

# Zooplankton Feeding Experiments

## Description of methods' details



- Feeding is the main route for the transfer of energy and material from lower to higher trophic levels within communities.
- Its quantification is a key factor when trophic interactions are studied
- However, quantification of feeding behavior is not necessarily straightforward because the methods used must be appropriate for the specific organism studied.
- When selecting an appropriate method to measure feeding rate it is therefore important to define clearly the objective and the complexity level.
- Knowledge about the feeding mechanism of the studied species together with information on the size of prey and predator is important when designing an experiment with a minimum of constraining factors.

## Expression of zooplankton feeding rates

Zooplankton feeding is usually expressed as clearance rate, ingestion rate, or daily ration.

There are many ways these feeding rates have been calculated, making it difficult to compare the results of different investigations. In addition, scientists commonly use conversions between measurements and carbon, nitrogen or energy content, amplifying the difficulty in comparisons.

- **Clearance rate (ml ind<sup>-1</sup>d<sup>-1</sup>)**

This is formerly known as filtration rate. It is defined as the volume cleared by a consumer organism per unit time and per consumer or consumer mass. This corresponds to the volume of water processed if we assume 100% capture efficiency and a homogenous food concentration in the experimental vessel.

$$CR = [\ln (C_t/C_0) - \ln (C_t/C_0)] \times V/(t \times n)$$

C number of cells in time t and 0, V the volume of water, t total incubation time and n copepod number used for the experiment

- **Ingestion rate**

IR is the amount (number or mass units) of ingested food per unit of time and predator. If number of food items is used, information on mass per unit of food should also be given. It is recommended to use carbon as a general expression of mass.

$$I = CR \times C_0$$

CR the clearance rate and  $C_0$  the initial concentration of the food

- **Daily ration**

**Daily ration (DR) is the mass of food ingested per day, expressed as a percentage of predator body mass (B):**

$$DR = I \times 24 / (B \times t) \times 100\%$$

The daily ration is a valuable concept for two main reasons:

- 7) It is easy to compare the feeding potential of different sized predators by a direct ranking of their DR
- 8) The total daily consumption may be calculated by multiplying the biomass predator population by its DR.

