Does Predation Control Adult Sex Ratios and Longevities in Marine Pelagic Copepods?

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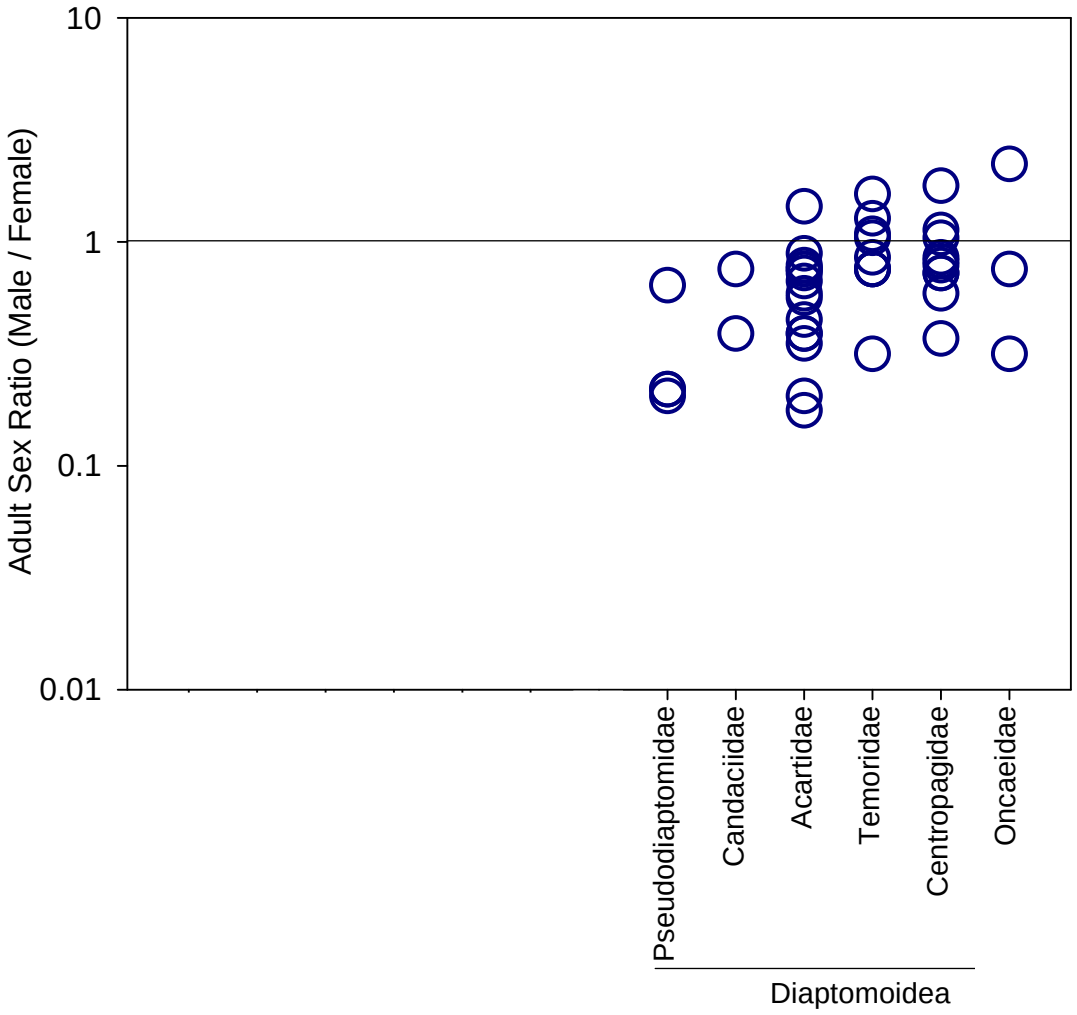
Queen Mary
University of London

Adult Sex Ratios

- Adults can be biomass dominant stage in planktonic copepods
- Critically they are the reproductive stage
- Sex ratio skew can impact mate encounter rates, and limit fertilisation and population growth rates (Kiørboe 2007, Choi & Kimmerer 2008)
- We will address whether adult sex ratios can be used to give new insight into the causes of mortality

Adult Sex Ratios



Redrawn from Kiørboe (2006), data from Hirst & Kiørboe (2002)

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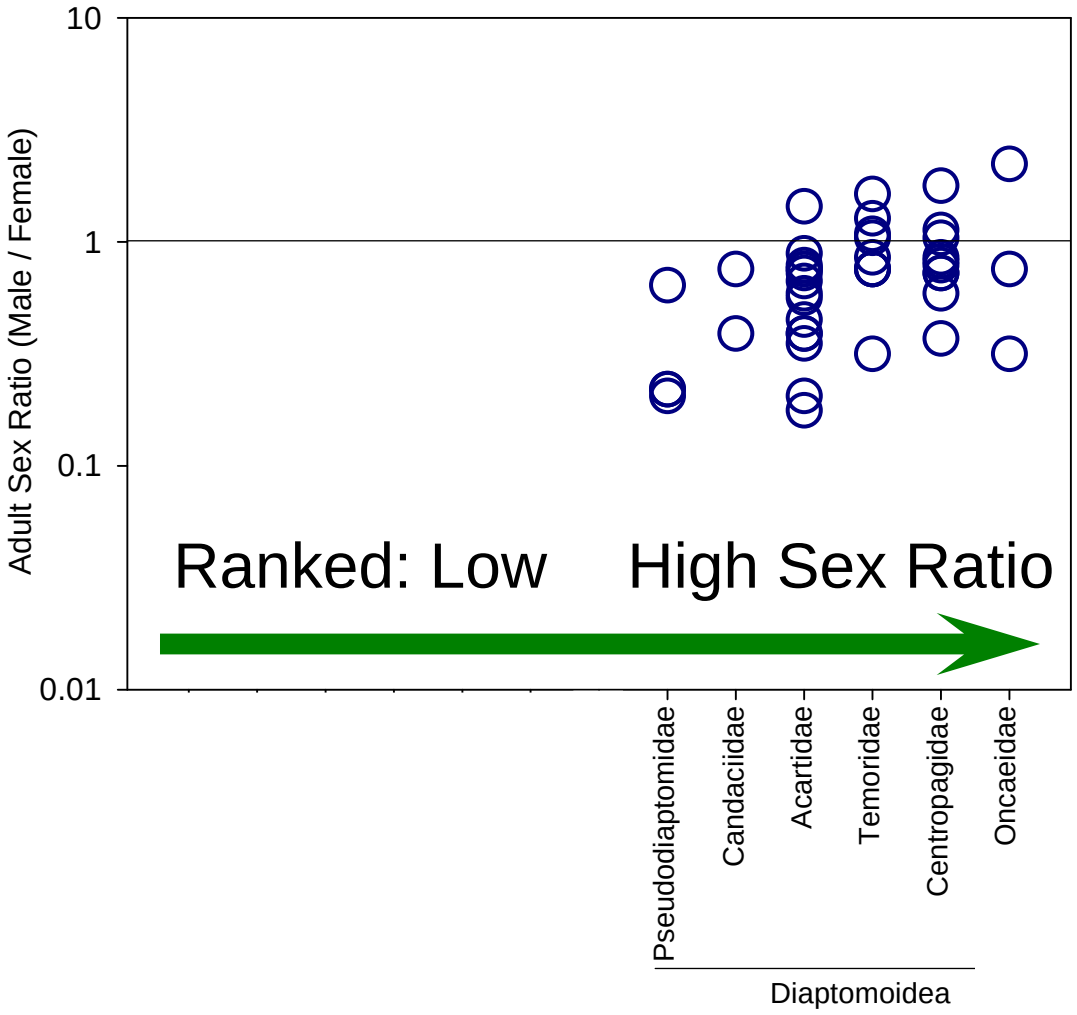

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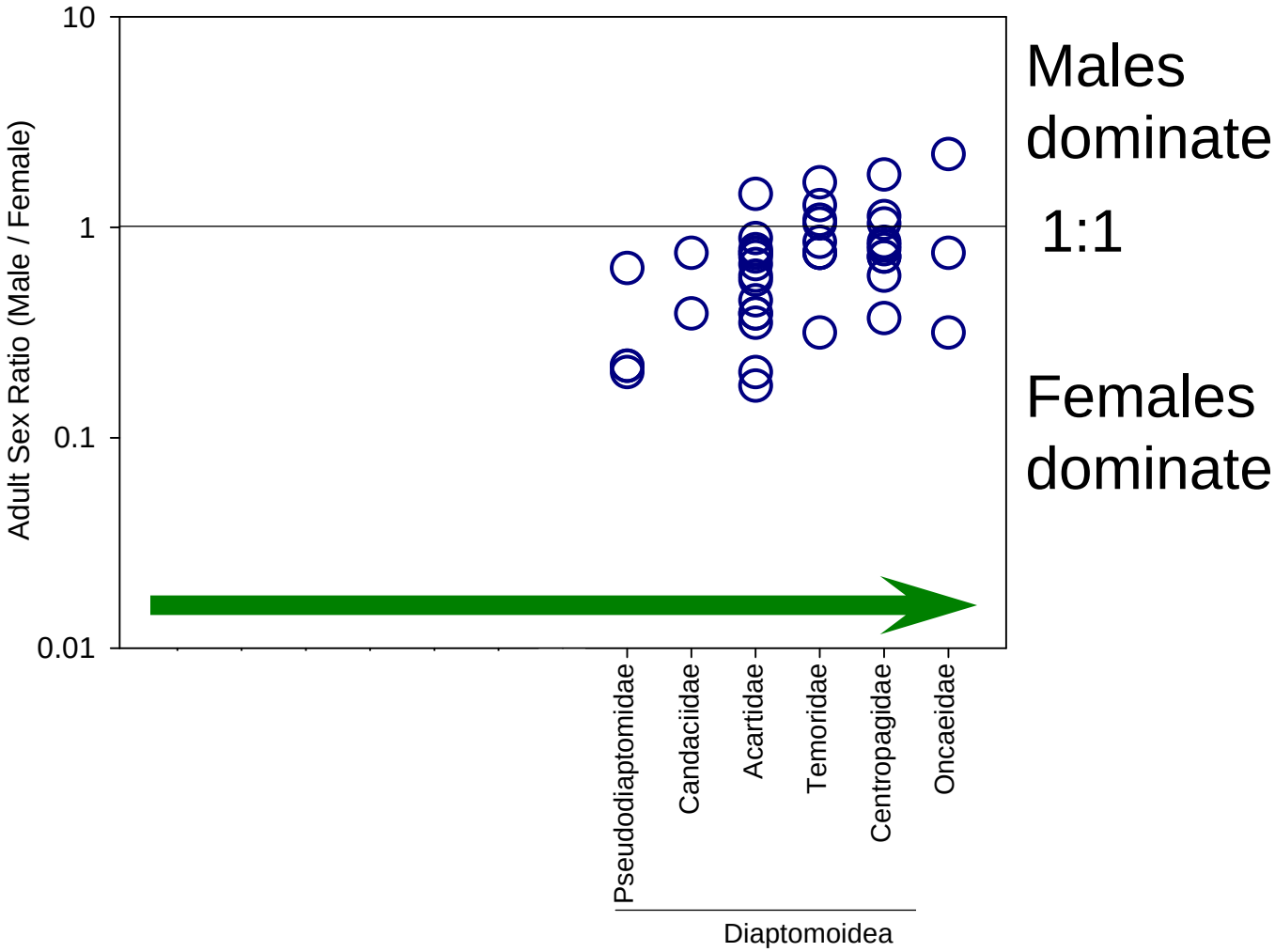

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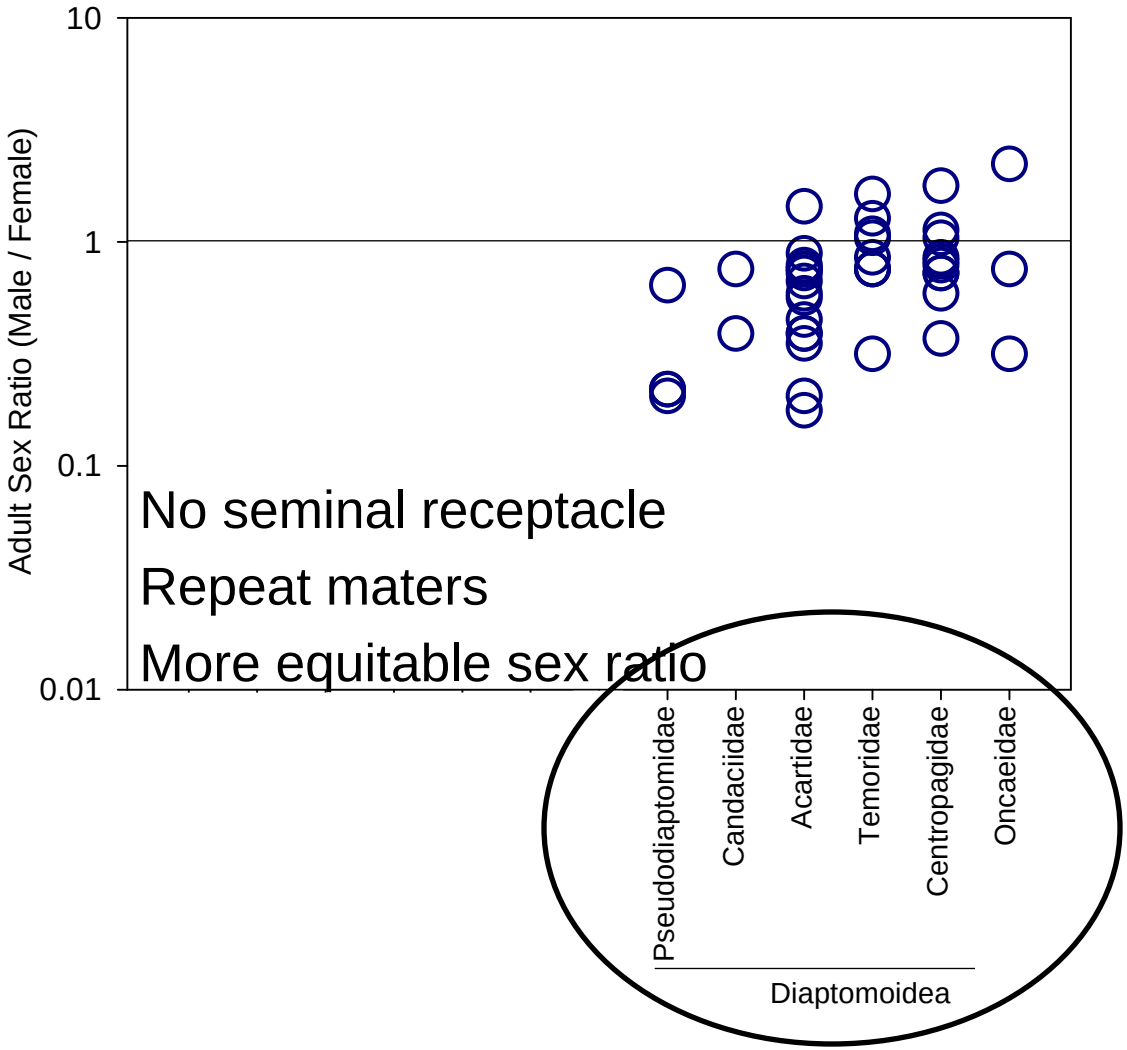

