# Metabolism of mesozooplankton across the Benguela upwelling system in terms of ETS and GDH activities

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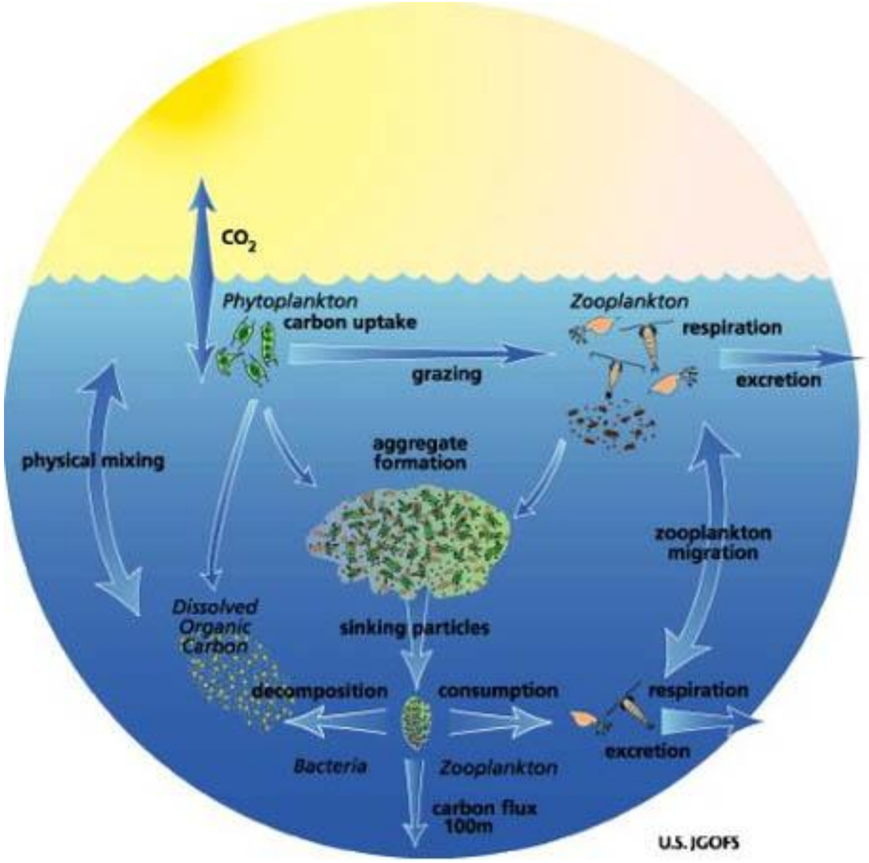
# INTRODUCTION

## Respiration in the ocean ecosystems

**Respiration** is a ubiquitous process which constitutes a key component in the estimation of the carbon flux. However, its magnitude in ocean ecosystems remains uncertain (Del Giorgio and Duarte, 2002) due to the difficulty on quantifying *in situ* respiration rates.



