Climate and anthropogenic effects on structure and functioning of the North Sea ecosystem

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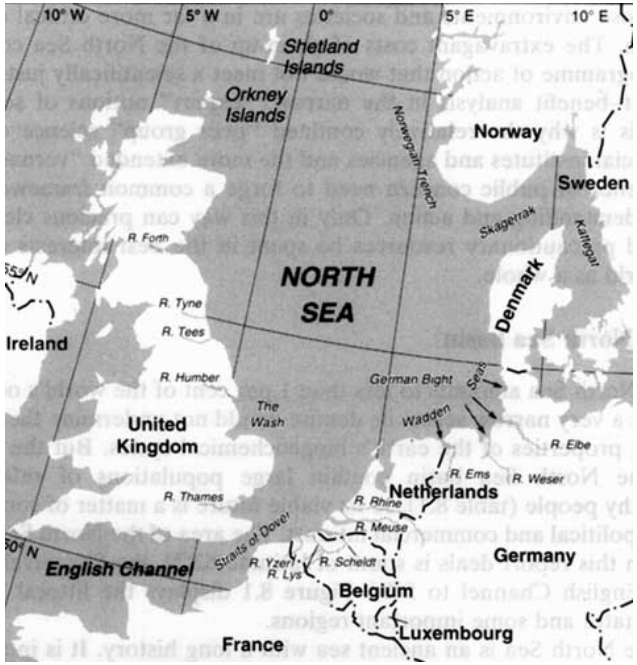

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ECO DRIVE
Drivers of Change in the North Sea Ecosystem

Methods & Analyses

- **Generalized Additive Models** (GAMs)
- **Non-Additive Threshold-GAMs** (T-GAMs; Ciannelli et al. 2004)
  - Finds periods with and without (or different functional) relationships & and a threshold

1. AMO & NAO effect on North Sea SST

- Additive models vs. non-additive (effect of NAO relative to AMO)

2. AMO, NAO & SST effects on Trophic Levels

- Additive AMO- & NAO-models vs. SST-models
- Non-additive vs. additive AMO- & NAO-models

3. AMO & Fisheries effects on Trophic Levels

- Non-additive vs. additive AMO- & Fishing mortality-models

Data

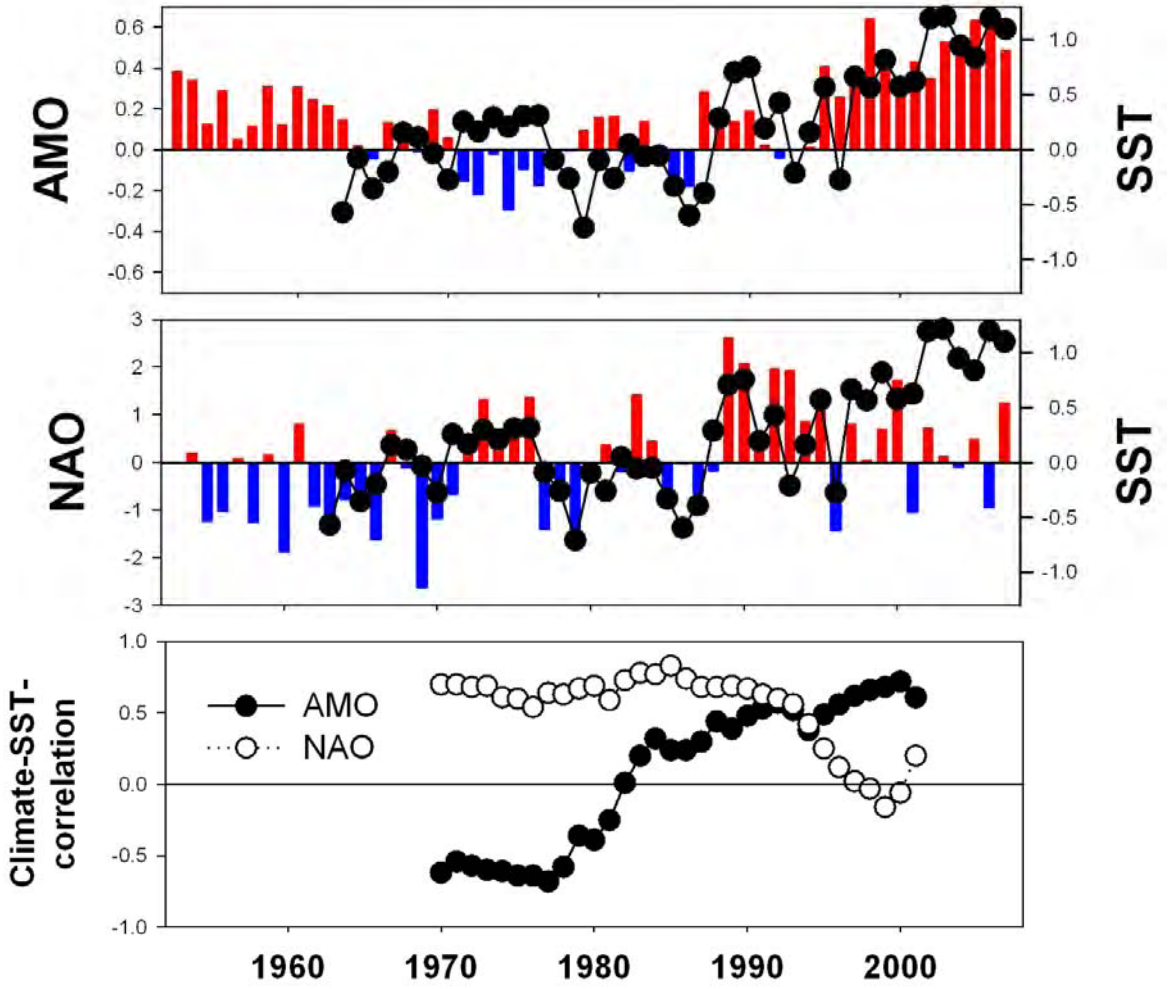
Data (1963- 2007)

- Plankton – Continuous Plankton Recorder (SAHFOS)
- Fish – multispecies fisheries model output (SMS)

