet weight (g) = 0.0002 x (length [mm])$^{2.6518}$

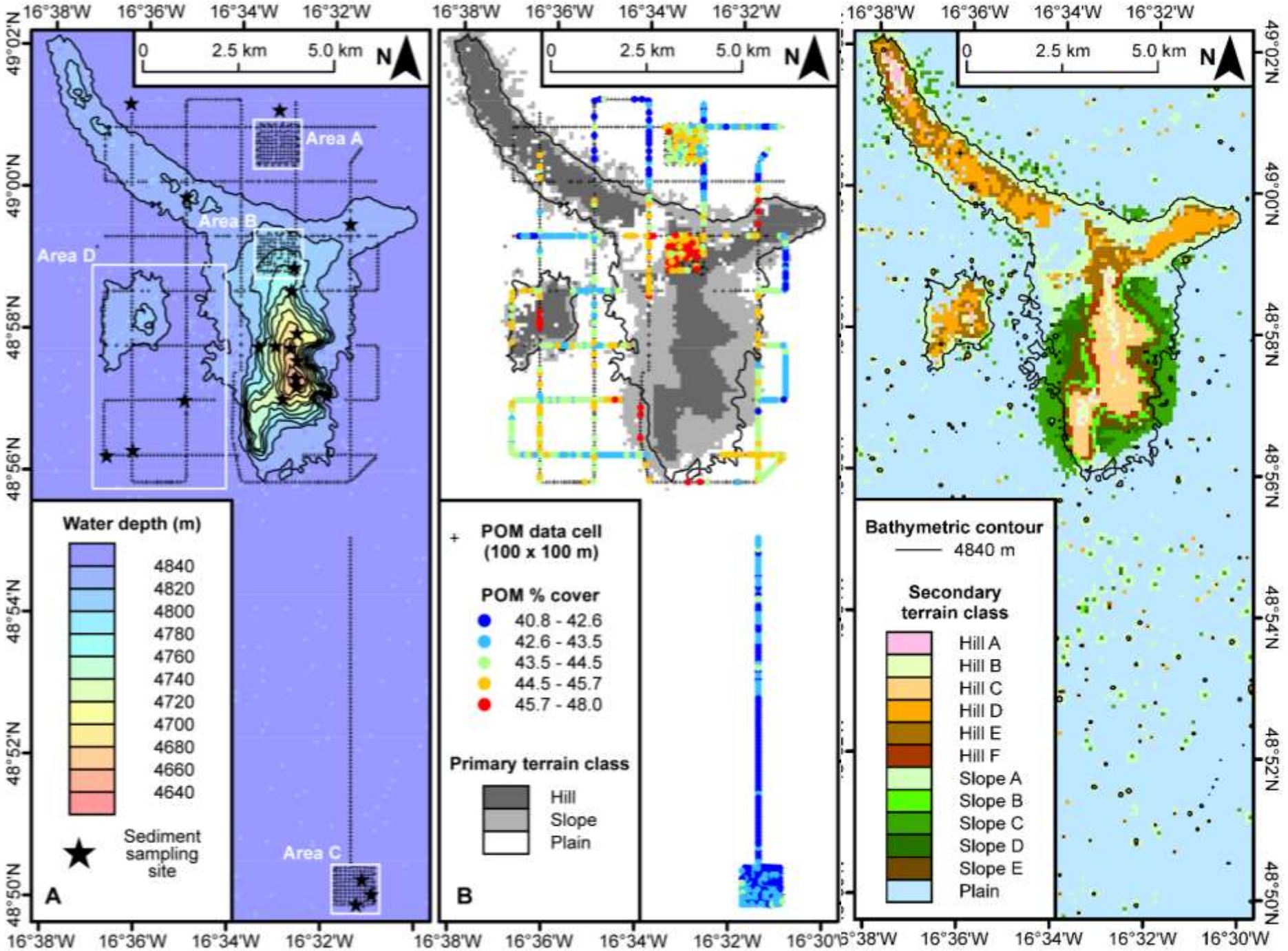
Durden et al. 2016, Milligan et al. 2016, Morris et al. 2016.

