Linking climate change to community-level impacts on copepods via a new, trait-based model

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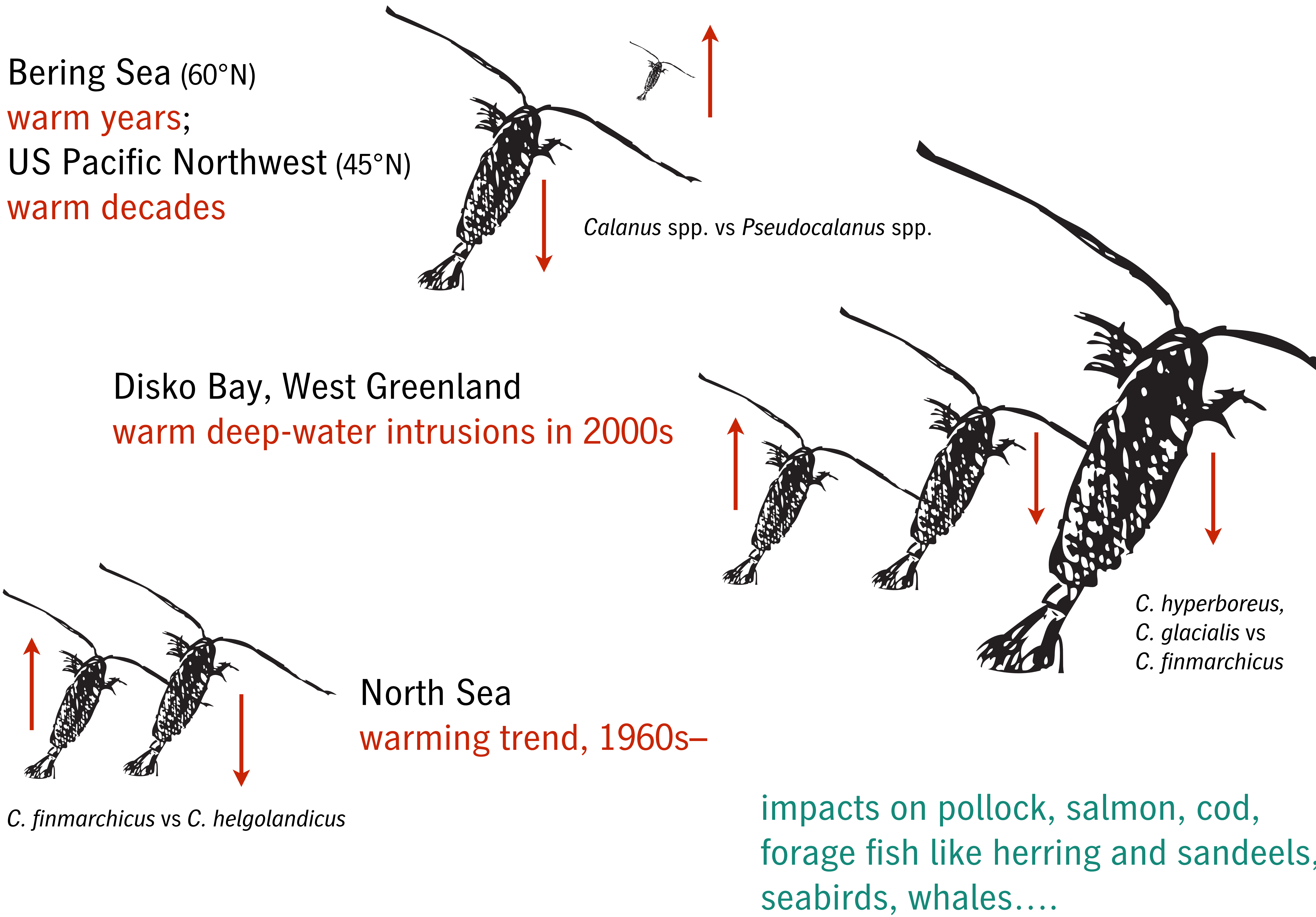
Region-specific shifts in zooplankton community composition



Past approaches

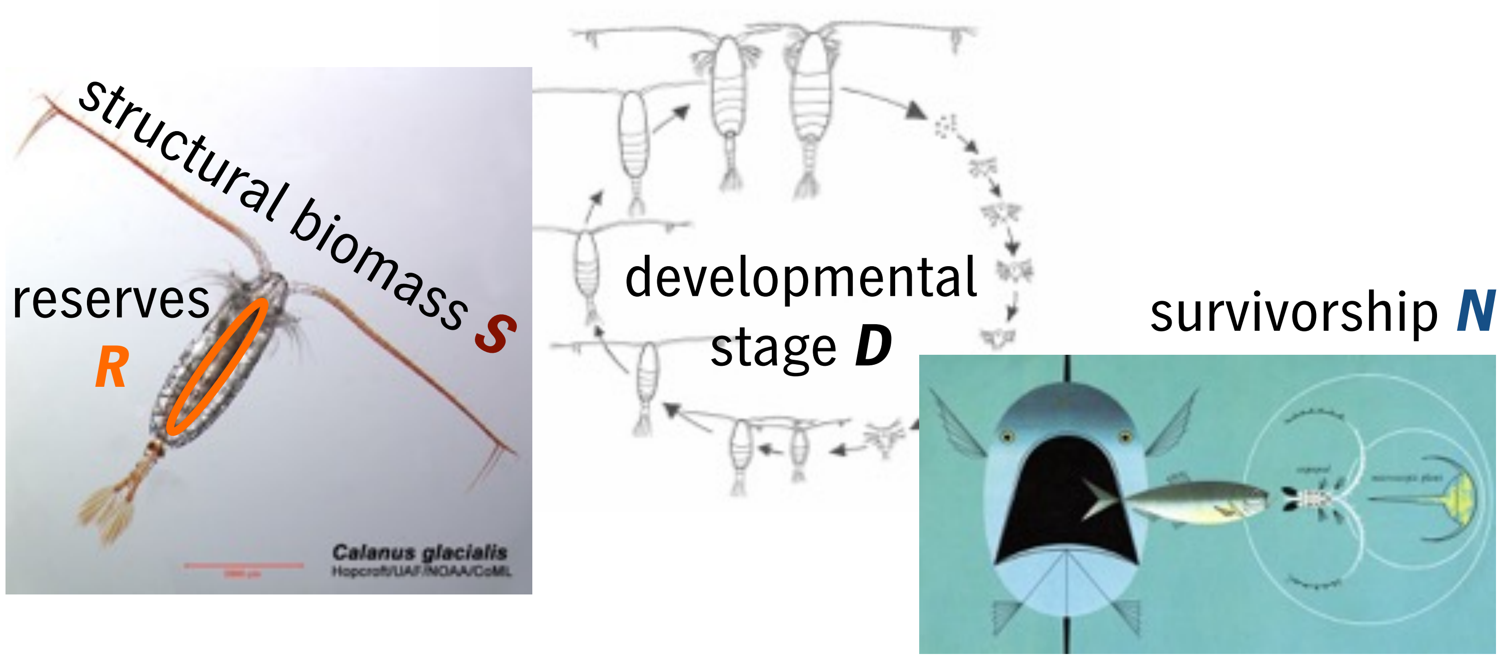
Optimal annual routines
(Varpe et al. 2007, 2009; Houston & McNamara 1999, Clark & Mangel 2000)

focus on reserves and timing

Emergent copepod communities
(Record et al. 2013)

trait-based metacommunity

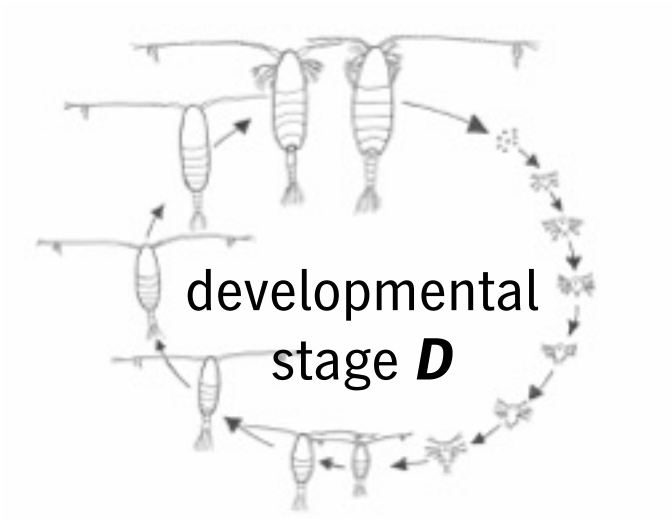
Coltrane (Copepod Life-history traits and adaptation to novel environments)



→ **population:** annual cycle, net growth rate

×

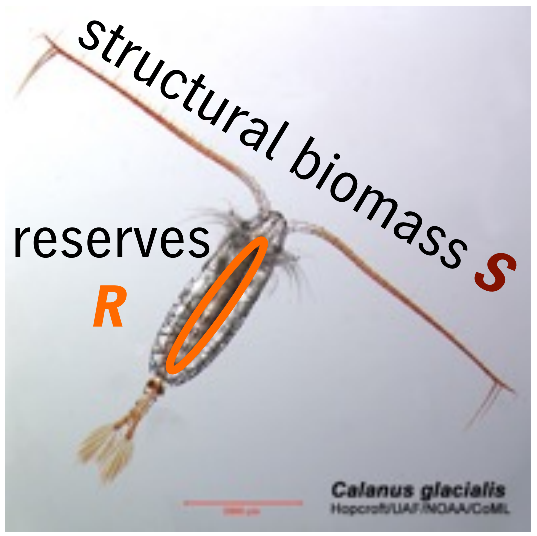
small number of variable traits → **community** associated with a given environment



