Classical food webs and the microbial loop off Western Australia: A new method to estimate simultaneously micro- and mesozooplankton grazing impacts

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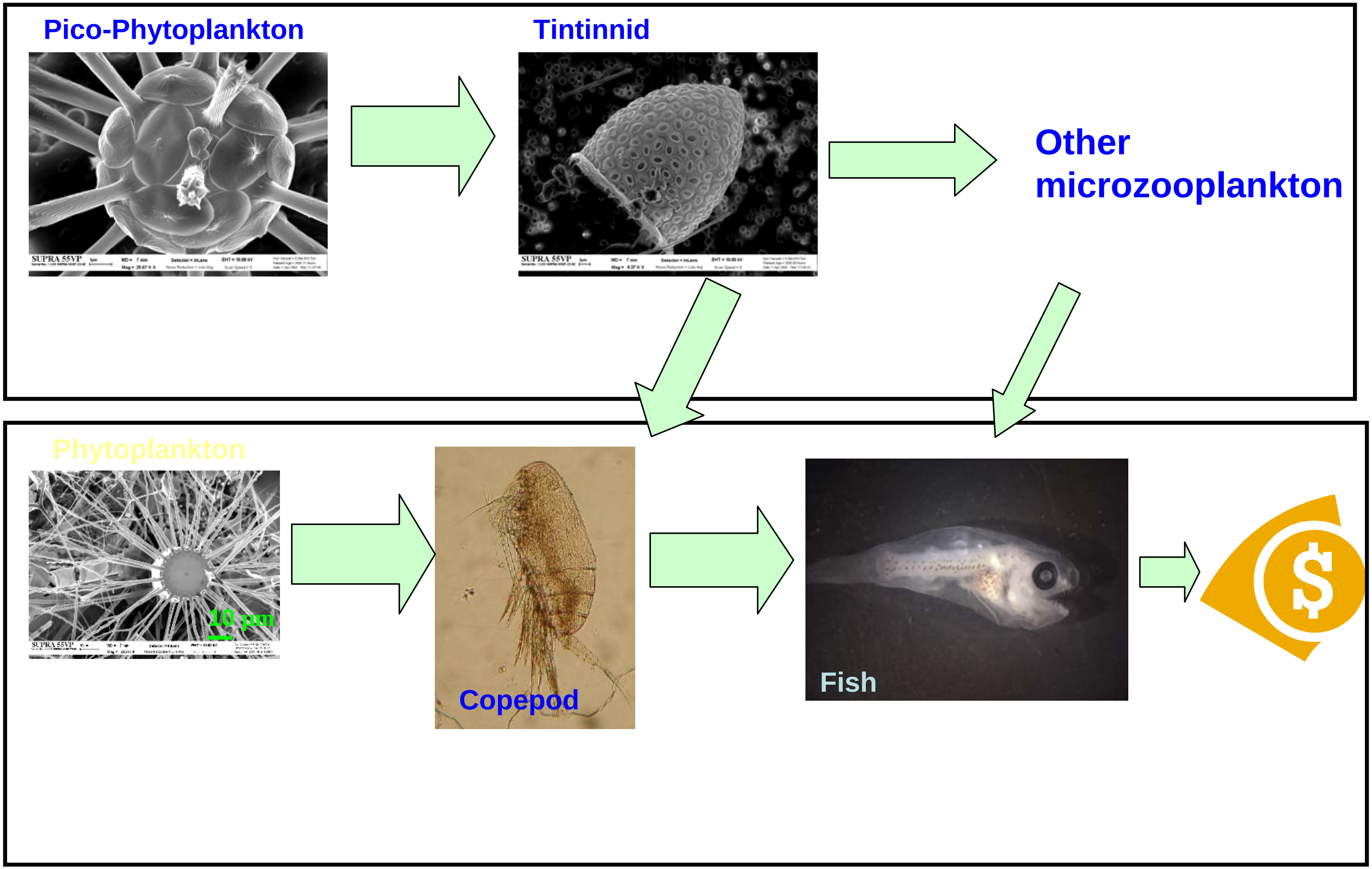
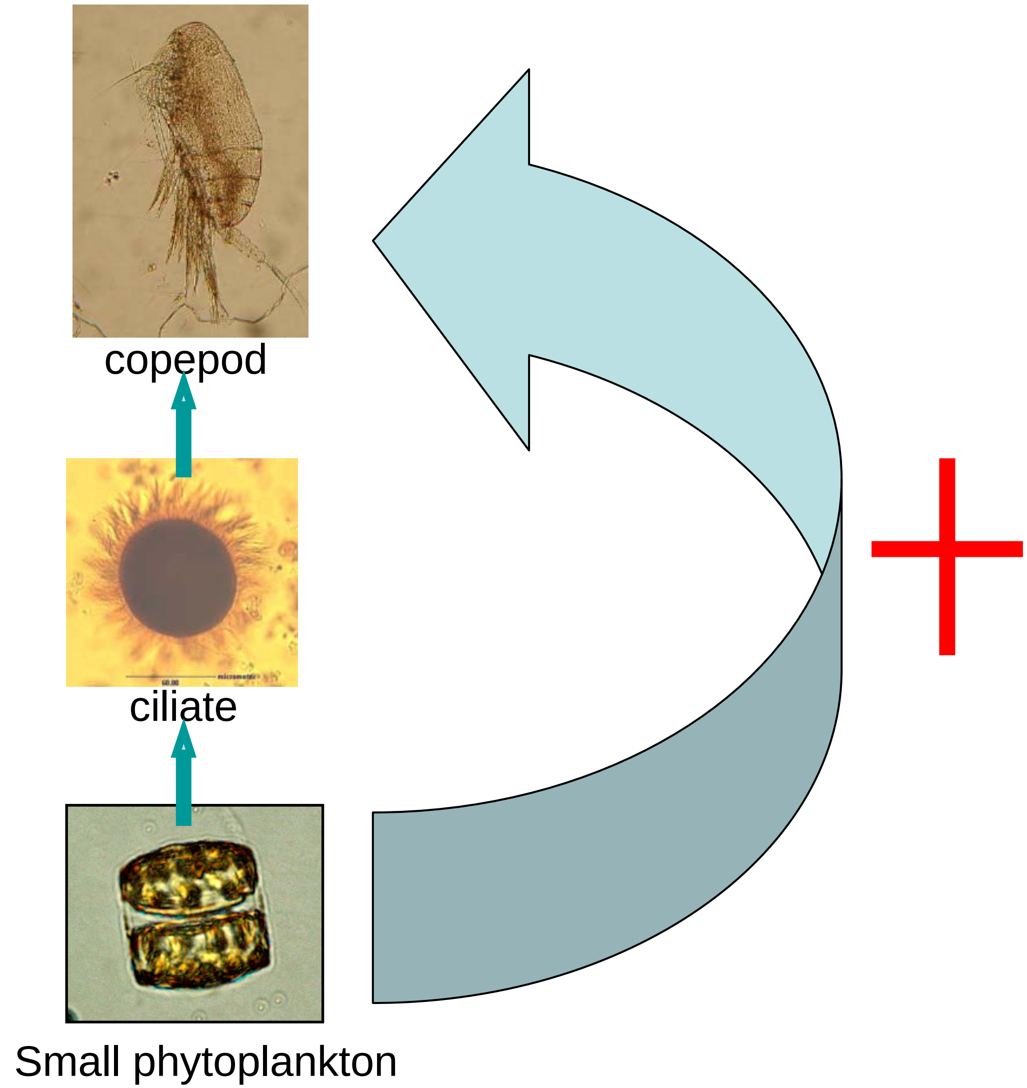
Classic and microplankton food webs



Trophic cascades

Copepods may release small phytoplankton from grazing pressure by intermediate consumers (protists)

Trophic cascades may be strong in oligotrophic waters where the dominant phytoplankton are too small (<5µ) to be directly consumed by most mesozooplankton



How to measure simultaneously micro- & mesozooplankton grazing + interactions?

