Fishing impacts on benthic-pelagic coupling: upscaling ecological functioning experiments

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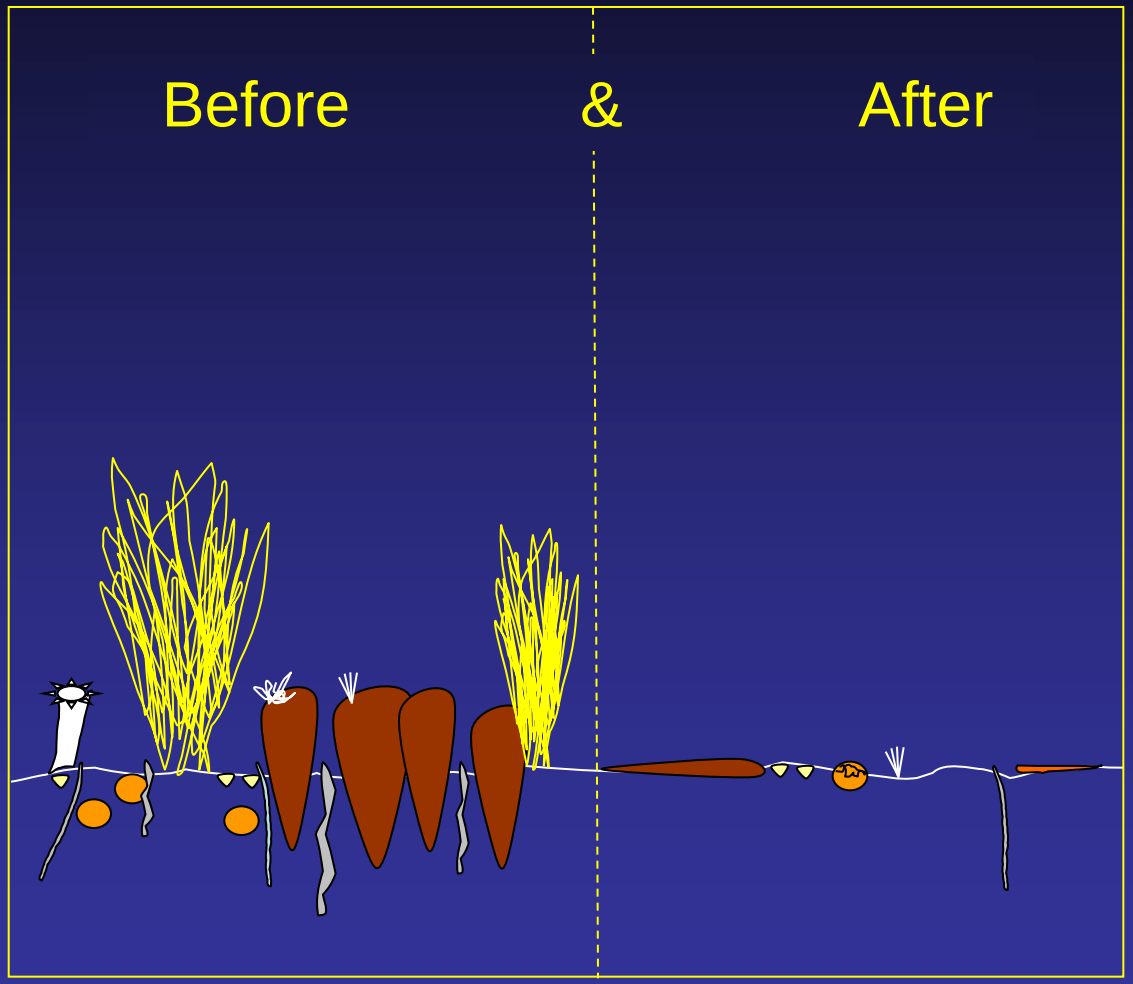
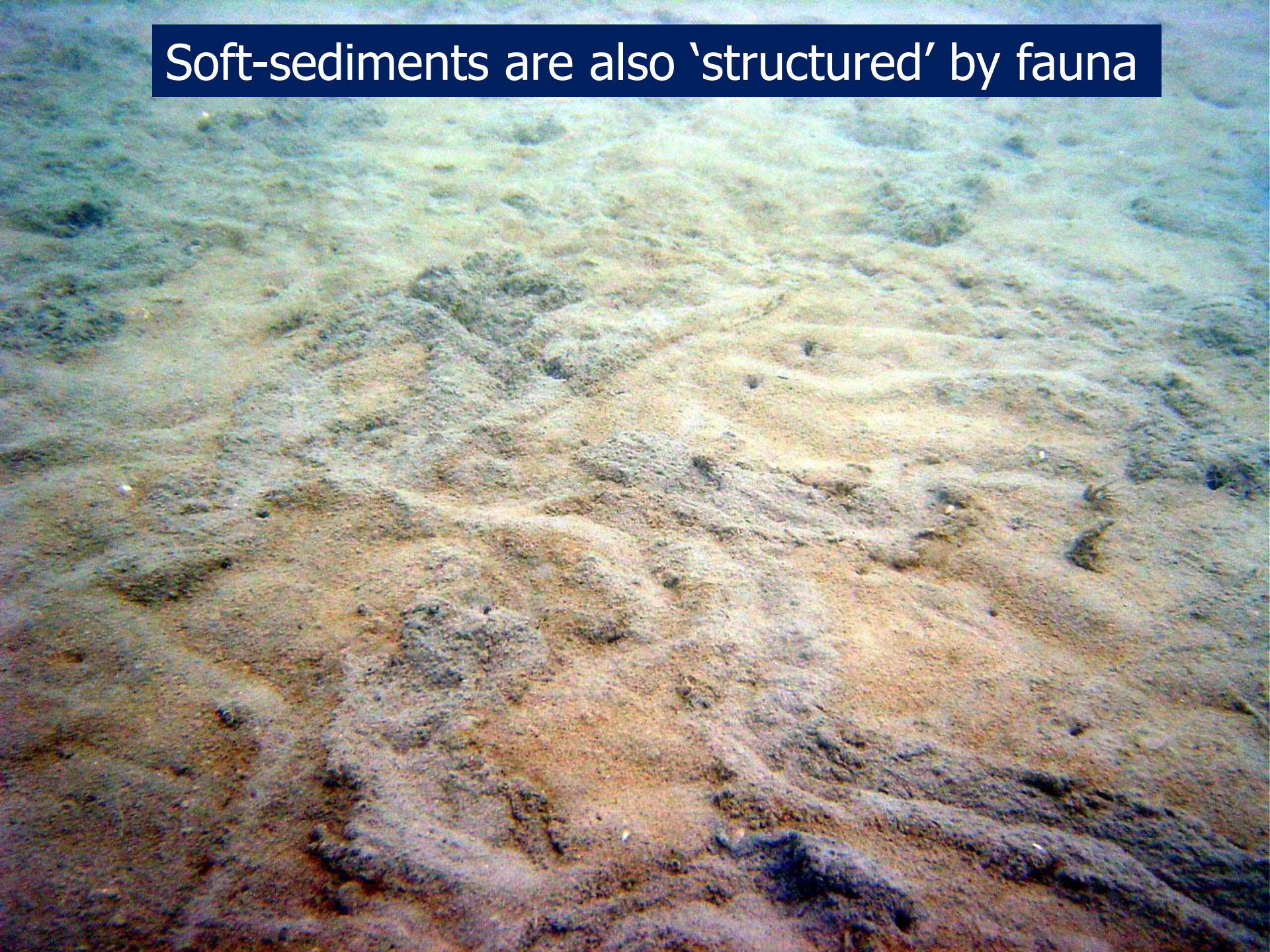
Trawling disturbs benthic communities

Structure formers

sponges, bryozoans, gorgonians, anemones, reef forming worms & bivalves

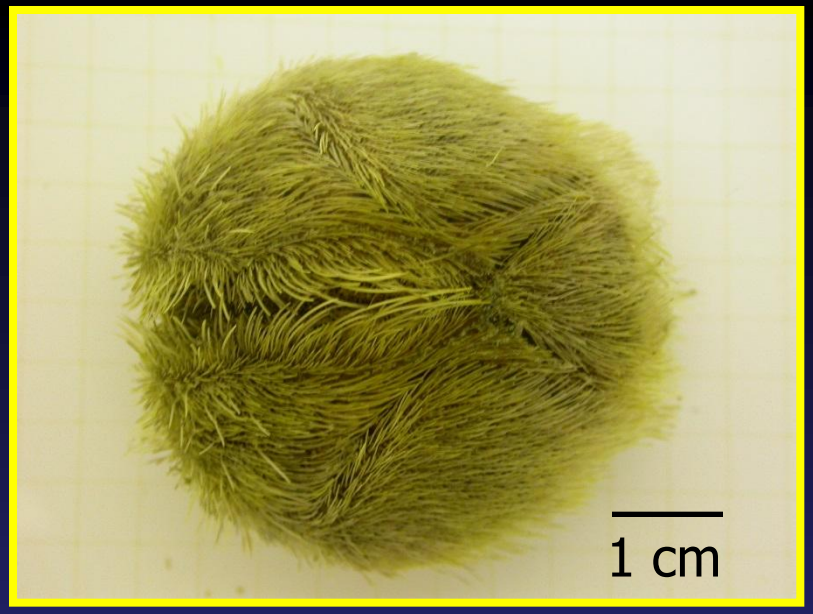


Soft-sediments are also ‘structured’ by fauna



- Marine coastal systems are highly productive
  - Sediments are critical to productivity
    - Bioturbation is a key process

- Species do not make equal contributions to functioning
  - Species have differing susceptibilities to fishing
    - Impacts depend on correlations between "effects traits" & "response traits"


