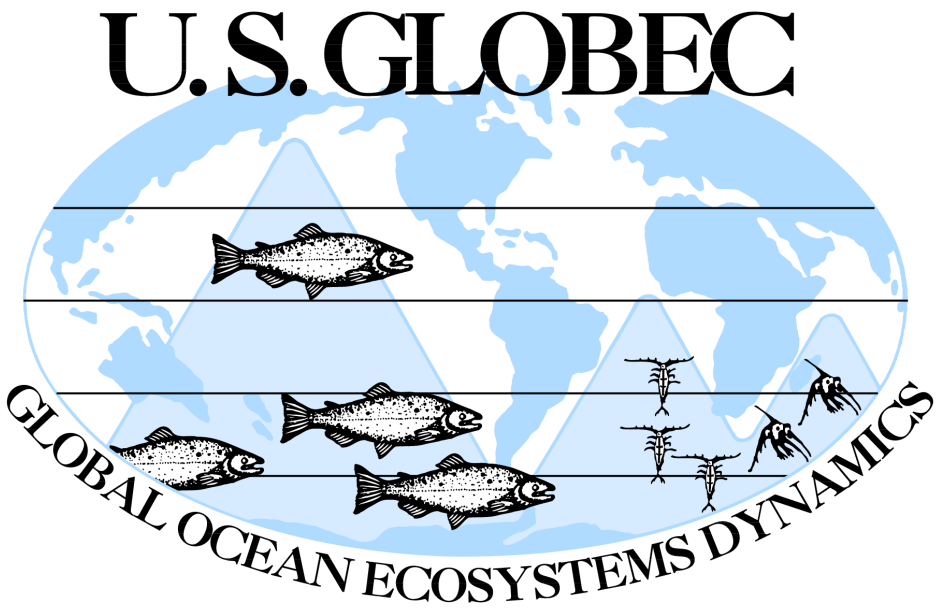


Calanus life histories

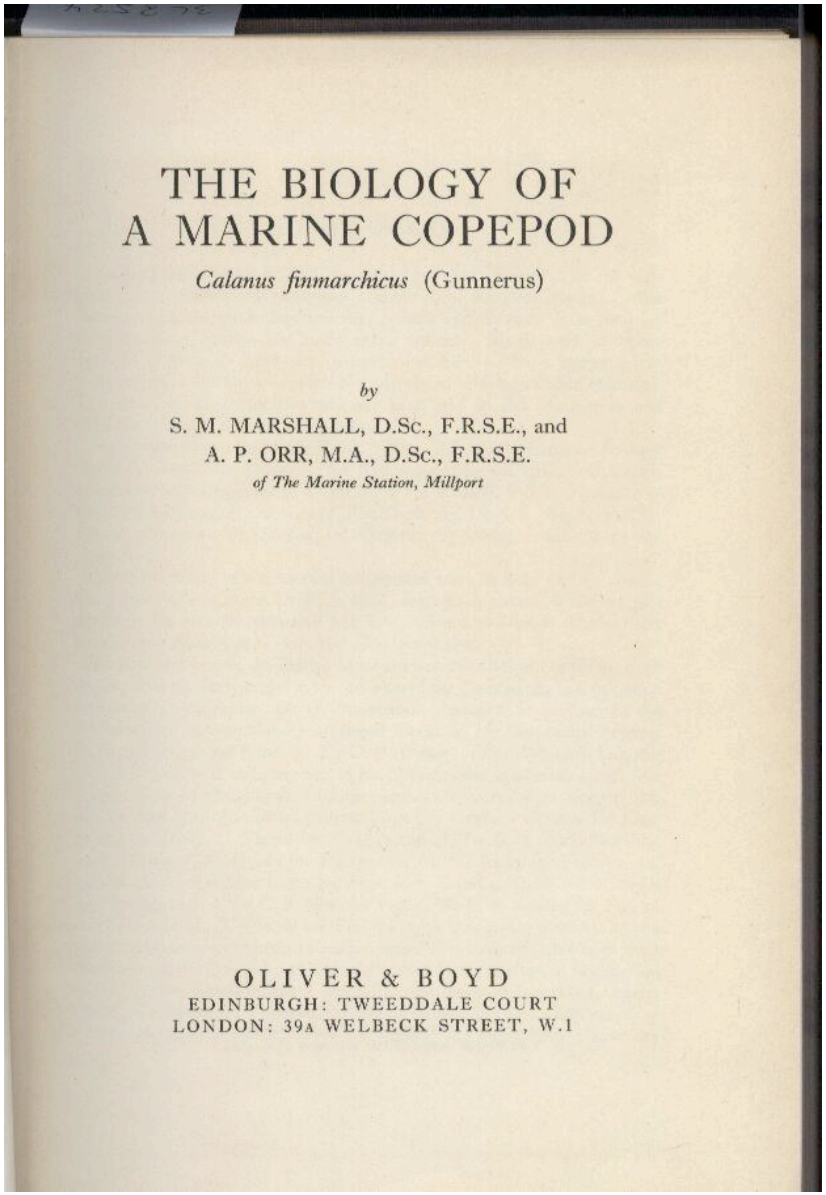
Data: Needs, Wants, Haves, and Synthesis