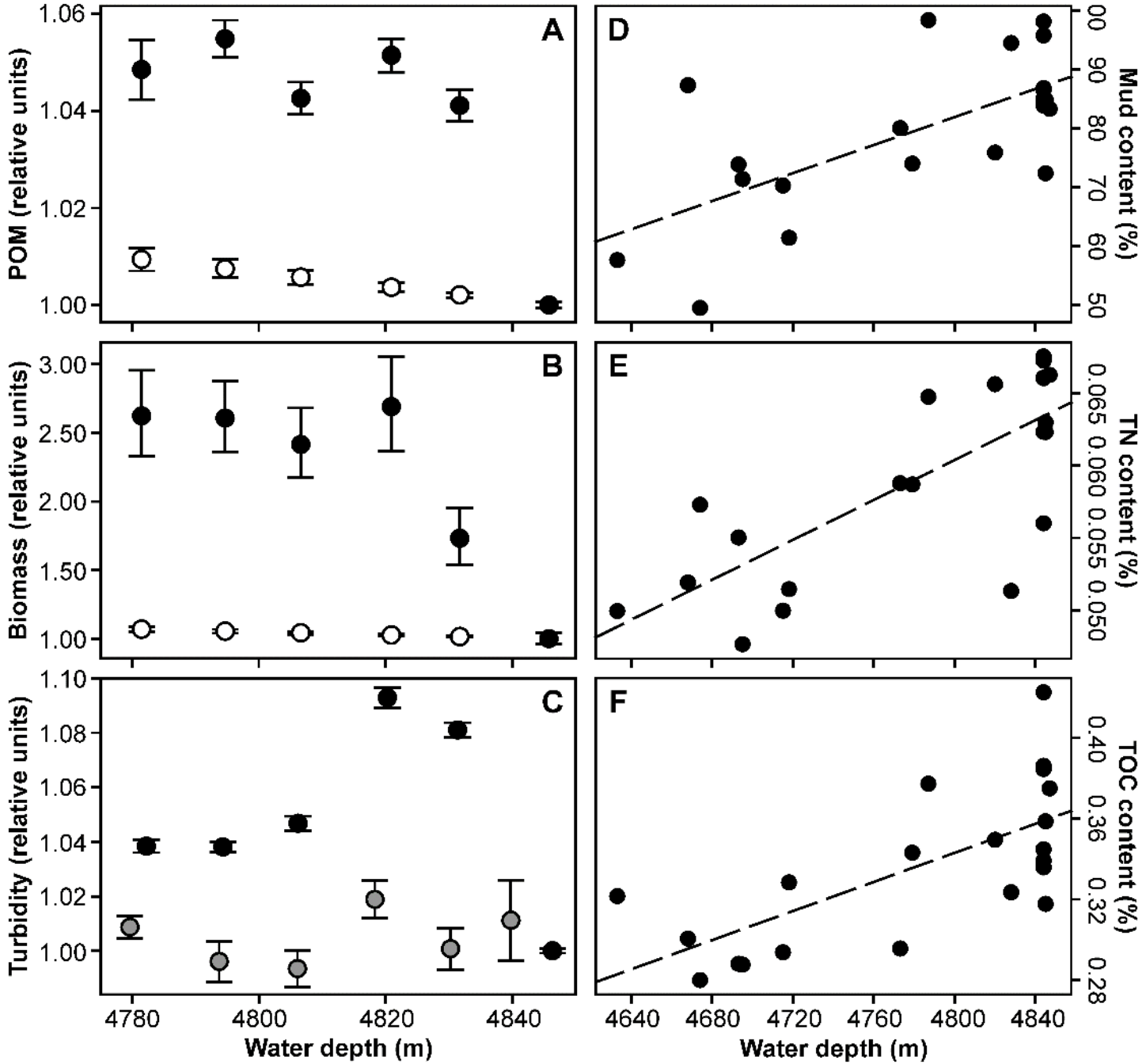
Computer vision of food supplies



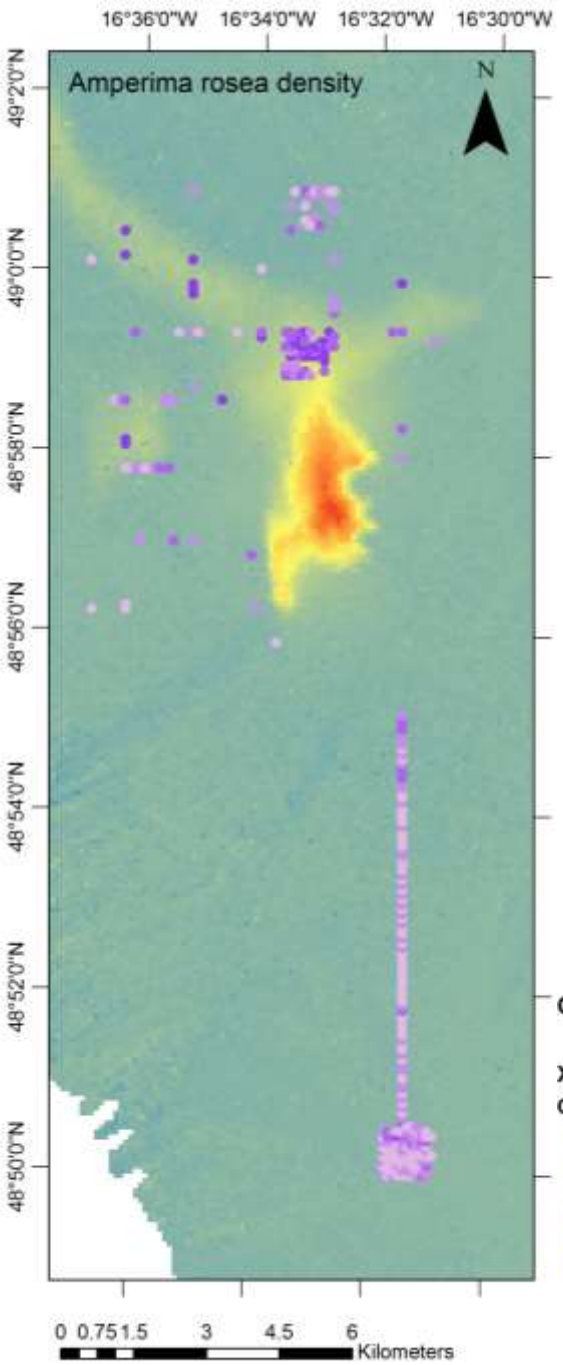
- We estimated seafloor POM % cover using *Autosub6000* images and machine annotation techniques.
- 92,348 vertical seafloor images