1 cm

Trawling and dredging affects *Echinocardium*

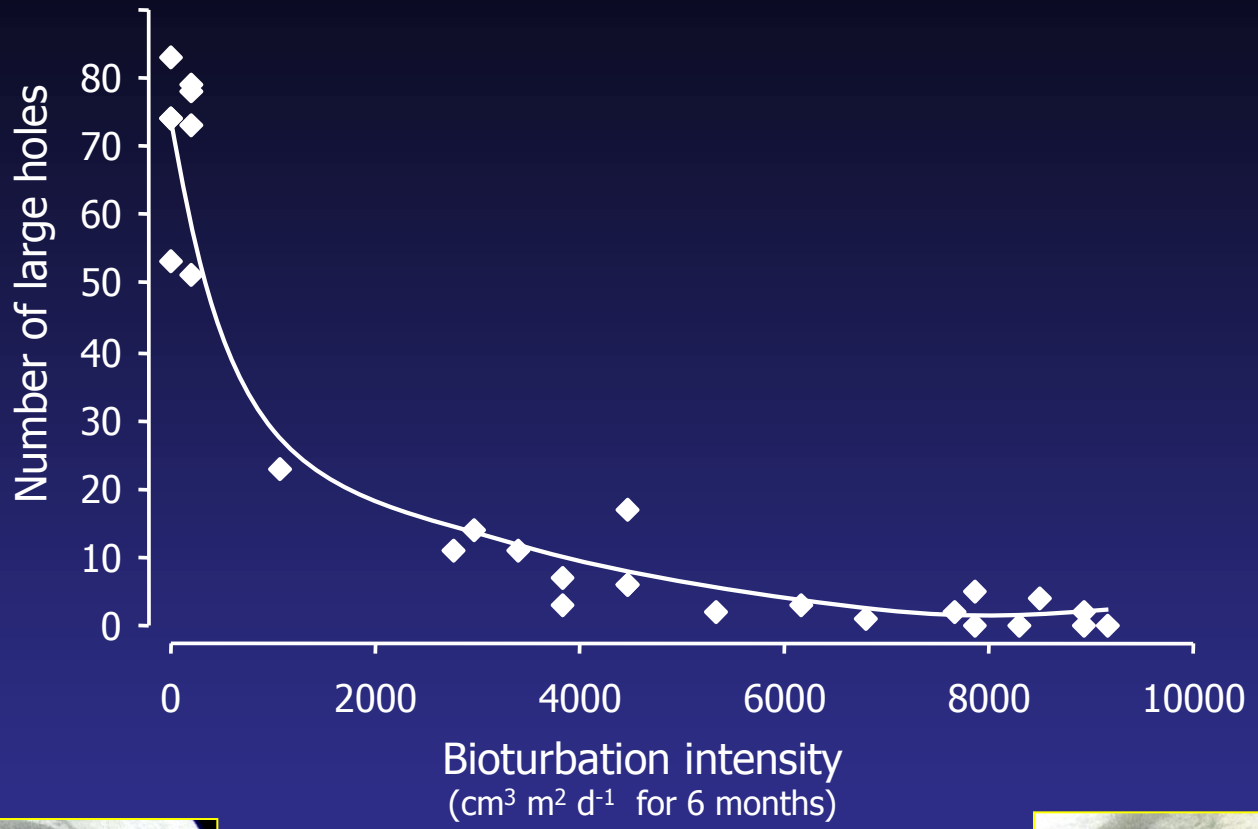
"clogging of trawl nets with tests of *E. cordatum* has often occurred in recent years" – Nakamura 2001

"catches of *E. cordatum* in trawls that penetrate 1-6 cm into the sediment"– Jennings and Kaiser

"decrease in the abundance of the fragile burrowing heart urchin"–Holtmann et al. 1996

"fishing activity may have been the main cause"– Jennings and Kaiser

Echinocardium affects multiple sediment properties

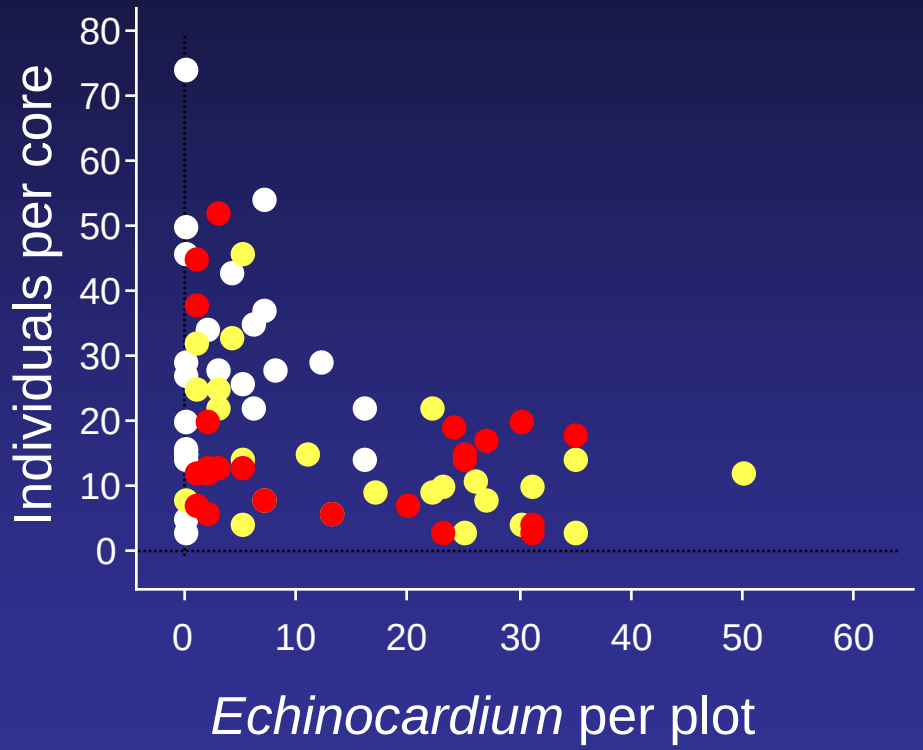


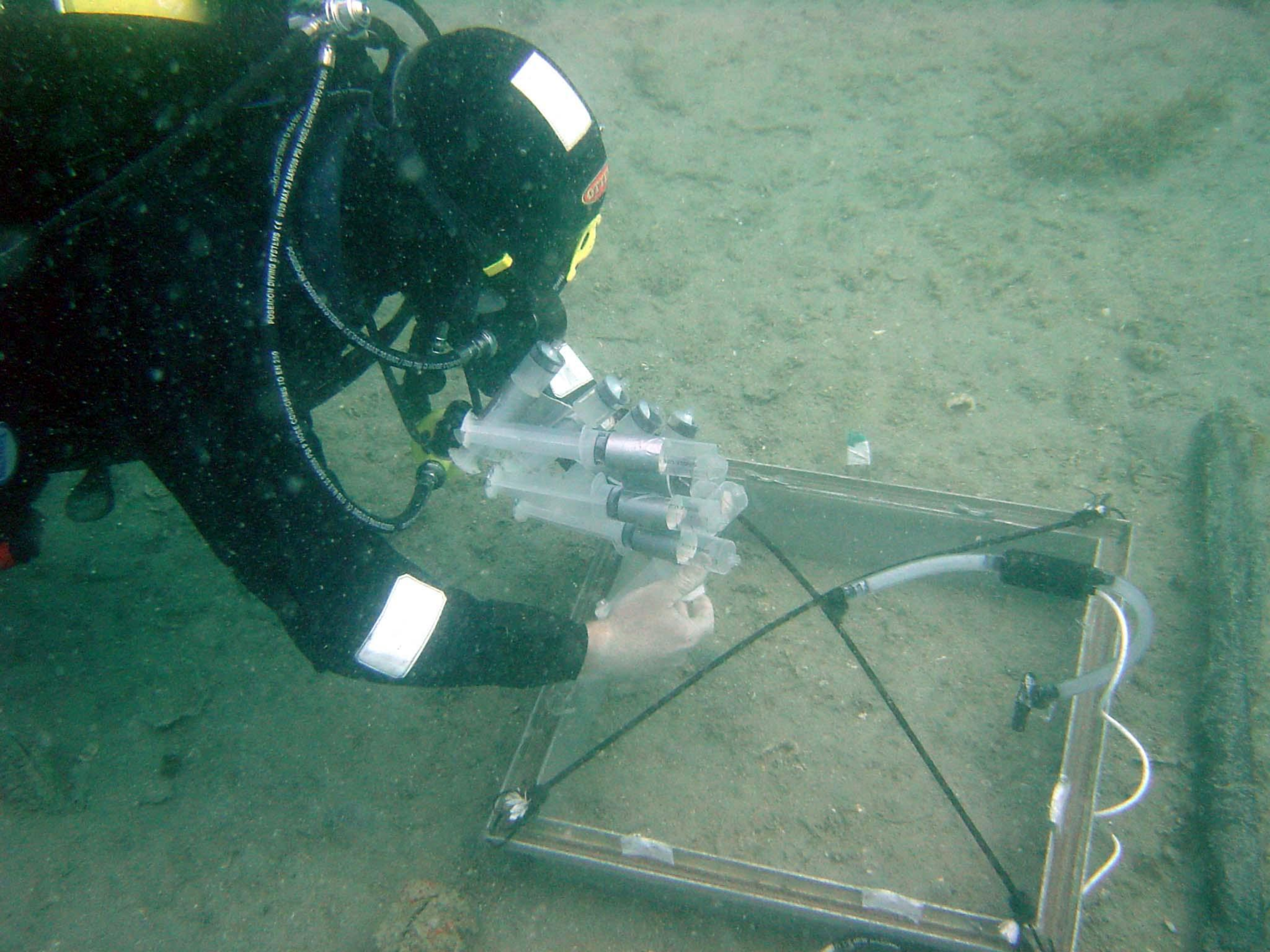
0 urchins

>10 urchins

Plots are 1 m diameter

Echinocardium affects macrofaunal communities





Echinocardium affects key rates and processes

Bioturbators enhance ecosystem function through complex biogeochemical interactions