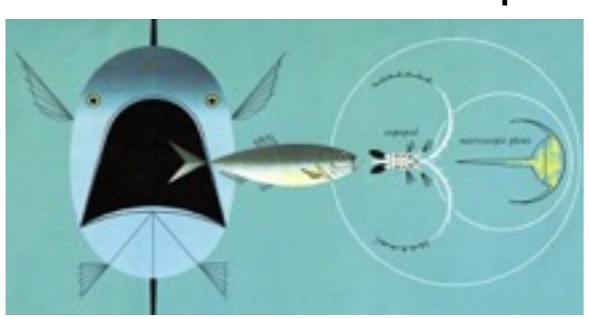
(Saiz and Calbet 2007;
Forster et al. 2011)

$Q_{10} = 3$

u_0 (development rate corrected to 0°C)
is the key trait generating size diversity
(Banas and Campbell, MEPS, submitted; **see poster**)



survivorship ***N***

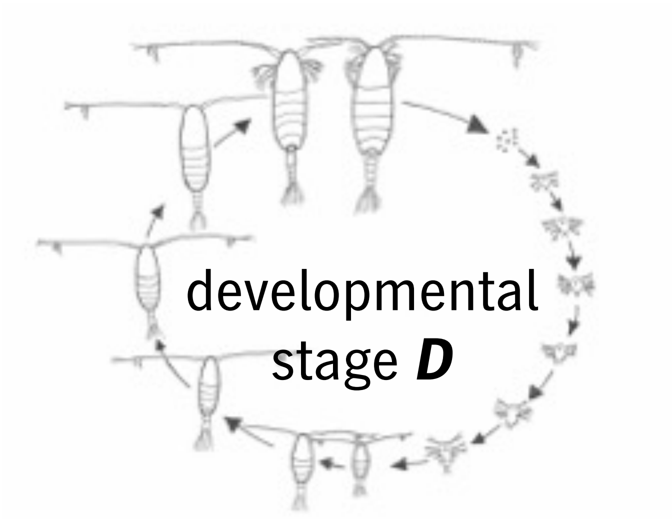


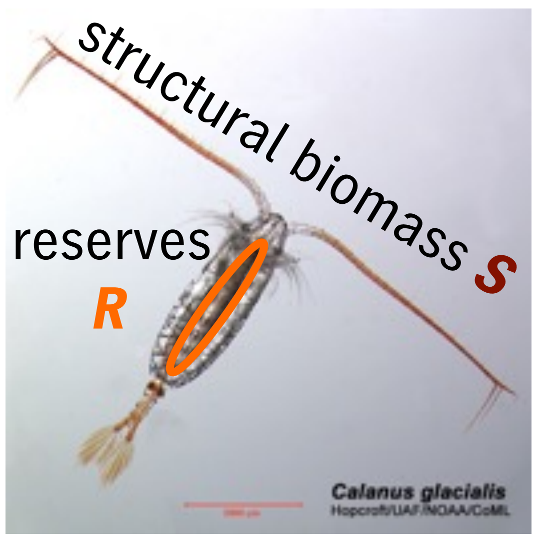
$Q_{10} = 2.5$;
rates ~ $S^{-0.3}$

net gain = ingestion – metabolism

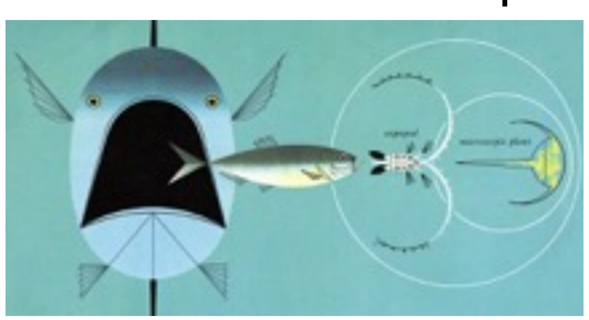
mortality

Diapause is on/off based on a “myopic” criterion;
turns off development, ingestion, and mortality,
and reduces metabolism to 1/4 (Maps et al. 2012)