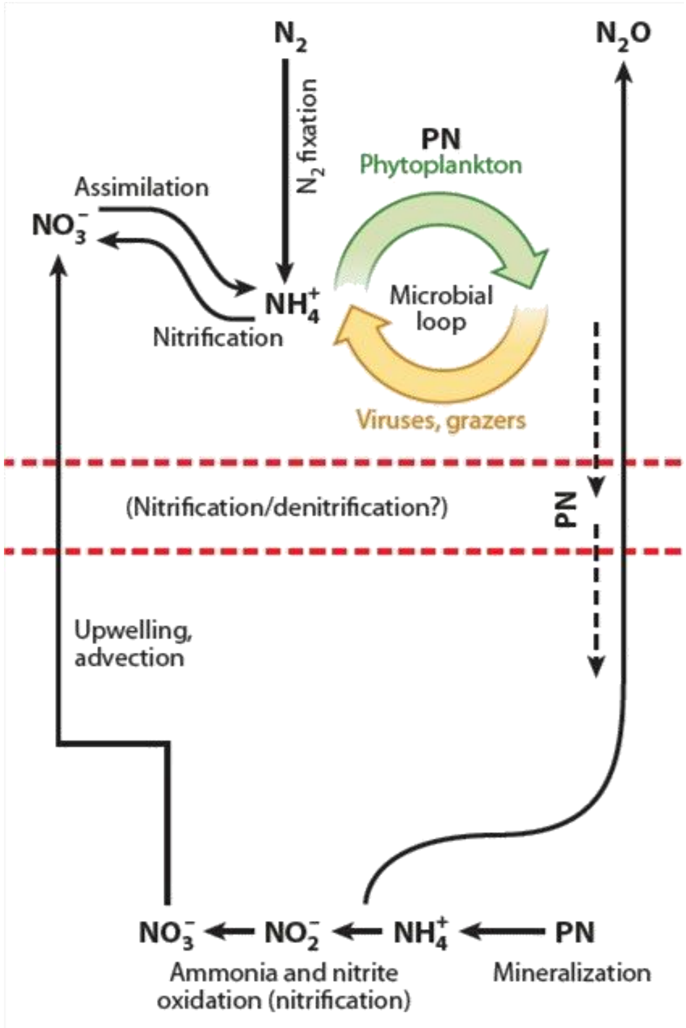

**WATER-BOTTLE INCUBATIONS**

They provide low data acquisition rates and are complicated by organisms manipulation, overcrowding and starvation (Bidigare, 1983).

**Potential measurements such as ETS avoid these methodological artifacts!!**

# INTRODUCTION

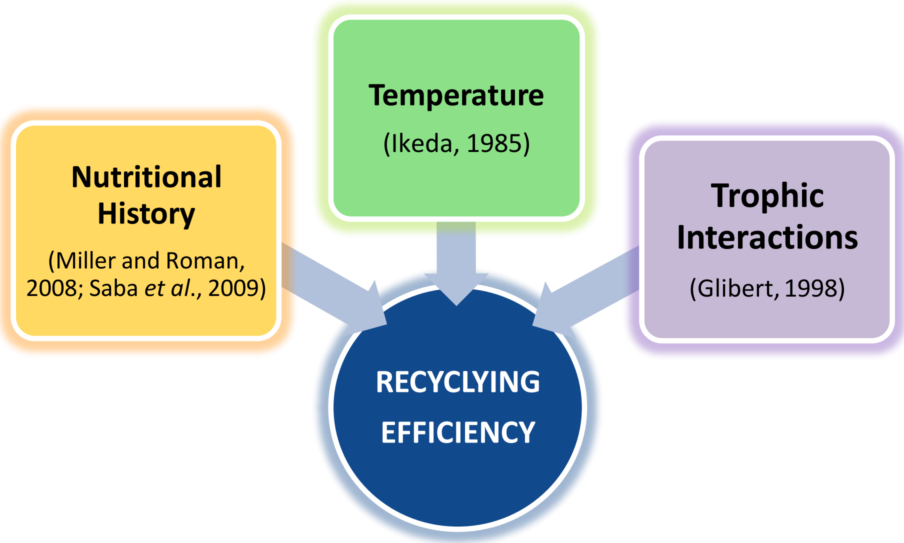
## Importance of $NH_4^+$ in marine systems




Zehr and Kudela (2011)