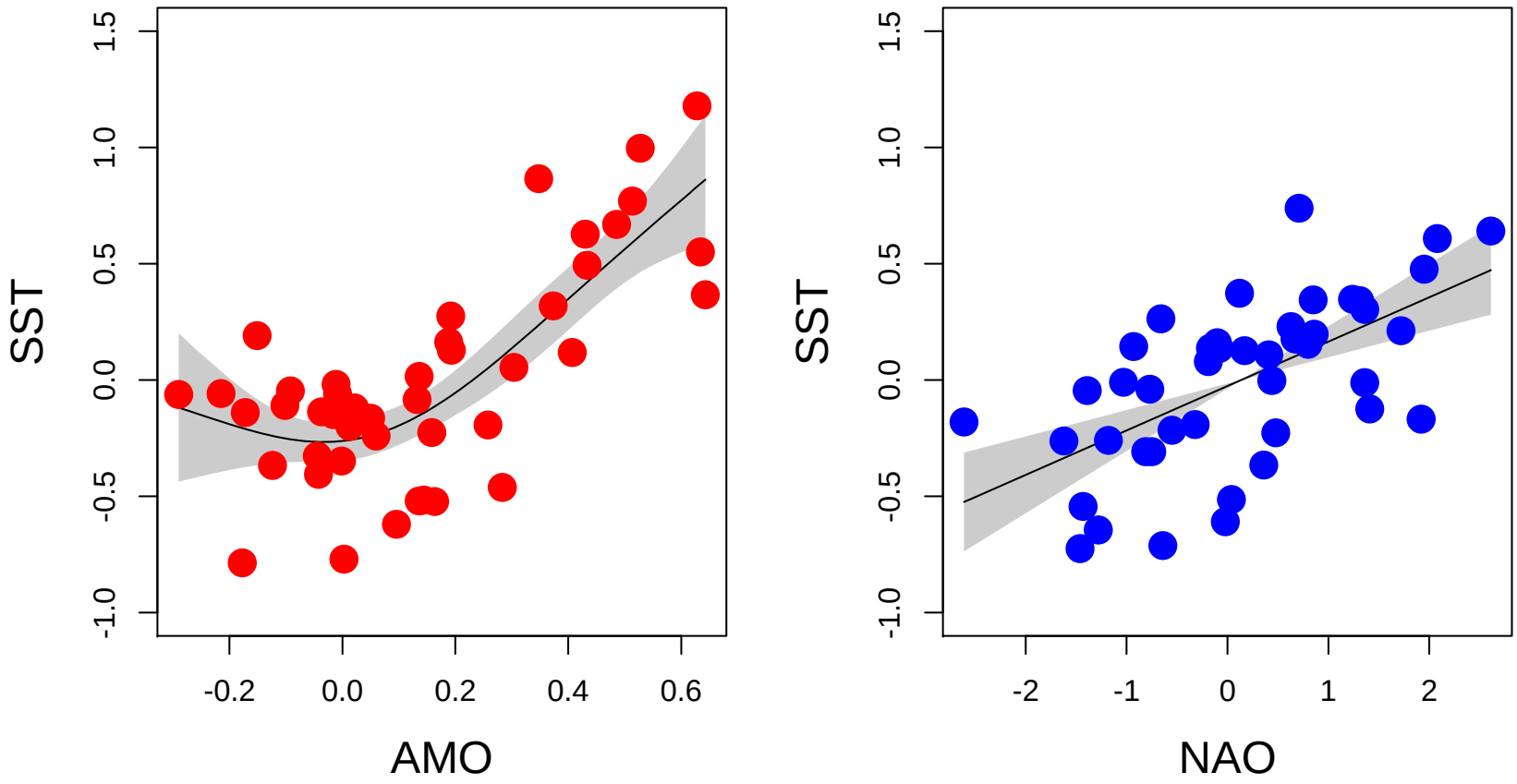
- <u>Trophic Level Indicators</u>
  - Phytoplankton: CPR „phytoplankton colour index“
  - Zooplankton: CPR „total copepods“
  - Planktivores: herring, sandeel, norway pout
  - Piscivores: Cod, haddock, saithe, whiting

- SST (Hadley 3), North Atlantic Oscillation (NAO), Atlantic Multidecadal Oscillation (AMO)