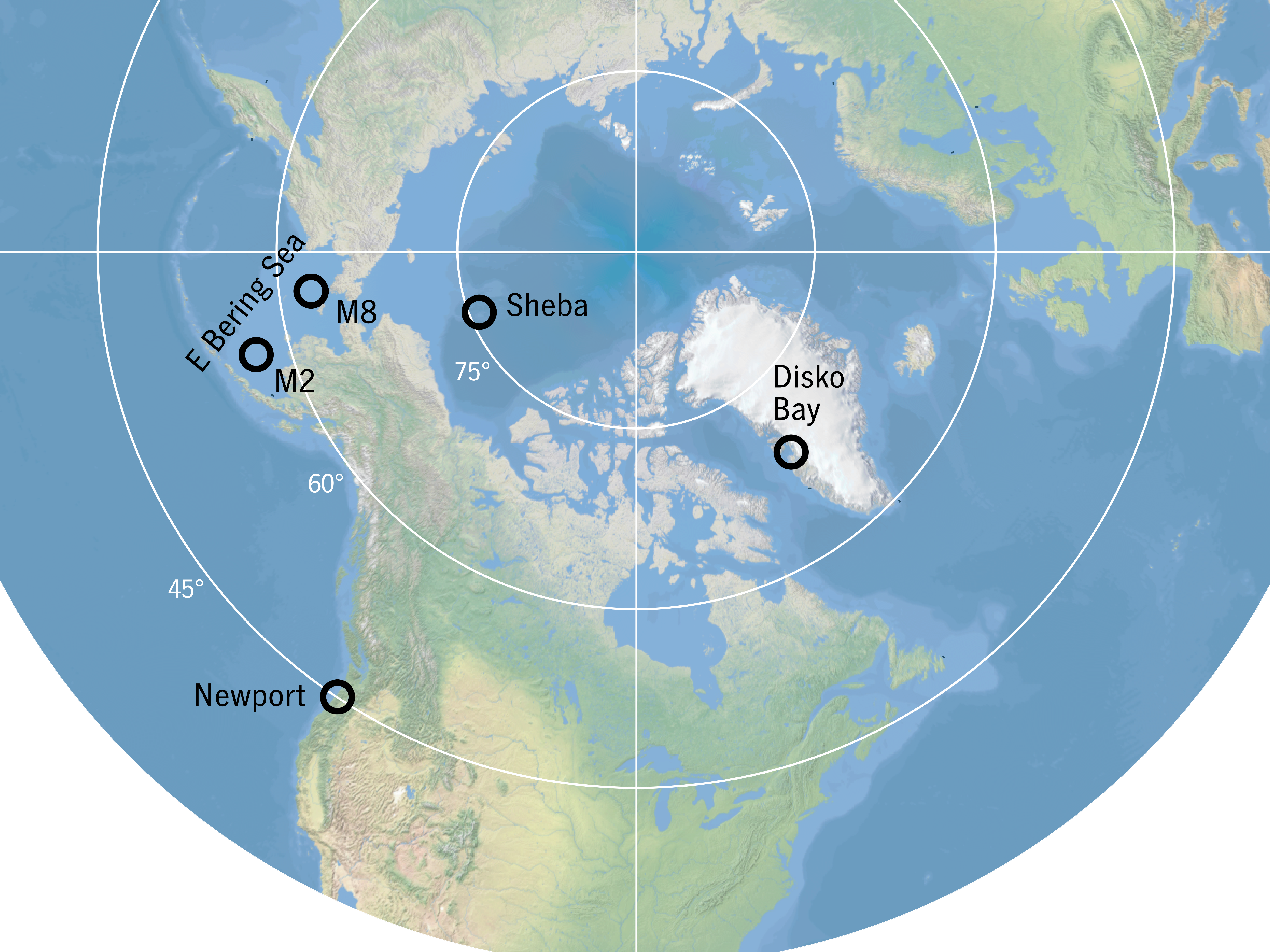
survivorship N



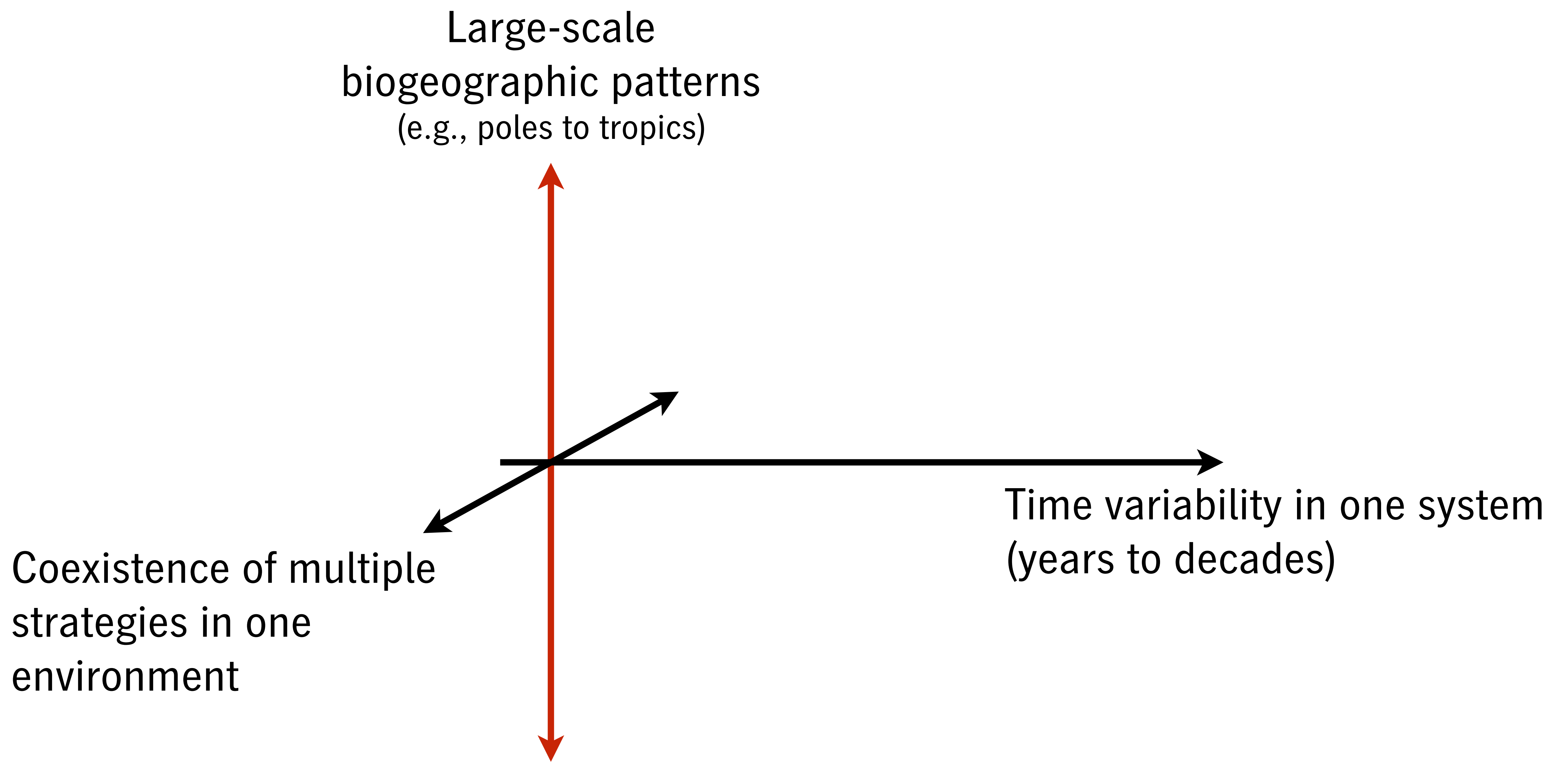
Two versions:

"egg/reserves": explicit model for income egg production (from ingestion) and capital egg production (from ***R***)

"potential": replace ***R*** with free scope φ; look for the optimal date on which to spend it on eggs (i.e. the stable cycle that maximises egg fitness)

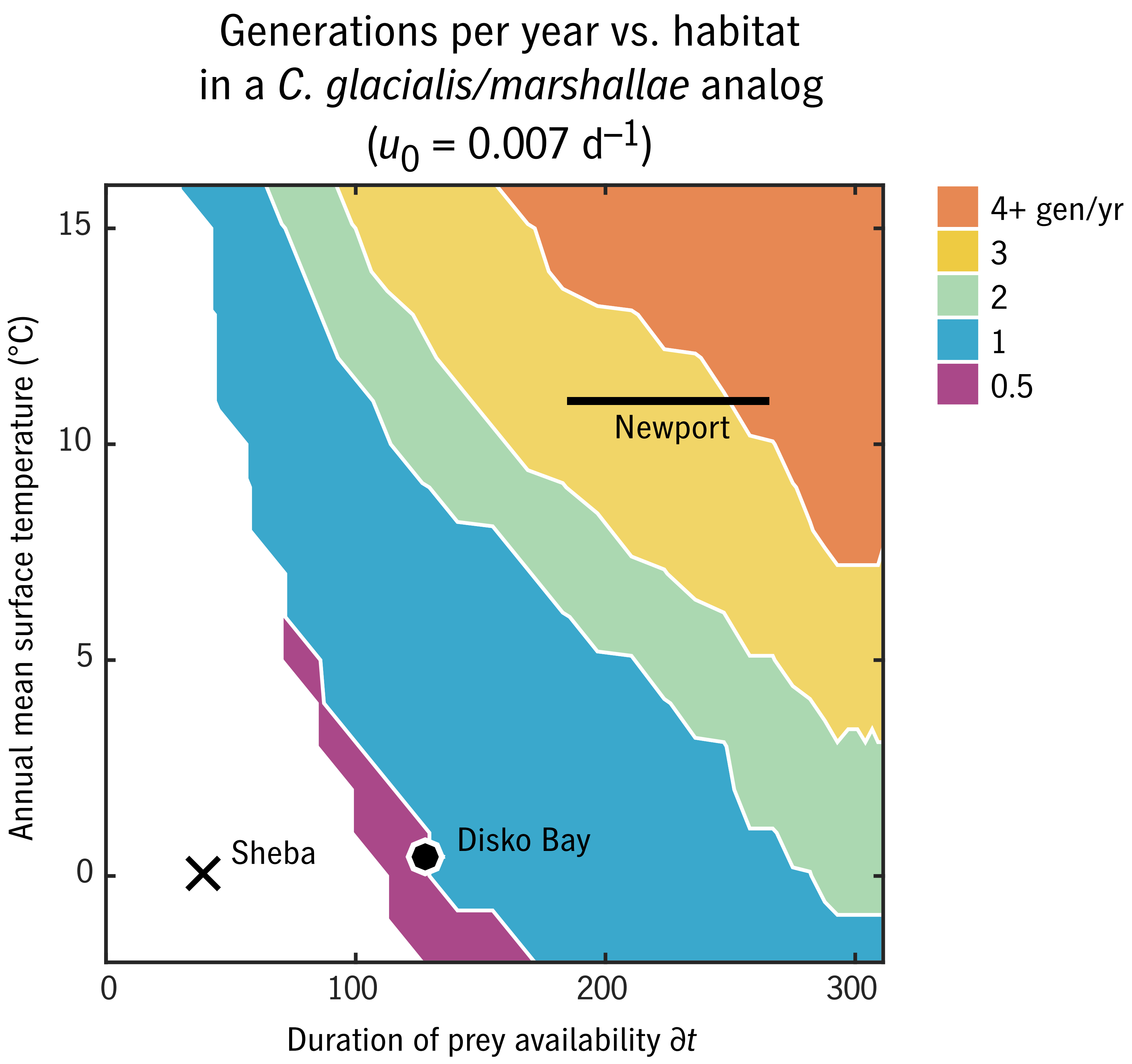

E Bering Sea
M8
M2
Sheba
75°
60°
45°
Disko
Bay
Newport

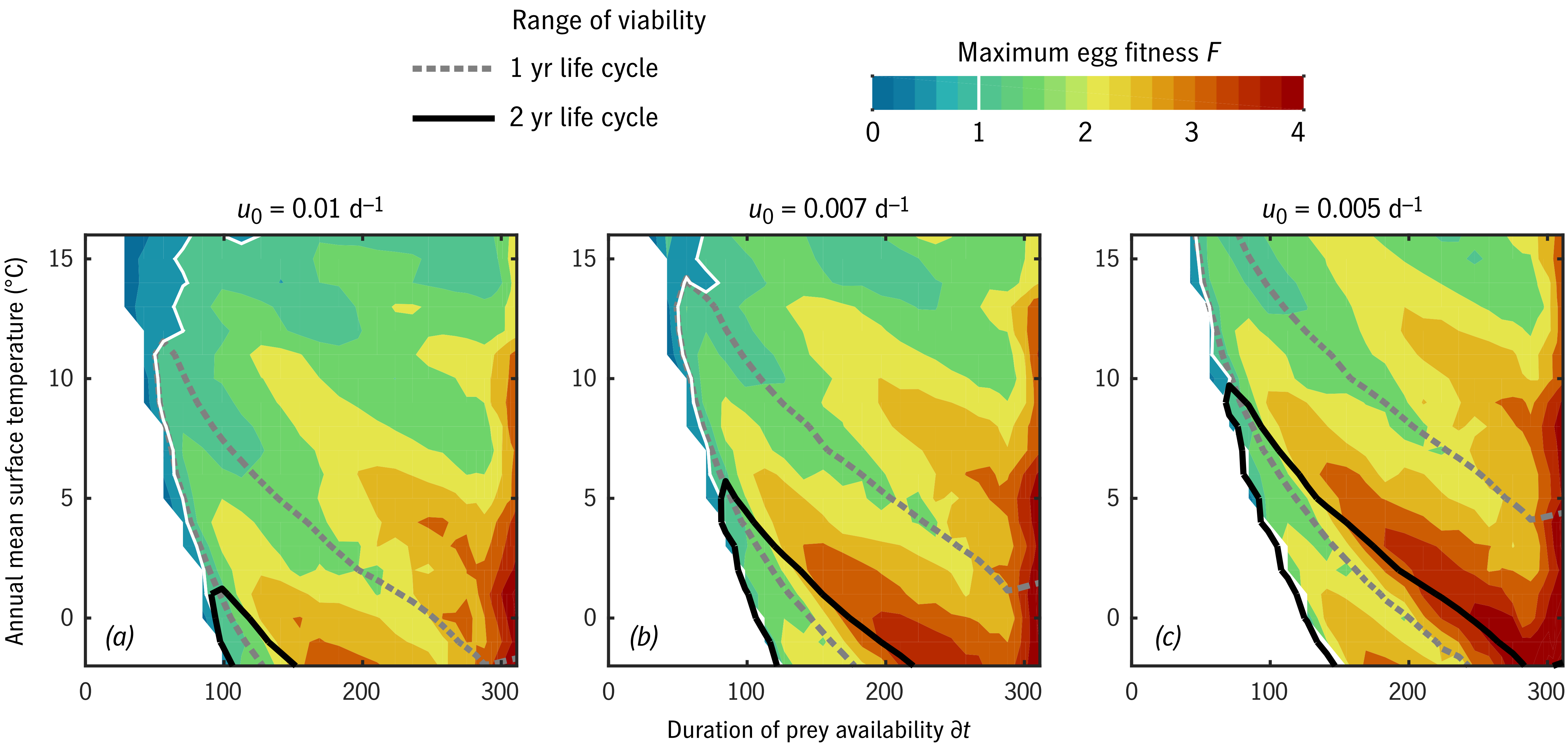
A general theory of large zooplankton in relation to environment ought to be able to reproduce