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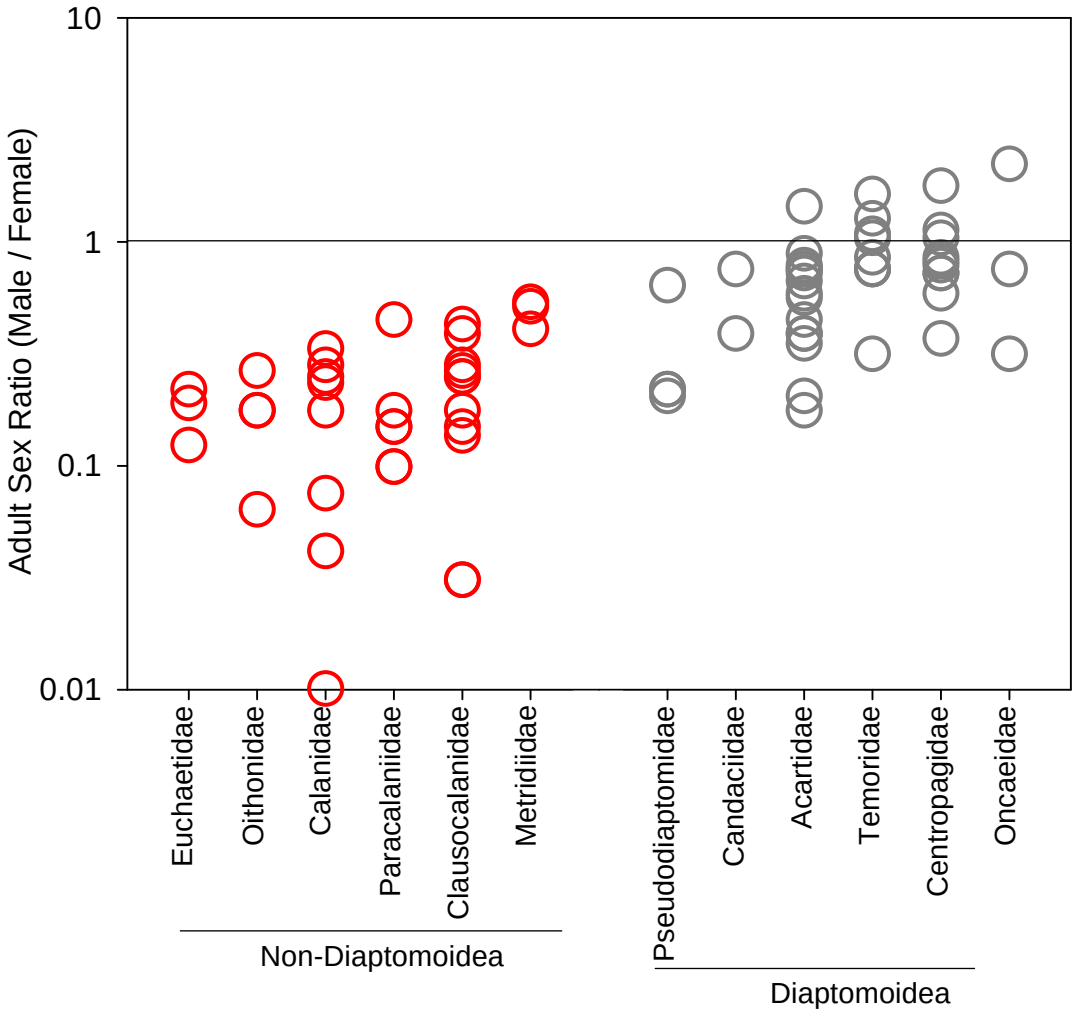

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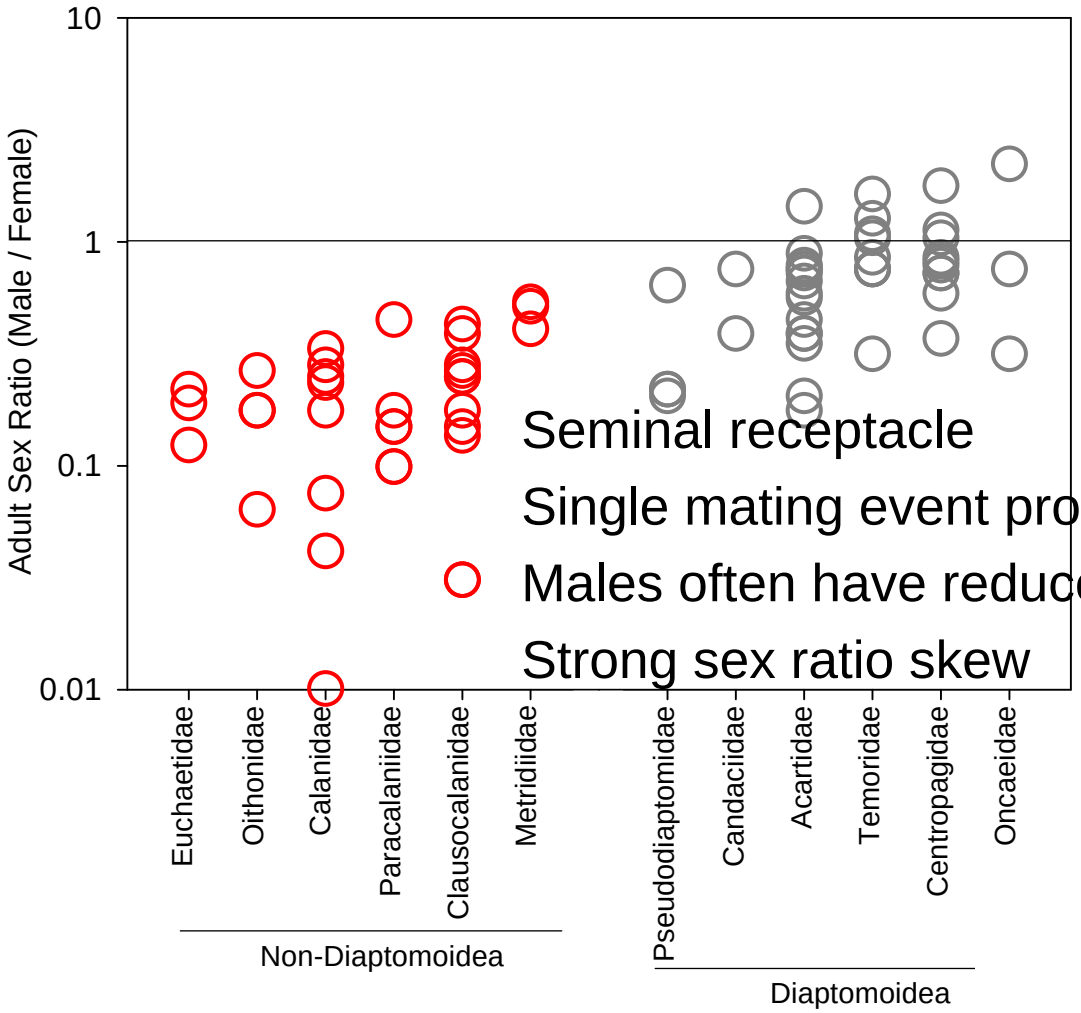

Seminal receptacle

Single mating event produces many progeny

Males often have reduced feeding rates

Strong sex ratio skew

Redrawn from Kiørboe (2006), data from Hirst & Kiørboe (2002)

Why the strong sex ratio skew in adults?

Why the strong sex ratio skew in adults?

In order to understand adult sex skew we need to identify where this arises:

1. Unequal Sex Ratio at Determination

2. Unequal mortality of the sexes in juveniles

3. Sex switching

4. Unequal mortality of the sexes in adults

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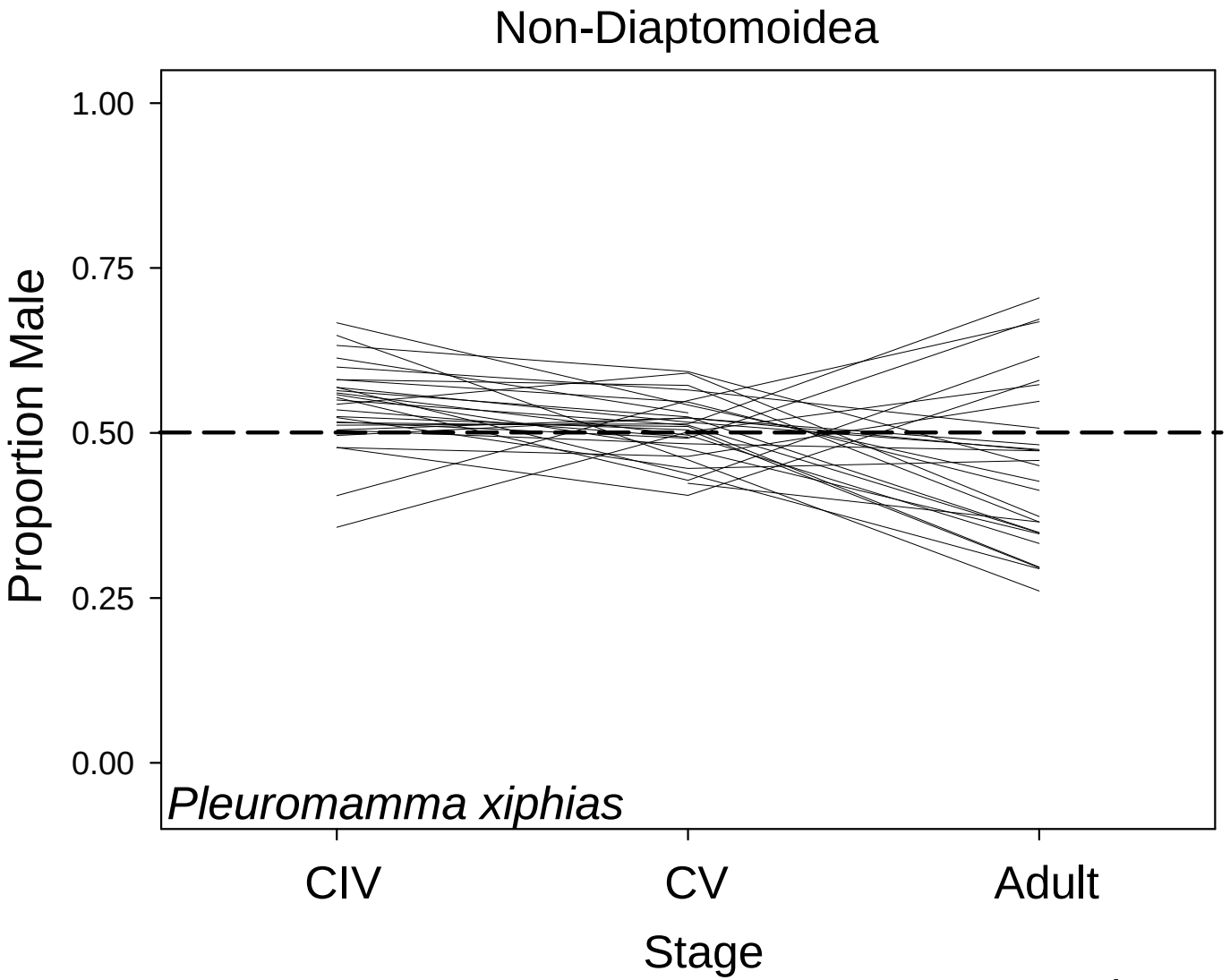
These are not mutually exclusive

Where does sex ratio skew arise?

To answer this we:

- Synthesised data across the literature where field sex ratios determined across juveniles to adults
- Sampled on a weekly basis over an annual cycle at the L4 site in the English Channel, sexed and staged copepods

Where does sex ratio skew arise?



Source: Ferrari & Hayek (1990)

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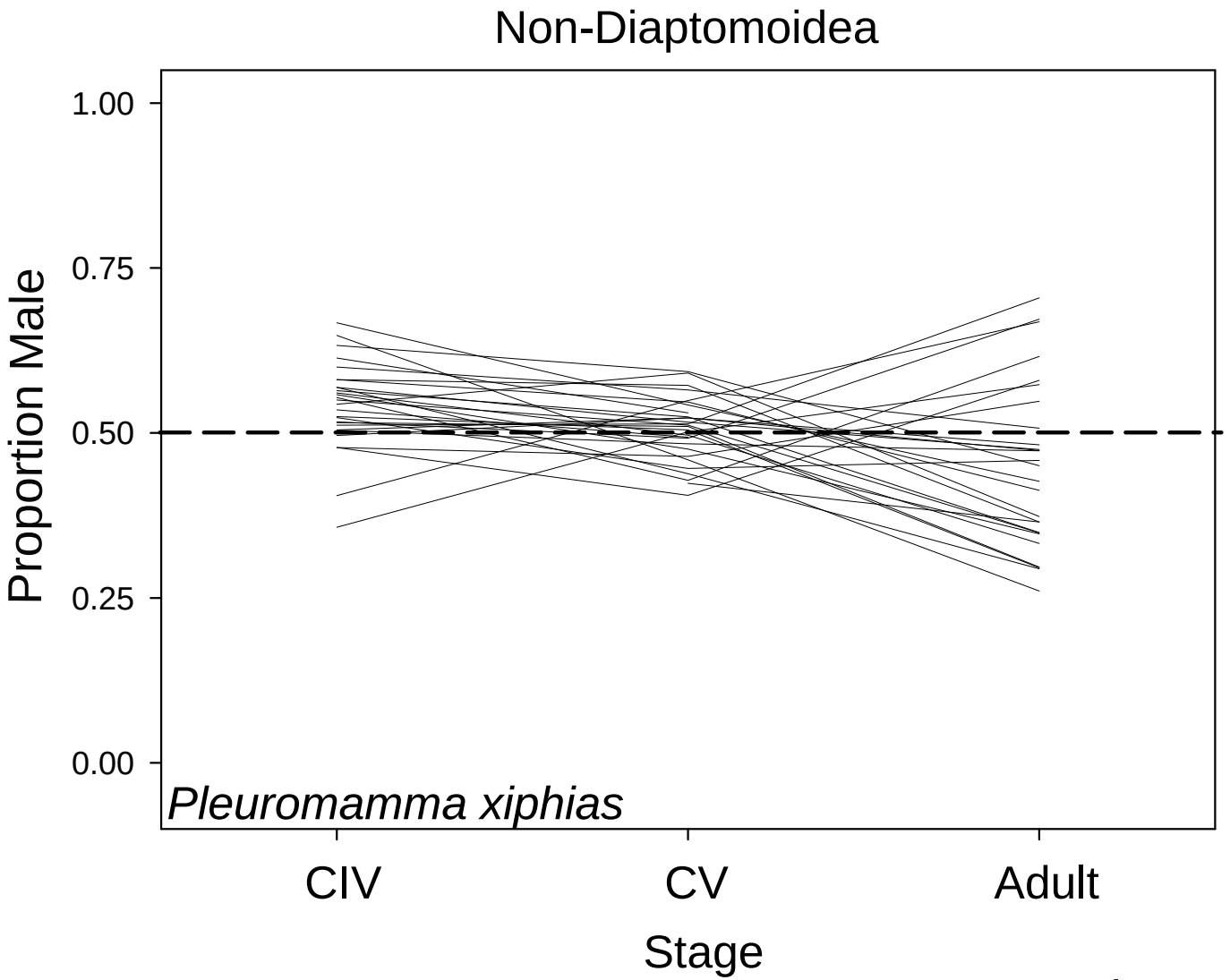