How can the effects of micro- and mesozooplankton grazing + their predator-prey interactions be estimated in an experiment?

Conventional solution:

Two sets of experiments:

1. Mesozooplankton

(Incubation method (Frost, 1972))

2. Microzooplankton

(Dilution method (Landry and Hassett, 1982))

But this is tedious & time-consuming

Can we determine:

- micro and mesozooplankton grazing on phytoplankton

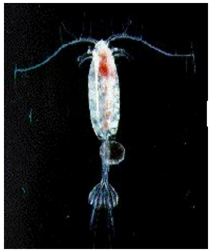
and

- mesozooplankton predation on microzooplankton

from a single experimental method?

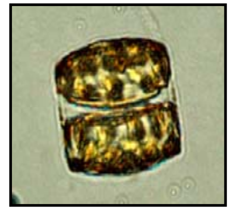
Grazing experiments

T_o – natural assemblages of plankton from surface water



mesozooplankton

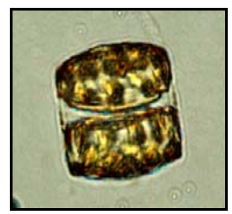
microzooplankton



phytoplankton

Control (24 hrs) Mesozoo excluded (= 0)

microzooplankton



phytoplankton

Treatments (24 hrs) from T_o with
natural assemblages of mesozooplankton
manipulated, varying concentrations in 3 treatment levels

Mesozooplankton

- short vertical tows from 0 – 5 m depth

Phytoplankton and microzooplankton

- bucket sampling

Incubation in ambient temperature and light

Measured:

Phytoplankton: Chl a and HPLC

Microzooplankton: abundance and biomass

Mesozooplankton: abundance and biomass

Feeding Rates

$P_t = P_0 \exp [(G_p - I_{zp} Z) \Delta t]$ (Frost 1972)

P_t & P_0 - phytoplankton concentrations at start and end of experiment

Δt - duration of experiment (e.g. 24 hr)

G_p – growth rate of phytoplankton

I_{zp} – Ingestion or grazing rate of mesozooplankton on phytoplankton

Z – Mesozooplankton concentration

Modified for microzoo + mesozoo grazing:

$P_t = P_0 \exp [(G_p - I_m M - I_{zp} Z) \Delta t]$

$M_t = M_0 \exp [(G_m - I_{zm} Z) \Delta t]$

I_m – Grazing of microzooplankton on phytoplankton

M – Microzooplankton concentration

G_m – Growth rate of microzooplankton

I_{zm} – Grazing of mesozooplankton on microzooplankton

How can we solve for Gm, Im, I_{zm} & I_{zp} from one set of incubation experiments?

1) $P_t = P_0 \exp[(G_p - I_m M - I_{zp} Z)\, \Delta t]$

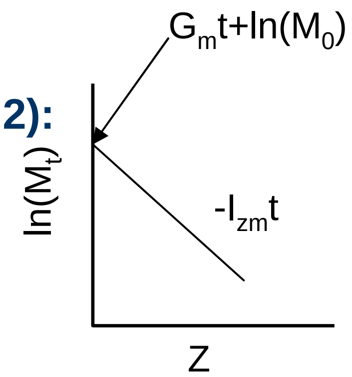
2) $M_t = M_0 \exp[(G_m - I_{zm} Z)\, \Delta t]$

In control, Z = 0, solve for G_m from Eq 2:

1) $M_t = M_0 \exp[(G_m)\, \Delta t]$

2) Solve G_m from intercept in regression (Eq 2):