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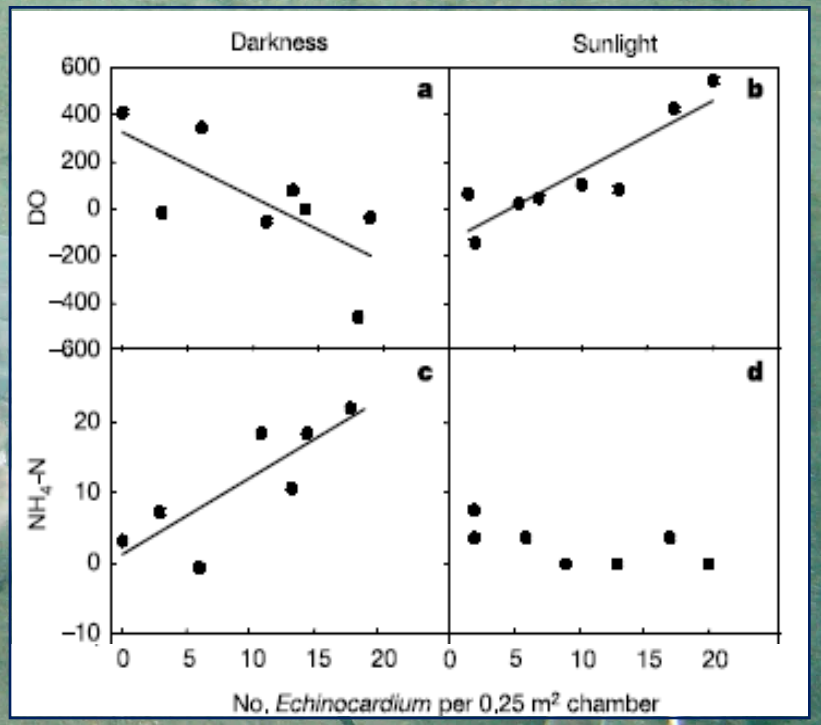
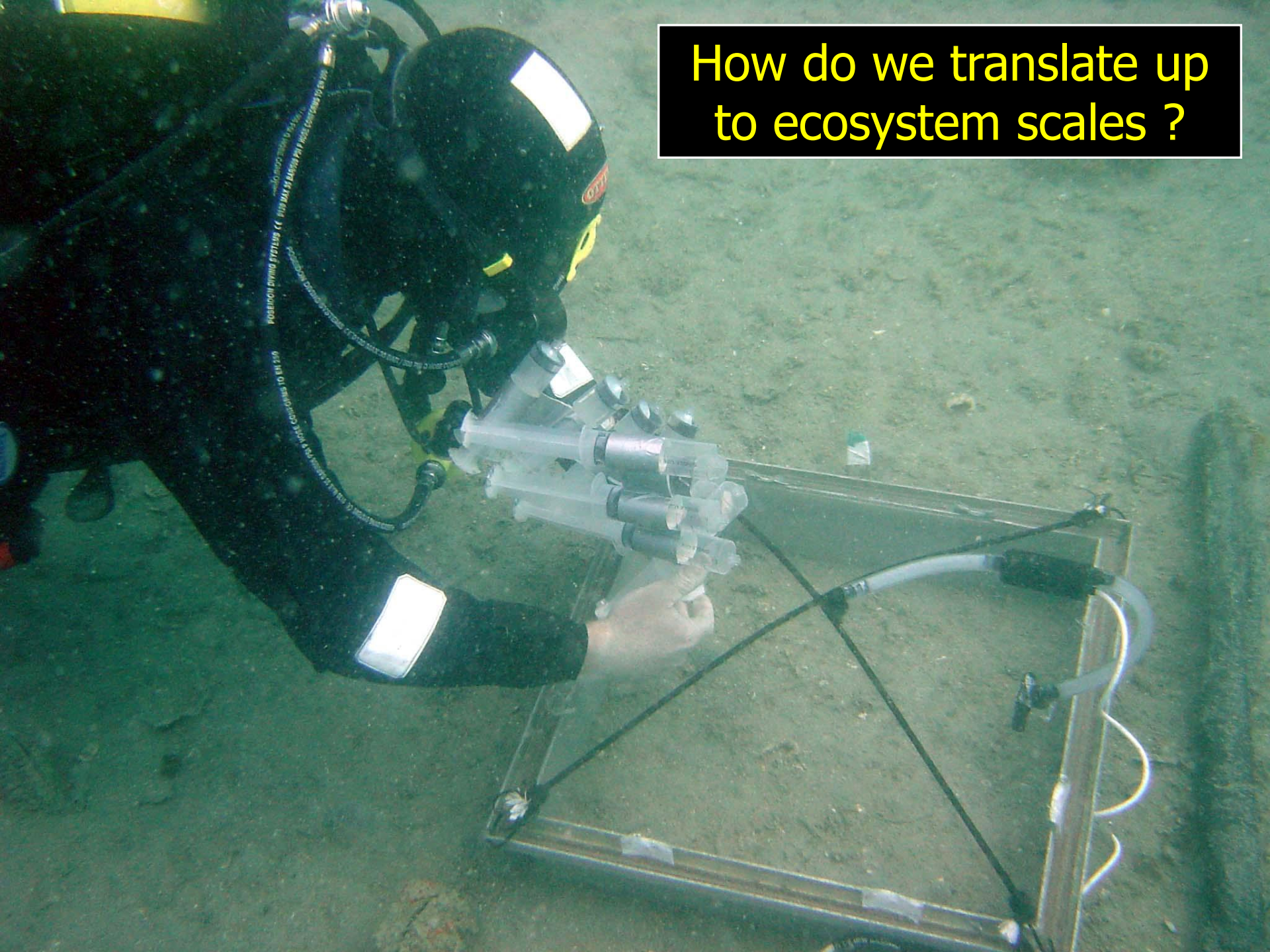
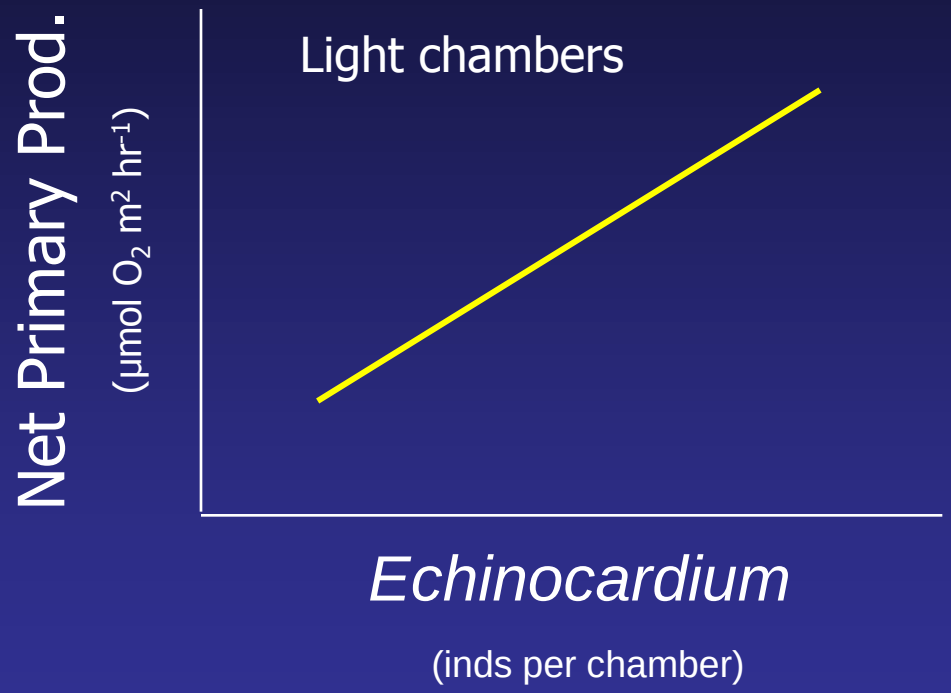
Predicting the consequences of species loss is critically important, given present threats to biological diversity such as habitat destruction, overharvesting and climate change[1]. Several empirical studies have reported decreased ecosystem performance (for example, primary productivity) coincident with decreased biodiversity[2–4], although the relative influence of biotic effects and confounding abiotic factors has been vigorously debated[5–7].




How do we translate up to ecosystem scales ?

Benthic primary production is positively related to *Echinocardium* density



Benthic microphytes utilised nutrients released by *Echinocardium*

Ammonium flux
(µmol NH_4^+-N m^2 hr^{-1})