Morris et al. *Scientific Reports*, 2016.


16°38'W
16°36'W
16°34'W
16°32'W
16°30'W
49°02'N
49°00'N
48°58'N
48°56'N
48°54'N
48°52'N
48°50'N
0
2.5 km
5.0 km
N
Area A
Area B
Area C
Area D
Water depth (m)
4840
4820
4800
4780
4760
4740
4720
4700
4680
4660
4640
Sediment sampling site
A
POM data cell (100 x 100 m)
POM % cover
40.8 - 42.6
42.6 - 43.5
43.5 - 44.5
44.5 - 45.7
45.7 - 48.0
Primary terrain class
Hill
Slope
Plain
B
Bathymetric contour
4840 m
Secondary terrain class
Hill A
Hill B
Hill C
Hill D
Hill E
Hill F
Slope A
Slope B
Slope C
Slope D
Slope E
Plain



Morris et al. Scientific Reports, 2016.

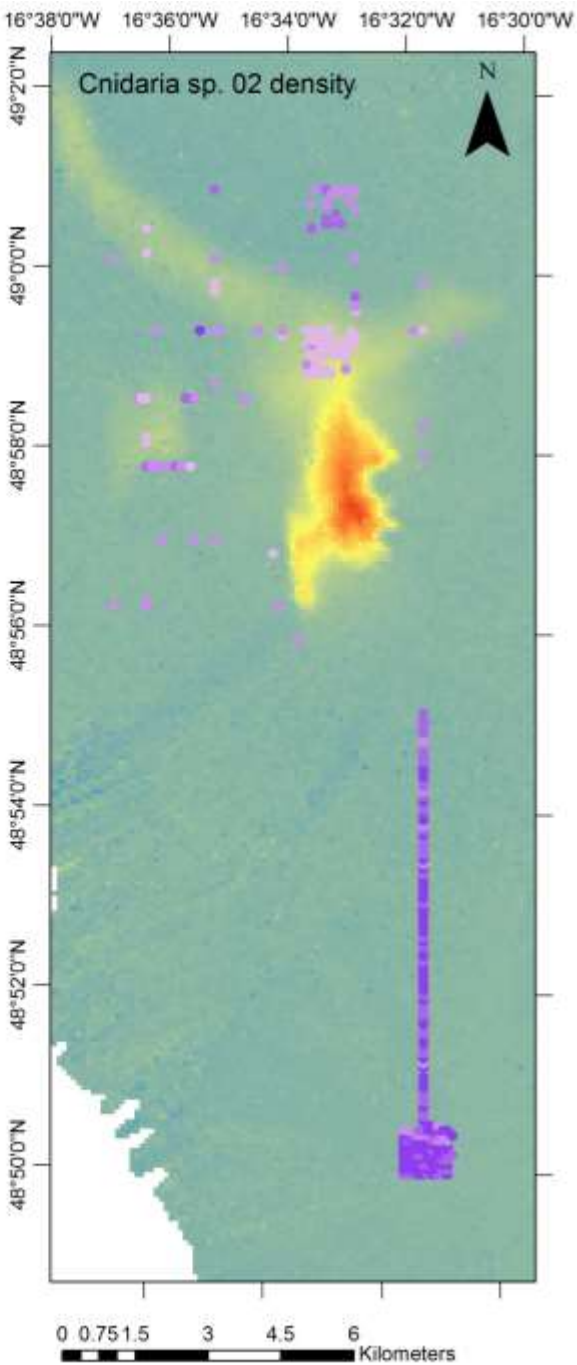


Amperima rosea density

XY'5_density_dominant$'

