Benthic production and energy export from man-made structures to natural soft bottoms: repercussions for food provisioning services?

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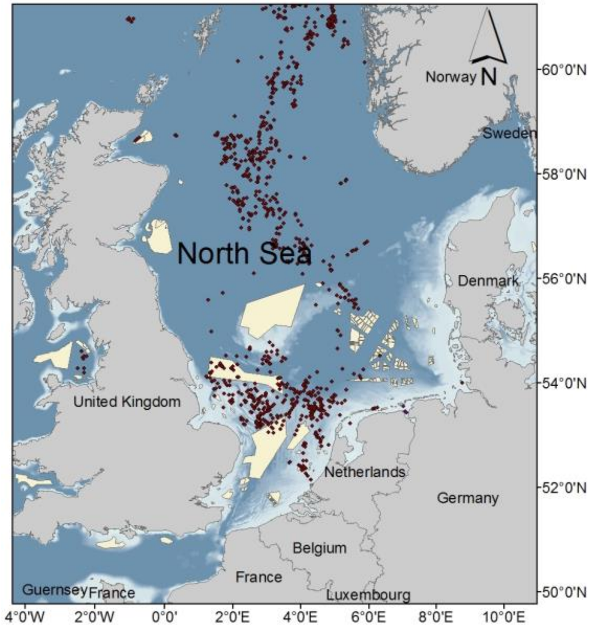
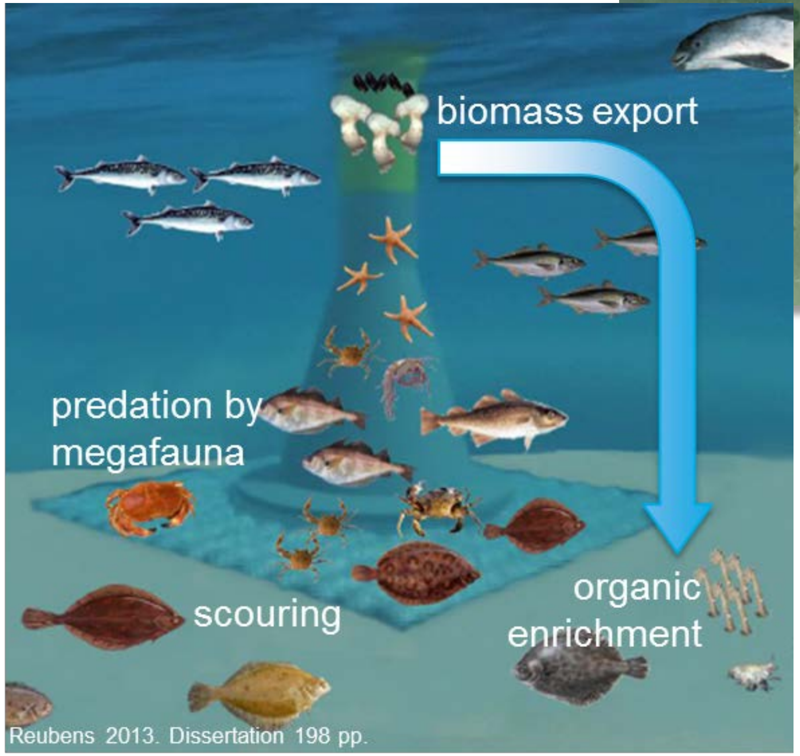
background and study aims

- rapid expansion of man-made structures (MMS) → offshore wind farms
- faunal differences – new players: hard substrates ←→soft sediments
- benthic production (species energy turned into biomass) major food source and relevant ecosystem service

