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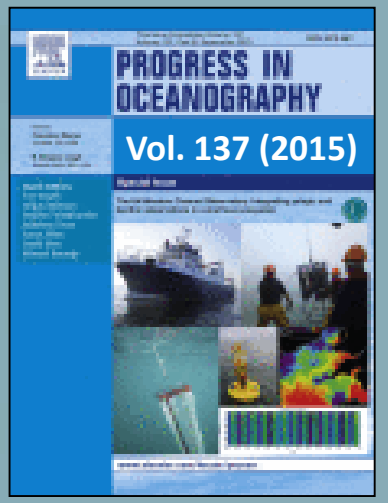
# Mortality of the NE Atlantic copepod *Calanus helgolandicus*




**Jacqueline Maud**

Dr Angus Atkinson (PML)
Dr Andrew Hirst (Queen Mary University of London)
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ICES CIEM

Zooplankton Symposium
9th – 13th May 2016

jama@pml.ac.uk

Western Channel Observatory

Marine Ecosystems Research Programme

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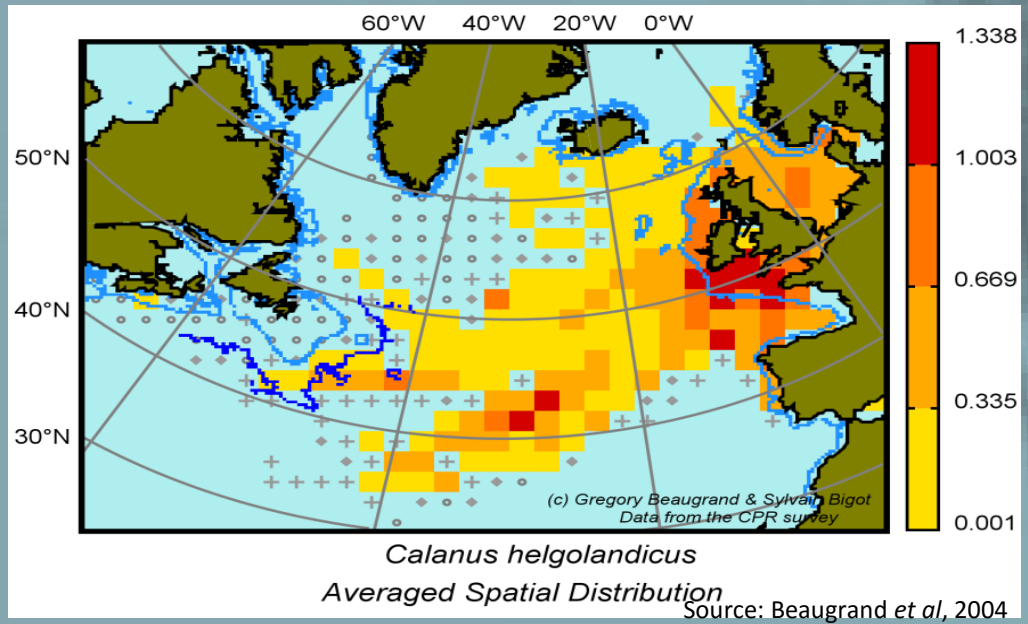
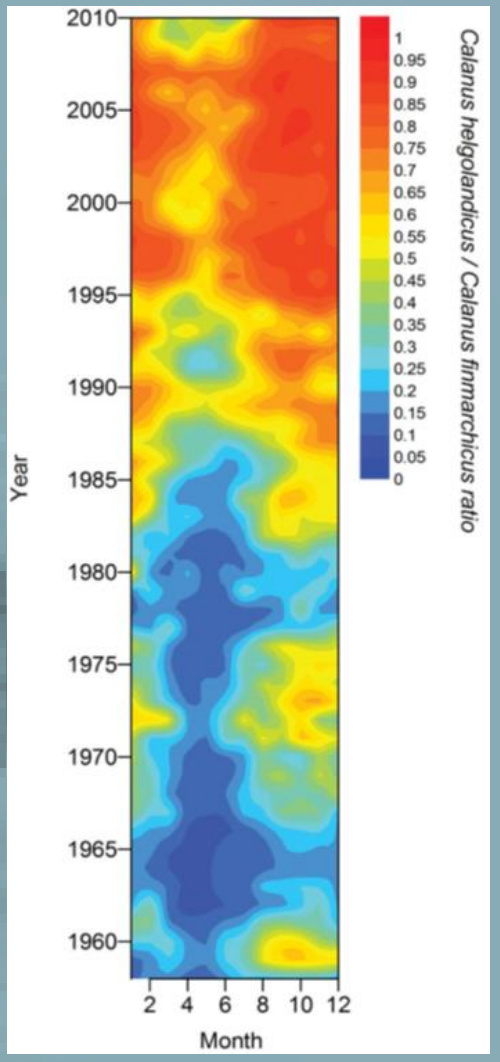
# Background: *Calanus helgolandicus*

- Key copepod species – European waters, NE Atlantic
- Warm water, temperate species




Source: Beaugrand *et al*, 2004




Source: Edwards *et al*, 2013

- Impact of warming oceans
- Expansion of distribution
- Substitution for *C. finmarchicus*

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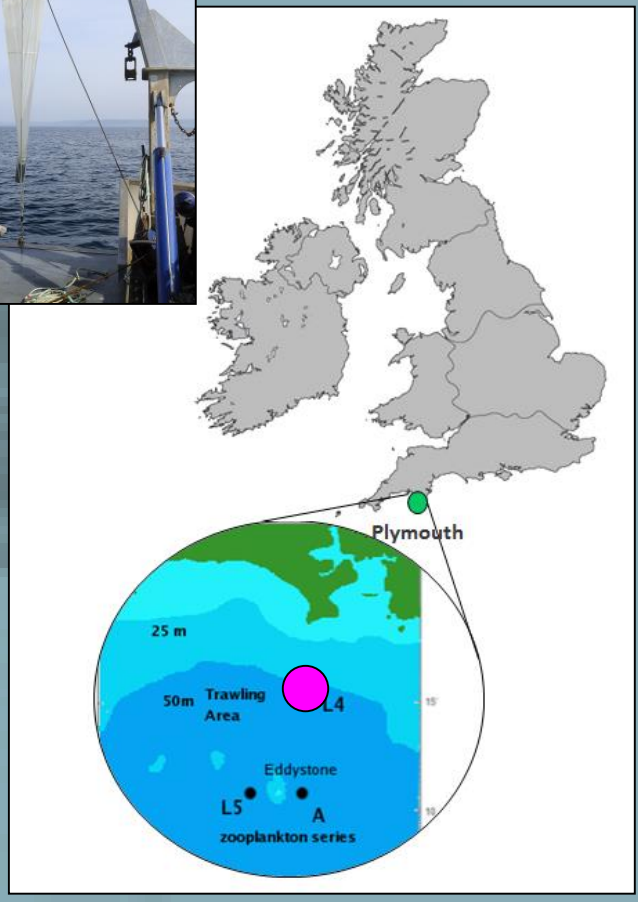
# Background: Station L4 sampling

- 15 nm SW of Plymouth
- Inshore, shallow site (~55m)
- Weekly sampling (1988 - present)
  - mesozooplankton (200 & 63µm WP2 nets)
  - phytoplankton
  - microzooplankton
  - environmental data
  - *C. helgolandicus* egg production experiments (1992 - present)



# Research objectives

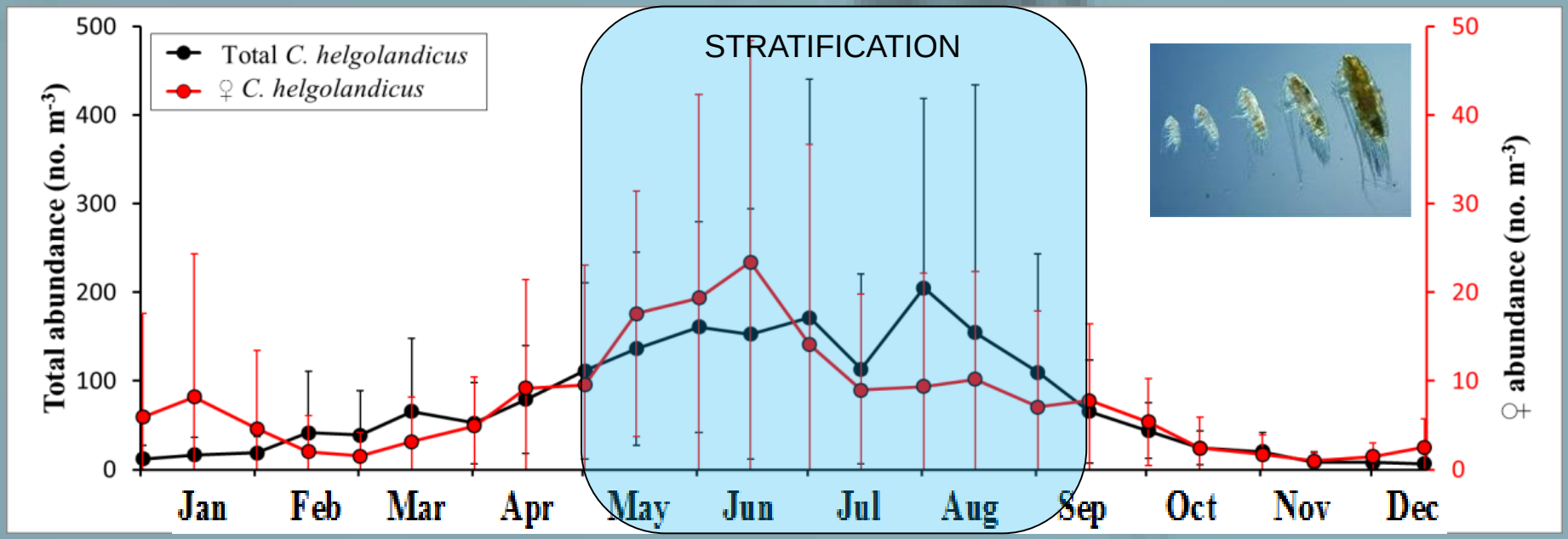
1. What processes control *C. helgolandicus* population at L4?