## **Methodological approaches**

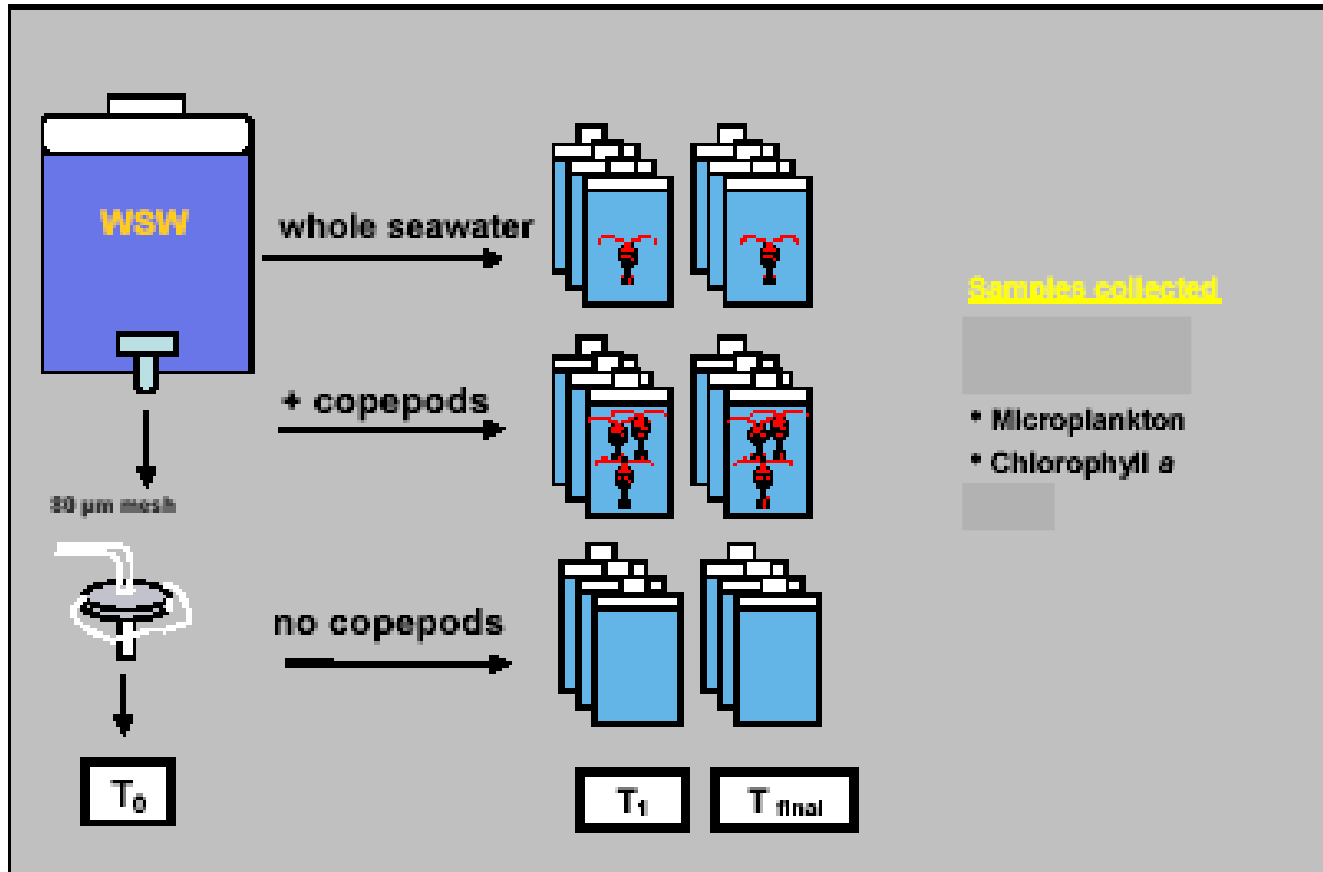
The high diversity within the zooplankton assemblages makes it impossible to present methods suitable for all kind of organisms and the investigator has to critically evaluate which constraints the target organism will give to the potential method

- Empirical relationships
- Gut fluorescence
- Methods based on budgets of material or energy
- Radioisotope tracers
- Biochemical indices
- Food removal methods

