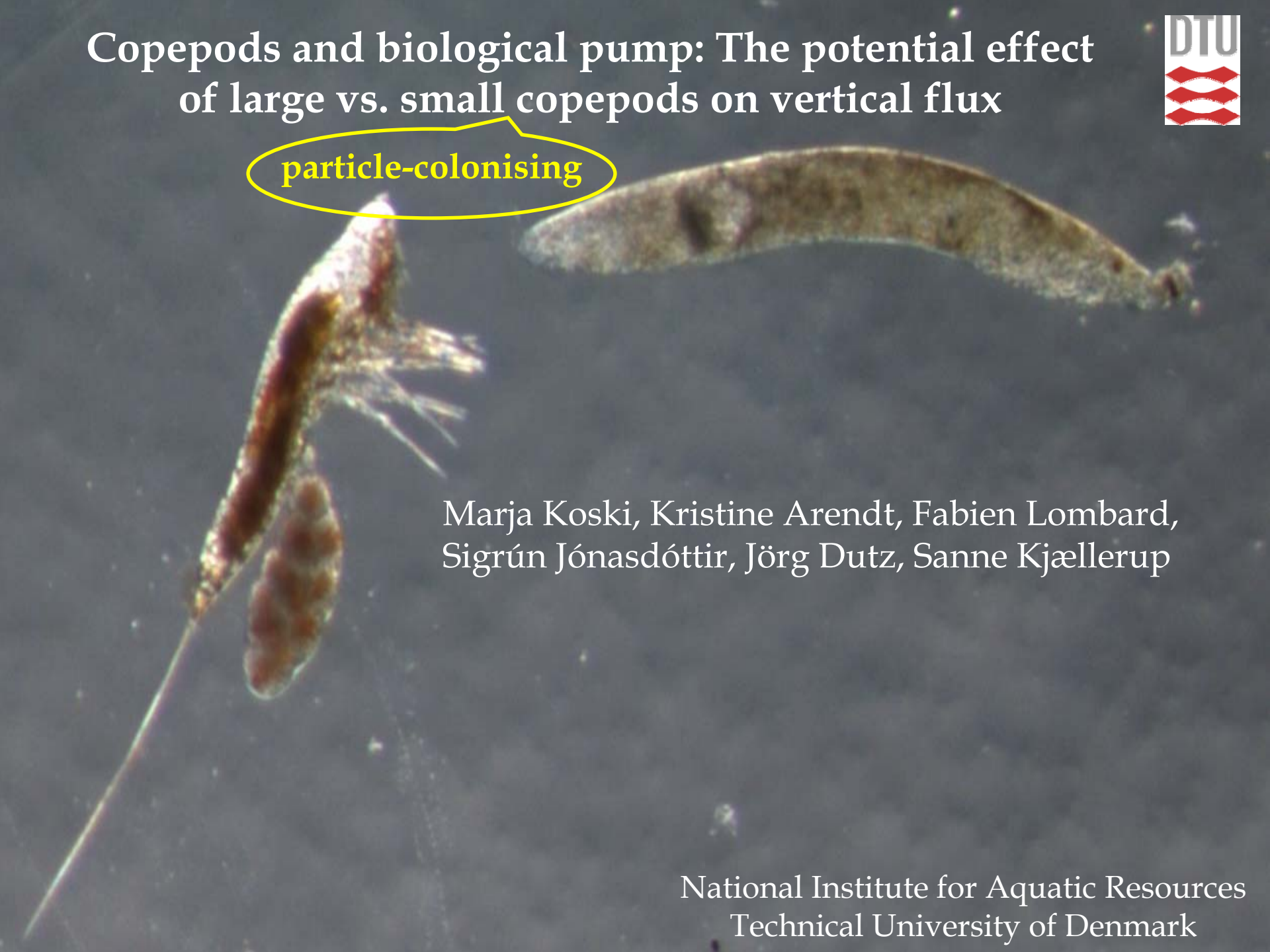
Copepods and biological pump: The potential effect of large vs. small copepods on vertical flux

particle-colonising



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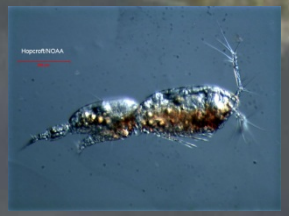
Background: Large vs. small copepods

Large copepods: *Calanus* spp.