2. What are the mortality rates of *C. helgolandicus*?

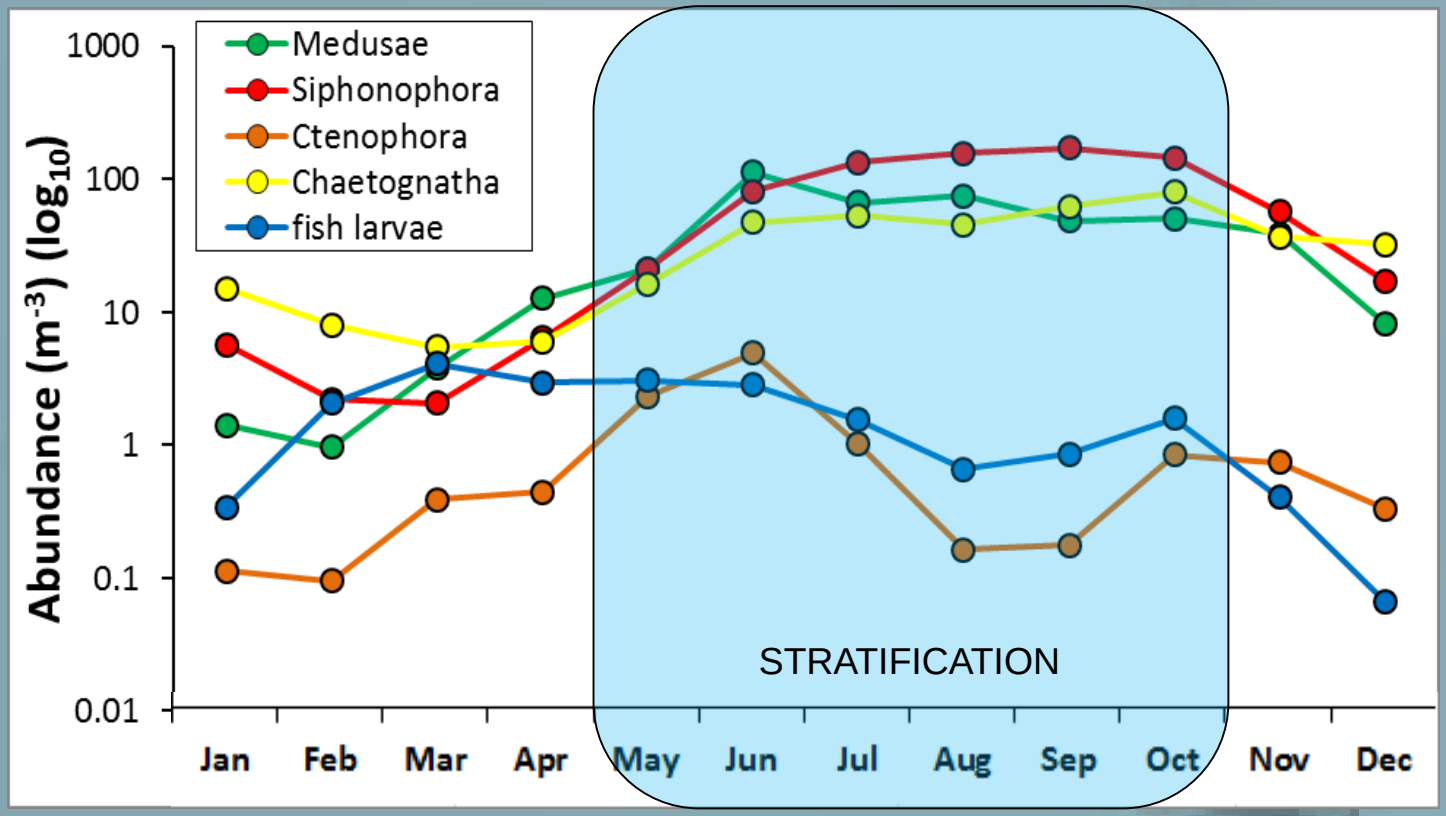
3. What are the major sources of *C. helgolandicus* mortality?

# L4 time-series: seasonal cycles

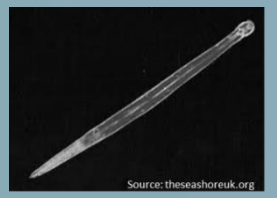
- *C. helgolandicus* abundance
- Average seasonality (25 yrs)

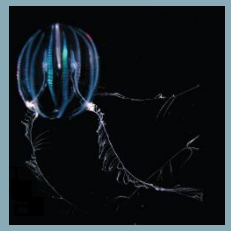


# L4 time-series: predators





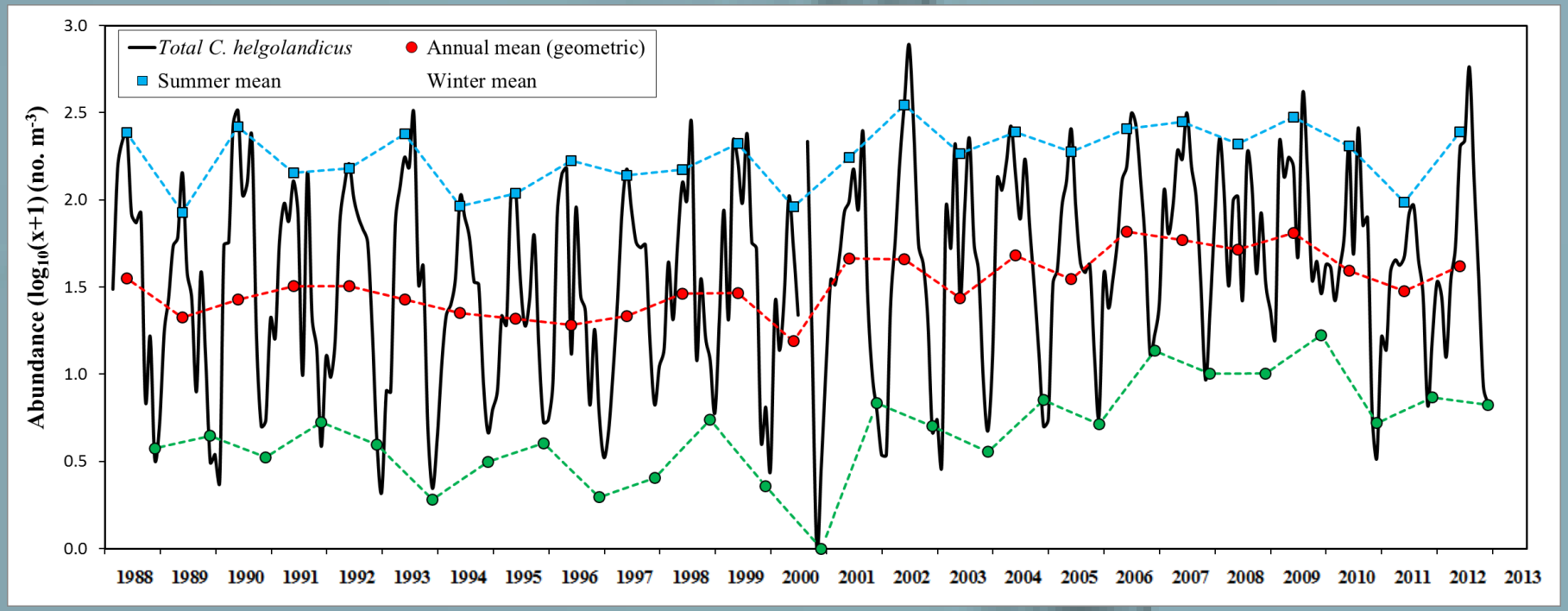



- Other copepods (cannibalism, intraguild predation)