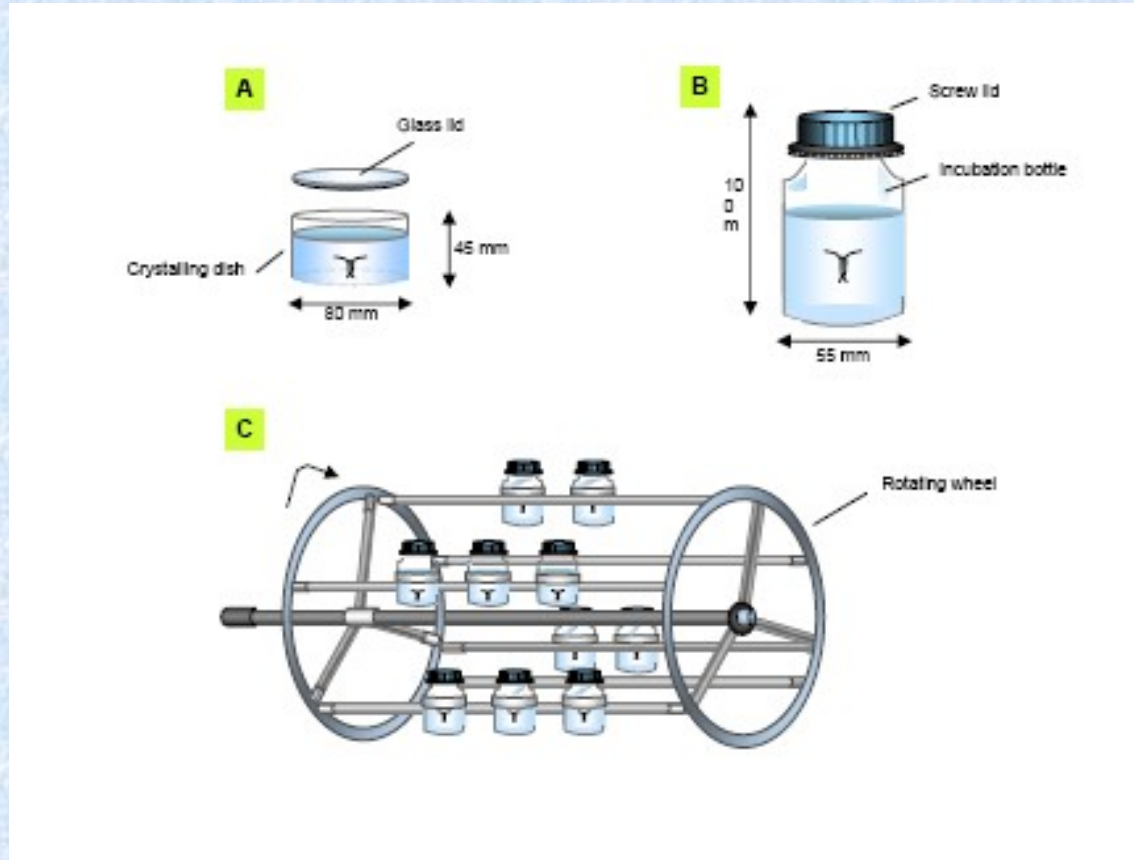
## Food removal methods

- This method involves incubating zooplankton in bottles with food for a fixed length of time, measuring the decrease in food concentration compared to that in control bottles with no grazers, and thus calculating the feeding rate.
- The incubation method is a simple direct method to estimate zooplankton grazing on natural plankton assemblages and it is the one longest in use (Gauld, 1951; Paffenhofer, 1988).
- Despite the “bottle effect” such as stress of capture, possibly unnatural food sources, reduced turbulence, crowding of grazers, particle generation by grazing copepods, nutrient enrichment (ammonium excretion) and enhanced growth of algae assemblages compared to control bottles (Roman and Rublee, 1980; Peters and Downing, 1984) that may lead to an underestimation of grazing rates is the only available method which allows to quantify the grazing of zooplankton on non phytoplankton prey (Båmstedt et al., 2000).

# EXPERIMENTAL APPROACH

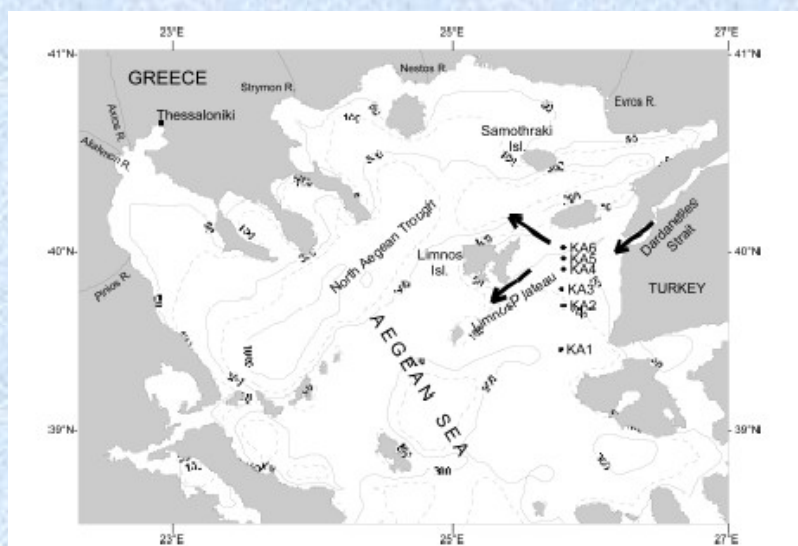


Details are given in the relevant protocol



# Use of the obtained data

## An example from NE Aegean Sea



<u>Stations</u>	<u>Depth</u>	
<b>KA1</b>	320	Mixed DCM
<b>KA3</b>	75	Strong Pycnocline surface & DCM
<b>KA6</b>	80	Weak Pycnocline DCM

Zervoudaki et al. 2007, JPR 29(4), 317-338.