$\ln(M_t) = [G_m t + \ln(M_0)] - I_{zm} Z t$



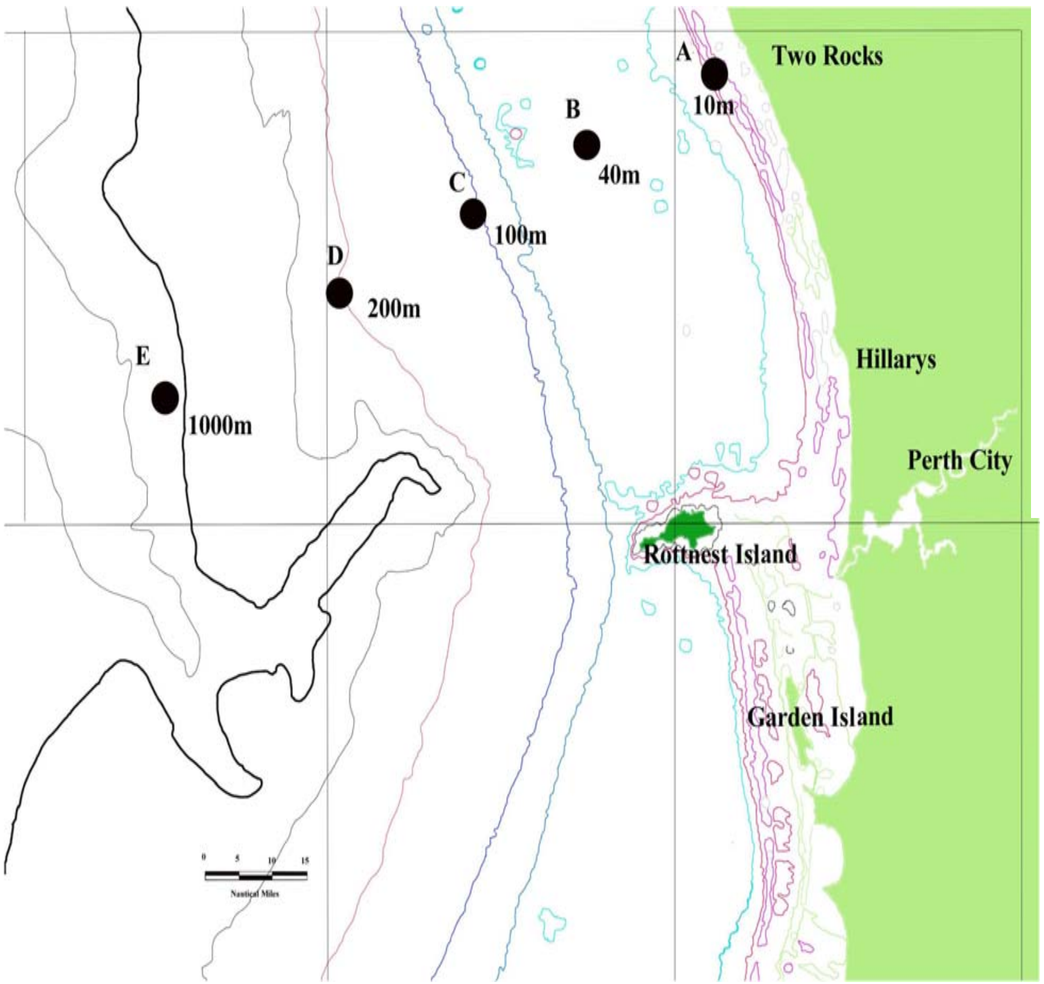
Solve for I_m

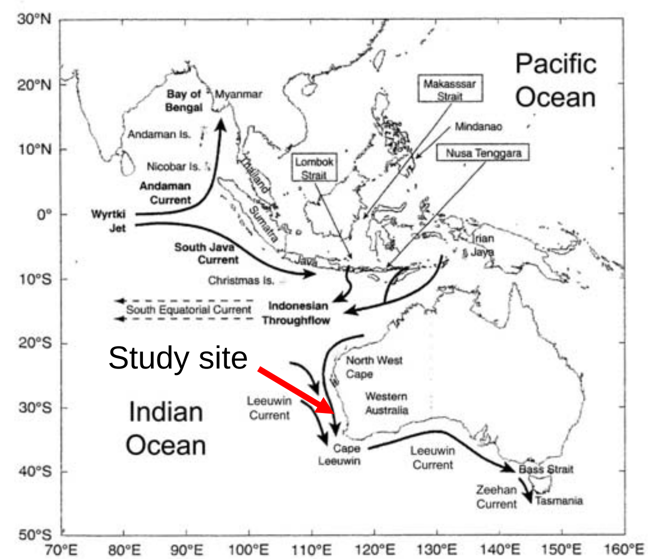
1) $I_m \simeq G_m / 0.33$ (0.33: growth efficiency)

2) In control, $P_t = P_0 \exp[(G_p - I_m M)\, t]$ (G_p estimated from C^{14} incubations)

I_{zp} & I_{zm} – from slopes of linearized Eq 1) & 2)

Study site





Stations:

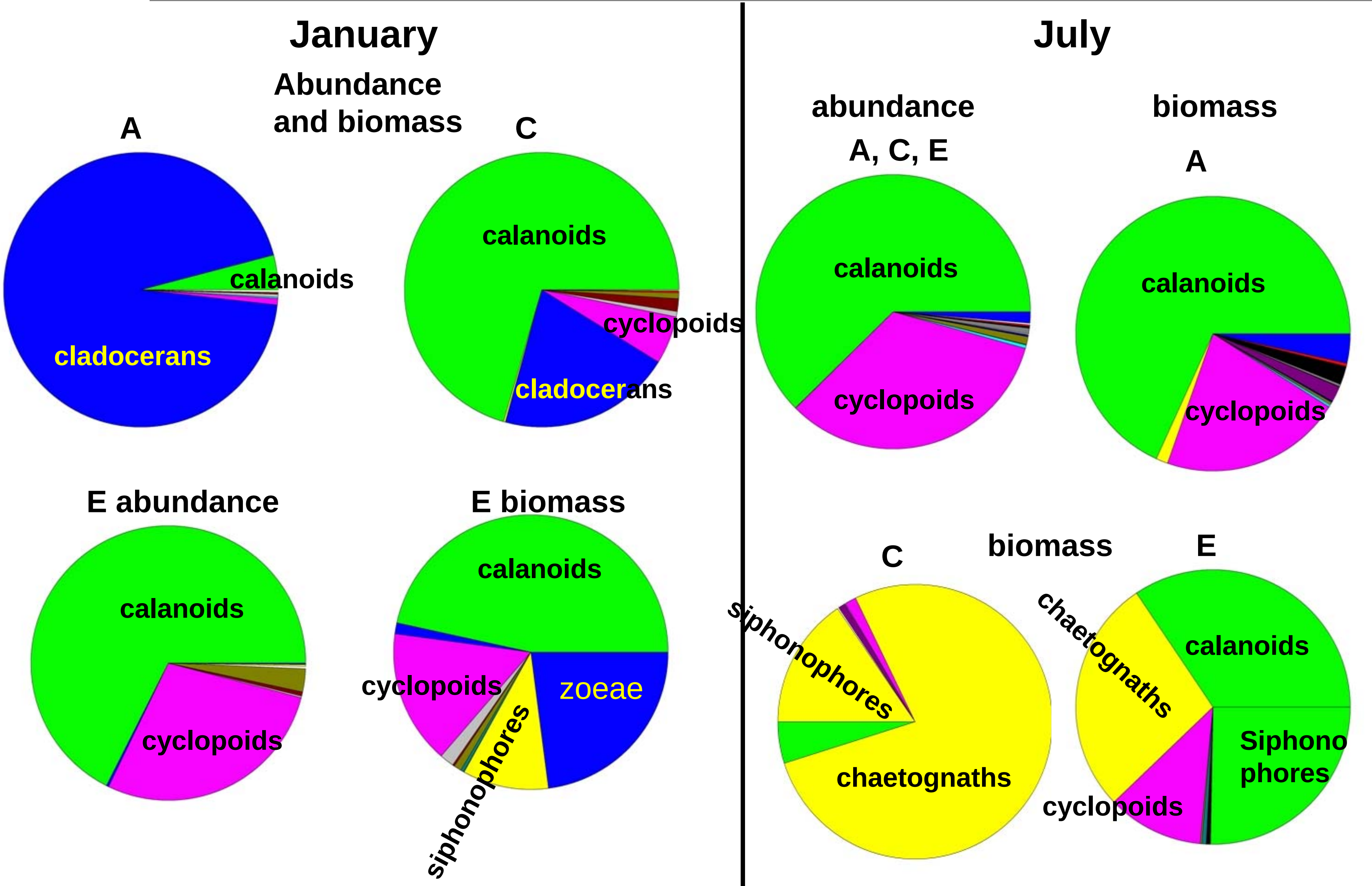
A - 10 m

C - 100 m

E – 1000 m

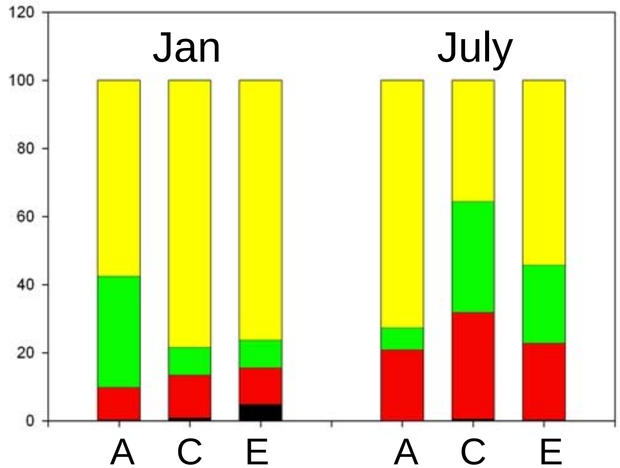
Quarterly sampling over 3 years

Composition of grazers

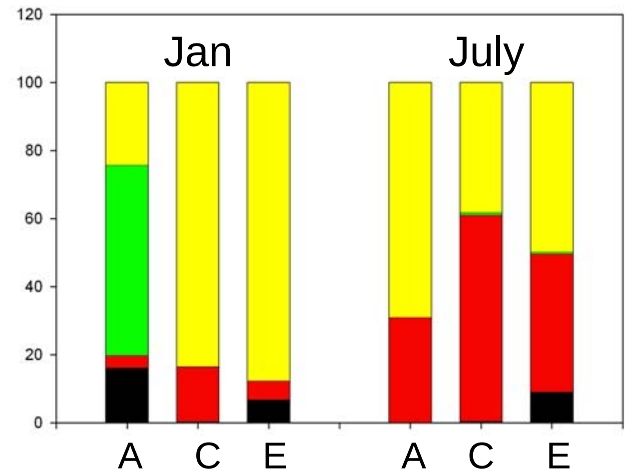


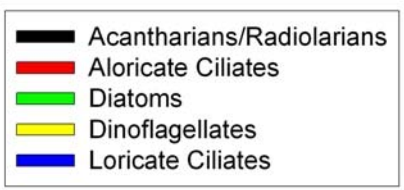
Composition of prey (microzooplankton & phytoplankton)

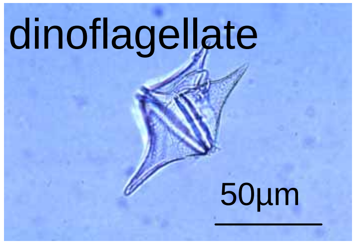
Abundance

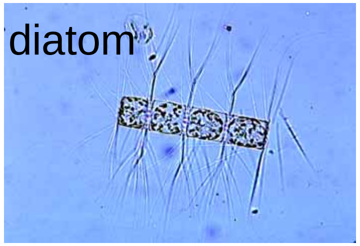


Biomass



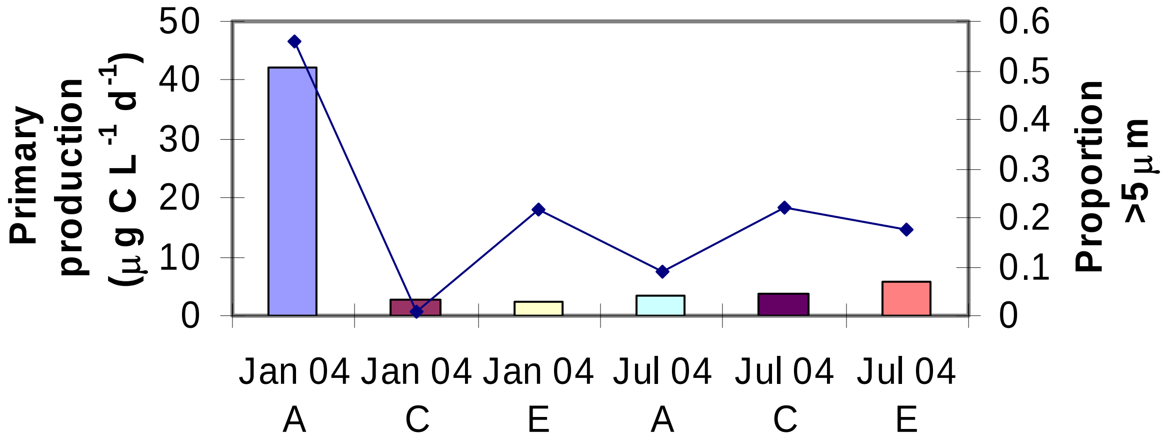




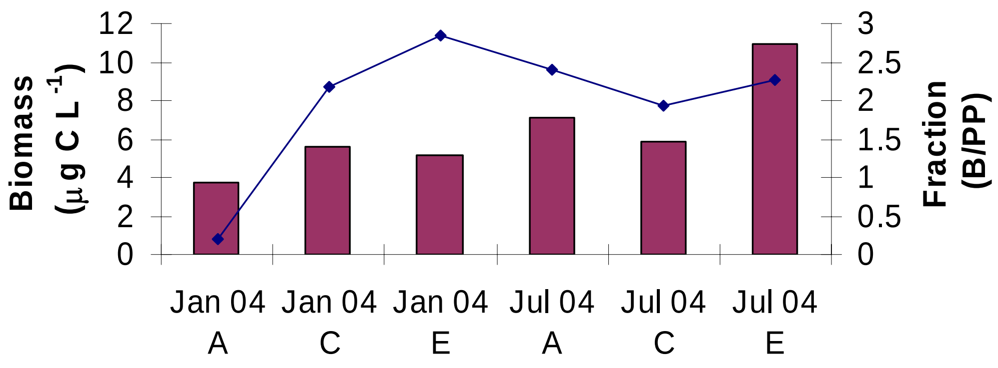


Phytoplankton production & size structure, Microzooplankton biomass

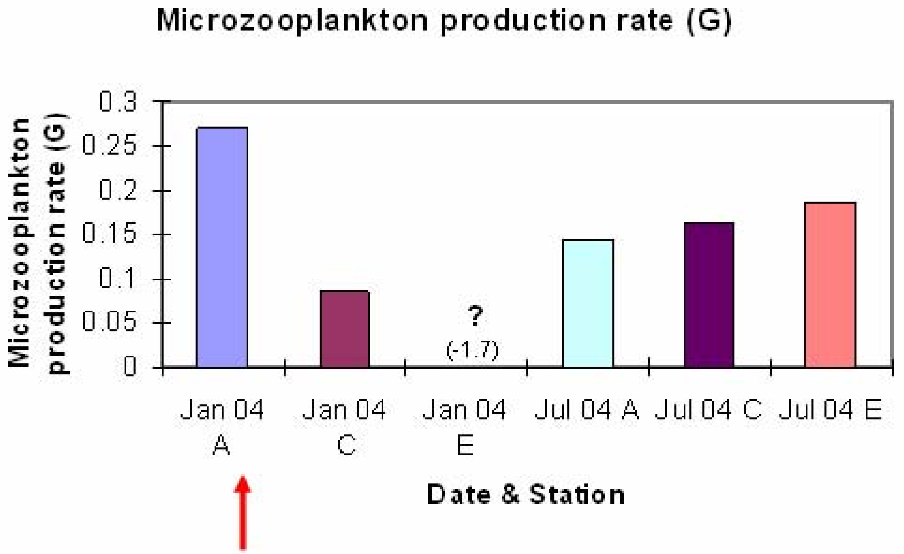
Primary production (bars) & proportion > 5 um (line)