# L4 time-series: *C. helgolandicus*

## Total *C. helgolandicus* abundance (1988-2012)




Maud et al., 2015; Progress in Oceanography, Vol. 137B; WCO Special Issue

- **Only 4-fold inter-annual variation**


Progress in Oceanography 137 (2015) 498–512

Contents lists available at ScienceDirect

Progress in Oceanography

journal homepage: www.elsevier.com/locate/pocean

ELSEVIER

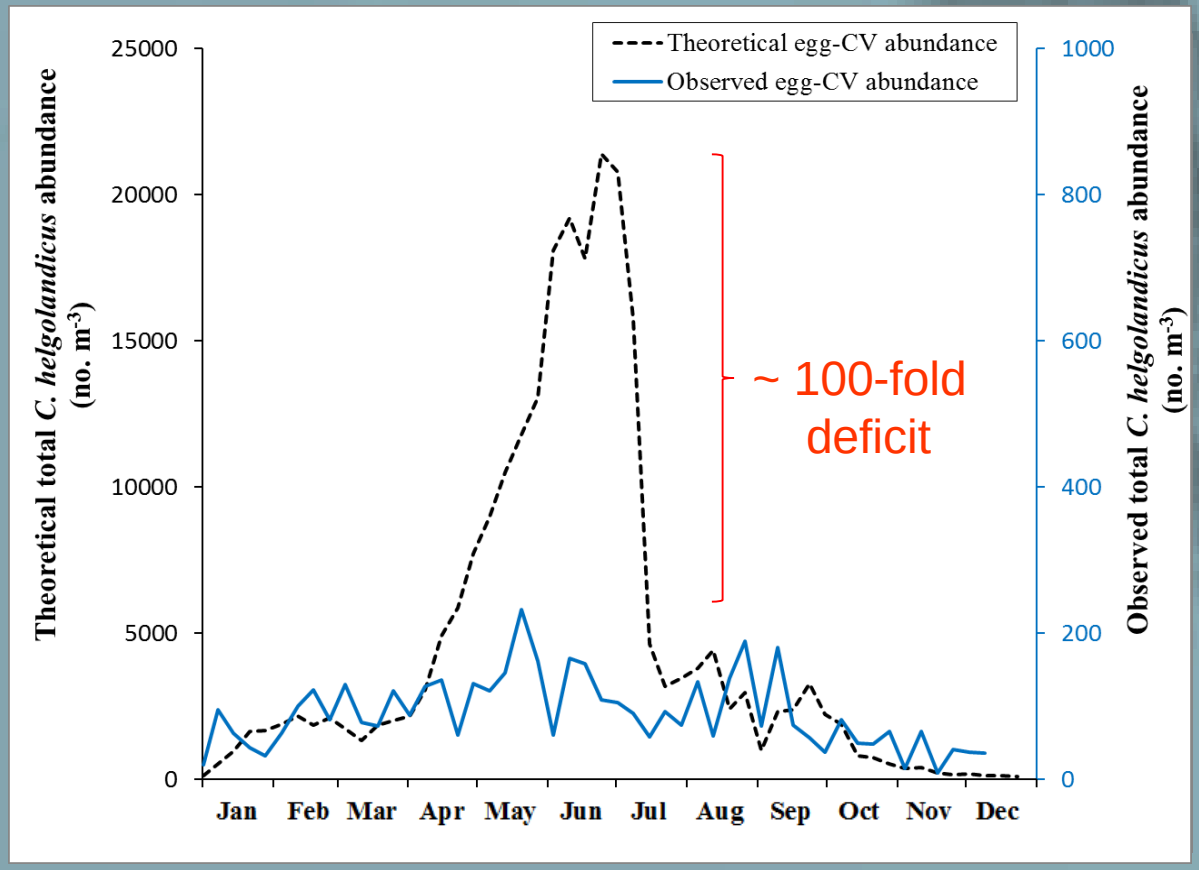
Questioning the role of phenology shifts and trophic mismatching in a planktonic food web

Angus Atkinson *, Rachel A. Harmer, Claire E. Widdicombe, Andrea J. McEvoy, Tim J. Smyth, Denise G. Cummings, Paul J. Somerfield, Jacqueline L. Maud, Kristian McConville

Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth PL13DH, United Kingdom

# L4 time-series: population model

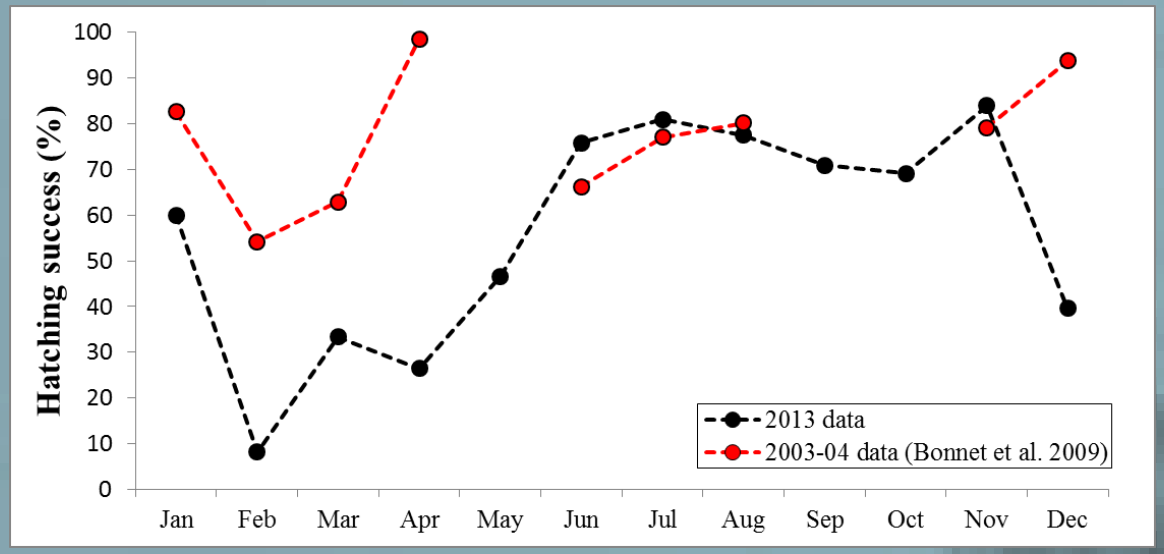
- *C. helgolandicus* egg production time-series (mean EPR)
- EPR x ♀ abundance ($m^{-3}$) = Total Reproductive Output (TRO)

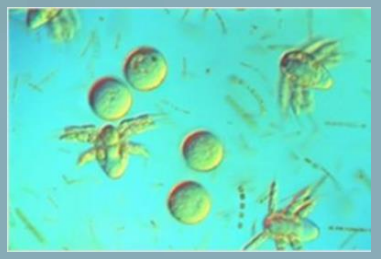


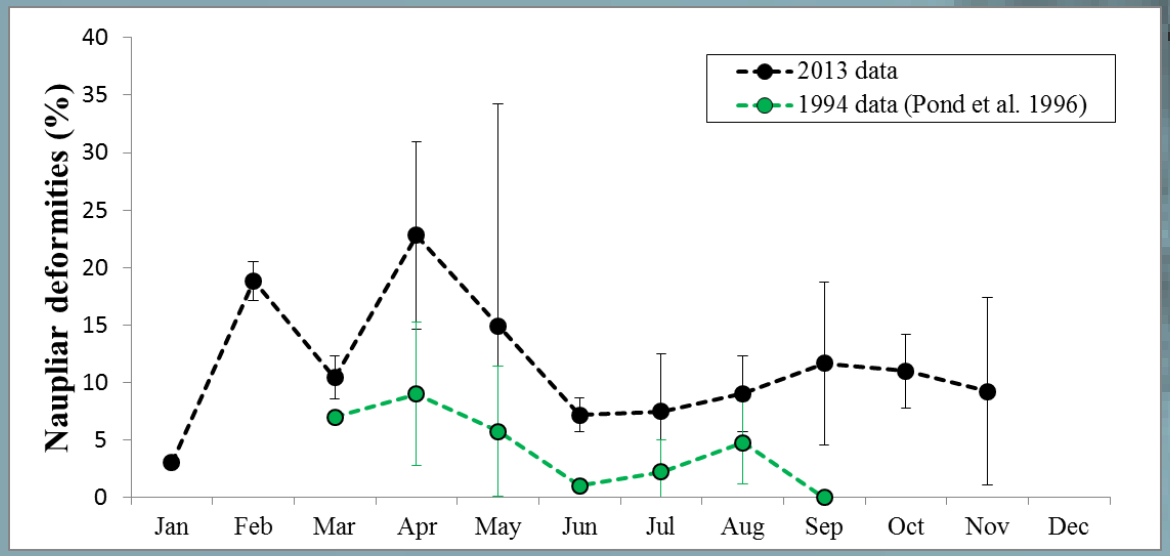

- "Grow" population through a year from egg to CV – no mortality

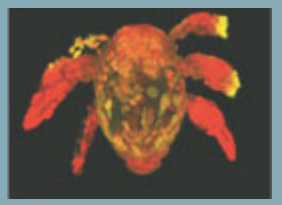
Maud et al., 2015; Progress in Oceanography, Vol. 137B; WCO Special Issue