Goals

- Reviews and synthesize knowledge for sibling species in two sympatric species pairs:
  - *C. marshallae and C. pacificus in the North Pacific Ocean*
  - *C. finmarchicus and C. helgolandicus in the North Atlantic*

- Hypothesis:

"The timing of ***entry and exit from dormancy***, as modulated by species-specific physiology and effects of climate-forced variability of food and ambient temperature on lipid accumulation, exerts an important control on population dynamics. "



THE BIOLOGY OF
A MARINE COPEPOD

Calanus finmarchicus (Gunnerus)

by

S. M. MARSHALL, D.Sc., F.R.S.E., and
A. P. ORR, M.A., D.Sc., F.R.S.E.
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OLIVER & BOYD
EDINBURGH: TWEEDDALE COURT
LONDON: 39A WELBECK STREET, W.1

One potential outcome?

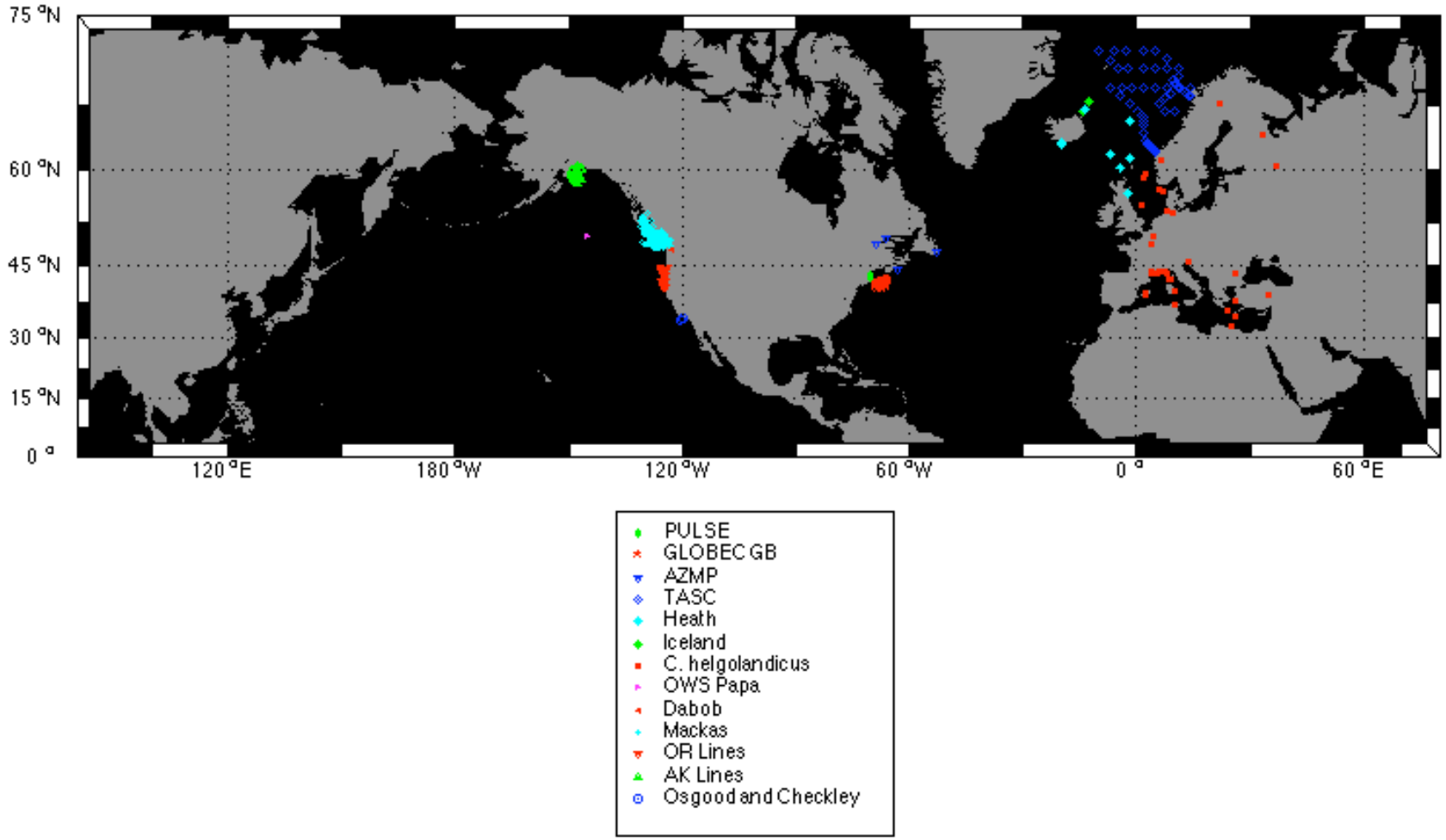
Demography

Data and goals

Demographic data set list

PACIFIC	Study	Location	Temporal resolution	Horiz. resolution
	Johnson (unpubl.)	Trough / Bight	2 wk - 3 mo / discrete months	one station / 10s – 100s km
	Osgood & Checkley 1997		several-month	10s km
	Osgood & Frost 1994 Pierson et al. 2005 Frost (unpubl.)	Puget Sound / Dabob Bay	1 month composite / weekly – monthly / ca. 2 week	one station
	US GLOBEC NEP – CCS Peterson et al.	(Line)	monthly/bi-monthly	multiple stations
	Mackas et al.	Is.	several-month	10s km
	US GLOBEC, NEP – CGOA Koyle et al.	(Seward Line)	monthly/several months	10s km
	Waddell & McKinnell 1995	Ocean Weather Station P	monthly/bi-monthly	one station

ATLANTIC	Study	Location	Temp. resolution	Horiz. resolution
	PULSE Runge (unpubl.)	(Jeffrey's Ledge)	weekly	one station
	GLOBEC- Georges Bank		monthly	ca. 40-50 km
	AZMP	Scotian Shelf / Shelf / Anticosti Gyre (GSL)	monthly/ bi-monthly	one station
	Plourde et al. (2001, 2002, unpubl.)	Lower St. Lawrence Estuary (LSLE)	bi-monthly composite	one station / grid of 29 stations
	TASC		monthly / several months	ca. 10s-100s kms
	Hirst et al (2007)		weekly	one station
	Lindeque et al (2006)		several months	ca. 10s-1000s km
	Gislason & Astthorsson (1996, 1998) Gislason et al. (2000, 2007) Astthorson & Gislason (2003)		monthly/ bi-monthly	several stations


75 °N
60 °N
45 °N
30 °N
15 °N
0 °
120 °E
180 °W
120 °W
60 °W
0 °
60 °E
PULSE
GLOBEC GB
AZMP
TASC
Heath
Iceland
C. helgolandicus
OWS Papa
Dabob
Mackas
OR Lines
AK Lines
Osgood and Checkley

"Population metrics, including…

- peak abundance,…
- timing of the abundance peak,…
- duration of the reproductive period (defined as the time between emergence from and entry into dormancy; methods in Johnson et al. 2008),…
- the rate of population growth between emergence and the population abundance peak,…
- the relative timing of emergence from dormancy and the spring bloom…

…will be used to compare populations at different locations."

Dormancy Metrics

Johnson et al. 2008 ICES J. Mar. Sci

- **Dormancy onset**:
  - "…date when the proportion of CVs in the population rose to half its overall maximum, calculated as each year's maximum CV proportion averaged over all years at that station."

- **Emergence**:
  - "…first date when adults were more than 10% of the population of stages from copepodid stage 1 to adult."
  - "…back-calculating the spawning dates of the first early copepodid stages to appear in spring.

