Population responses of Antarctic top predators to climate changes

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cnrs dépasser les frontières

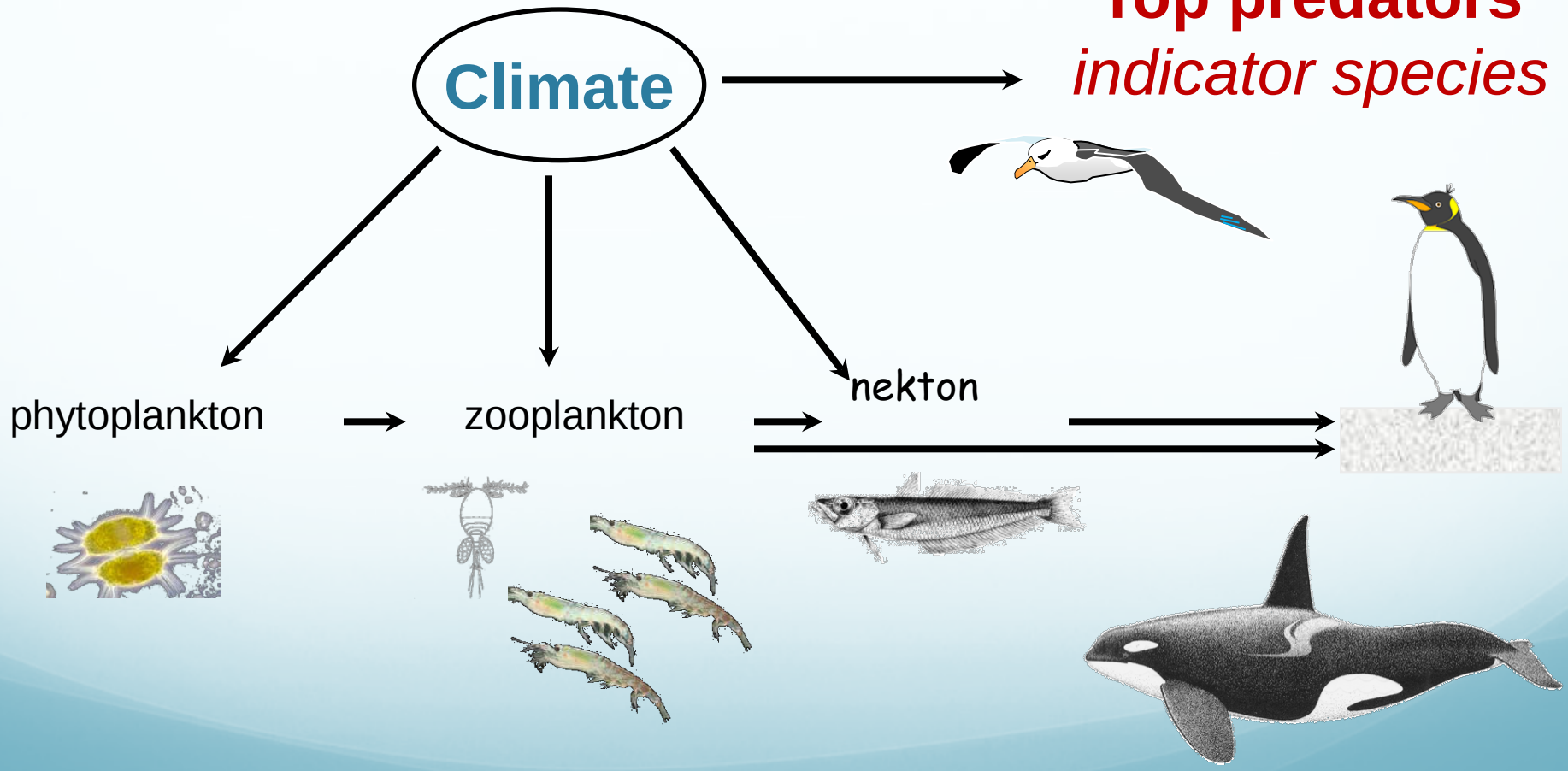
IPEV Institut Polaire Français Paul Emile Victor

Woods Hole Oceanographic Institution 1930

NCAR

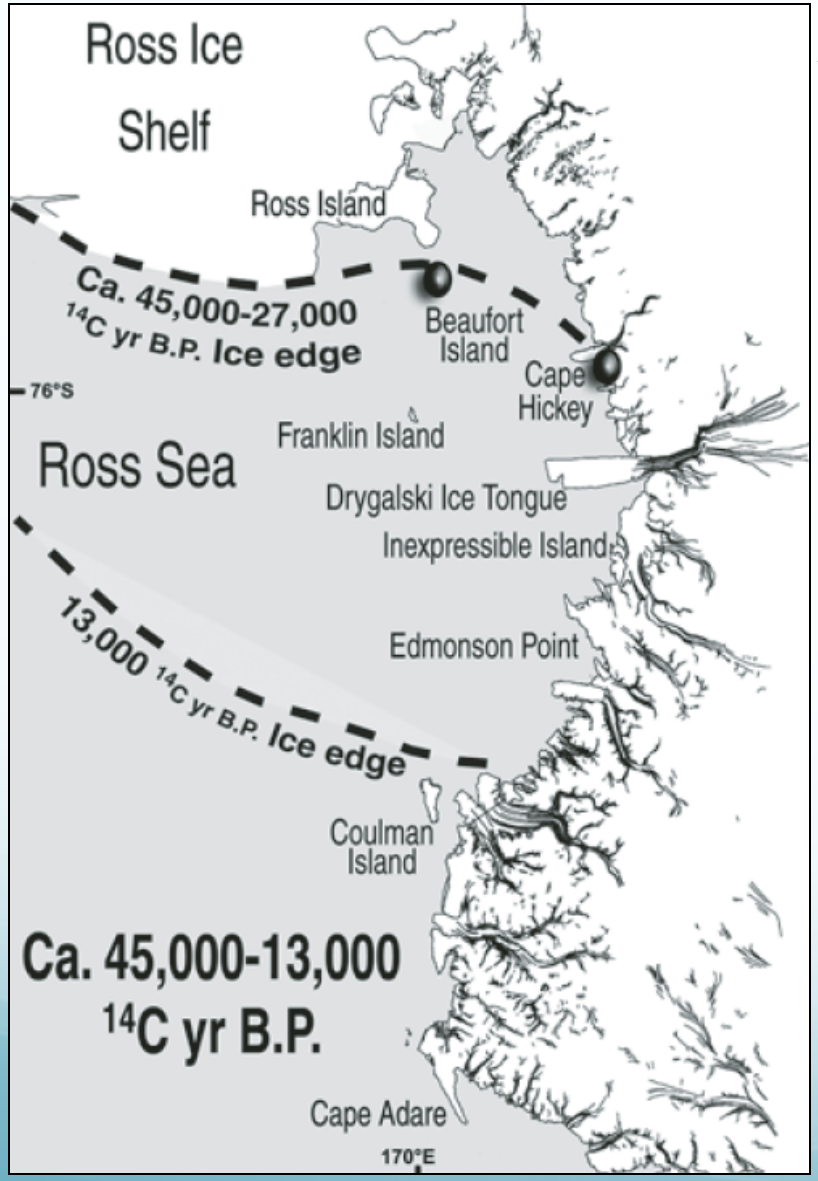
NSIDC

Top predators provide an integrative view of the ecological consequences of change in their environment



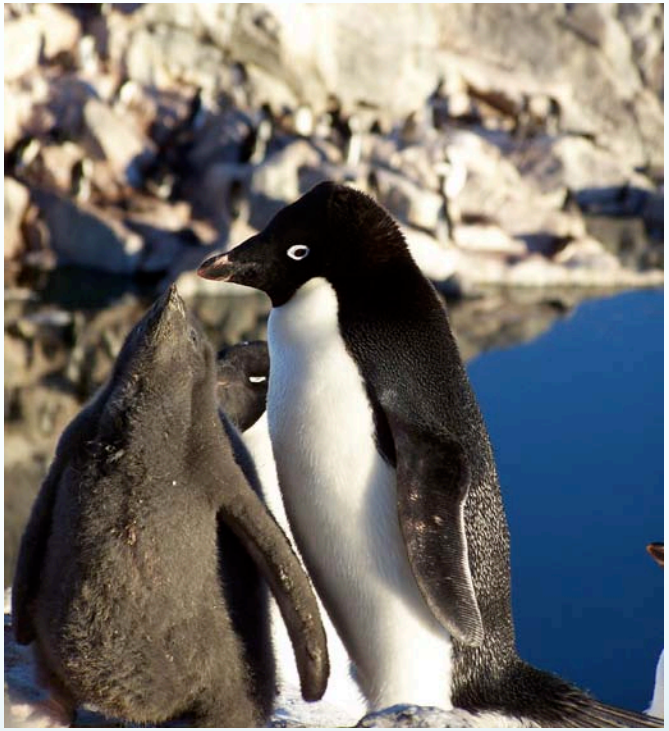
Furness and Greenwood 1993

Historical changes of Adélie penguin distribution indicate changes in the marine environment