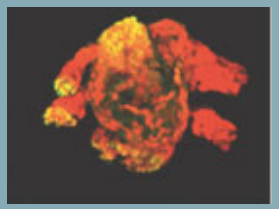
# Mortality: egg hatching success







- ~30% - ~70% of eggs to N2

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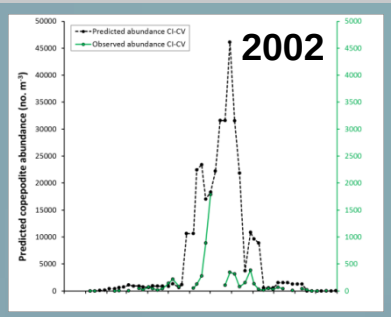
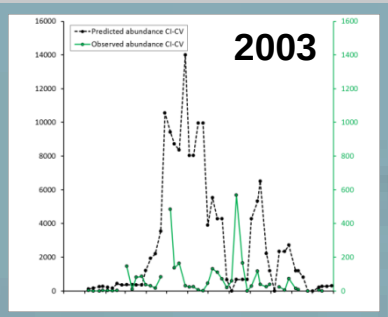
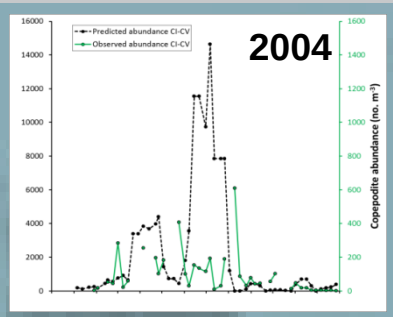
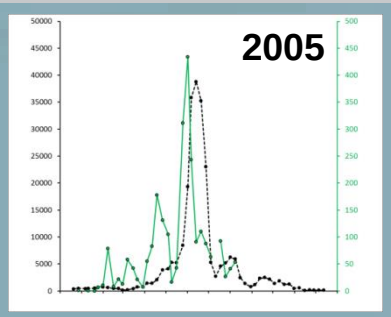
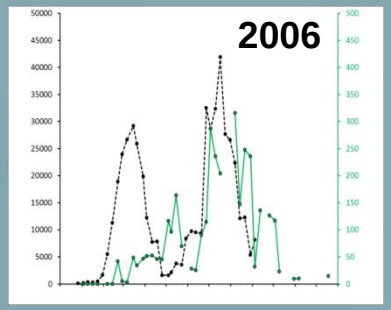
# Mortality: matrix model

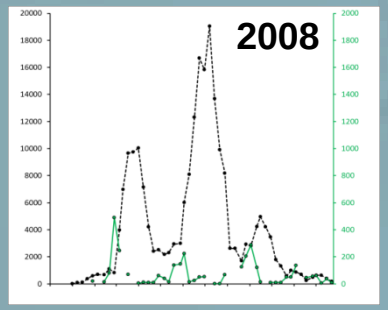


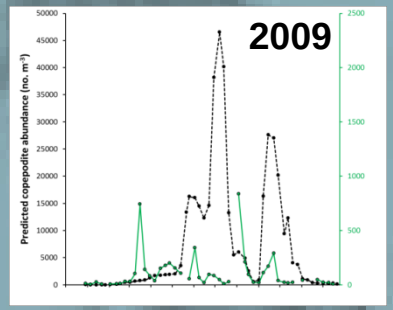



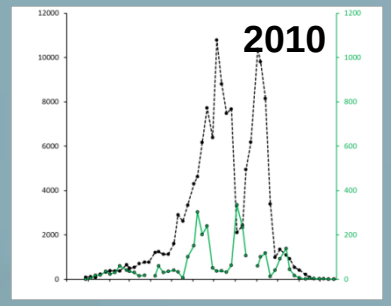



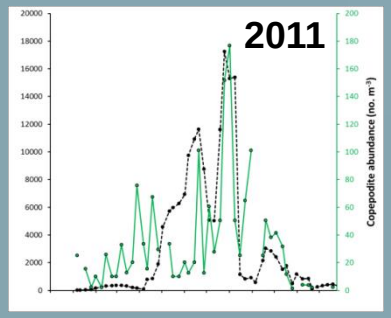



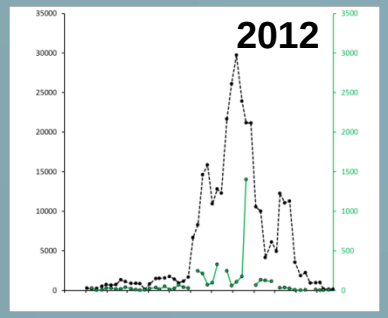



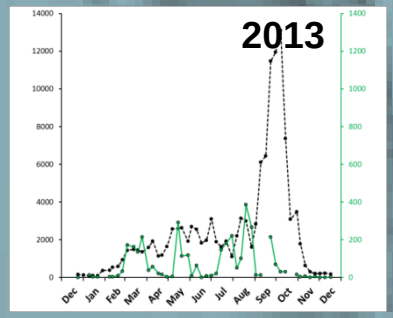



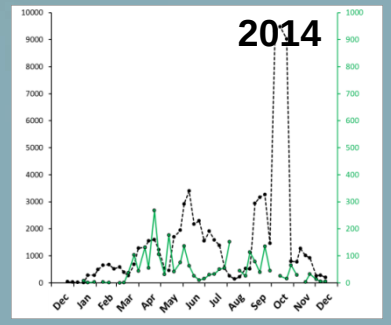



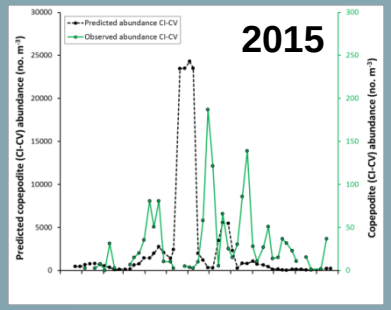



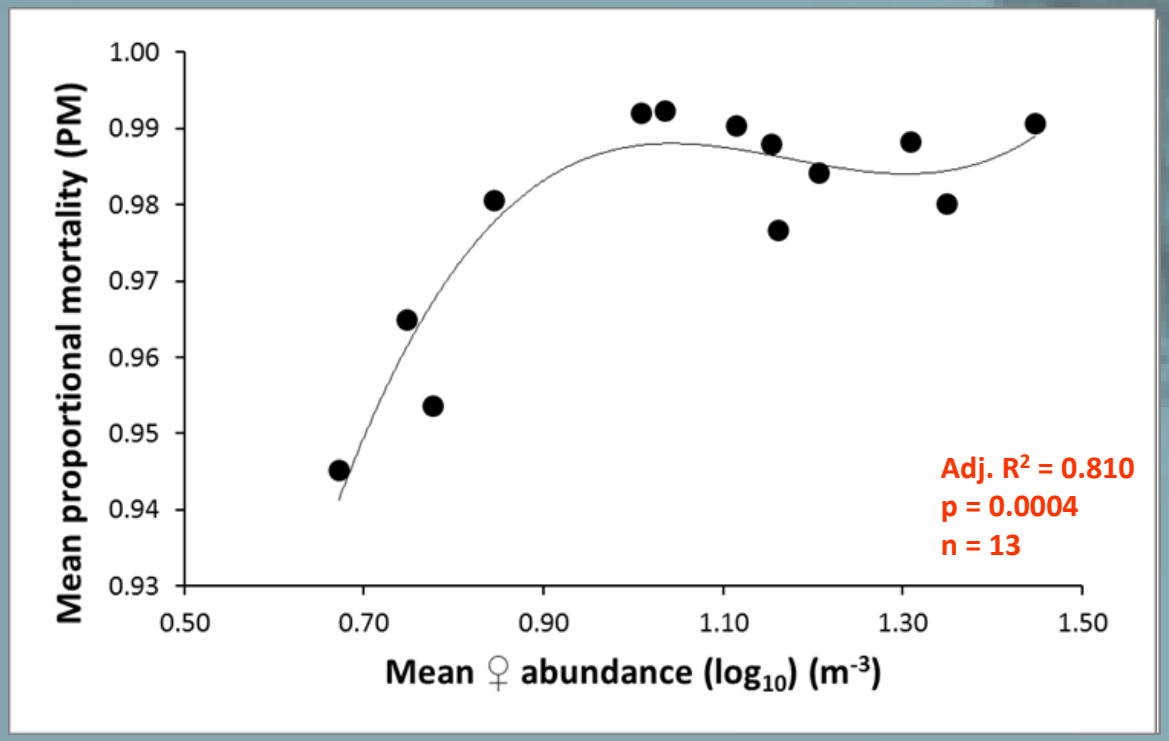




**Theoretical copepodite (CI-CV) abundance and observed copepodite (CI-CV) abundance (2002 – 2015)**

# Mortality: matrix model

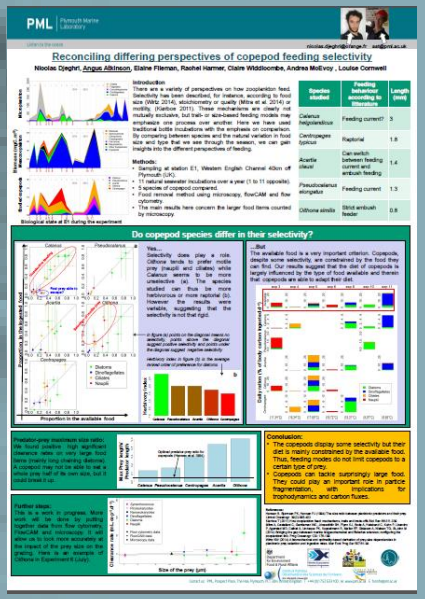
- Proportional mortality
- Density – dependent effects?