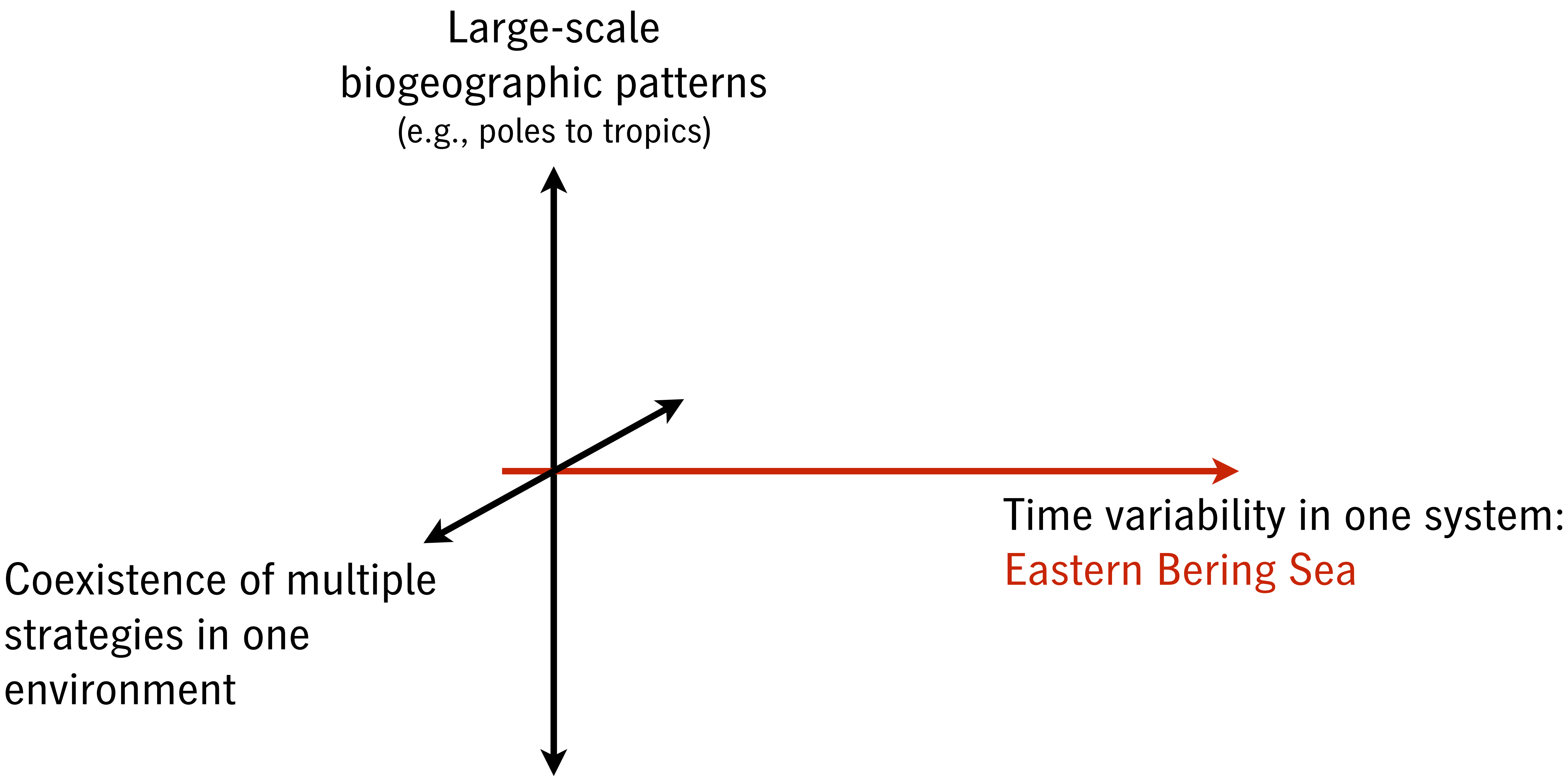
Idealised "global biogeography" testbed

Gaussian window of prey availability;
constant surface temperature;
deep temperature = 0.4 · surface