Dark cha

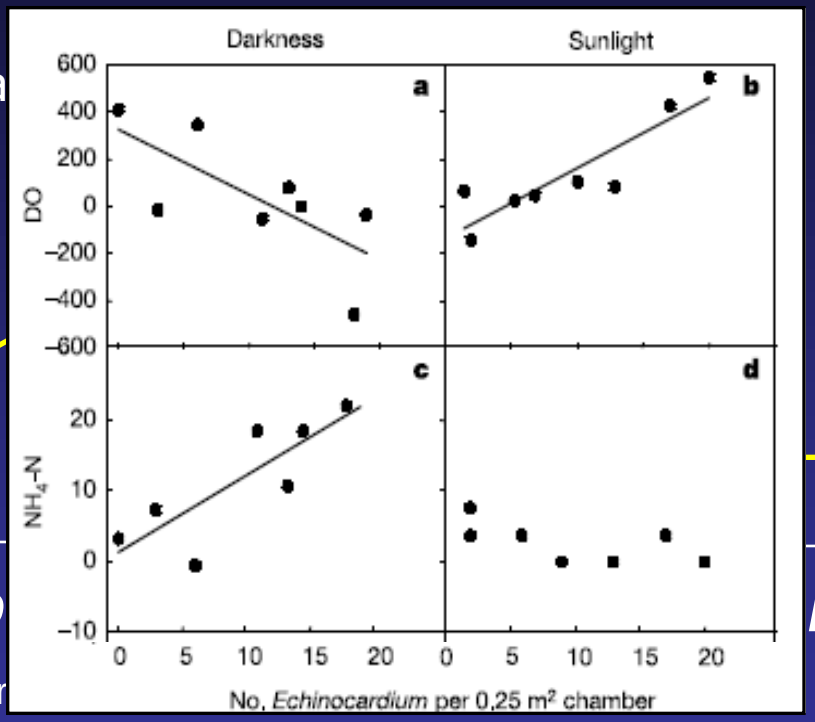
Light chambers

Echino

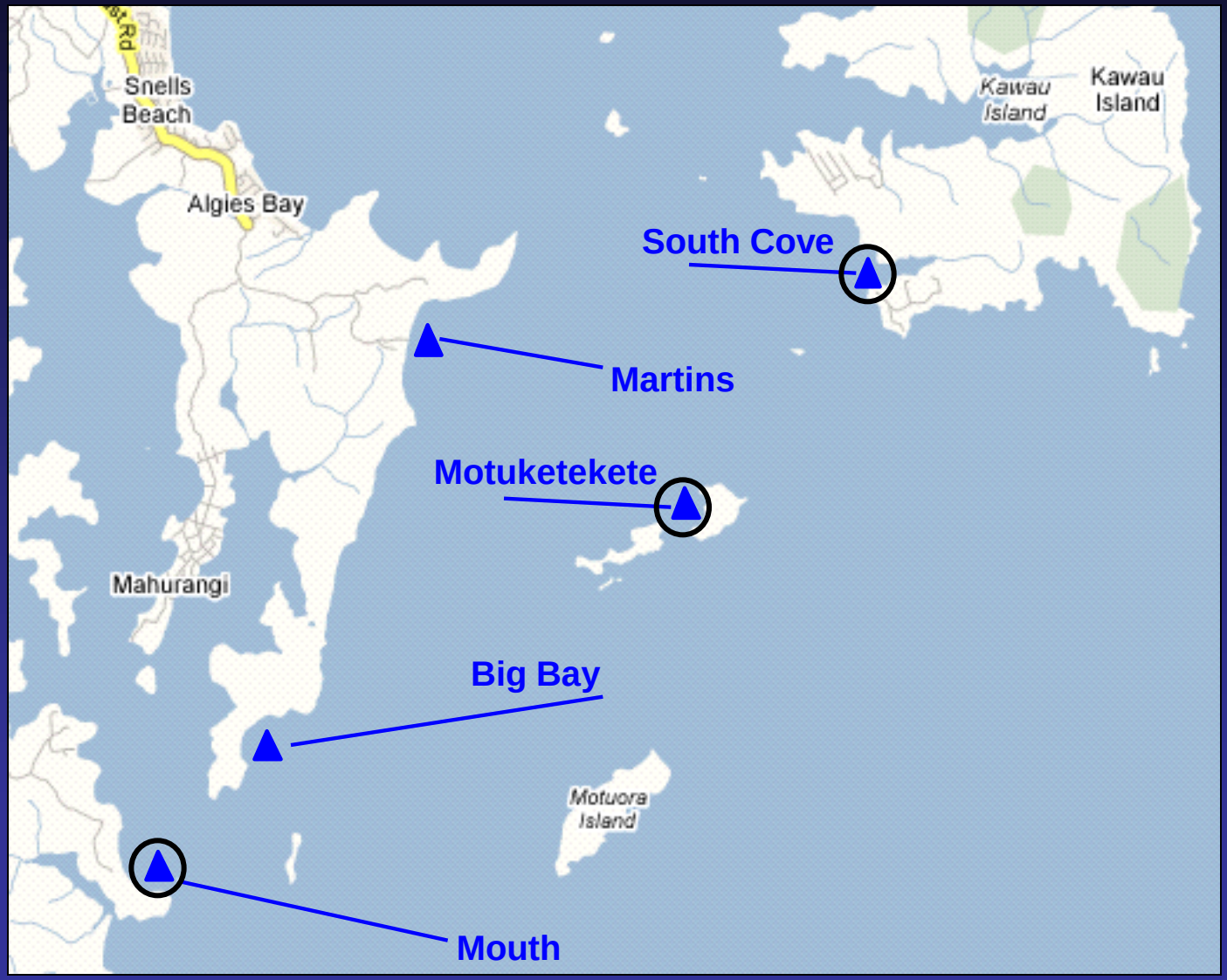
(inds per

Echinocardium

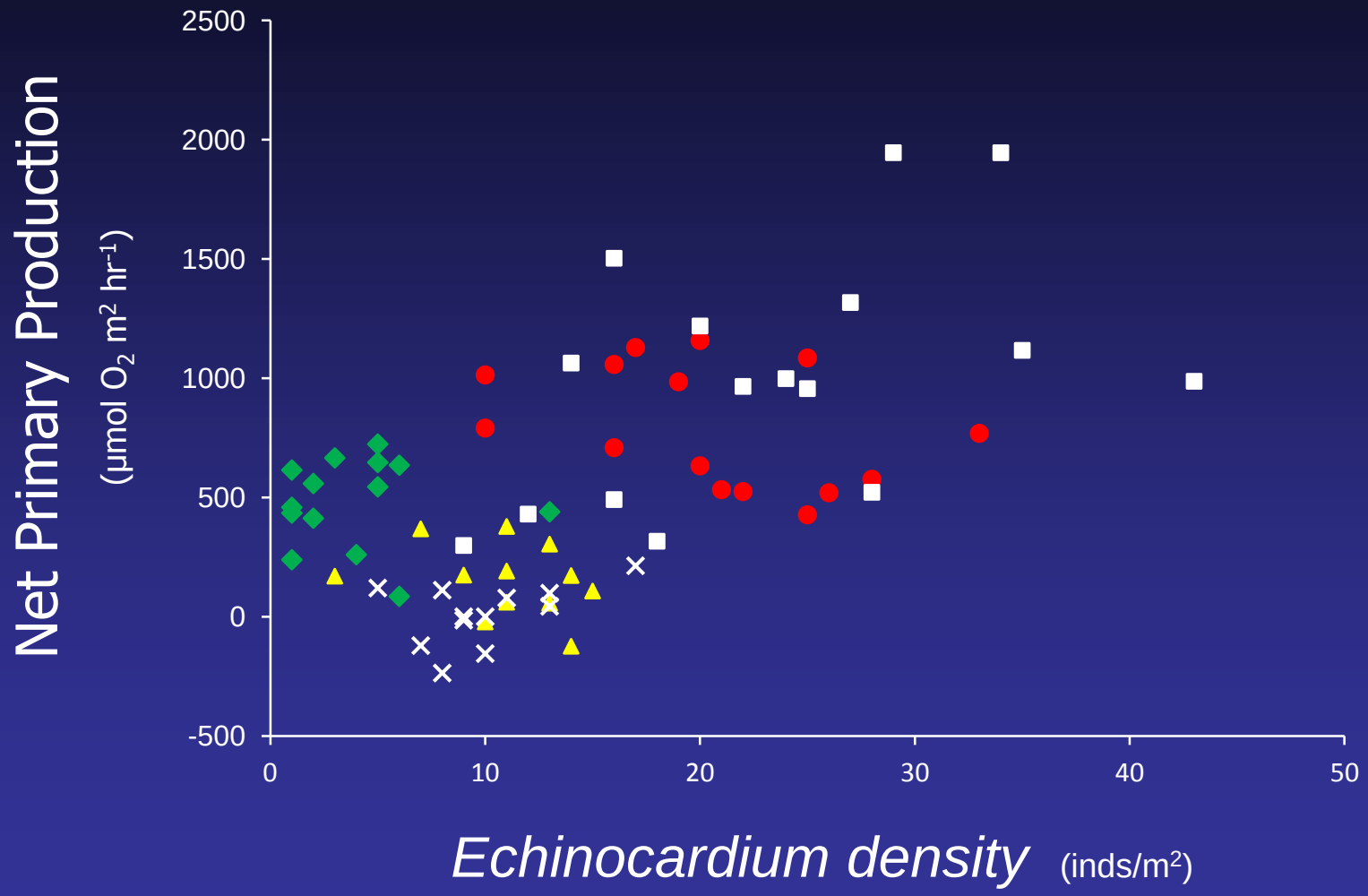
(inds per chamber)