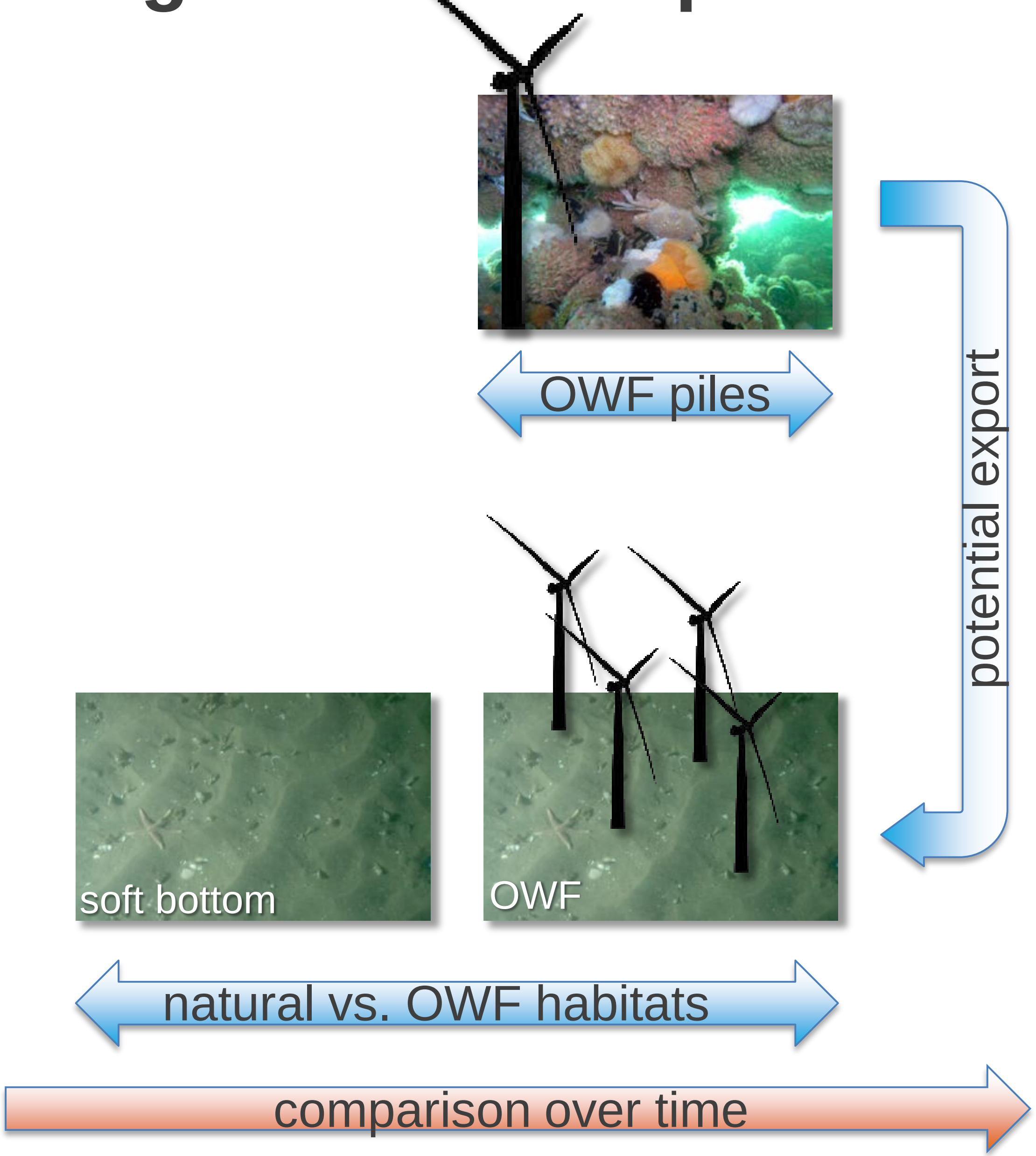
do the potential discharges from OWF piles affect benthic functioning?

- how much extra biomass on piles?
- how much energy is potentially exported?
- is production increased in the soft bottom?