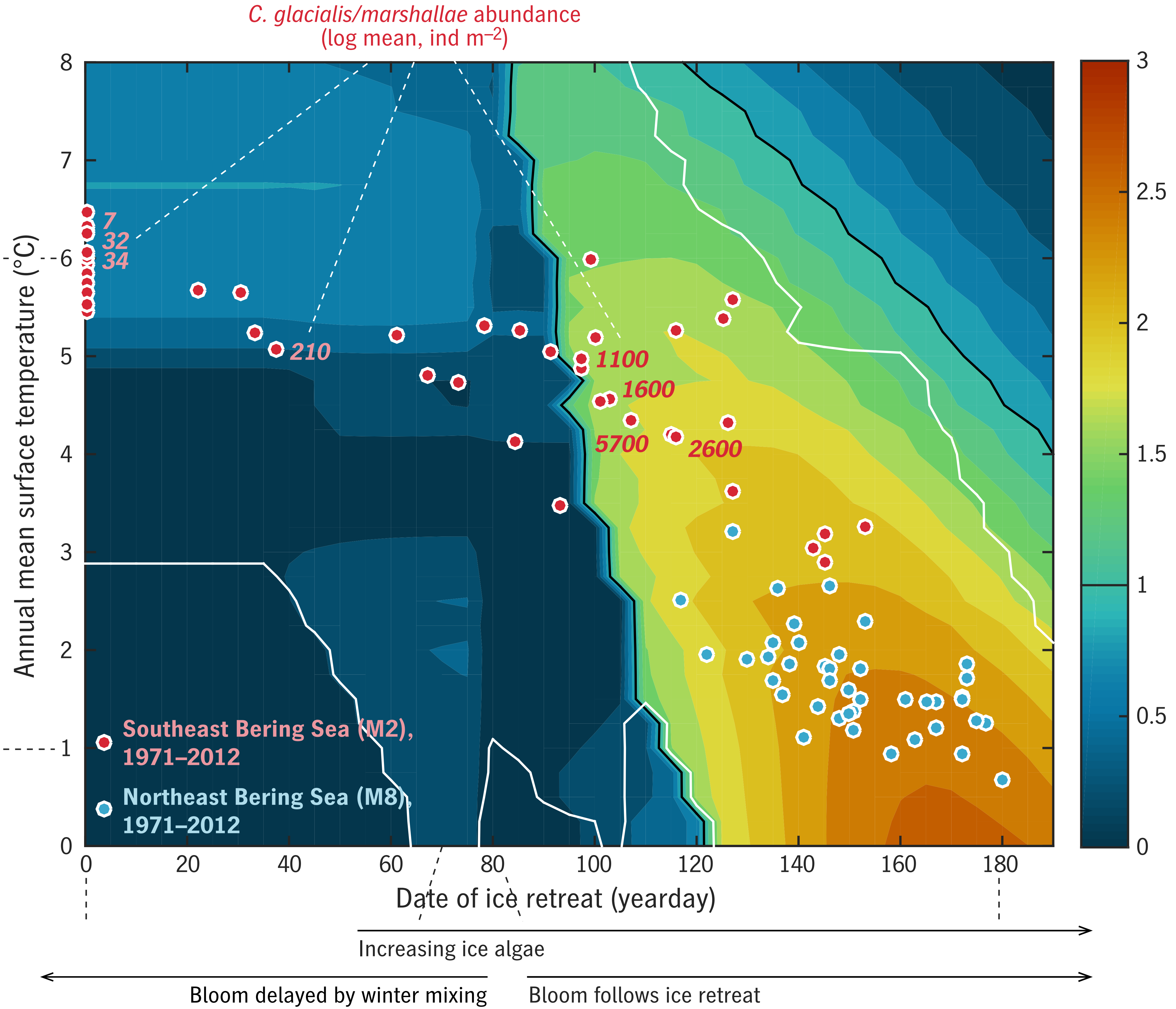




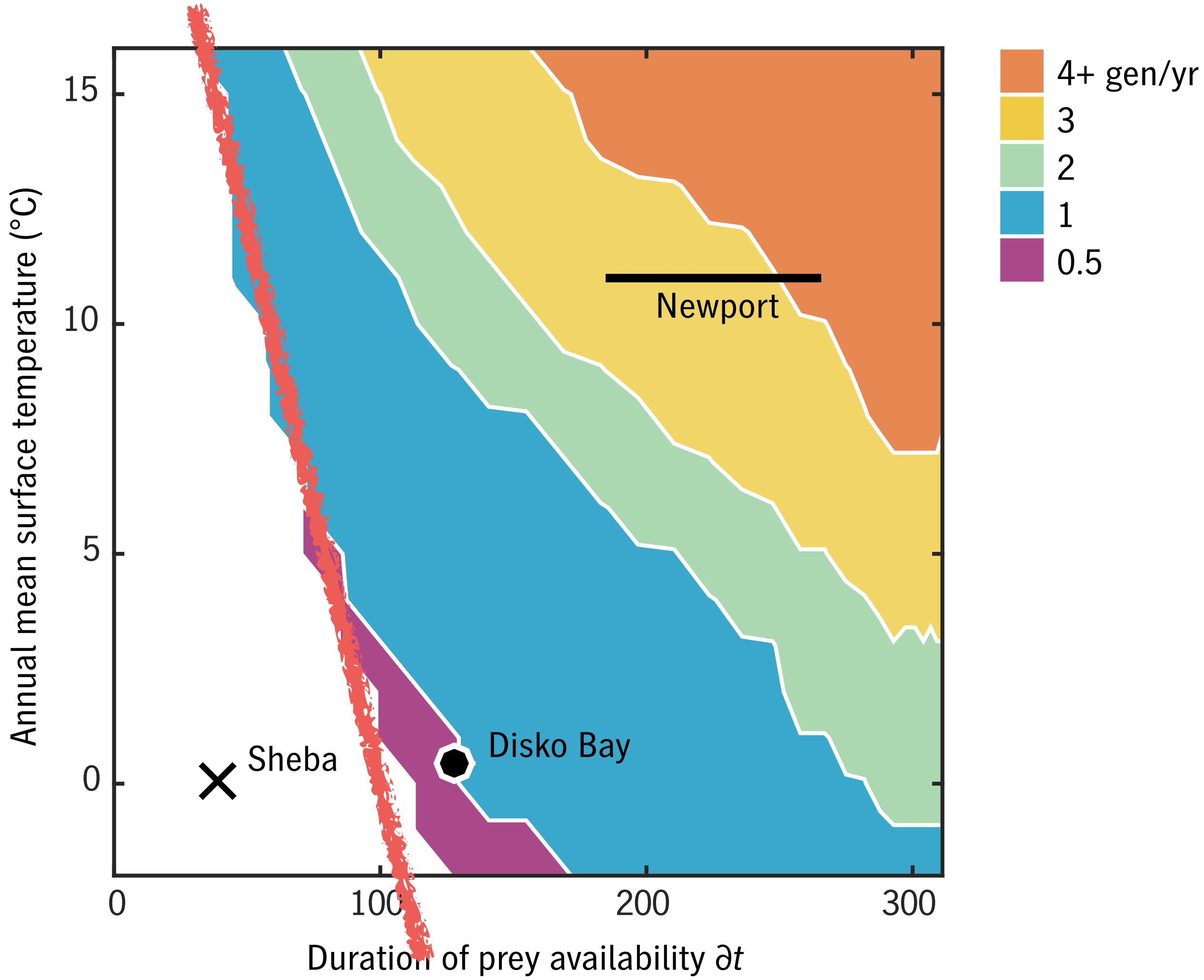
Range of viability
1 yr life cycle
2 yr life cycle
Maximum egg fitness F
0
1
2
3
4
u0 = 0.01 d−1
u0 = 0.007 d−1
u0 = 0.005 d−1
Annual mean surface temperature (°C)
15
10
5
0
(a)
(b)
(c)
0
100
200
300
Duration of prey availability ∂t


Large-scale
biogeographic patterns
(e.g., poles to tropics)
Time variability in one system:
Eastern Bering Sea
Coexistence of multiple
strategies in one
environment

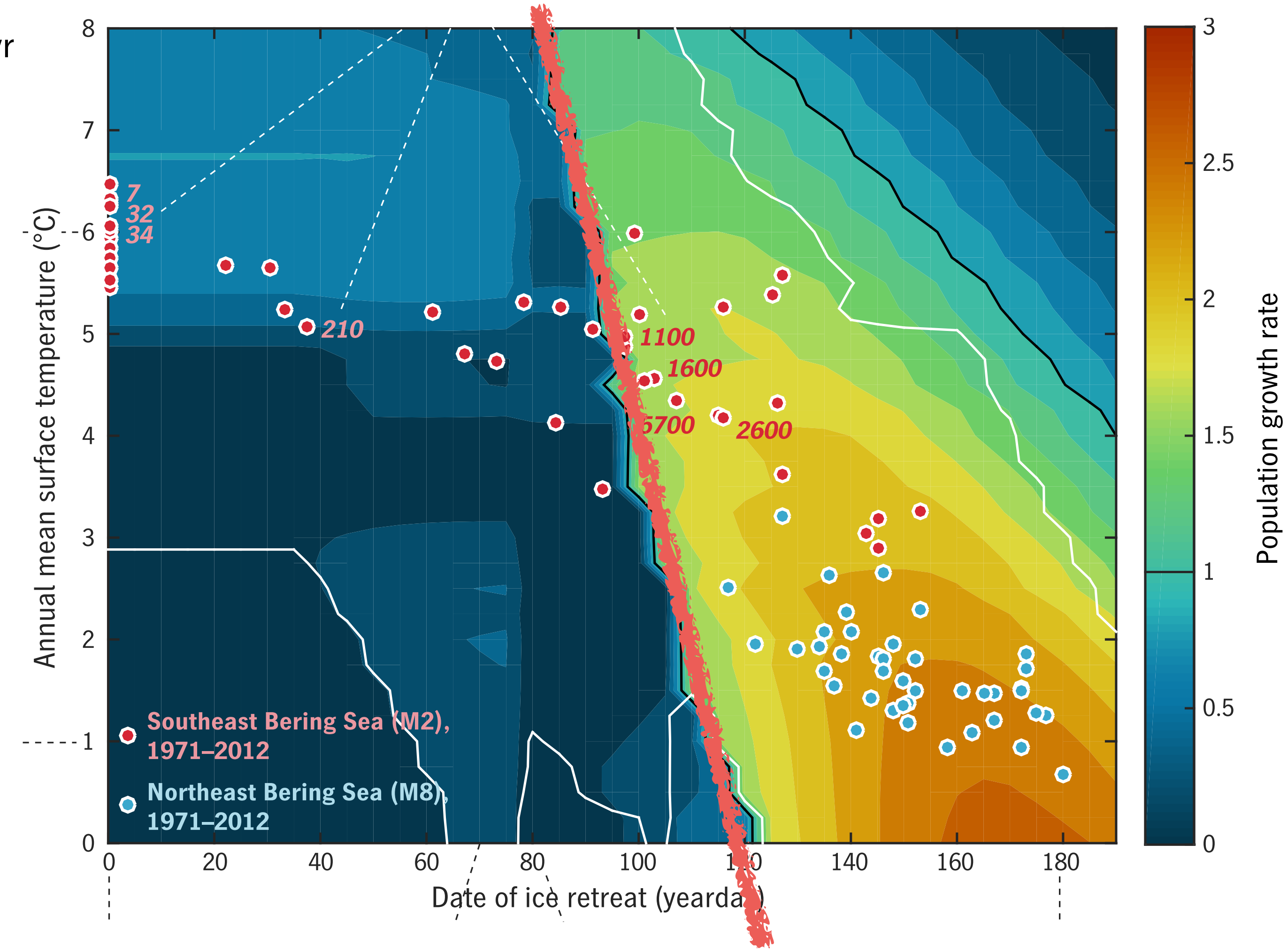
Bering Sea, *C. glacialis/marshallae*



global (idealised)