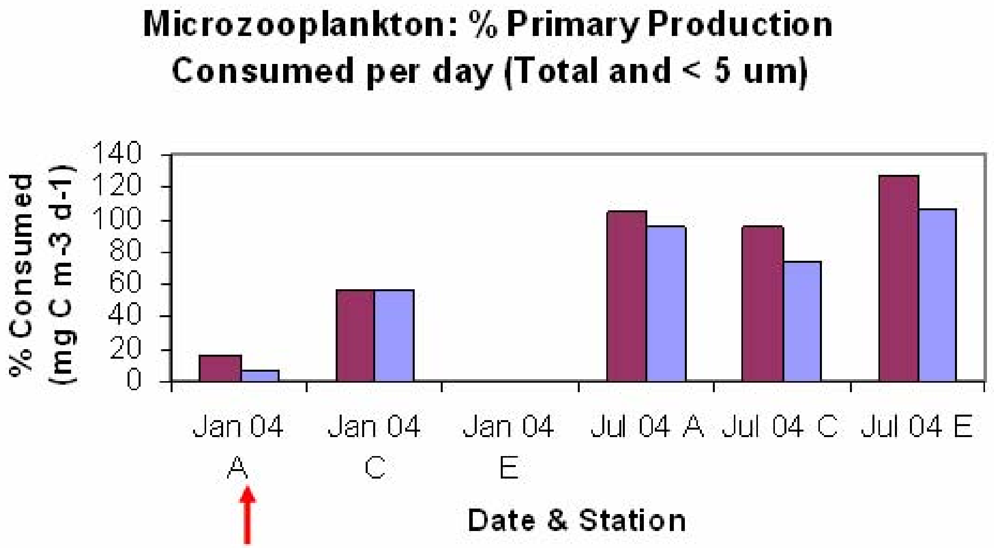


Microzooplankton biomass (control) (bars) and fraction of daily primary production (line)



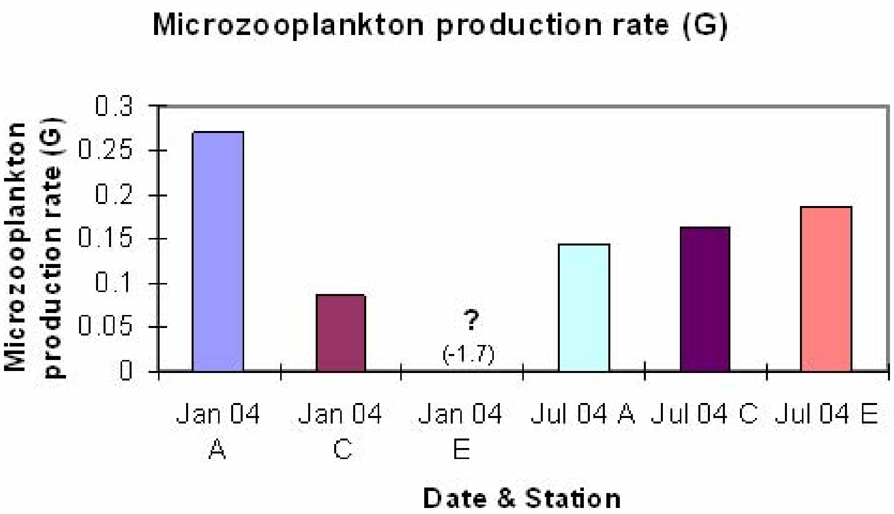
Microzooplankton production & grazing

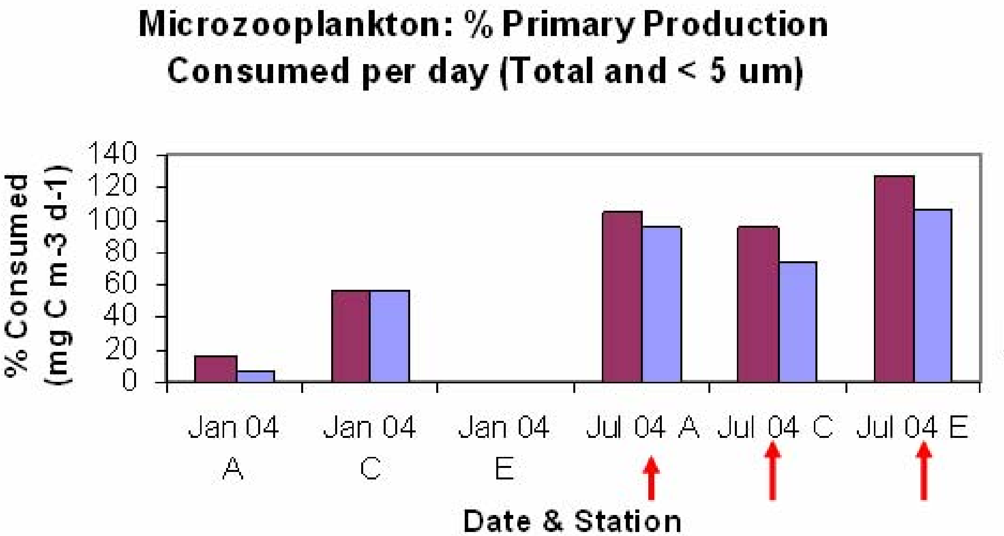




- **Microzooplankton production highest & % primary production consumed lowest where biomass was the smallest proportion of small phytoplankton production**