Emslie et al. Geology 2007

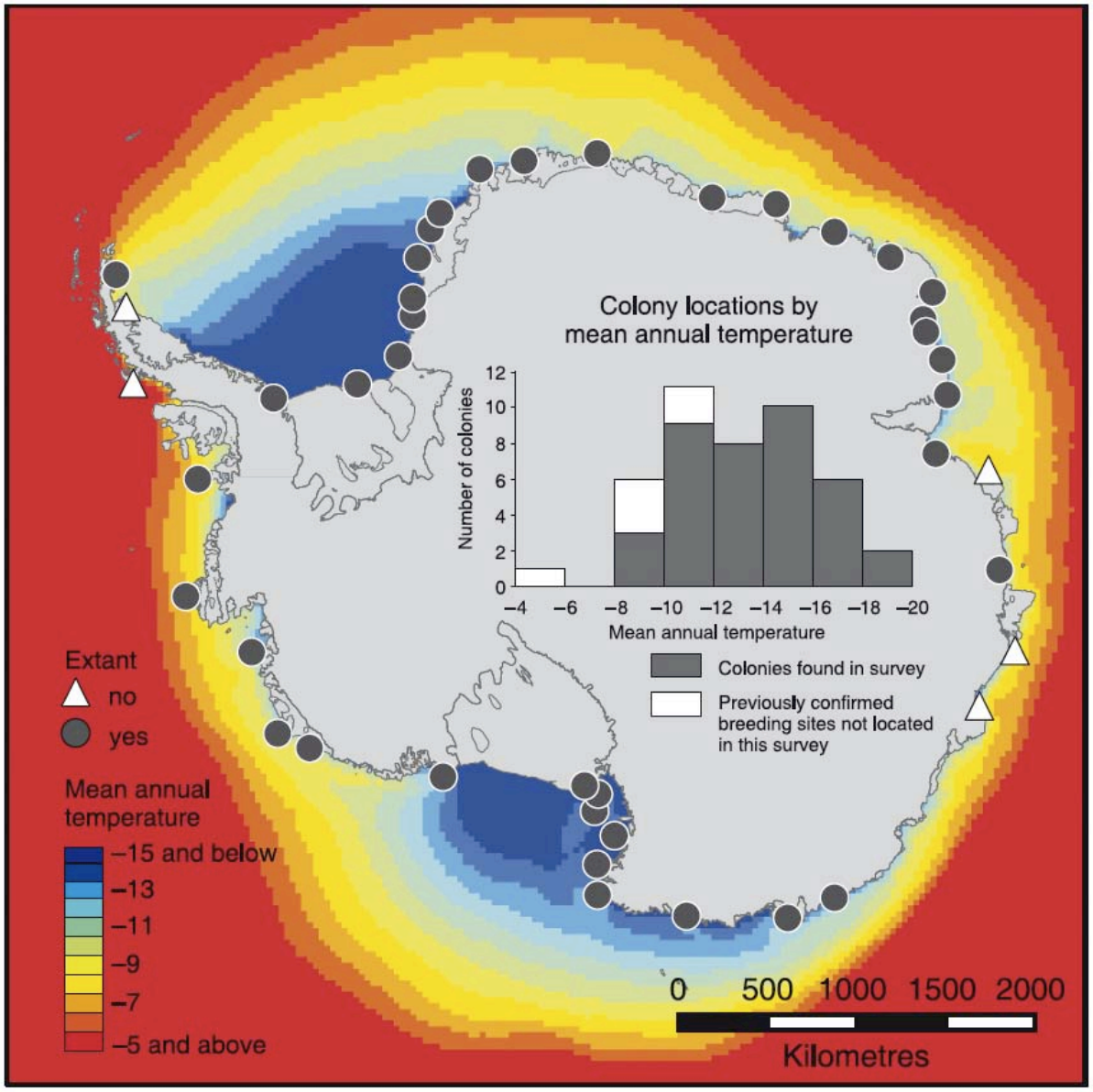
Adélie penguin distributions have shifted over millennia with sea-ice extent.



Adélie penguin breed in summer in open-water area

Radiocarbon dates on penguin remains provide an occupation history

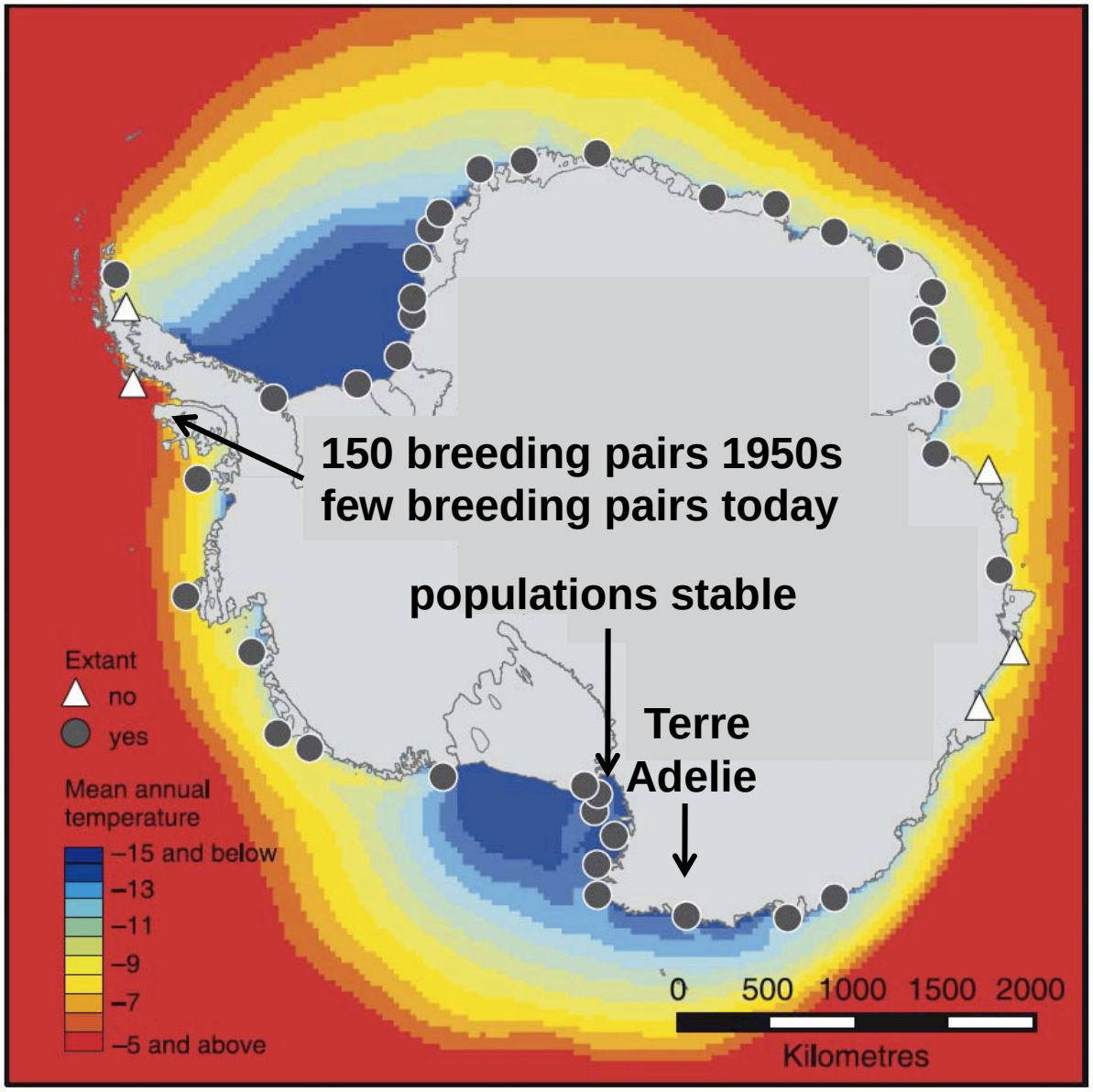
Present changes of emperor penguin distribution correlated to climate variation



Emperor penguin breed in winter on sea- ice

Fretwell and Trathan 2009

Present changes of emperor penguin populations correlated to climate variation



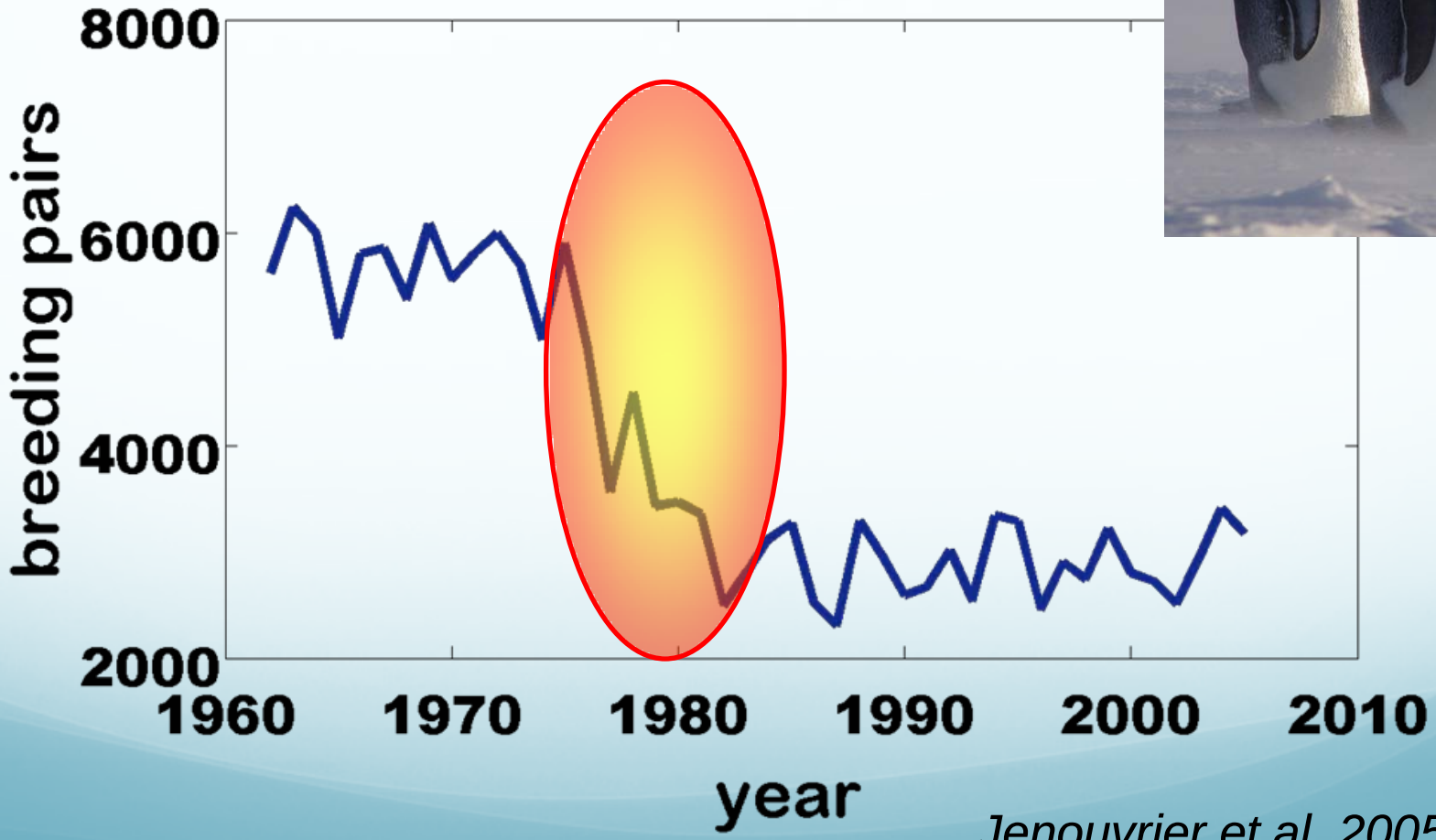
Emperor penguin breed in winter on sea- ice