*Table 1: Copepod species used for the incubation experiments performed in April 2000 and the number of copepods incubated in the three experiments listed in descending order of biomass*

Stations	Copepod species	Number of animals per bottle	Mean carbon biomass ( $\mu\text{gC ind}^{-1}$ )
KA1	<i>C. helgolandicus</i>	$3 \pm 1$	$58 \pm 8$
	<i>C. typicus</i>	$14 \pm 1$	$9 \pm 0.3$
	<i>A. clausi</i>	15	$3 \pm 0.1$
	<i>P. parvus</i>	14	$2 \pm 0.1$
	<i>O. media</i>	$29 \pm 3$	$1 \pm 0.2$
KA3	<i>C. typicus</i>	$14 \pm 1$	$8 \pm 0.1$
	<i>A. clausi</i>	$12 \pm 1$	$3 \pm 0.4$
	<i>O. media</i>	$27 \pm 2$	$0.5 \pm 0.1$
	<i>O. similis</i>	$31 \pm 1$	$0.2 \pm 0.002$
KA6	<i>C. typicus</i>	$14 \pm 1$	$7 \pm 0.3$
	<i>A. clausi</i>	$18 \pm 1$	$3 \pm 0.1$
	<i>O. similis</i>	$78 \pm 2$	$0.2 \pm 0.01$

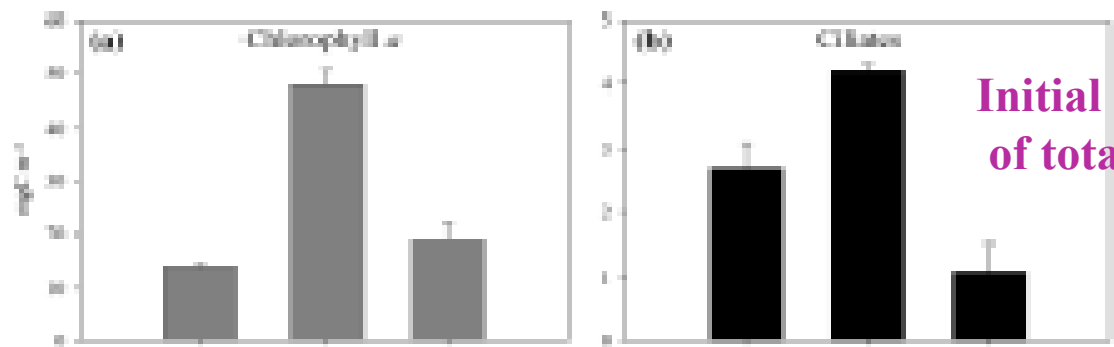
## Estimations

**Copepod clearance rates** on phytoplankton (based on chlorophyll) and ciliates were calculated according to Frost (1972).

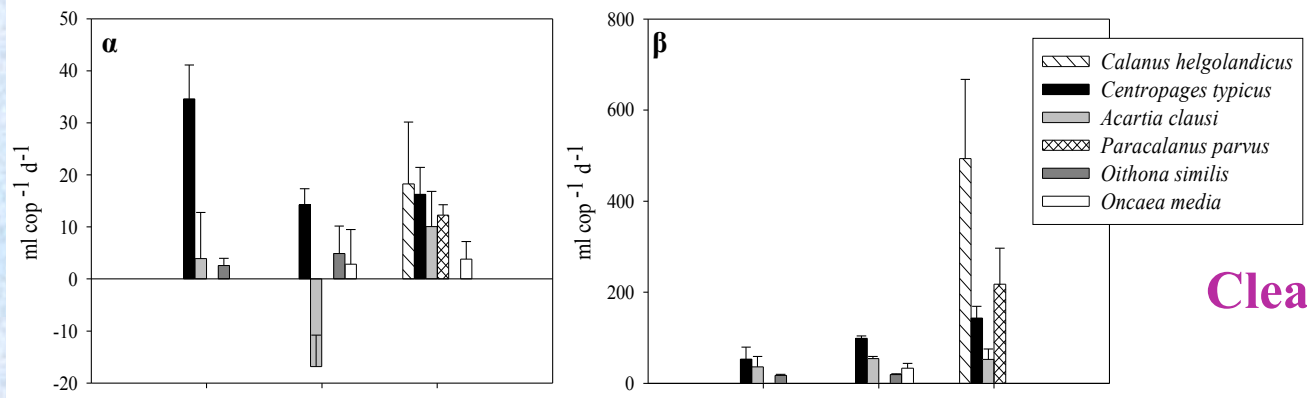
**Ingestion rates** were calculated by multiplying clearance rates by the initial standing stocks.

