

Long-term trends and seasonal patterns for
Calanus finmarchicus
and
Calanus helgolandicus
in the Coastal Water off southwest Norway
during 1996-2012

Nicolas Dupont^a, Leif Christian Stige^b,
Espen Bagøien^a, Webjørn Melle^{a,*}

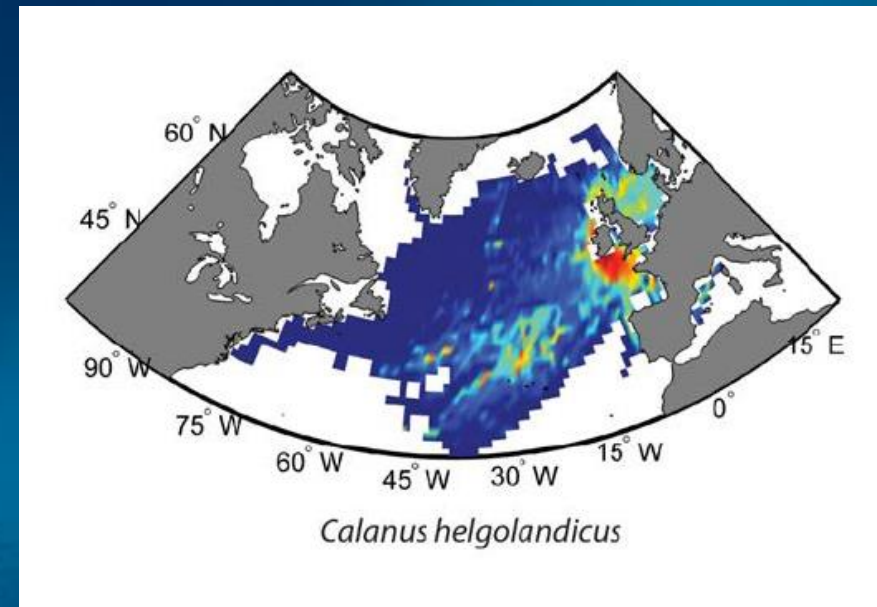
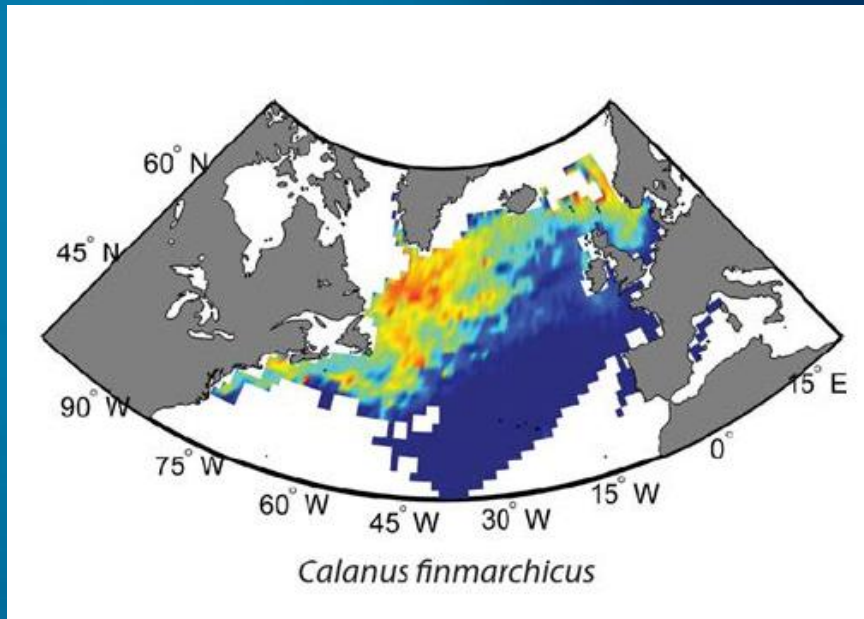
^a Institute of Marine Research, Bergen, Norway

^b Centre for Ecological and Evolutionary Synthesis (CEES), Oslo, Norway



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Calanus finmarchicus & Calanus helgolandicus



Two morphologically similar species

Can be morphologically identified when reaching copepodite stage 5 (CV) or adulthood (Adult ♀/♂)

However biogeographically one is a cold water species and the other a temperate water species



Global Change

North Sea ecosystem: Increasing Sea Surface Temperature (SST)

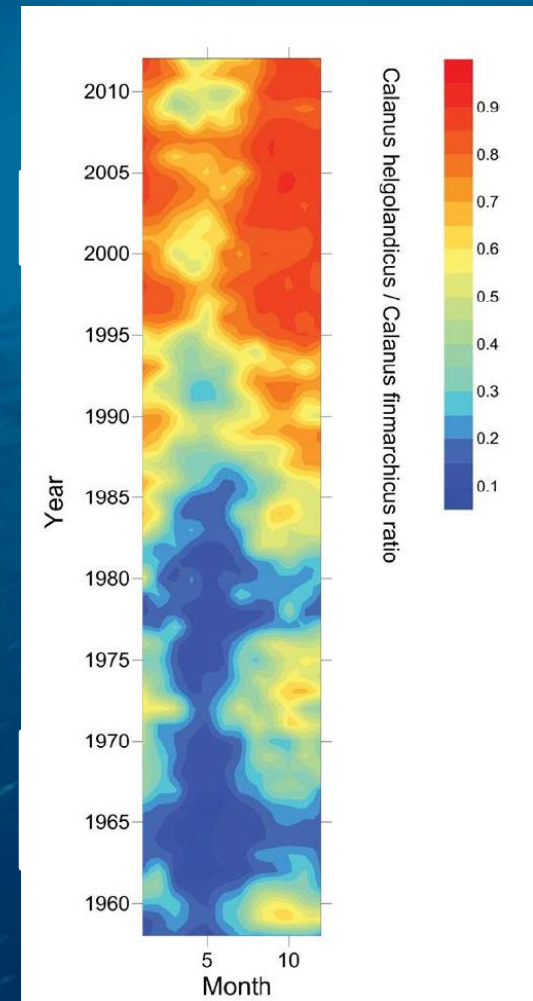
Cold Years → *Calanus finmarchicus*

Warm Years → *Calanus helgolandicus*

North Sea ecosystem: Changes in Calanoid community

In accordance to a thermal critical geographic boundary
Annual yearly mean 9-10 °C

Predicted to move northward along the
Norwegian Coast during 21st century



Data Set Svinøy Transect

Time period:

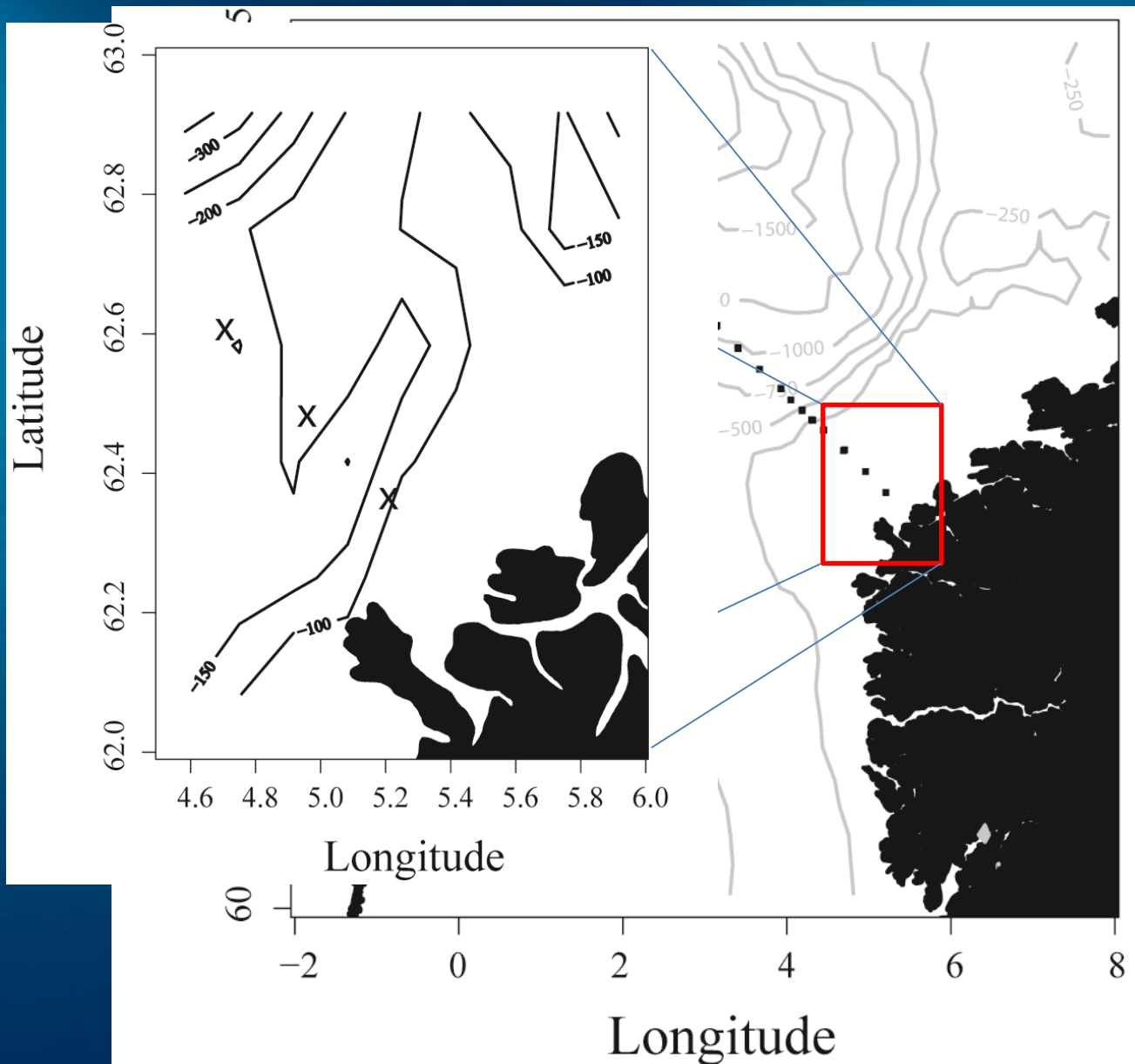
1996-2012

January-December

Both Species:

200 observations
for CV

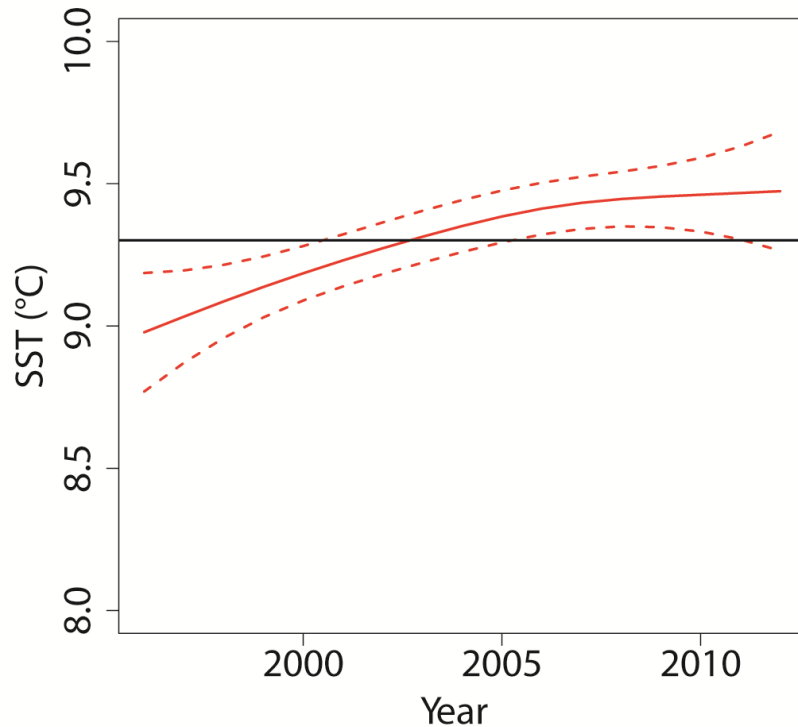
209 observations
for Adult ♀



Global Change

In our sampling area: from the (ICOADS) 1-degree enhanced data

<http://icoads.noaa.gov>; Woodruff et al. 1987

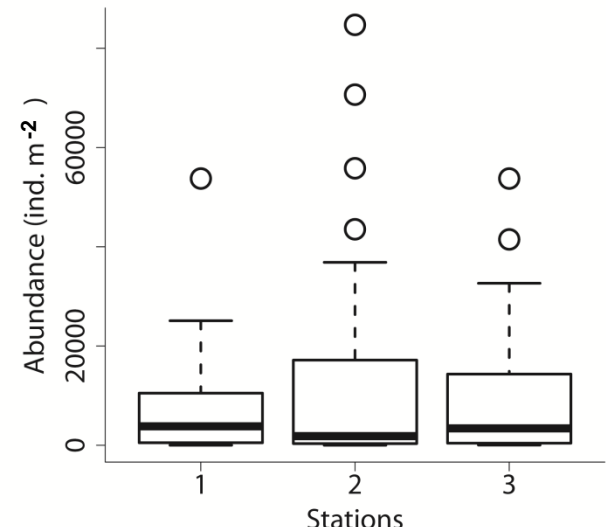
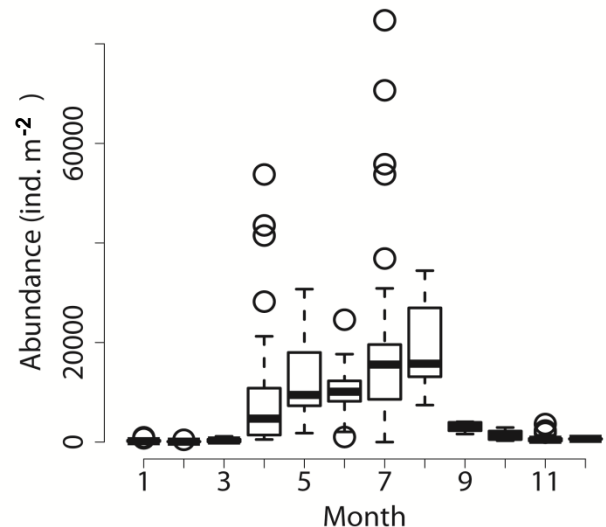
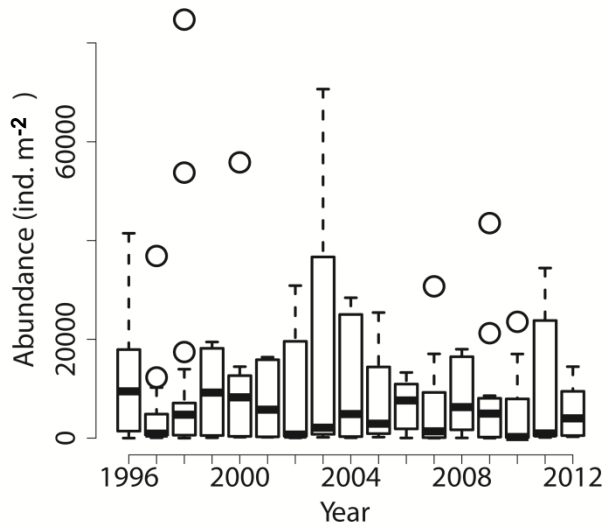


Yearly Sea Surface Temperature have been increasing by 0.5 °C in the period 1996-2012