Fretwell and Trathan 2009

Emperor penguin population in Terre Adelie

Regime shift

warm environmental conditions:
more moisture from warm subtropical sources to the Antarctic coast, *Masson-Delmotte et al. 2003*
SIE decline by 11% on average

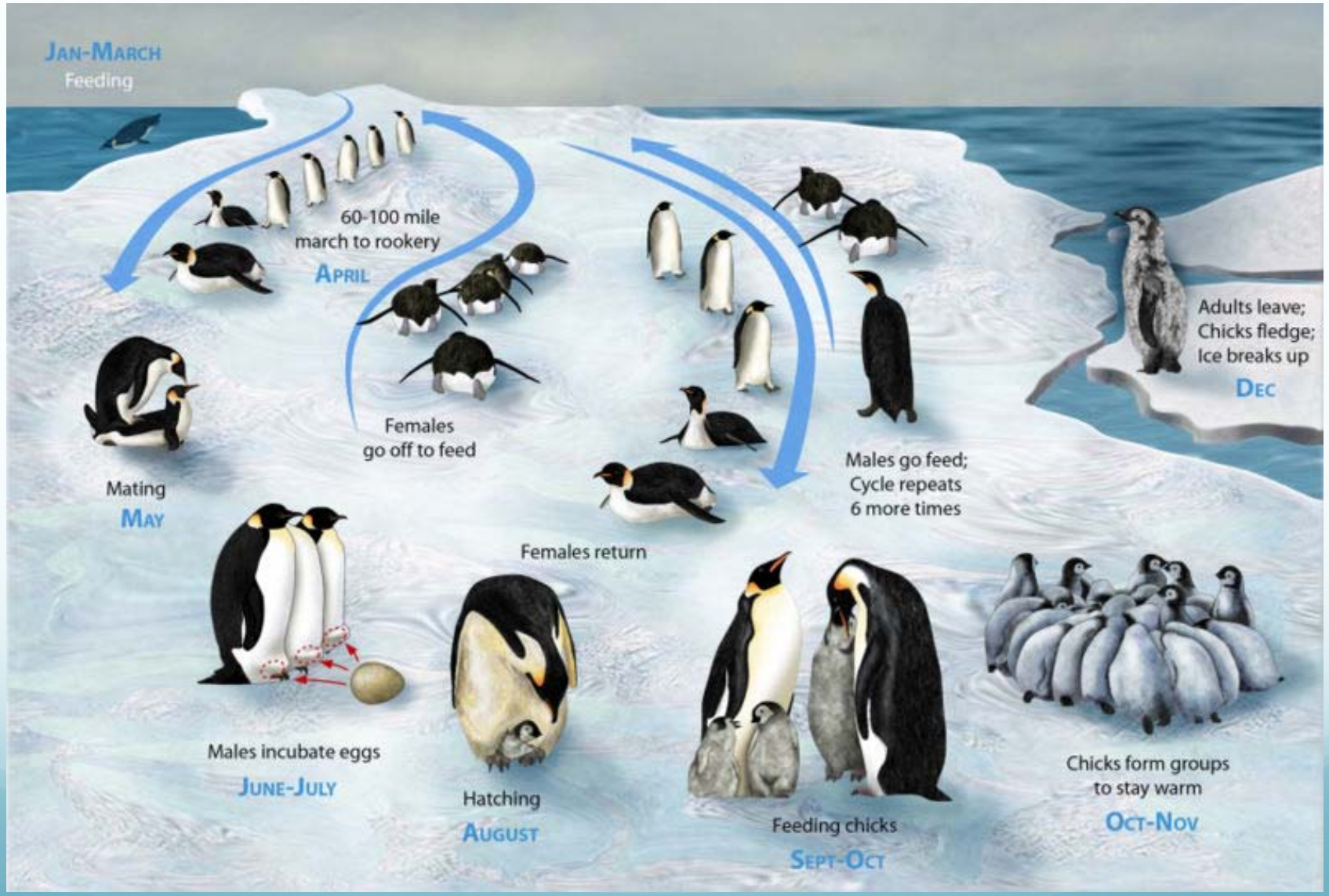


Jenouvrier et al. 2005 PRS

Are penguins marching toward extinction under future climate change?

Habitat and sea ice

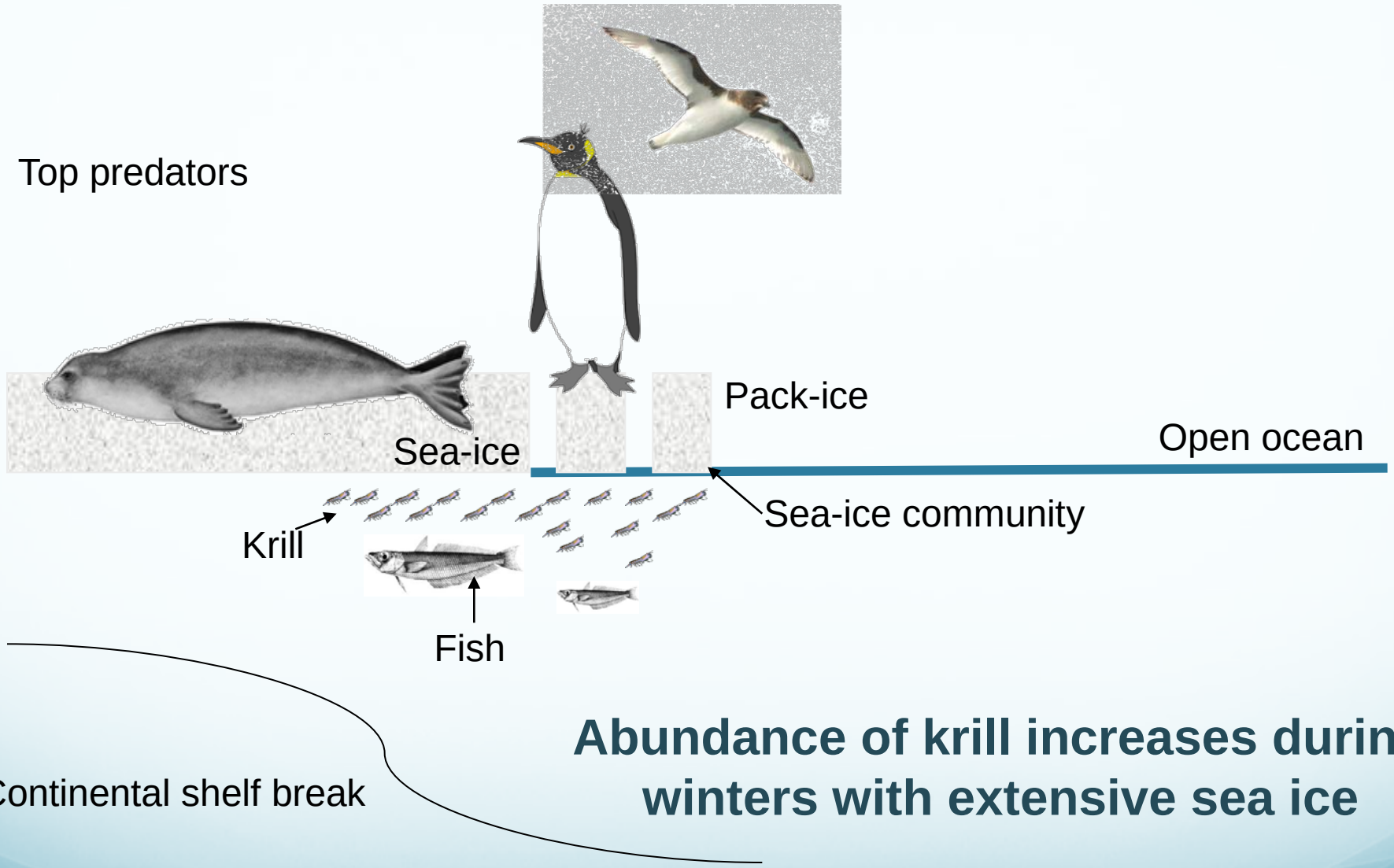
In years with dense and extensive sea ice cover, foraging trips are longer, energetic costs for adults are higher, and chick provisioning is lower.