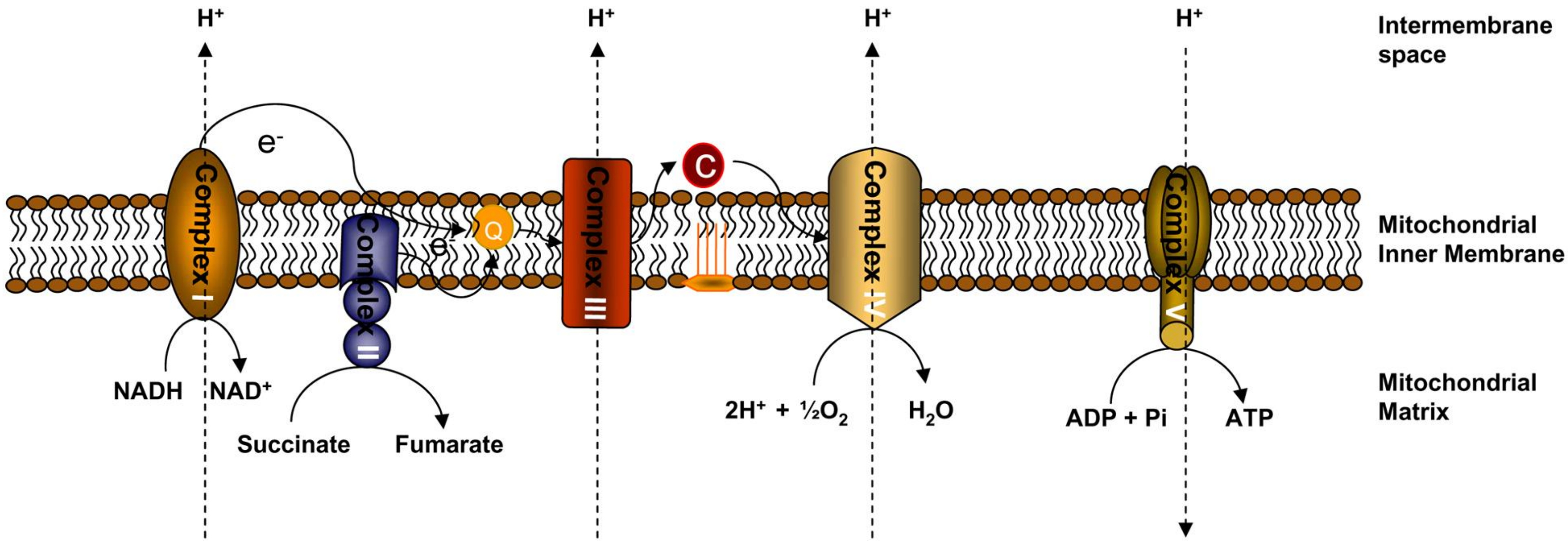
**(I)** $NH_4^+$ is an intermeditate product in decomposition of organic matter, which constitutes **the most reduced form of N**.

**(II)** $NH_4^+$ sustains a **global average of 80 %** of the authotroph's requeriments (Harrison, 1992), with the mesozooplankton responsible for 12 – 23 % (Hernández-León, 2008).



# INTRODUCTION

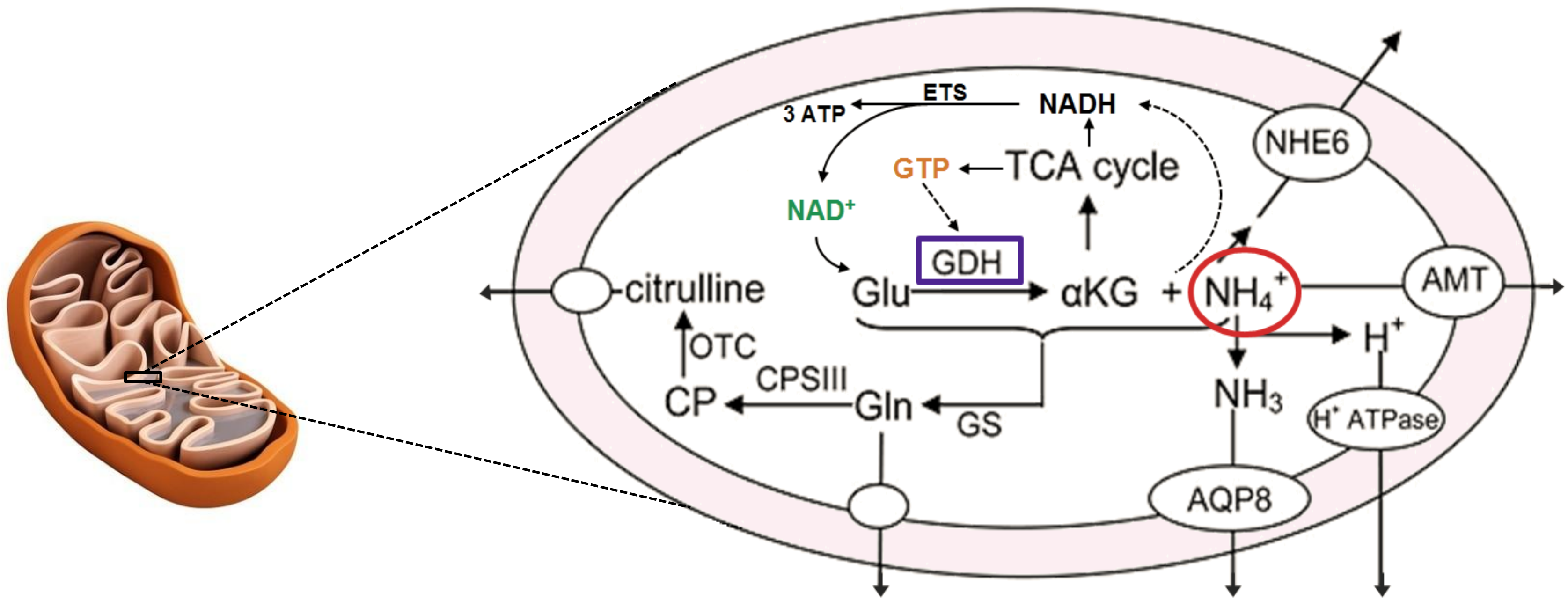
## Electron Transport System as index for $O_2$ respiration