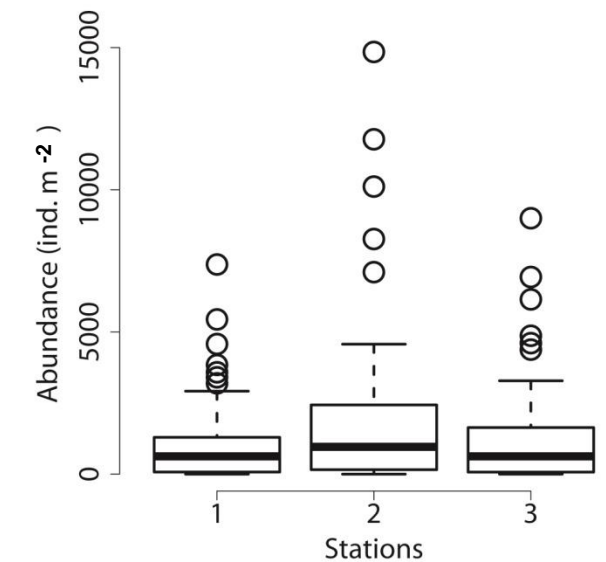
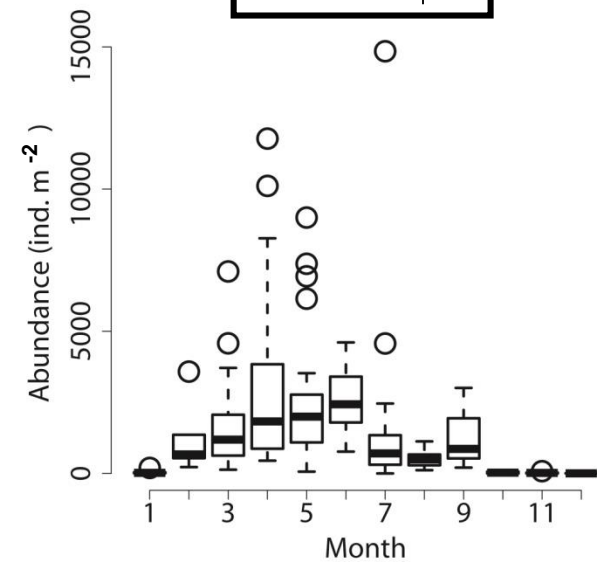
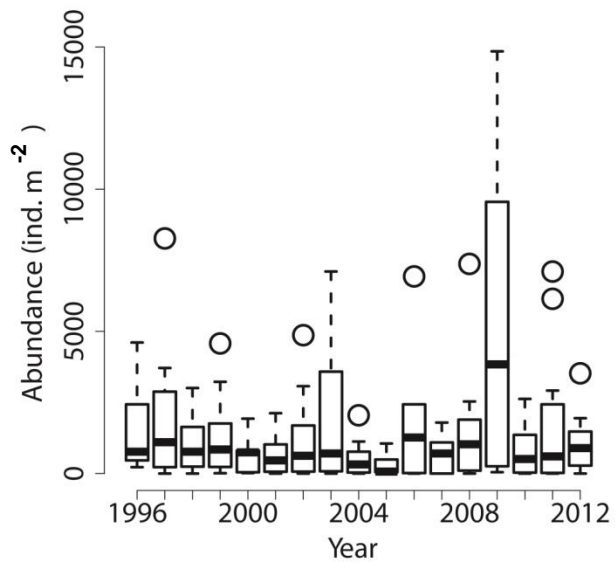
In the Norwegian coastal water both species are found

We take a look at the demography of the species over the period 1996-2012



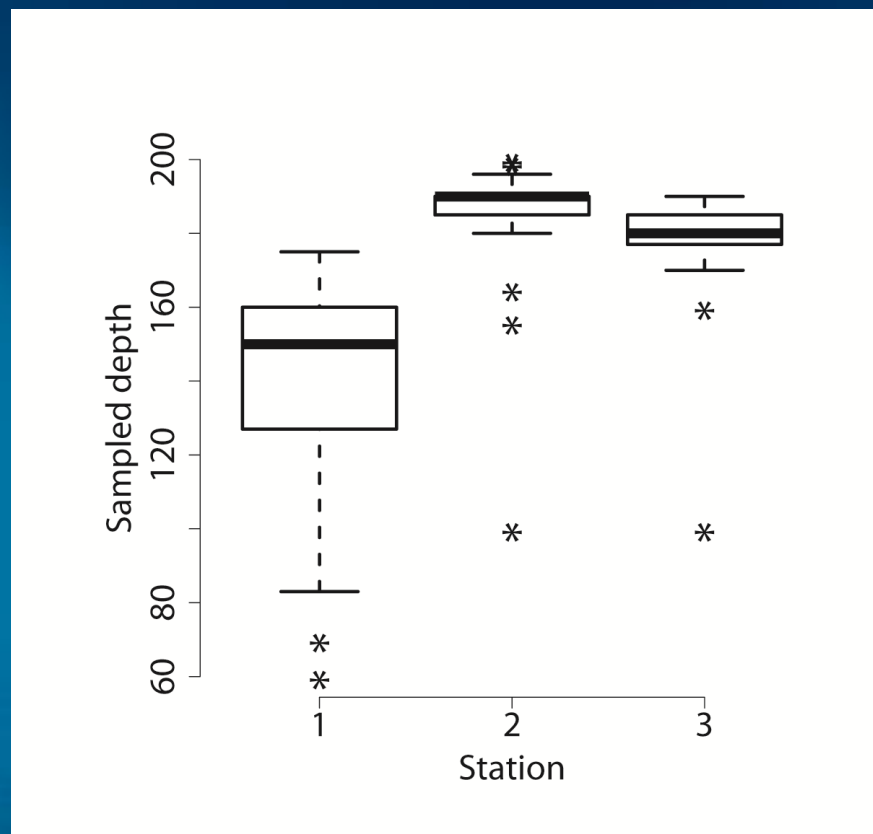


Adult ♀



Sampling plan

Sample Depth



GAM model (fits smoothers $s()$ to the data): Negative Binomial distribution
Logarithm link function

$$C_{fin} = \exp(s(\text{Year}) + s(\text{Day}) + s(\text{Year}, \text{Day}) + \text{Stations} + \text{offset}(\text{Depth}))$$

