Calanus species in a warmer northwest Atlantic: comparing projections performed with habitat models based on surface (CPR) and depth-integrated (plankton net) data

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- Continuous Plankton Recorder (CPR): unique dataset in the NATL widely used in zooplankton studies, including estimates of distribution changes in the past or in the future based on Habitat Models (**HMs**)

- The Atlantic Zone Monitoring Programme (AZMP) collects water column physical, chemical and biological oceanographic data in Canadian waters since 1999, a good basis to build **HMs** based on both occurrence and abundance data **(Albouy-Boyer et al. 2016)**

- CPR and AZMP data presents different characteristics:
  - **Surface (CPR) vs depth-integrated (AZMP) zooplankton sampling**
  - **CPR: semi-quantitative abundance data**
  - **Environmental data: concurrently sampled in AZMP, not with CPR**
  - **Better spatial coverage with CPR than in AZMP**

- Predictions with **HMs** : sensitive to the modelling methods and to the type of input data (ex: data poor vs data rich, etc….) **(ex: Lobo et al. 2008, Villarino et al. 2015, Brun et al. 2016)**

OBJECTIVE:

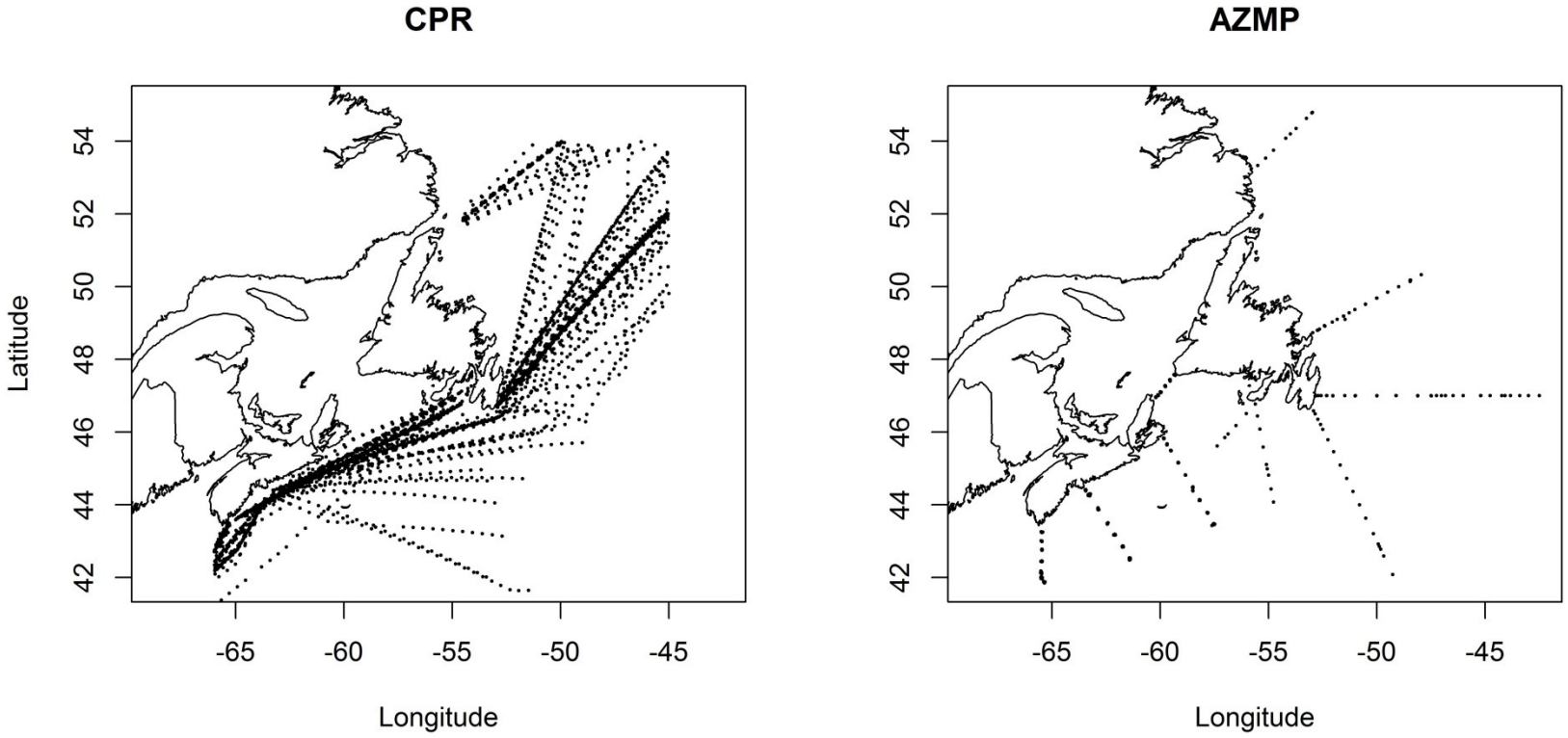
To perform a **NUMERICAL EXPERIMENT** **TO OBJECTIVELY** compare the use of epi-pelagic and depth integrated data to build **HMs** and predict the present and future spatial distribution of *Calanus* species

Approach:

1) Build **HMs** using CPR and AZMP data over the same region/period using the same statistical modelling approach

2) Compare present and future distribution of *Calanus* estimated with CPR- and AZMP-based occurrence **HMs**

DATA: spatial and temporal scales



- **CPR data restricted to the AZMP region**
- **Gulf of St. Lawrence excluded from analyses- no CPR sampling**
- **Years: 1999-2012 (Albouy-Boyer et al. 2016)**
- **Season: April to December (AZMP sampling)**
- **Similar environmental envelopes among dataset**

- **Response variables: CPR *Calanus* categories**
  - ***C. glacialis* CV-VI, *C. hyperboreus* CV-VI, *C. finmarchicus* CV-VI**

- **Predictor variables**
  - **AZMP data** (*Albouy-Boyer et al. JPR 2016*):
    - T_0-50m
    - S_0-50m
    - T_NB
    - DEPTH
    - STRATIFICATION
  - **CPR: surface satellite imagery data**
    - SST
    - SSS (climatology) complemented with 3-D physical model
    - DEPTH

Generalized additive mixed model (GAMM)

- **GAMM (Albouy-Boyer et al. 2016)**
  - **YEAR included as a Mixed Effect (=random effect) to avoid the potential influence of long-term trends in environmental conditions on future prediction**