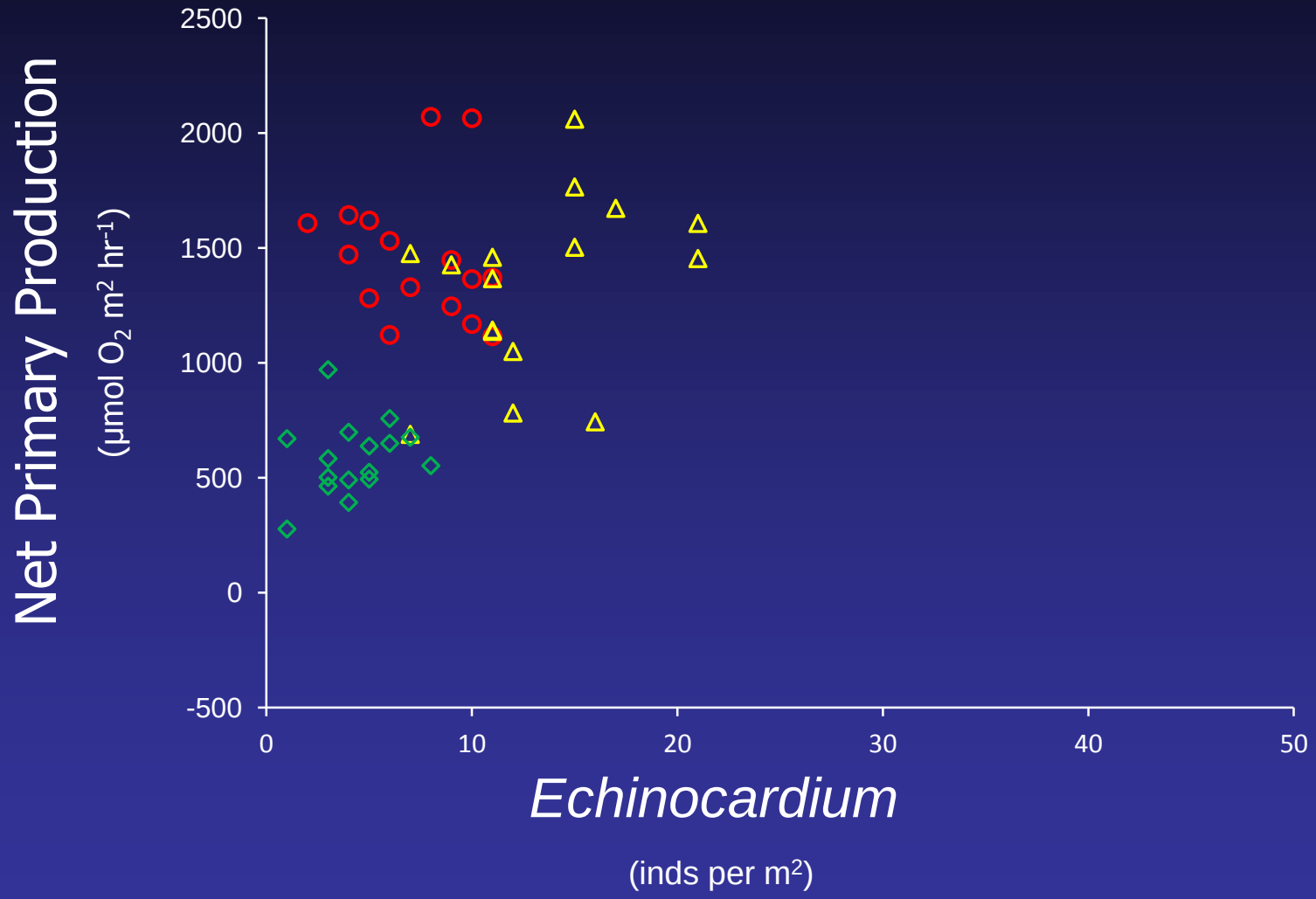
Fluxes measured at multiple sites, encompassing significant spatial and temporal heterogeneity



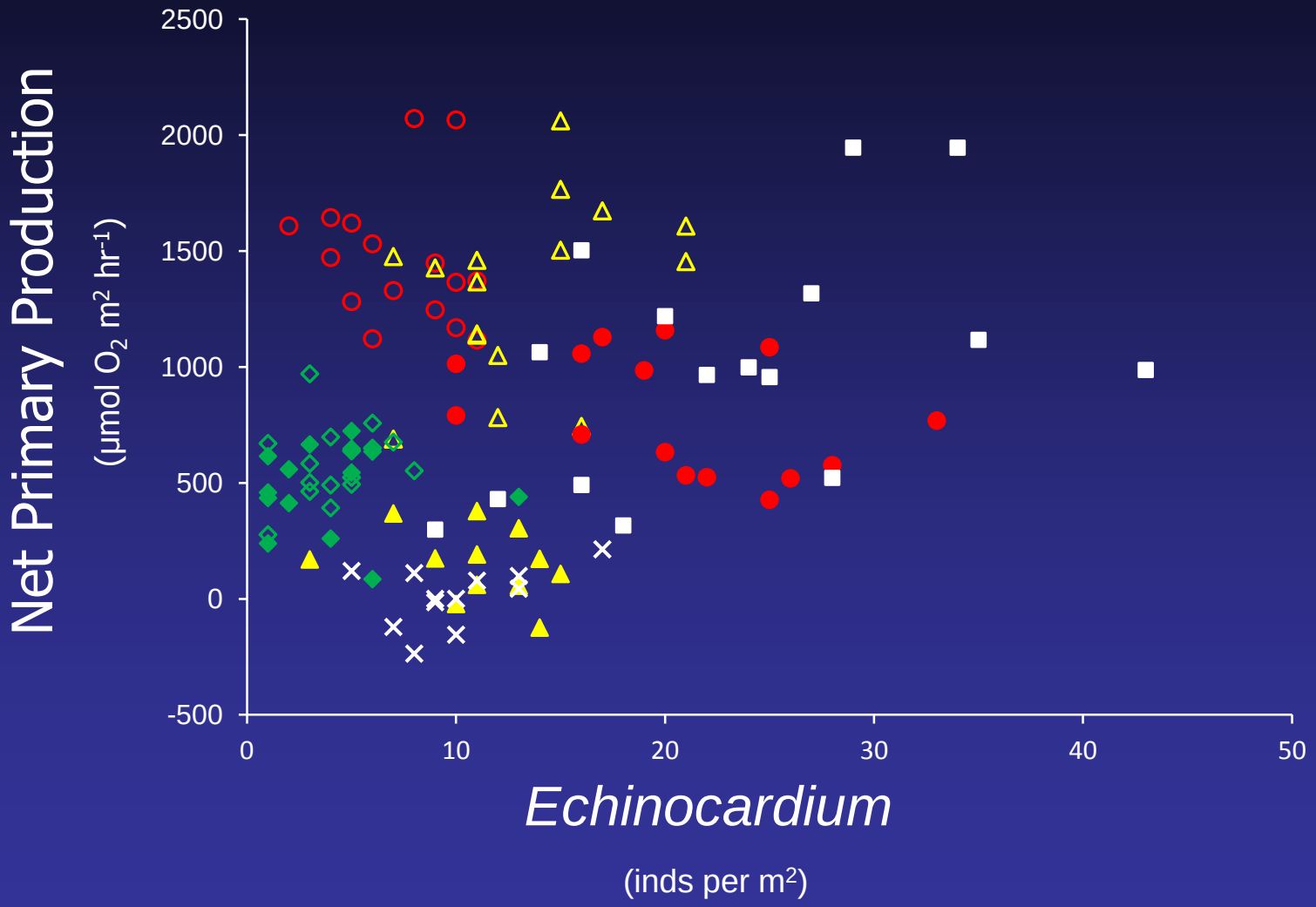
The positive *Echinocardium*-NPP relationship holds



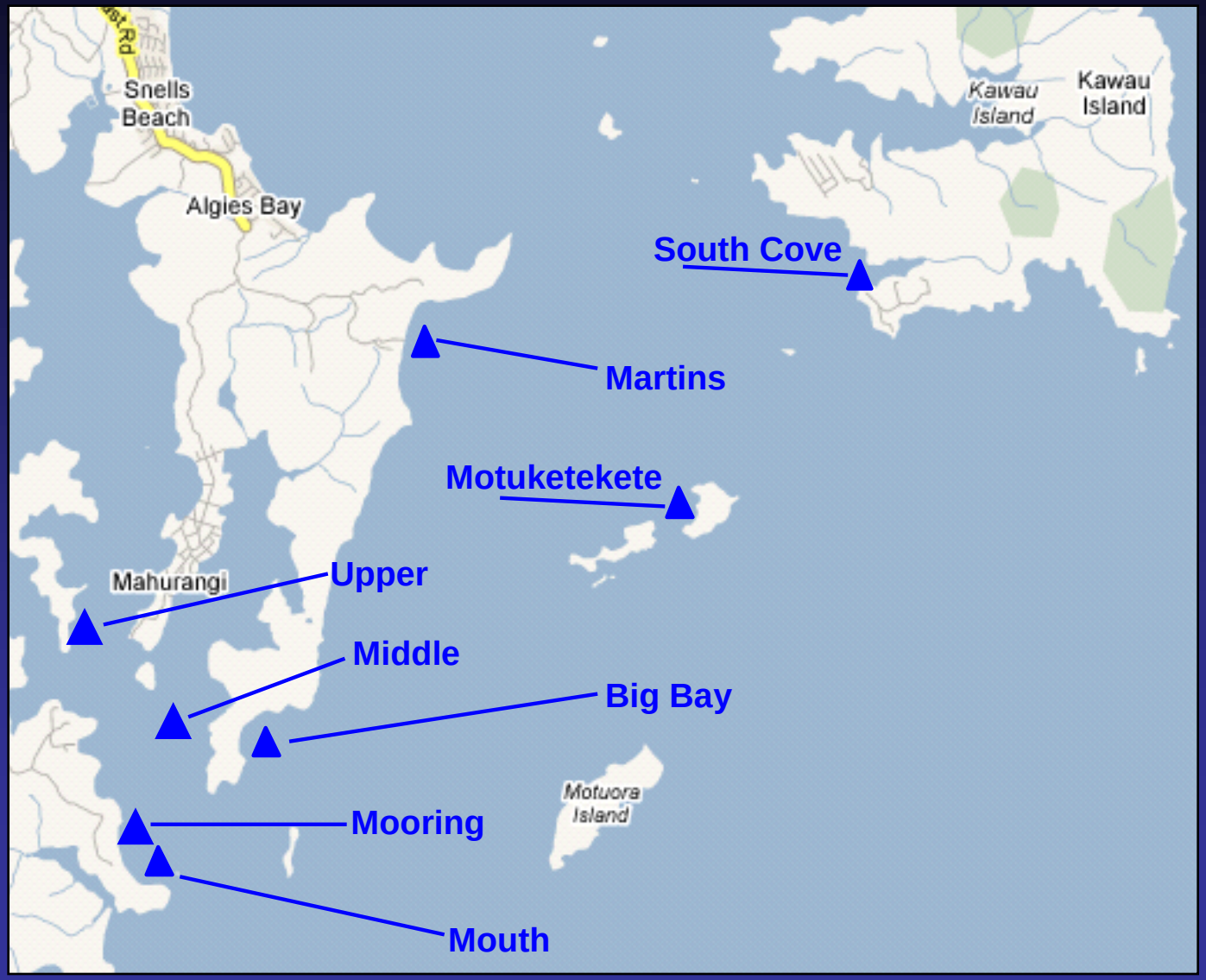
Echinocardium was the strongest predictor of NPP