Year
Trend

Seasonal
cycle

Seasonal
cycle
variation

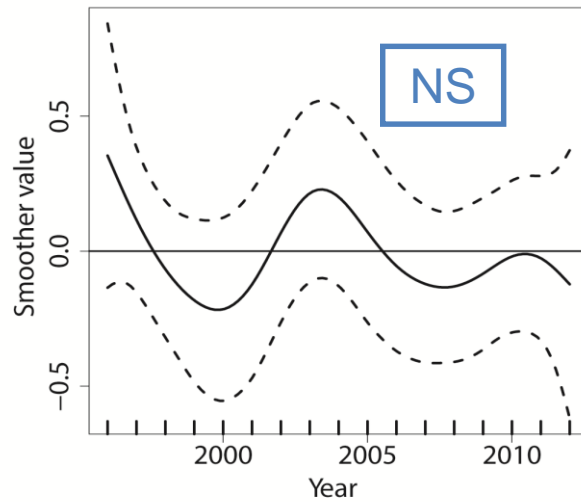
Station
effect

Sampling
depth
effect



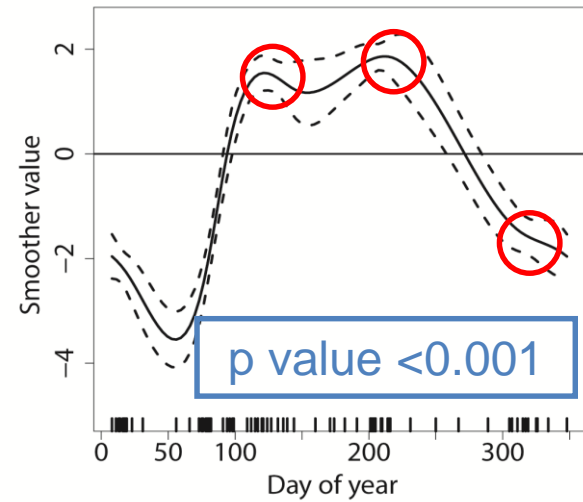
Calanus finmarchicus: model results

s(Year): Year trend



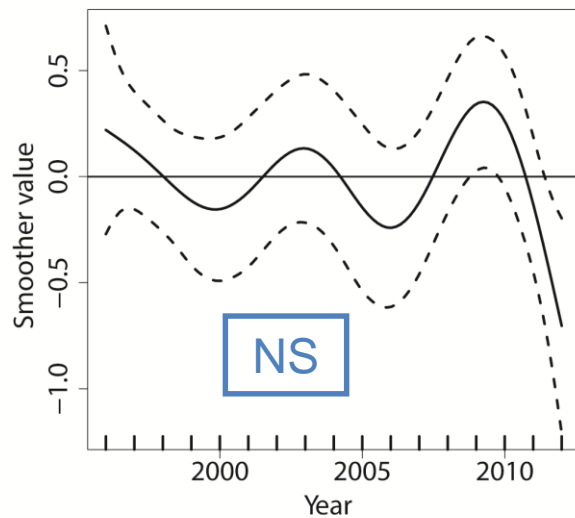
CV

s(Day): Seasonal cycle

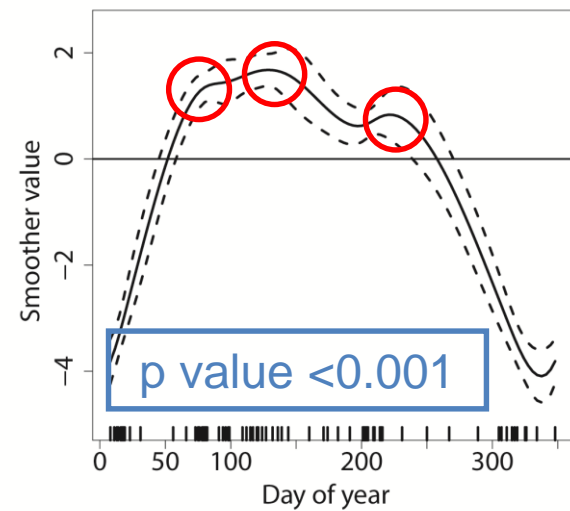


p value <0.001

Adult ♀



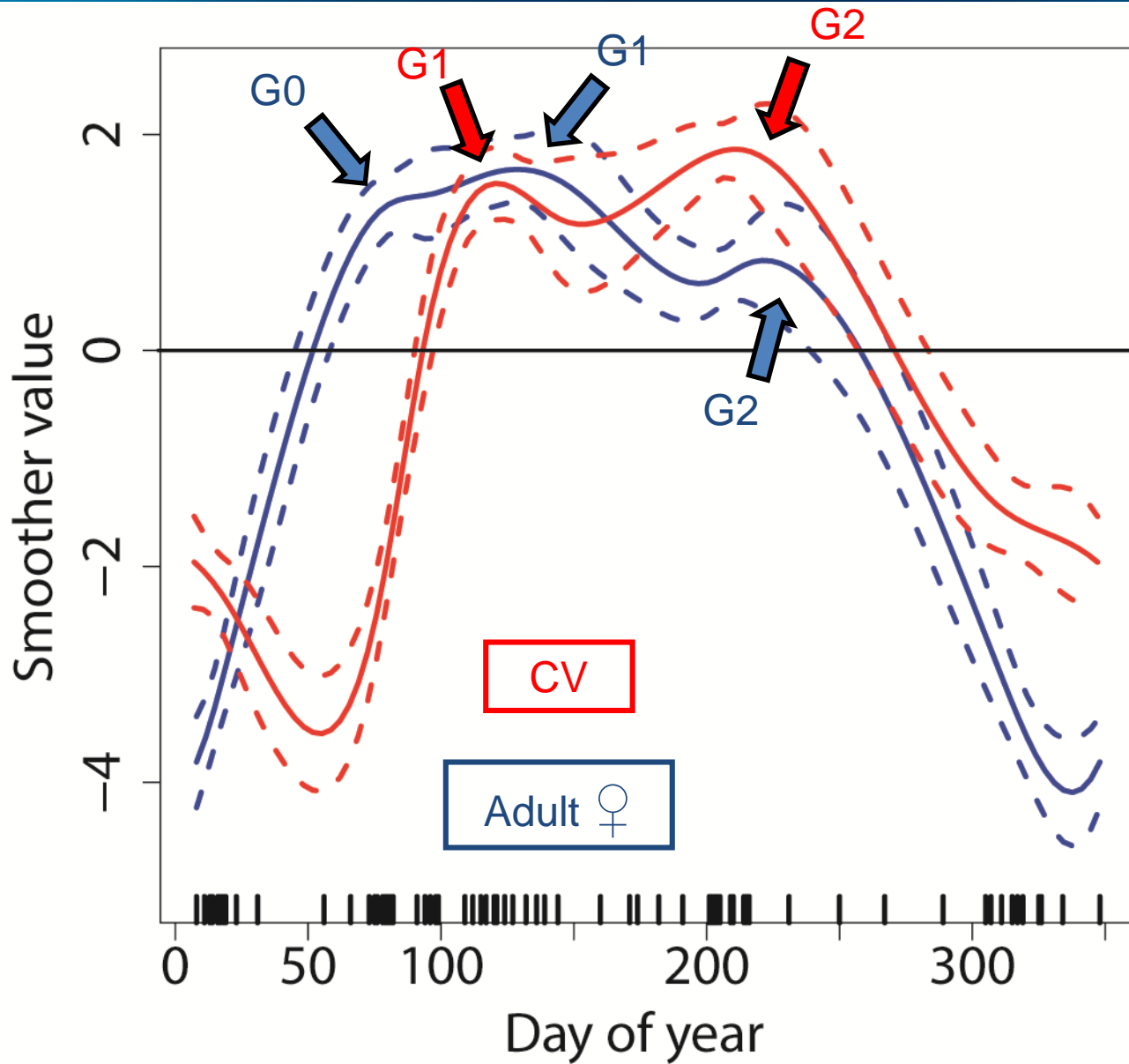
NS

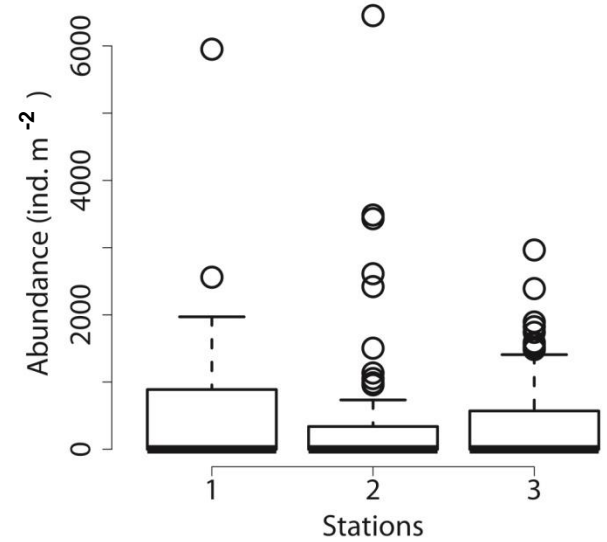
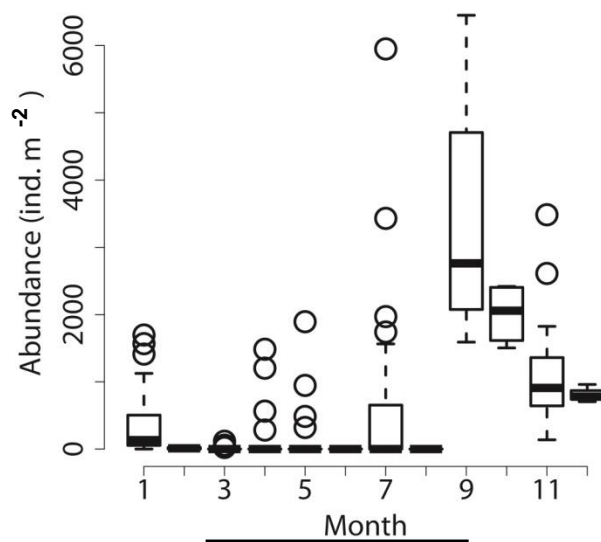
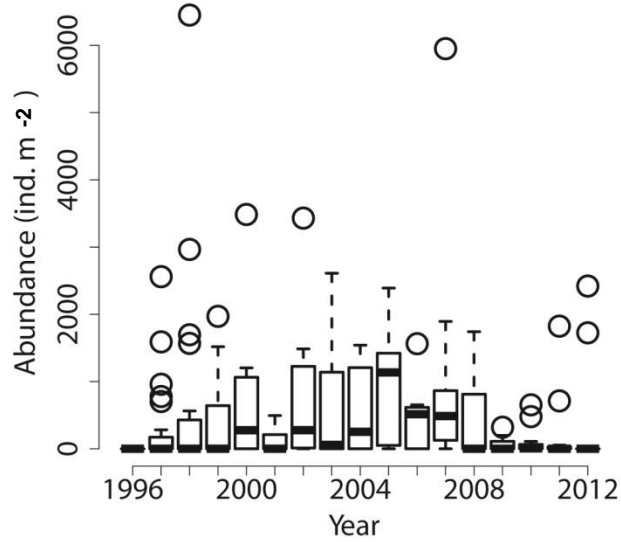