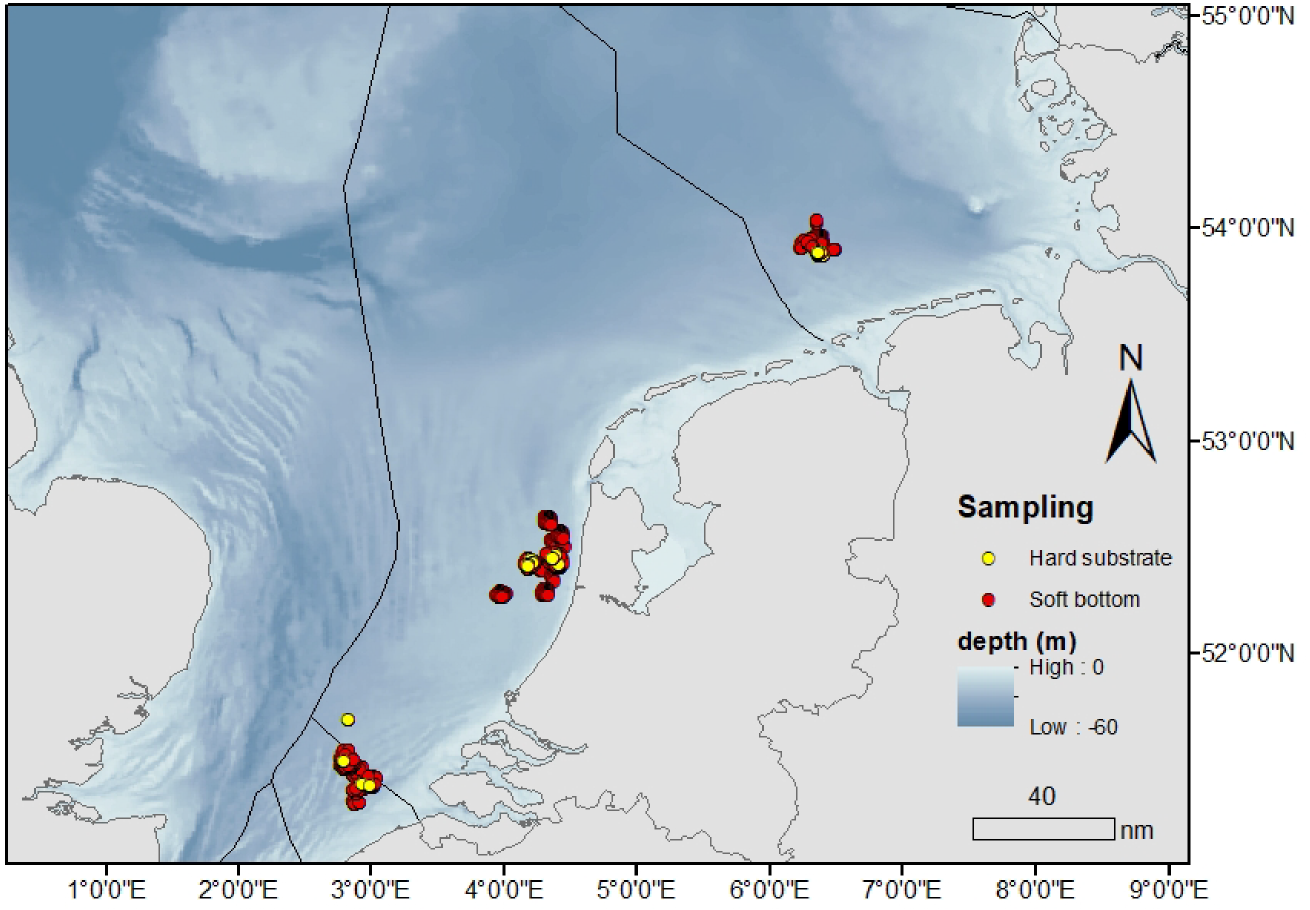




general concept



meta analysis: 6 OWF, Southern North Sea



methods: meta analysis

- Generalised linear mixed models (GLM) to link production to environmental parameters (OWF as random factor)
- effect size (Cohen's d with Hegde's correction[2]) for comparability between different structures & habitats

$$Cohen's\ d = \frac{\bar{X}_I - \bar{X}_C}{S}$$

$\bar{X}_I$ mean of impact group
$\bar{X}_C$ mean of control group
S pooled standard deviation

- calculation of potential export ($B_{L/G}$: biomass loss/gain)

$$B_{L/G}\ [gC\ m^{-2}] = Biomass_{t2} - (Biomass_{t1} + Production_{t1 \rightarrow t2})$$

- calculation of potentially Production Impacted Area (PIA)

$$PIA\ [m^{-2}] = \frac{1}{Detection\ Level} * \left(\frac{Biomass - Export_L * Trophic\ Efficiency}{Production_{soft-bottom\ community}}\right)$$

data

~4300 samples from ~540 stations

~ 800 taxa

fouling community & infauna (soft bottom)

UNDINE

INSITE

parameter

biodiversity, abundance, biomass (B $gC\ m^{-2}$)

secondary production, model[1] (P $gC\ m^{-2}\ y^{-1}$)

[1]Brey (2012) Limnology and Oceanography Methods, 10, 581-589
[2]Hedges, Gurevitch, Curtis (1999) Ecology, 80, 1150-1156
[3]Lindeman (1942) Ecology, 23, 399-418