C. pacificus clade distribution

Nuwer dissertation 2008

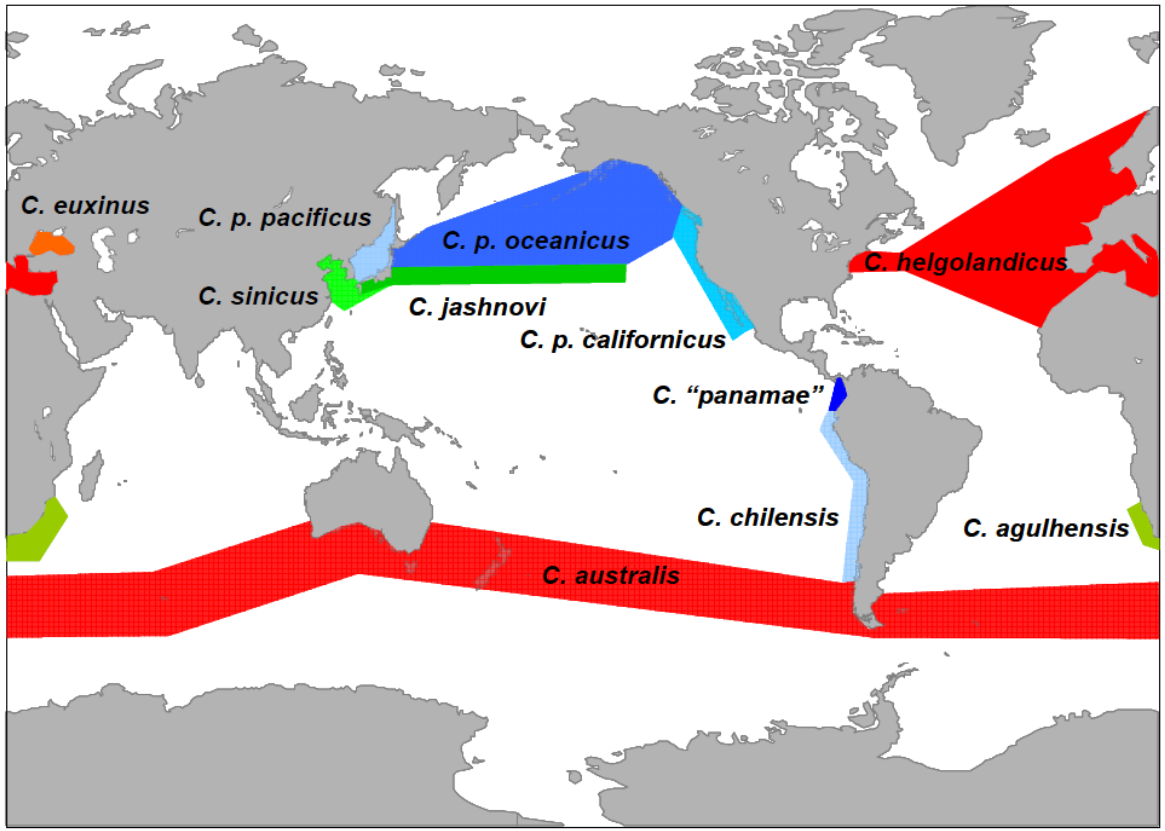


Figure 1-1. World distribution of the *Calanus helgolandicus* clade taxa (adapted from an unpublished chart of Fleminger and Hulsemann, and Hulsemann 1994).

Egg production

Data and goals

Egg production data sets

Species & Location	Reference
Calanus spp.	
	Harris et al 2000
Calanus finmarchicus	
	Melle and Skjoldal 1998
	Rey-Rassat et al. 2002a
Faroe shelf	Debes and Eliasen
	Ohman and Runge 1994
	Plourde and Runge 1993
	Plourde et al. 2001
	Starr et al. 1999
Icelandic shelf	Gislason 2005
	Gislason and Astthorsson 2000
	Mayor et al. 2006
	Biegala et al 1999
	Hirche et al 1997
	Koski 2007
	Richardson et al. 1999
	Jonasdottir et al 2005
	Niehoff 2000
	Niehoff et al 1999
	Pasternak et al 2004
NW	Cabal et al 1997
	Campbell and Head 2000
	Runge and Plourde 1996
NW Atlantic/Georges Bank	Runge et al. 2006
NW Atlantic/GoM	Campbell et al. 2001
	Durbin et al 1997
	Durbin et al 2003
	Jonasdottir et al 2002
	Helland et al. 2003
	Hirche 1996

Species & Location	Reference
Calanus finmarchicus (cont.)	
mesocosm	Nejstgaard et al. 1997
	Nejstgaard et al. 2001
Calanus helgolandicus	
	Hirst et al 2007
	Irigoien et al. 2000a
	Irigoien et al. 2000b
	Pond et al 2006
	Rey-Rassat et al. 2004
	Rey-Rassat et al. 2002a
	Rey-Rassat et al. 2002b
	Biegala et al 1999
	Bonnet et al 2005
	Jonasdottir et al 2005
	Kang and Poulet 2000
Calanus marshallae	
upwelling	Peterson et al 2002
	Gomez Gutierrez & Peterson 1999
	Baier and Napp 2003
Chukchi/	Plourde et al 2005
Calanus pacificus	
upwelling	Gomez Gutierrez & Peterson 1999
	Peterson et al 2002
	Uye 1996
Puget Sound/Dabob Bay	Runge 1984
	Frost 1988
	Pierson et al 2005
	Ohman et al 1998
	Mullin 1991

EPR data sets available by species

	Pacific	Atlantic
"*finmarchicus*" clade	*C. marshallae*	*C. finmarchicus*
	2	29
"*helgolandicus*" clade	*C. pacificus*	*C. helgolandicus*
	5	11

Egg Production metrics I

- Egg production rate (EPR)
  - Eggs female^{-1}day^{-1}
  - Mass specific rates: %C day^{-1} ,%C day^{-1}