**The weight-specific clearance** ( $\text{ml } \mu\text{g}^{-1}\text{C d}^{-1}$ ) and **ingestion** ( $\mu\text{gC } \mu\text{g}^{-1}\text{C d}^{-1}$ ) rates were estimated using the mean female carbon weight of the respective copepod species.

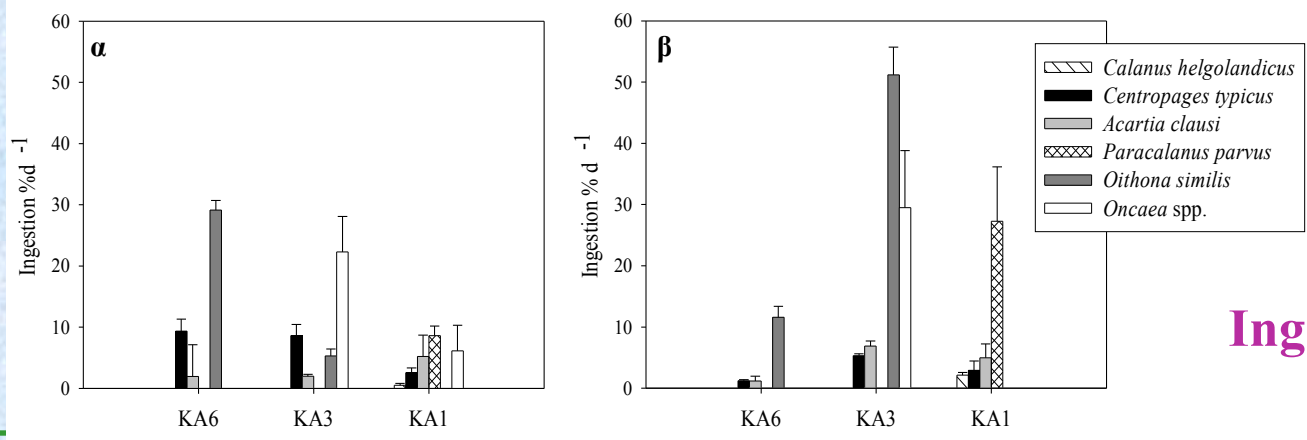
**Copepod community feeding impact** in the water column was calculated as ingestion rate as percentage of standing stocks of phytoplankton and ciliates