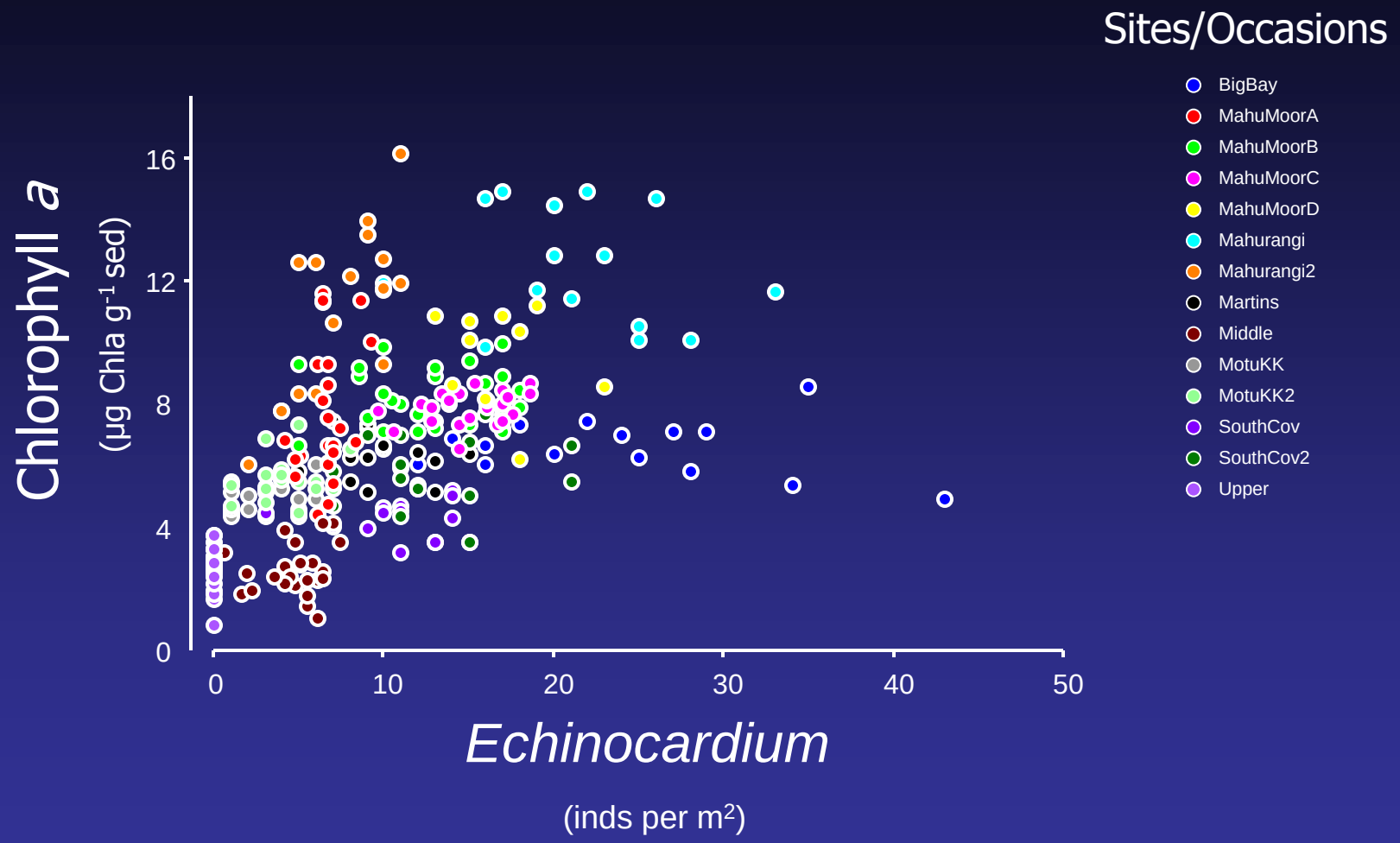
Weather-related variables explain variation in NPP when data from both years considered



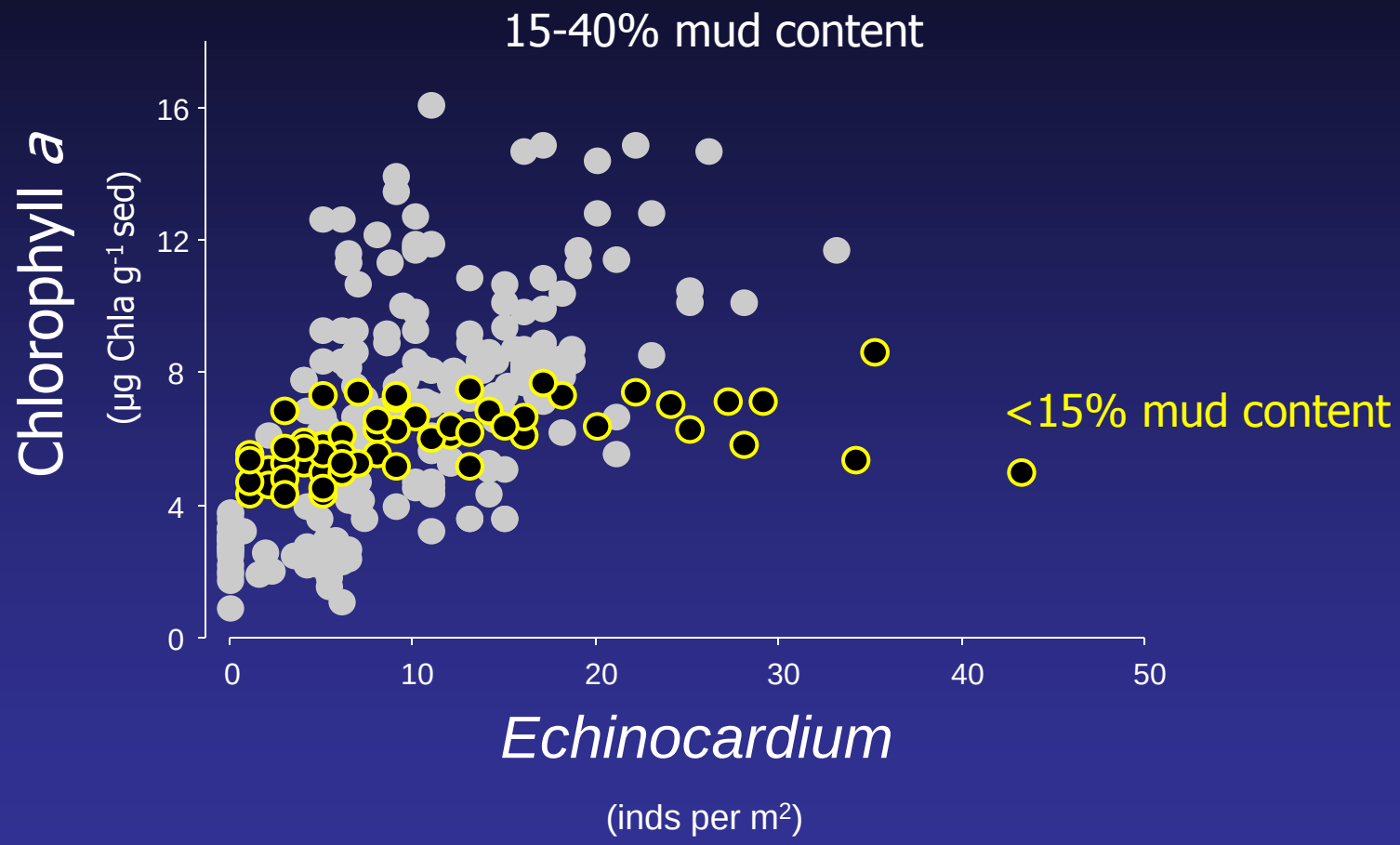
8 sites (14 occasions) with >16 paired *Echinocardium*-Chla measurements