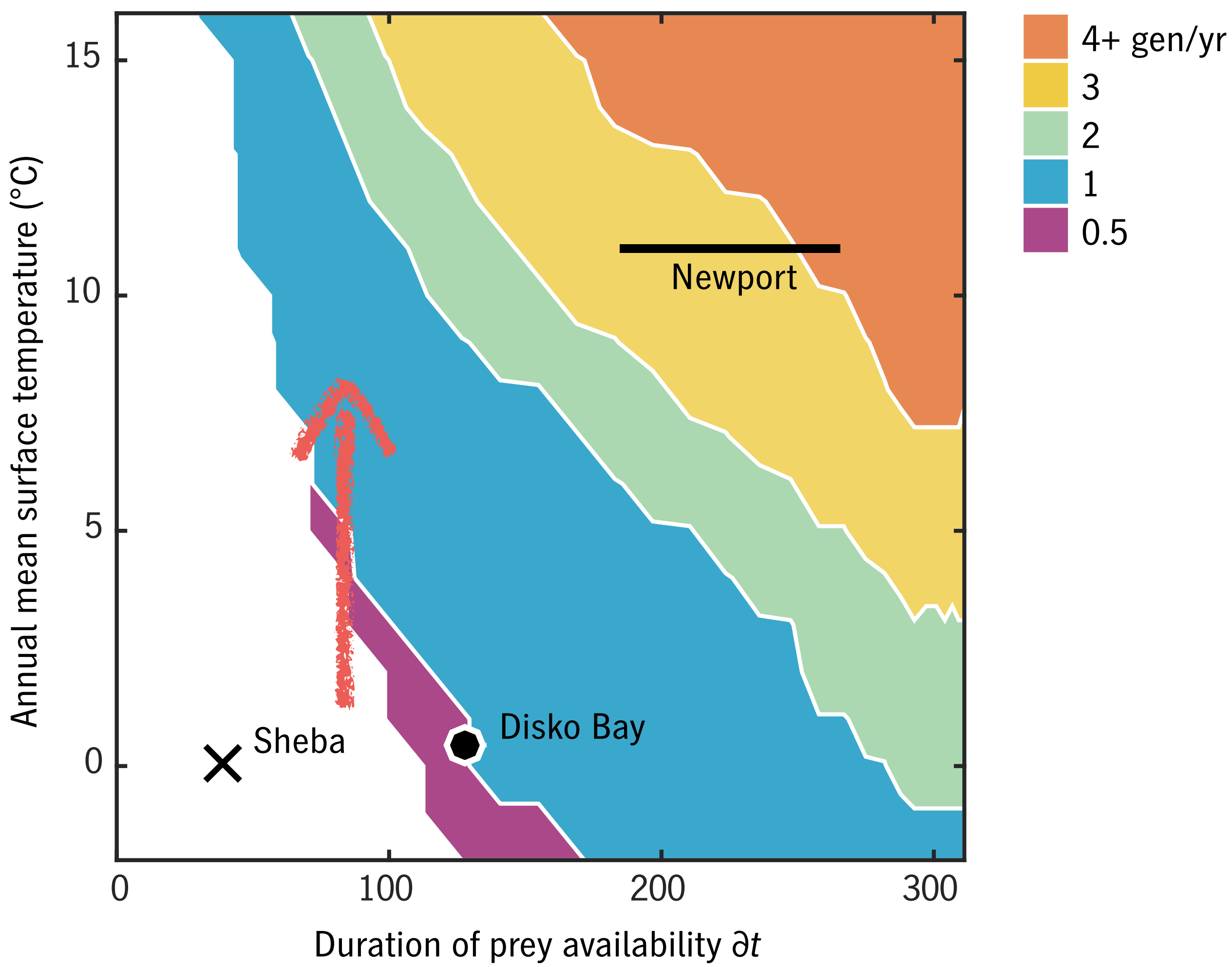


Bering Sea, *C. glacialis/marshallae*

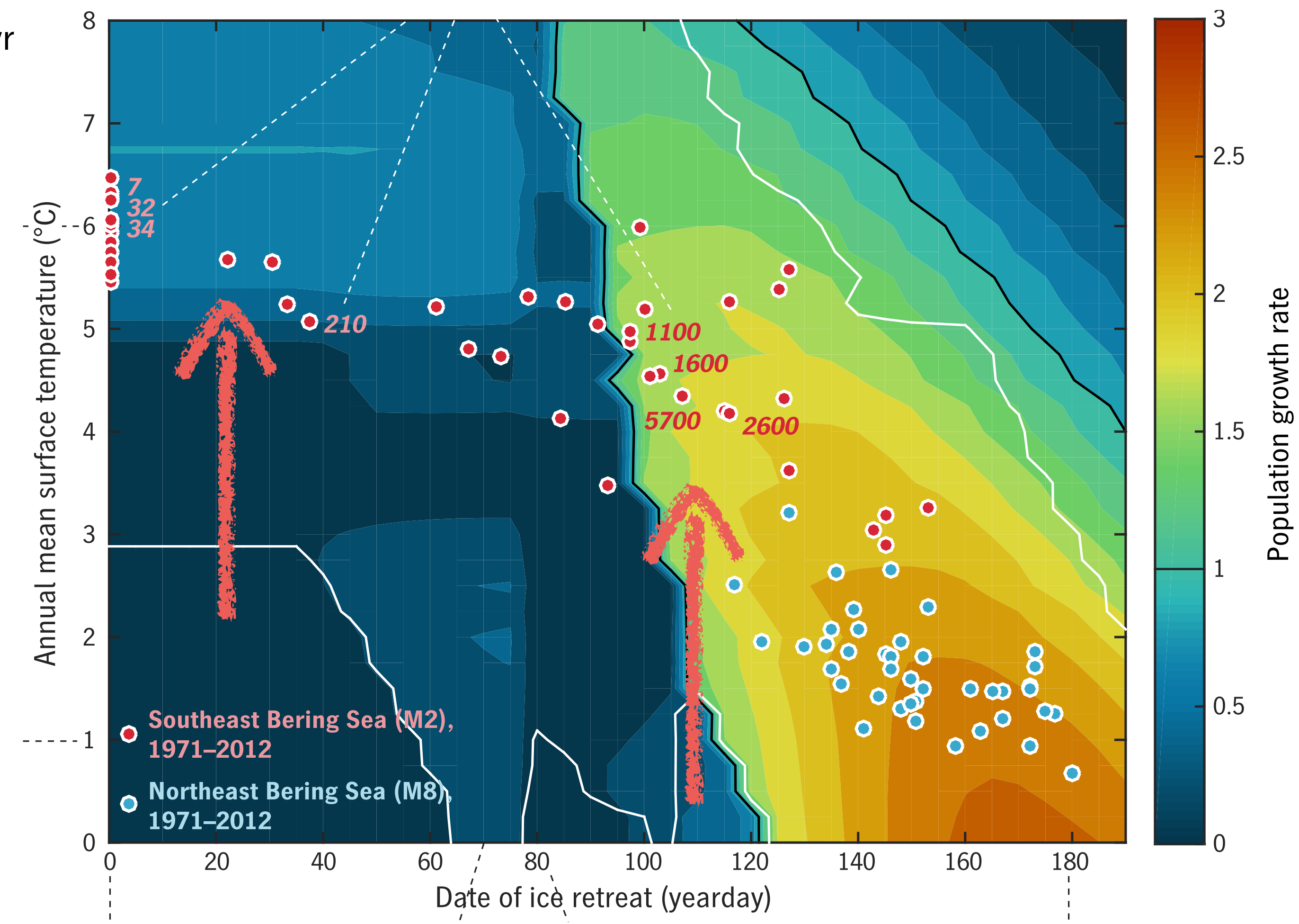


At both coarse and fine levels of detail,
the threshhold for viability of high-latitude *Calanus*
is mainly a matter of **timing, not temperature**