p value <0.001

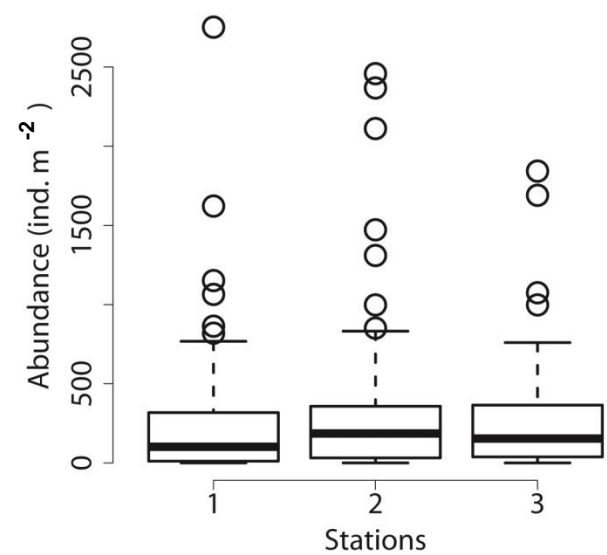
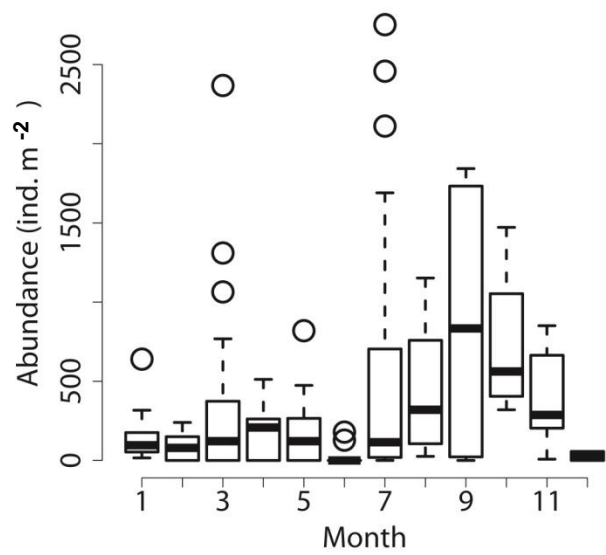
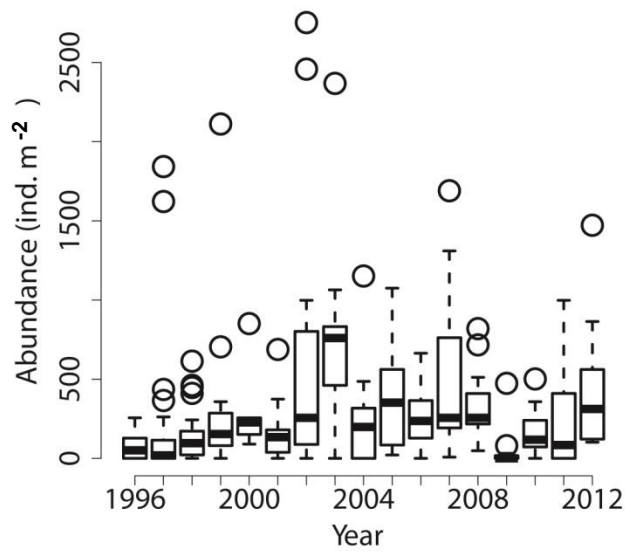


Calanus finmarchicus: model results





Adult ♀

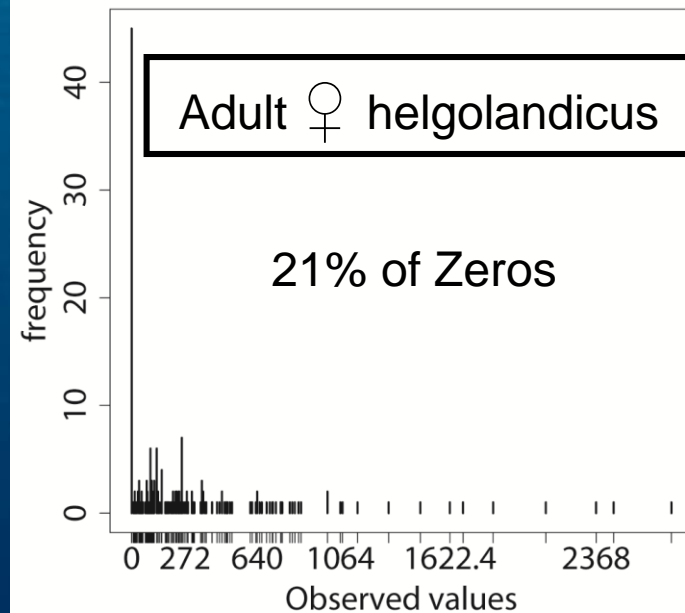
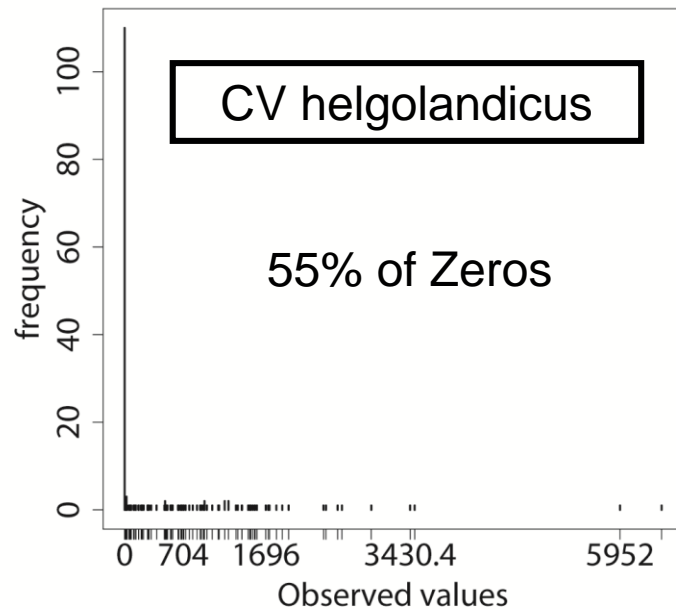


GAM model (fits smoothers $s()$ to the data): Negative Binomial distribution
Logarithm link function

$$\text{Chel} = \exp(s(\text{Year}) + s(\text{Day}) + s(\text{Year,Day}) + \text{Stations} + \text{offset}(\text{Depth}))$$

Year Trend Seasonal cycle Seasonal cycle variation Station effect Sampling depth effect

However...



GAM model (fits smoothers $s()$ to the data): Negative Binomial distribution
 Logarithm link function

$$\text{Chel} = \exp(s(\text{Year}) + s(\text{Day}) + s(\text{Year,Day}) + \text{Stations} + \text{offset}(\text{Depth}))$$

Year
Trend

Seasonal
cycle

Seasonal
cycle
interaction

Station
effect

Sampling
depth
effect

Count Data

Zero Inflated Negative Binomial

GAM model (fits smoothers $s()$ to the data): Binomial distribution
 Logit link function

$$\text{PA_Chel} = 1 / (1 + \exp(- (s(\text{Year}) + s(\text{Day}) + s(\text{Year,Day}) + \text{Stations})))$$