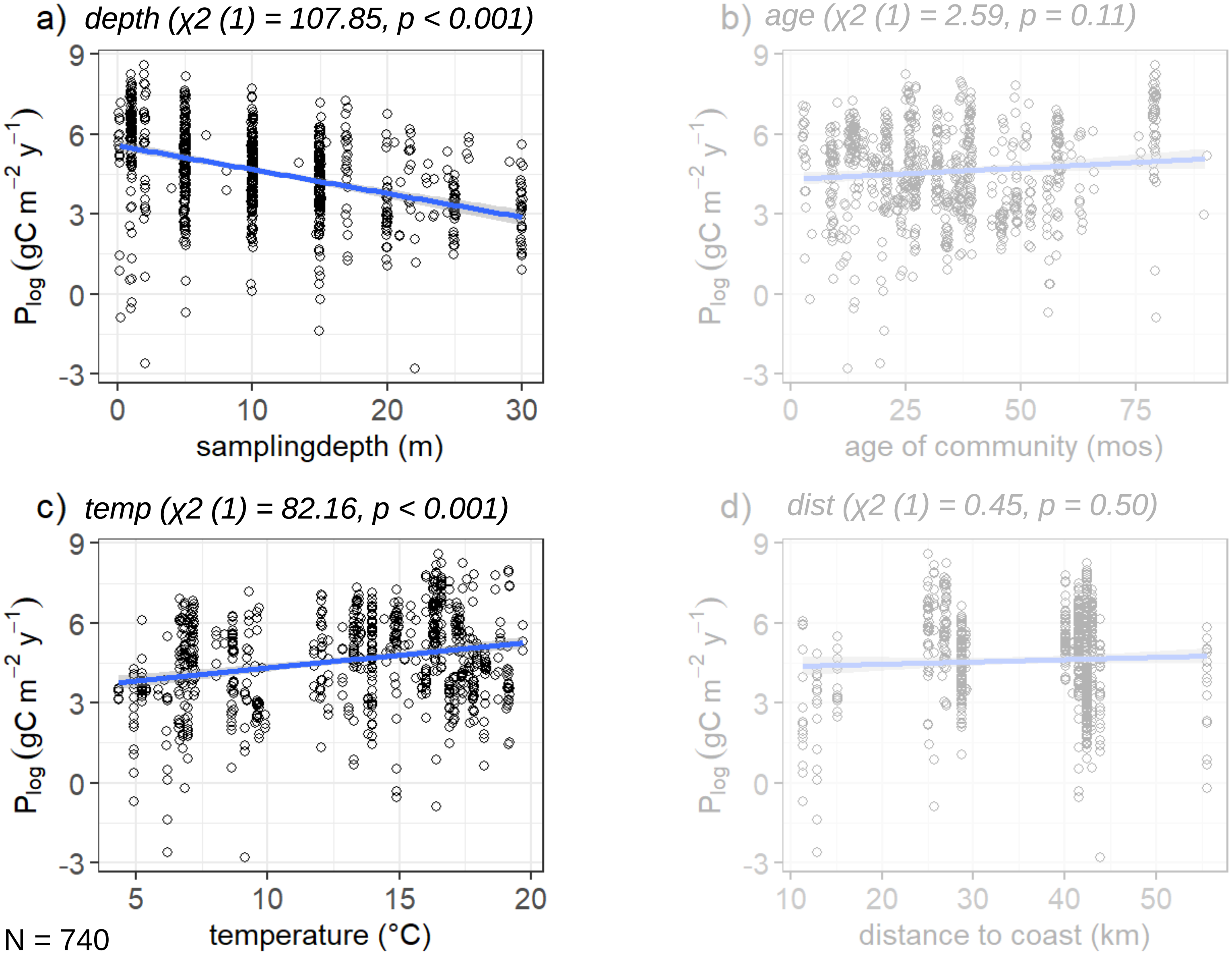
energy flow: hard substrate

↓ depth at structure

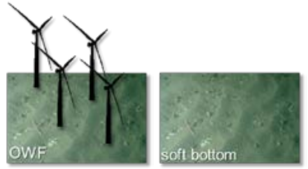
↑ temperature

no change over age

no change to coast distance