1 – Climate effect on North Sea SST



Additive Climate-SST relationship

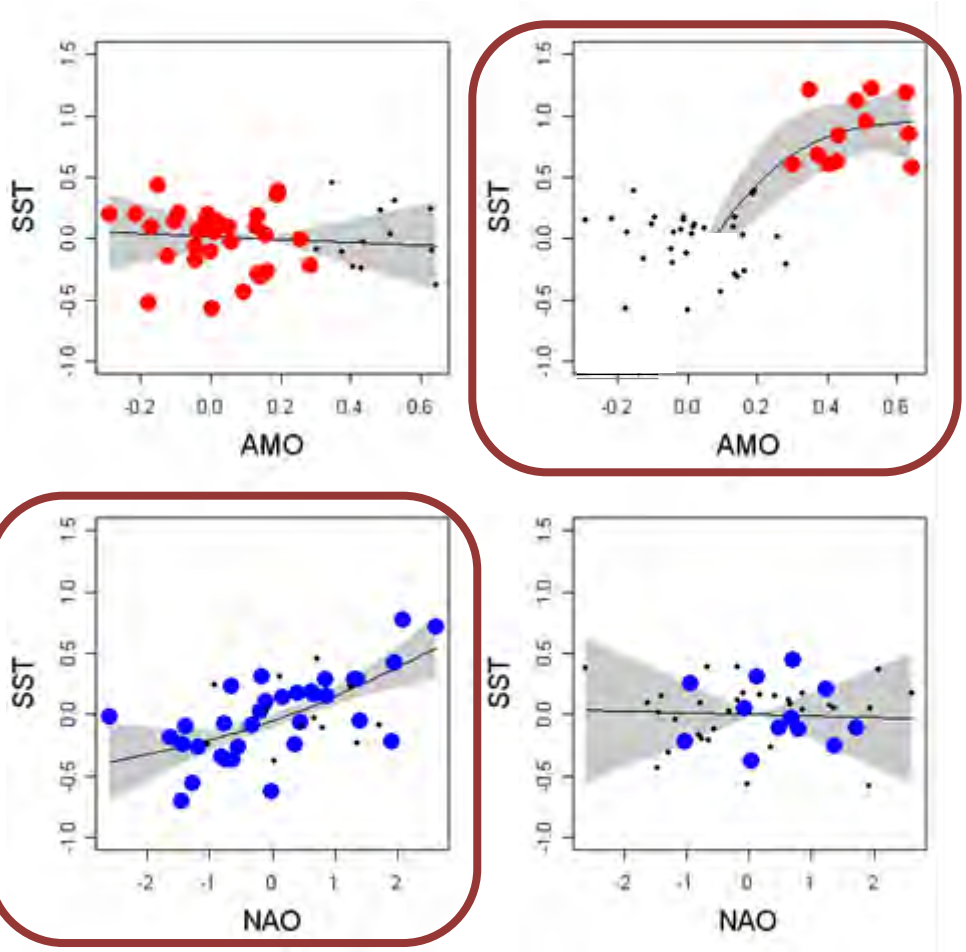


Generalized Additive Model (GAM): $r^2 = 0.663$; both predictors $p < 0.001$

Non-Additive Climate-SST relationship

AMO low (≤ r)

AMO high(> r)



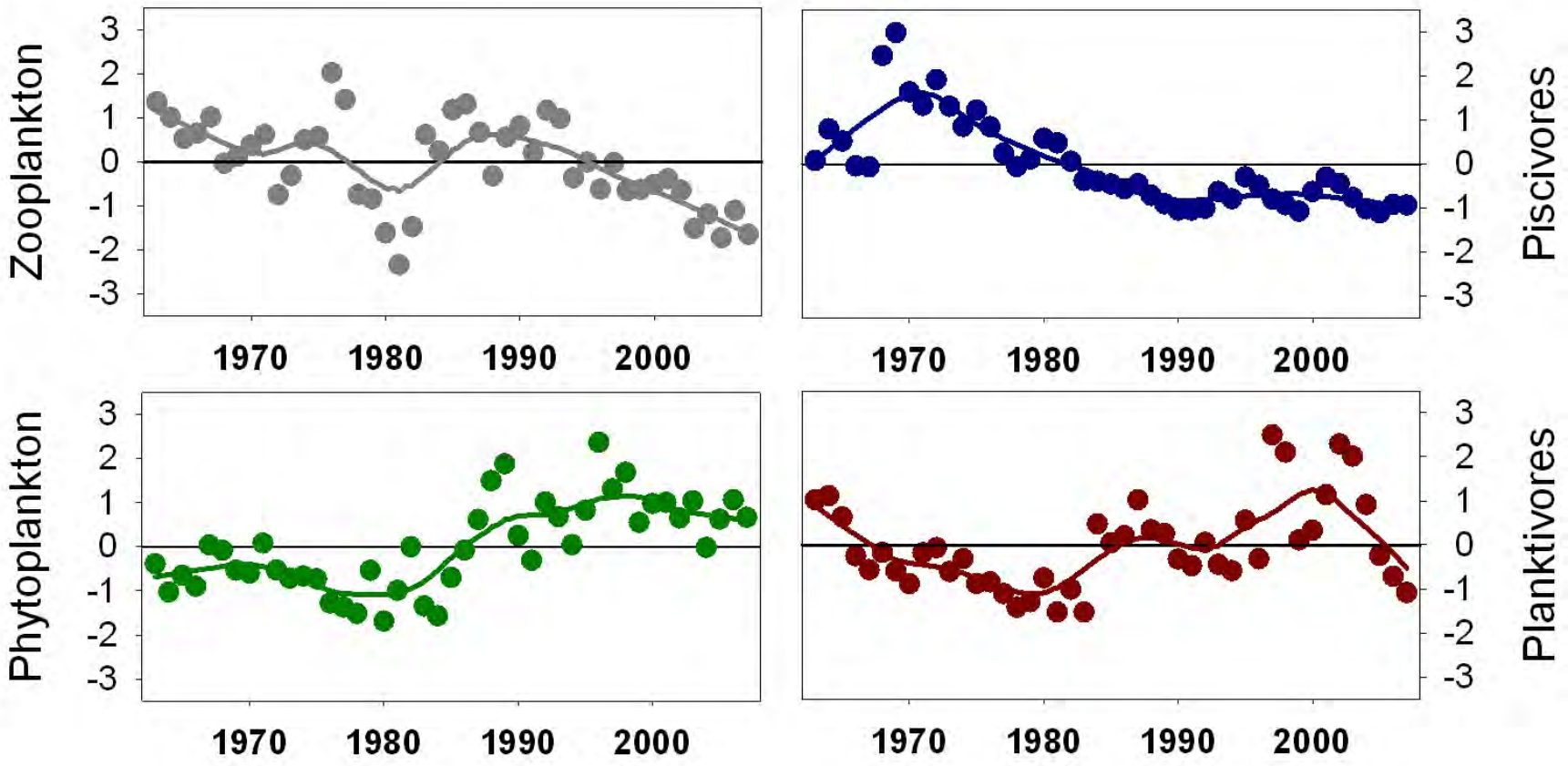
Threshold Generalized Additive Model (TGAM): $r^2 = 0.723$

Predictor	AMO-state	P - values
AMO	low	0.733
AMO	**high**	**< 0.001**
NAO	**low**	**< 0.001**
NAO	high	0.904

Conclusions

- TGAM „better“ than GAM
- AMO has significant effect when in a „high state“
- **NAO has ONLY a significant effect when AMO is low !**