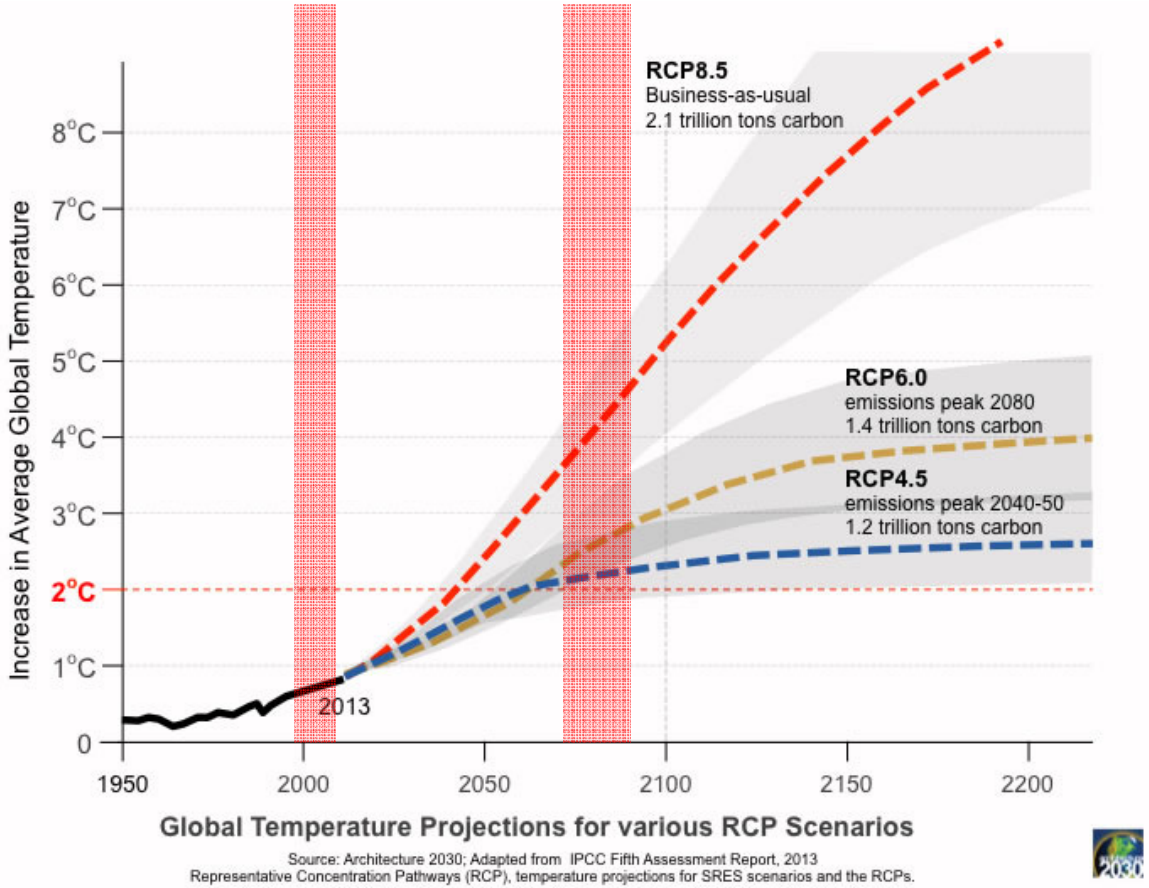
- **Model performance/validation (*Chust et al. 2014, Villarino et al. 2015, Albouy-Boyer et al. 2016*)**
  - **K-fold partitioning: 30 % of independent observations**
  - **True Skills Statistics (TSS)**
    - **TSS= specificity + sensitivity -1.**
    - **Value between 0 and 1, 0.4 = good model**
  - **Area Under the characteristic Curve *(*AUC): measure of ability of occurrence predictions to discriminate presence from absence**
    - **0.5 = random, 1 = perfect discrimination**
  - **Occurrence probability threshold for presence/absence: sensitivity-specificity sum maximizer (Jiménez-Valverde and Lobo, 2007)**

Environmental conditions for predictions: NEMO-OPA model

- Atmospheric-Oceanic model of the ATL
- Downscaling in Atlantic Canada - Horizontal resolution of 1/12° ~ 5km (Brickman et al 2015, Brickman et al 2016)
- Includes sea-ice model and river inputs
- 50 vertical layers
- RCP8.5: projection under current rate of CO_2 emission
- Monthly climatology used with GAMM for numerical experiment

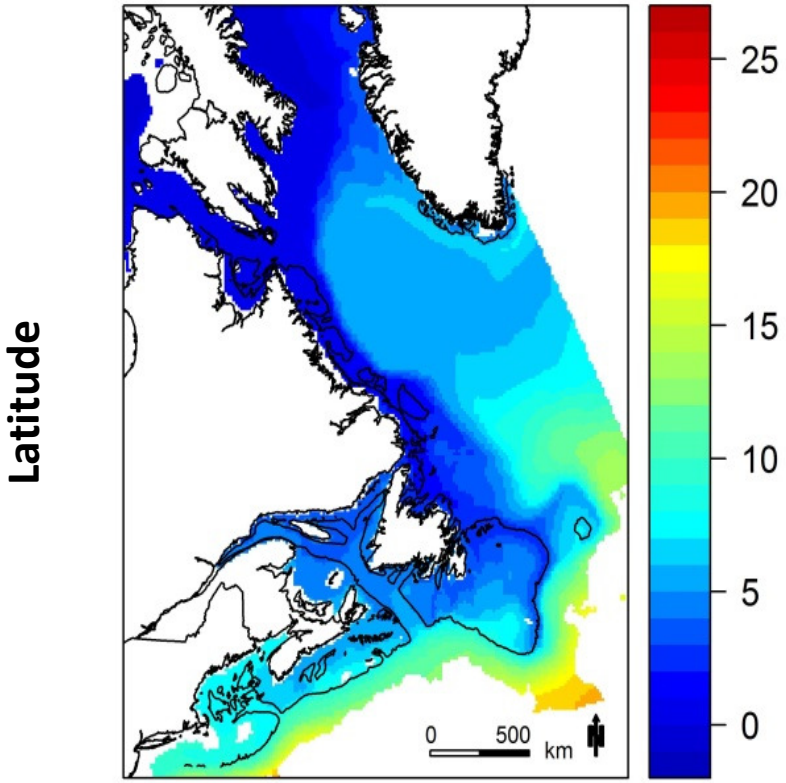
Present : 1999-2012

Future: RCP8.5 2066-2085

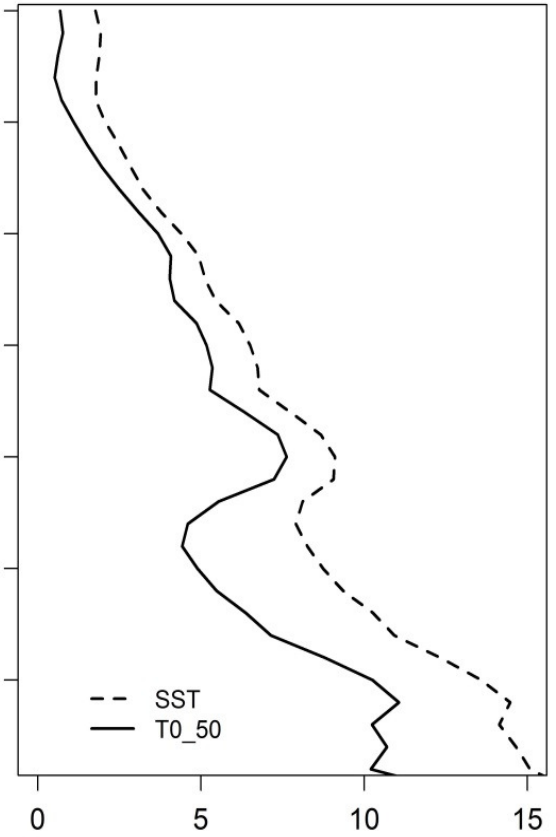


Environmental conditions in the present and future: NEMO-OPA model April-September

Temperature in 1999-2012: T_0-50

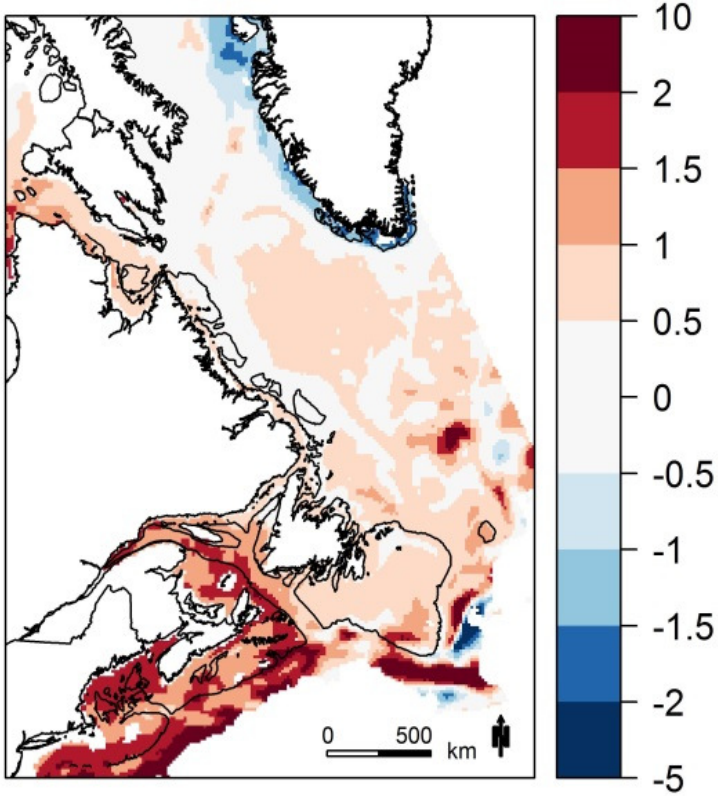


Temperature in 1999-2012: T_0-50 vs SST



Environmental conditions in the present and future: NEMO-OPA model April-September