Density-dependent mortality in an oceanic copepod population

M. D. Ohman† & R. J. Kirche‡

Ohman and Kirche, (2001), Nature, Vol 412



Reconciling differing perspectives of copepod feeding selectivity

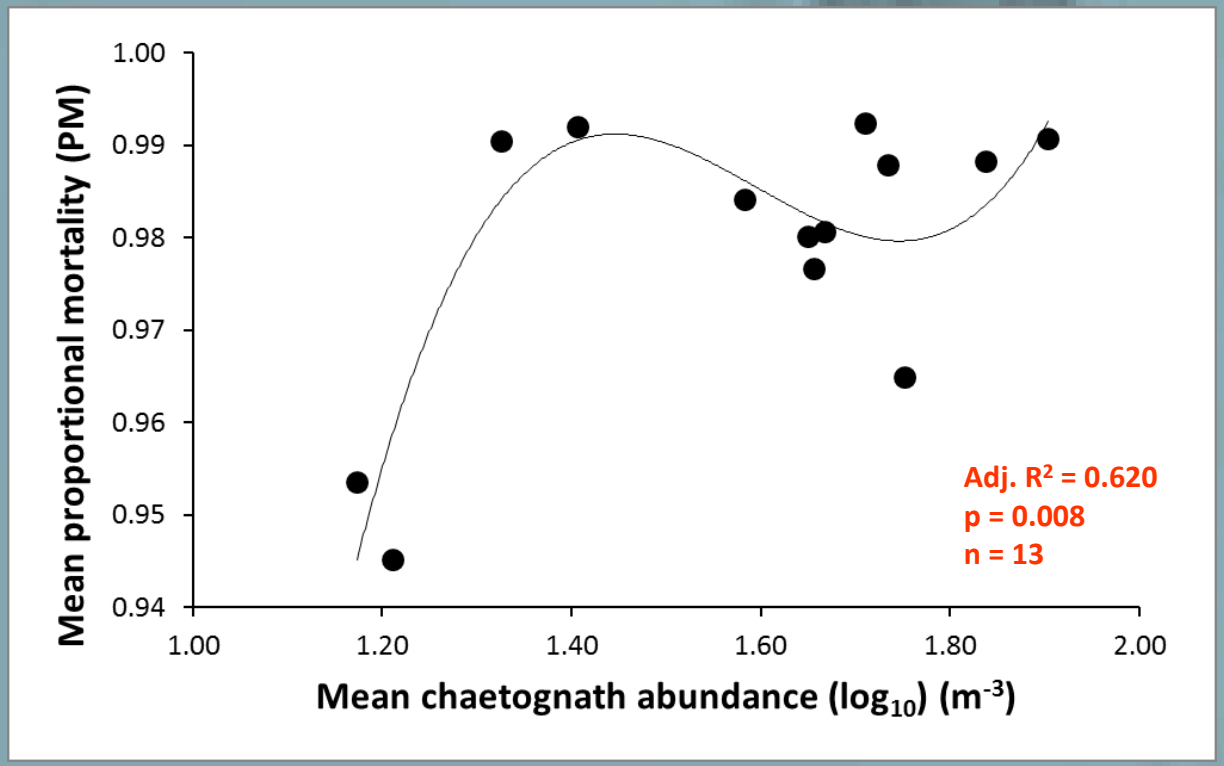
Nicolas Djeghri, Angus Atkinson, Elaine Fileman, Rachel Harmer, Claire Widdicombe, Andrea McEvoy , Louise Cornwell

Do copepod species differ in their selectivity?

S8: Poster 341 Djeghri and Atkinson

# Mortality: matrix model

- Multiple regression predators (medusae, siphonophores, ctenophores, chaetognaths, fish larvae)



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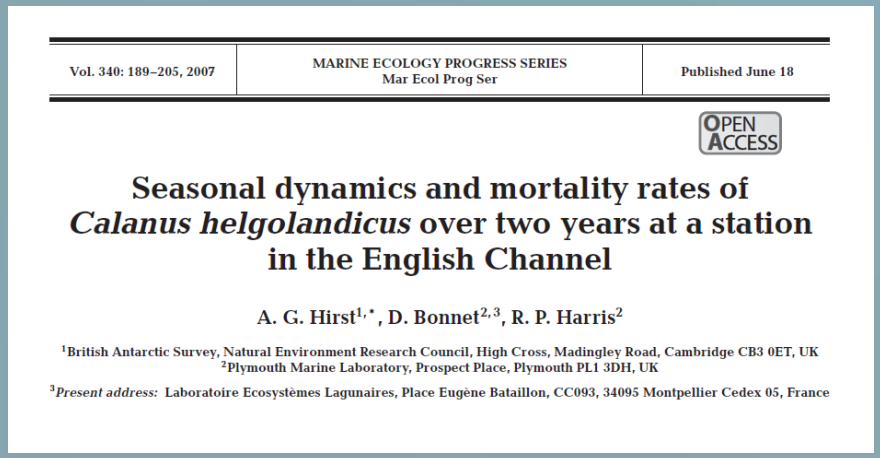
# Mortality: ratio "VLT" method

- Vertical life-table (VLT) methods (single time-point)
- Mortality across stage-pairs - ratio (i.e. egg-NI, CV-CVI)



Vol. 340: 189–205, 2007 | MARINE ECOLOGY PROGRESS SERIES Mar Ecol Prog Ser | Published June 18

OPEN ACCESS

**Seasonal dynamics and mortality rates of *Calanus helgolandicus* over two years at a station in the English Channel**

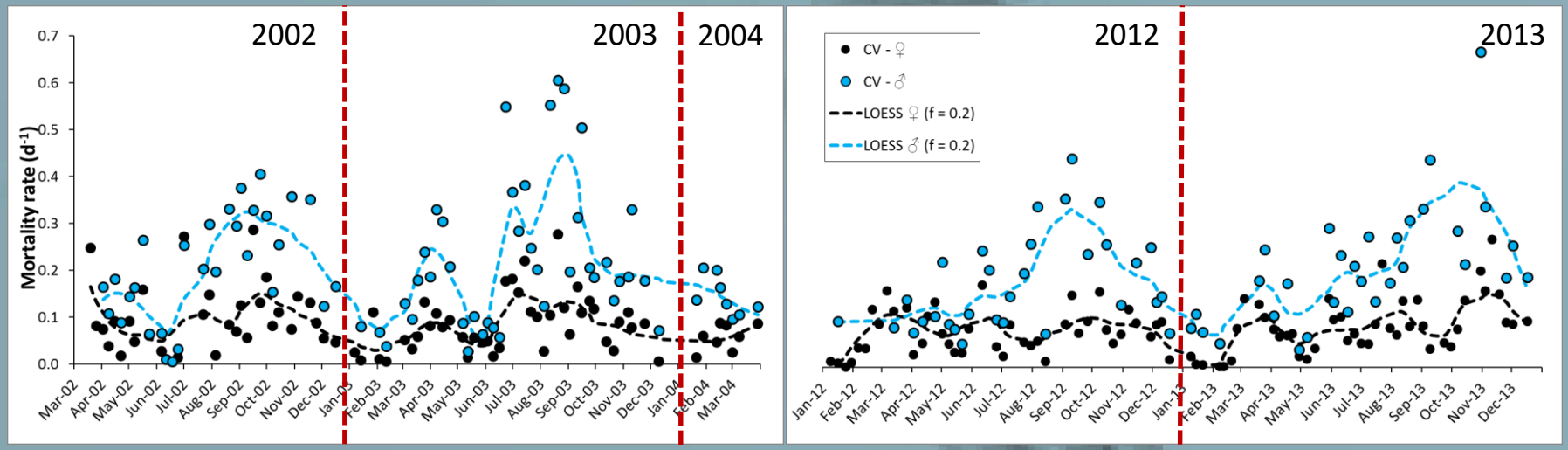
A. G. Hirst[1,*], D. Bonnet[2,3], R. P. Harris[2]

[1]British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, UK
[2]Plymouth Marine Laboratory, Prospect Place, Plymouth PL1 3DH, UK
[3]*Present address:* Laboratoire Ecosystèmes Lagunaires, Place Eugène Bataillon, CC093, 34095 Montpellier Cedex 05, France