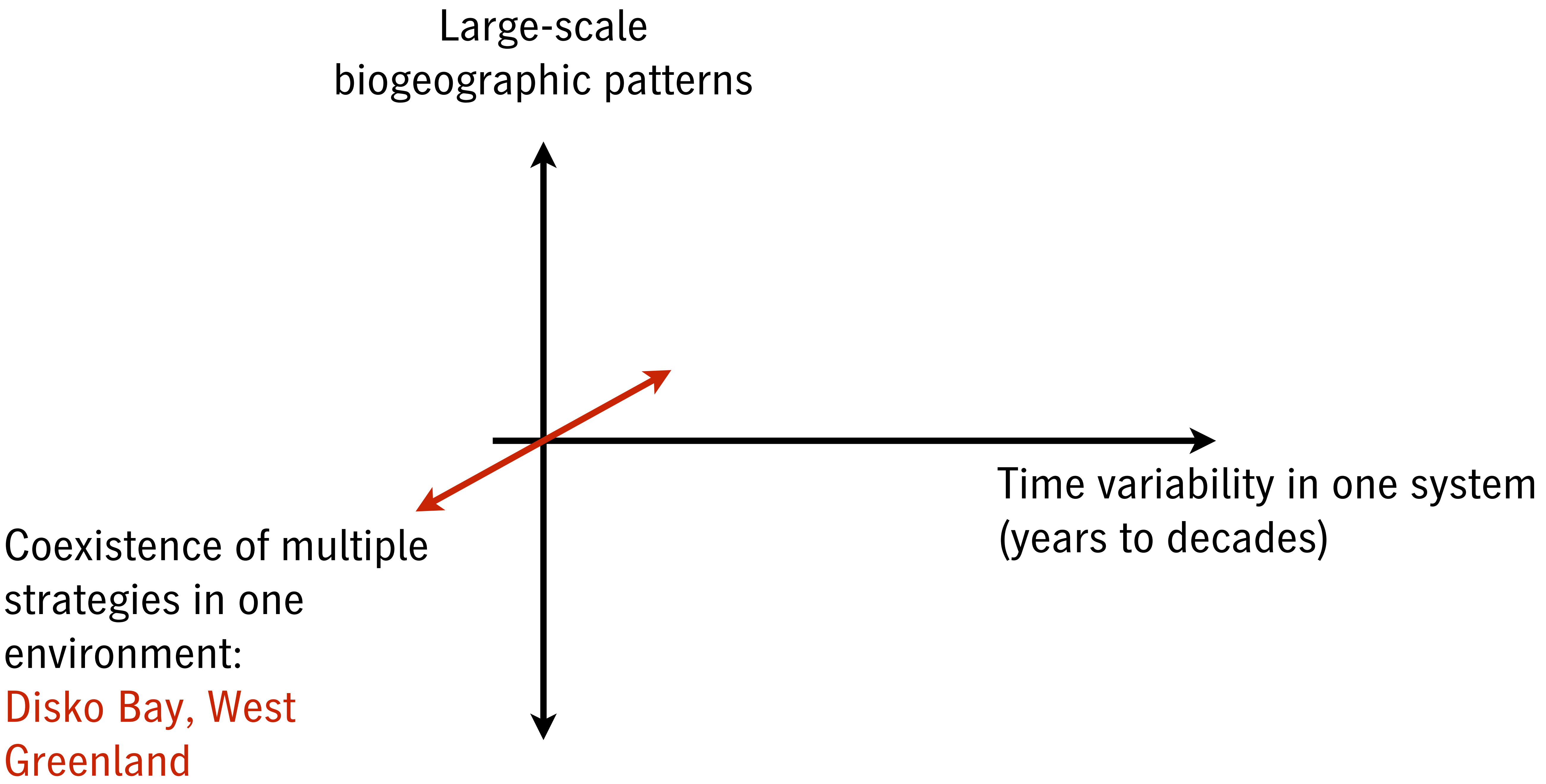
global (idealised)



Bering Sea, *C. glacialis/marshallae*

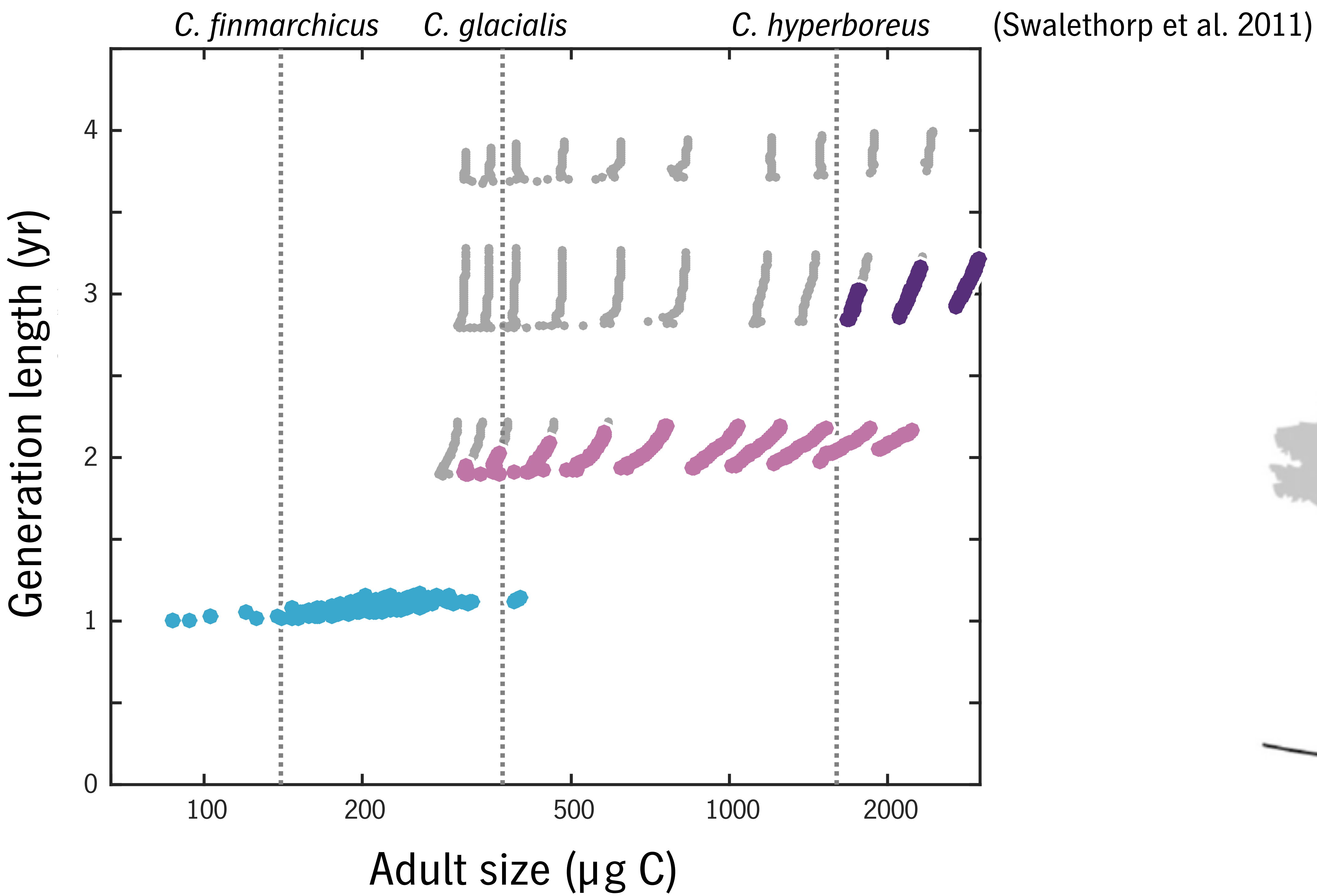


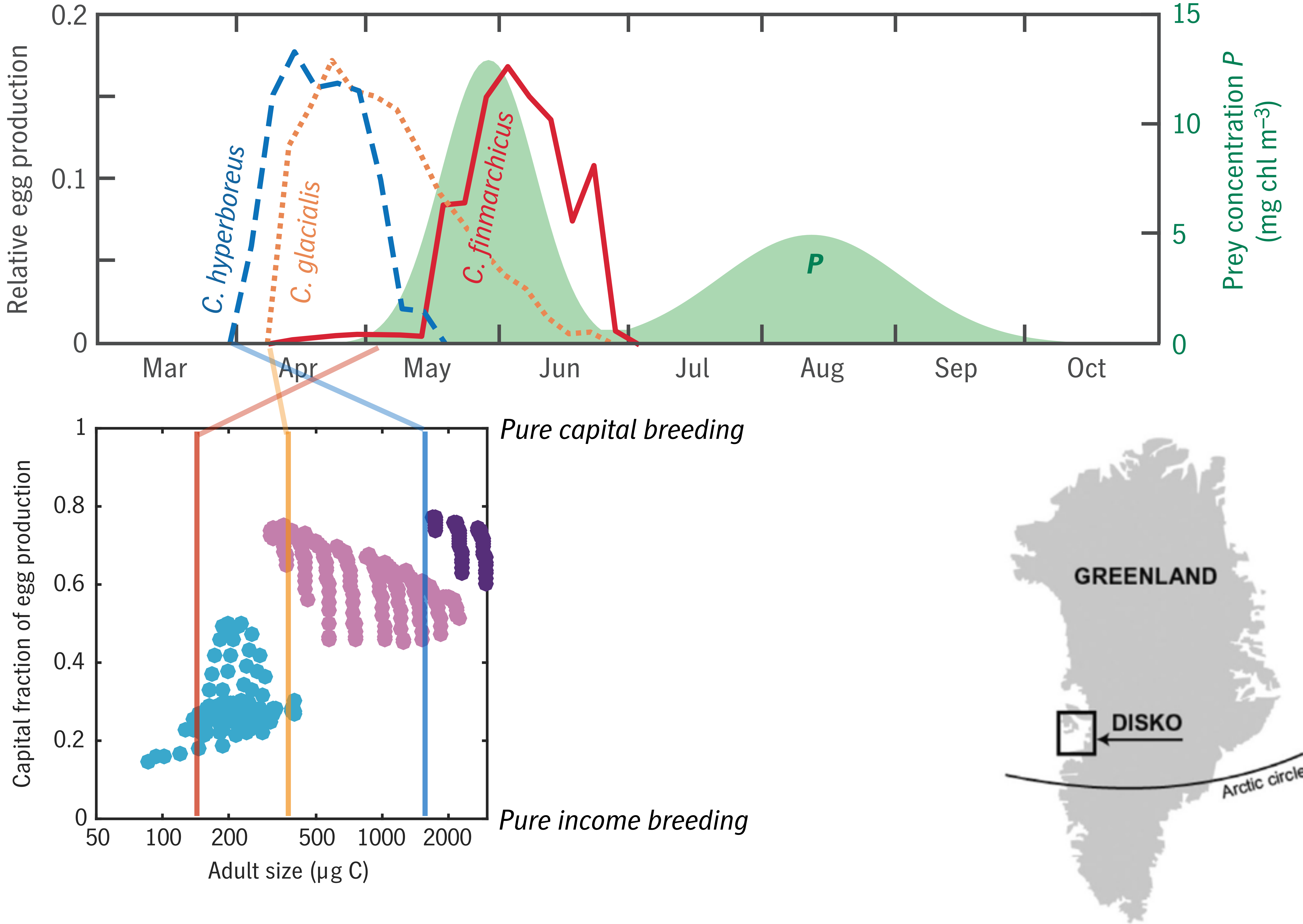
Warming per se is not necessarily a stressor