- Feed at one depth and produce the fecal pellets at another depth

→ Changes one particle to another

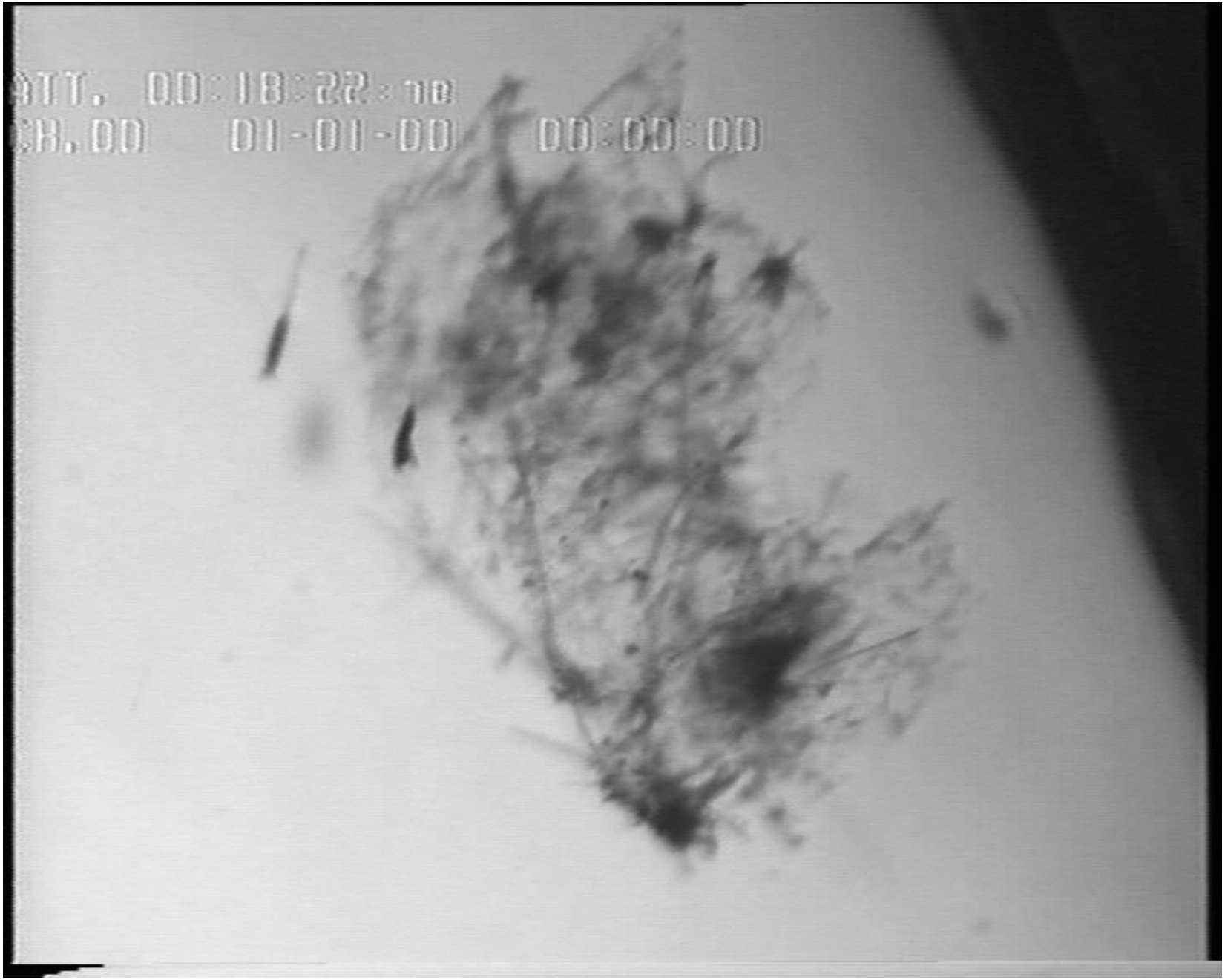
Small particle colonising copepods: *Microsetella, Oncaea,* benthic harpacticoids