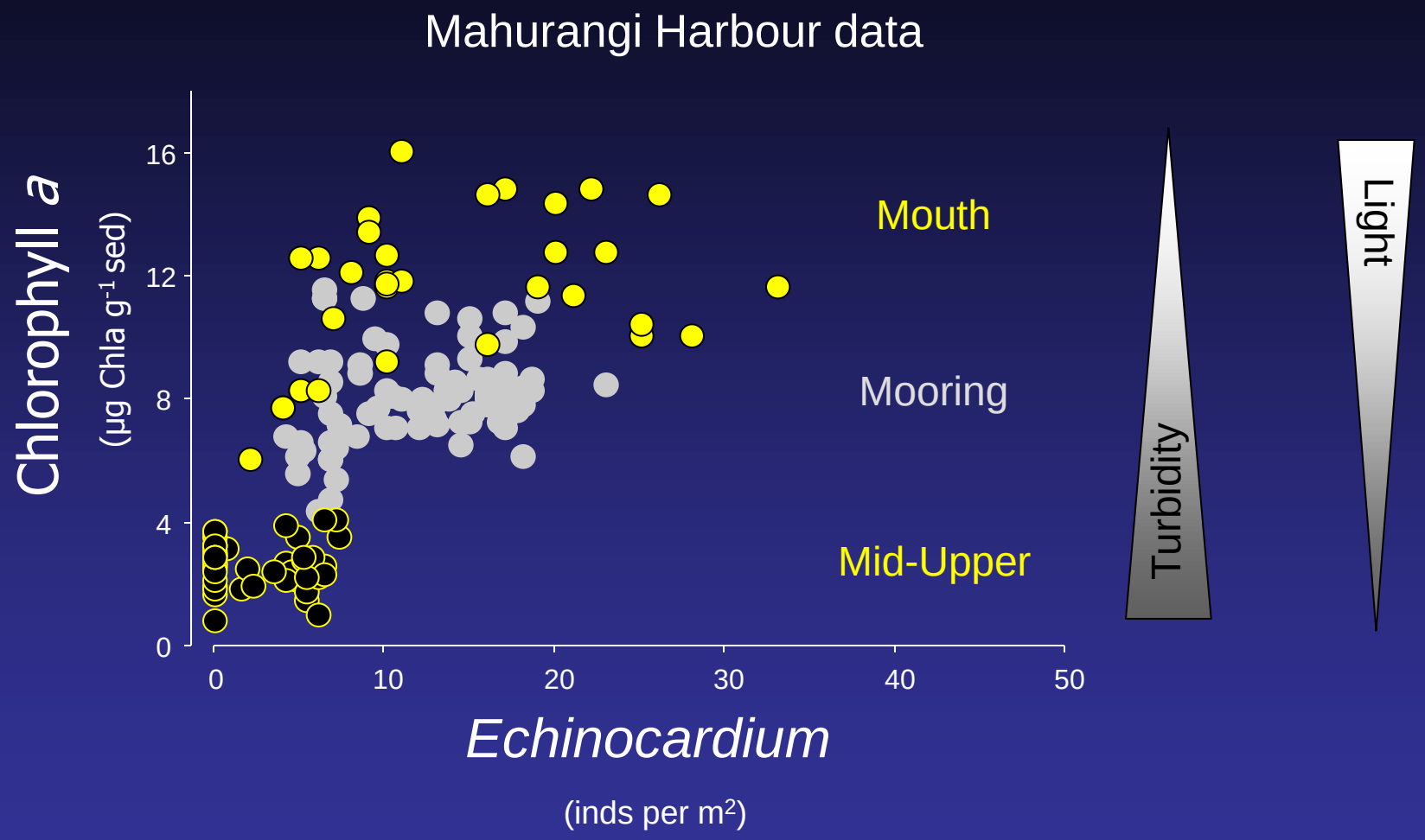
Echinocardium & Chla: all available data



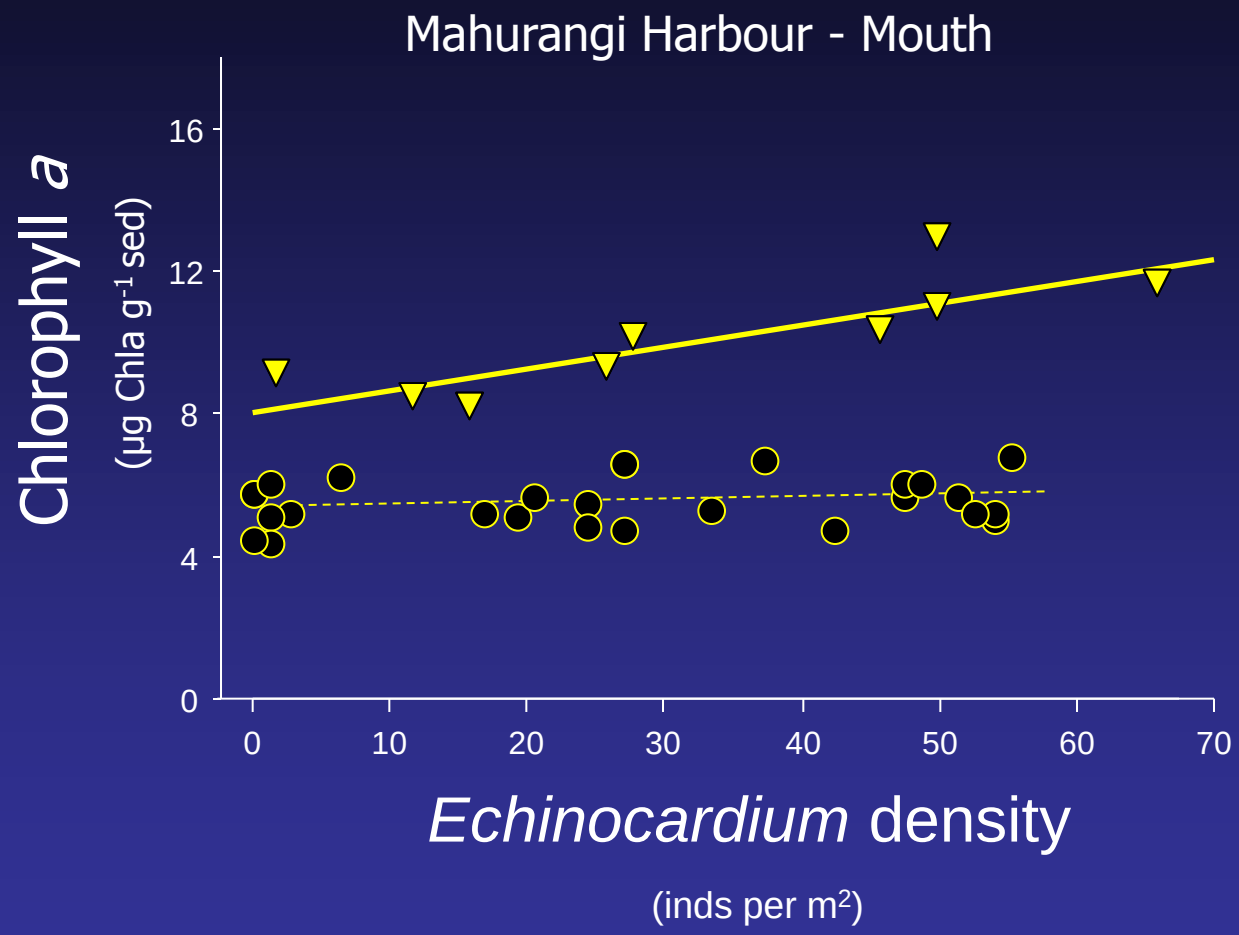
Habitat dependent *Echinocardium*-Chla relationship