Source: wikipedia

Wienecke et al. 1997; Massom et al. 2008

Food availability and sea ice



Abundance of krill increases during winters with extensive sea ice

Loeb et al. Nature 1997; Brierley et al. Science 2002

Effect of sea ice on life history traits

Extended sea-ice

longer feeding trips

more food

Breeding success

Survival

Population

Jenouvrier et al. 2005 Ecology

Effect of sea ice on population: population models

Population models based on dividing individuals into categories *Caswell 2001*

Population

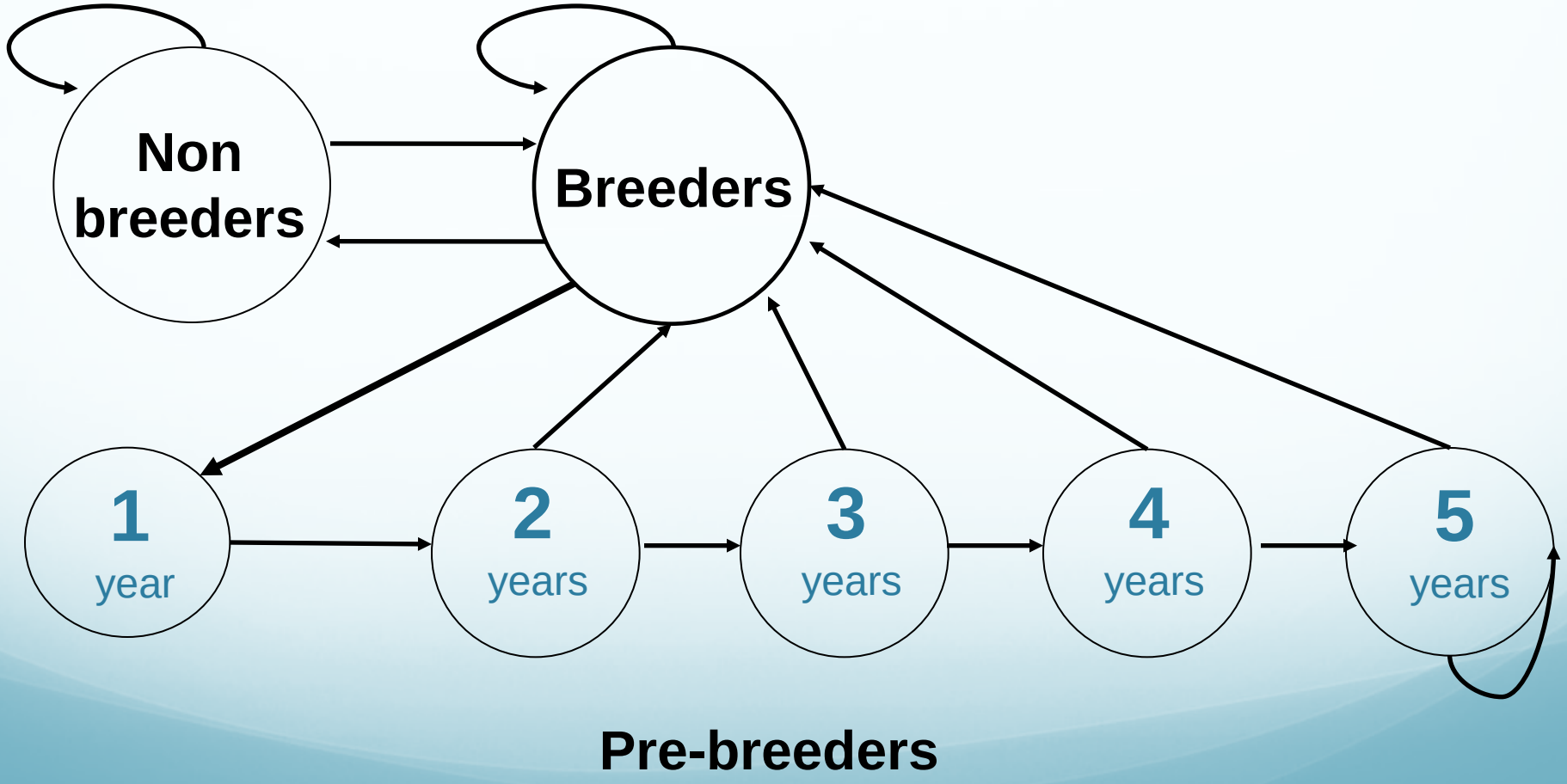
Non-breeders

Breeders

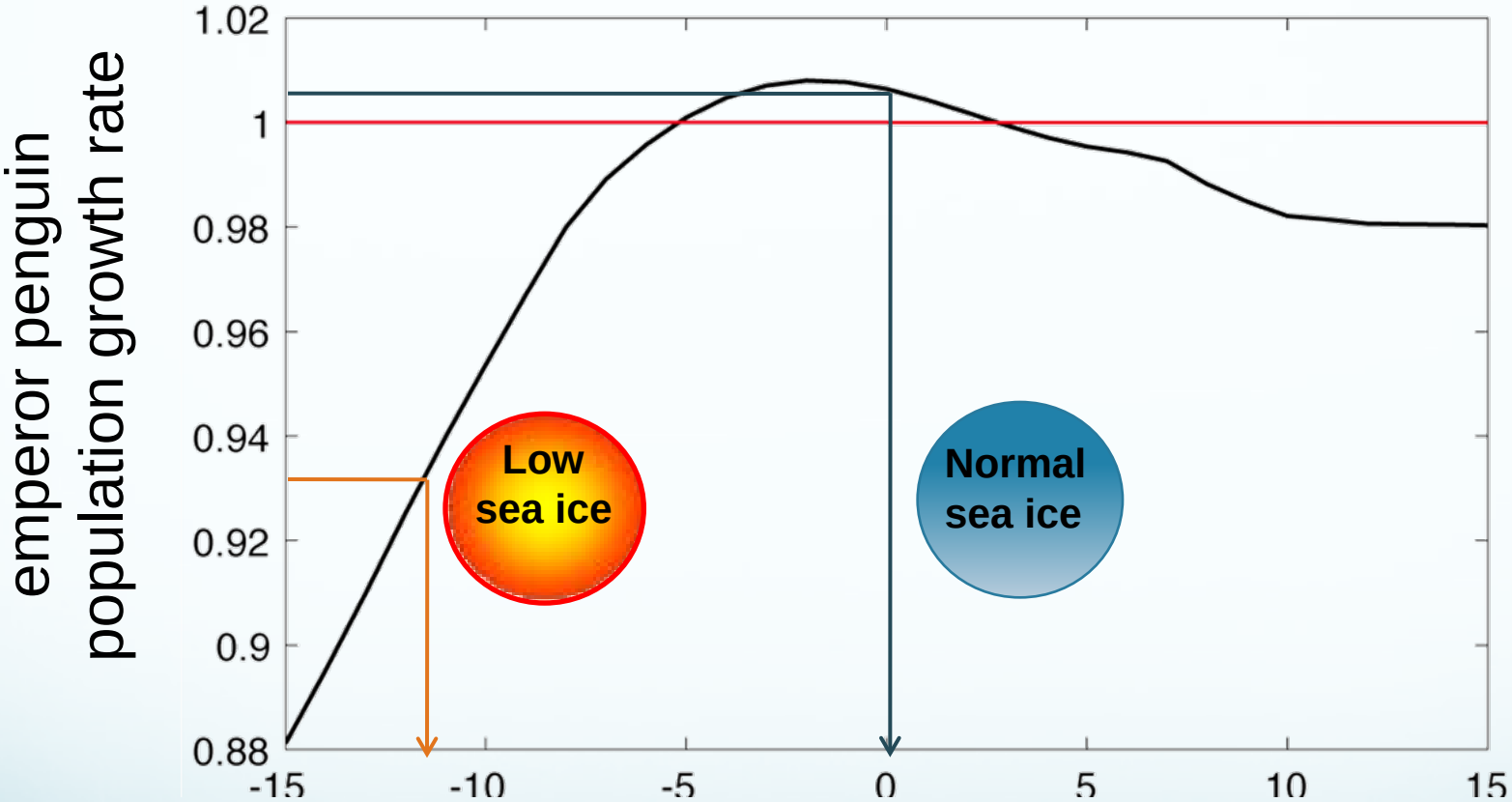
Pre-breeders

Population models

$$\mathbf{n}_{t+1} = \mathbf{A}_t \mathbf{n}_t$$

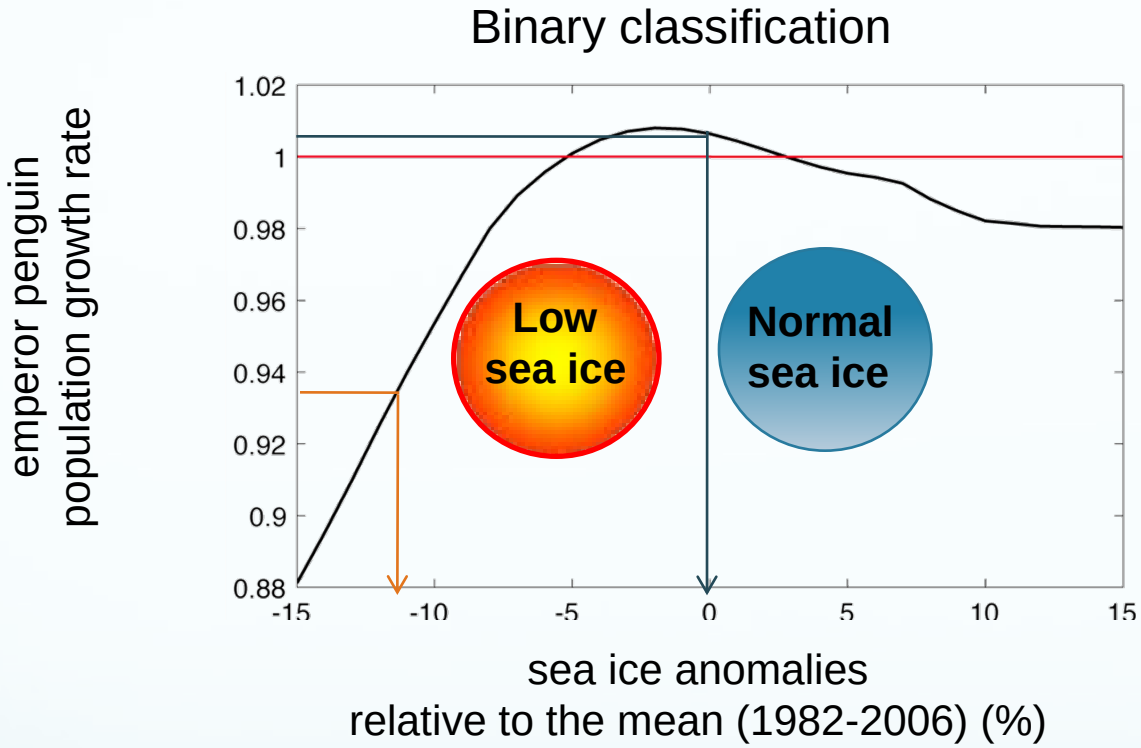


Sea ice and emperor penguin population



Jenouvrier et al. unpublished

Predict population responses to future climate change : linking demographic models and IPCC climate projections

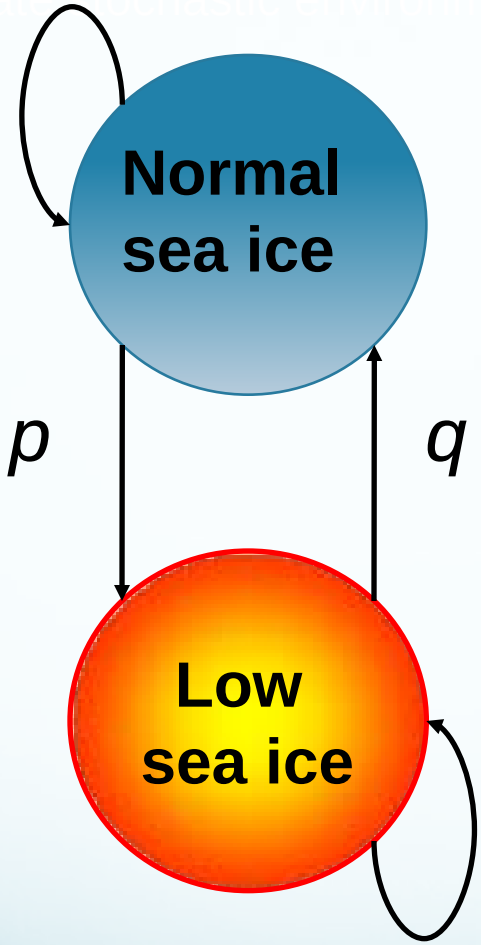


IPCC forecasts may carry sea ice conditions well outside the range of values ever observed in the past.