- Colonise particles and reside on them feeding and producing pellets

→ Modifies the particle

Microsetella feeding on an old appendicularian house

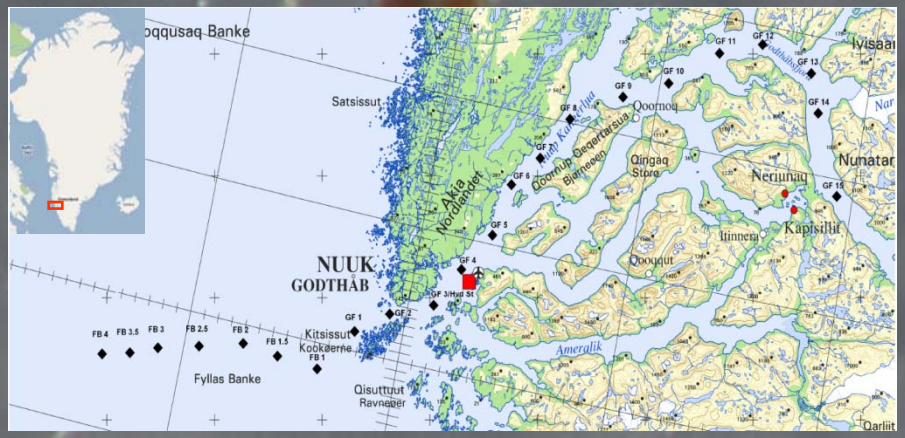


Measurements

Large copepods

- Vertical day / night distribution
- Diurnal rhytm (5-h intervals) of pellet production
- Gut evacuation time

- *Calanus* spp. at Godthåbsfjord (SW Greenland); 4 stations along a salinity / production gradient

