Chasing all kinds: Heterospecific mating and reproductive isolation in planktonic marine copepods

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Mating ecology and reproductive isolation in planktonic copepods

What biological traits serve as reproductive isolating barriers between planktonic species?

How do these barriers evolve?
Copepods: How to find the **right** mate?

**Pre-mating isolation:** multiple potential sources of information for species recognition by males

**Chronological cue hierarchy**

1. Diffusible pheromone → Pursuit
2. Hydromechanical
3. Contact chemosensory → Capture
   - Morphological
   - Gametic
4. Post-zygotic → Fertilization
Objectives and Approach

Objectives
1. Identify the mating signals that play a role in species recognition.
2. Determine the frequency and fate of heterospecific mating.
3. Examine the importance of heterospecific mating behavior to the reproductive ecology of natural populations.

Paired Mating Experiments
Motility Experiments

Calculations
- Male mate-search volume rates
- Hetero- and conspecific encounter rates in North Sea populations

Centropages, Temora
Copepod mating: *C. typicus* female + *C. hamatus* male
Incomplete pre-mating isolation for 3 species pairs

<table>
<thead>
<tr>
<th><strong>Centropages</strong></th>
<th>Track</th>
<th>Contact</th>
<th>Capture</th>
<th>Sperm</th>
</tr>
</thead>
<tbody>
<tr>
<td>typicus F / hamatus M</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>hamatus F / typicus M</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Temora</strong></th>
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</thead>
<tbody>
<tr>
<td>stylifera F / longicornis M</td>
</tr>
<tr>
<td>longicornis F / stylifera M</td>
</tr>
</tbody>
</table>

Other forms of isolation:

- Reduced frequency of heterospecific mating attempts?
- Gametic (post-mating, prezygotic) or post-zygotic isolation?
Males frequently pursue the wrong female

C typicus F - C. hamatus M
C hamatus F - C. typicus M

Control: C. hamatus
Control: C. typicus

1. Males attempt heterospecific mating at comparable frequencies to conspecific controls.
2. Spermatophore transfers rare.
Mating signals used in species recognition?

Is any species information contained in chemical or hydromechanical cues detectable prior to capture?

**Observations:**
- Male velocity during pursuit
- Duration of chase
- Trail age at encounter
- Length of pursued trail
- Along track distance at encounter
- Proportion of time trail is lost
- Proportion of time male initiates tracking in incorrect direction

*Heterospecific:* 24 events (14 captures)
*Conspecific:* 27 events (10 captures)
No species information in the pheromone signal

No difference in male tracking behavior between hetero- and conspecific mating events

<table>
<thead>
<tr>
<th>Conspecific</th>
<th>Heterospecific</th>
<th>Sig?</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td>35%</td>
<td>32%</td>
<td></td>
</tr>
<tr>
<td>22.4 (13.4 - 33.8)</td>
<td>25.3 (13.5 - 57.2)</td>
<td>NS</td>
</tr>
<tr>
<td>0.8 (0.3-9.6)</td>
<td>1.2 (0.2 - 8.6)</td>
<td>NS</td>
</tr>
<tr>
<td>4.1 (0.2 - 7.6)</td>
<td>3.1 (0.36 - 26.5)</td>
<td>NS</td>
</tr>
<tr>
<td>26.3 (11.7 - 57.9)</td>
<td>26.1 (8.7 - 138.8)</td>
<td>NS</td>
</tr>
<tr>
<td>17.1 (4.8 - 41.4)</td>
<td>16.3 (5.6 - 97.8)</td>
<td>NS</td>
</tr>
</tbody>
</table>

- Lost trail
- Incorrect initial tracking direction
- Male velocity during pursuit (mm/sec)
- Duration of chase (sec)
- Trail age at detection (sec)
- Length of pursued trail (mm)
- Along track distance at detection (mm)
Heterospecific mating: Important in natural populations?

Is the ocean filled with sexually attractive pheromone trails?
Heterospecific mating: Important in natural populations?

**Encounter rate:** \( \beta = \beta_{C_f C_m} \)

\[ \beta_{\text{trail,cruiser}} = 2 Lu_{2D} \left( \sqrt{\frac{D_p L}{v}} + S \right) \]

Kjørboe and Bagoien, 2005

<table>
<thead>
<tr>
<th></th>
<th>C. hamatus</th>
<th>C. typicu s</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \beta_{\text{typicus}} )</td>
<td>168</td>
<td></td>
</tr>
<tr>
<td>( \beta_{\text{hamatus}} )</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>( \beta_{\text{hamatus M, typicus F}} )</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>( \beta_{\text{typicus M, hamatus F}} )</td>
<td>43</td>
<td></td>
</tr>
</tbody>
</table>

* from Kjørboe and Bagoien, 2005
Encounter rates in the North Sea

*C. typicus*  
*C. hamatus*  

*(SAPHOS WinCPR, 2005)*
Highest heterospecific encounter rate in August (~2000 enc m\(^{-3}\) day\(^{-1}\))

Same order of magnitude for hetero- and conspecific encounter rates
Specific encounter rates, *C. typicus* females:

- *C. typicus* is chemically ‘conspicuous’ to males of both species, and bears the higher fitness cost of heterospecific mating attempts.

- Often encounters heterospecific males at higher rates than conspecific males (up to 100+ encounters day $^{-1}$).

- Selection for temporal + spatial isolation of species?
Broader implications......... so far

1. Diffusible pheromone signal highly non-species specific
   • Males may detect and respond to pheromone trails created by a variety of species

2. No or nearly no species information contained in pheromone or hydromechanical cues
   • Cues detectable at contact - surface proteins, morphological shape - are primary in species recognition

3. Heterospecific mating attempts can be a significant fraction of total mating events during part of the reproductive season
   • Higher pheromone producing, faster, rarer species will suffer the greatest burden of heterospecific mating
   • Selection against heterospecific mating attempts: mechanism to create habitat isolation between congeners?
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