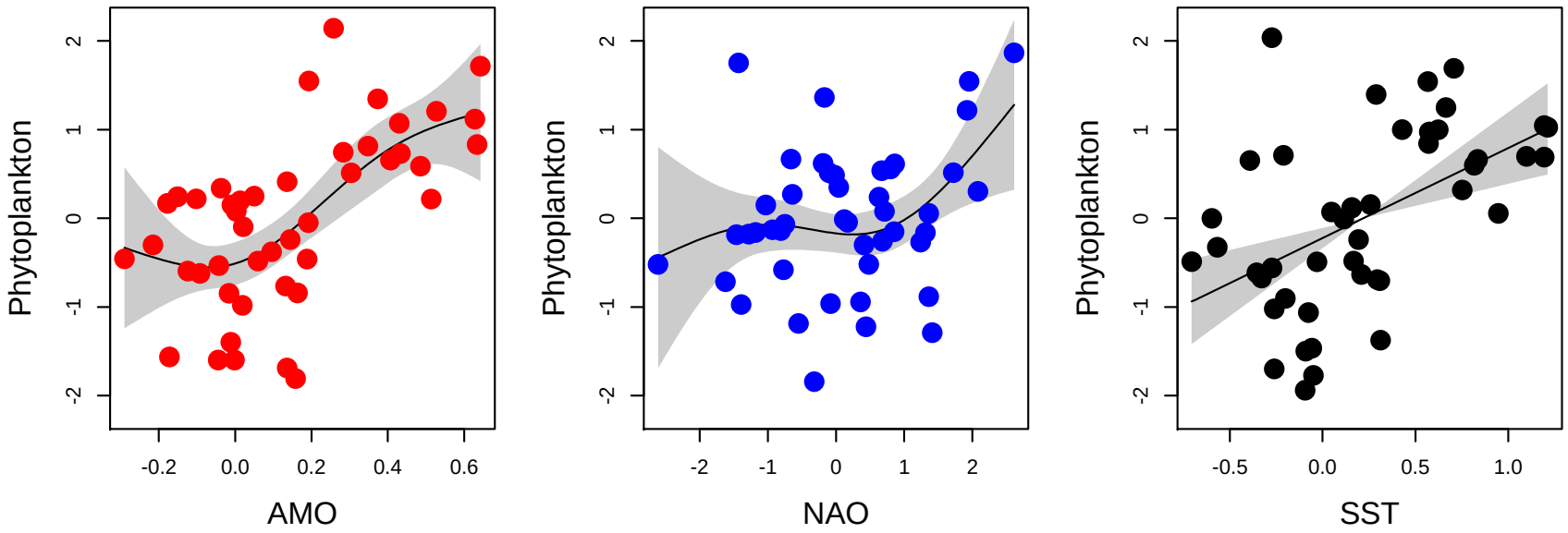
2 – Climate/SST effect on North Sea ecosystem



Phytoplankton vs. Climate – **Additive**

Generalized Additive Model (GAM):

$r^2 = 0.404$; AMO – $p < 0.001$; NAO – $p < 0.05$



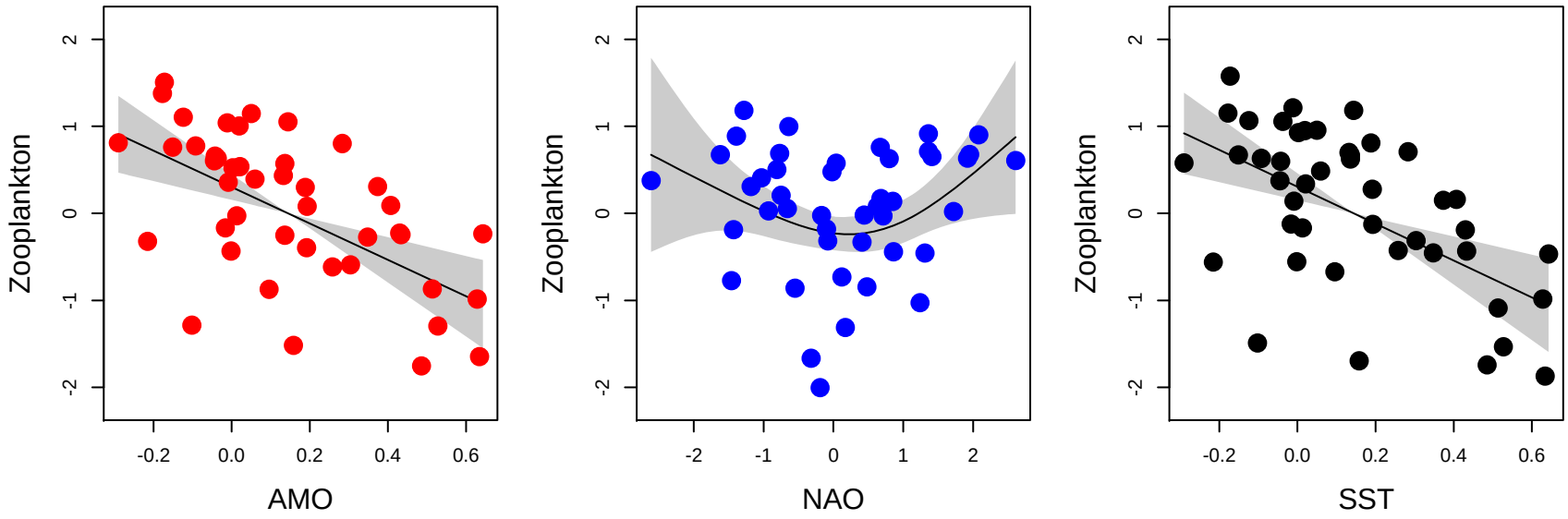
Univariate Model:

$r^2 = 0.246$; $p < 0.001$

Zooplankton vs. Climate – **Additive**

Generalized Additive Model (GAM):