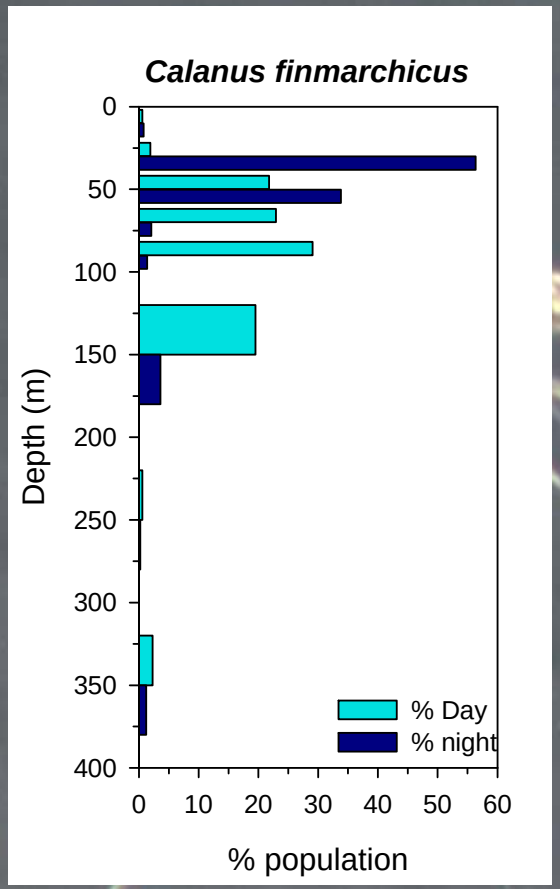


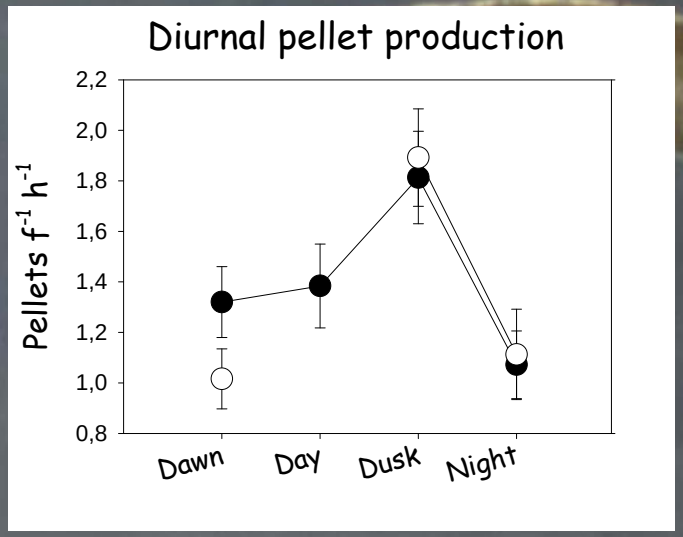
Small copepods

- Vertical day / night distribution
- Feeding on diverse types of aggregates
- Behavioral observations

- Vertical day / night distribution; 4 stations (Greenland)
- Functional response of 3 copepod species vs. 3 types of aggregates (lab)
  - Houses
  - Diatom aggregates
  - Cyanobacteria aggregates
- Degradation of pellets by *Microsetella* and *Oncaea* (Greenland)
- Filming of *Microsetella* and pellets

Results: Diurnal pellet production of *Calanus finmarchicus*





Data from Tang et al., submit.

- Majority of pellets produced during late afternoon- evening at the depth
- *Calanus finmarchicus* density ca 6500 ind. m^{-2}; ca 50% migrates down to 100 m producing some 30 000 pellets m^{-2} during the night

Mechanisms of aggregate degradation by small copepods

	Copepod	*Aggregate*	*Environment*
Encounter rate	Search volume - swimming behaviour, hunger Concentration	Concentration, size	Food-web structure, productivity, turbulence, hydrography
Residence time	Swimming velocity Feeding efficiency	Quality (origin, size) concentration	Food-web structure, productivity, predation
Feeding rate	Metabolic rate + growth / reproduction , diet preference, hunger	Quality (origin, size, composition, ballast, TEP..)	Food-web structure, productivity, temperature, CO_2
Egestion rate	Assimilation efficiency Gut passage time Feeding rate	Quality (origin, size, composition, ballast, TEP..)	Food-web structure, productivity, temperature, CO_2

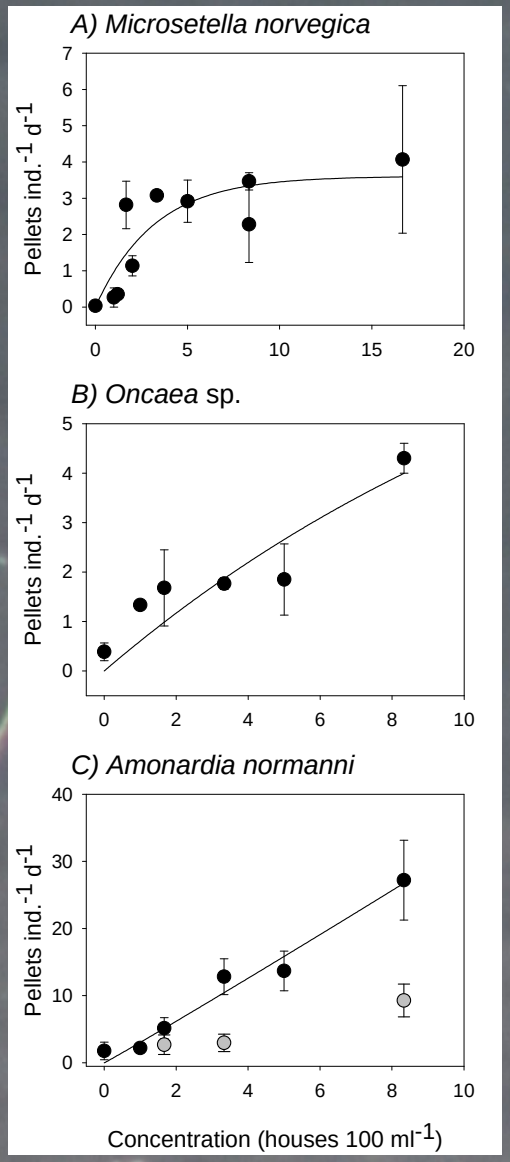
Amonardia:

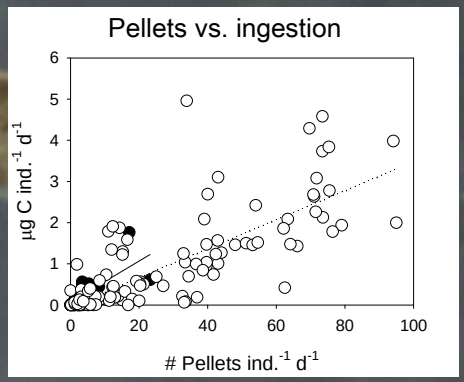
Search volume: 280 ml / d
Residence time: 3-51 h

Microsetella:

Search volume: 1200 ml/d
Residence time: 2.2 min.

Results: Species-specific feeding on appendicularian houses



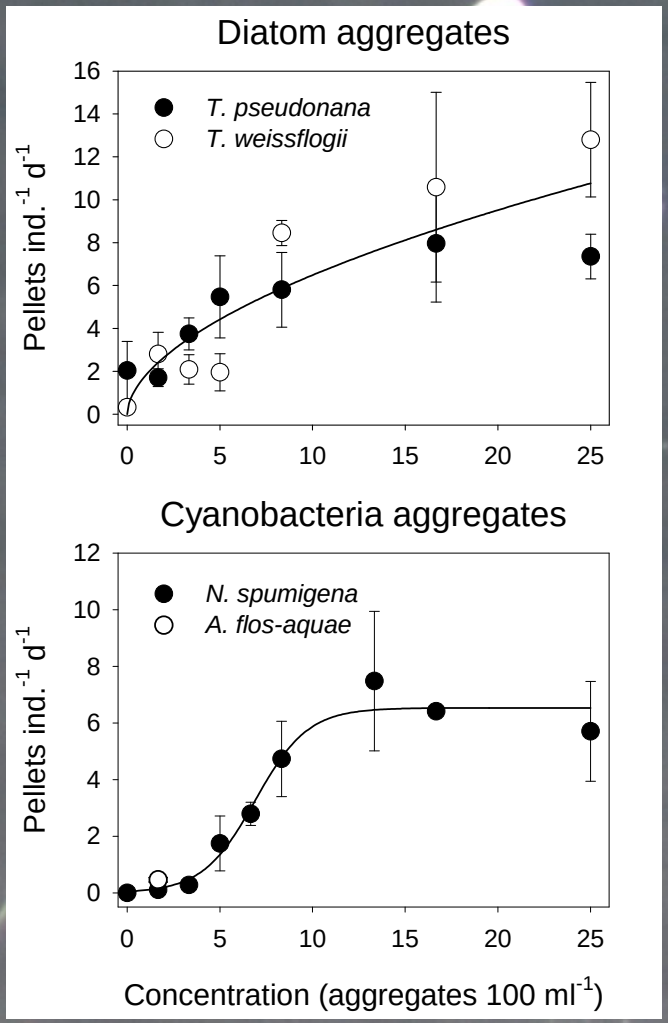


- Pellet production of *Amonardia* significantly higher than that of other species

- Max. ingestion of *Microsetella* and *Oncaea* ~ **0.27 µg C ind.$^{-1}$ d^{-1}** (ca 15% body weight d^{-1} for *Oncaea*, ca 39% body weight d^{-1} for *Microsetella*)

- Max. ingestion of *Amonardia* ~ **1.0 µg C ind.$^{-1}$ d^{-1}** (ca 45% body weight d^{-1})