- 4 years:
  - Mar 2002-Mar 2004
  - 2012-2013
- Copepod stage abundance data

# Mortality: ratio "VLT" method

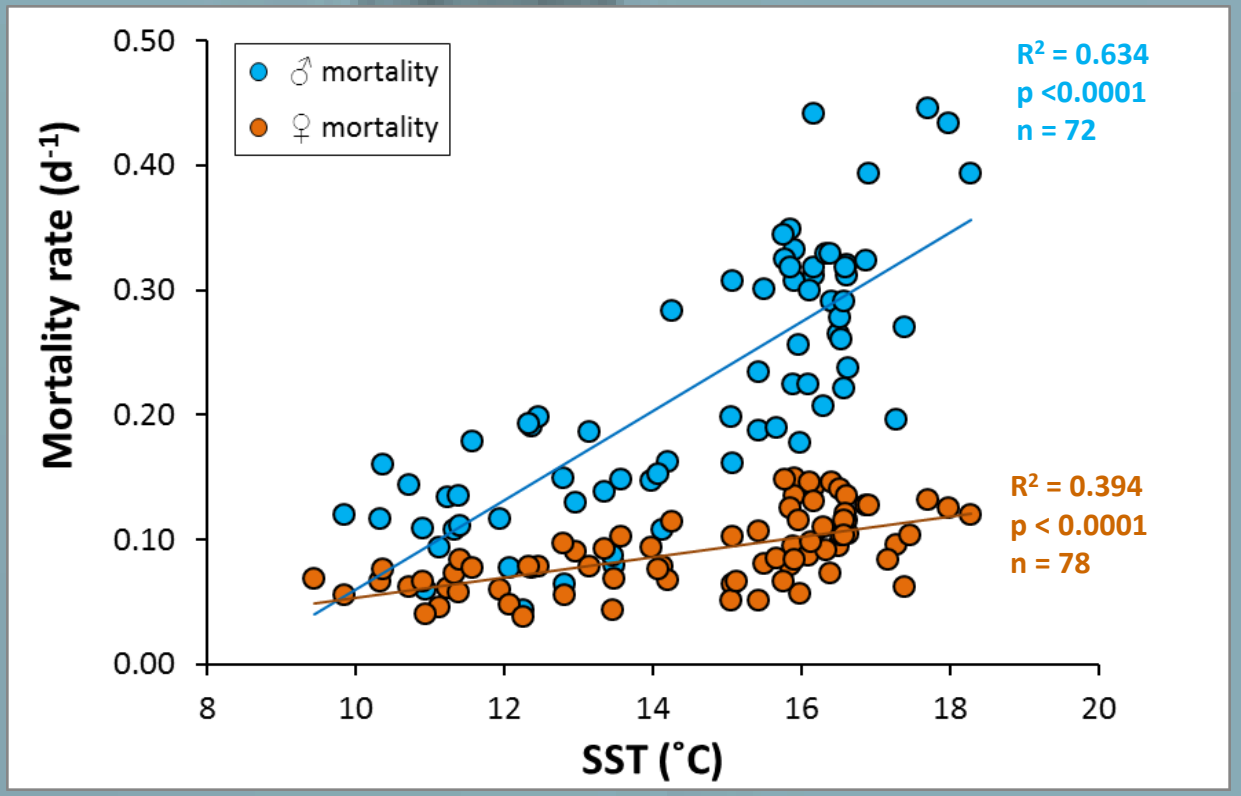
## CV-CVI (♂+♀) mortality rates ($d^{-1}$)




- Mean ♀ rate - 0.084 $d^{-1}$
- Mean ♂ rate - 0.202 $d^{-1}$

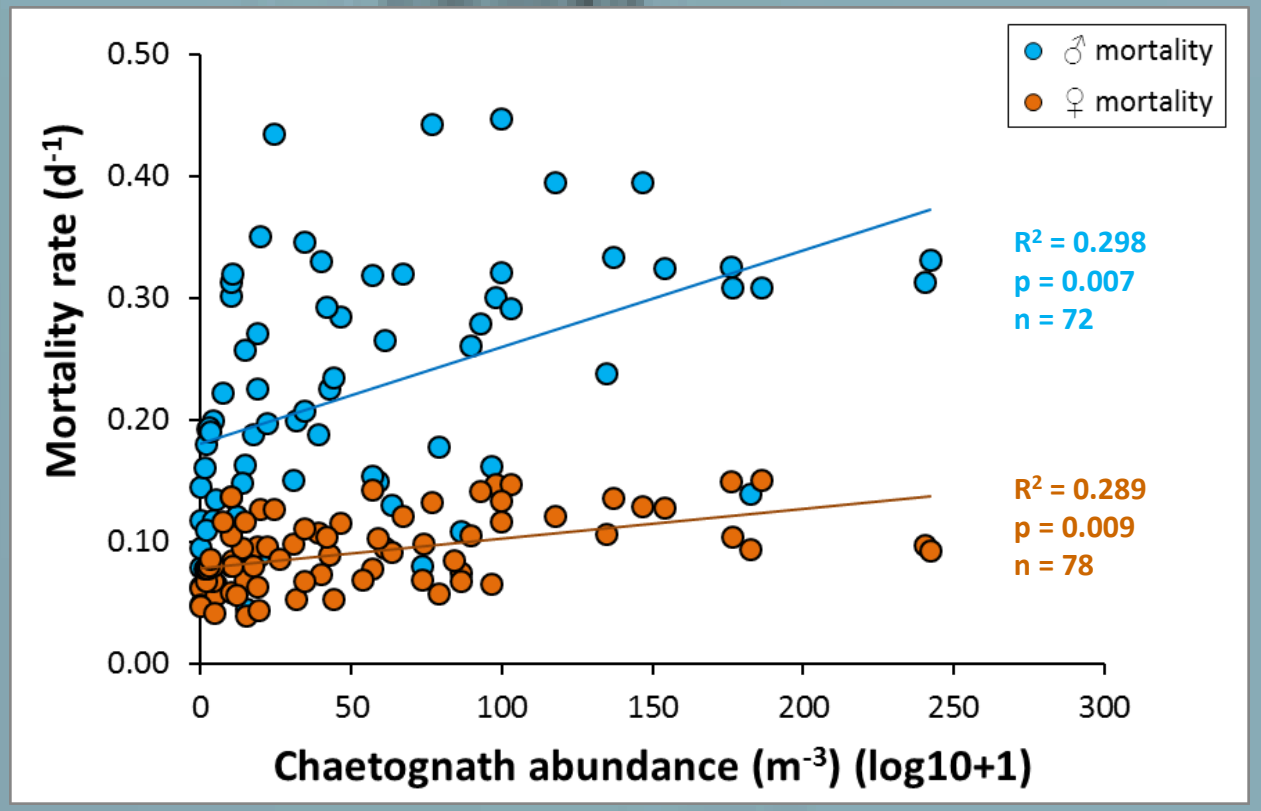
# Mortality: ratio "VLT" method

- Active summer growth period (May-Sept)
- Relationship with SST



# Mortality: ratio "VLT" method

- Active summer growth period (May-Sept)
- Predators (multiple regression)



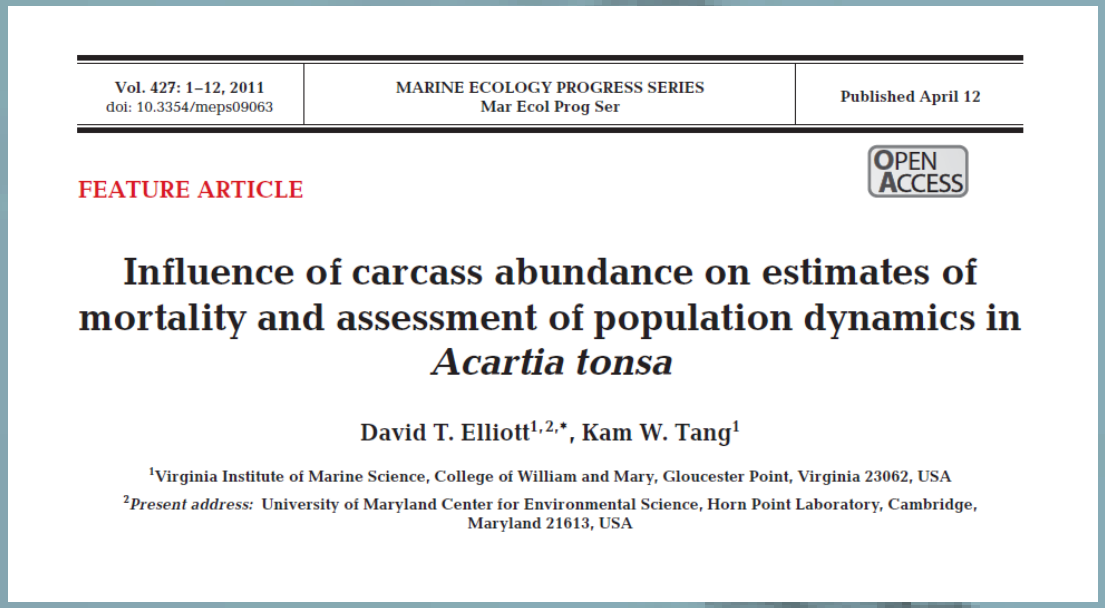
# Mortality: non-consumptive

- Feb 2013-Jan 2014 – weekly sampling (38 weeks)
- Vital stain – neutral red


- "Live" copepods
  - red/bright pink
- "Dead" copepods (carcasses)
  - white/pale pink

# Mortality: non-consumptive

## Non-consumptive mortality calculation



Vol. 427: 1–12, 2011
doi: 10.3354/meps09063

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published April 12

FEATURE ARTICLE

OPEN ACCESS

**Influence of carcass abundance on estimates of mortality and assessment of population dynamics in *Acartia tonsa***

David T. Elliott[1,2,*], Kam W. Tang[1]