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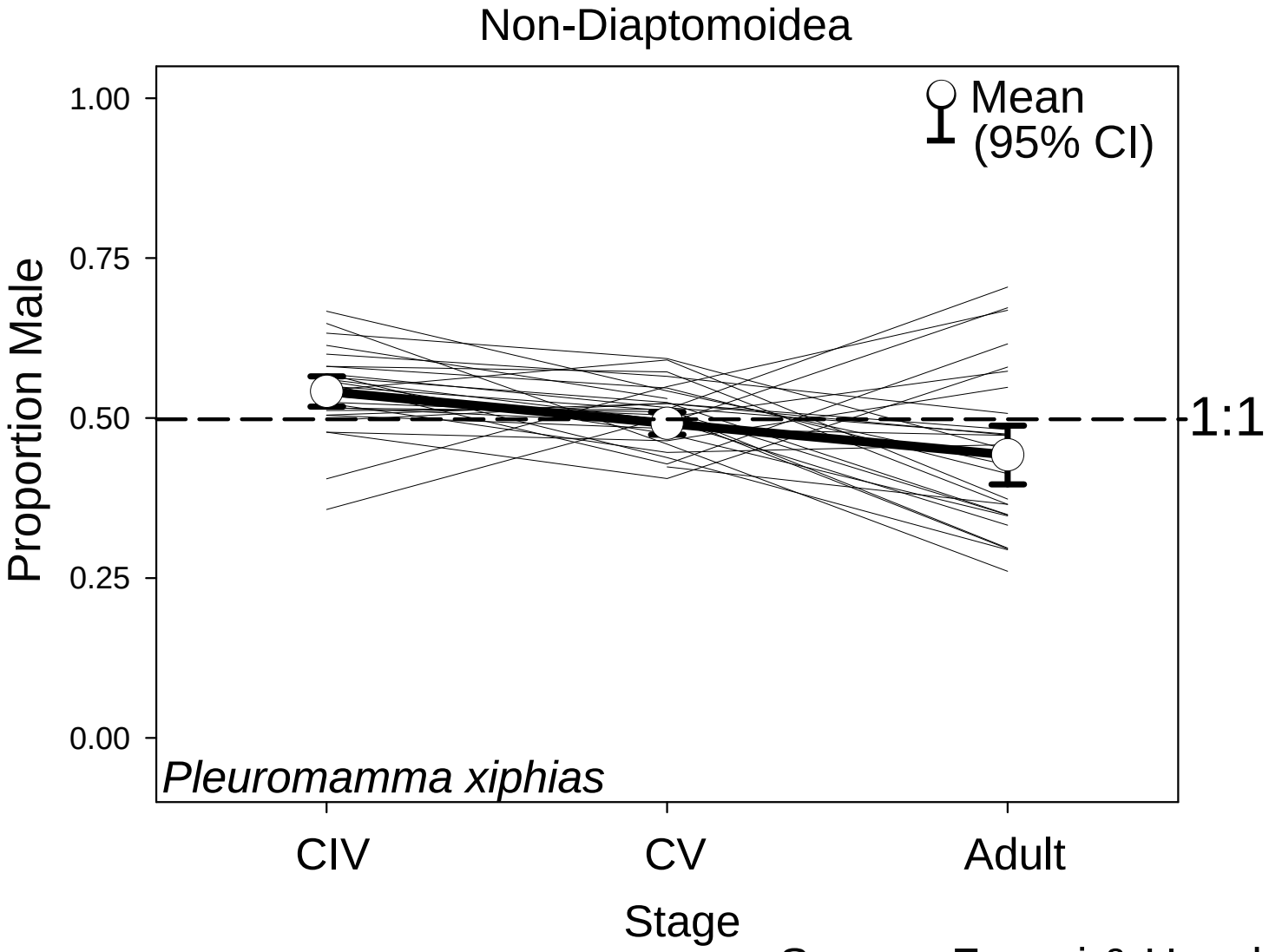

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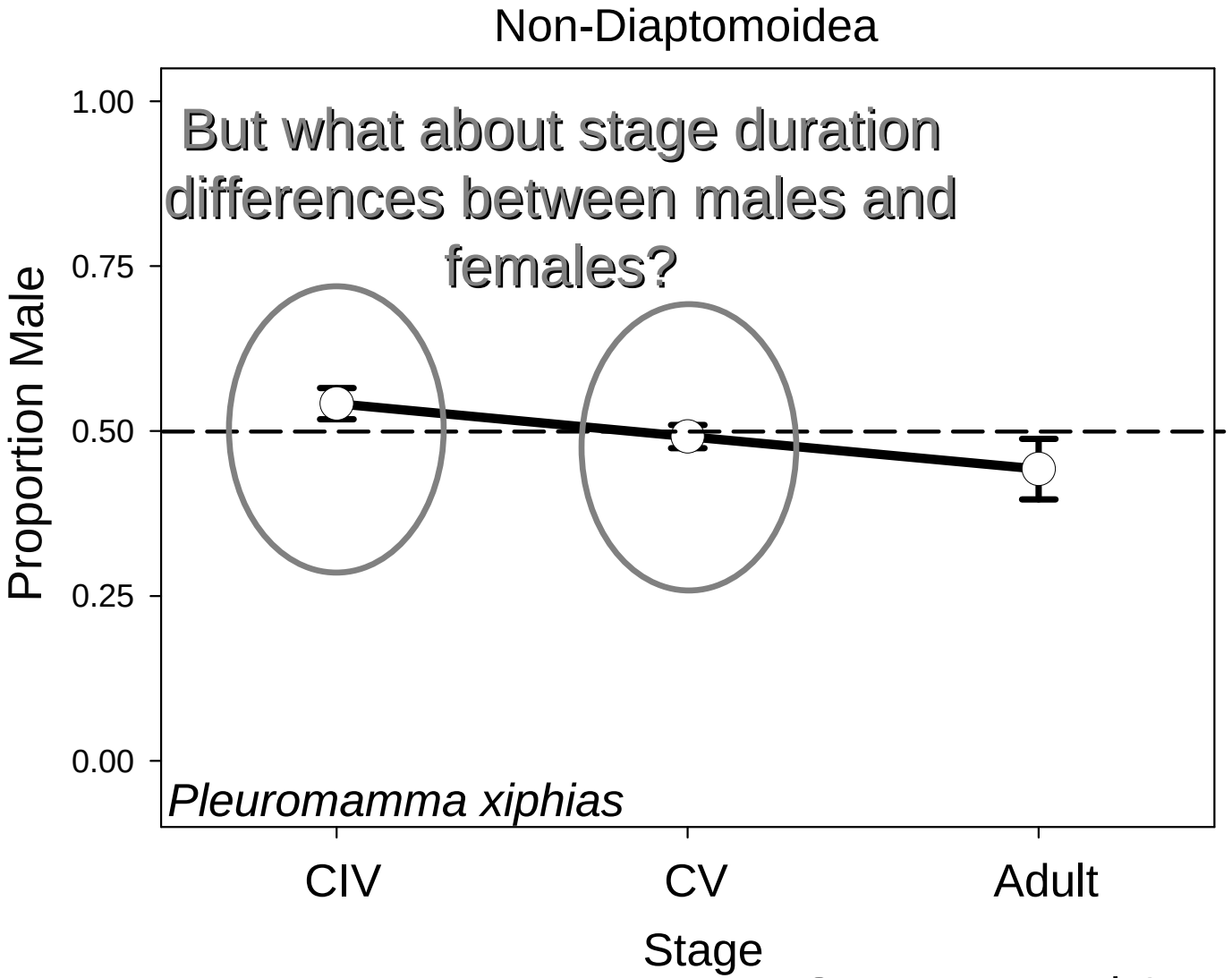

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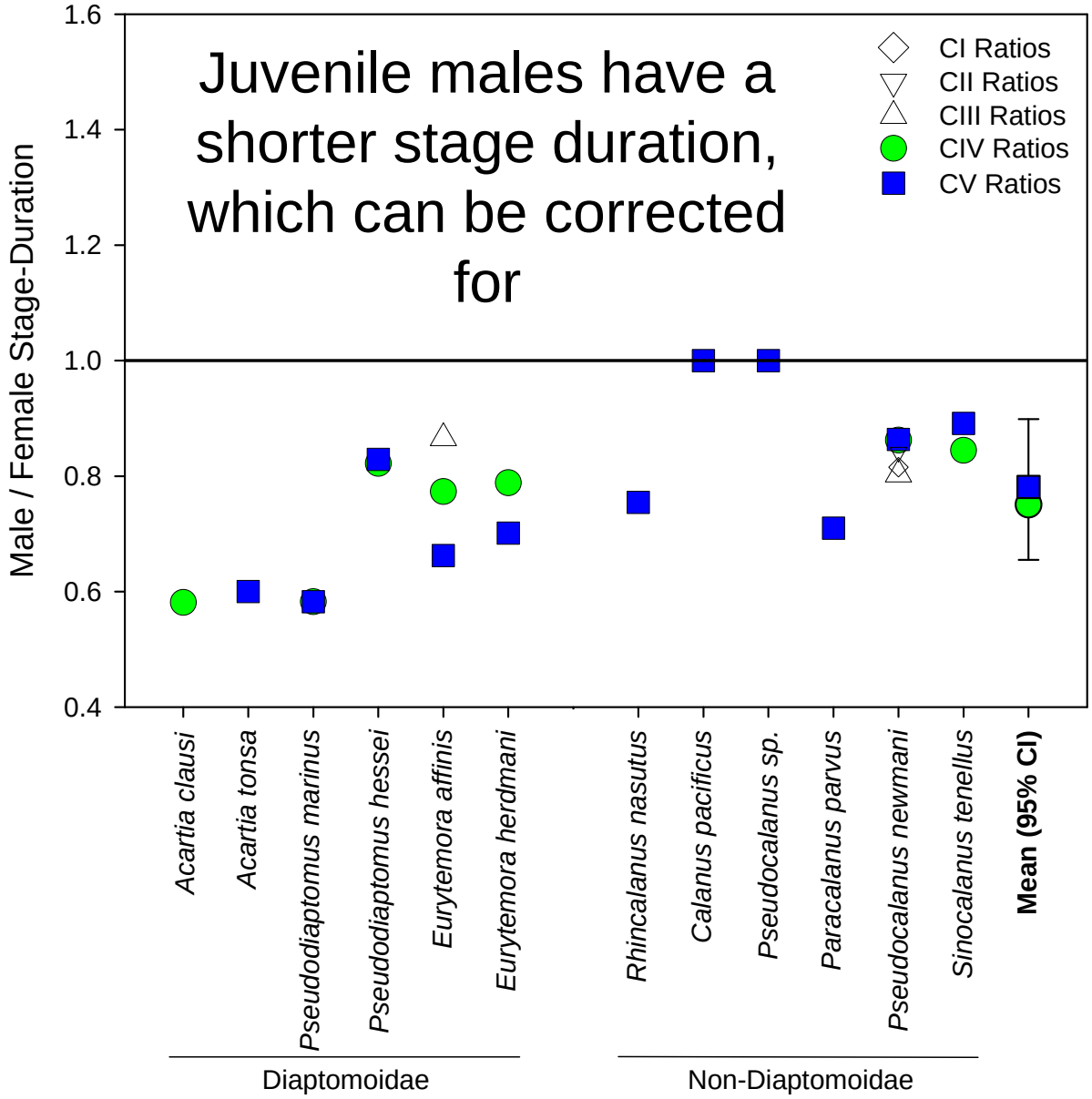
Stage duration correction