$r^2 = 0.332$; AMO – $p < 0.001$; NAO – $p > 0.05$



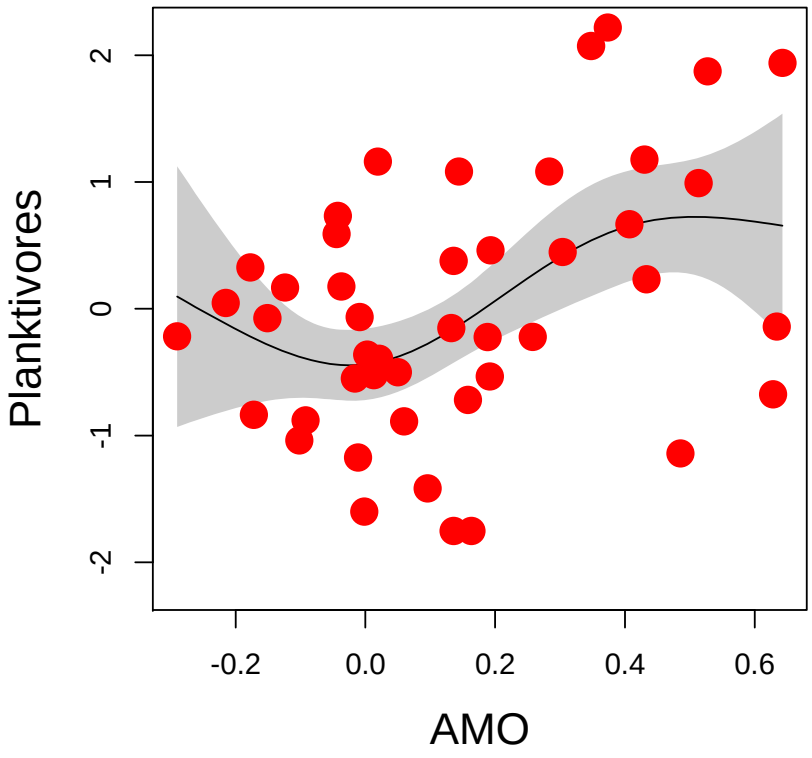
Univariate Model:

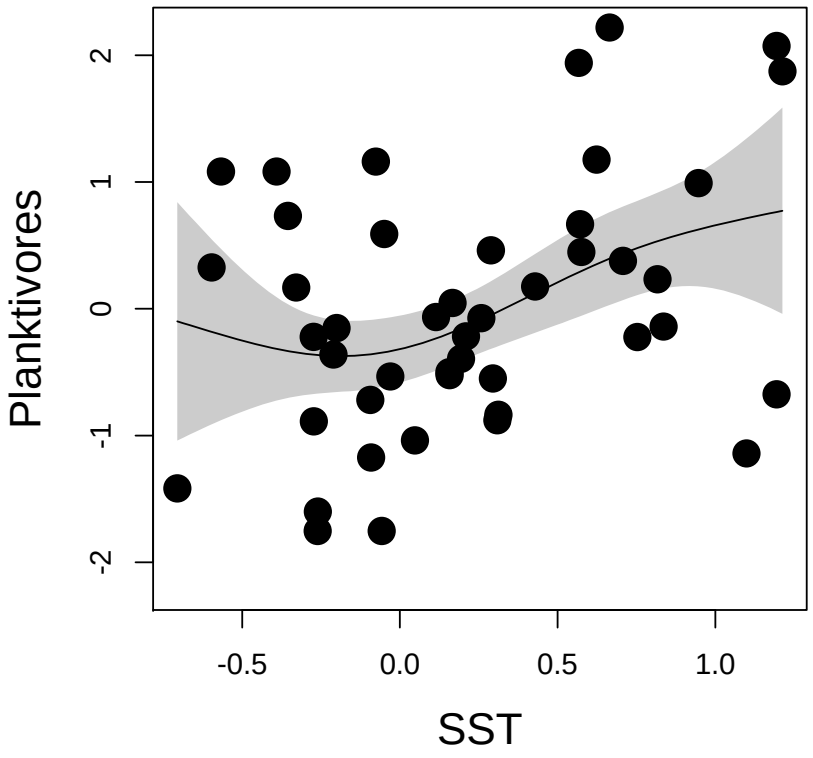
$r^2 = 0.144$; $p < 0.05$

Planktivores vs. Climate – **Additive**

Generalized Additive Model (GAM):

$r^2 = 0.177$; AMO – $p < 0.02$





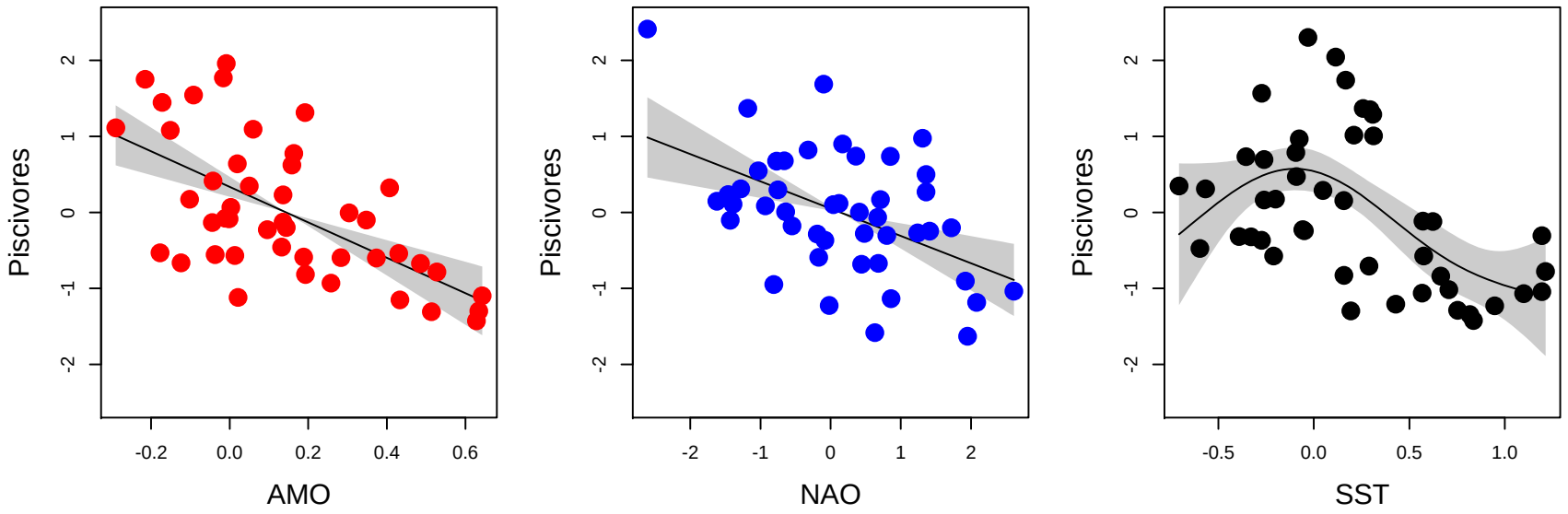
Generalized Additive Model (GAM):