Water column turbidity plays a role as well



Climatic context influences the result of the *Echinocardium* nutrient subsidy



March 2005

p = 0.006, r^2 = 0.690

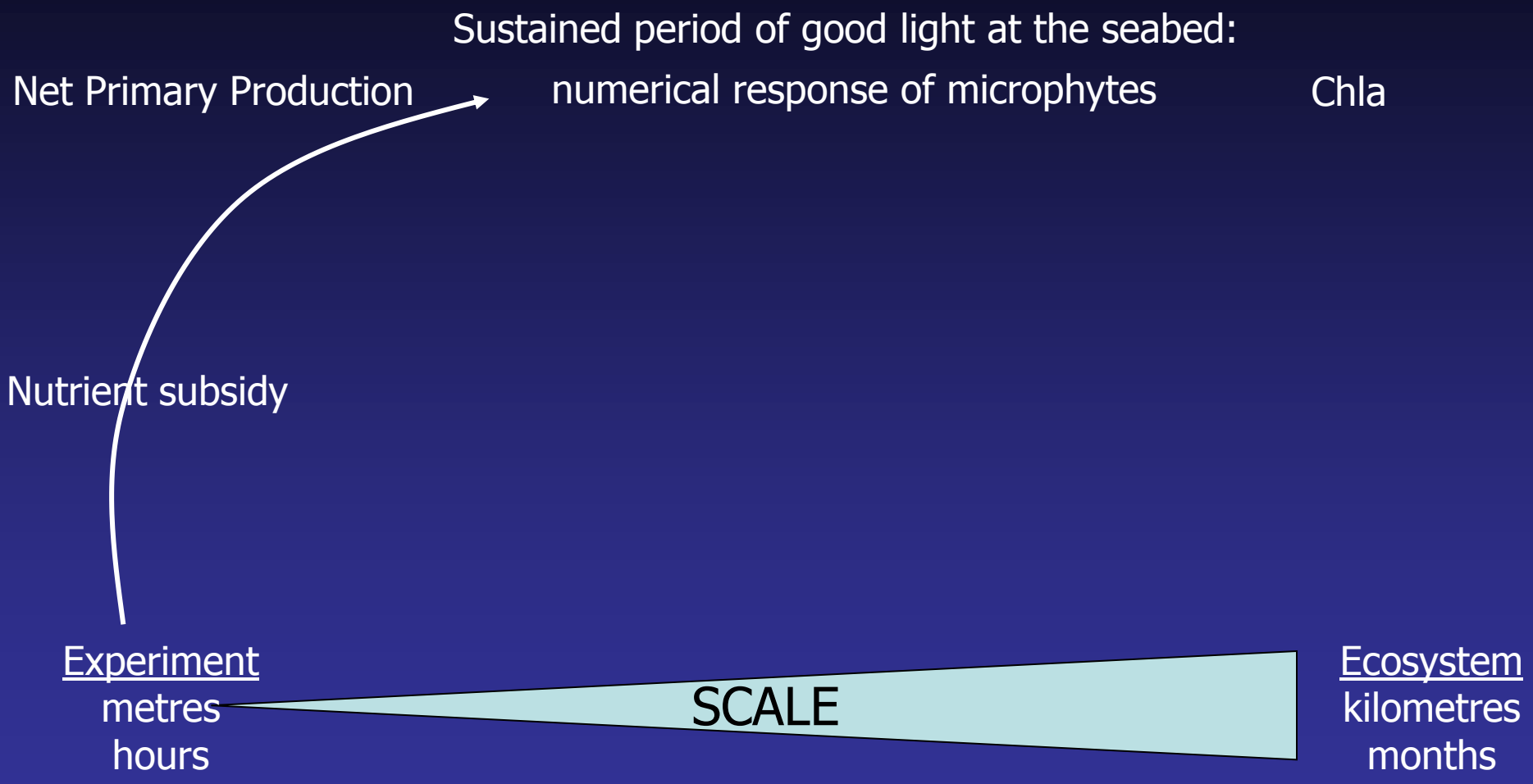
Good light climate

March 2006

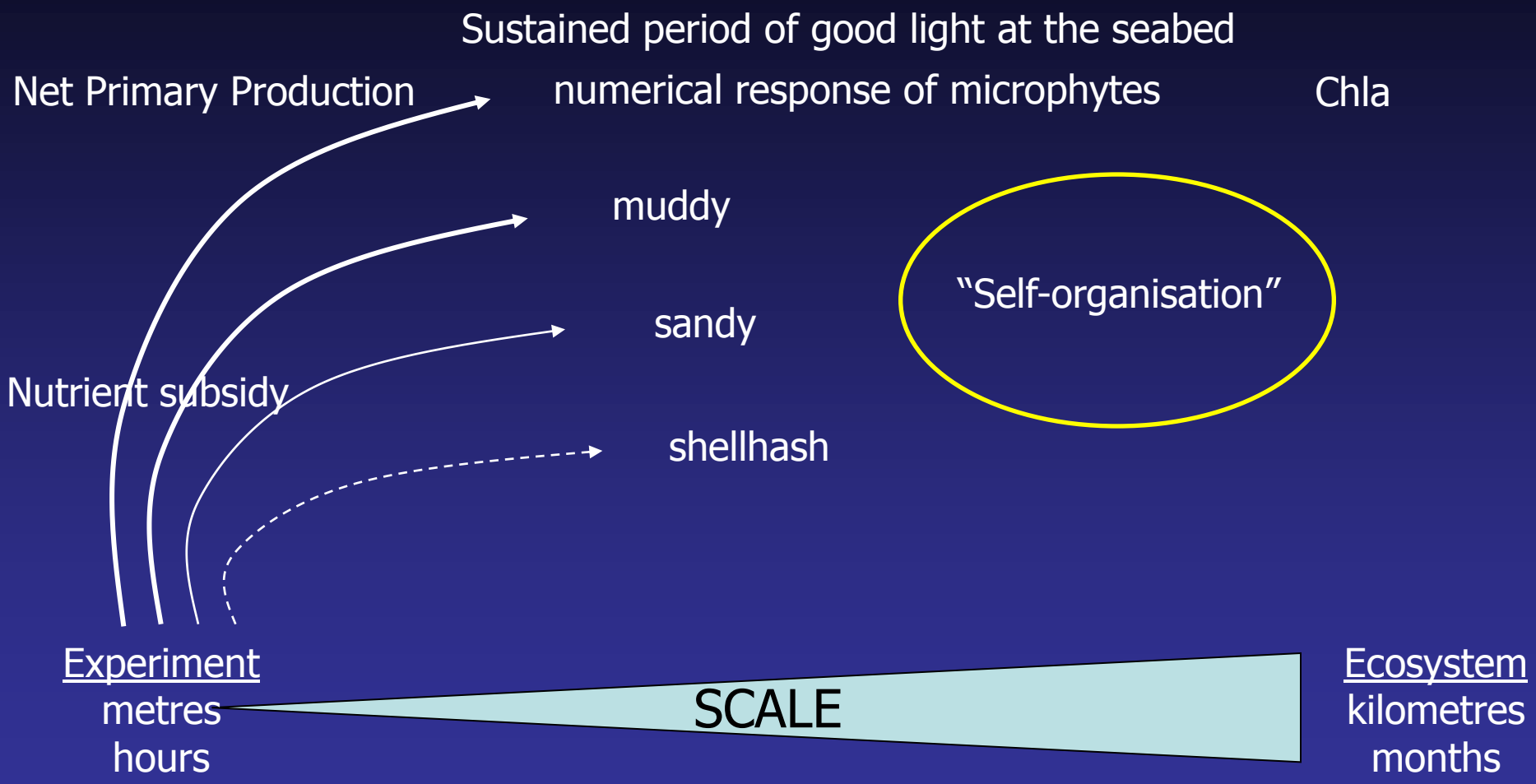
p = 0.277, r^2 = 0.047

Poor light climate

Summation


Sustained period of good light at the seabed:
Net Primary Production
numerical response of microphytes
Chla
Nutrient subsidy
Experiment
metres
hours
SCALE
Ecosystem
kilometres
months

Summation


Sustained period of good light at the seabed
Net Primary Production
numerical response of microphytes
Chla
muddy
sandy
shellhash
"Self-organisation"
Nutrient subsidy
Experiment
metres
hours
SCALE
Ecosystem
kilometres
months

CONCLUSIONS

Understanding the effects of fishing on benthic ecosystem functioning requires scaling up

We show the scalability of ecosystem functioning experiments involving a key bioturbating species that is affected by fishing

The *Echinocardium*-NPP relationship persisted across substantial environmental heterogeneity

The *Echinocardium*-NPP relationship amplified over time, resulting in a positive *Echinocardium*-CHla in the longer term

Results were modified by climatic context and habitat heterogeneity

Cross-scale interactions and mutually reinforcing feedbacks were evident, suggesting some degree of self-organisation in the system

Although the approach takes time (many observations, experiments) it is likely the most promising path to predicting large scale impacts

Acknowledgements

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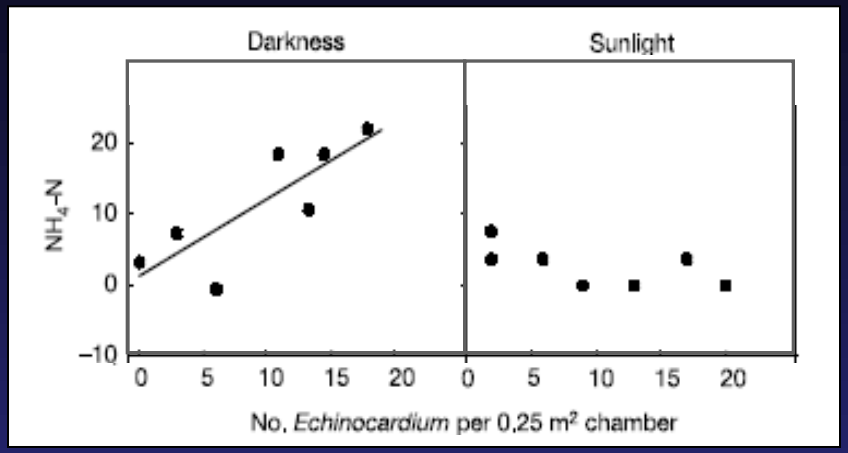
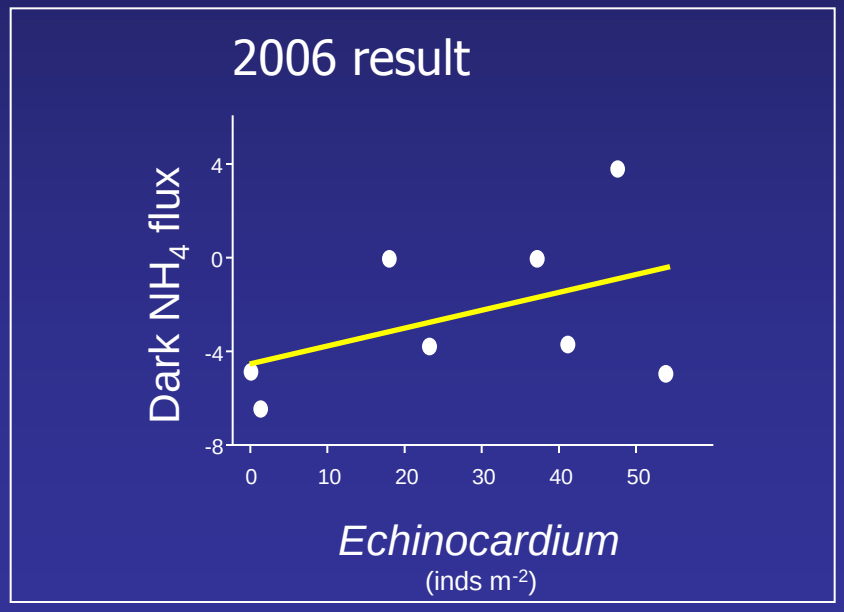
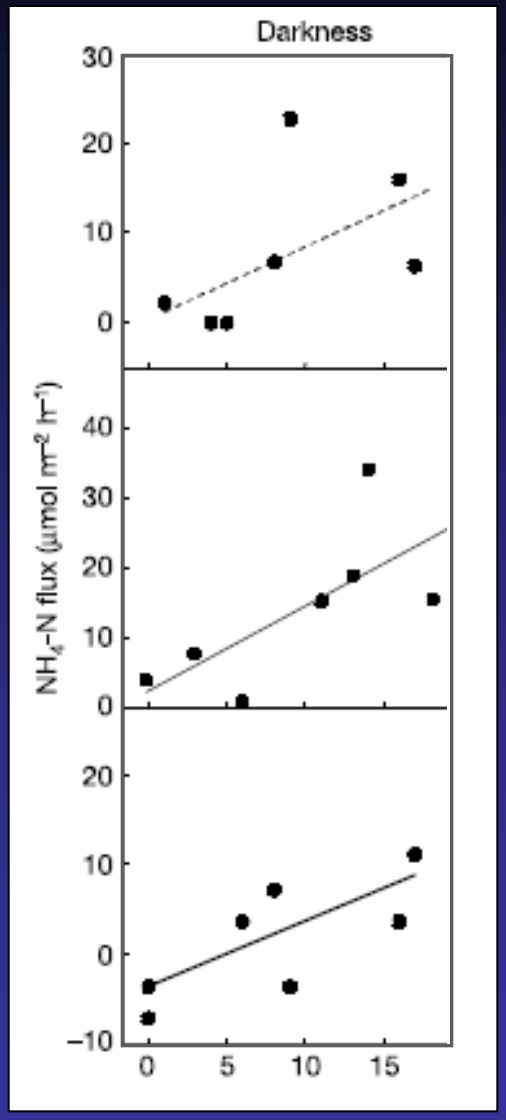
Taihoro Nukurangi

Thanks to the many divers & biolab technicians

Ammonium release by *Echinocardium* is consistent







Jan 03

May 04

Jan 04