Extrapolating observed relationships well outside the domain of the data used to estimate it is not a safe practice.

Jenouvrier et al. 2009 PNAS

A two-state environment - population model



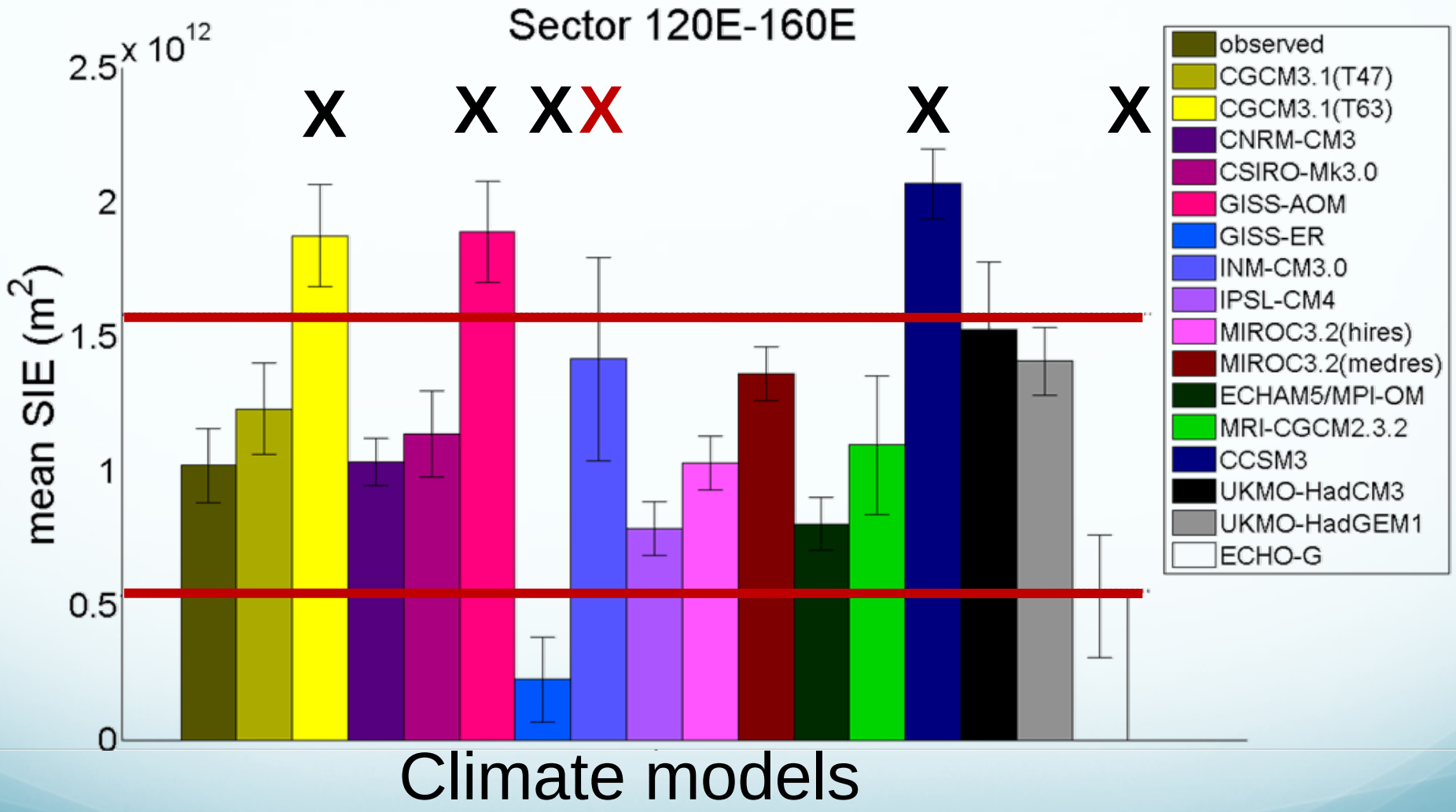
$$\mathbf{n}_{t+1} = \begin{cases} \mathbf{A}_t & \\ & \mathbf{n}_t \\ \mathbf{A}_t & \end{cases}$$

frequency of warm events

w=p/(p+q)

Jenouvrier et al. 2009 PNAS

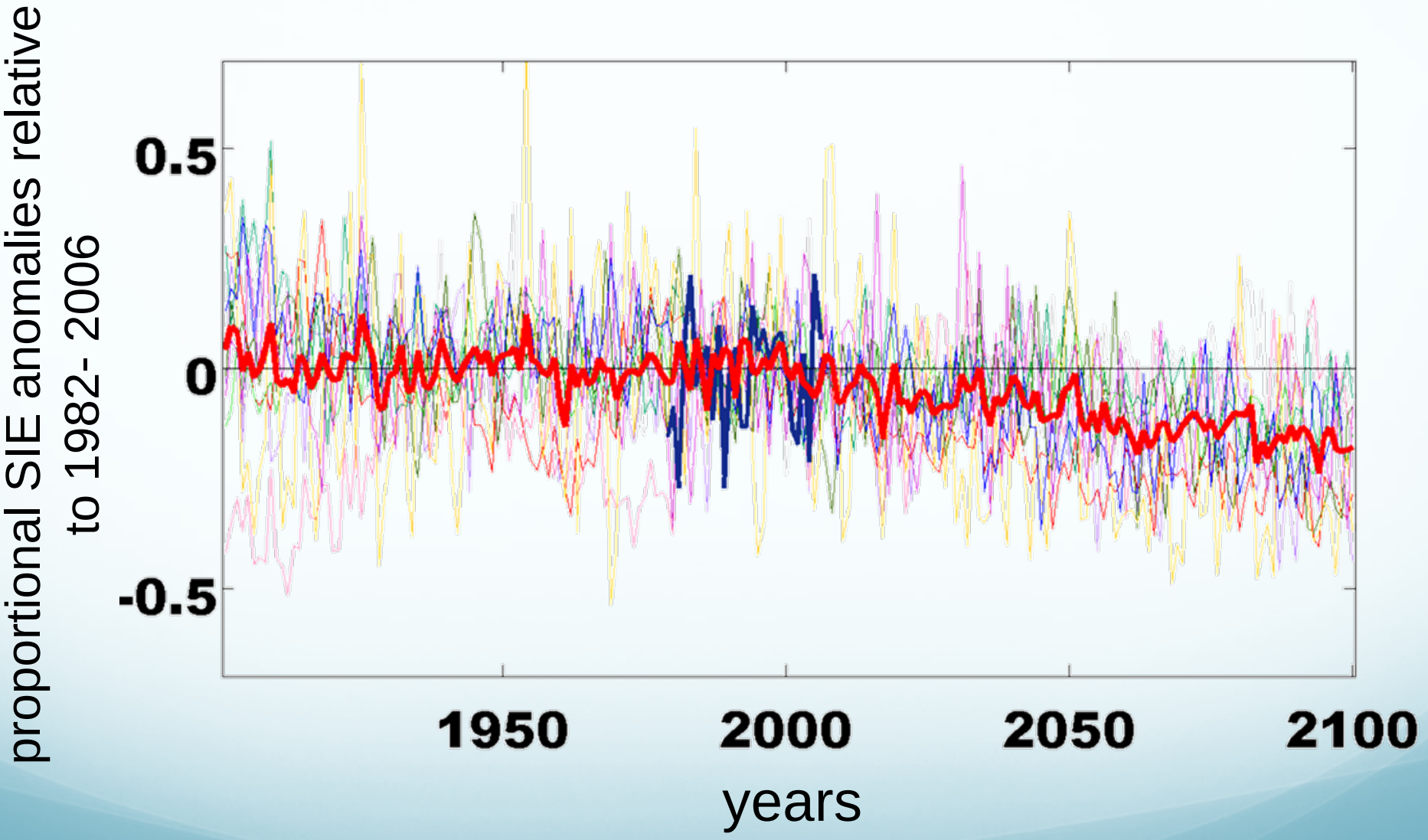
Winter sea ice extent and selection of climate models



Future SIE data : WCRP's – CMIP3 multi-model dataset http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php
Observed data: NSIDC