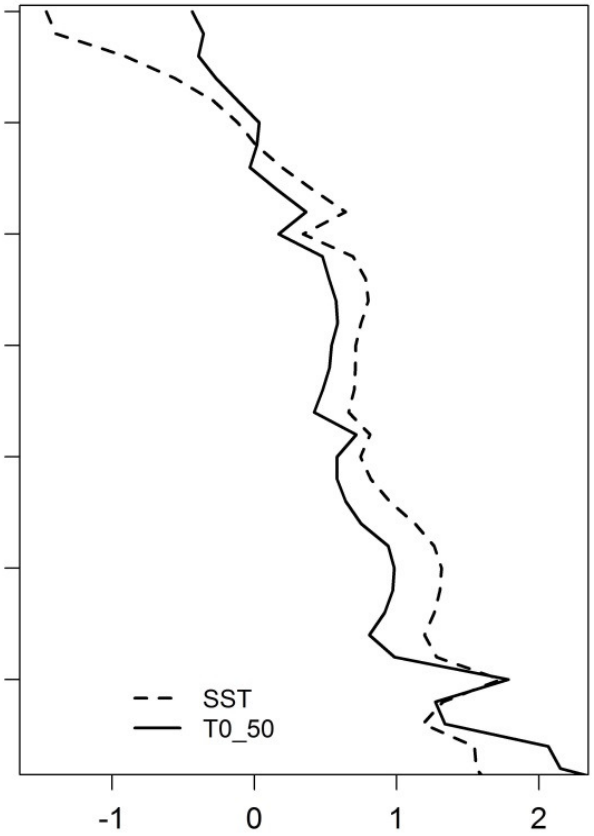
Anomaly in 2066-2085: T_0-50



Latitude

Longitude

Anomaly in 2066-2085: T_0-50 vs SST



Temperature (°C)

GAMM based on occurrence

CPR — **Comparable to Chust et al. 2014 and Villarino et al. 2015**

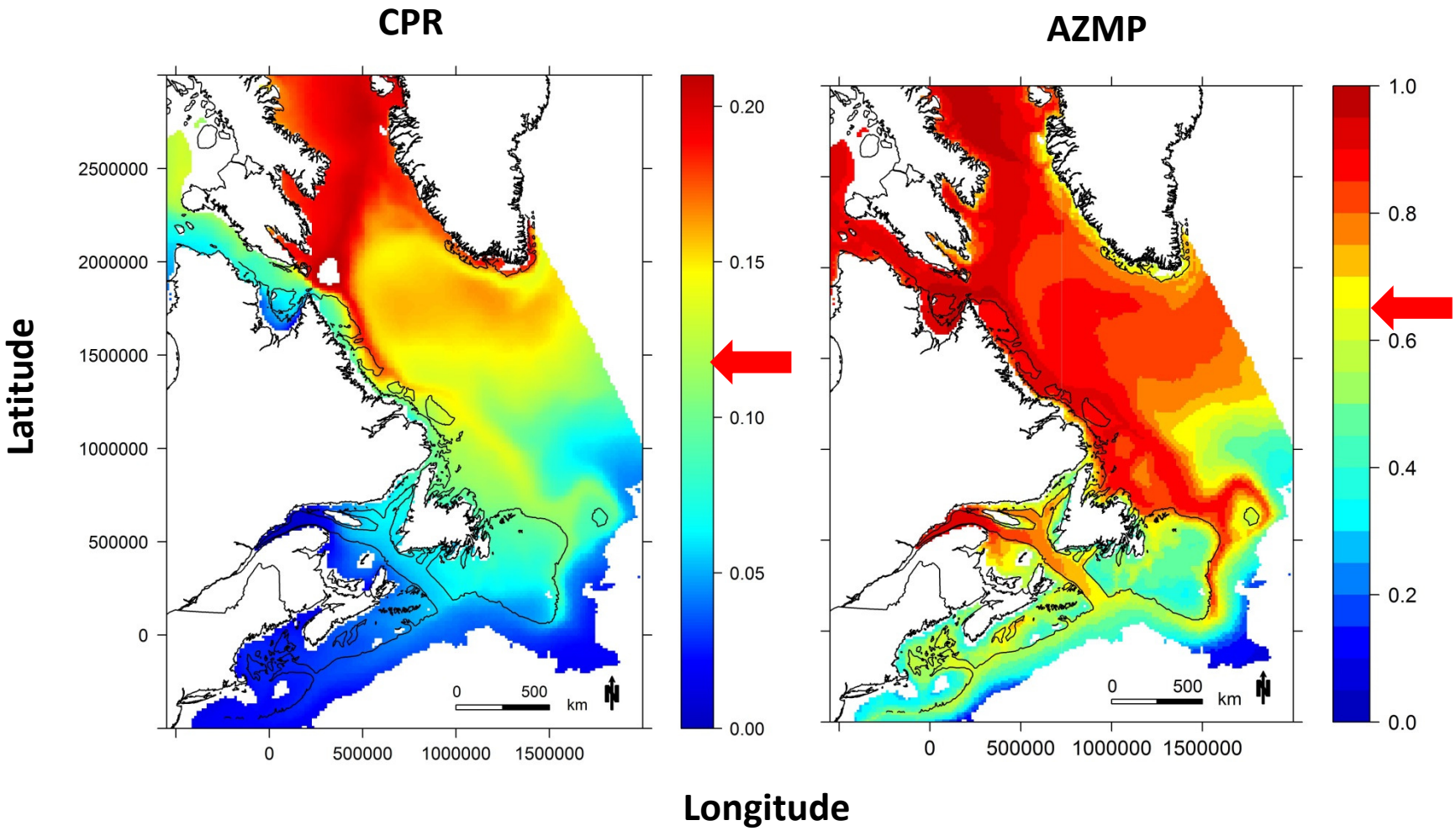
Species	Equation	N	Intercept	Prevalence	Threshold	TSS	AUC
C glacialis V-VI	Occ ~ SSS*** + SST***	4555	Spr:-2.6198*** S-F :-1.033***	**0.08**	**0.12**	**0.50**	**0.81**
C. hyperboreus V-VI	Occ ~ SSS*** + SST***	4555	Spr:-3.3356*** S-F :-3.0663***	**0.06**	**0.08**	**0.72**	**0.92**
C. finmarchicus V-VI	Occ ~ SSS*** + SST***	4555	Spr:0.8174*** S-F :0.129ns	**0.69**	**0.70**	**0.28**	**0.68**

AZMP — **Comparable to Albouy-Boyer et al. 2016**

Species	Equation	N	Intercept	Prevalence	Threshold	TSS	AUC
C glacialis V-VI	Occ ~ lDEPTH** + lSTRAT*** + S0_50* + T_NB** + T0_50***	602	Spr:0.2667ns S-F:0.6717*	**0.63**	**0.61**	**0.44**	**0.77**
C. hyperboreus V-VI	Occ ~ lDEPTH*** + lSTRAT*** + T_NB*** + T0_50***	602	Spr:2.2191*** S-F:-1.4833***	**0.70**	**0.68**	**0.55**	**0.84**
C. finmarchicus V-VI	**NO OCCURRENCE MODEL**			**0.99**			