energy flow: soft bottom

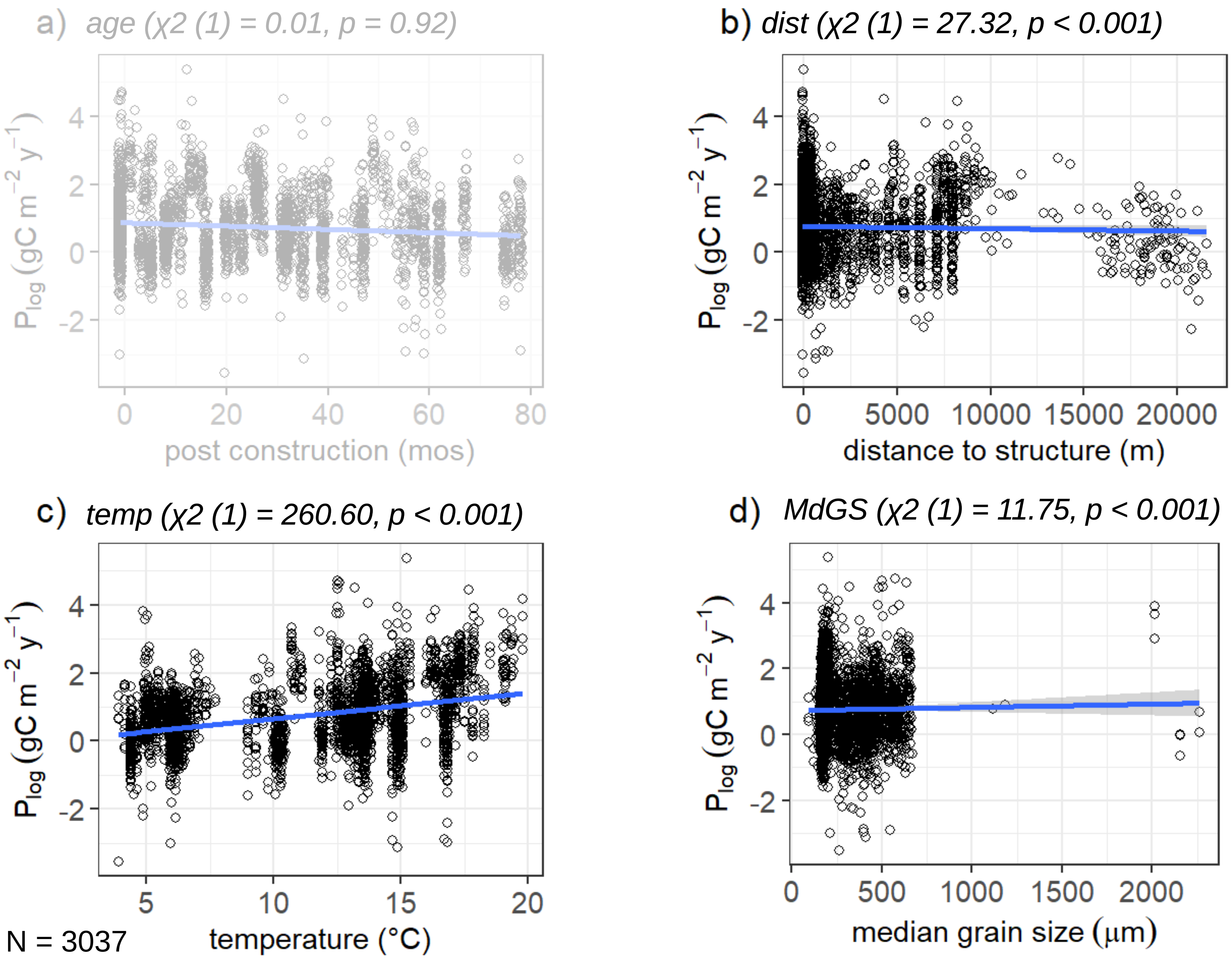


no change over age

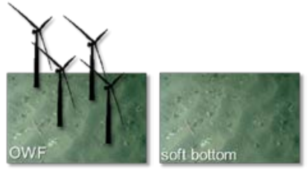
↑ distance to structure

↑ temperature

↓ median grain size, projects