- Relate to Chlorophyll *a* → Ivlev function
  - cf. Runge et al. 2006

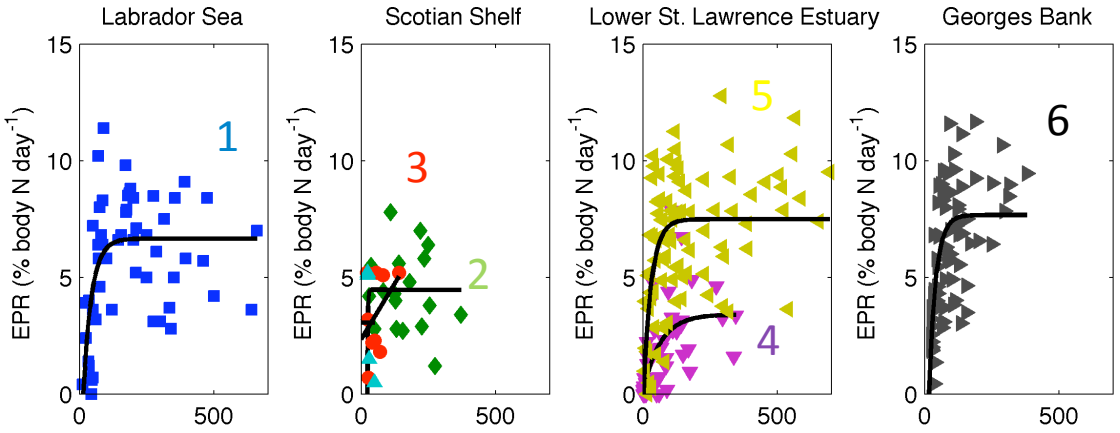
- Critical concentration → 90% of the fitted maximum EPR.

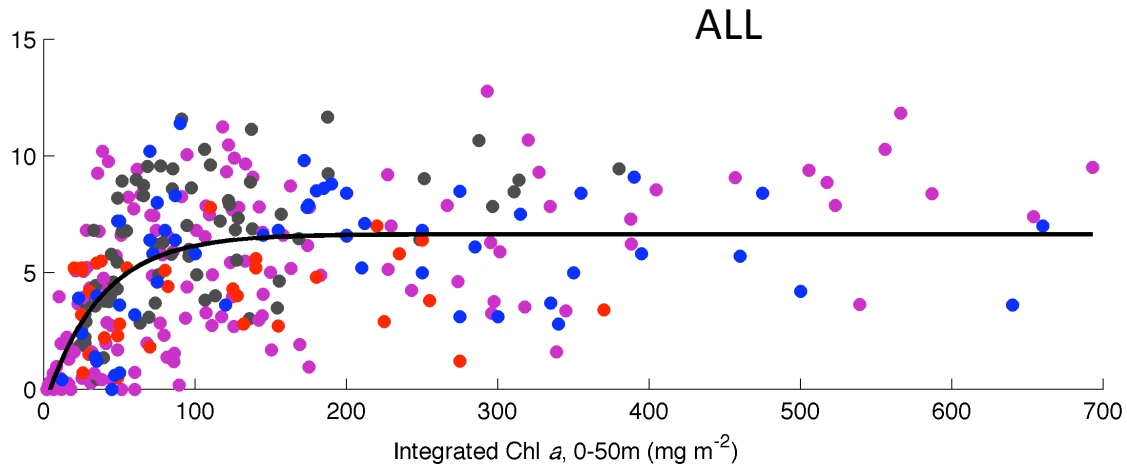
Egg Production metrics II

- Also test
  - Mixed layer temperature
  - Other measures of food availability

- Generalized linear model (GLM) approach (Bonnet et al. 2005)
  - Predictors are
    - Mixed layer temperature
    - Chlorophyll a concentration
    - Latitude, longitude
    - Time of year