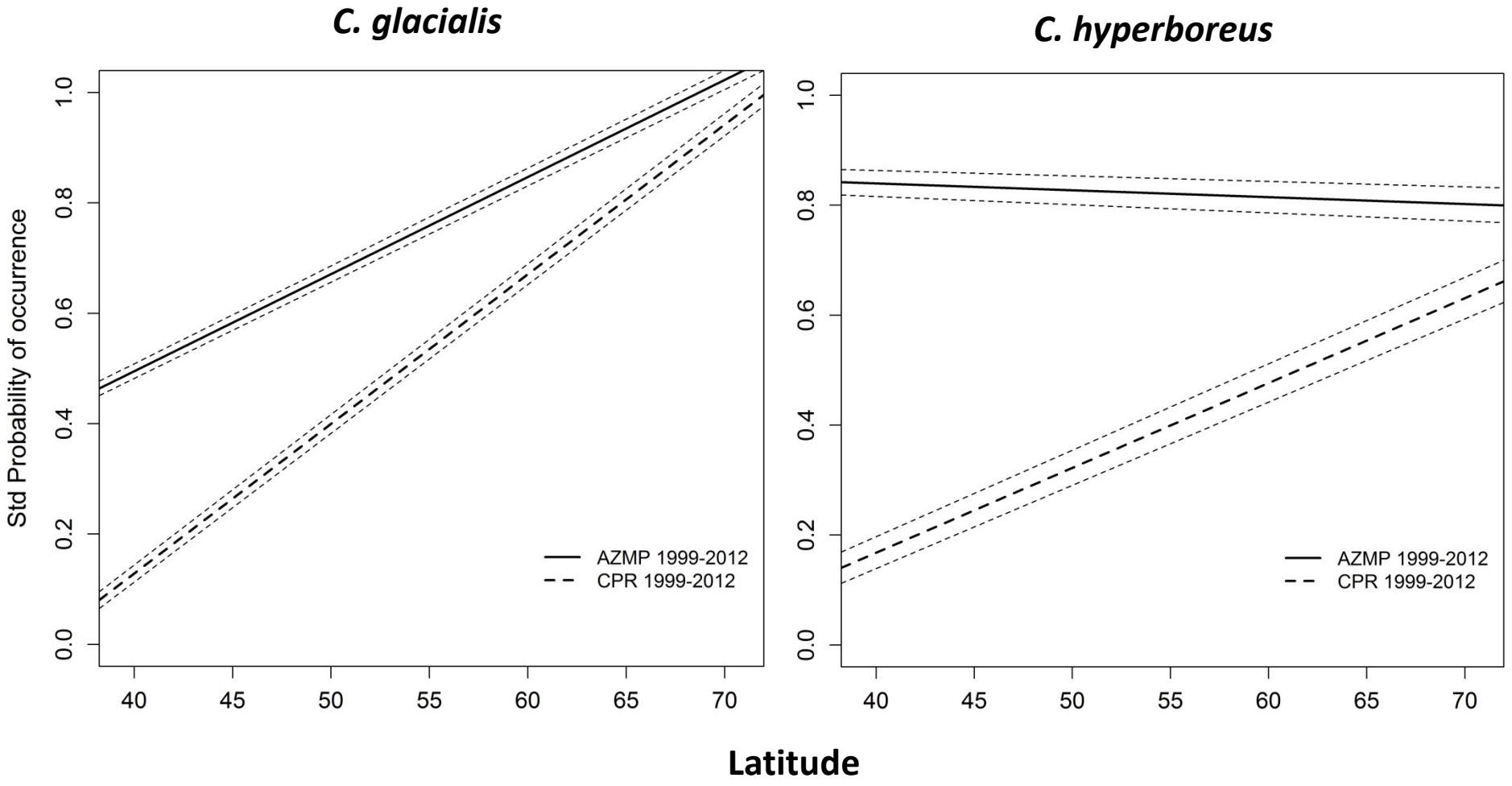
The present: April-September 1999-2012

Predicted occurrence probability of *C. glacialis* with CPR and AZMP models



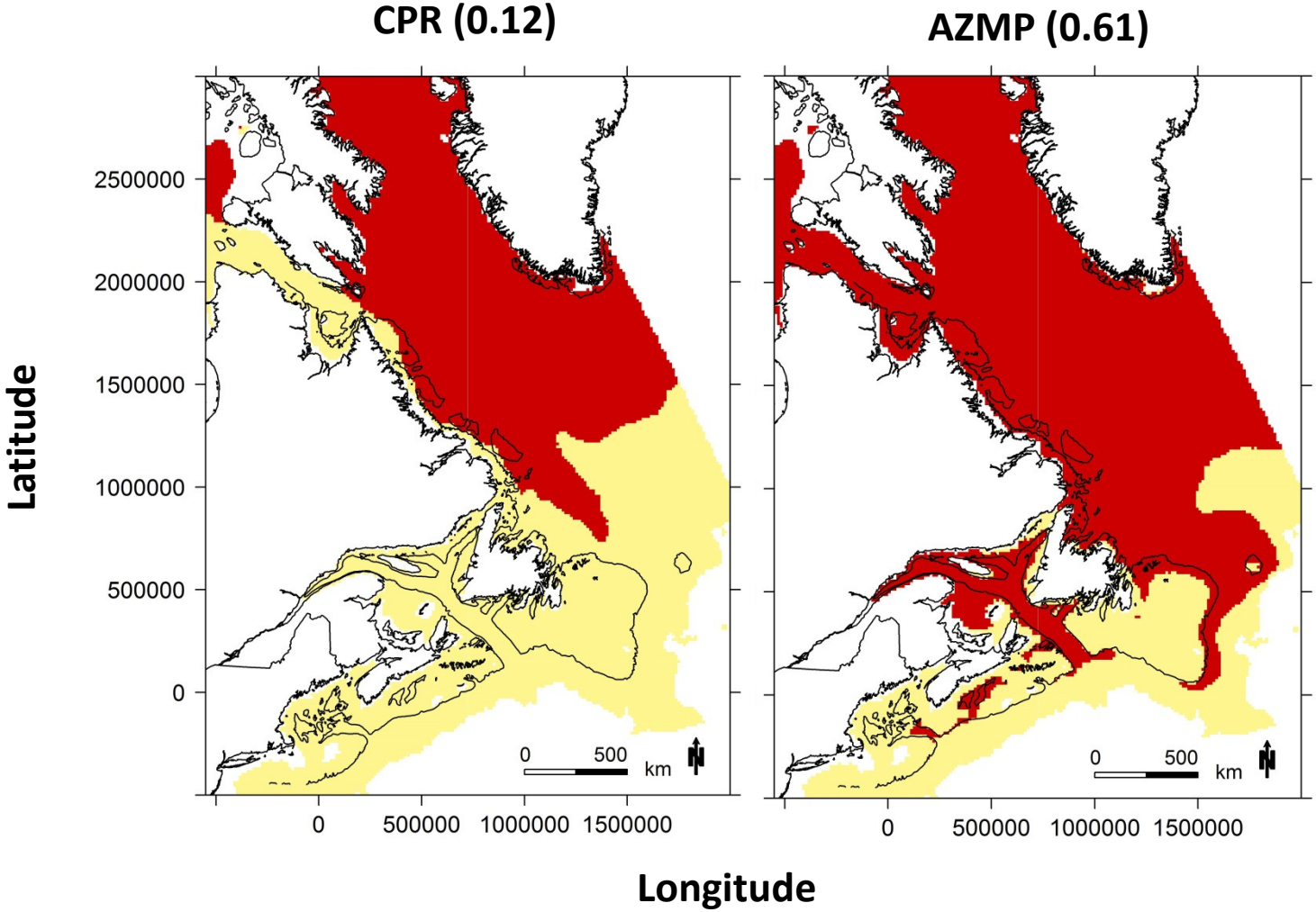
The present: April-September 1999-2012

Predicted occurrence probability vs Latitude



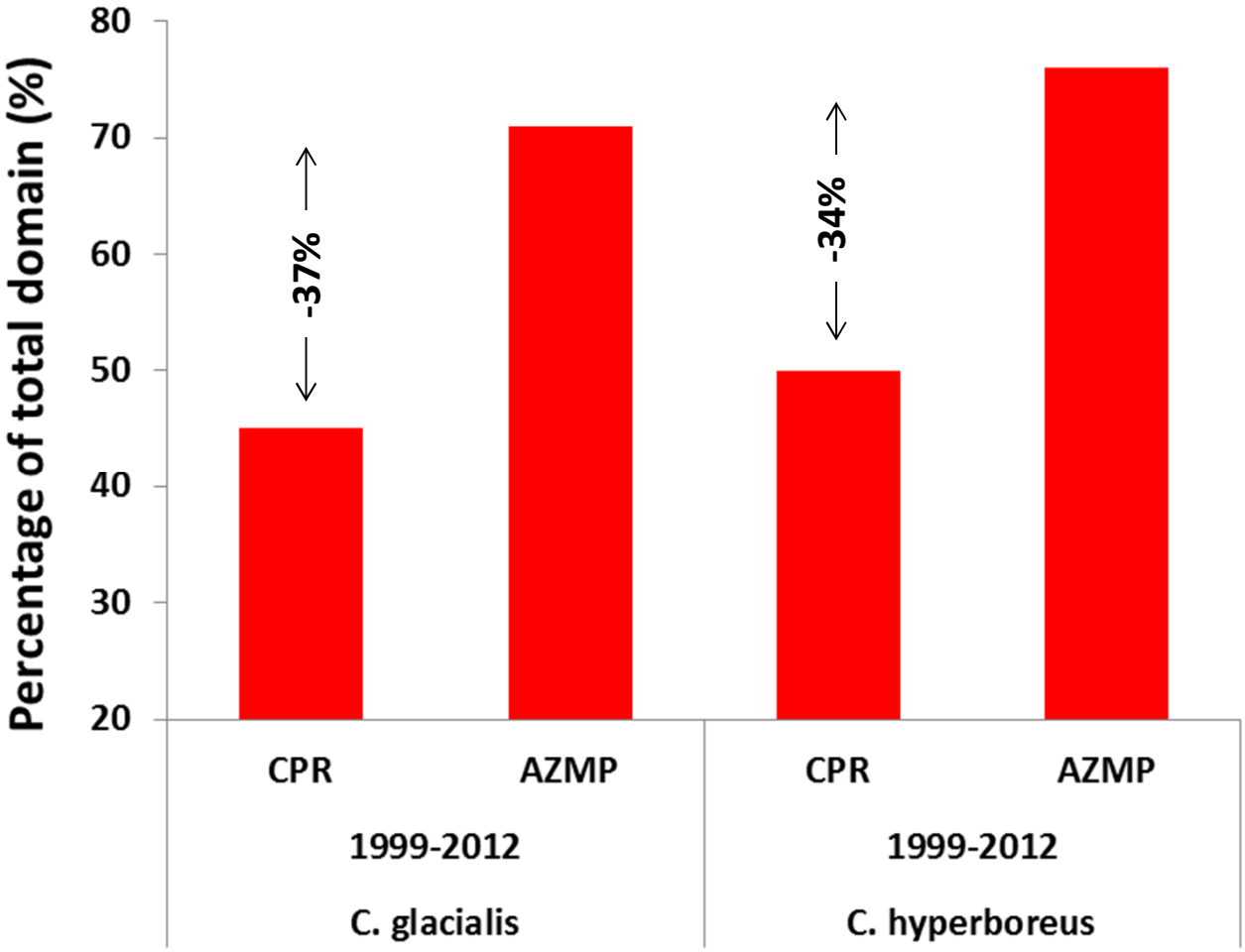
The present: April-September 1999-2012

Predicted presence/absence of *C. glacialis*



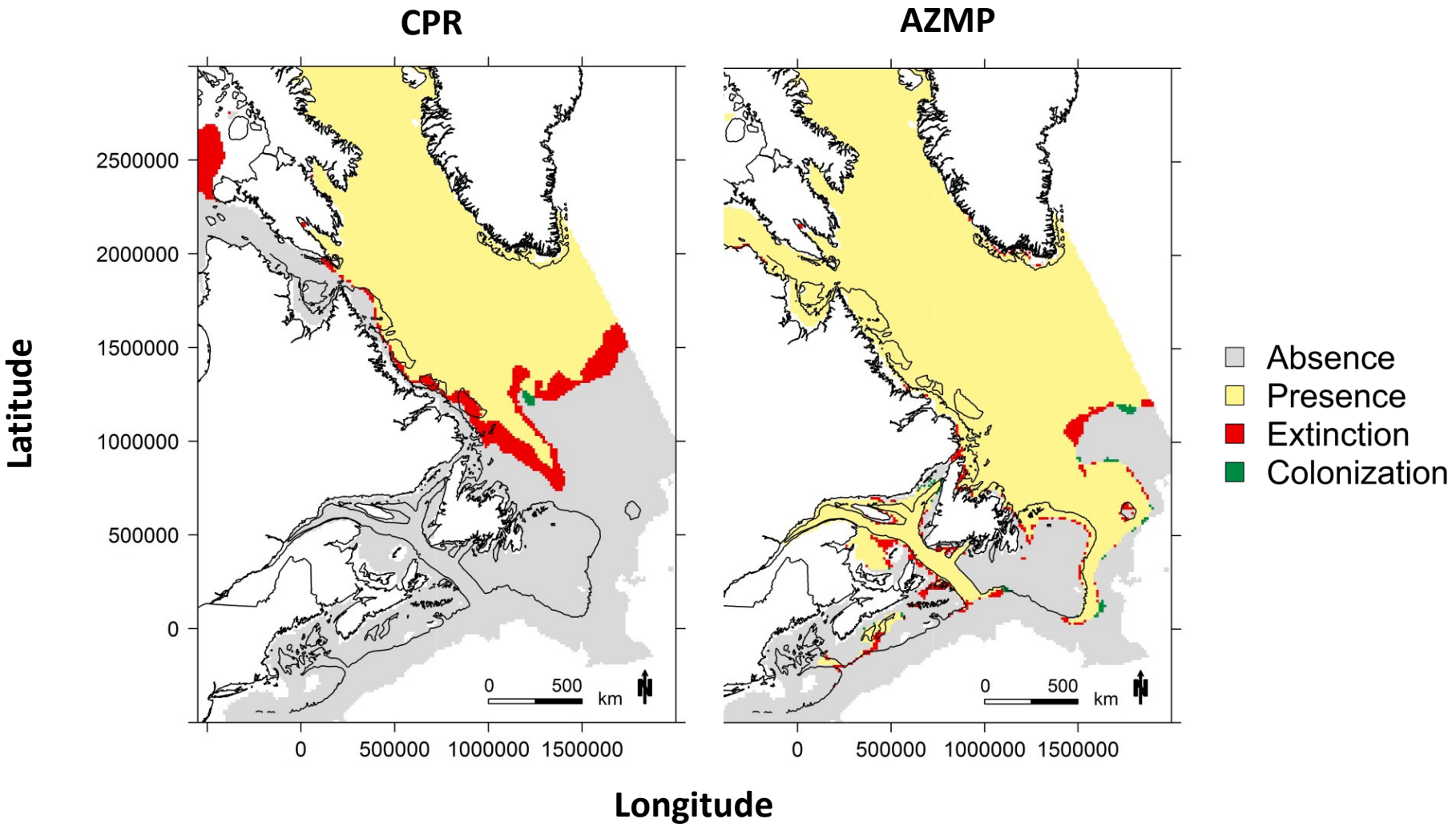
The present: April-September 1999-2012

Presence area of *C. glacialis* and *C. hyperboreus*



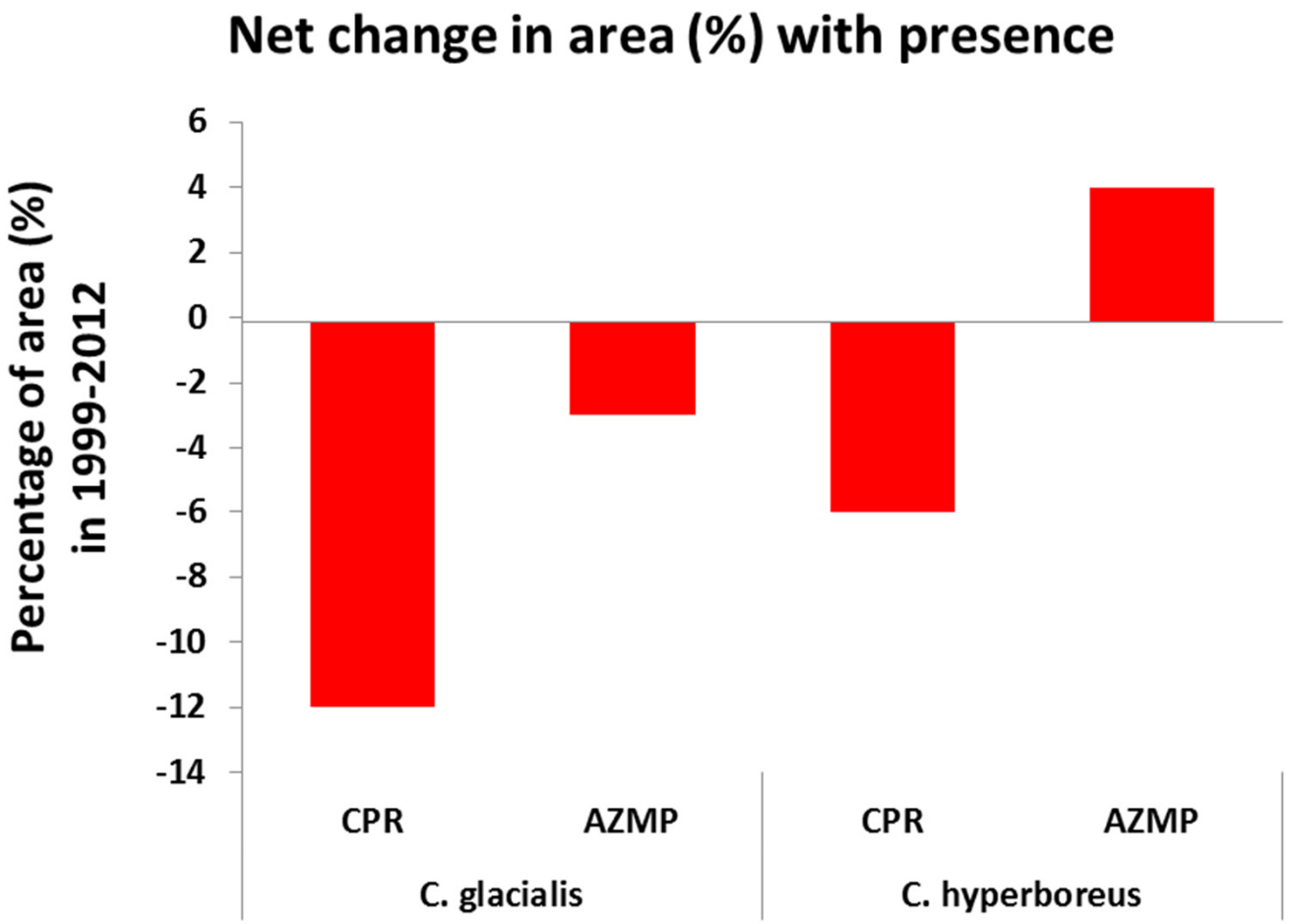
The future: April-September 2066-2085

Change in presence of *C. glacialis* vs present