**INTRACELLULAR SUBSTRATES** → $V_{max}$

# INTRODUCTION

## Glutamate dehydrogenase as index for $NH_4$+ respiration



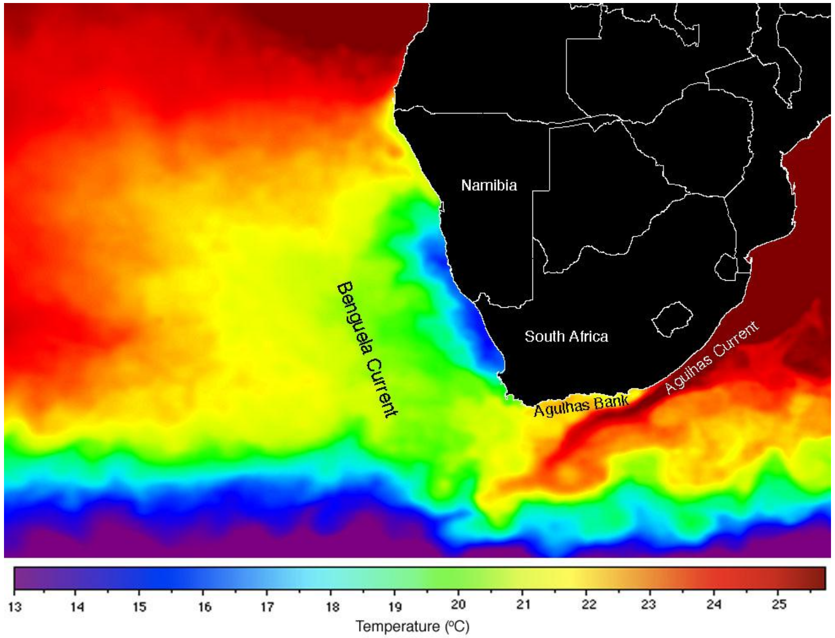

Modified from Yuen and Chiew (2010)

GDH (EC 1.4.1.3) is found in **high levels** in planktonic crustaceans (Regnault, 1987).