Results: *Amonardia* feeding on different types of aggregates



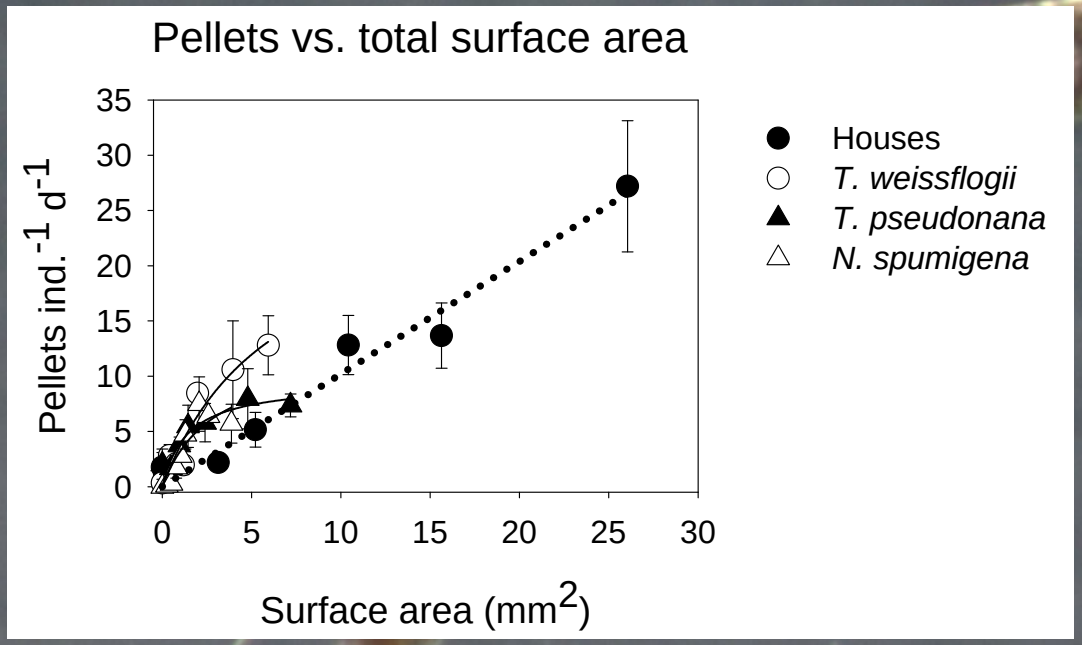
Max. pellet production / ingestion varies depending on aggregate type:

- Houses 1 µg C ind.$^{-1}$ d^{-1}
- Diatom aggregates 0.38 µg C ind.$^{-1}$ d^{-1}
- Cyanobacteria aggregates 0.17 µg C ind.$^{-1}$ d^{-1}

Why?