$r^2 = 0.133$; SST – $p < 0.05$

Piscivores vs. Climate – **Additive**

Generalized Additive Model (GAM):

$r^2 = 0.465$; AMO – $p < 0.001$; NAO – $p < 0.001$

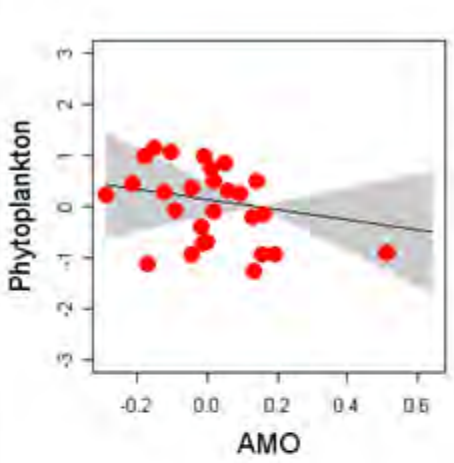


Univariate Model:

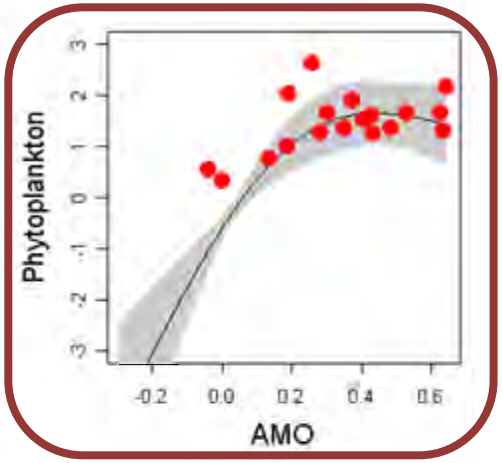
$r^2 = 0.308$; $p < 0.001$

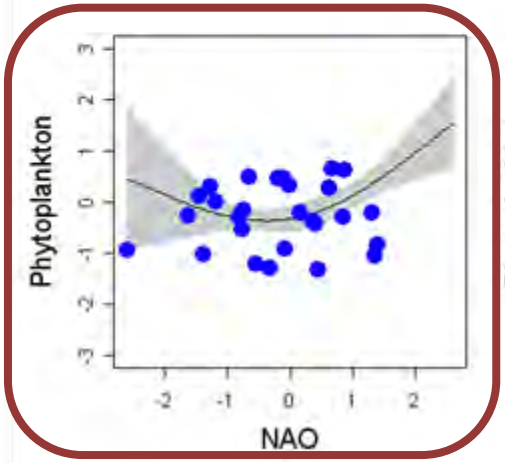
Phytoplankton vs. Climate – **Non-Additive**

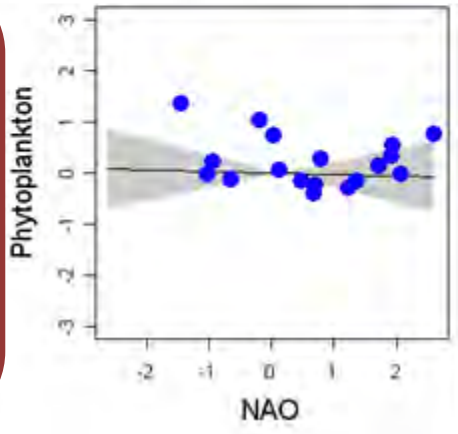
AMO low (≤ r)



AMO high(> r)







Threshold Generalized Additive Model (TGAM): $r^2 = 0.520$

Predictor	AMO-state	P - values
AMO	low	0.401
AMO	**high**	**< 0.001**
NAO	**low**	**< 0.01**
NAO	high	0.841