Jenouvrier et al. 2009 PNAS

Sea ice extent projections by 10 selected IPCC models

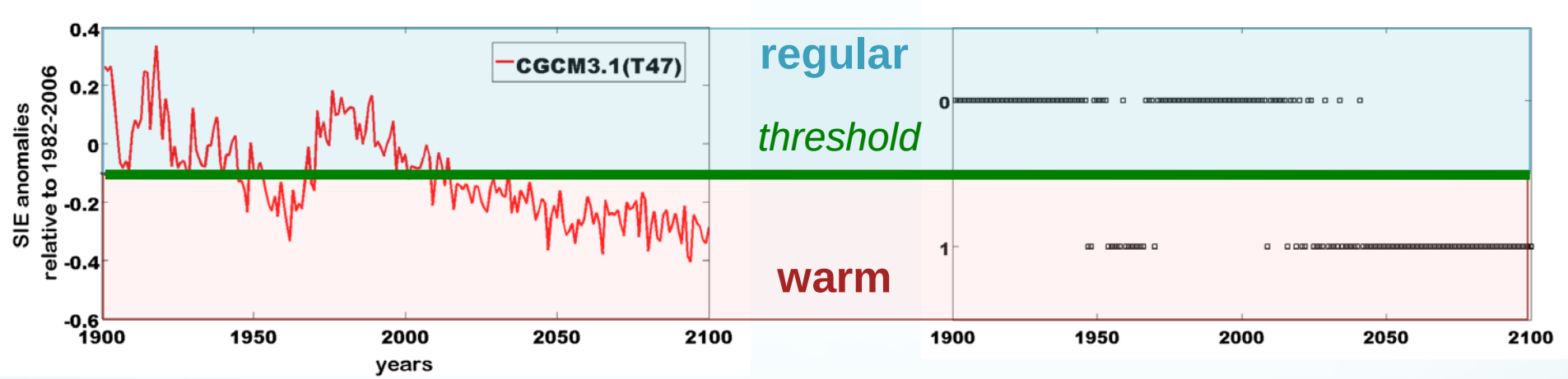


Jenouvrier et al. 2009 PNAS

Binary sequence of warm versus regular years

SIE projections

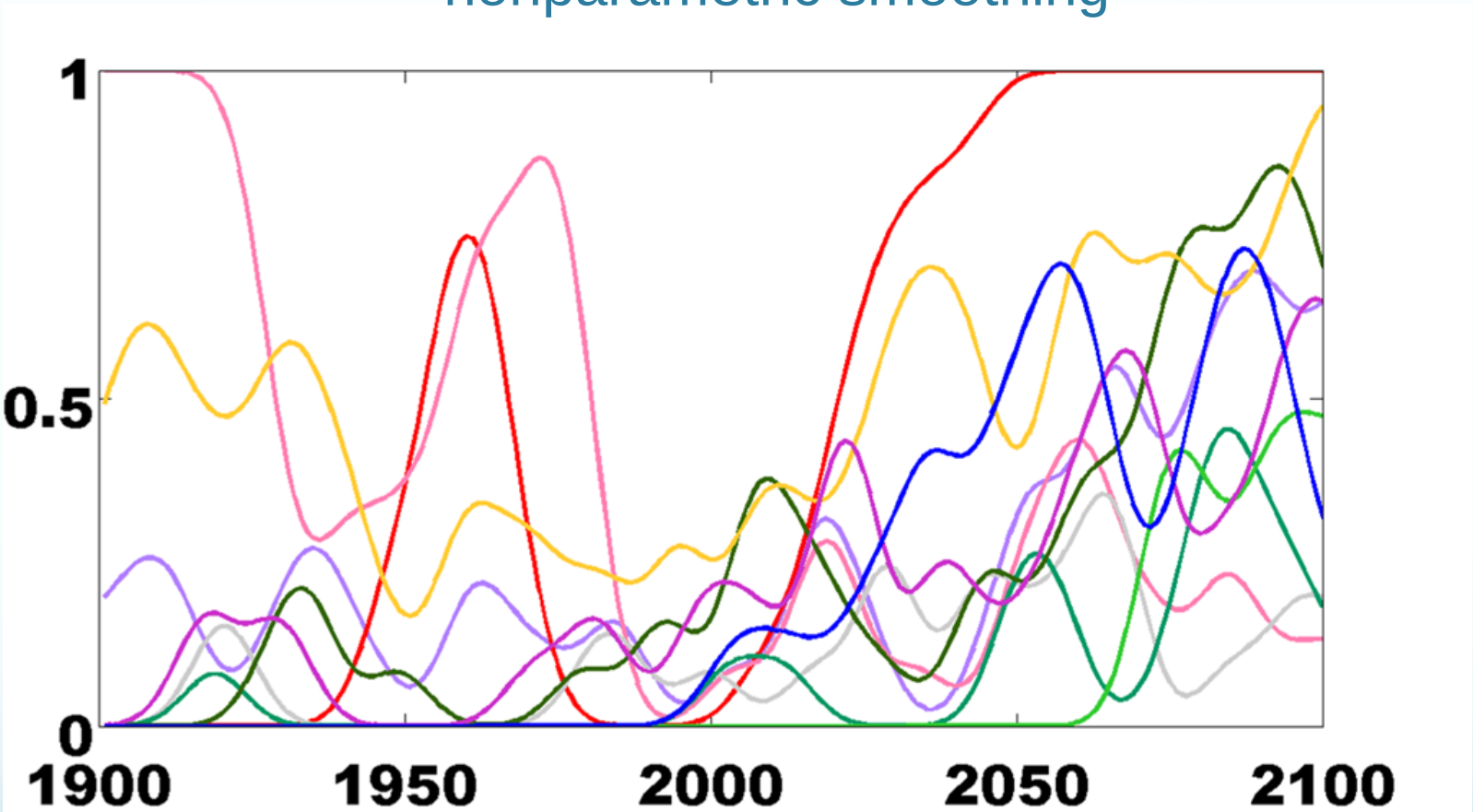
Binary sequence of
regular versus warm condition



Classification of each year into regular or warm conditions, by comparing the proportional decline in ice in that year to a specified SIE threshold

Jenouvrier et al. 2009 PNAS

Binary sequence of warm versus regular years, are translated in frequency of warm events using nonparametric smoothing

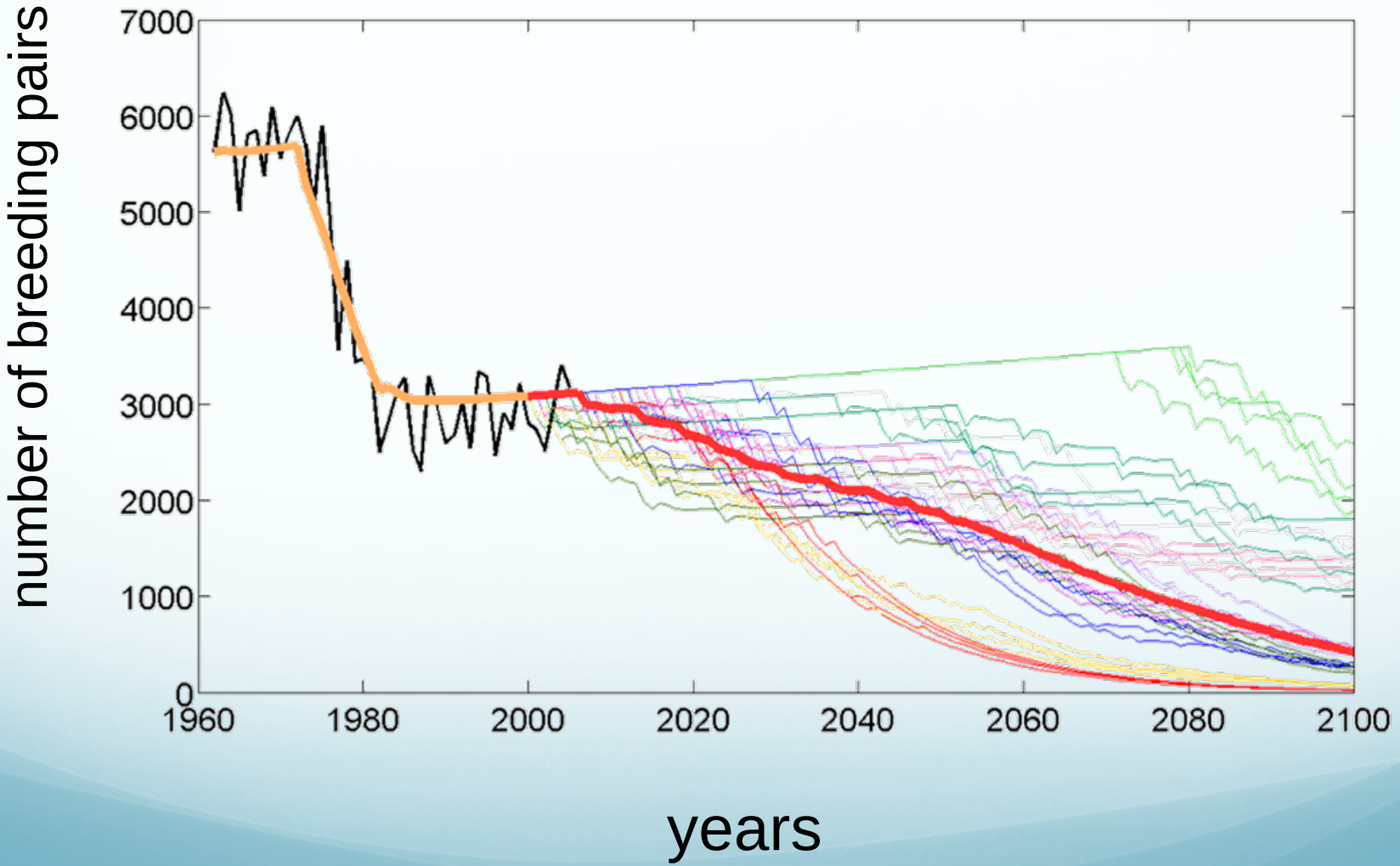


Most conservative threshold :

warm year= SIE anomalies decline>15% relative to present

Jenouvrier et al. 2009 PNAS

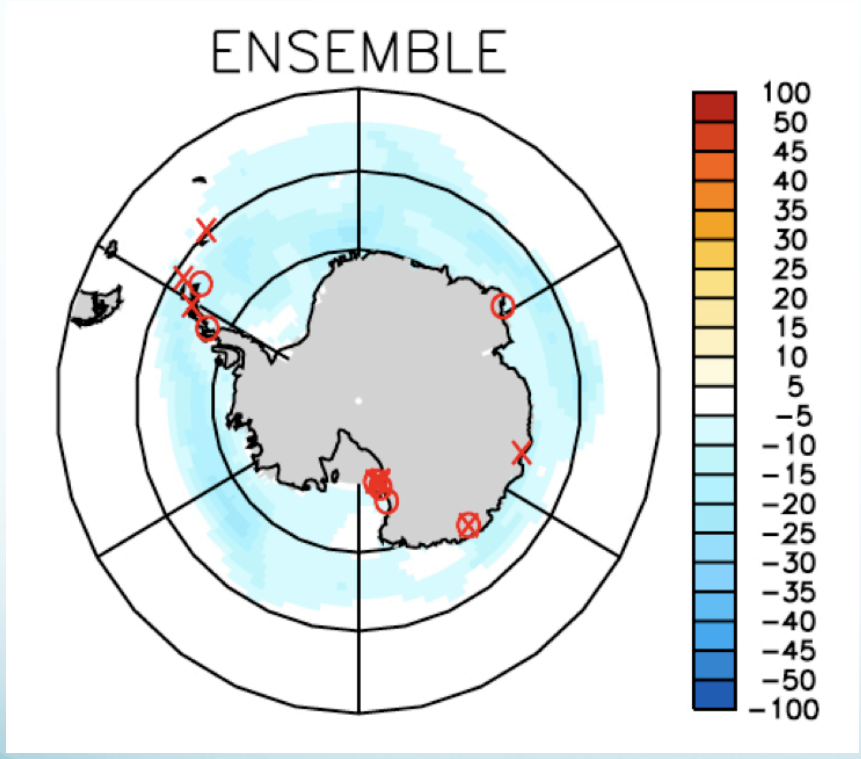
The emperor penguin population in Terre Adélie will decline dramatically by 2100



Jenouvrier et al. 2009 PNAS

The emperor penguin distribution will shrink under future climate change

Sea-ice coverage
will have decreased everywhere



Change by the year of 2˚ C warming
5 relative to the modern era (1981-2000 average) ; Ainley et al. 2007- 2009