Year
Trend

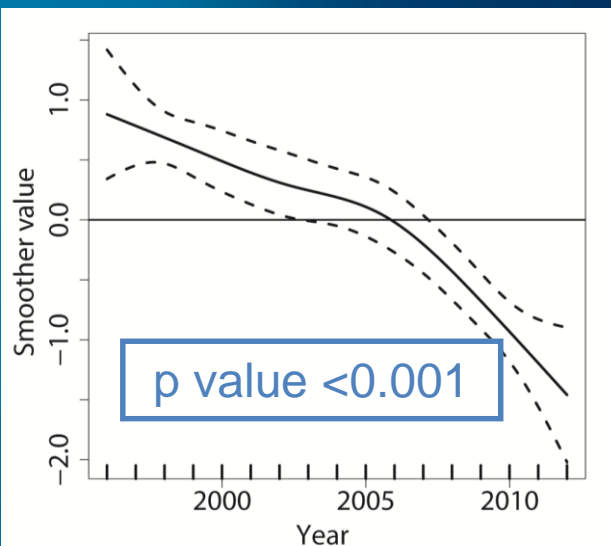
Seasonal
cycle

Station
effect

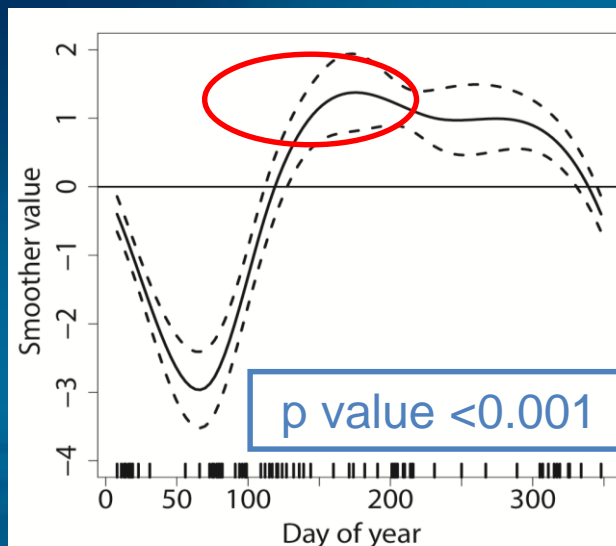
Presence Absence Data

Calanus helgolandicus CV: model results

s(Year): Year trend

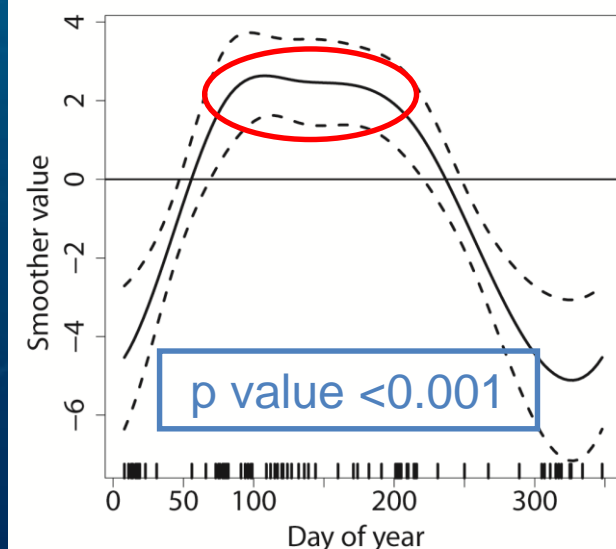
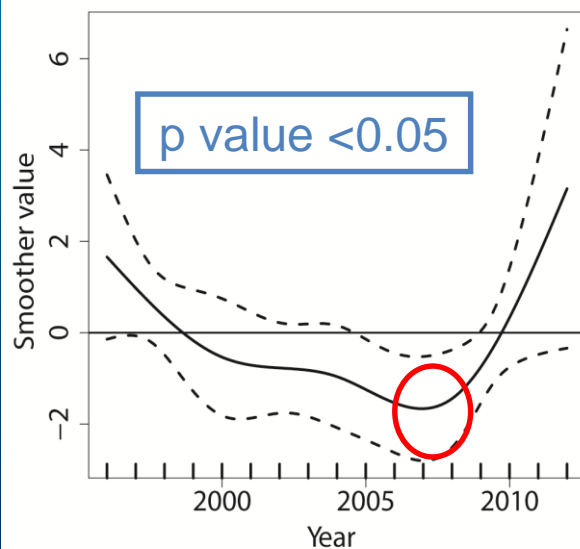


s(Day): Seasonal cycle



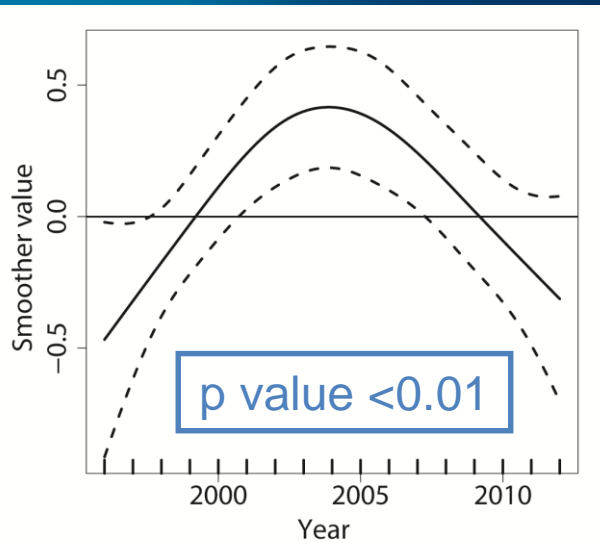
Count Data

Presence
Absence Data

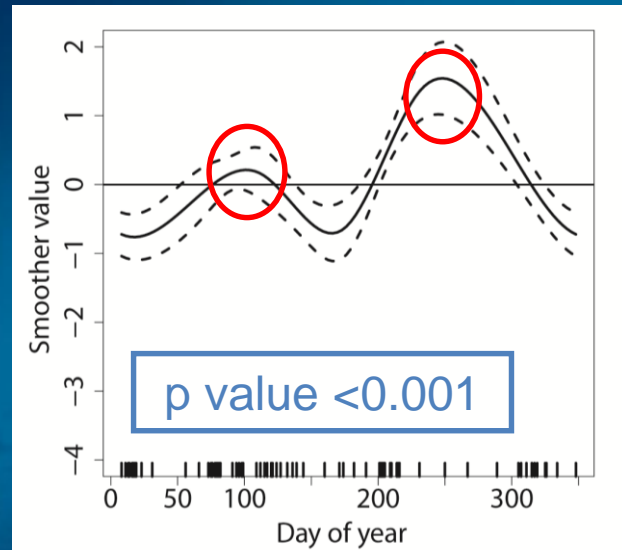


Calanus helgolandicus Adult ♀: model results

s(Year): Year trend

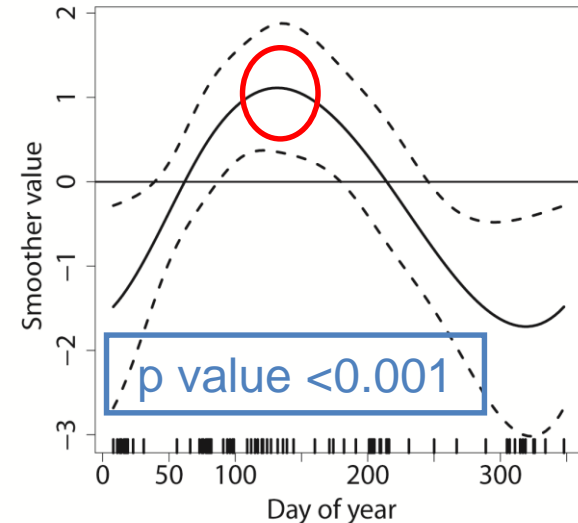
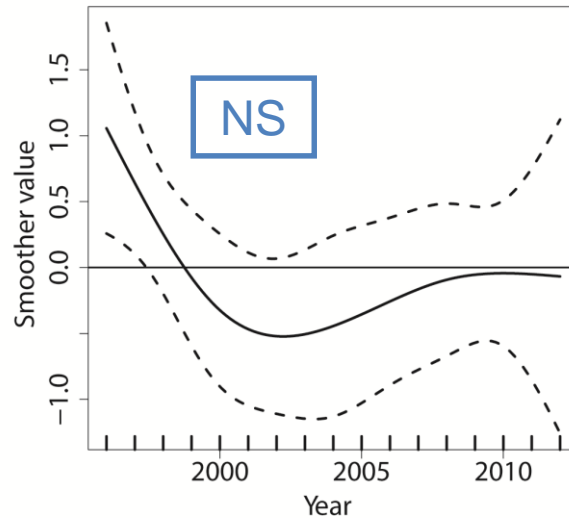


s(Day): Seasonal cycle



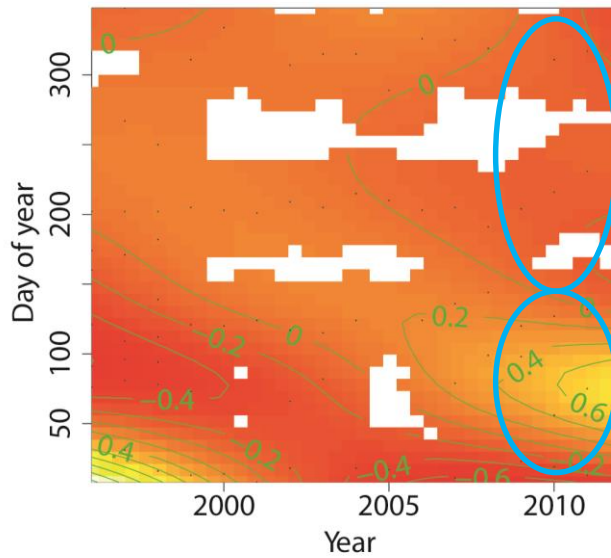
Count Data

Presence
Absence Data



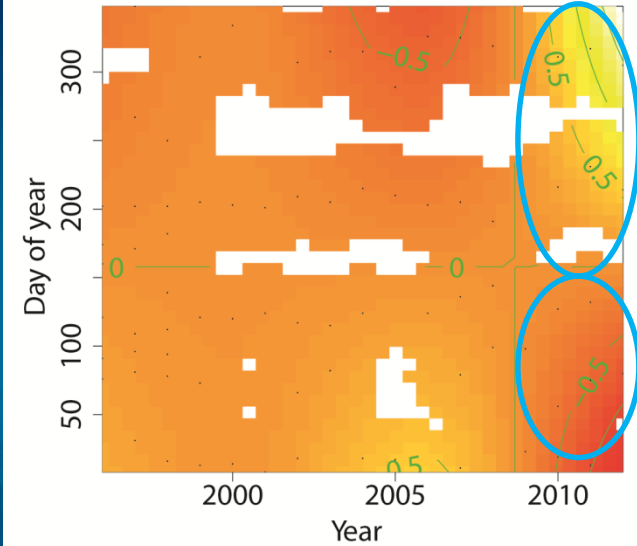
Calanus spp: model results $s(\text{Year}, \text{Day})$