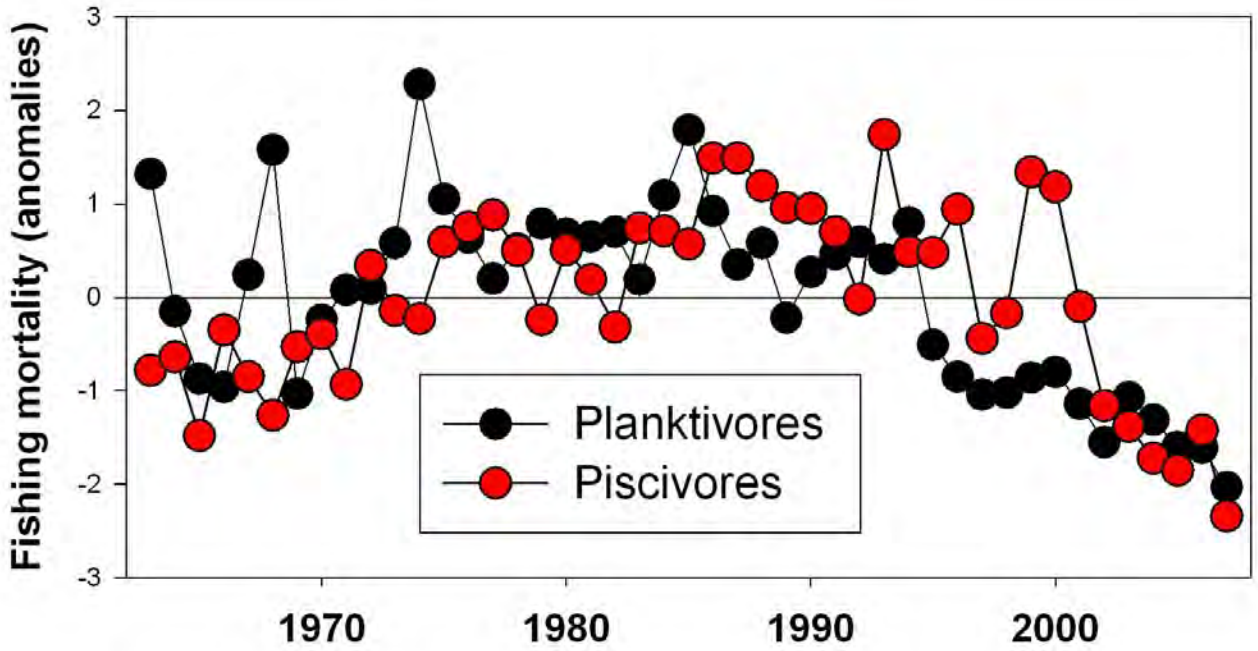
Conclusions

- TGAM „better“ than GAM
- AMO has significant effect when in a „high (warm) state“
- **NAO has ONLY a significant effect when AMO is low (cold state) !**

Trophic Levels vs. Climate – **Additive** vs. **Non-Additive**

Predictor	AMO-state	Phyto-plankton	Zooplank-ton	Planktivores	Piscivores
AMO	low	0.401	**< 0.01**	**< 0.05**	**< 0.01**
AMO	high	**< 0.001**	**< 0.05**	**< 0.01**	**< 0.001**
NAO	low	**< 0.01**	**< 0.01**	0.348	0.274
NAO	high	0.841	0.884	0.195	**< 0.001**
T – GAM	-	**r^2=0.520**	**r^2=0.390**	**r^2=0.421**	**r^2=0.498**
GAM	-	r^2=0.404	r^2=0.332	r^2=0.177	r^2=0.465

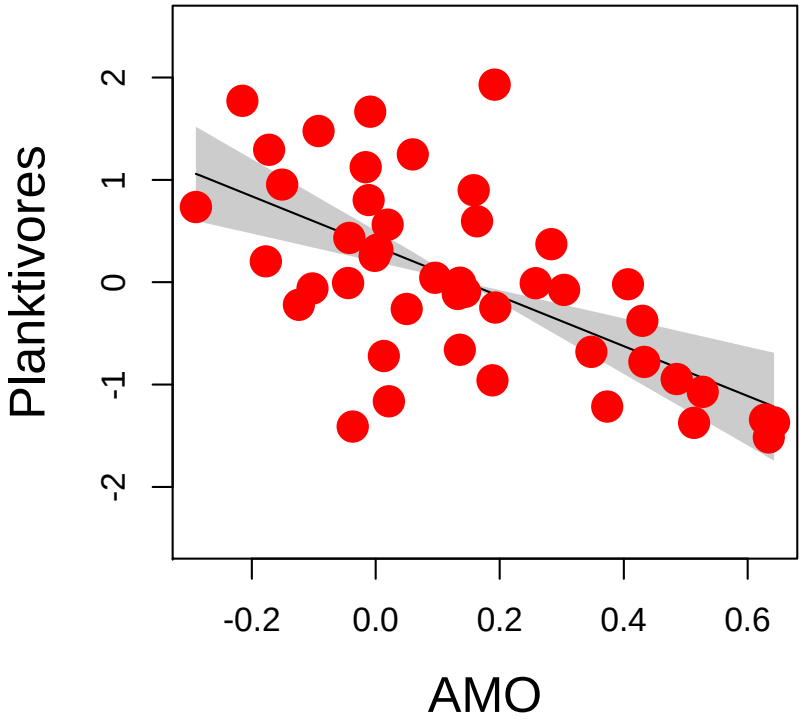
3 – Climate & fishing effect on North Sea ecosystem