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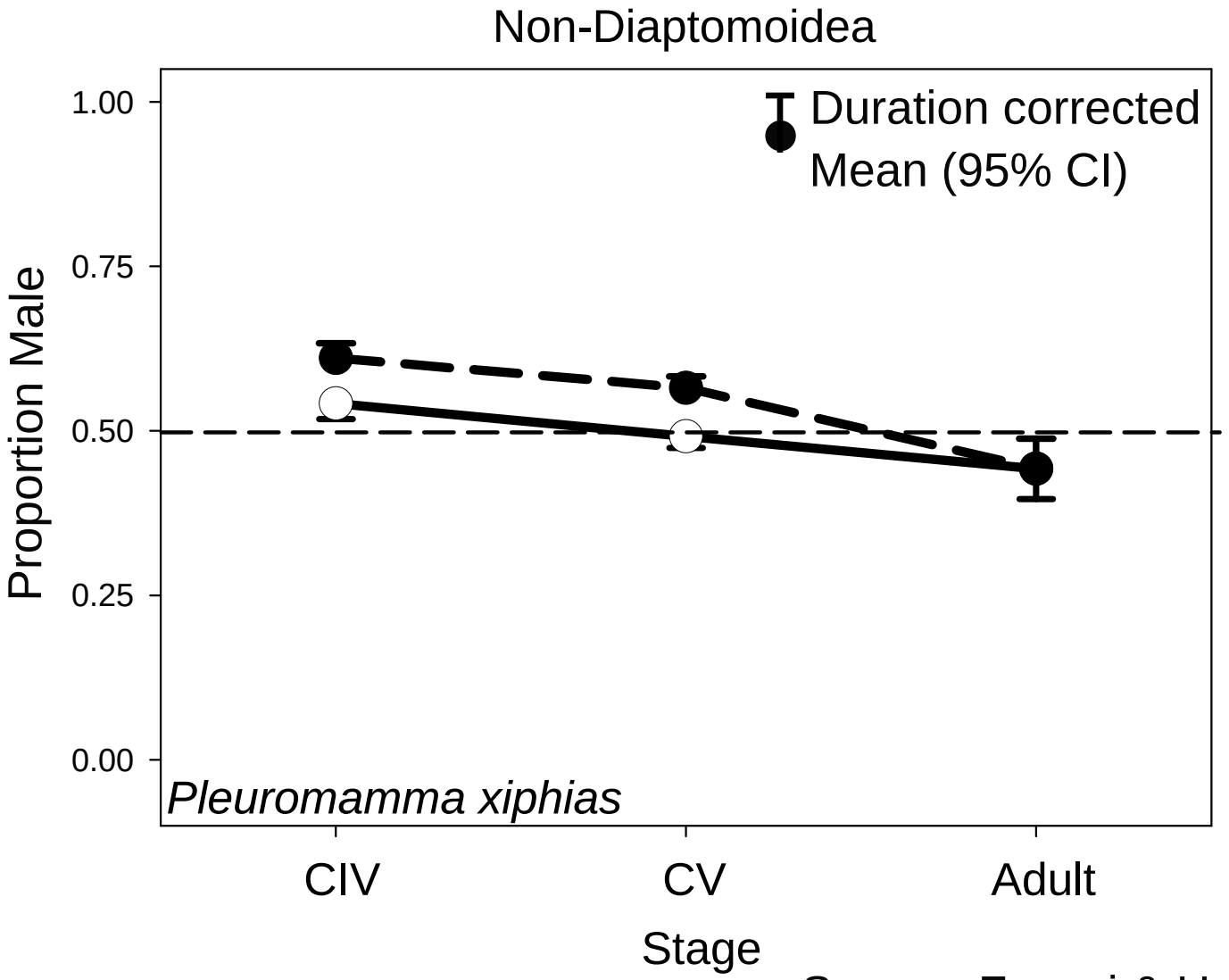

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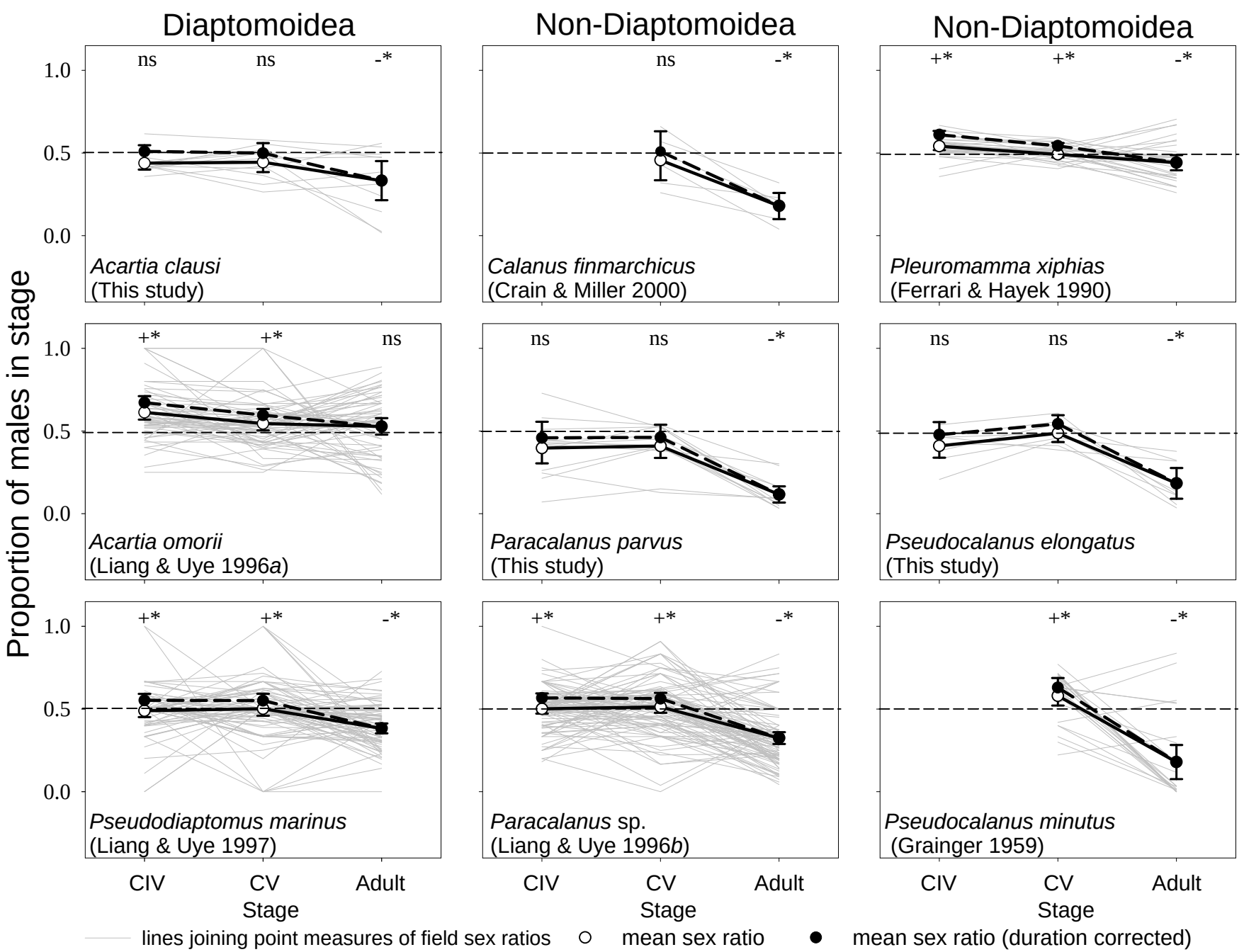
Diaptomoidea
Non-Diaptomoidea
Non-Diaptomoidea
Proportion of males in stage
1.0
0.5
0.0
ns ns -*
Acartia clausi
(This study)
ns -*
Calanus finmarchicus
(Crain & Miller 2000)
+* +* -*
Pleuromamma xiphias
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+* +* ns
Acartia omorii
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Paracalanus parvus
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Pseudocalanus minutus
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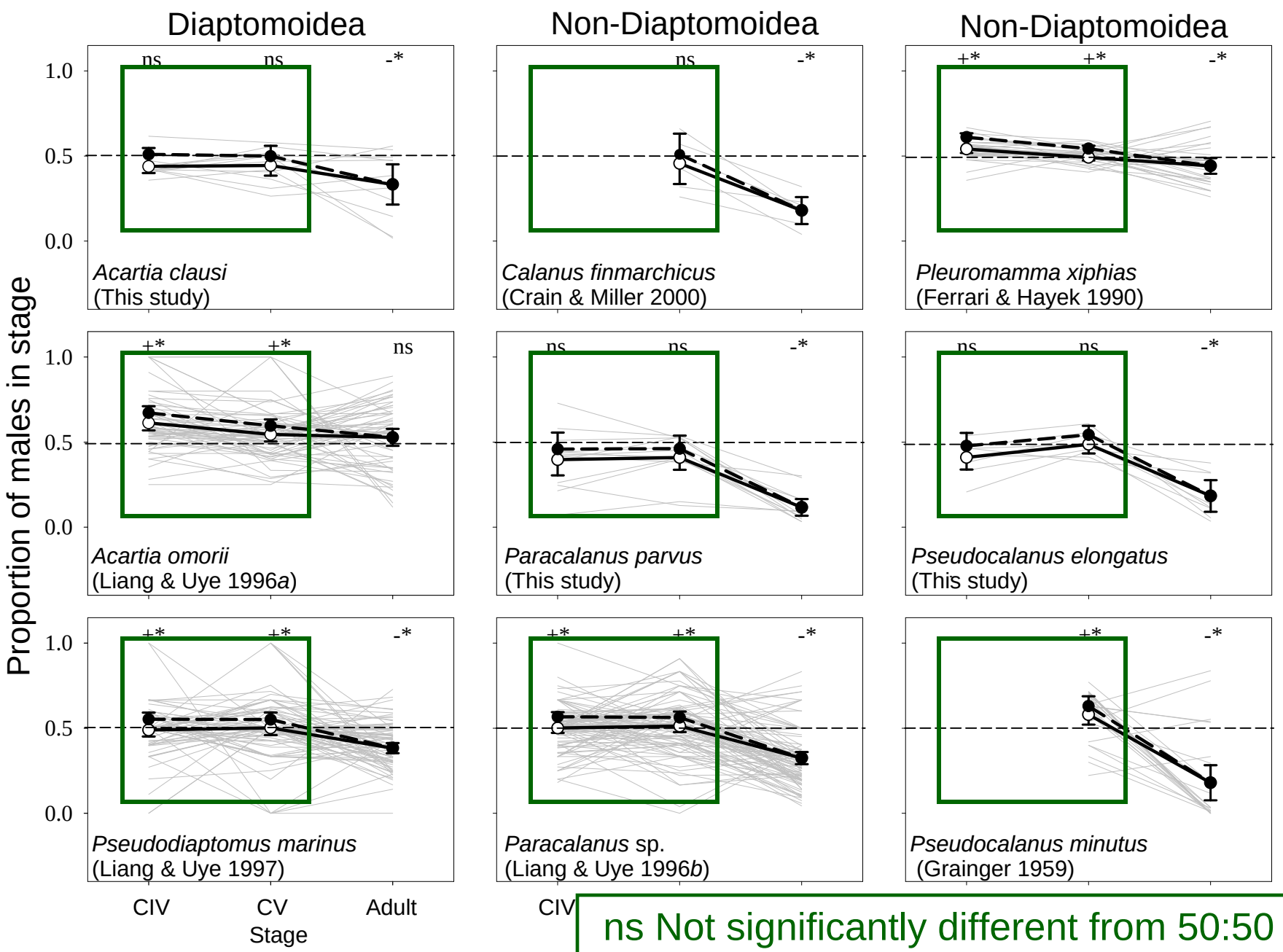
CIV CV Adult
Stage
lines joining point measures of field sex ratios
mean sex ratio
mean sex ratio (duration corrected)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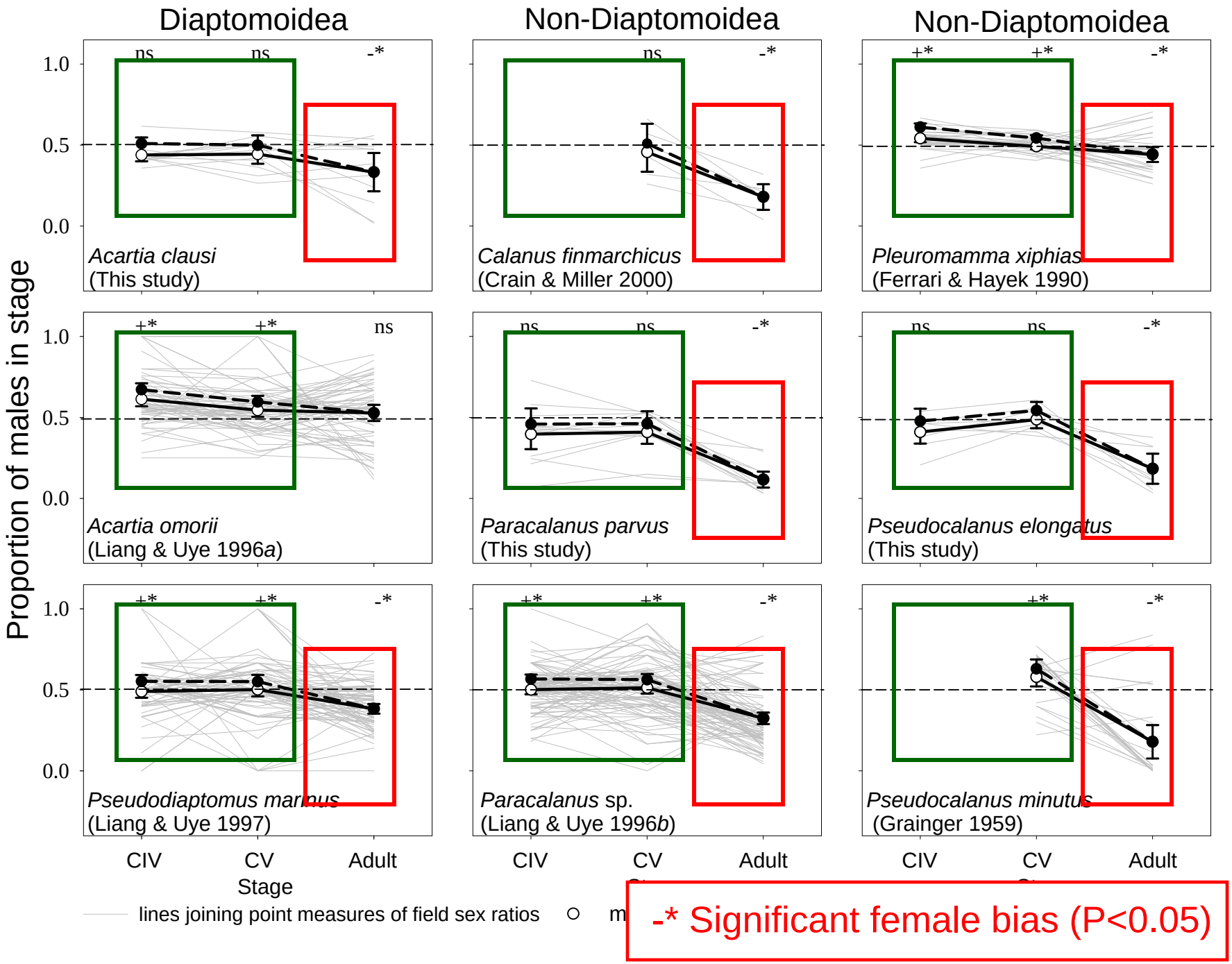
+* Significant male bias (P<0.05)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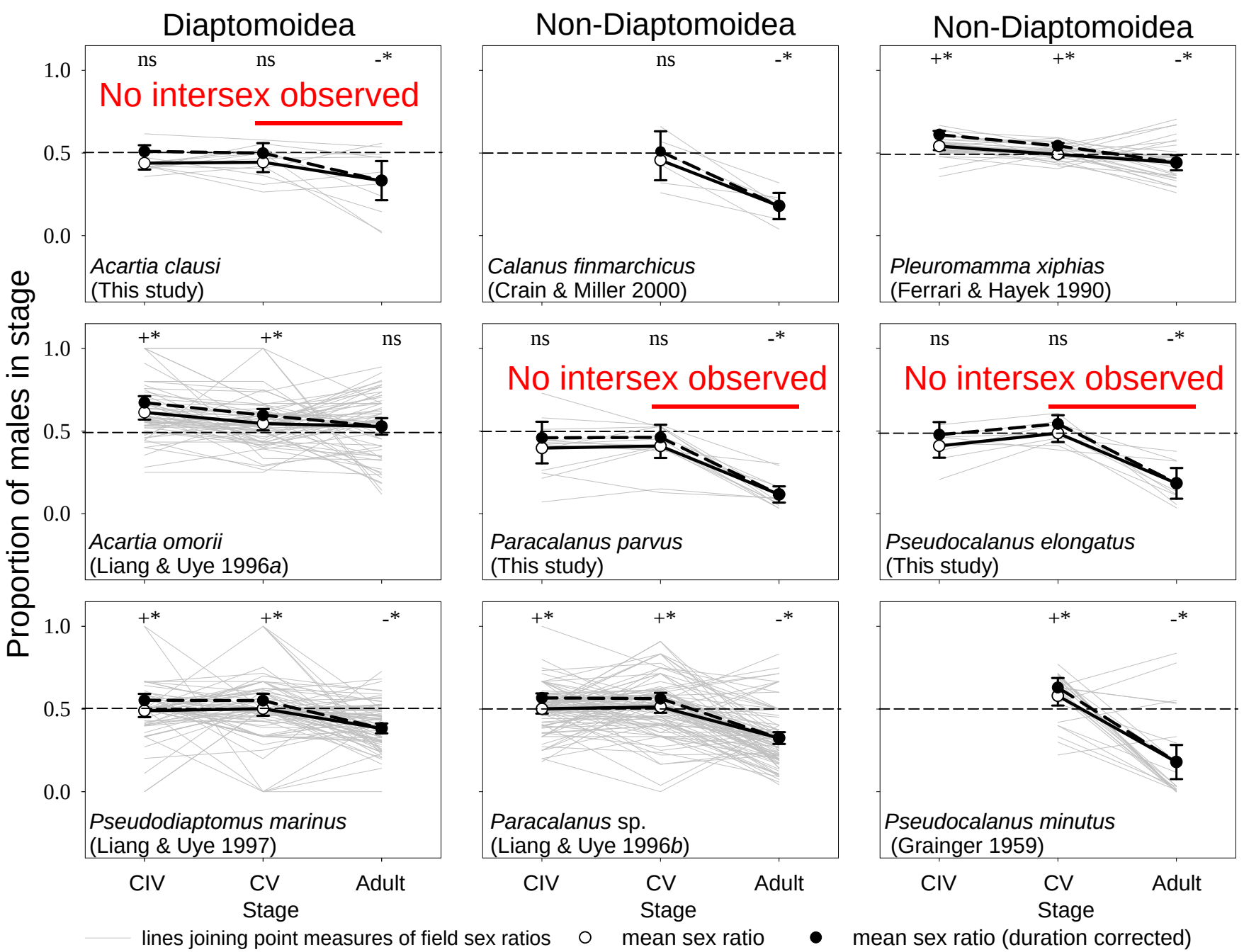
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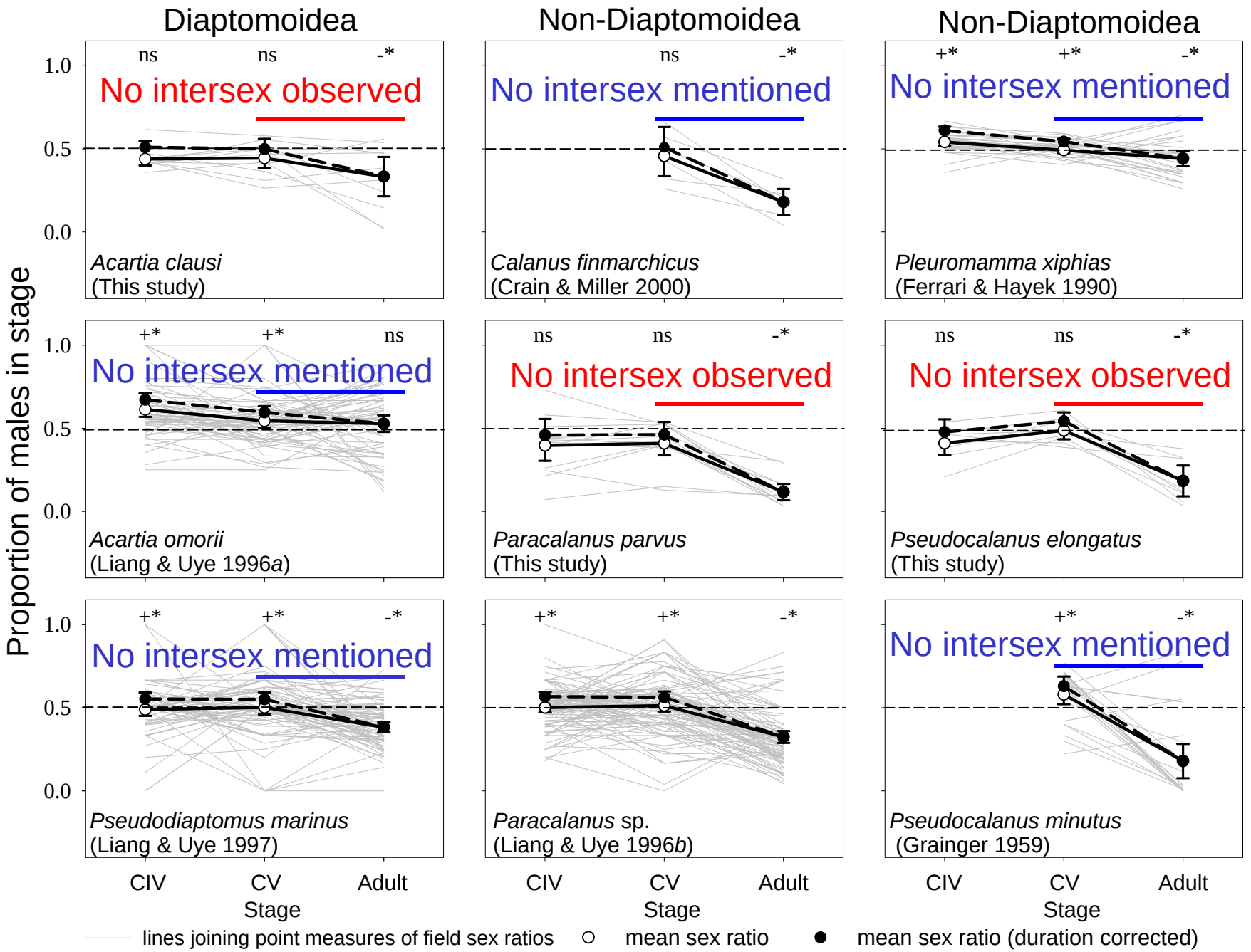
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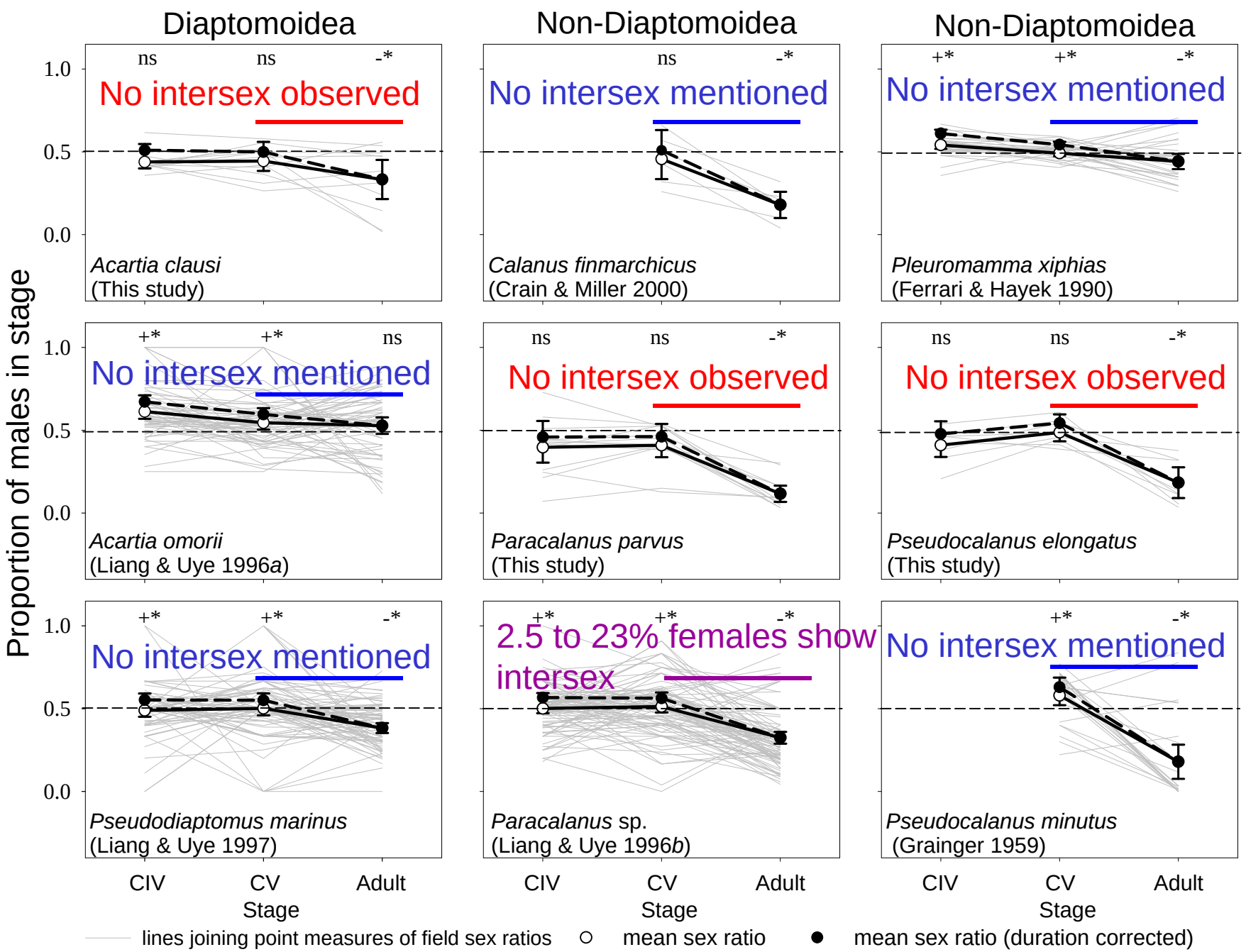
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2.5 to 23% females show intersex
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Adults males commonly have higher mortality rates than females, especially in those families which have the ability to store sperm (non-Diaptomoidea)