effect size



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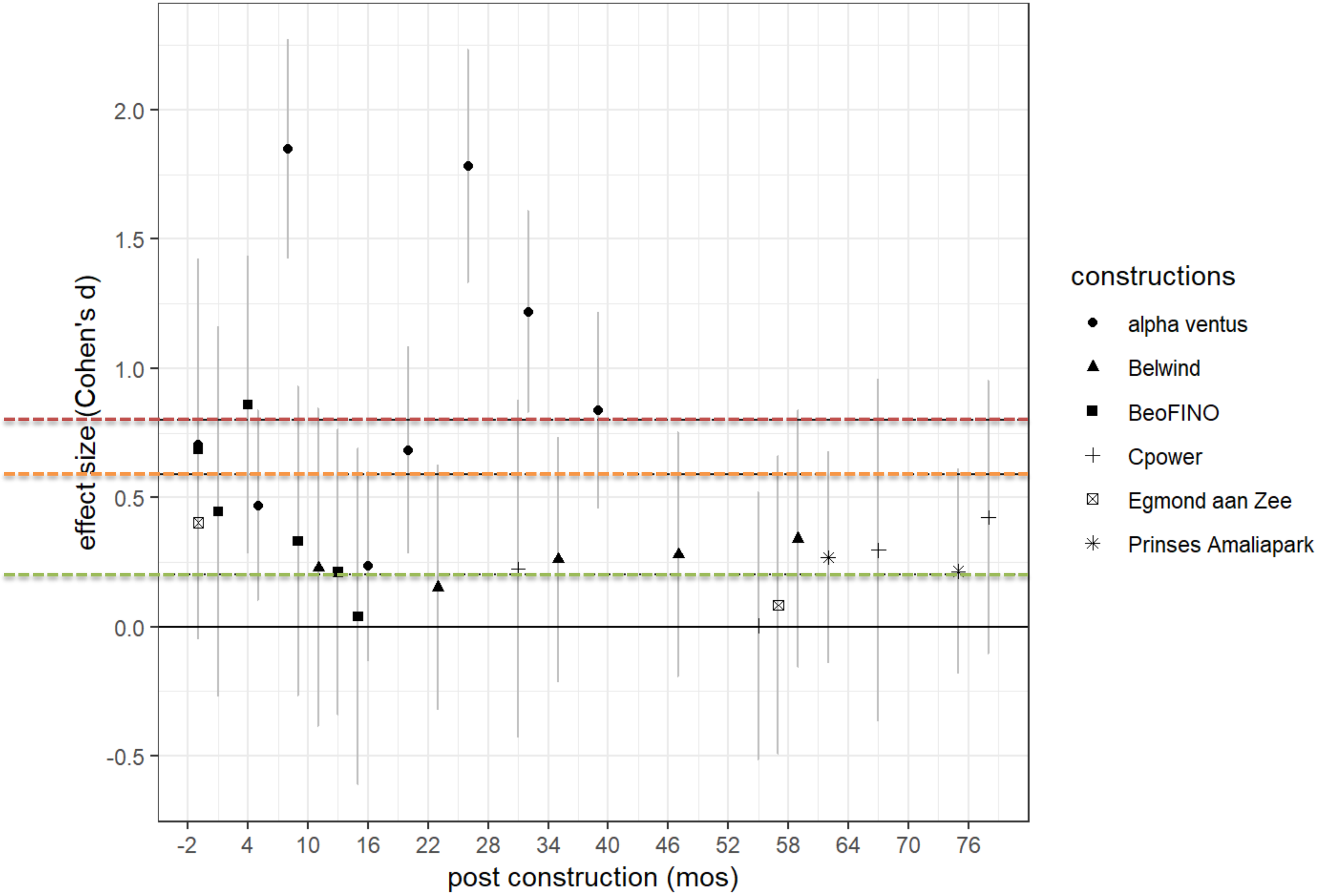
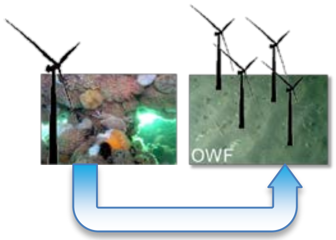
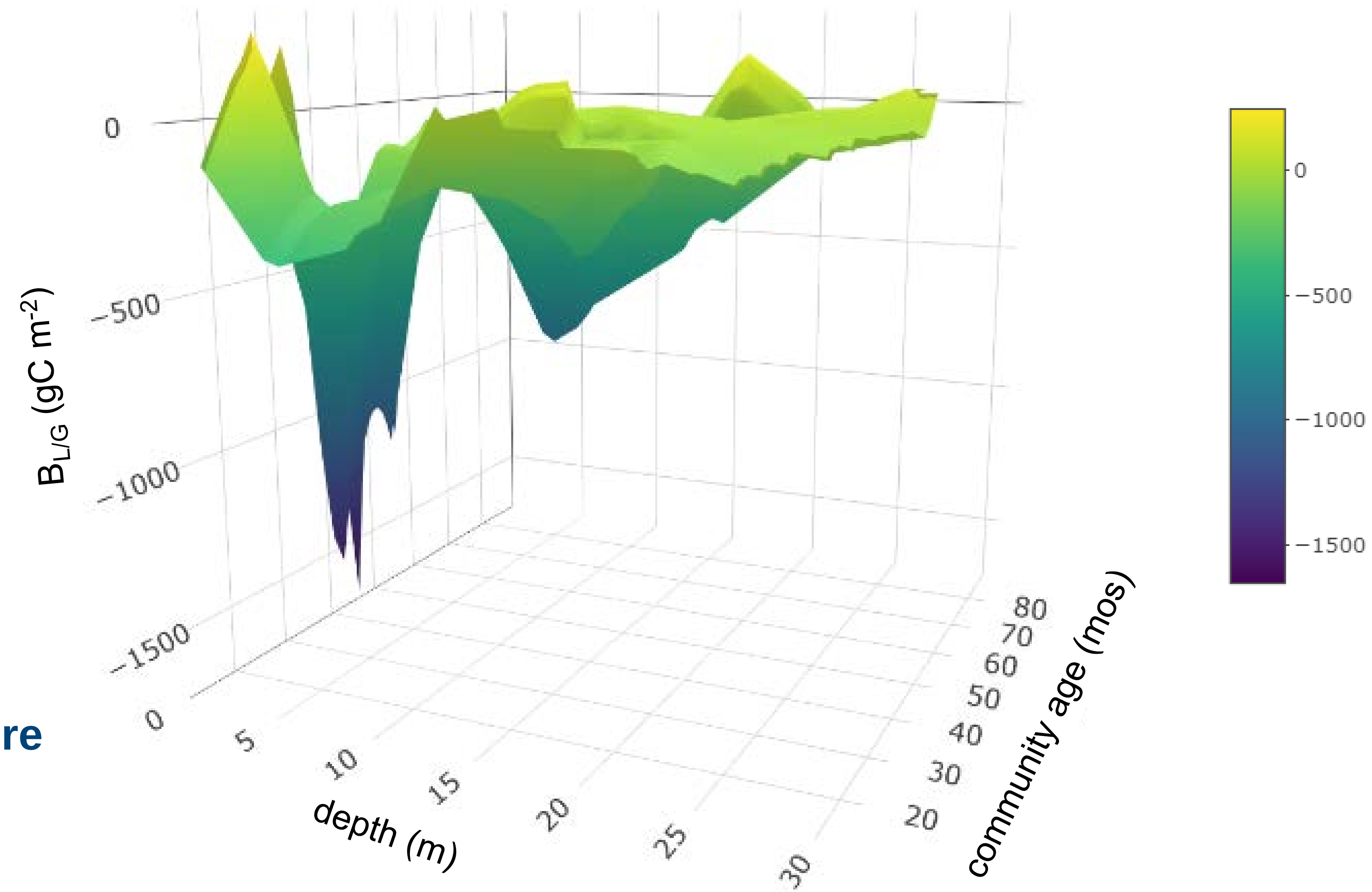