The future: April-September 2066-2085

C. glacialis



1) **HMs** built for *C. glacialis* and *C. hyperboreus* with CPR occurrence data in the NW ATL were comparable to those including using the entire North ATL domain. The performance of **HMs** based on AZMP occurrence data was also comparable to previous models.

2) Surface based, present condition (1999-2012) **HMs** using CPR data predicted both lower occurrence probability and smaller area occupied than **HMs** based on AZMP data for both *Calanus* species

3) A greater decrease in the area occupied by *C. glacialis* and *C. hyperboreus* in the future (2066-2085) was predicted with surface-based **HMs** than with AZMP **HMs**

4) This comparison at the scale of the NW ATL suggests that historical spatial distributions and **HM** used to make predictions of *Calanus* spatial distribution in the North ATL are sensitive to different types of monitoring data.

5) A comparison at the scale of the NATL would be beneficial for our overall understanding of pros and cons associated to the use of various statistical approaches and datasets, including using abundance data (**Brun et al. 2016, Albouy-Boyer et al. 2016**)

Acknowlegments

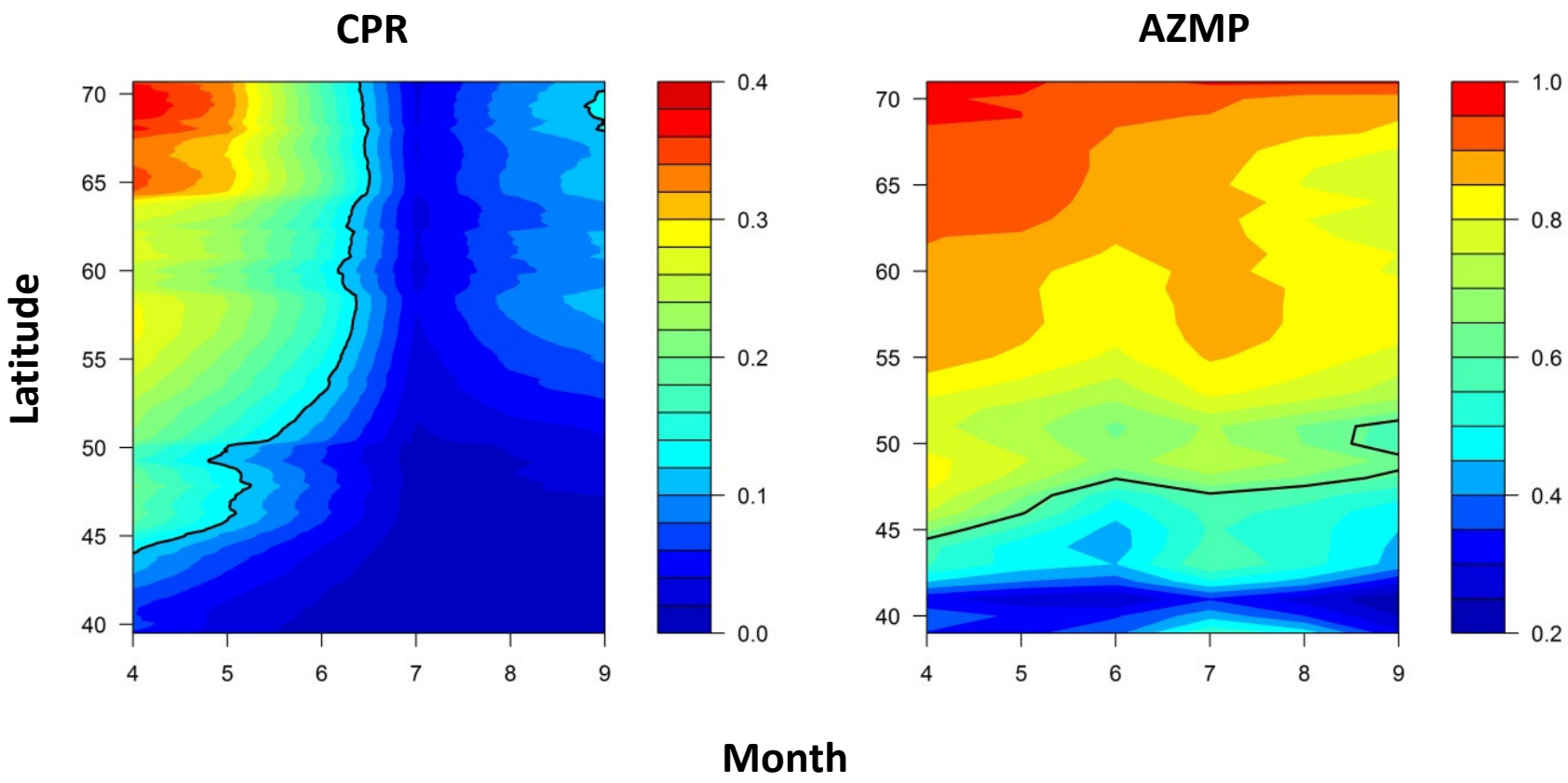
We gratefully acknowledge the contribution of the different crews providing an excellent service on the various research vessels used to achieve AZMP.