EPR Relationships I





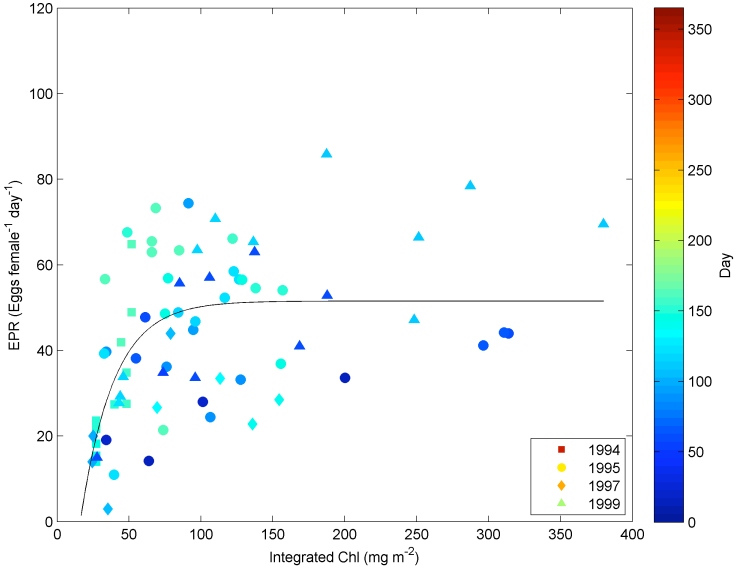
$$Y = C_1 e^{C_2 (x + C_3)}$$

Curve	C_1	C_2	C_3
1	6.7	0.03	-13.9
2	4.5	-0.52	-22.6
3	193.2	0.00	120.7
4	3.4	0.02	1.3
5	7.5	0.03	-2.1
6	7.7	0.04	-16.5
ALL	6.6	-0.03	-4.2