Initial concentrations of total CHL α and CILs



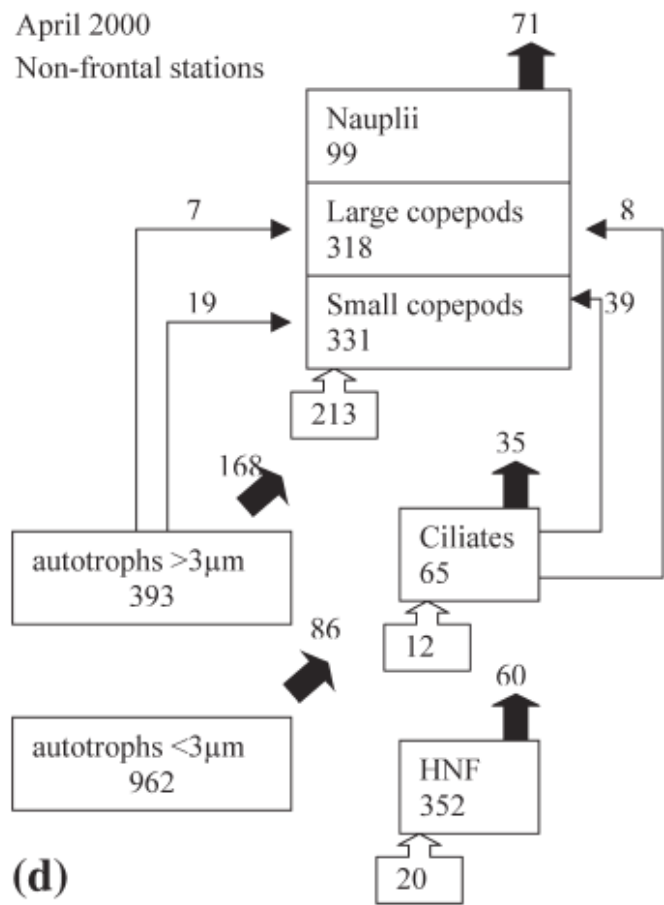
Clearance rates



Ingestion rates

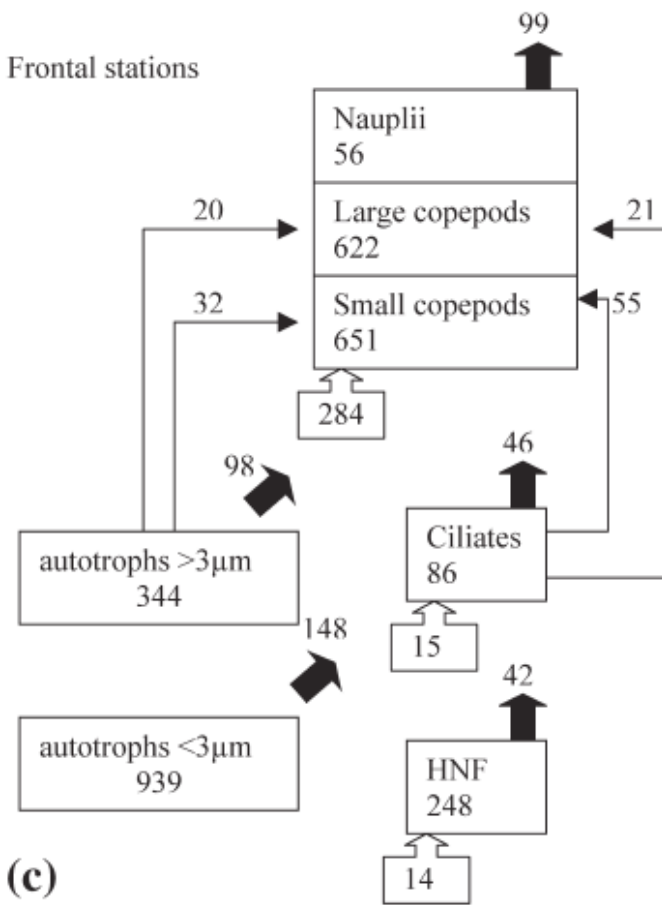
	<i>April 2000</i>	
	<b>Frontal area</b>	<b>Non Frontal area</b>
<b>Biomass mgCm<sup>-2</sup></b>	<b>651</b>	<b>330</b>
<b>Production mgCm<sup>-2</sup> d<sup>-1</sup></b>	<b>62</b>	<b>36</b>
<b>Consumption on Phytoplankton mgC m<sup>-2</sup>d<sup>-1</sup></b>	<b>42</b>	<b>21</b>
<b>Consumption on Ciliates mgC m<sup>-2</sup>d<sup>-1</sup></b>	<b>56</b>	<b>39</b>
<b>%Grazing Impact on Phytoplankton</b>	<b>12</b>	<b>5</b>
<b>% Grazing Impact on Phytoplankton Production</b>	<b>43</b>	<b>24</b>
<b>% Grazing Impact on Ciliates</b>	<b>65</b>	<b>60</b>
<b>% Grazing Impact on Ciliate Production</b>	<b>160</b>	<b>112</b>

April 2000  
Non-frontal stations



(d)

Frontal stations



(c)

## Concluding remarks

- The choice of grazing rate method is dedicated by the scale of the study objective and by the type of zooplankton and food.
- Each method has its specific problems, it is recommended taking all possible steps to reduce artifacts and evaluate potential errors
- Using two approaches is a powerful tool for two reasons
  4. It provides an independently derived cross-check on the results
  5. They inform on contrasting aspects of feeding.
- Despite the list of problems associated with each approach the numerous papers highlight that when the methods are followed carefully and fully there can be a surprisingly good agreement between them (Kiørboe et al. 1985, Peterson et al. 1990, Zervoudaki et al. 2007).