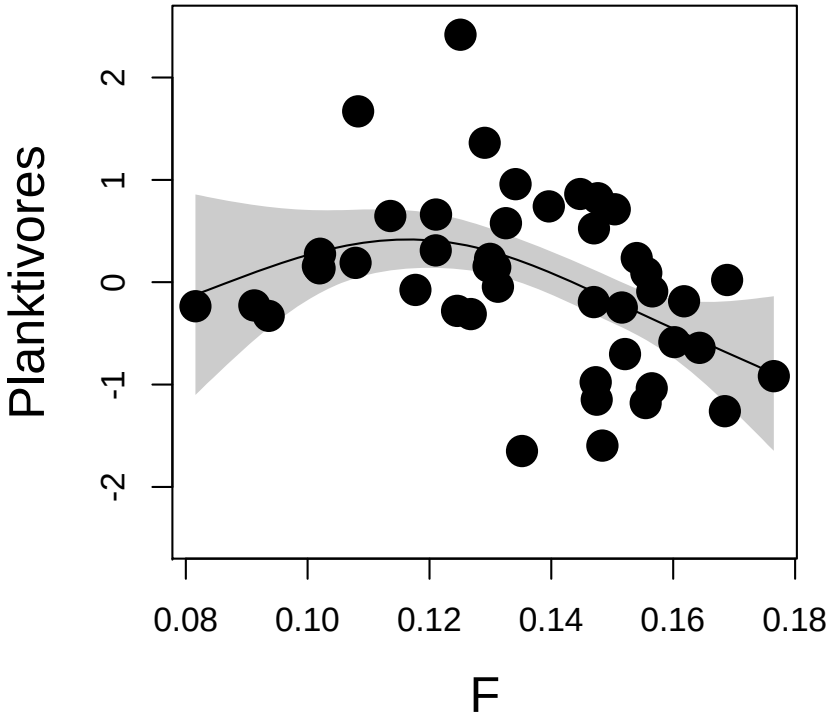


Piscivores vs. Climate & *Fishing* – **Additive**

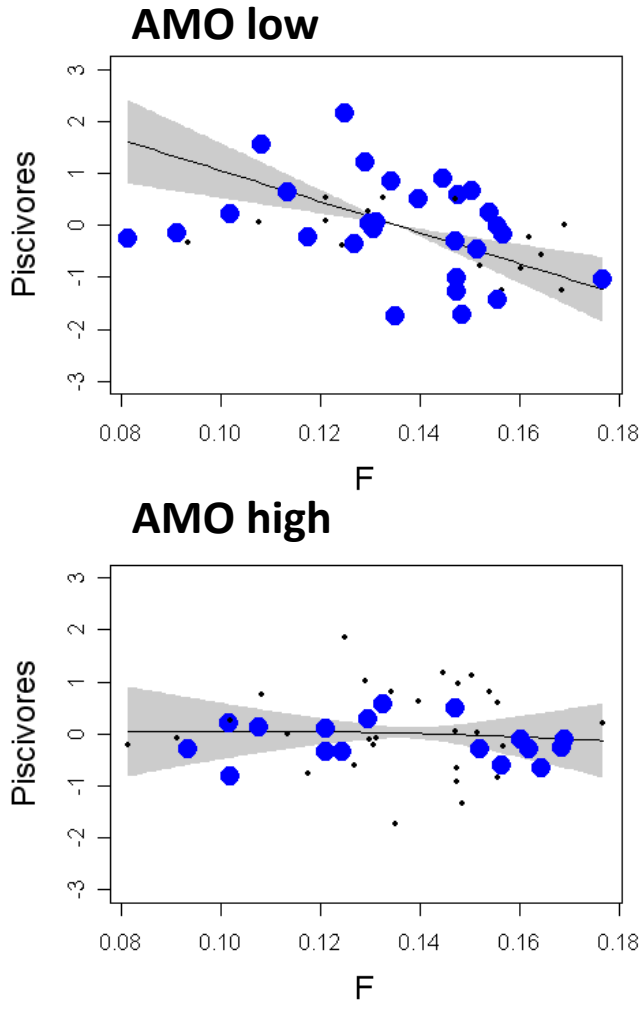
Generalized Additive Model (GAM):

$r^2 = 0.437$; AMO – $p < 0.001$; F – $p < 0.01$





Piscivores vs. Climate & *Fishing* – **Non-Additive**

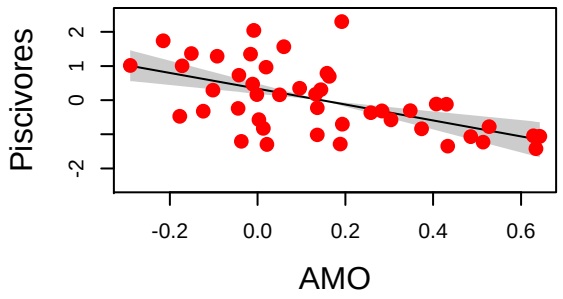


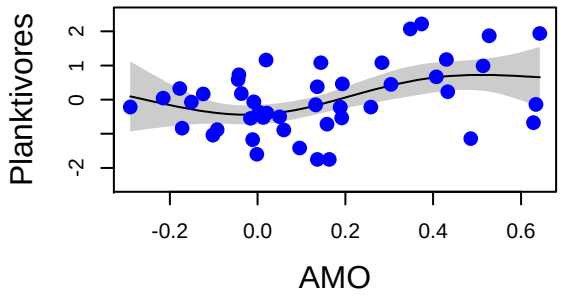
Threshold Generalized Additive Model (TGAM): $r^2 = 0.458$

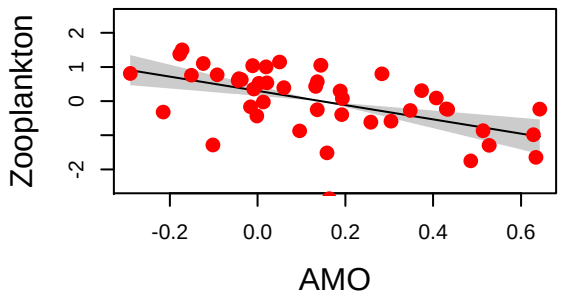
Predictor	AMO-state	P - values
AMO	low	0.094
AMO	**high**	**< 0.01**
F	**low**	**< 0.001**
F	high	0.563

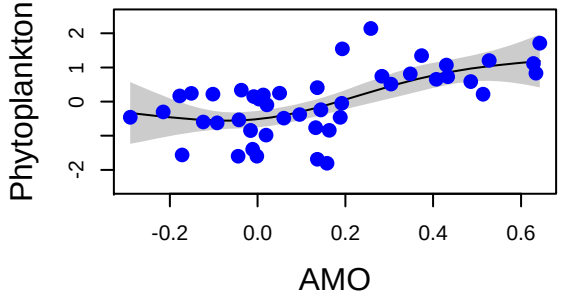
Conclusions

- **Fishing has only a significant effect when AMO is low (in a cold state !**
- **When AMO is high (in a warm state), fishing effect not detectable anymore !**





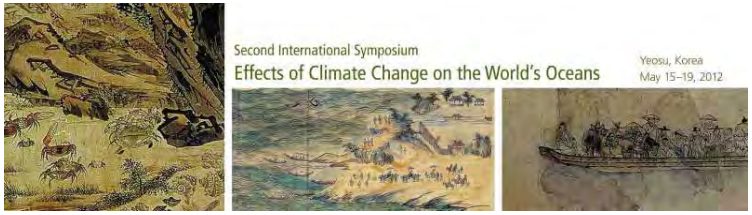




„Cascading AMO-effect“ on Trophic Levels

Summary

- **Multidecadal (AMO) and decadal (NAO) climate effects** seem to determine North Sea SST in a non-additive way (NAO only important when AMO is low)
- **Trophic Levels**
  - Additive models of AMO & NAO generally perform better than simple SST-model
  - Non-additive models (T-GAMs) perform generally better than additive models (GAM)
  - For lower TLs NAO only important when AMO is in a low (cold) state
  - For higher TLs this pattern slightly reverses (impact of fishing?)
  - Effect of fishing on Piscivores only significant when AMO low (i.e. a cold state–positive for piscivores); when AMO is high (i.e. warm state–negative for piscivores) fishing „does not matter“ anymore
  - **AMO shows a striking „cascading effect“ on TLs, which indicates tremendous trophic reorganization with warming**



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