EPR Relationships II

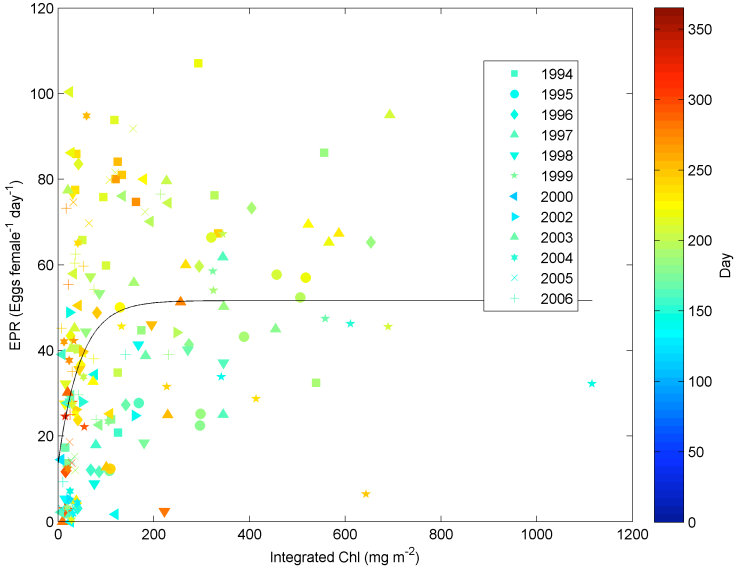
Georges Bank

$Y = 51.54*(1-e^{-0.04*(x-16.10)})$

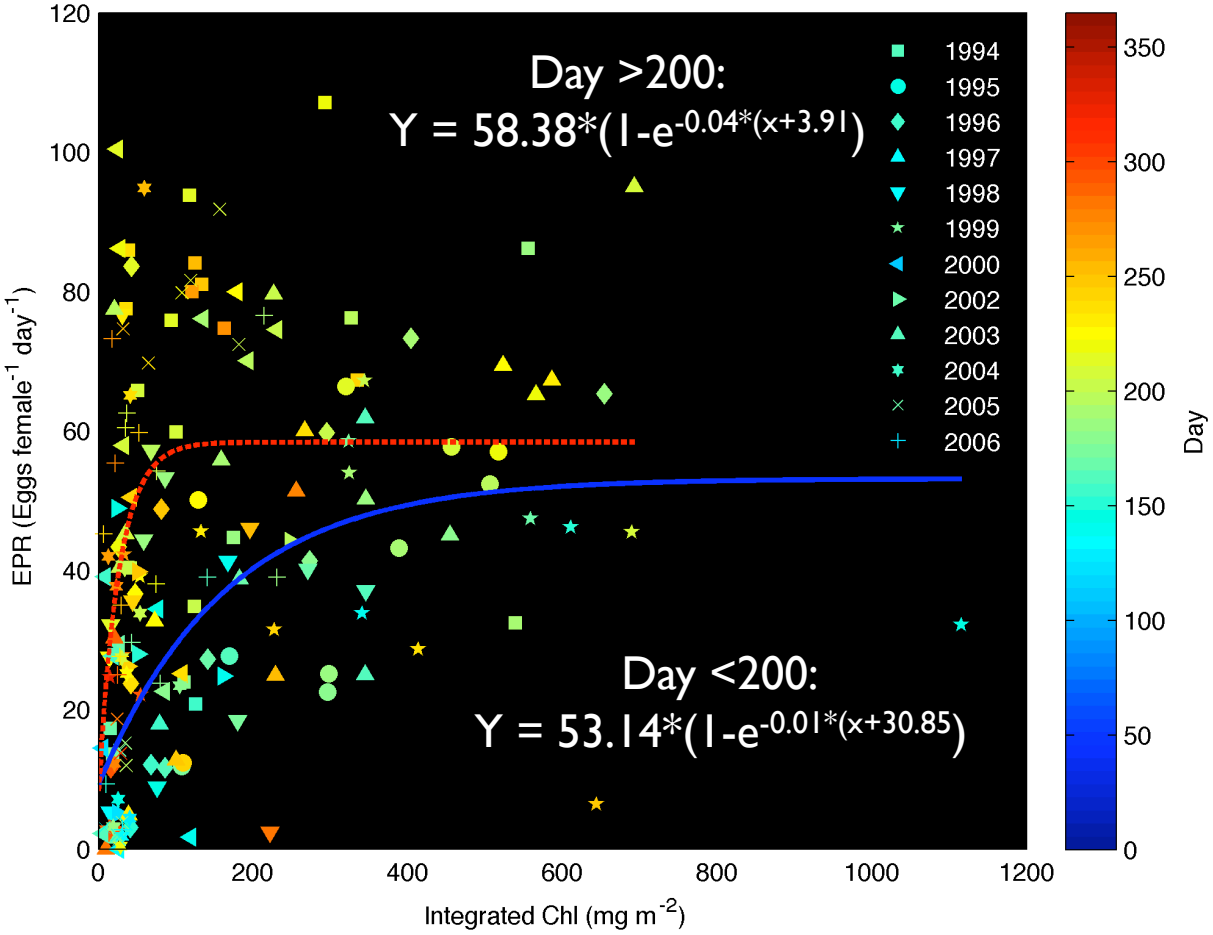


Gulf of St. Lawrence

$Y = 51.64*(1-e^{-0.02*(x+14.13)})$



GSL: Seasonal differences?



The next steps…

Timeline for data synthesis

SUBJECT TO CHANGE, HOPEFULLY EARLIER…

- By 2010
  - Compile data sets for demography and EPR
  - Perform standard analyses
    - Entry / Exit dormancy
    - Ivlev fits
- By summer 2010
  - Develop new/enhanced metrics
  - Data into BCO-DMO database