Large-scale
biogeographic patterns
Time variability in one system
(years to decades)
Coexistence of multiple
strategies in one
environment:
Disko Bay, West
Greenland

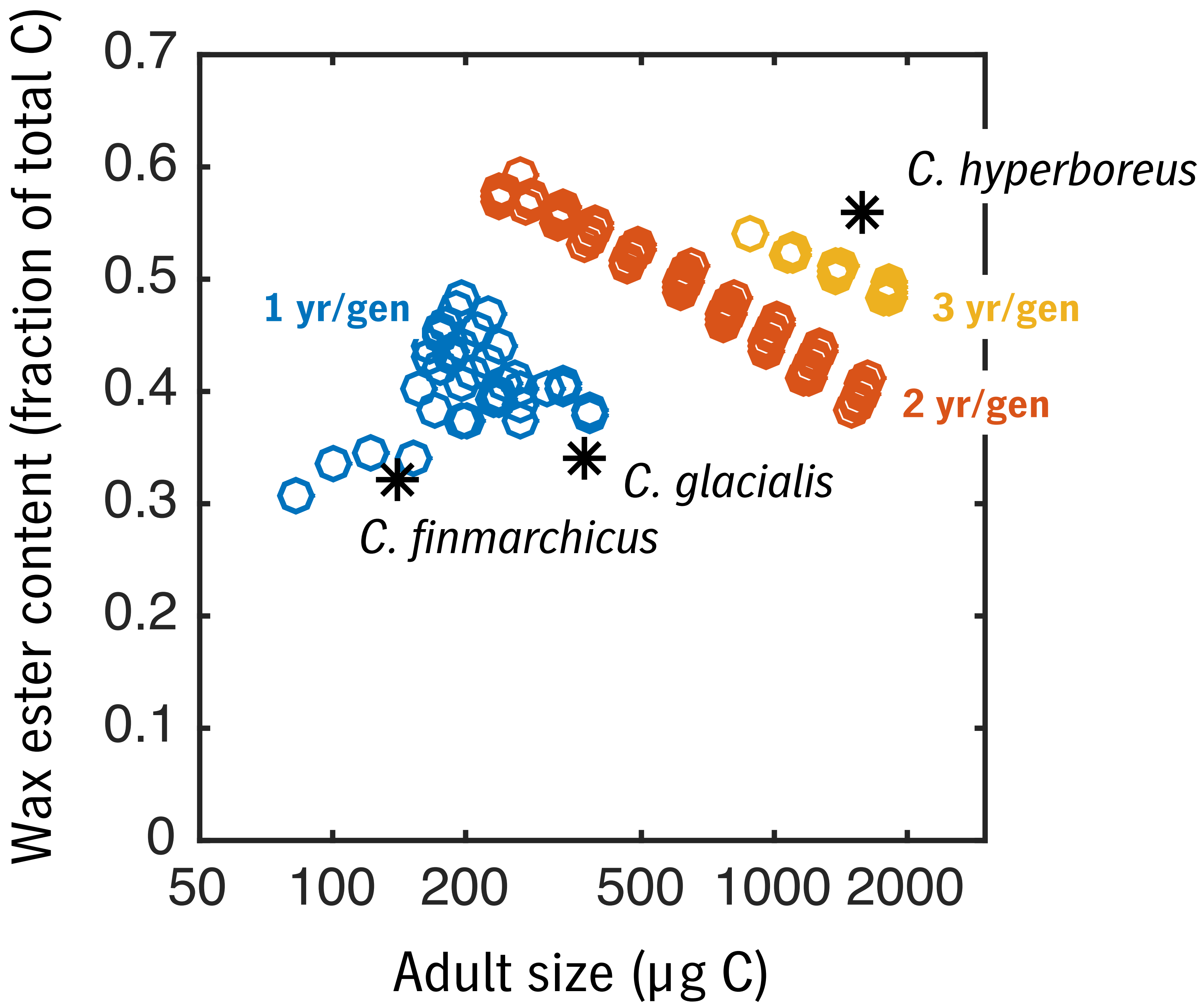
Disko Bay

1996–97 annual cycle + two axes of diversity:
u_0 (development rate → adult size)
t_{egg} (delay between maturation and egg production)





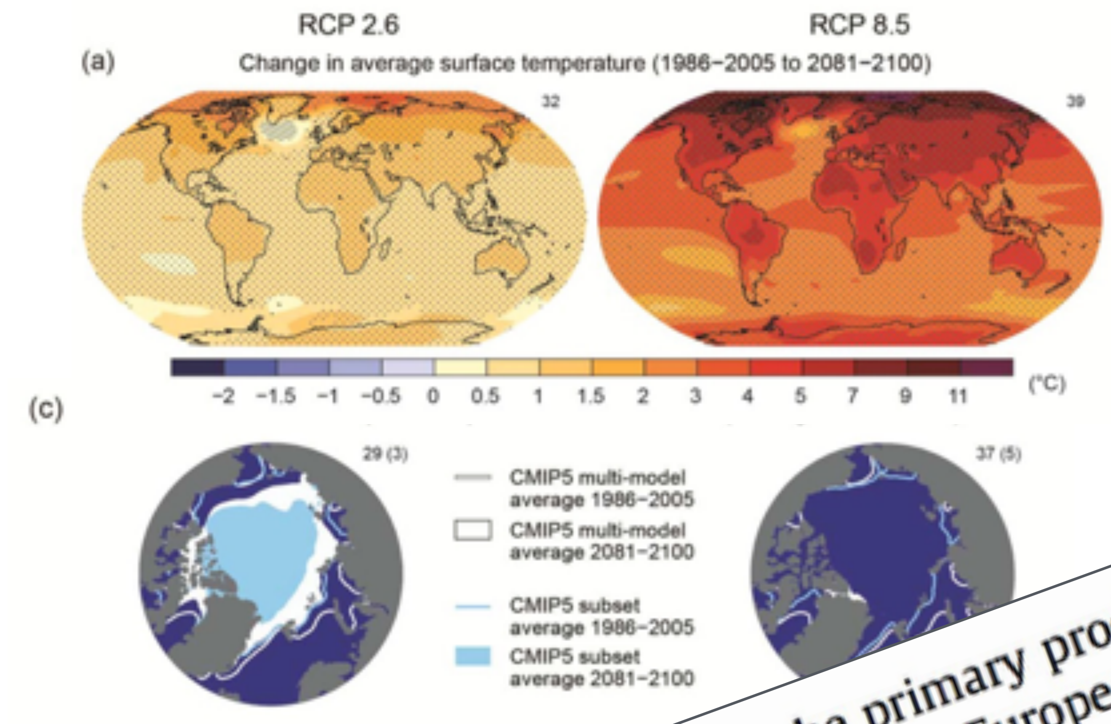
Relative egg production
0.2
0.1
0
15
10
5
0
Prey concentration P
(mg chl m^-3)
C. hyperboreus
C. glacialis
C. finmarchicus
P
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Capital fraction of egg production
1
0.8
0.6
0.4
0.2
0
50
100
200
500
1000
2000
Adult size (µg C)
Pure capital breeding
Pure income breeding
GREENLAND
DISKO
Arctic circle



(✱ = Swalethorp et al. 2011)

Where this is headed

IPCC AR5



Potential impacts of climate change on the primary production of regional seas: A comparative analysis of five European seas

Jason Holt[a,*], Corinna Schrum[b,c], Heather Cannaby[d,1], Ute Daewel[c,e], Icarus Allen[f], Yuri Artioli[f], Laurent Bopp[g], Momme Butenschon[f], Bettina A. Fach[d], James Harle[a], Dhanya Pushpadas[c,e], Baris Salihoglu[d], Sarah Wakelin[a]

Physical constrains and productivity in the future Arctic Ocean

Dag Slagstad[1], Paul F. J. Wassmann[2] and Ingrid Ellingsen[1]*

highly realistic, single-species copepod models

current rules transposed to a new ocean

(actual adaptive capacity somewhere in between)

Coltrane metacommunity predictions

all possible ways to be an anthropocene copepod

Summary

Many patterns in *Calanus* spp. (in latitude, time, and trait space) can be reproduced as a consequence of a handful of constraints in an individual's energy budget…

total energy available in an environment per year;
energy and time required to build a body;
metabolic and predation penalties for taking too long to mature and reproduce;
size and temperature scalings for vital rates

Phenology is crucial, but *not* (in these examples) through match/mismatch.

This approach constitutes a metacommunity model on top of which one can layer other species-level or region-specific constraints: cues for diapause, physiology of egg production, prey quality and selectivity, environmental dependence of predation, and so on.

neilbanas.com/projects/coltrane