Calanus finmarchicus

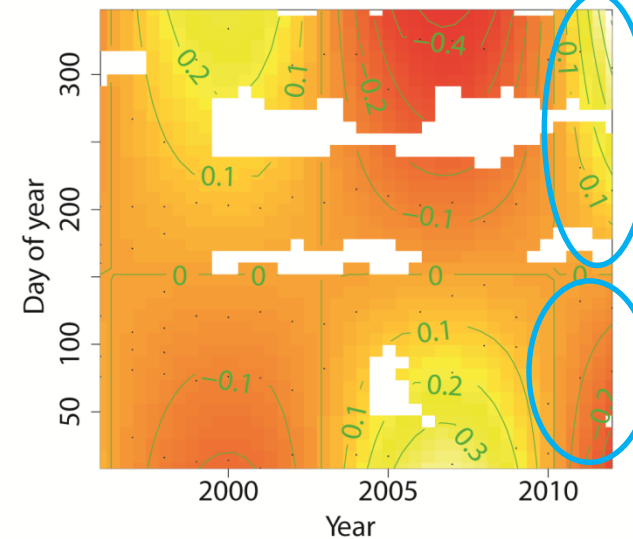
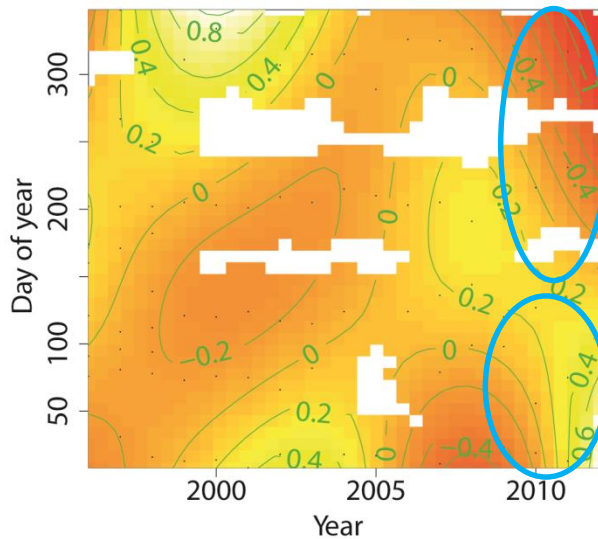


CV

Calanus helgolandicus



Adult ♀



Summary

Given the studied model

$C_{fin} = \exp(s(\text{Year}) + s(\text{Day}) + s(\text{Year}, \text{Day}) + \text{Stations} + \text{offset}(\text{Depth}))$

Calanus finmarchicus

- CV

- Spring/Summer development
- Possibly 2 generations (G1 and G2)
- Non significant Year trend
- Residual population during winter?

- Adult ♀

- Spring /Summer development
- Early rising (day of year 70)
- Possibly 3 generations (G0, G1 and G2)
- Non significant year trend
- Low abundance/absence in winter



Summary

Given the studied model

$$\text{Chel} = \exp(s(\text{Year}) + s(\text{Day}) + s(\text{Year}, \text{Day}) + \text{Stations} + \text{offset}(\text{Depth}))$$
$$\text{PA_Chel} = 1 / (1 + \exp(s(\text{Year}) + s(\text{Day}) + \text{Stations}))$$

Calanus helgolandicus

- CV

- Summer/Autumn development
- Early occurrence in summer Threshold appearance?
- Significant decreasing Year trend
- Increased occurrence until 2007

- Adult ♀

- Spring /Autumn development
- Early occurrence in spring Threshold appearance?
- Significant year trend with maximum 2004
- Non significant change in occurrence



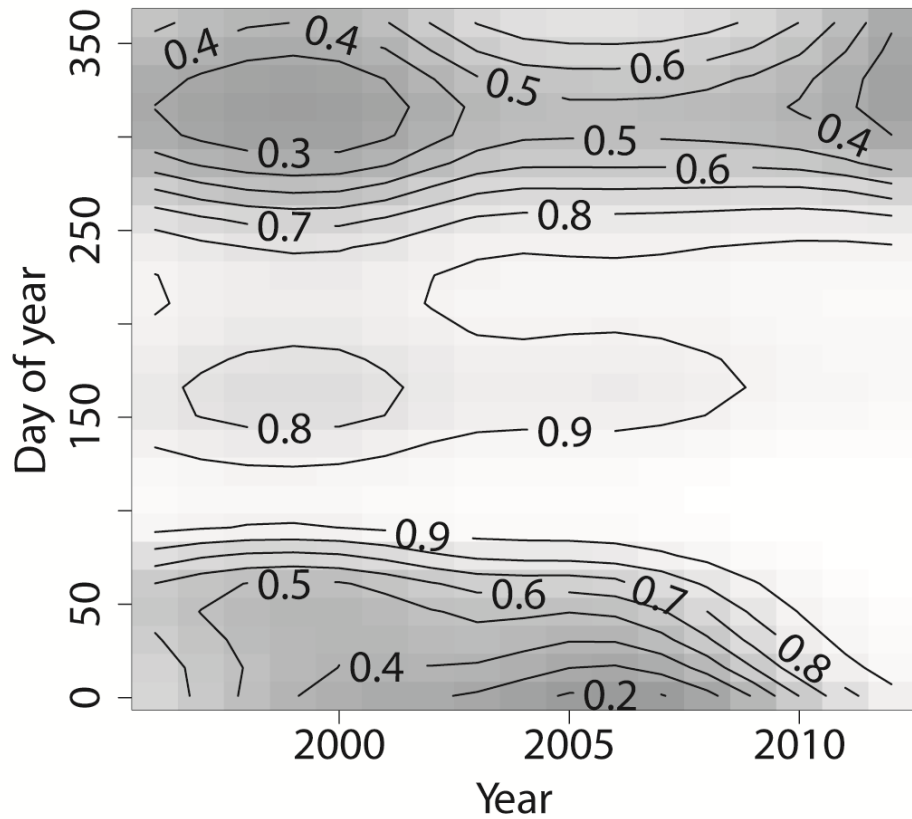
Both species seasonalities appear negatively related in the last years (however to be investigated further... role of temperature ?)

Thank you for your attention!