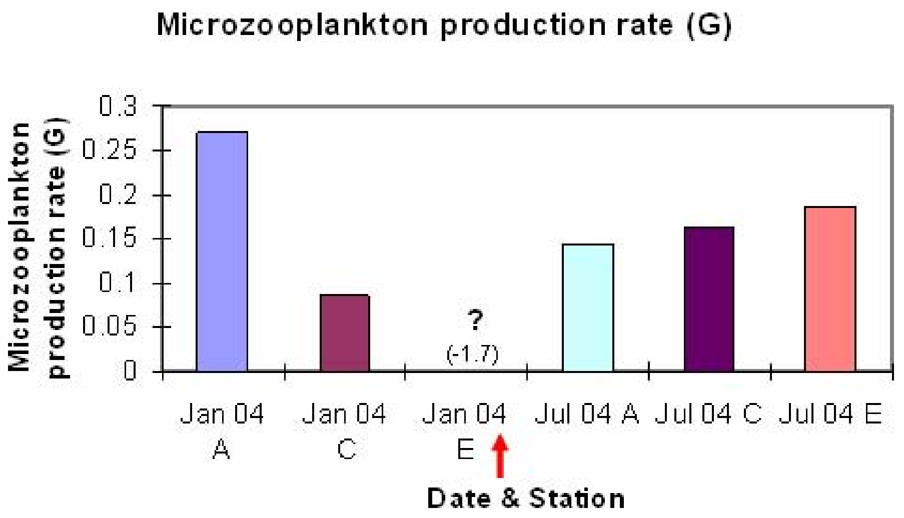
Microzooplankton production & grazing

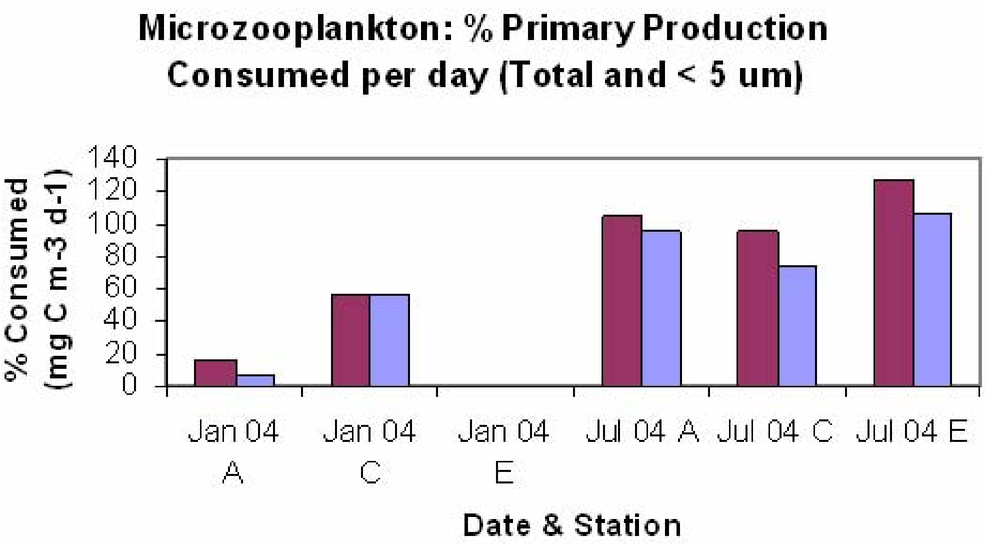




- **Microzooplankton production highest & % primary production consumed lowest where biomass was the smallest proportion of small phytoplankton production**
- **~100% primary production consumed where B/PP ~ 2.0**

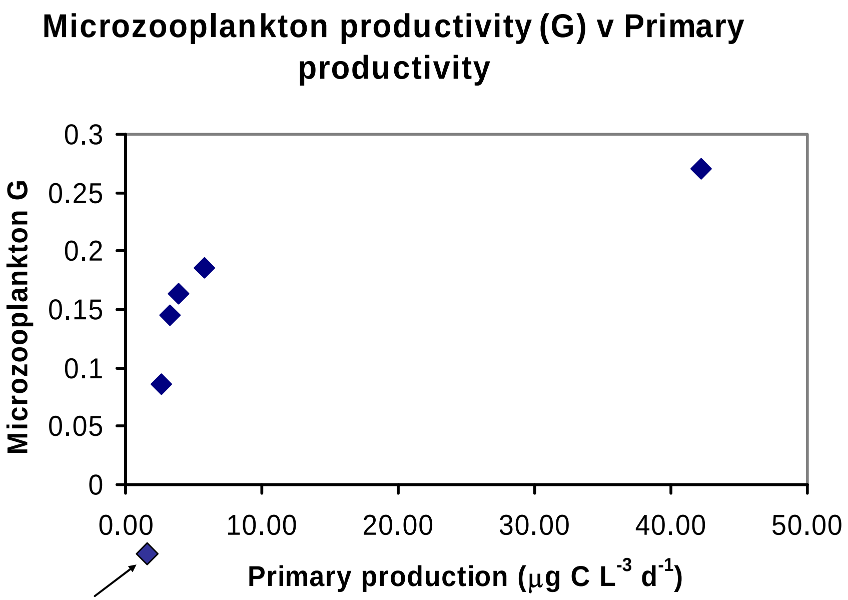
Microzooplankton production & grazing

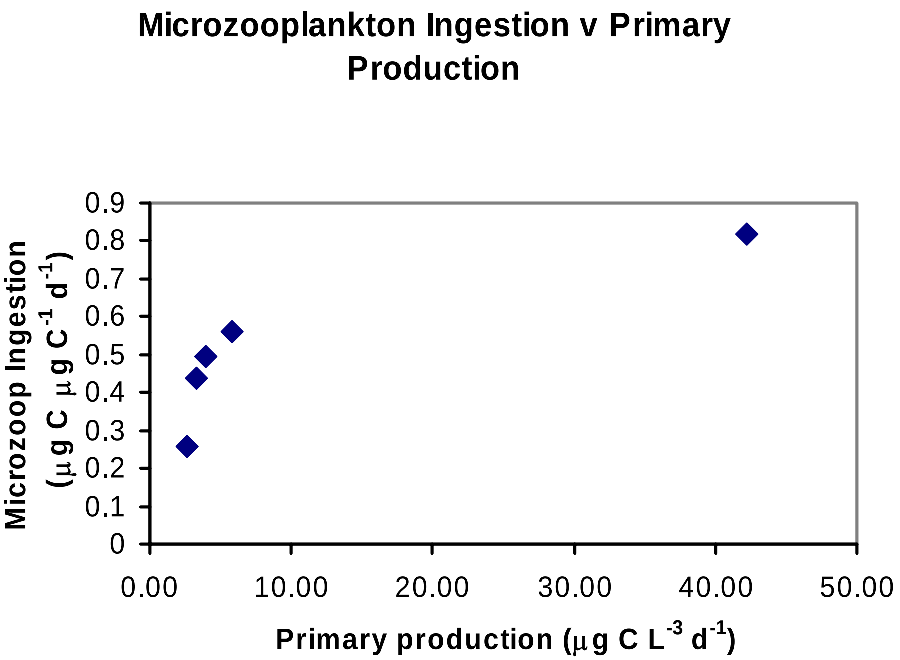




- Microzooplankton production highest & % primary production consumed lowest where biomass was the smallest proportion of small phytoplankton production
- ~100% primary production consumed where B/PP ~ 2.0
- Jan 04 Stn E: Was microzooplankton too high a proportion of the primary production? Artifact?