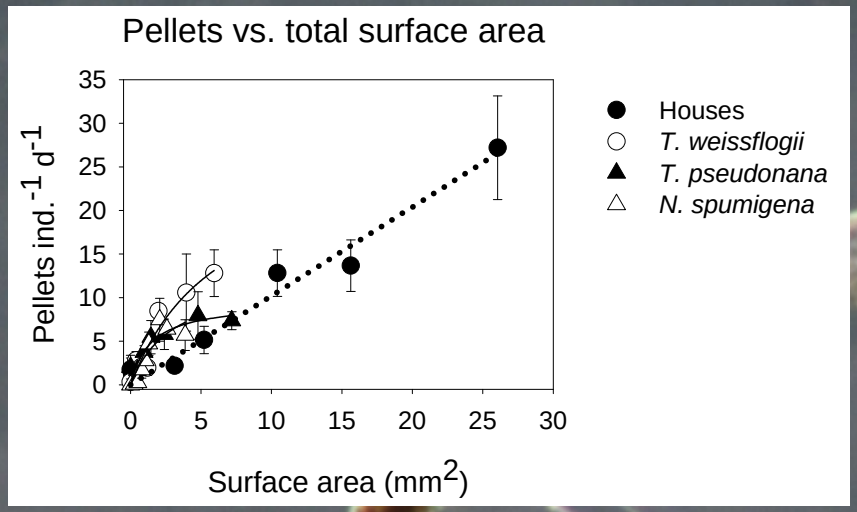
Encounter, colonise, reside, handle

Results: Ingestion as a function of aggregate size



$$y = \frac{ax}{b+x}$$

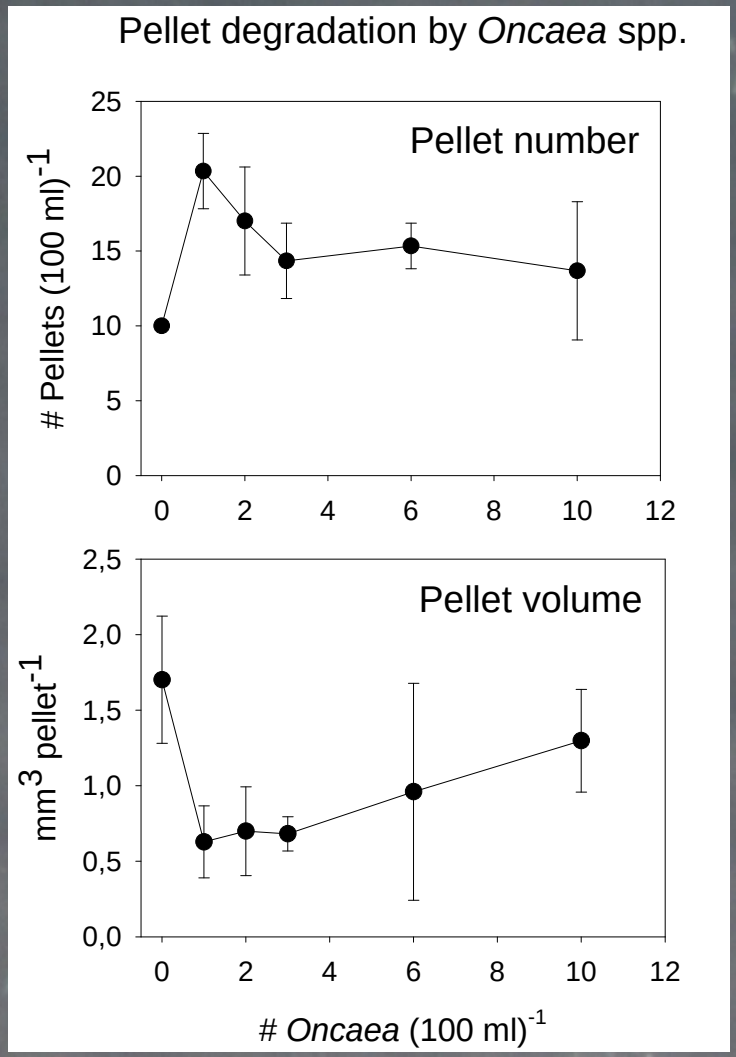
Aggregate type	Encounter rate (a/b)	Handling time (1/a)	R^2
House	1.0	1.7×10^{-10}	0.96
TW	4.2	0.04	0.92
TP	6.7	0.1	0.81
Nod	4.3	0.08	0.81



- Phytoplankton aggregates are easier to find, but houses provide food faster
- Handling time determines maximum ingestion

  - Aggregate concentrations relatively high
  - *Amonardia* has a long residence time compared to *Microsetella* (hours vs. minutes)

Results: *Microsetella* and *Oncaea* feeding on pellets



- Neither *Microsetella* nor *Oncaea* seems to have an influence on total pellet carbon, but *Oncaea* appears to fragment pellets

- Behavioral observations of *Microsetella* with pellets suggest indifference towards pellets

Conclusions on small copepods:

- Small particle colonising copepods can feed on aggregates up to ca 1 µg C ind.$^{-1}$ d-1, depending on aggregate type (up to 10-fold differences) and copepod species (up to 3-fold differences)