We also thanks members of the DFO oceanographic monitoring team and data management from DFO Quebec, Maritimes and Newfoundland regions for their highly professional sampling and sample analysis work associated to AZMP.

Extra stuff……..

The present: April-September 1999-2012

Predicted occurrence probability of *C. glacialis*



GAMM based on abundance only

CPR

Species	Equation	N	Intercept	rho	r2
C glacialis V-VI	Abund ~ SSS*** + SSTns	375	Spr: 1.0615*** S-F: -0.4377***	**0.25**	**0.07**
C. hyperboreus V-VI	Abund ~ SSS*** + SST**	264	Spr: 1.6584*** S-F: -0.5762ns	**0.38**	**0.13**
C. finmarchicus V-VI	Abund ~ SSS*** + SST***	3158	Spr: 2.5404*** S-F: -0.2222***	**0.24**	**0.06**

AZMP **Comparable to Albouy-Boyer et al. 2016**

Species	Equation	N	Intercept	rho	r2
C glacialis V-VI	Abund ~ lDEPTH*** + lSTRAT*** + S0_50*** + T0_50***	382	5.652***	**0.56**	**0.37**
C. hyperboreus V-VI	Abund ~ lDEPTH*** + lSTRAT*** + S0_50*** + T0_50***	420	Spr:6.2824*** S-F:-0.6351***	**0.69**	**0.55**
C. finmarchicus V-VI	Abund ~ lDEPTH*** + T_NB*** + T0_50***	602	Spr:8.3201*** S-F:0.5041***	**0.60**	**0.27**

The present: April-September 1999-2012

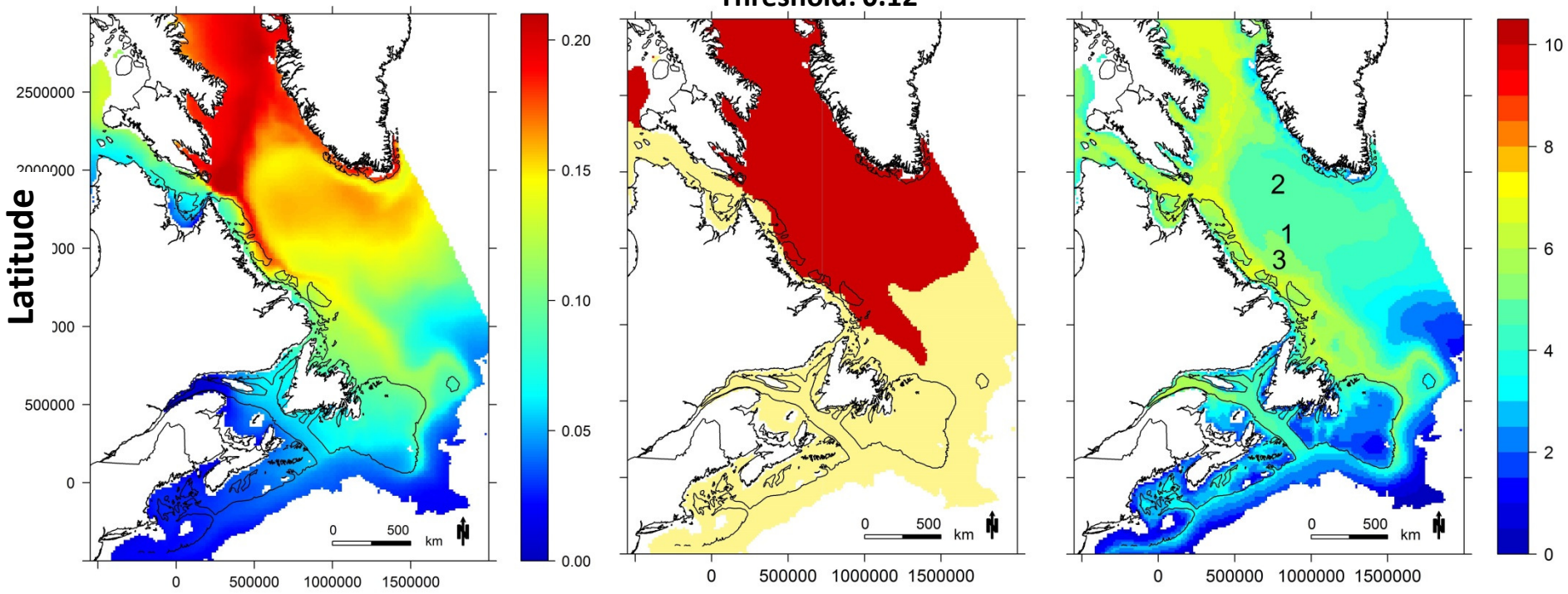
Occurrence- (CPR) and abundance-based (AZMP) habitat models: *C. glacialis*