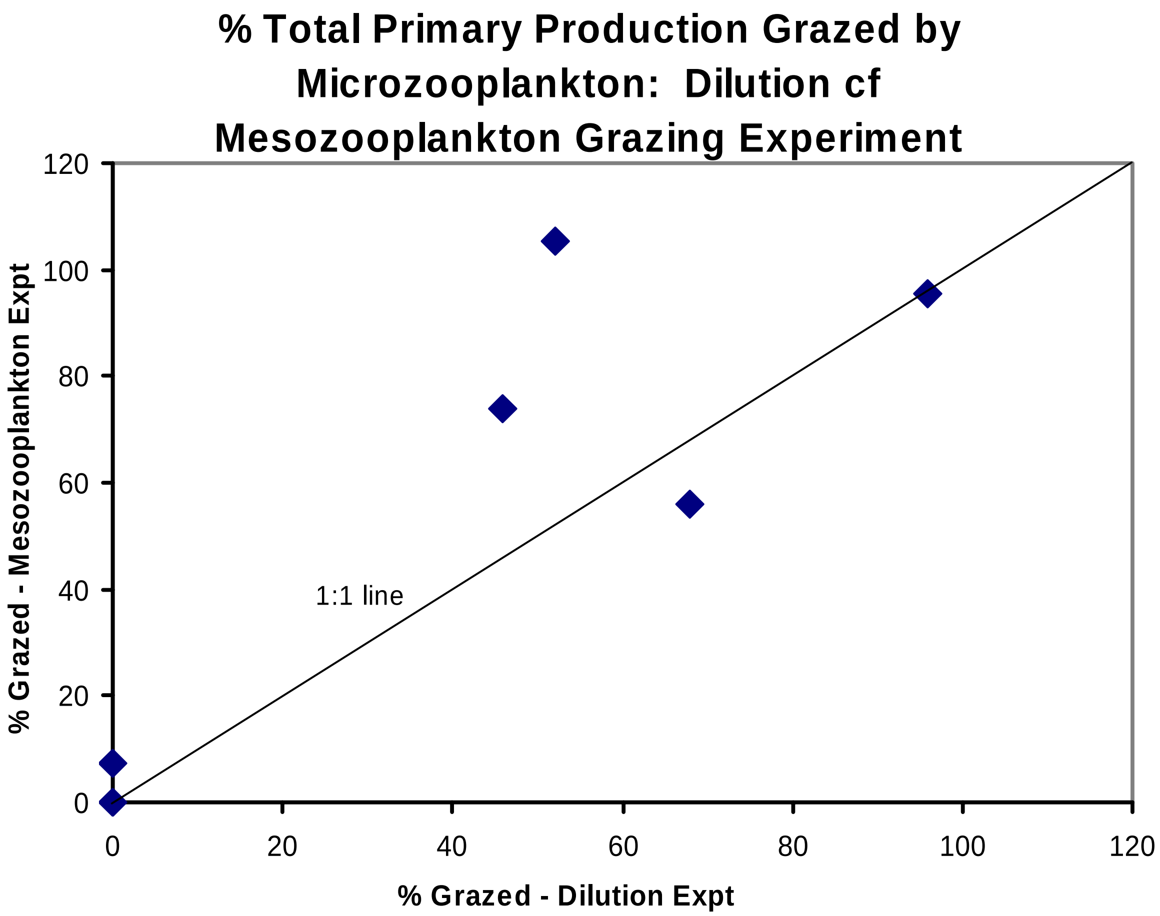
Microzooplankton growth rate & ingestion: relation to primary production



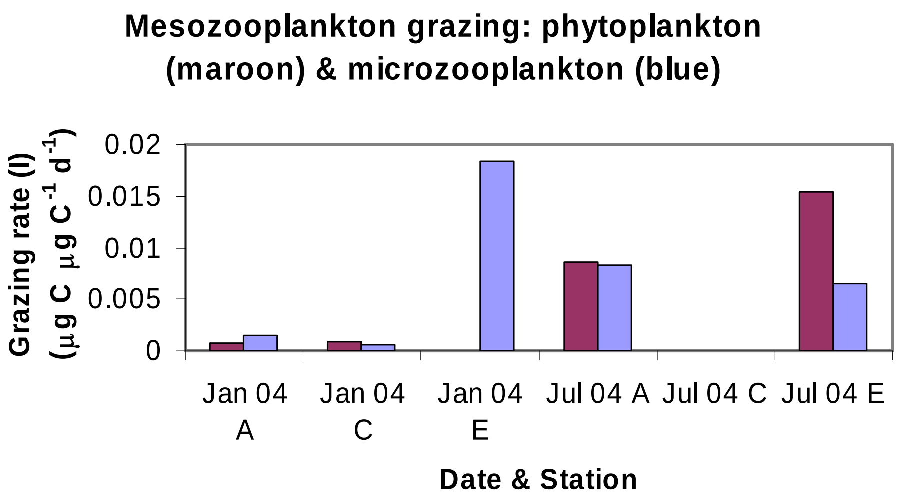


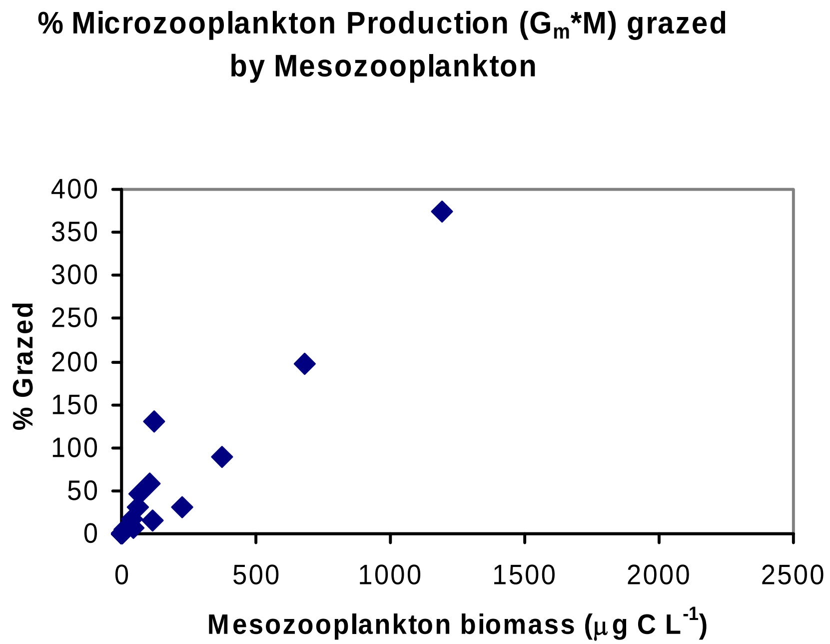
Apparent asymptotic relationship between microzooplankton rates of production & ingestion and primary productivity