Sex dependent adult mortality

Differences attributed to two main causes:

1. Adult males feed less and have reduced ‘physiological longevity’

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e.g. in males of many non-Diaptomoidea genera the mouthparts are reduced or non-functioning

Sex dependent adult mortality

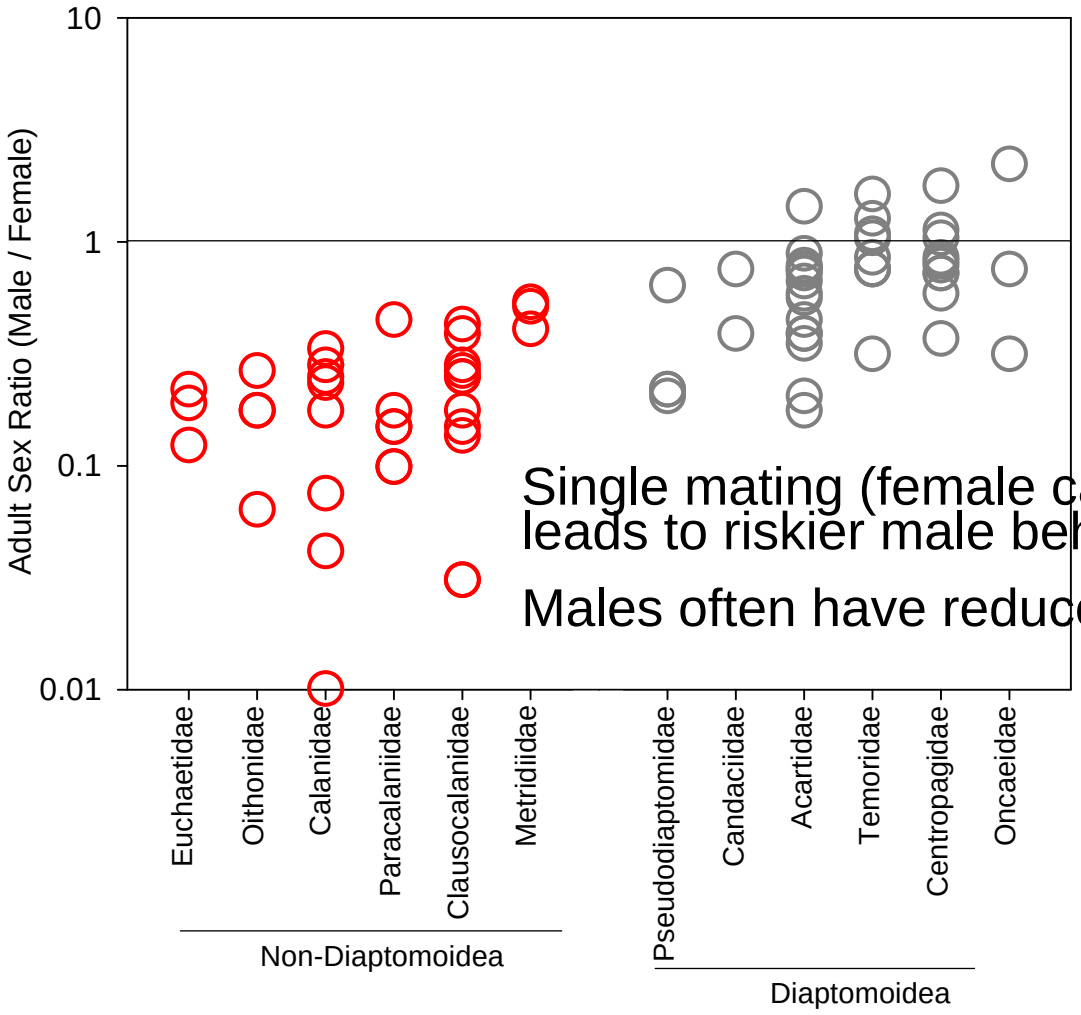
Differences attributed to two main causes:

1. Adult males feed less and have reduced ‘physiological longevity’

2. Mate searching by adult males leads to greater predation on them

We need to understanding the relative importance of these two

Adult Sex Ratios



Single mating (female can store sperm) leads to riskier male behaviour

Males often have reduced feeding rates

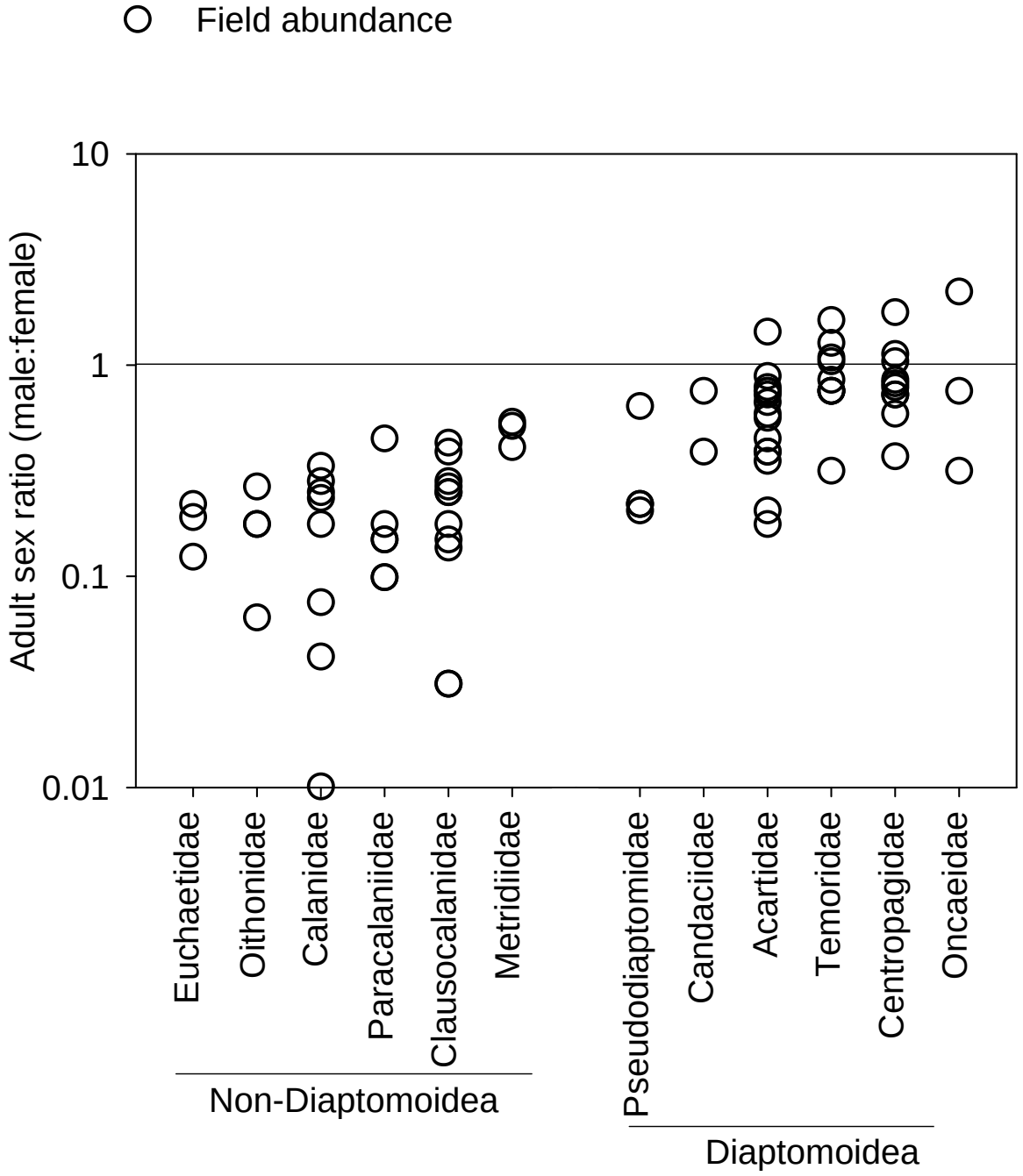
Redrawn from Kiørboe (2006), data from Hirst & Kiørboe (2002)

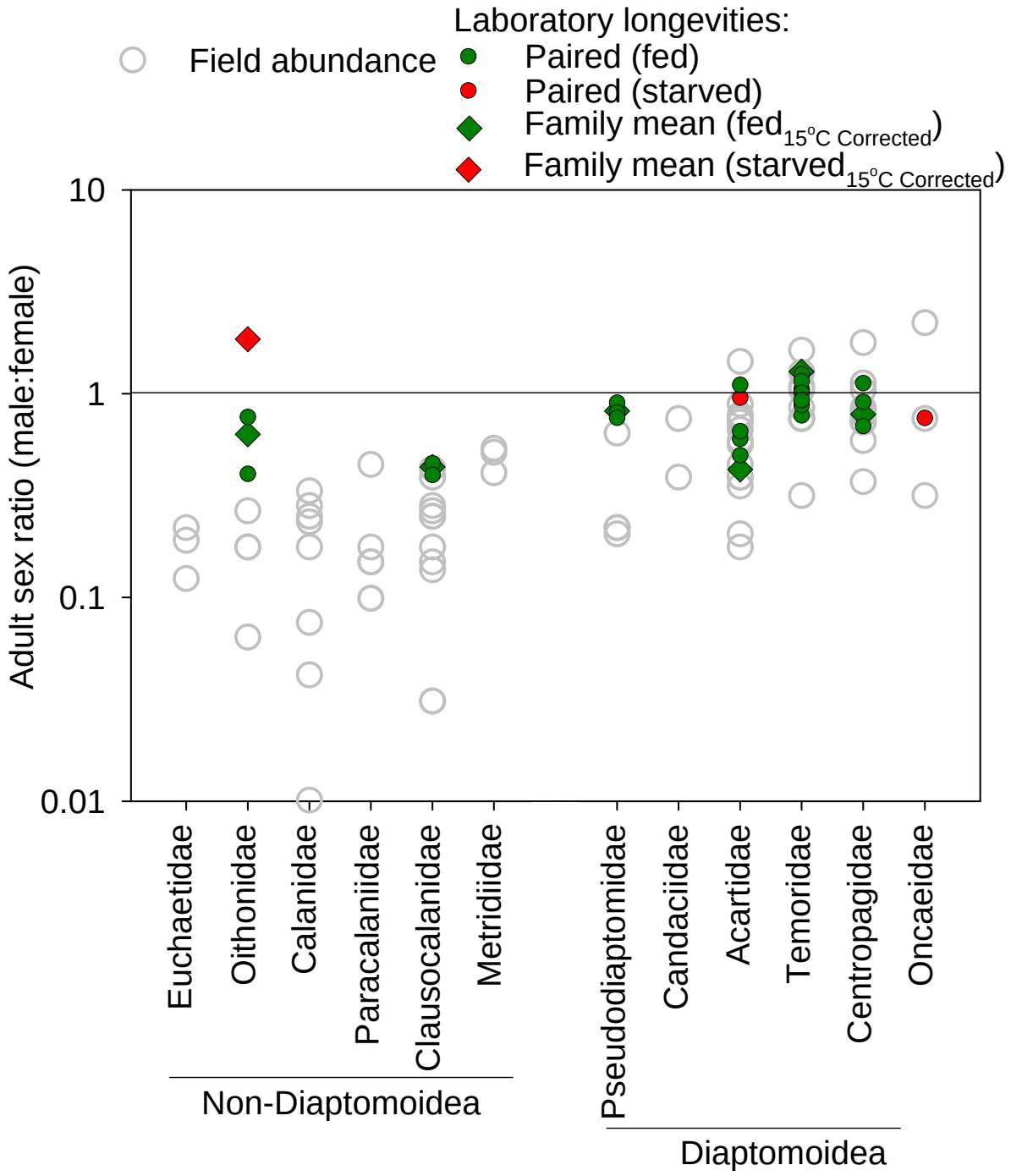
Sex dependent adult mortality

Differences attributed to two main causes:

1. Adult males feed less and have reduced ‘physiological longevity’

- If correct then average adult sex ratios would simply be the ratio of male to female longevities
- Synthesised measurements of adult physiological longevity under laboratory conditions
- New measures made (on *Acartia*, *Oithona*, *Centropages* and *Temora*)


Field abundance
Adult sex ratio (male:female)
10
1
0.1
0.01
Euchaetidae
Oithonidae
Calanidae
Paracalaniidae
Clausocalanidae
Metridiidae
Pseudodiaptomidae
Candaciidae
Acartidae
Temoridae
Centropagidae
Oncaeidae
Non-Diaptomoidea
Diaptomoidea


Laboratory longevities:
Field abundance
Paired (fed)
Paired (starved)
Family mean (fed15°C Corrected)
Family mean (starved15°C Corrected)
Adult sex ratio (male:female)
10
1
0.1
0.01
Euchaetidae
Oithonidae
Calanidae
Paracalaniidae
Clausocalanidae
Metridiidae
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Candaciidae
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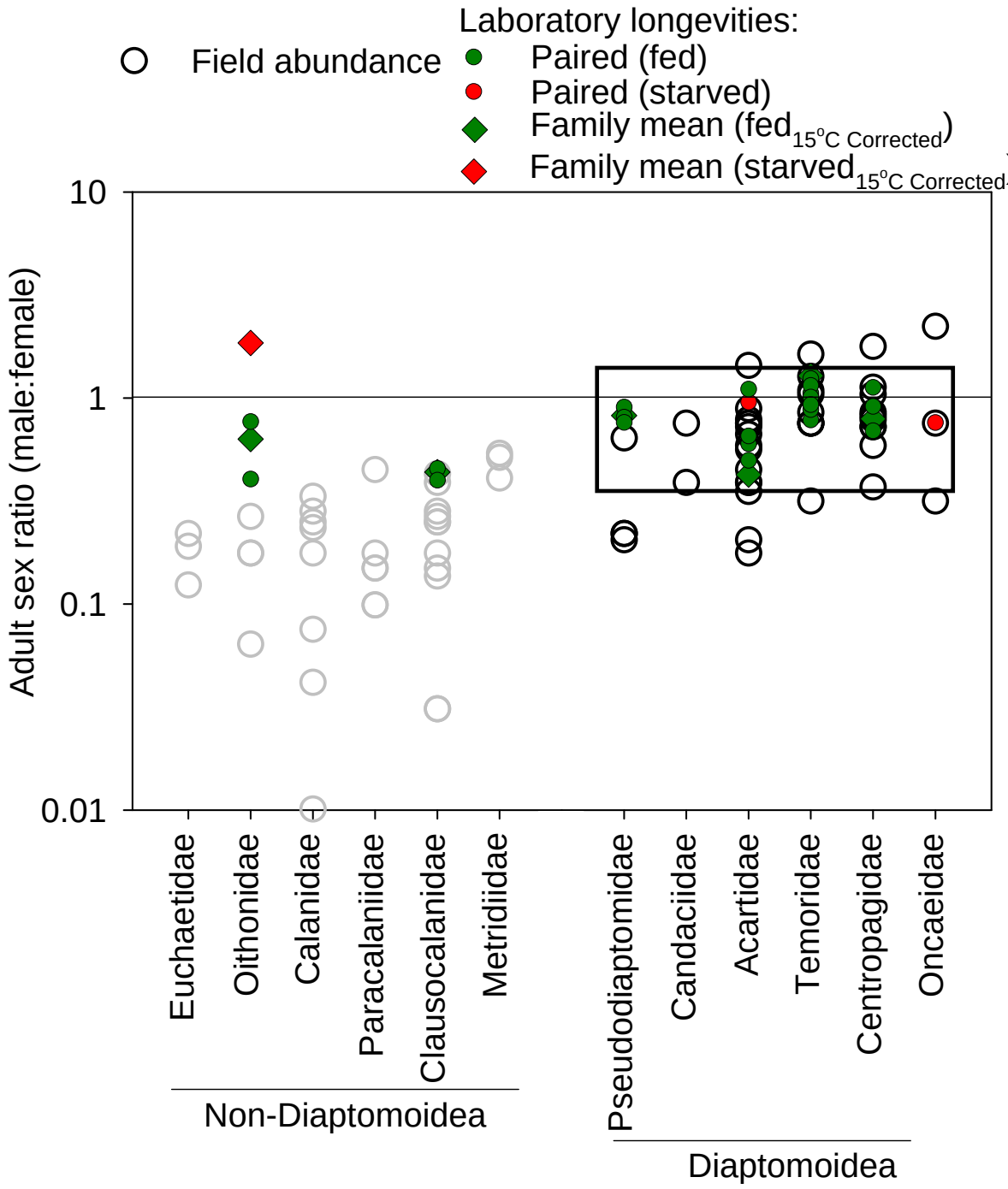
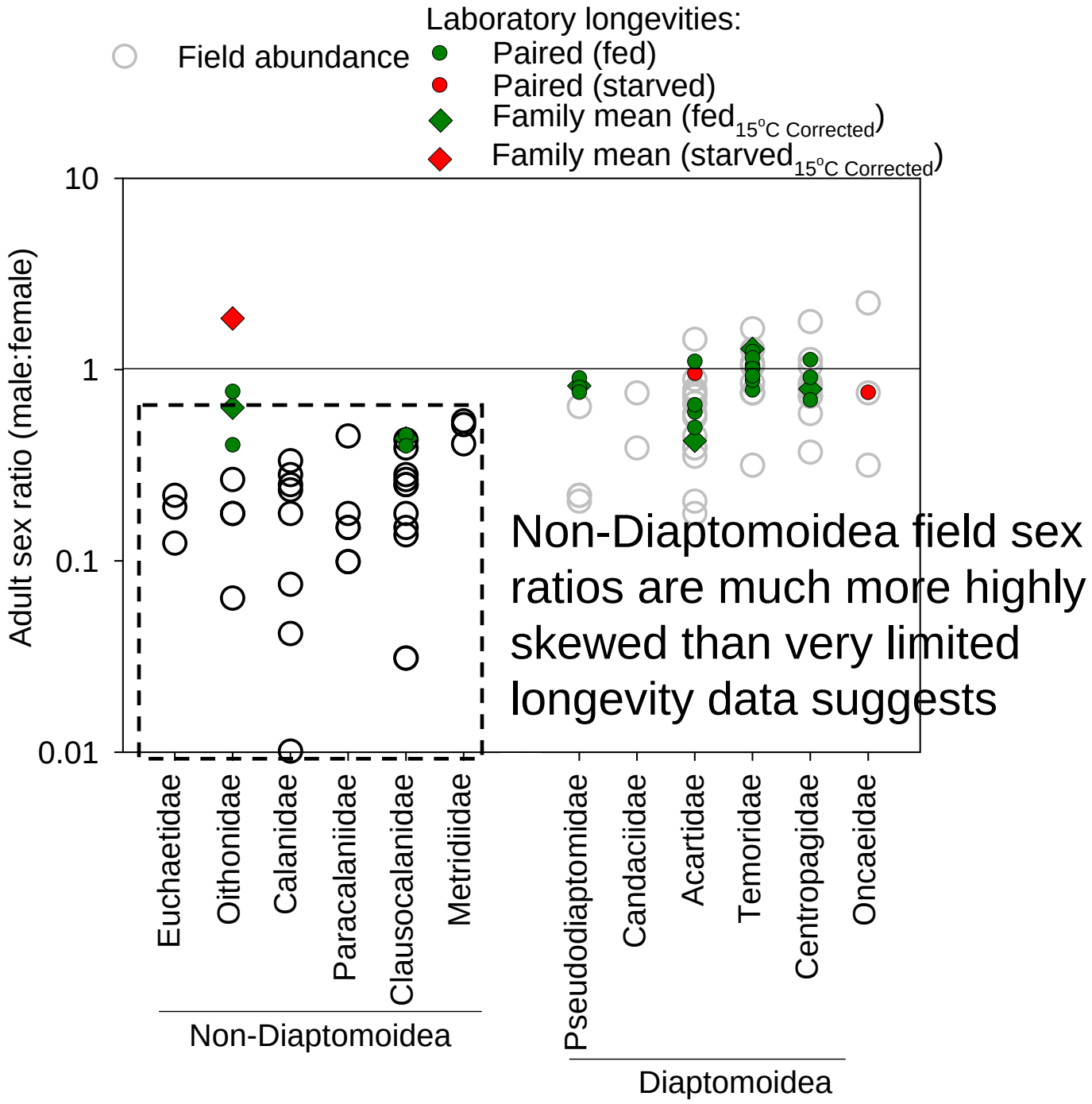