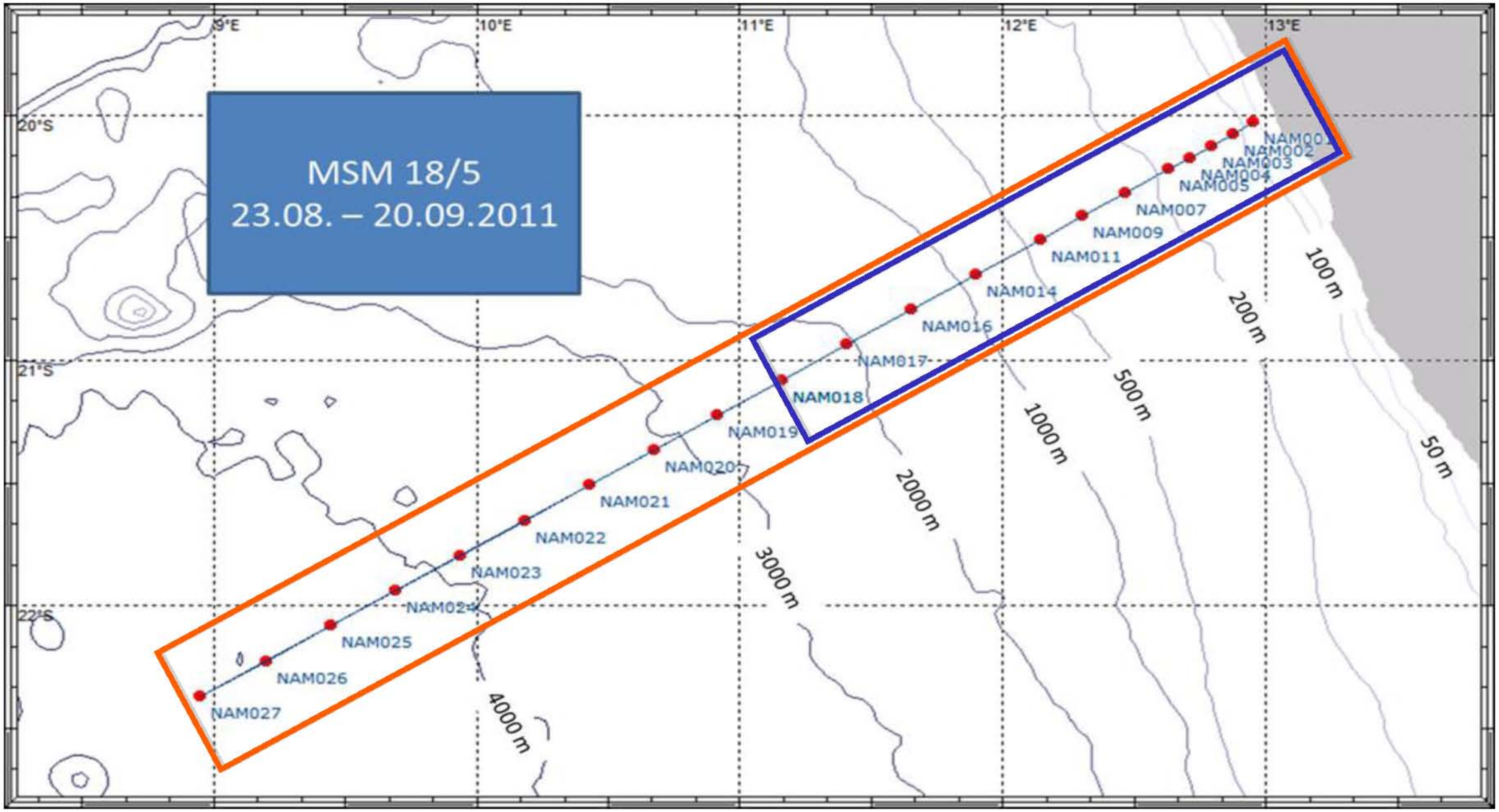
⇨ Its role in amino acids catabolism agues for its control over a great proportion of $NH_4^+$ excretion.

Namibian coast is characterized by intense coastal upwelling associated with Benguela current. These upwelling areas provide high organic production linked to phytoplankton bloom.

We estimated biomass, as well as the potential respiration (ETS) and $NH_4^+$ excretion (GDH) in mesozooplankton community in three depths along a transect with different oceanographic conditions to understand how affect phytoplankton bloom in the zooplankton metabolism.



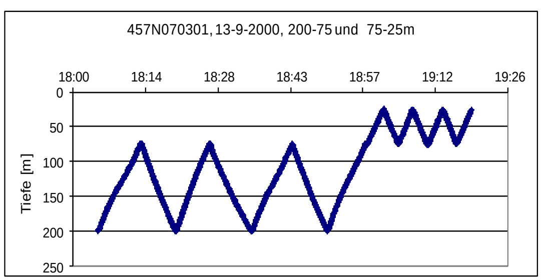

Map of sea surface temperature from the MODIS sensor on board NASA Aqua satellite (3 Feb.2008).




**4 sections across the northern Benguela upwelling system**: LT1,LT2 and LT3 with 12 stations, and LT4 with 21 stations.