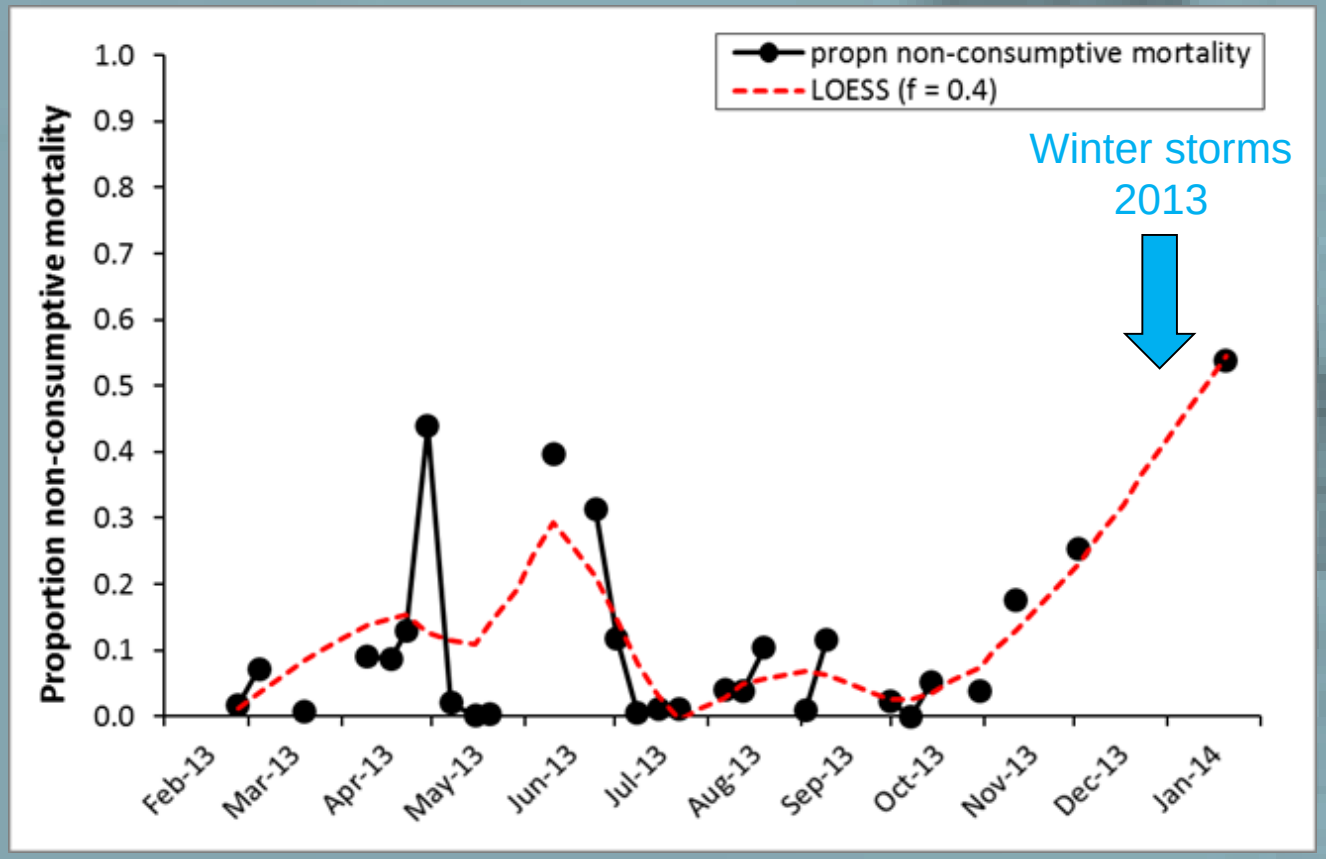
[1]Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia 23062, USA

[2]*Present address:* University of Maryland Center for Environmental Science, Horn Point Laboratory, Cambridge, Maryland 21613, USA

- Modified VLT equation
- Total mortality - predator mortality = non-consumptive mortality

# Mortality: non-consumptive

## Proportion non-consumptive mortality of *C. helgolandicus* copepodites (CI-CVI) - 2013



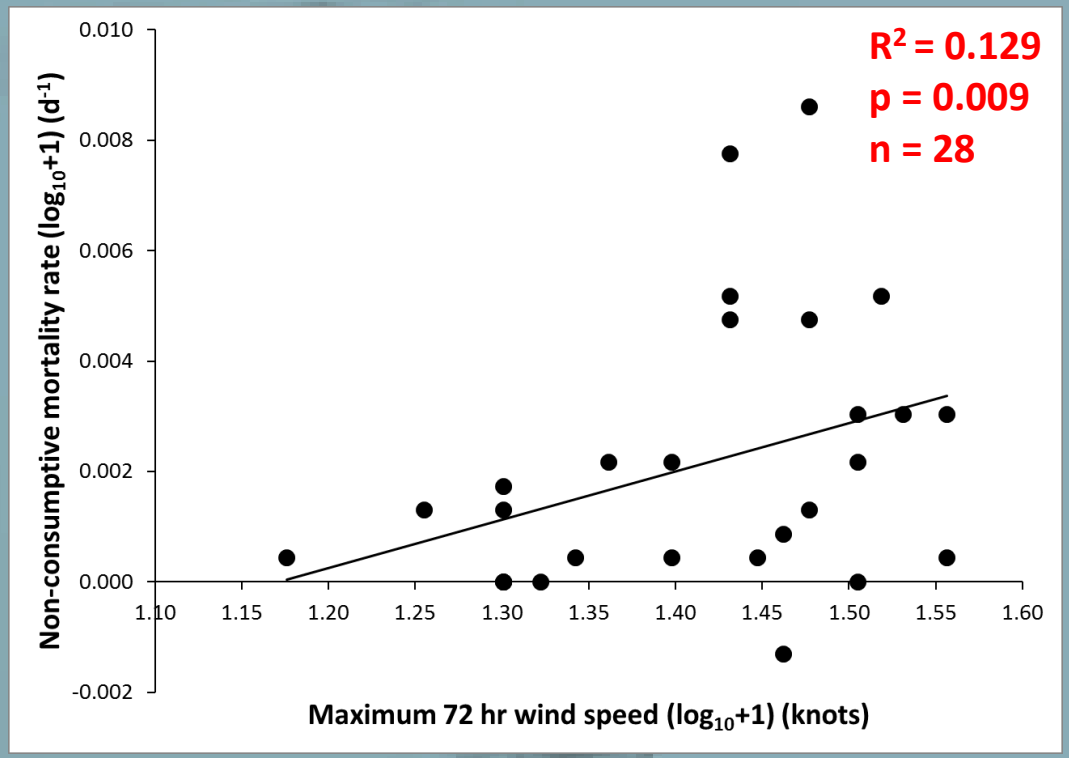


# Mortality: non-consumptive

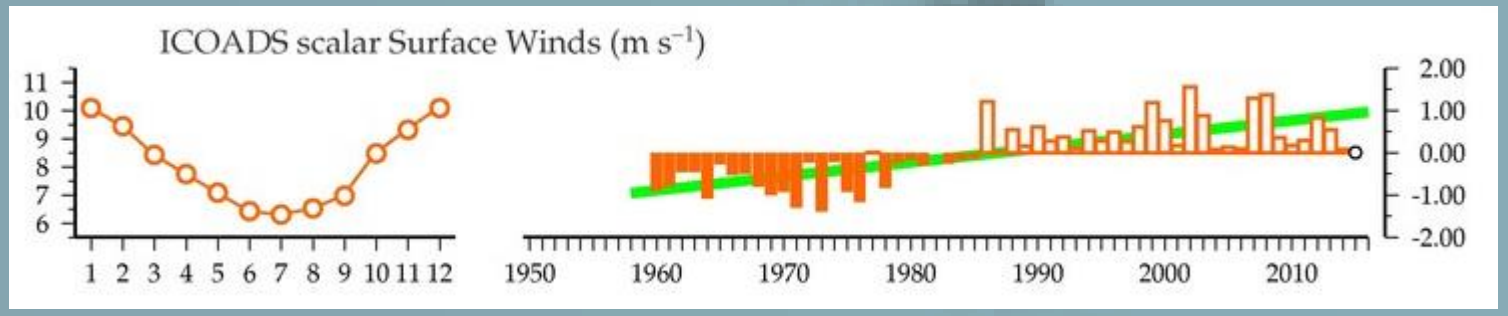
## Predictors

- SST
- Stratification Index
- Wind speed

  (24, 48 and 72 hr)
- Tidal data







# Summary

1. What processes control the *C. helgolandicus* population at L4?

- Reproductive output sets up "potential recruitment", mortality governs ultimate population size
- "Stabilising" effects of mortality
- 4-fold interannual variation

# Summary

## 2. What are the mortality rates of *C. helgolandicus*?

- Estimate between 90-99% mortality (egg-CV)
- CV-CVI mortality peaked spring and late-summer
- Non-consumptive mortality (0-50%) peaked spring and autumn/winter

# Summary

3. What are the major sources of C. *helgolandicus* mortality?

- Different sources depending on development stage
- Early stages
    - hatching success/abnormalities (30-70%)
    - density-dependent mortality (egg cannibalism?)
- Later stages – successive suites of predators (chaetognaths implicated)
- Non-consumptive mortality not trivial (extreme weather?)