Physiological longevity can generate sex ratio skew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Field abundance
Paired (fed)
Paired (starved)
Family mean (fed15°C Corrected)
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Adult sex ratio (male:female)
10
1
0.1
0.01
Euchaetidae
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Candaciidae
Acartidae
Temoridae
Centropagidae
Oncaeidae
Non-Diaptomoidea
Diaptomoidea
Non-Diaptomoidea field sex ratios are much more highly skewed than very limited longevity data suggests

Sex dependent adult mortality

1. Adult males feed less and have reduced ‘physiological longevity’

Sex dependent adult mortality

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   Physiological differences may explain small sex ratio bias in Diaptomoidea

   The few measures of longevity in non-Diaptomoidea suggest much less skewed sex ratios than actually observed in the field

Sex dependent adult mortality

1. Adult males feed less and have reduced ‘physiological longevity’

2. Mate searching and behaviour of adult males leads to greater predation on them

Mate searching by *Centropages typicus* (Bagøien & Kiørboe 2005)

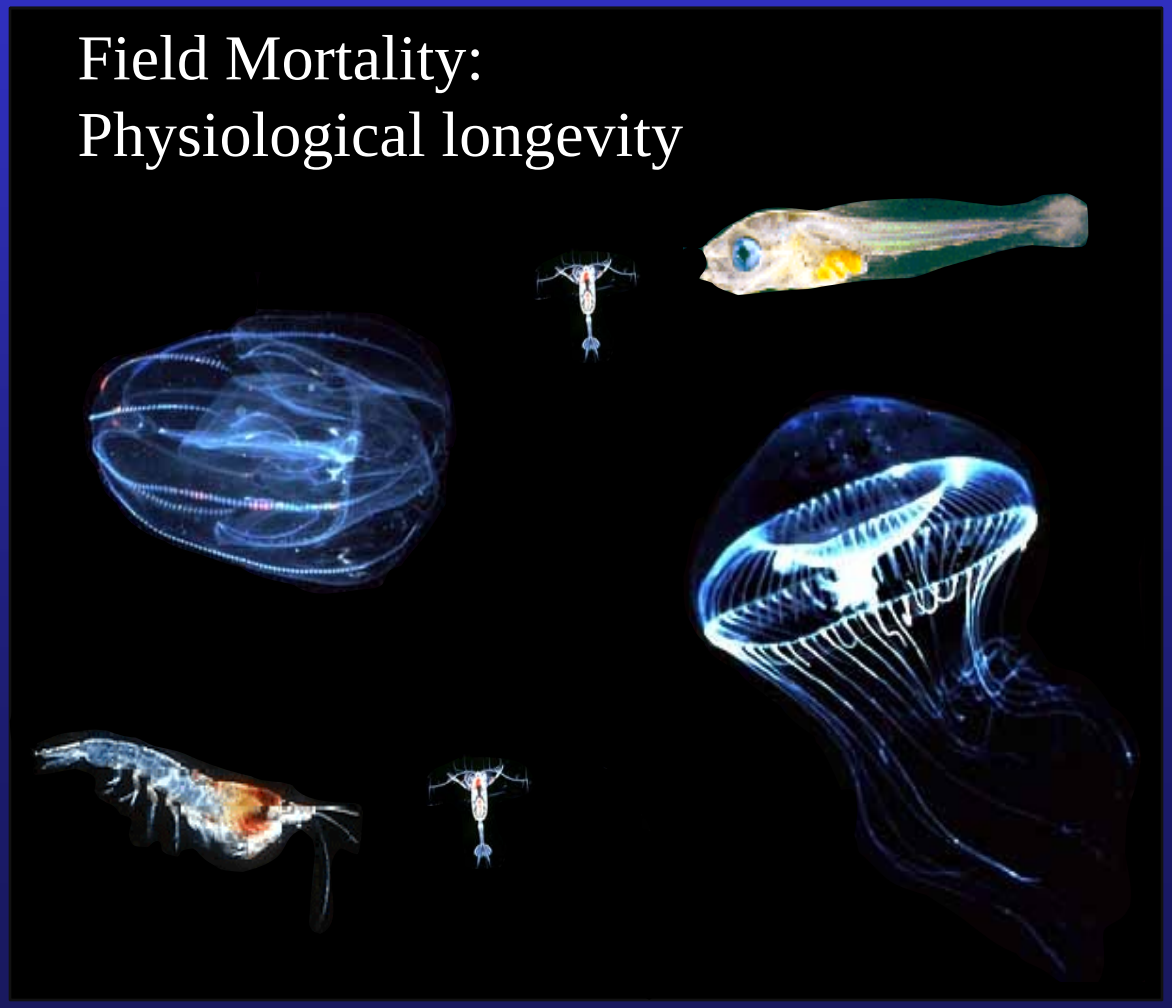
Sex dependent adult mortality

1. Adult males feed less and have reduced ‘physiological longevity’

2. Mate searching and behaviour of adult males leads to greater predation on them

We can use field mortality rates and physiological longevity to tell us more

Predation vs. Physiological Longevity



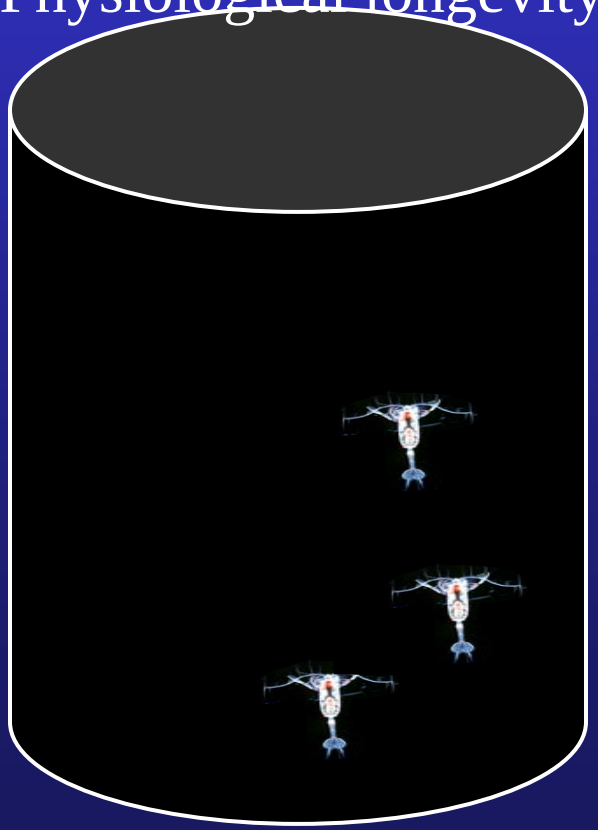
Predation vs. Physiological Longevity

Field Mortality:
Physiological longevity
Predation

Predation vs. Physiological Longevity

Field Mortality:
Physiological longevity
Predation

Laboratory:
Physiological longevity



Predation vs. Physiological Longevity

$$\frac{1}{\beta_{field}} = \frac{1-e^{-\beta_{pred}P}}{\beta_{pred}}$$

β_{field} = Field mortality rate (d^{-1})
β_{pred} = Field mortality from predation (d^{-1})
P = Physiological longevity (days)

From Kiørboe (2008)

Predation vs. Physiological Longevity

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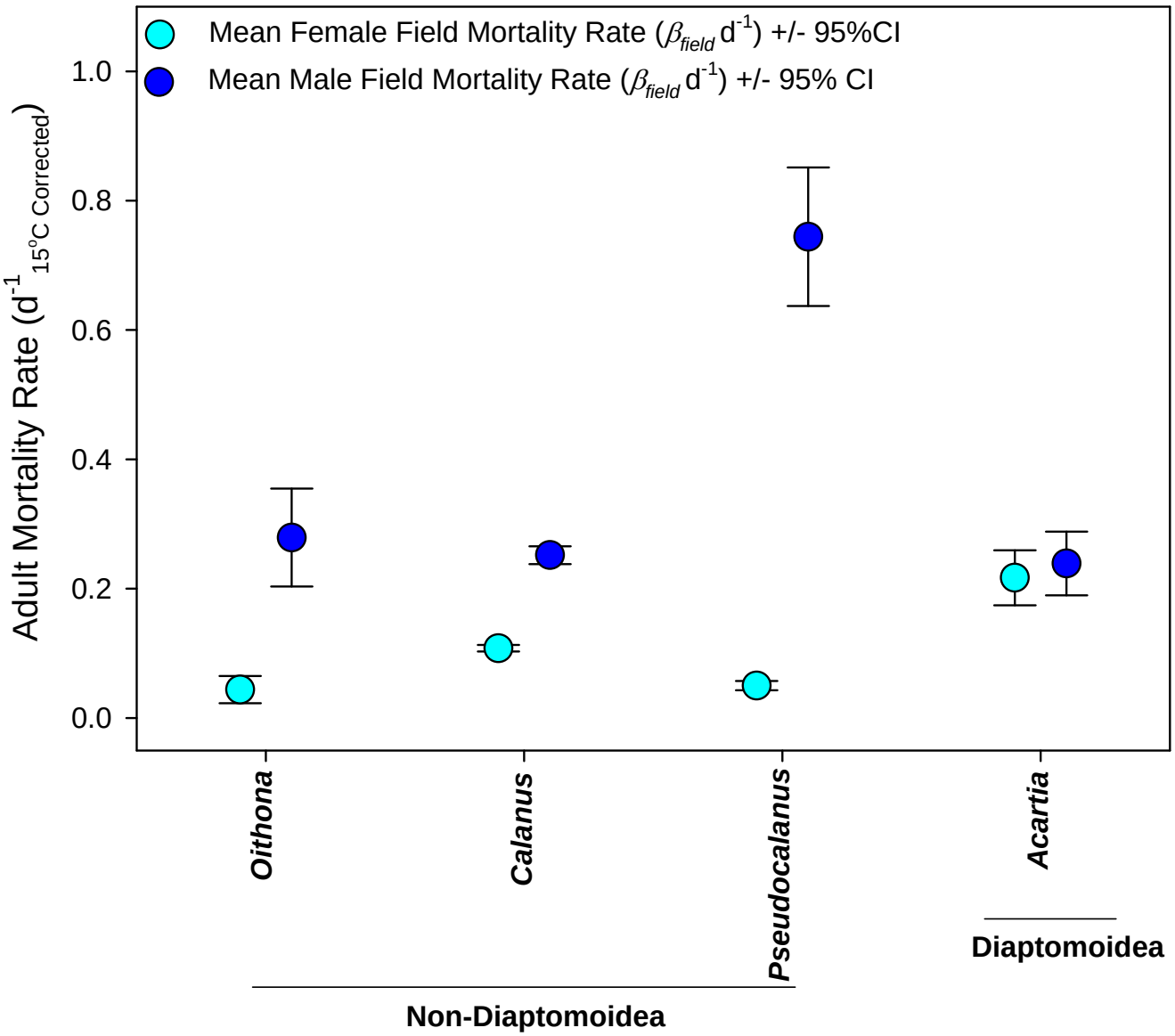
Predation vs. Physiological Longevity

- Adult field mortality rates, data for 4 dominant genera:
  - *Oithona* (Hirst & Ward 2008)
  - *Acartia* (Landry 1978; Johnson 1981; Kimmerer & McKinnon 1987)
  - *Pseudocalanus* (Ohman & Wood 1996; Ohman *et al*. 2002)
  - *Calanus* (Ohman *et al*. 2002; Hirst *et al*. 2007)

- Physiological longevities of adults of each genera (measured in the laboratory under fed and starved conditions)