Comparison of mesozooplankton grazing & dilution experiments



Mesozooplankton grazing

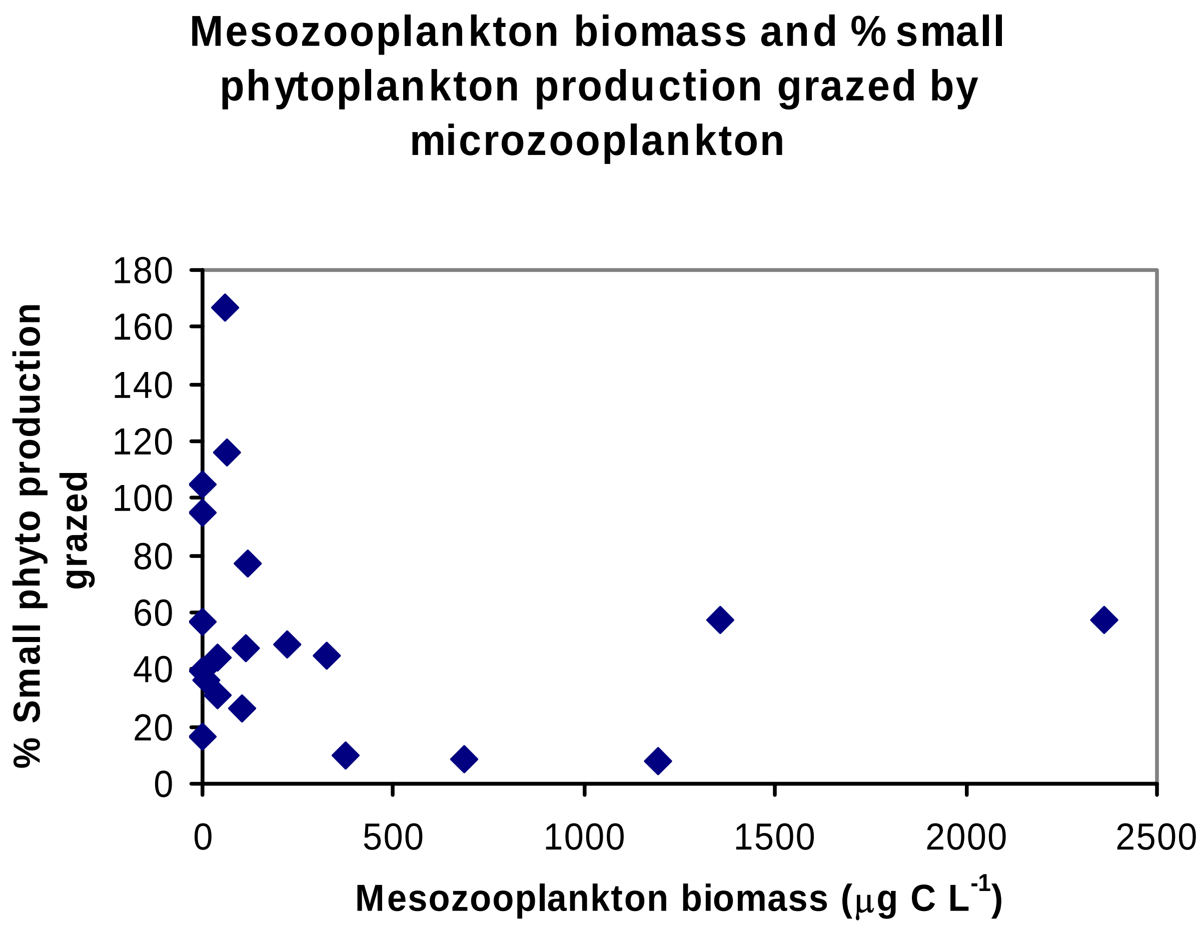




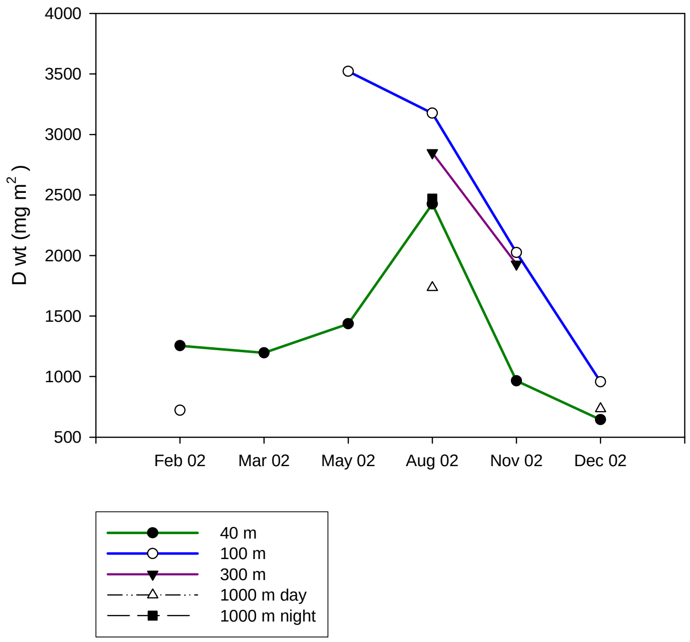
Mesozooplankton grazing (I) appears variable, low

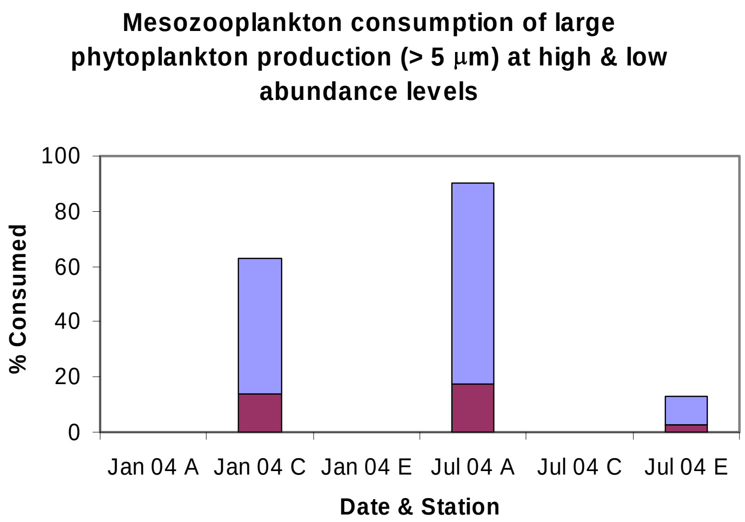
But it has a significant impact on microzooplankton production – at the experimental densities

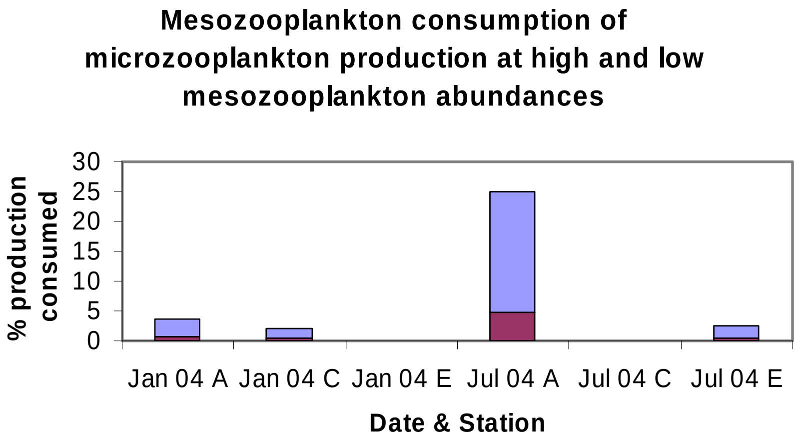
Trophic cascade?



Mesozooplankton grazing impacts at ambient prey densities







Natural prey densities:

2 – 25 μg C L^{-1}

Grazing impacts appear modest

Consistent with Calbet

Summary

Modified Frost equations used to calculate microzooplankton grazing (I), productivity (G), and mesozooplankton grazing rates on phytoplankton and microzooplankton from one set of experiments

Good agreement between microzooplankton grazing rates estimated from dilution and mesozooplankton grazing experiments

Microzooplankton grazed most of phytoplankton production (phytoplankton mostly in $< 5\ \mu m$ fraction)

Mesozooplankton grazing imposed a trophic cascade in experiments, but grazing rates were low, with little impact at natural grazer densities.

Acknowledgements

James McLaughlin - identification of microzooplankton

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