# Acknowledgements

Western Channel Observatory

## Crew and marine technicians RV Plymouth Quest




## Plankton analysts – past and present




THE MARINE BIOLOGICAL ASSOCIATION
Est. 1884
Incorporated by Royal Charter 2013

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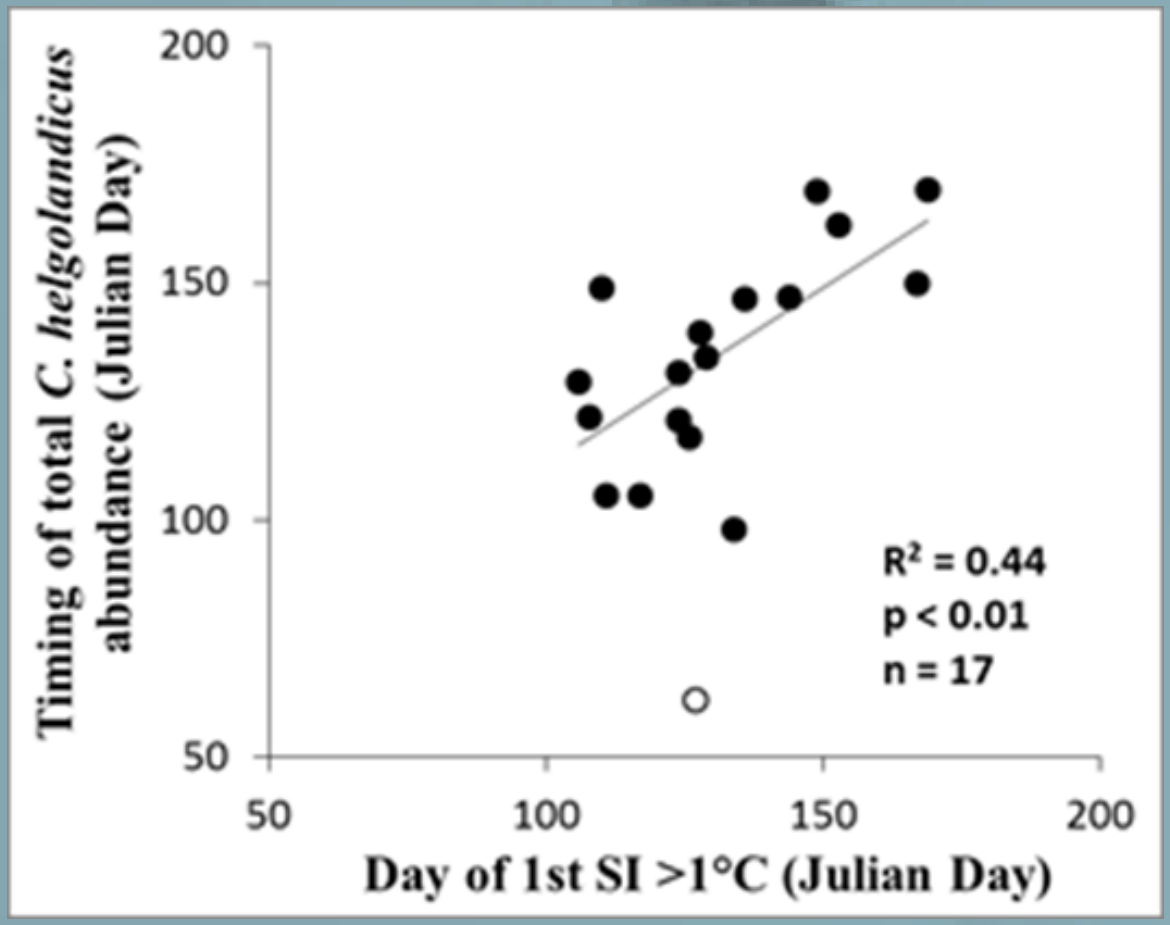
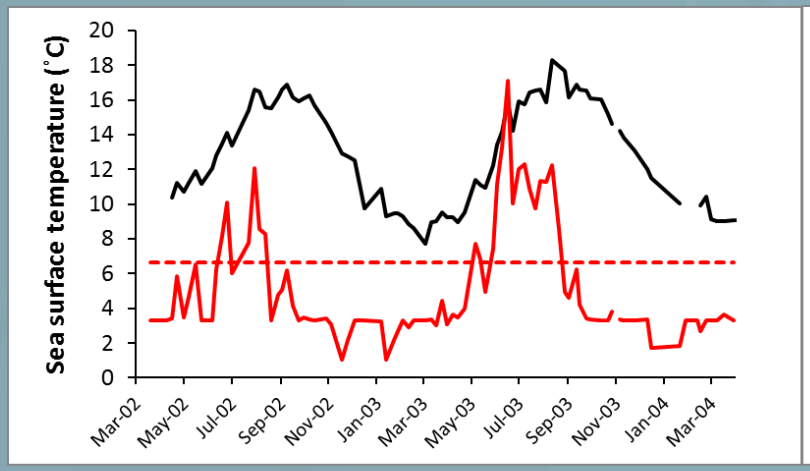
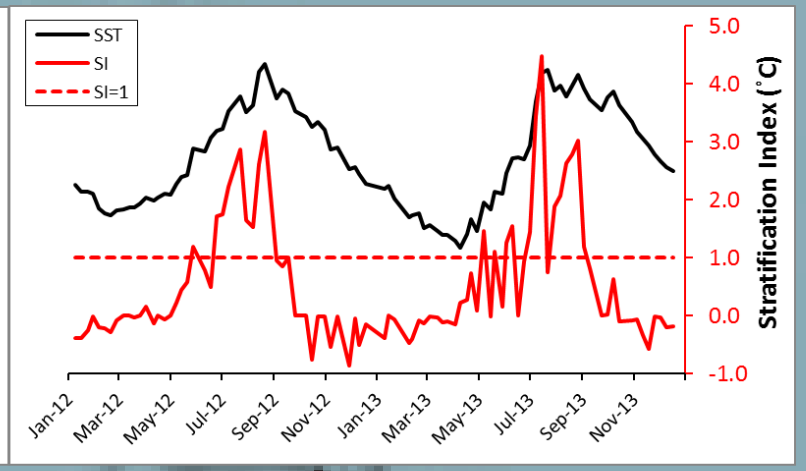
# Mortality: stratification

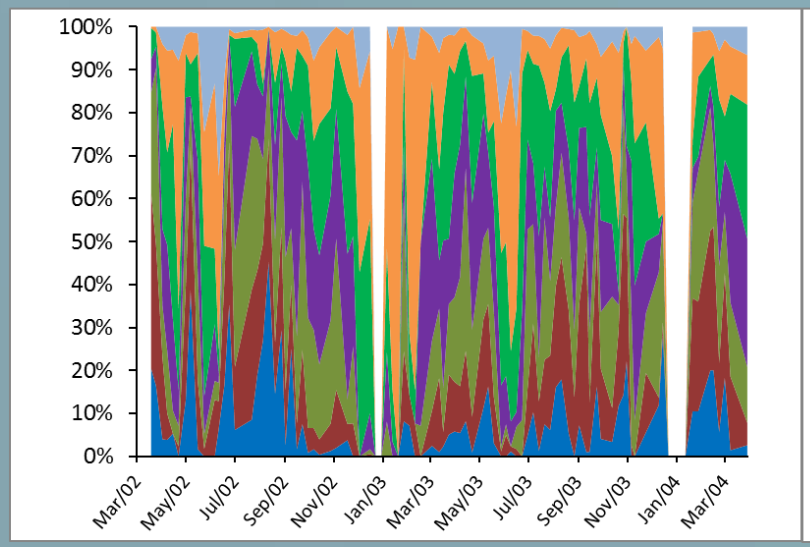
## Timing of onset of stratification as predictor of "start" of total *C. helgolandicus* population growth season

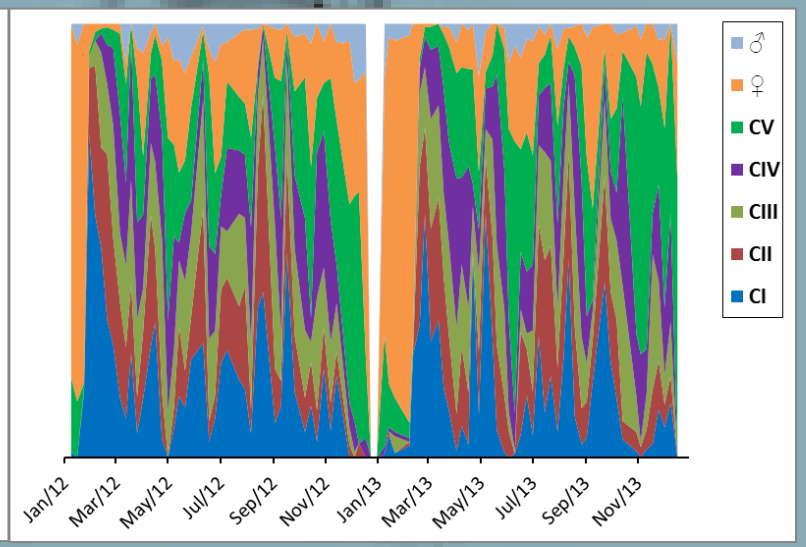



Maud et al., 2015; Progress in Oceanography, Vol. 137B; WCO Special Issue


Sea surface temperature (˚C)
20
18
16
14
12
10
8
6
4
2
0
Mar-02
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04


SST
SI
SI=1
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
Stratification Index (˚C)
Jan-12
Mar-12
May-12
Jul-12
Sep-12
Nov-12
Jan-13
Mar-13
May-13
Jul-13
Sep-13
Nov-13


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Mar/02
May/02
Jul/02
Sep/02
Nov/02
Jan/03
Mar/03
May/03
Jul/03
Sep/03
Nov/03
Jan/04
Mar/04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