Amperima_r

- 0.00 - 0.06
- 0.07 - 0.10
- 0.11 - 0.15
- 0.16 - 0.32
- 0.33 - 24.29



Cnidaria sp. 02 density

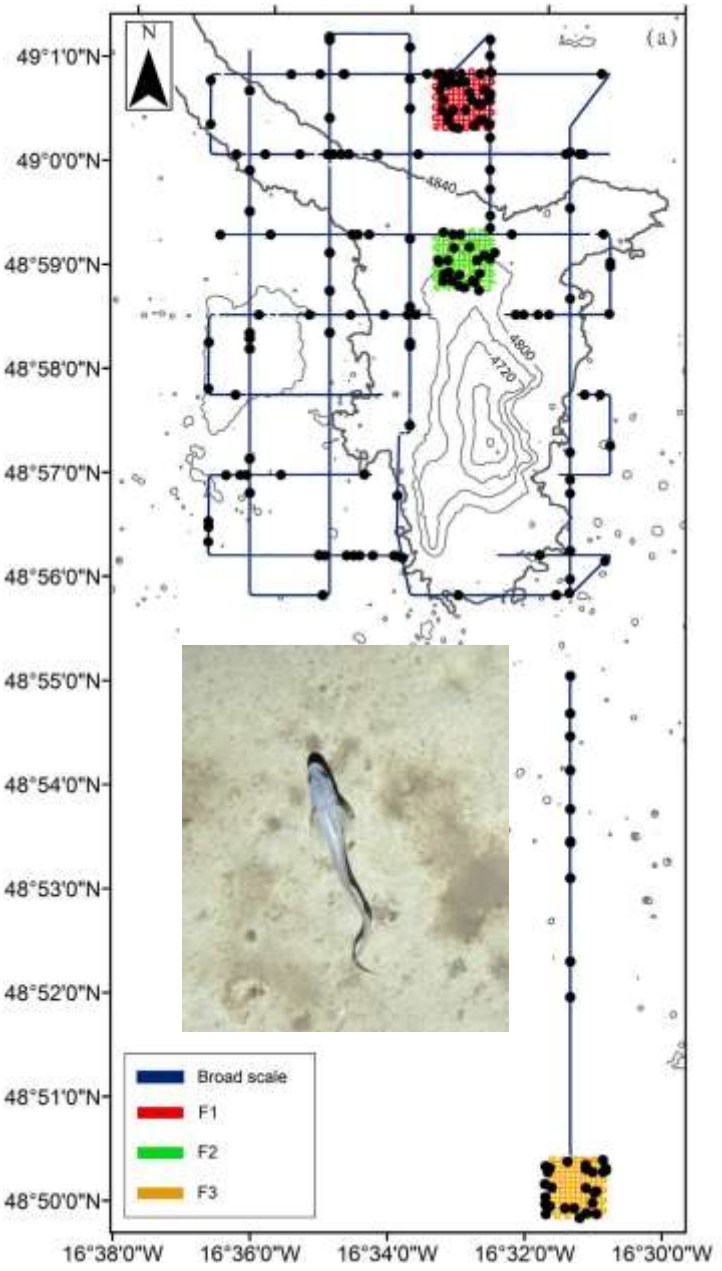
XY'5_density_dominant$'

Cnidaria_s

- 0.02 - 0.13
- 0.14 - 0.25
- 0.26 - 0.35
- 0.36 - 0.52
- 0.53 - 82.40

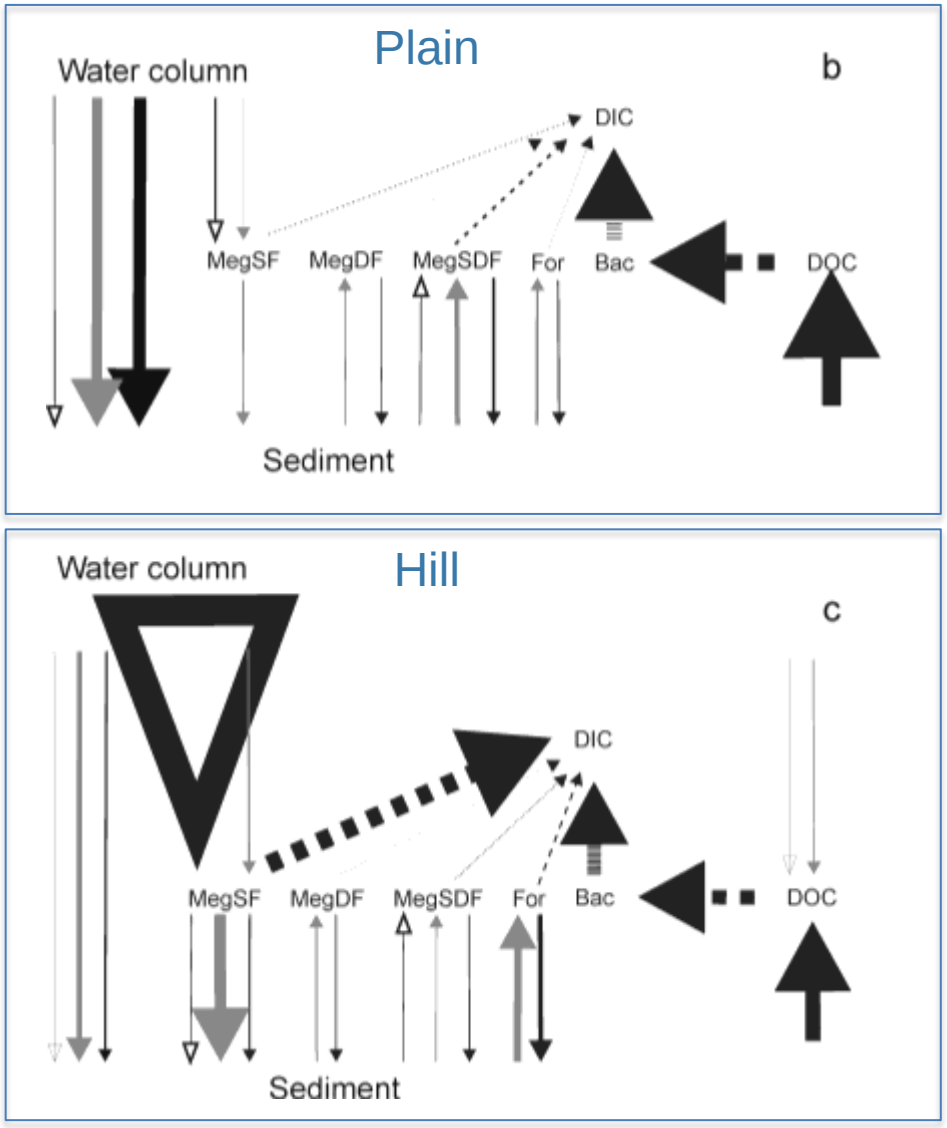
Autonomous Ecological Surveying of the Abyss