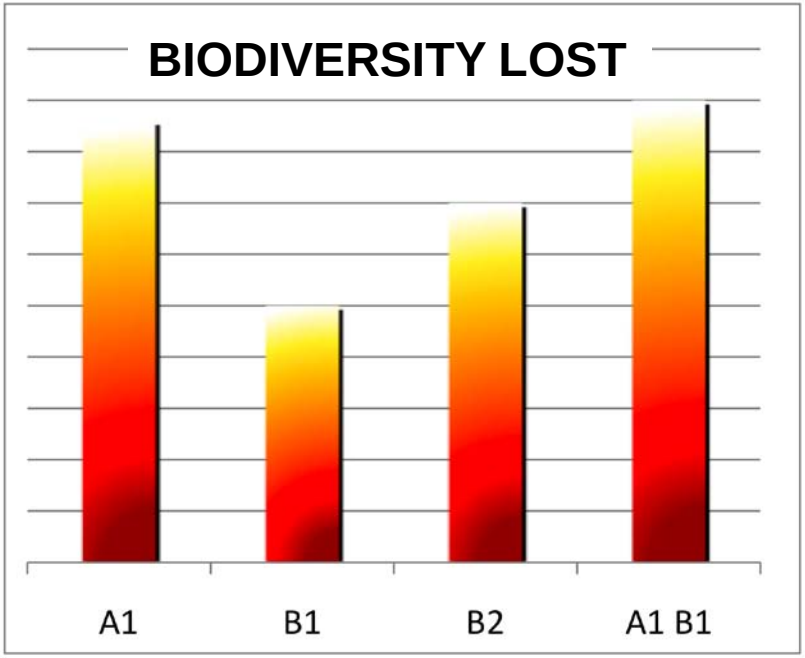
The geographical range of Antarctic penguins may shrink following climate warming

Existing north of 70^{o} S, are ≈50% of colonies, representing almost 40% of the total world population

Ainley et al. 2007- 2009

Challenges

Mankind faces a choice for the future socio-economic development of our planet



- spatial scale
- specific climate variable
- selection of climate model
-specific biological variables, e.g. primary production

Thank you for your attention, and a big thanks to…

All field workers since 1952 in Terre Adélie

People from the expeditions in 2003 and 2006 in Terre Adélie

for their support on the field and their photos

(photos from Samuel, Guillaume, Mika, Paul and Katel)

Fellowship «Women in science» - L'OREAL- UNESCO
Marie Curie fellowship - EUROPEAN COMMISSION
CIRES visting fellowship

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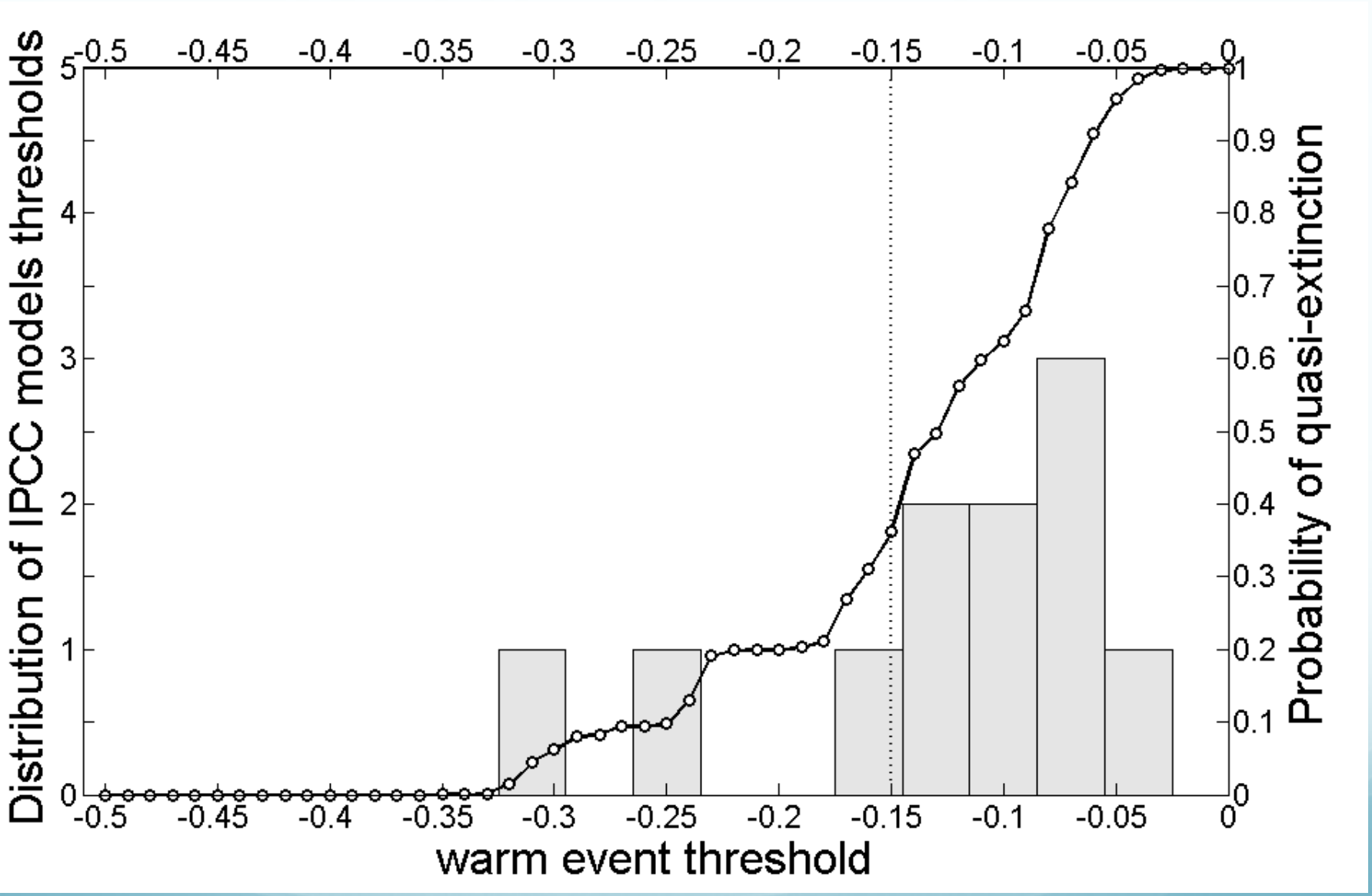
probability of quasi-extinction
(defined as a decline by 95%) occurring by 2100.

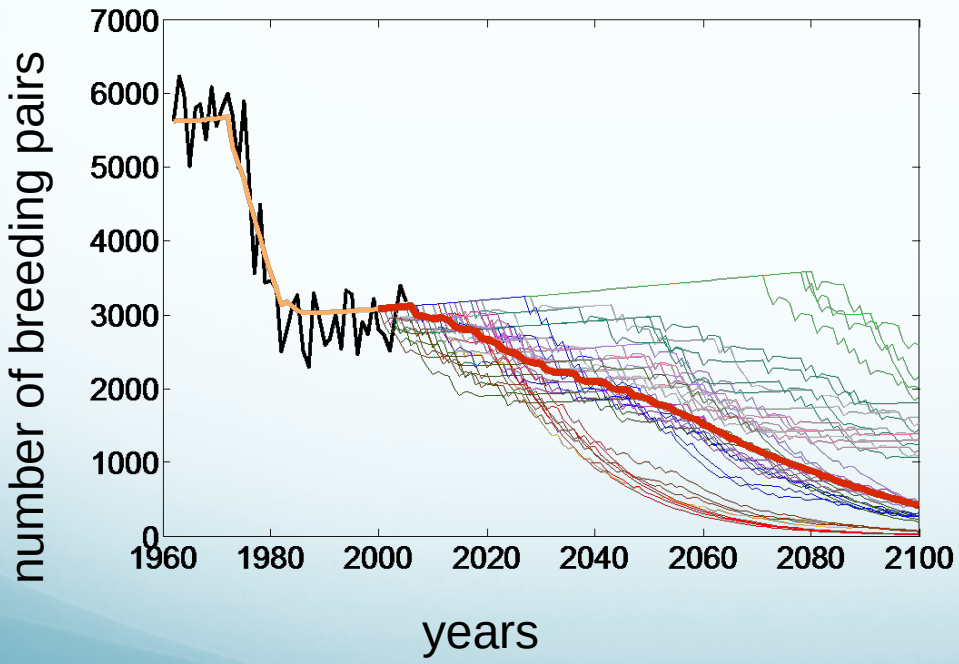


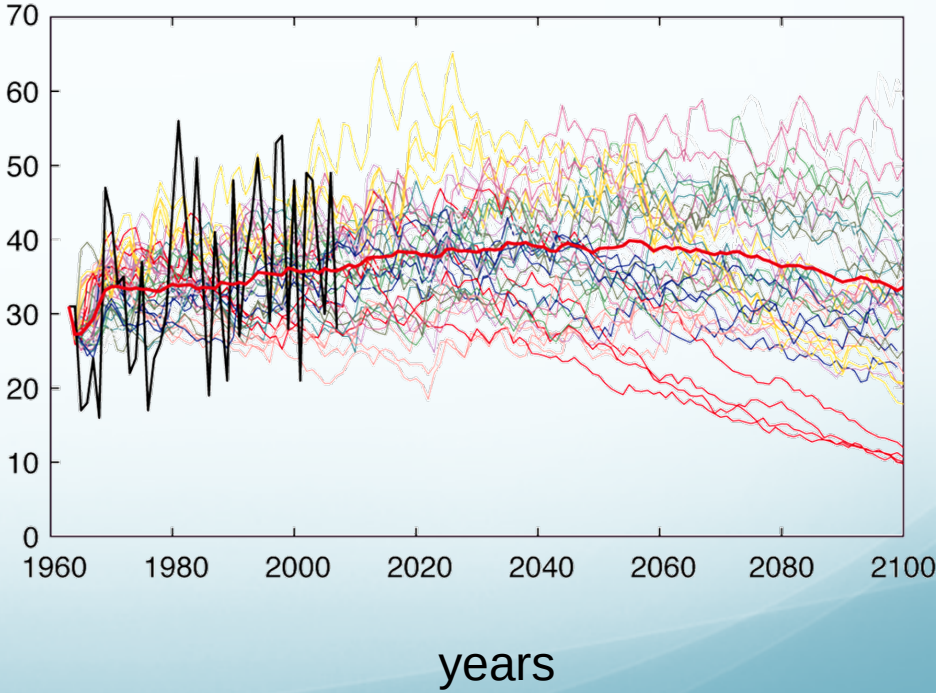
Other species will respond differently to future climate change

Emperor penguin

Southern fulmar skip reproduction during years with low SIE rather than compromising their survival and future opportunities to reproduce.