- By 2011
  - Drafts of monographs on demography and EPR circulate

Other data from M. Nuwer's dissertation

C. pacificus distributions

Nuwer dissertation 2008

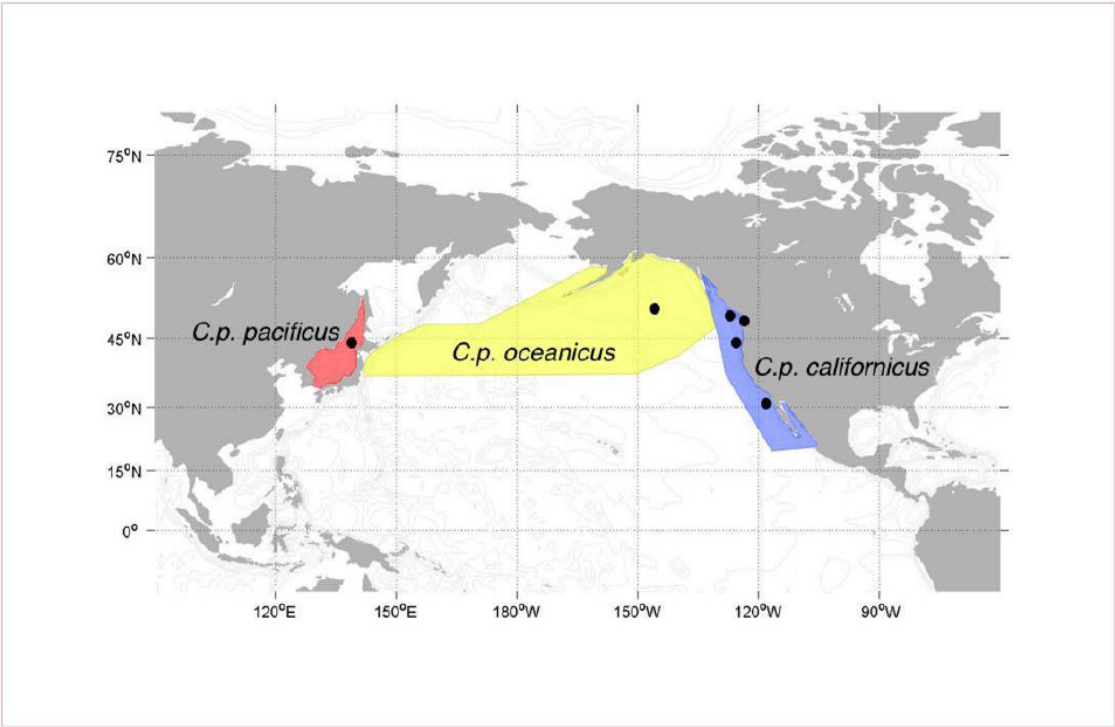


Figure 2-1. Geographic distribution of the *Calanus pacificus* subspecies as adapted from Bucklin and LaJeunesse (1994). Red indicates extent of *C. p. pacificus*; yellow indicates extent of *C. p. oceanicus*; blue indicates extent of *C. p. californicus*. Sampling locations are represented by filled circles.