- Fish are relatively less abundant than invertebrates and thus require more survey area for equal statistical skill.
- Our surveys reveal that while invertebrates have clear links to the hill terrain, fish distributions appear random.
- This finding re-affirms previous assumptions of baited camera deployments for estimating fish abundance.

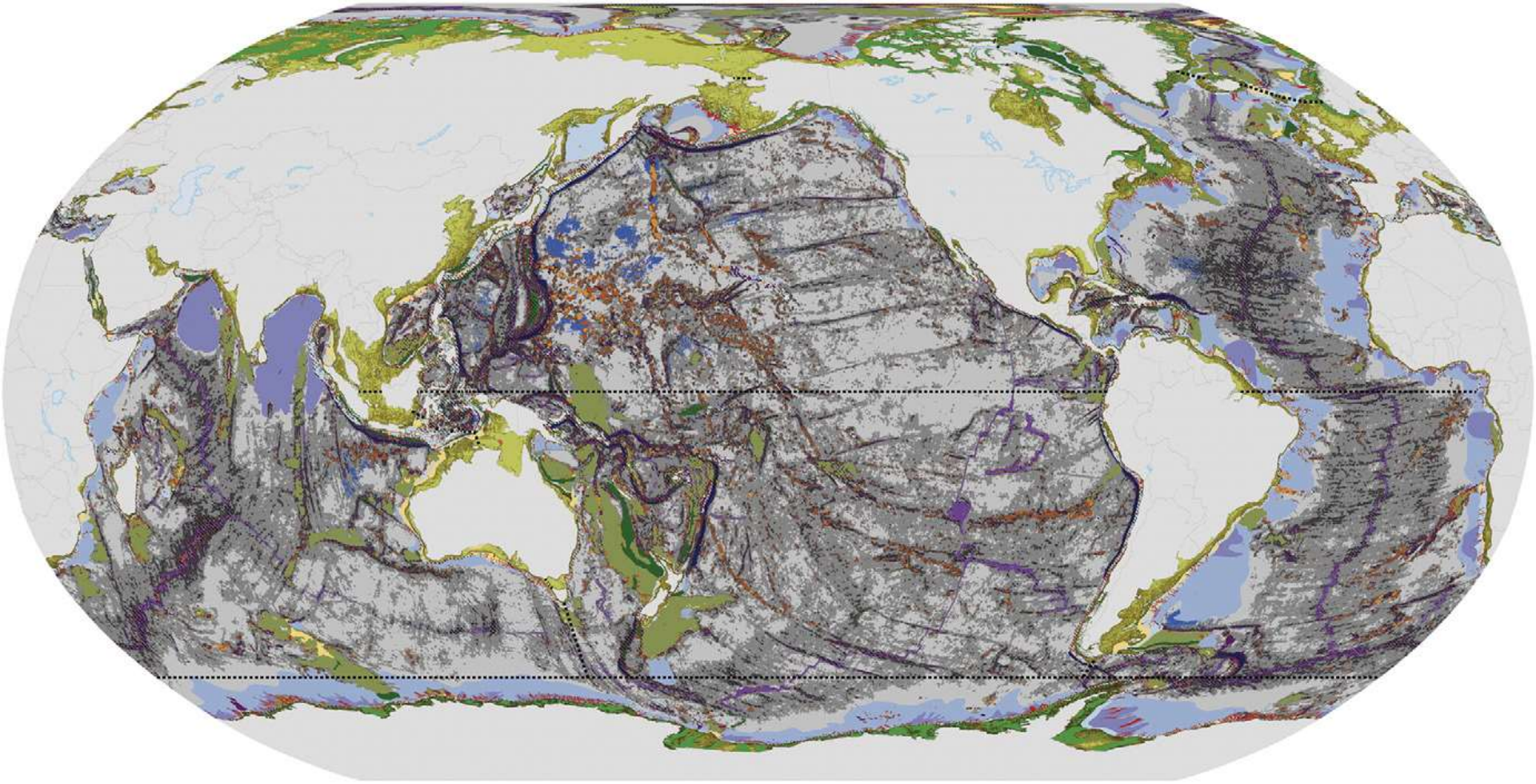


Carbon stocks and flows

- Linear inverse models (LIMs) can be used to estimate C stocks and flows.
- Using AUV photographic data we show that hills have very different C stocks and flows than the surrounding plain.
- Flows are represented by arrows proportional in size to their magnitude.
- Flows of detritus from the water column and the sediment are divided into labile (white arrowheads), semi-labile (grey arrows) and refractory (black arrows) fractions.
- Flows of carbon from respiration, and from DOC to DIC are shown as dashed arrows.