Cohen (1992) Psychological Bulletin, 112, 155-159
Hedges, Gurevitch, Curtis (1999) Ecology, 80, 1150-1156

potential energy export





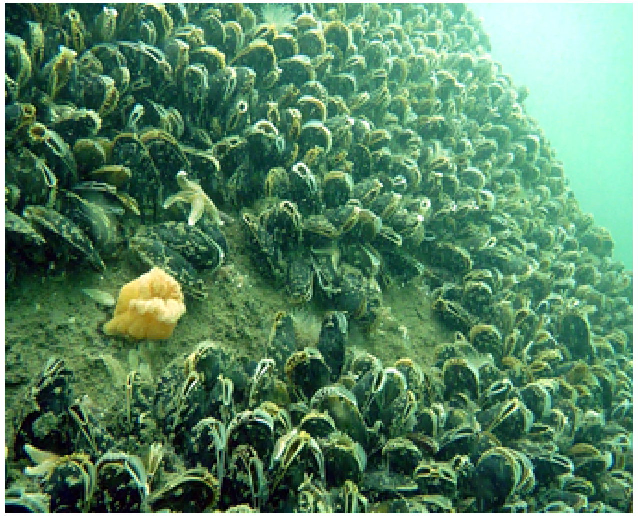
highest variability & highest loss in 0-5 m depth of structure