Predation vs. Physiological Longevity



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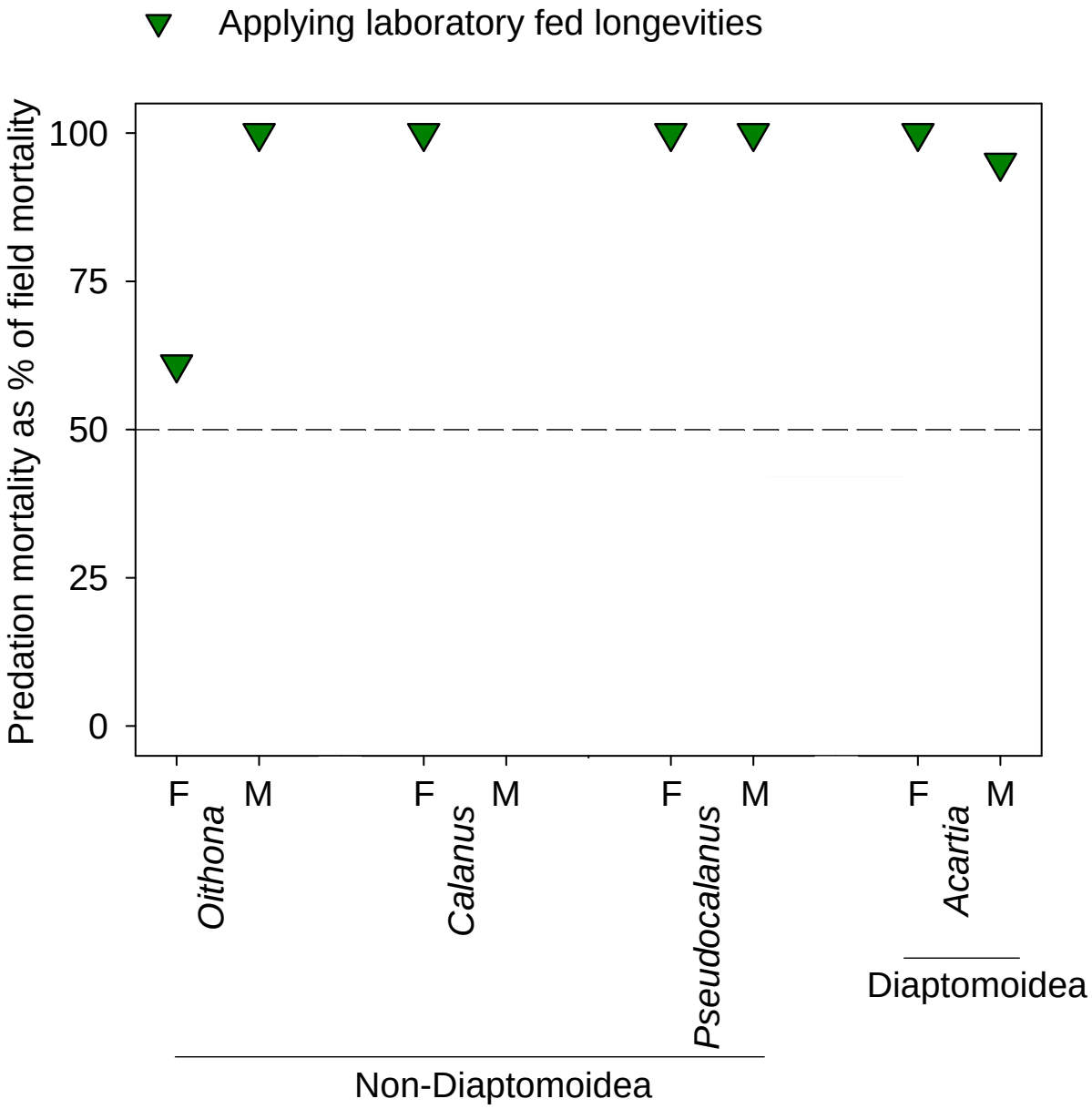

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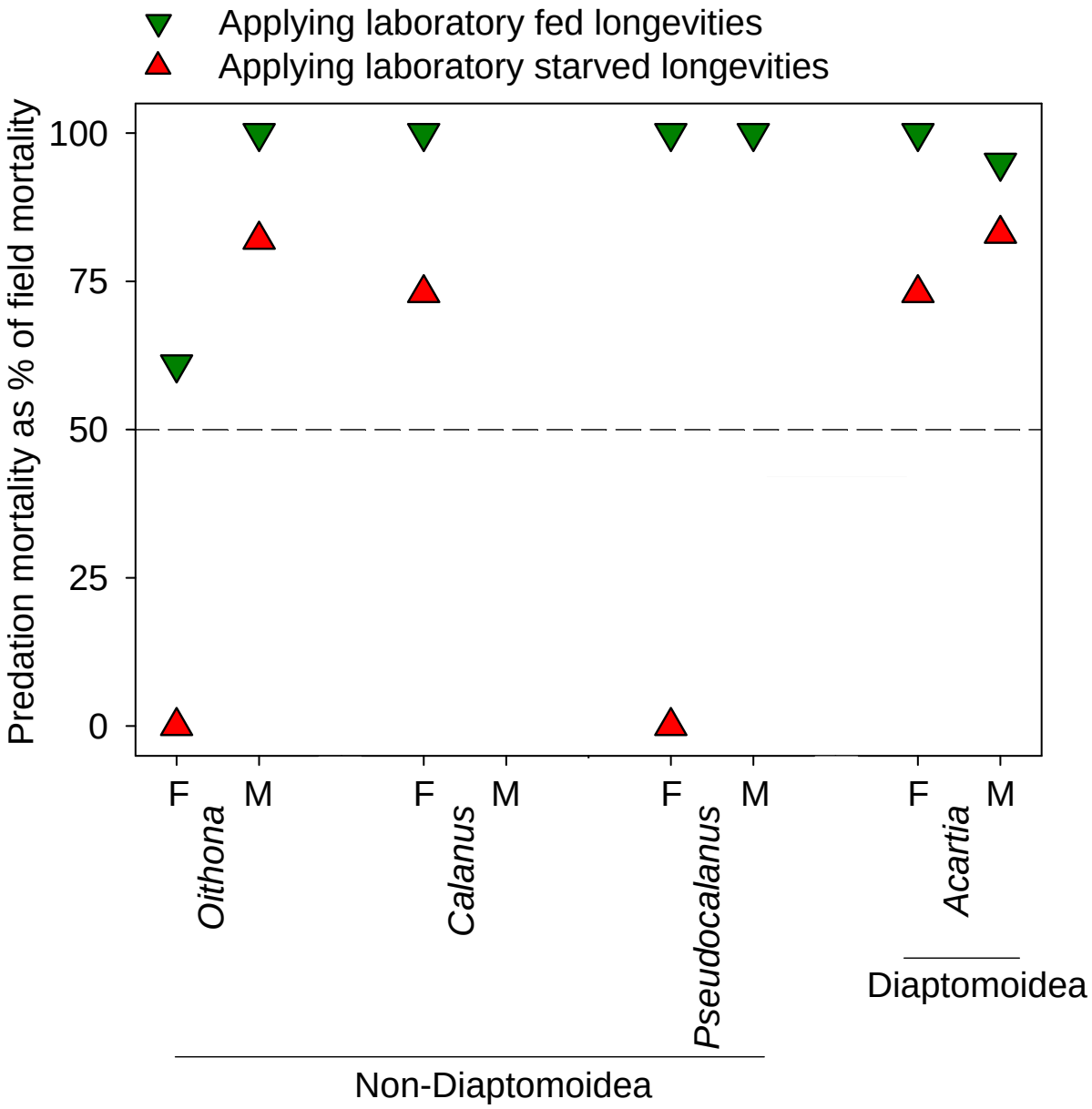
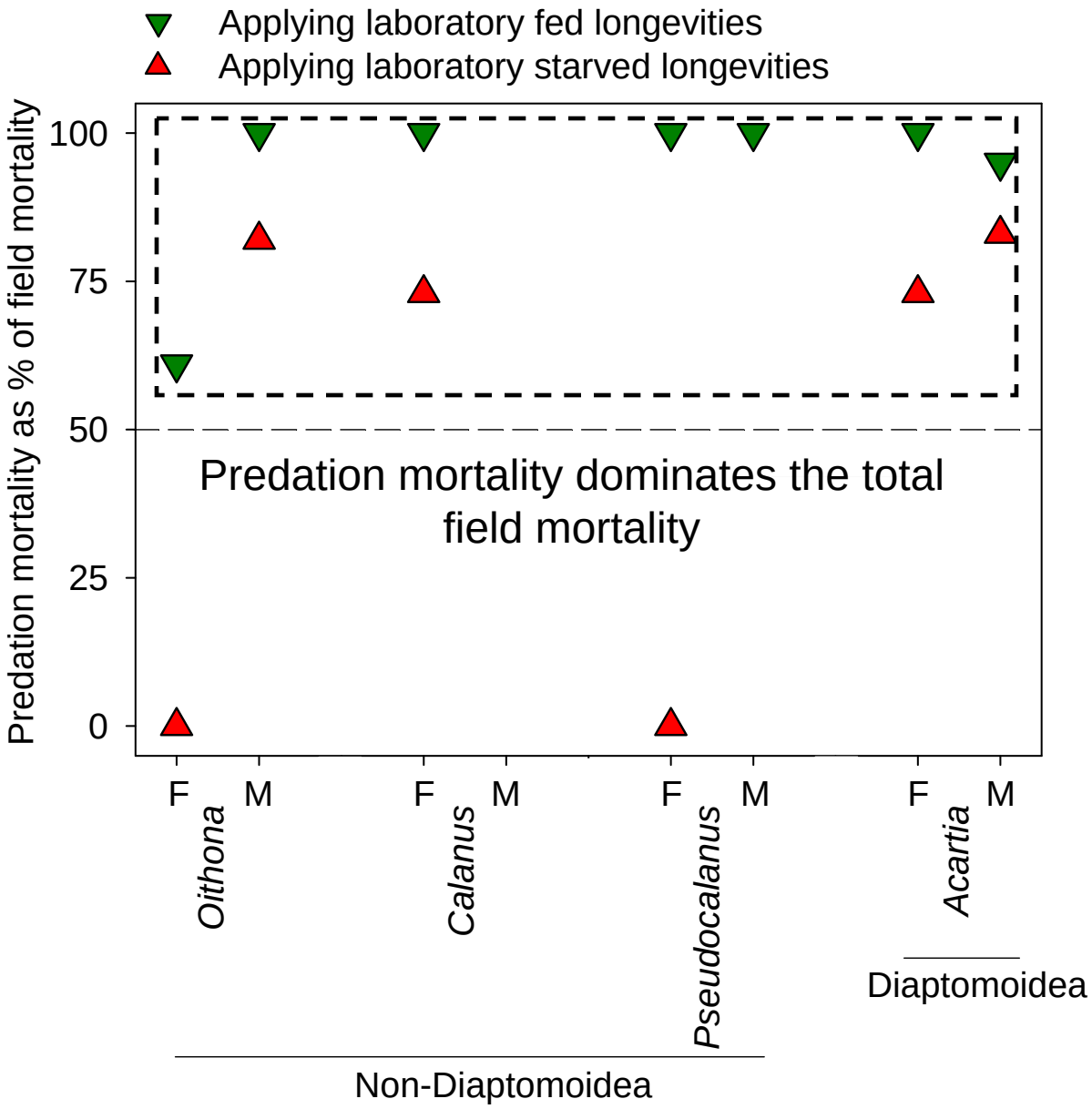
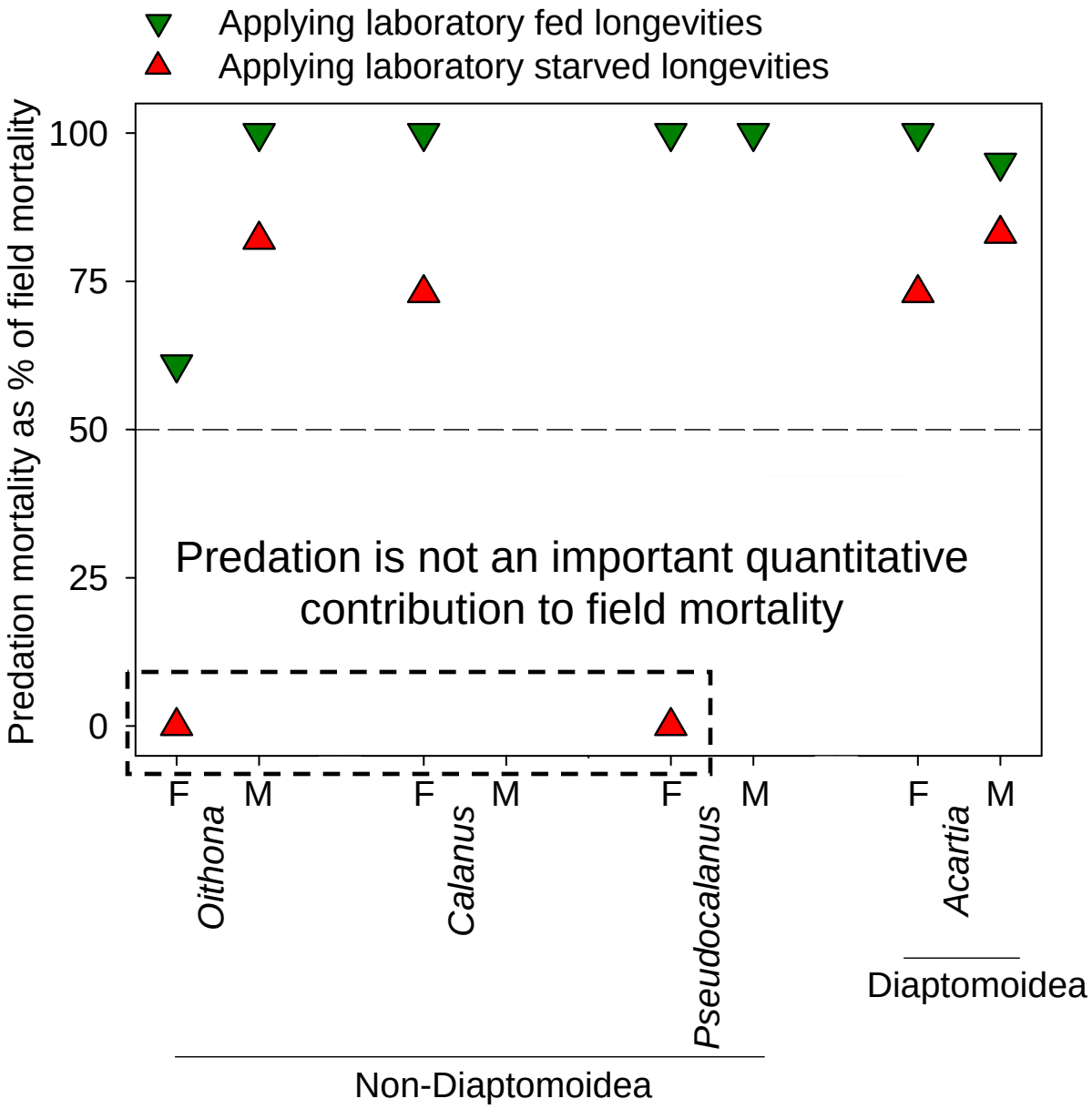


Predation vs. Physiological Longevity



Predation vs. Physiological Longevity



Conclusions for these 4 genera

- Physiological longevity is a minor contributor to adult copepod mortality in the field (except in some females when food limited)
- Reduced physiological longevity of males cannot account for large adult sex ratio skew
- Predation likely contributes much of the adult mortality – copepods don’t die of old age
- Differential predation on adult males and females main cause of strong sex ratio skew

What Next?

- We are measuring predation by a variety of predator guilds (fish larvae, chaetognaths, medusae) on male and female copepods, to determine if these rates do differ

- *'The influence of prey size, sex and behaviour on predation by the scyphomedusa Aurelia aurita'* Fitz-George Balfour *et al*. (Poster Session 2)

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