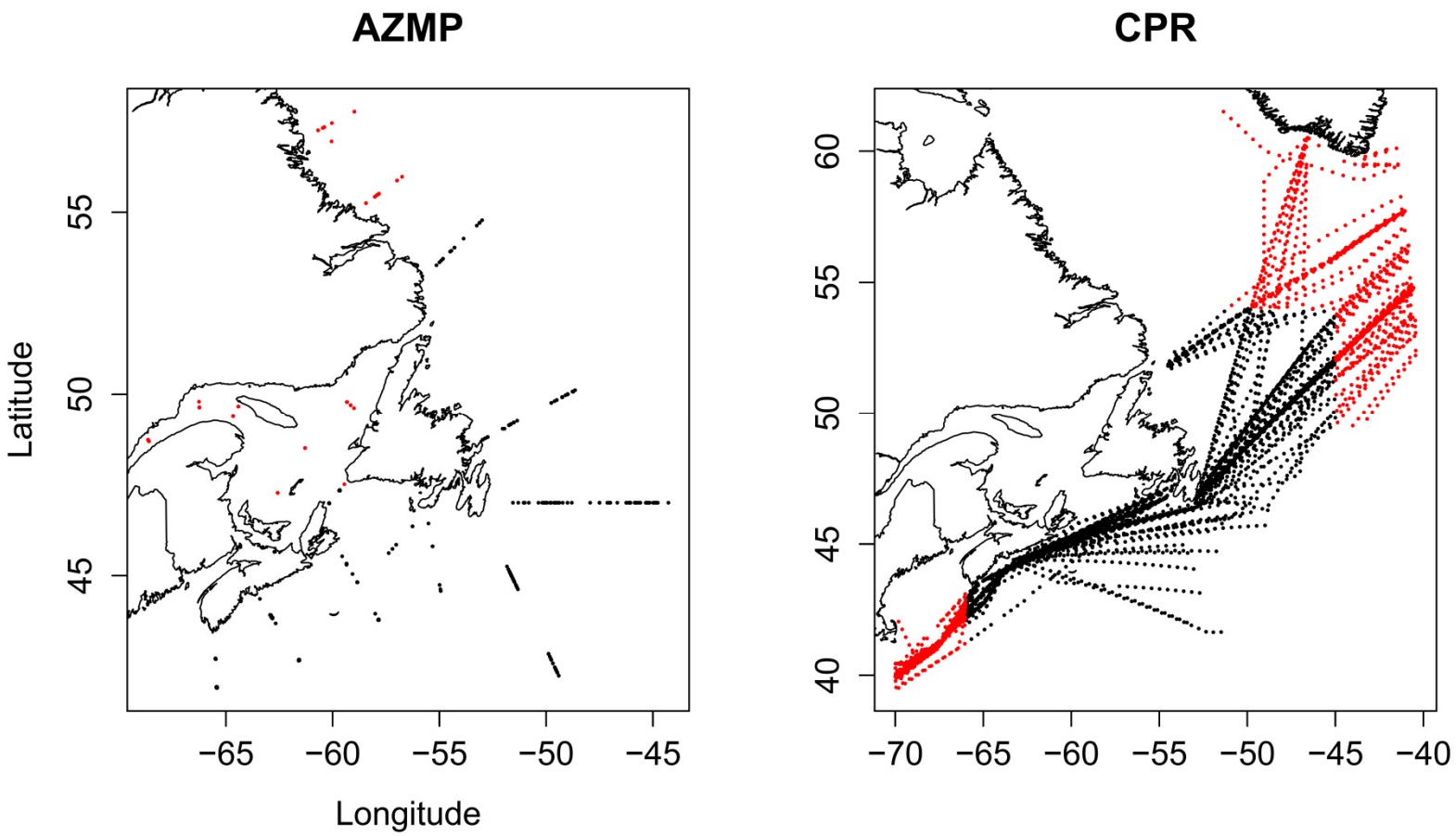
1. CPR: occurrence prob

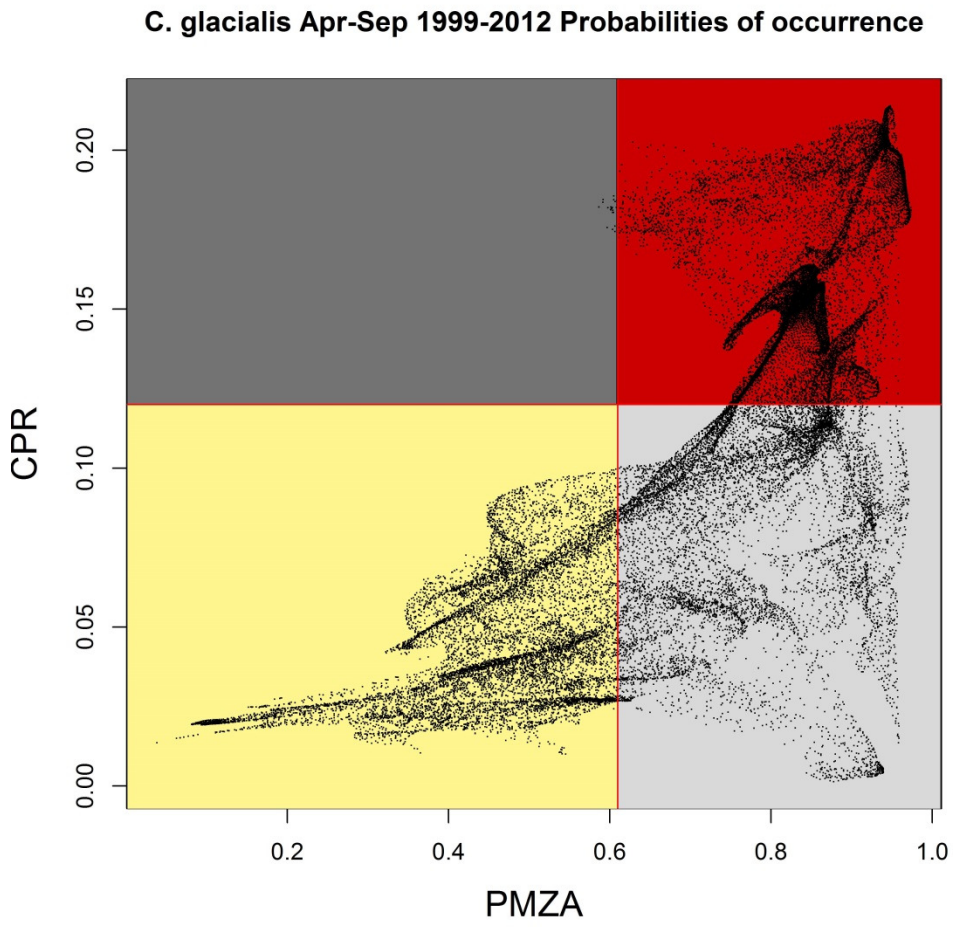
2. CPR: pres/abs

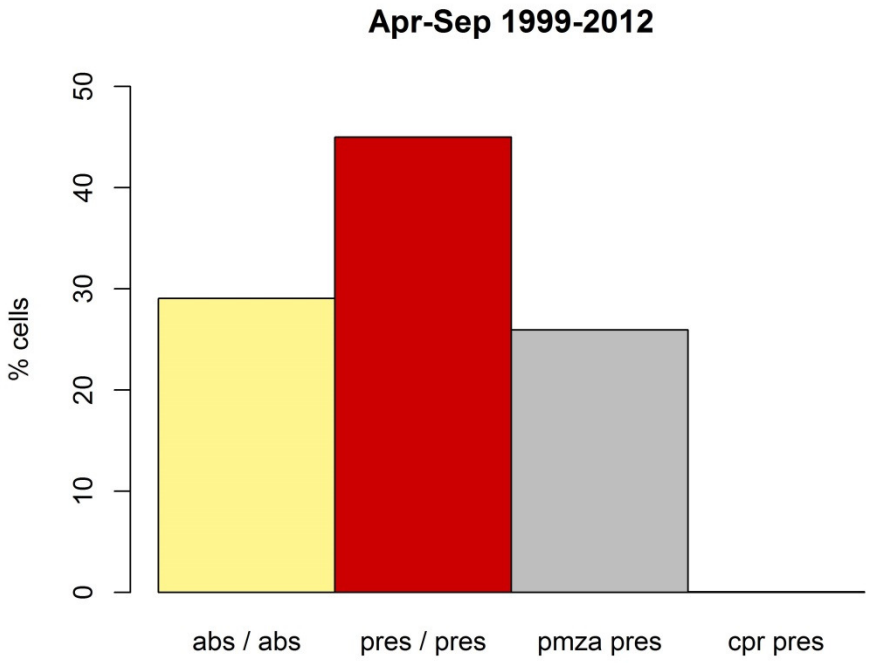
Threshold: 0.12

3. AZMP: occ prob*abund




AZMP
CPR
Latitude
Longitude
45
50
55
−65
−60
−55
−50
−45
40
60
−70
−40


C. glacialis Apr-Sep 1999-2012 Probabilities of occurrence
CPR
0.00
0.05
0.10
0.15
0.20
0.2
0.4
0.6
0.8
1.0
PMZA


Apr-Sep 1999-2012
% cells
0
10
20
30
40
50
abs / abs
pres / pres
pmza pres
cpr pres