- Appendicularian houses are easier to handle than phytoplankton aggregates - max. ingestion rates will be higher

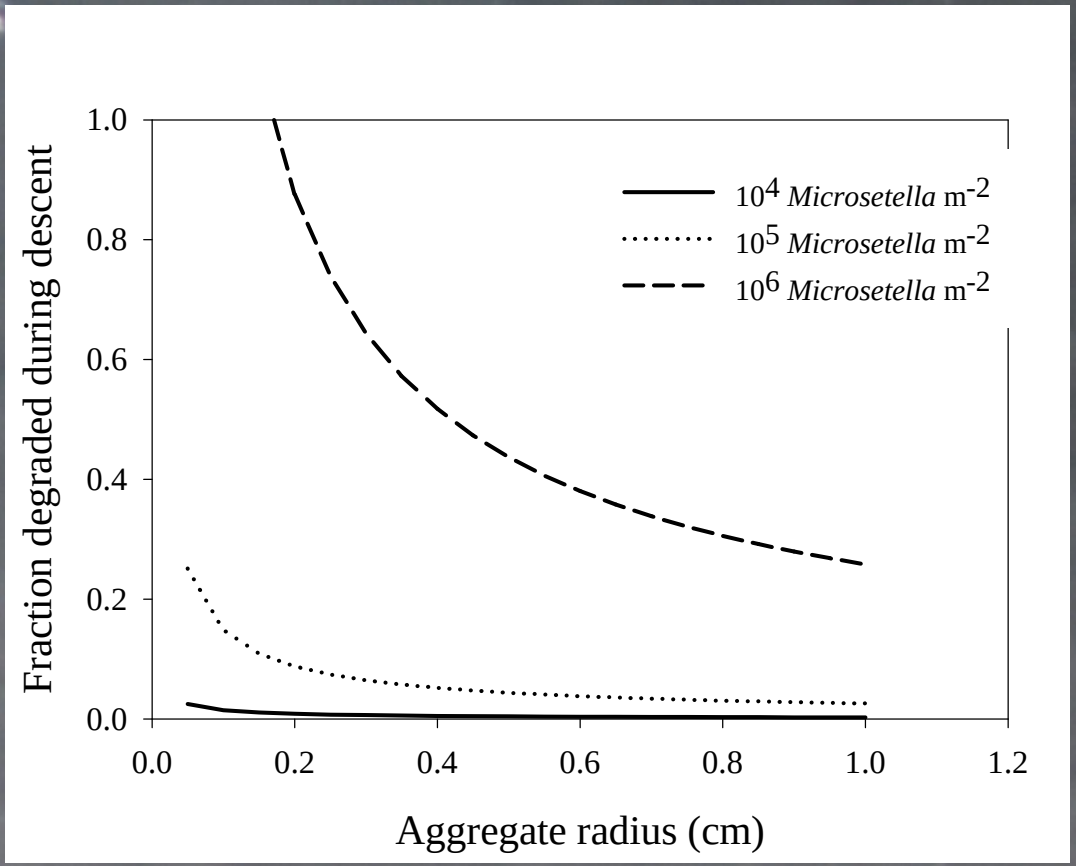
- If aggregate density is low or residence time short, phytoplankton aggregates will give a higher ingestion rate (higher encounter rate)

- Pellets might not be of great interest

So when would small copepods be important?

$$\kappa(a) = \frac{E(a)\delta^{-1}\cdot i}{POC(a)} = \frac{\beta(a)A_{Cop}\cdot\delta^{-1}\cdot i}{POC(a)\cdot u(a)}$$

E = encounter rate
δ = residence time
i = ingestion rate
A = abundance
u = sinking rate
a = radius



Koski, Kiørboe, Takahashi 2005

So when would small copepods be important?

Godthåbsfjord

- Max. concentration: 100 ind. l^{-1} at the surface (30m)
- Average feeding rate: 0.3 µg C $ind.^{-1}$ d^{-1}

900 mg C m^{-2}

Photo: Thomas Juul Pedersen