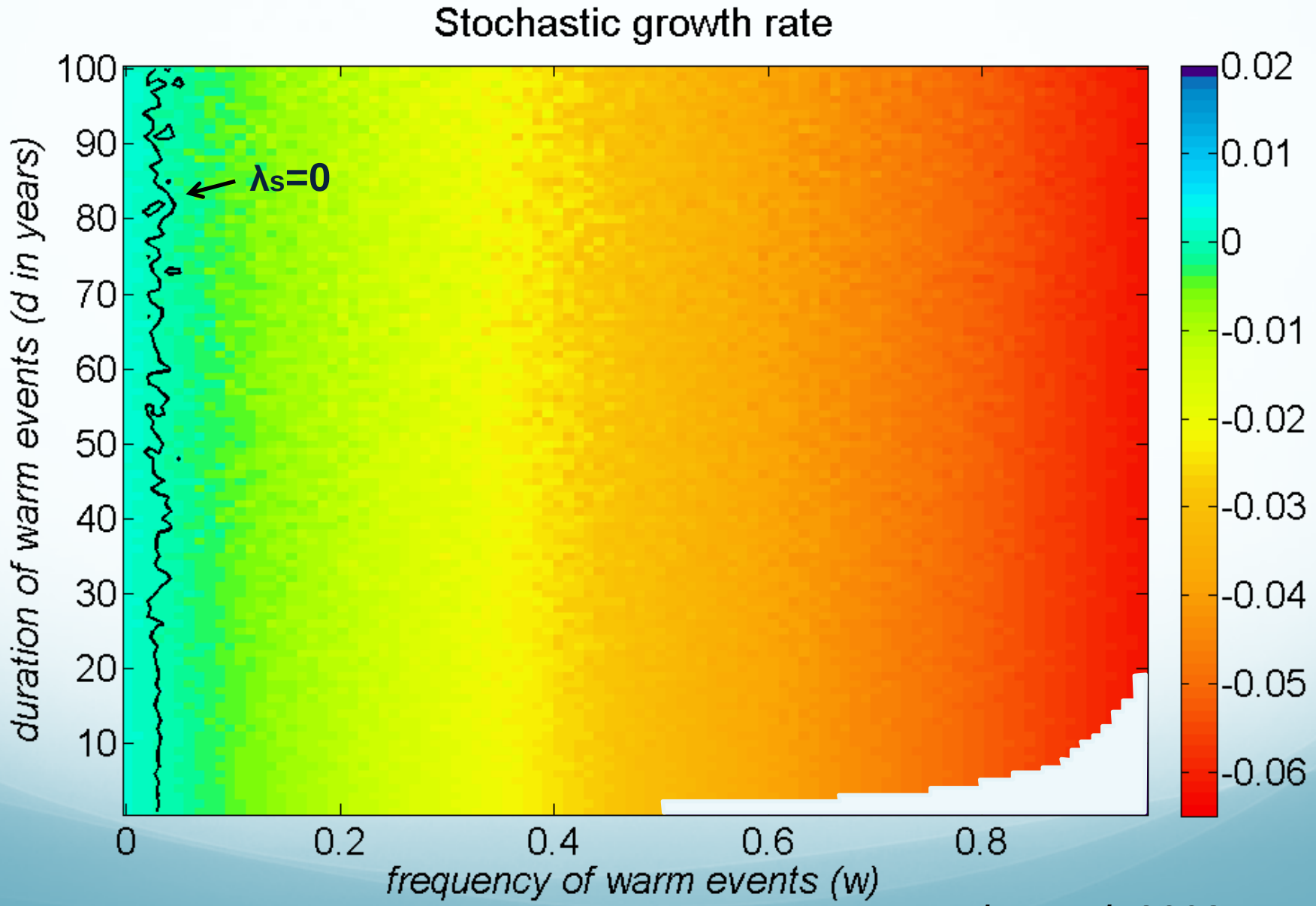
Southern fulmar





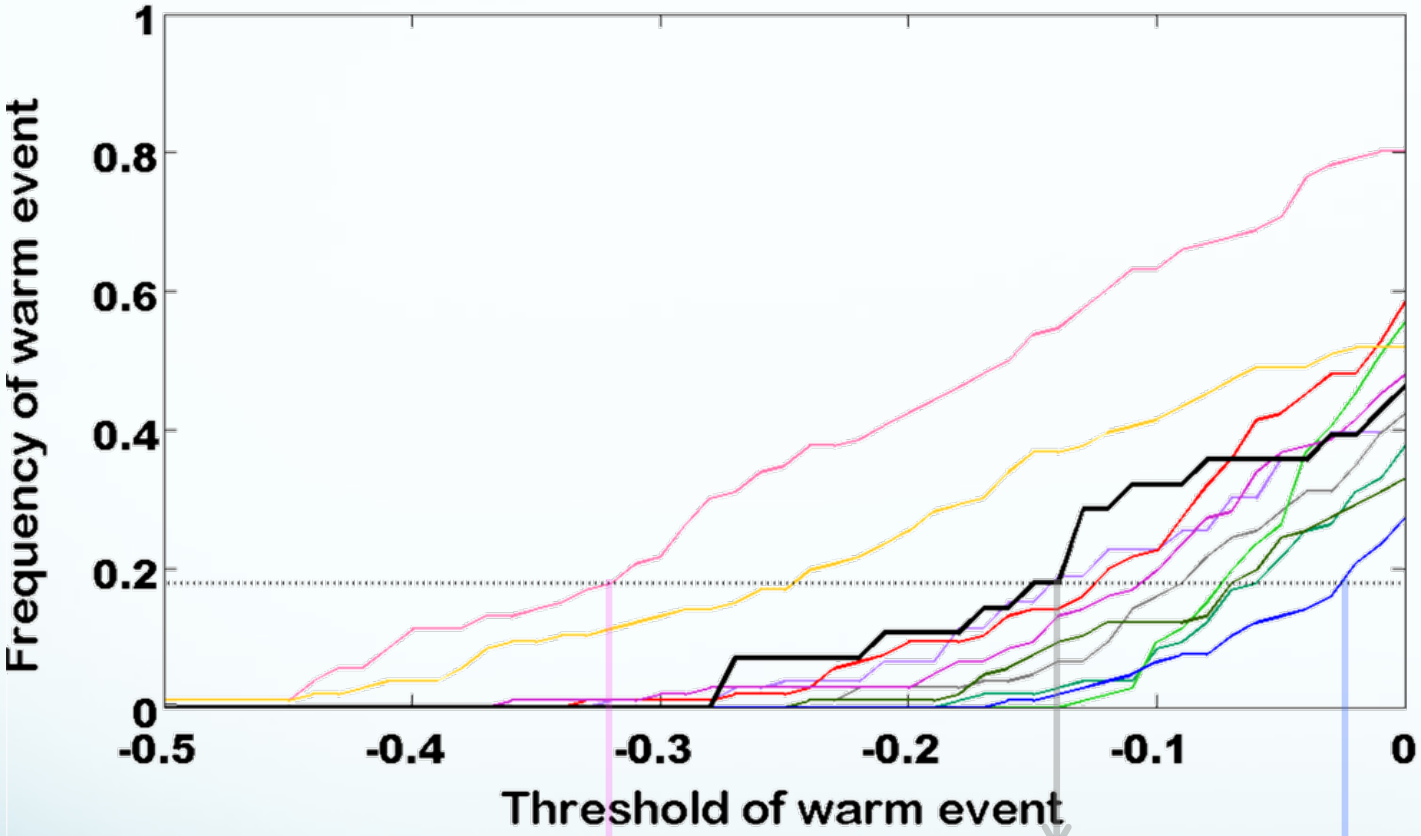
Jenouvrier et al. unpublished

As the frequency of warm events increases,
the stochastic growth rate decreases



Jenouvrier et al. 2008 PNAS

Choice of the SIE threshold



w_o = 10 warm events per 56 yr observation period = 0.18

from satellite data threshold of -0.15

from IPCC models

50% SIE threshold that produced a frequency of w_o over the observation period fall in the range [-0.14;-0.07].

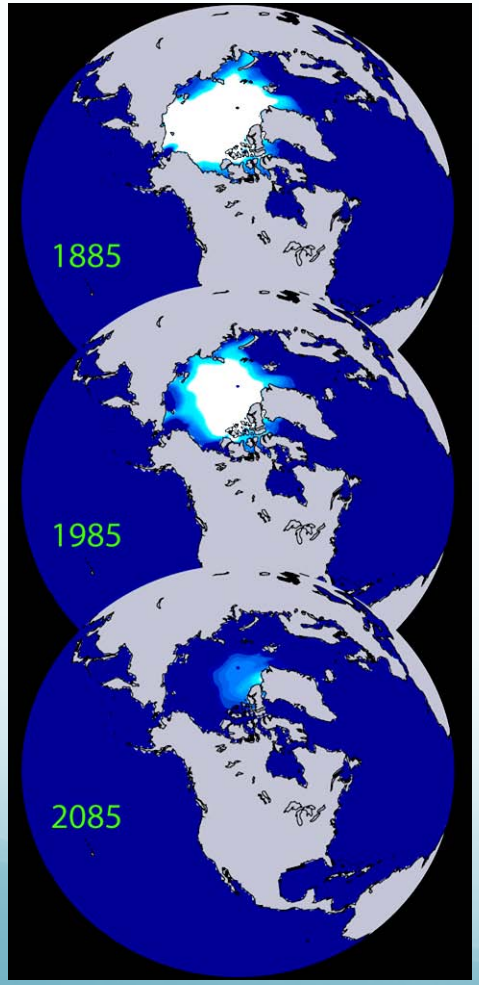
To avoid extinction, the emperor penguins must adapt

Selection processes may be slow due to their long generation time
So far, the dates of arrival to the breeding colony and
of egg laying have not changed in emperor penguins

Scientific approach: other species and systems

Listing of polar bear under The Endangered Species Act

If current ice melting trends continue, the bears are likely to become extinct in the southern Beaufort Sea region of Alaska and adjacent Canada



Model-simulated trend in reduced summertime sea ice in Arctic

Polar bear rely on sea ice for platforms to hunt for seals.

Hunter and Caswell 2007