Durden et al. 2017

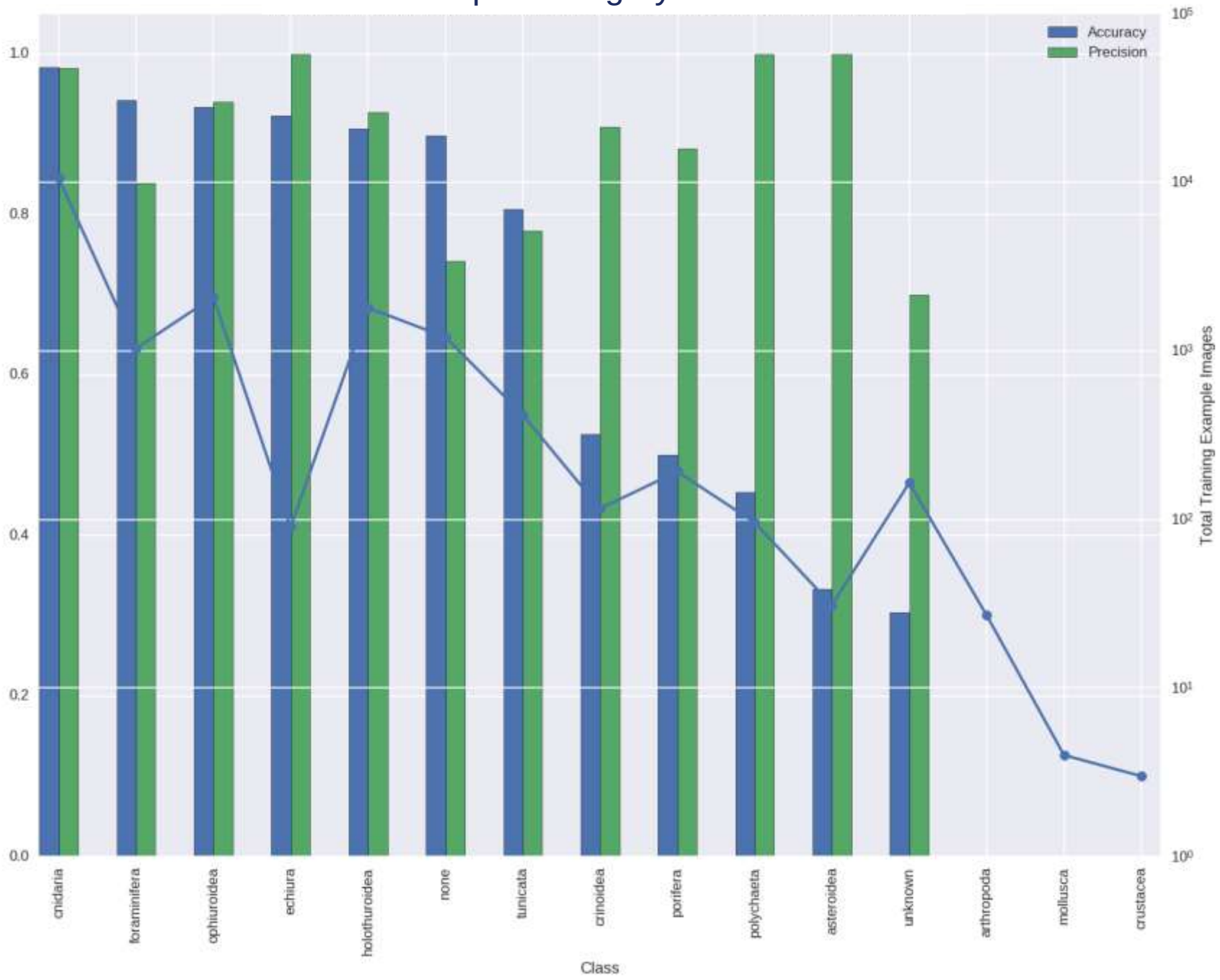


Harris et al. 2014

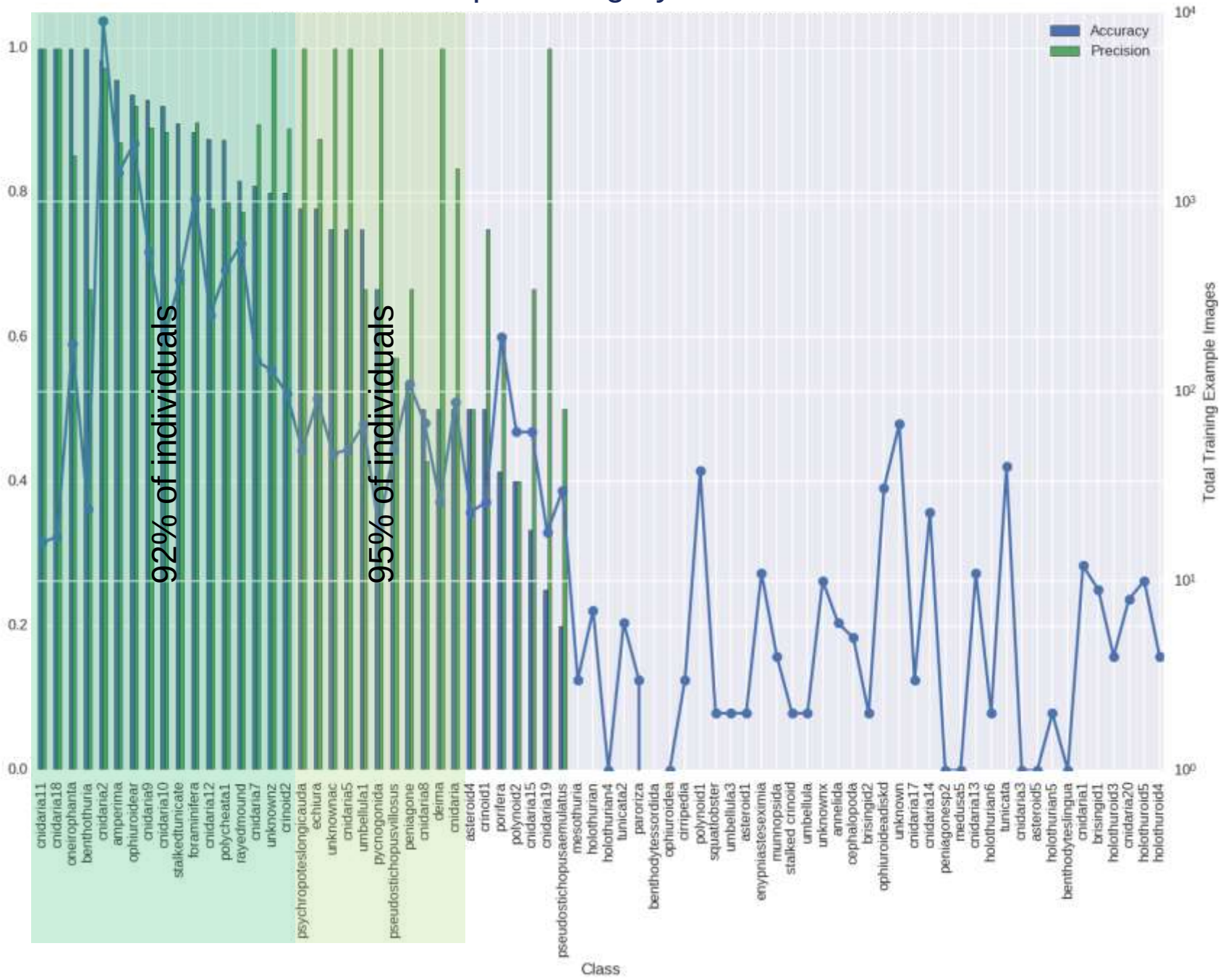
Computer vision

- Initial investigations suggested that SVM approaches would need considerable customization.
- TensorFlow and its Inception model offer new approaches for deep and transfer learning.
- We are applying large annotation (training image) libraries to a transfer learning approach.

Grouped category resolution



Grouped category resolution



Computer vision

Next steps include:

- Examining training image characteristics
- Screening towards ‘gold standard’ training library
- Further consideration of grouping
- Revisiting the SVM customisation

Conclusions

- Subtle features such as knolls rising only a few tens of meters above the surrounding plain support differing communities than the flat plains.