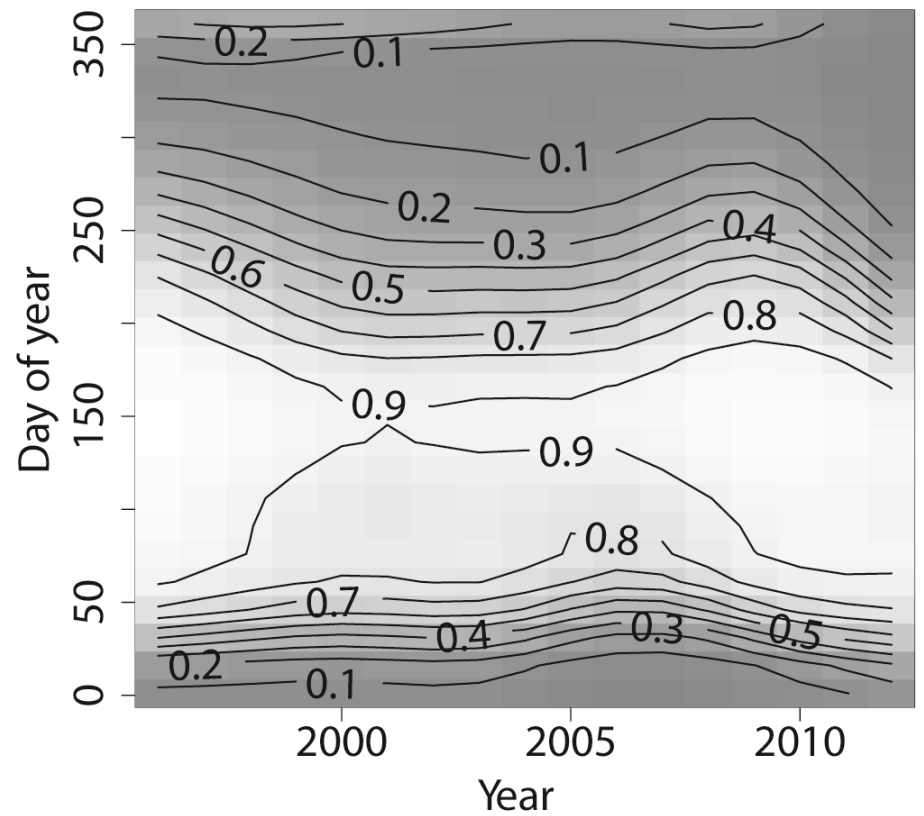
Questions?



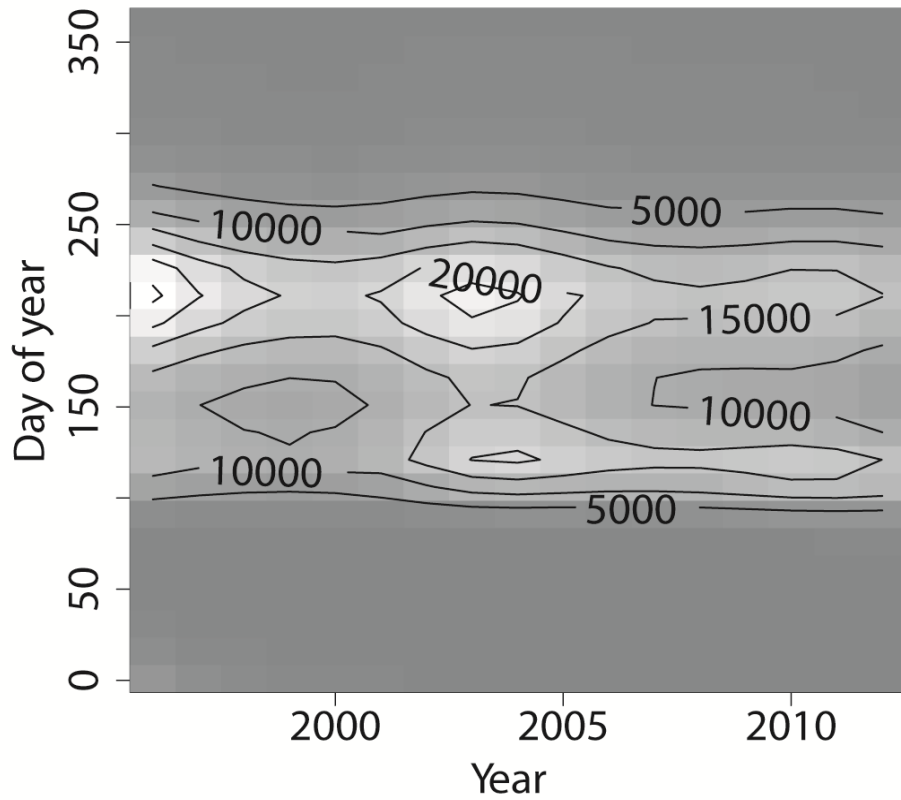
Proportion CV Cfin



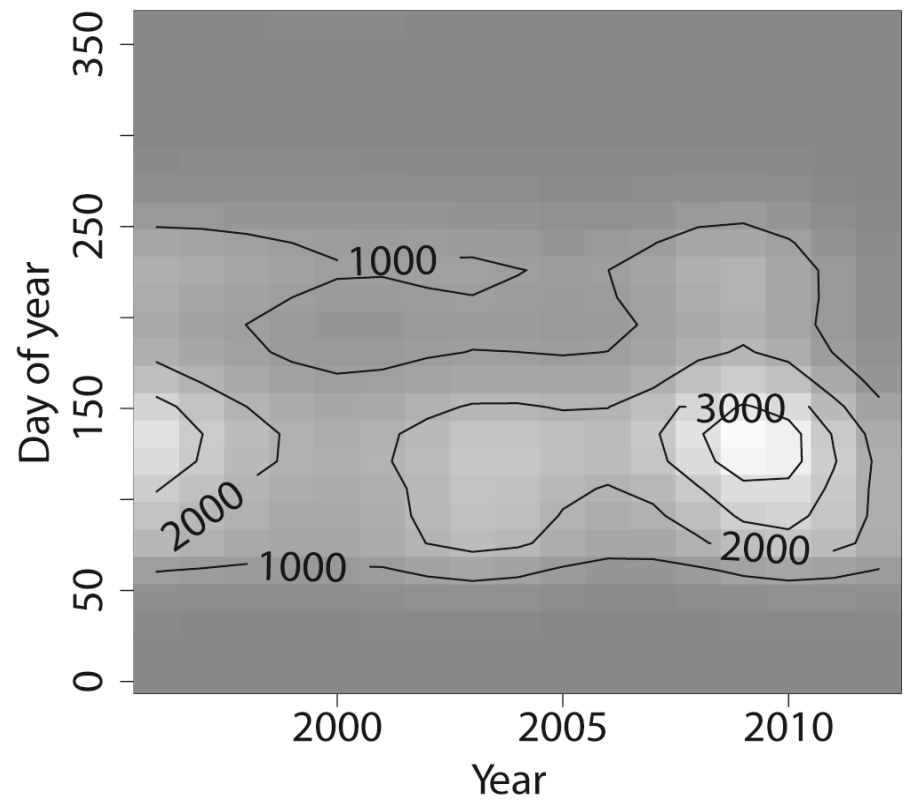
Proportion Adult ♀ Cfin



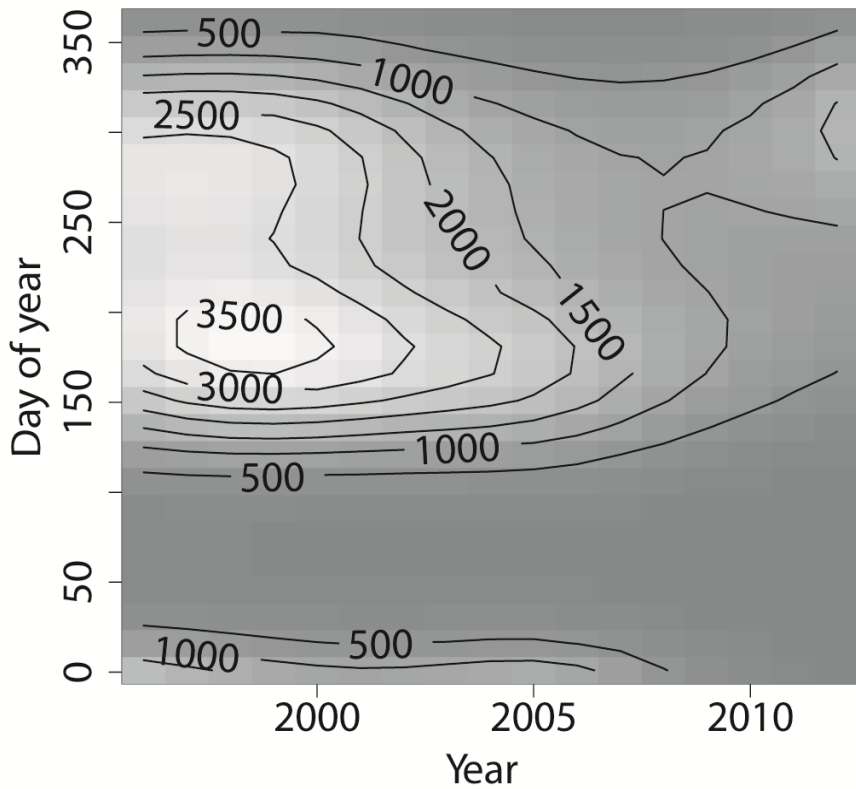
Prediction CV Cfin



Prediction Adult ♀ Cfin



Prediction CV Chel



Prediction Adult ♀ Chel