C. pacificus phylogeny

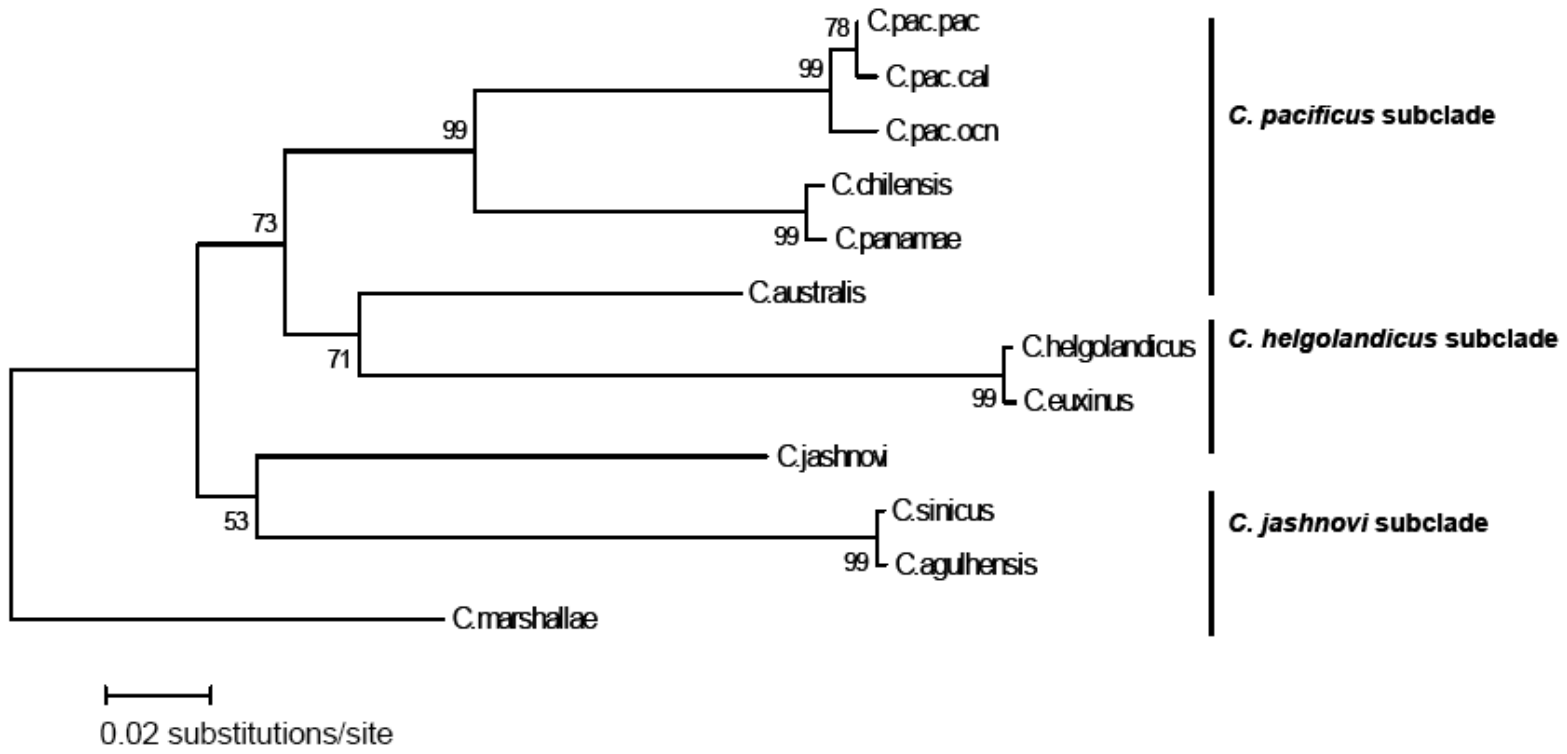


Figure 1-2. MtCOI gene tree of the 11 taxa in the *Calanus helgolandicus* clade based on the Jukes-Cantor distance method. Numbers at branch points are bootstrap values. The tree was bootstrapped 1000 times.

Nuwer dissertation 2008