$B_{L/G} = B_{t2} - (B_{t1} + P_{t1\rightarrow t2})$, N = 159

potential energy export

biomass export

biomass m^{-2} y^{-1}	5.3 kg
biomass / windmill (10m!)	1.7 t
biomass / alpha ventus farm	20.5 t
biomass / all German wind farms	15000 t

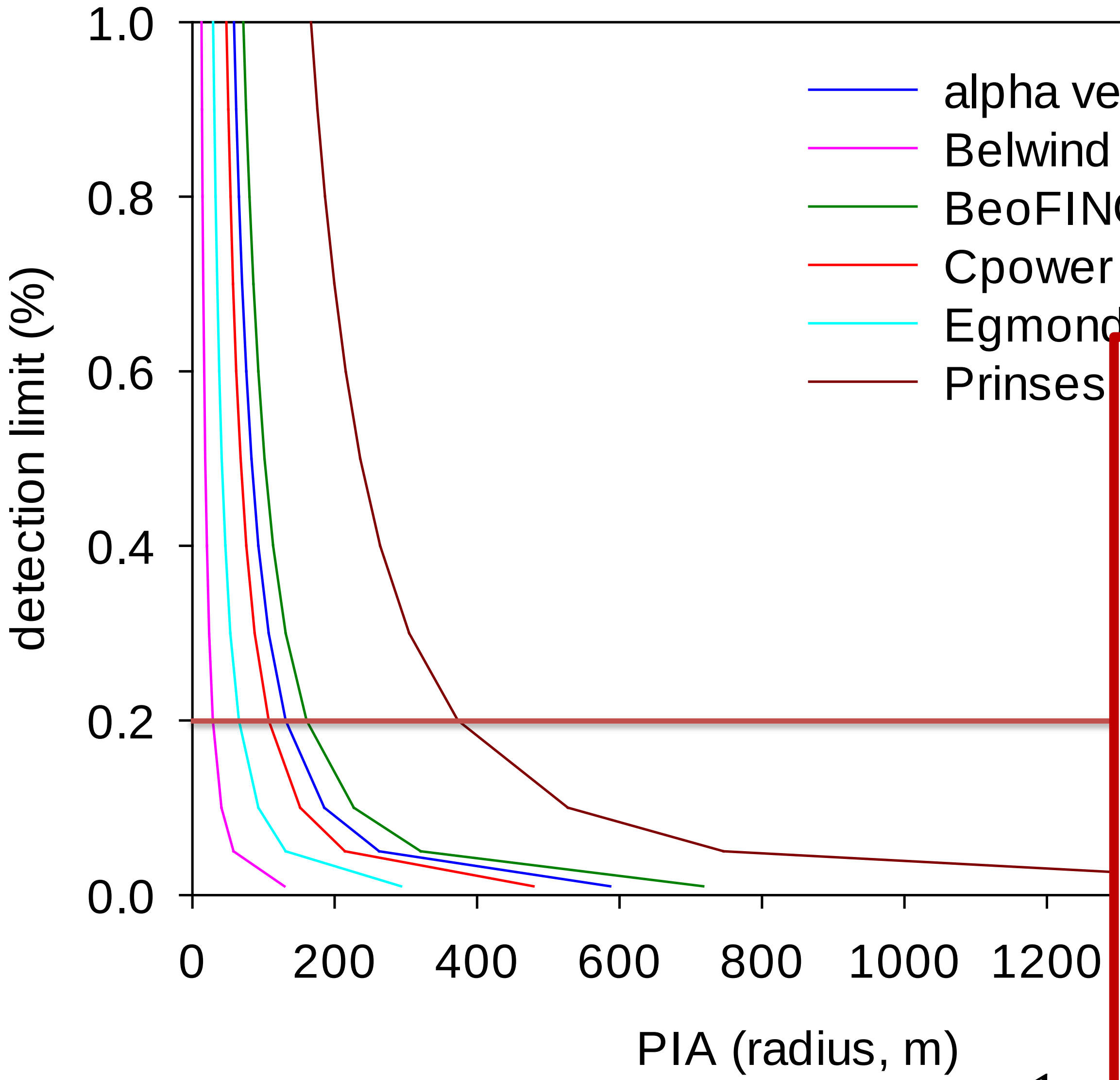


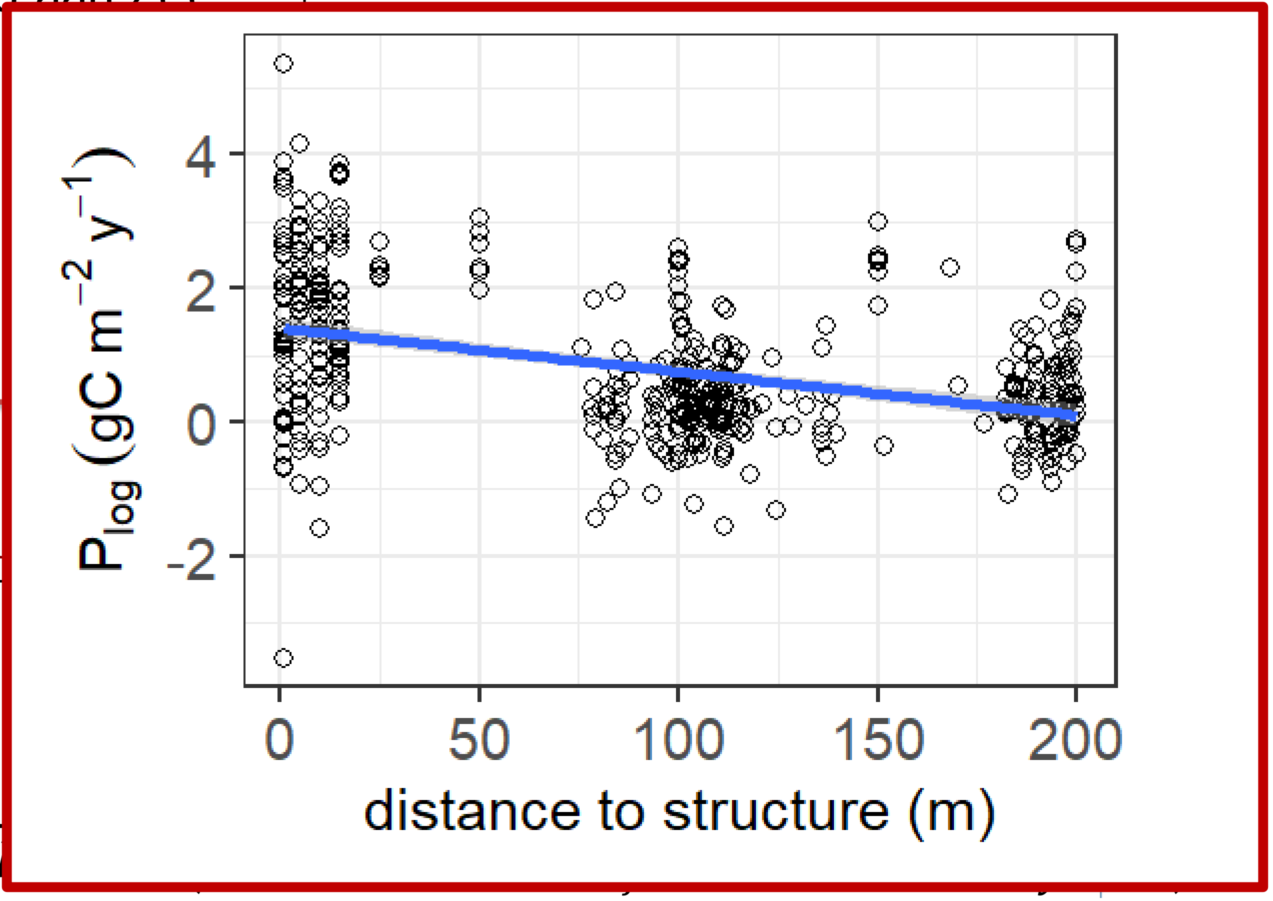
turbine scale
+ 38%

wind farm scale
+ 5%

regional scale (German EEZ)
+ 0.4%

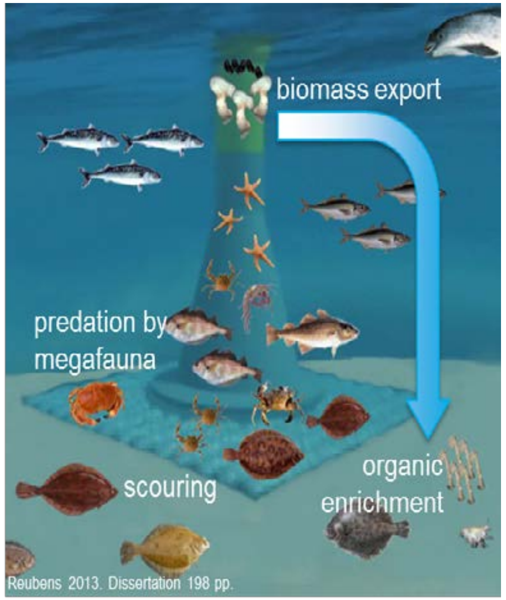
PIA: production impacted area





$$PIA\,[m^{-2}] = \frac{1}{Detection\ l}$$

summary and ecological relevance



hard substrate	• highest production at upper structure parts • spatial differences: higher production in German/Dutch waters
export	• high export from structure to surrounding but also recruitment • highest export from upper structure parts
soft bottom	• higher production in reference areas, however • soft bottom changes within natural range
PIA	• Detection limit of 20% ~200 m, local phenomenon • Overlapping PIA between turbines (>500 m) at <5%

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ANSWER: YES and NO

- soft bottom: changes too small to affect benthic invertebrates on larger scales

  changes within the natural range, local effects of benthic production (wrong scale in monitoring?)
- Hard-substrate: food source, direct feeding (megafauna/fish not part of this study)
- further studies needed on (a) large mobile epifauna & demersal fish species (attraction-production hypothesis) and (b) higher number of turbines and long-term changes

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Thank you