- ~25 × 10^6 intermediate or larger-scale topographic features, Wessel et al. 2010

- Suggests that the extent of such intermediate heterogeneity is important for our understanding of biogeography, ecology and biogeochemistry.

- Approach has since been used in:
  - HF – Marine Protected Area surveys and habitat classifications
  - SSB – Shelf Sea Biogeochemistry
  - MIDAS - Managing Impacts of Deep-seA reSource exploitation
  - STEMM-CCS - Strategies for Environmental Monitoring of Marine Carbon Capture and Storage

AESA Results

- **Durden, JM, HA Ruhl, C Pebody, SJ Blackbird, D van Oevelen. Differences in the carbon flows in the benthic food webs of abyssal hill and plain habitats. *Limnology and Oceanography*. (in press).**
- **Durden, JM, BJ Bett, T Horton, A Serpell-Stevens, KJ Morris, DSM Billett, HA Ruhl. Improving the gross underestimation of deep-sea megabenthos biomass data: Dimension-to-wet weight conversions for abyssal invertebrates in seabed photographs. *Marine Ecology Progress Series*. 552: 71-79.**
- **Durden, JM, BJ Bett, T Schoening, KJ Morris, TW Nattkemper, HA Ruhl. A comparison of image annotation data generated by multiple experts for benthic ecology. *Marine Ecology Progress Series*. 552: 61-70.**
- **Durden, JM, T Schoening, F Althaus, A Friedmann, R Garcia, A Glover, J Greinert, N Jacobsen-Stout, DOB Jones, A Jordt, J Kaeli, K Köser, L Kuhnz, D Lindsay, KJ Morris, TW Nattkemper, J Osterloff, HA Ruhl, H Singh, M Tran, BJ Bett. Perspectives in visual imaging for marine biology and ecology: from acquisition to understanding. In: Hughes, R.N.; Hughes, D.J.; Smith, I.P.; Dale, A.C., (eds.) *Oceanography and Marine Biology: An Annual Review, Vol. 54.* Boca Raton, FL, CRC Press, 1-72, 470pp.**
- **Durden, JM, BJ Bett, DOB Jones, VAI Huvenne, and HA Ruhl. 2015. Abyssal hills - hidden source of increased habitat heterogeneity, benthic megafaunal biomass and diversity in the deep sea. *Progress in Oceanography* 137: 209-218.**
- **Durden, JM, BJ Bett, HA Ruhl. 2015. The hemisessile lifestyle and feeding strategies of *Iosactis vagabunda* (Actiniaria, Iosactiidae), a the dominant megafauna species of the Porcupine Abyssal Plain. *Deep Sea Research I* 102: 72-77.**
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- **Morris, KJ, BJ Bett, JM Durden, NMA Benoist, V AI Huvenne, D OB Jones, K Robert, MC Ichino, GA Wolff, HA Ruhl. 2016. Landscape-scale spatial heterogeneity in phytodetrital cover and megafauna biomass in the abyss links to modest topographic variation. *Scientific Reports* 6, Article 34080, doi: 10.1038/srep34080.**
- **Morris, KJ, RJ Milligan, DOB Jones, BJ Bett, DM Bailey, JM Durden, S McPhail, K Robert, VAI Huvenne, and HA Ruhl. 2014. A new method for ecological surveying of the abyss using autonomous underwater vehicle photography. *Limnology and Oceanography: Methods* 12: 795–809.**
- Laguionie-Marchais, C, G Paterson, JM Durden, and HA Ruhl. Spatial heterogeneity in abyssal polychaete distributions. *Progress in Oceanography*. (in preparation).
- Stefanoudis, P et al., Abyssal hills: Influence of topography on benthic foraminiferal assemblages. *Progress in Oceanography* 148: 44-55.
- Stefanoudis, P et al., Agglutination of benthic foraminifera in relation to mesoscale bathymetric features in the abyssal NE Atlantic (Porcupine Abyssal Plain). Marine Micropaleontology 123: 15-28.
- Stefanoudis et al., Formation of agglutinated cysts by the foraminiferan *Sphaeroidina bulloides* on the Porcupine Abyssal Plain (NE Atlantic). *Marine Biodiversity* 46:747-749.

Thanks for your attention!

NERC SCIENCE OF THE ENVIRONMENT

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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Job Announcement!

Computer vision researcher

- NOC Southampton, Ocean Biogeochemistry and Ecosystems Group
- Starts ~May 2017 ≥18 month appointment
- Will build on existing tools (e.g. TensorFlow, BIIGLE) and create and evolve analysis workflows for biological oceanographic applications.
- Still, time-lapse, holographic and video image analysis.
- Work with a network of researchers at MBARI, Bielefeld, and GEOMAR.

Related projects include:

- EMSO - European Multidisciplinary Seafloor and water column Observatory
- STEMM-CCS - Strategies for Environmental Monitoring of Marine Carbon Capture and Storage

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