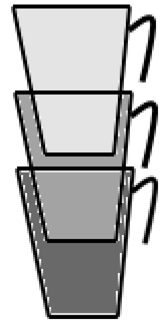
# MATERIAL AND METHODS

## Experimental design




ZOOPLANKTON SAMPLING

SIZE FRACTIONATION



> 1000 µm

500-1000 µm

200-500 µm

100-200 µm

**TAXONOMY, BIOMASS and METABOLISM**

More than 700 samples were analyzed for metabolic rates

***Storage in criovials at -80 ºC***

**GDH Activity**
(Bidigare and King, 1981)

**ETS Activity**
(Packard et al., 1971)

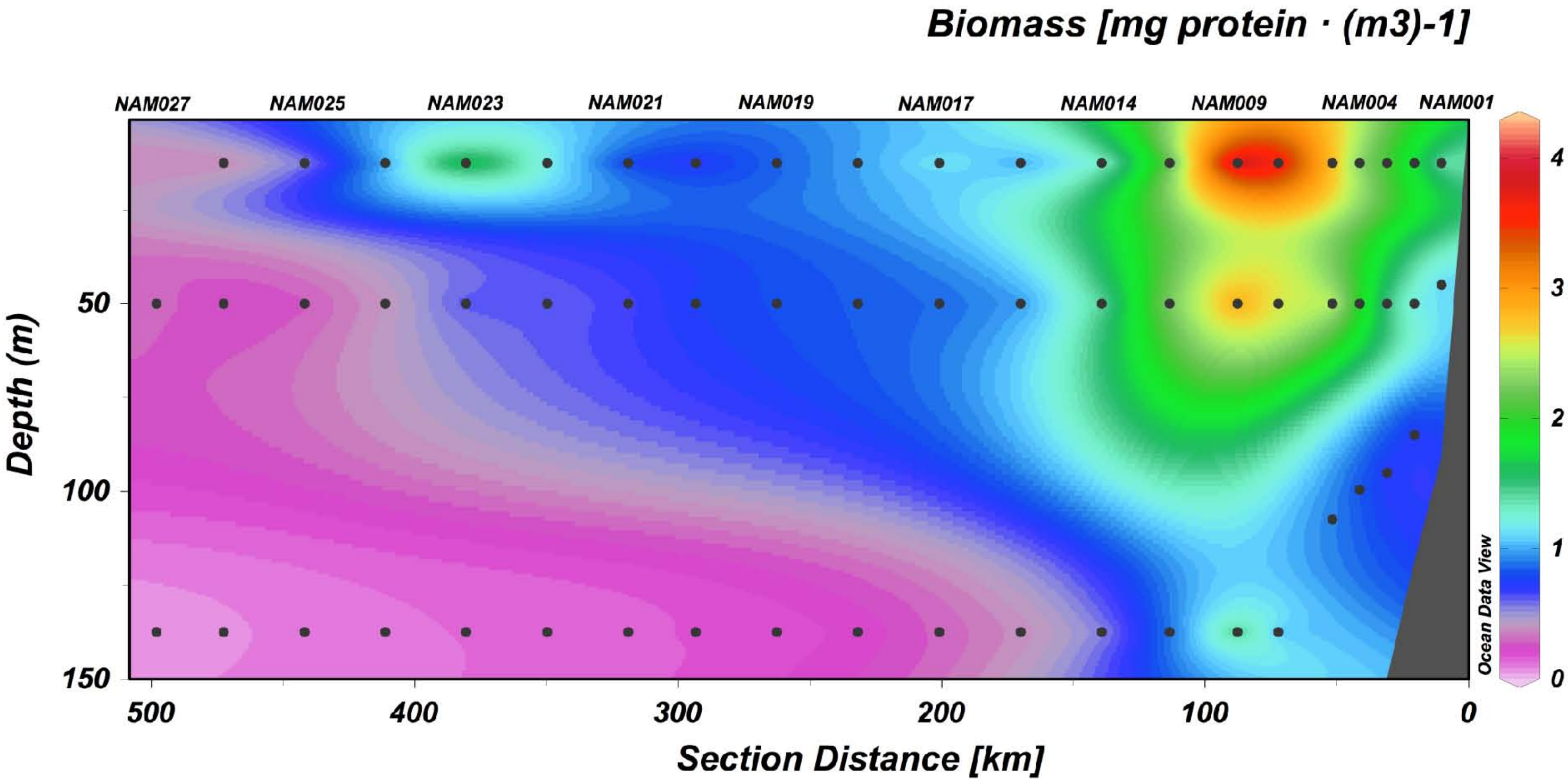
**Protein mass**
(Lowry, 1951)

**Laboratory work at institute**

**Data analysis**

# RESULTS

## Global averages from the different sections




The higher biomass values are coupled to the upwelled waters. ETS activity fits with the biomass pattern, while GDH activity present more dispersion since fitoplancton does not have effect in this rate. However, the GDH maximum rate is still next to the upwelling.

# RESULTS

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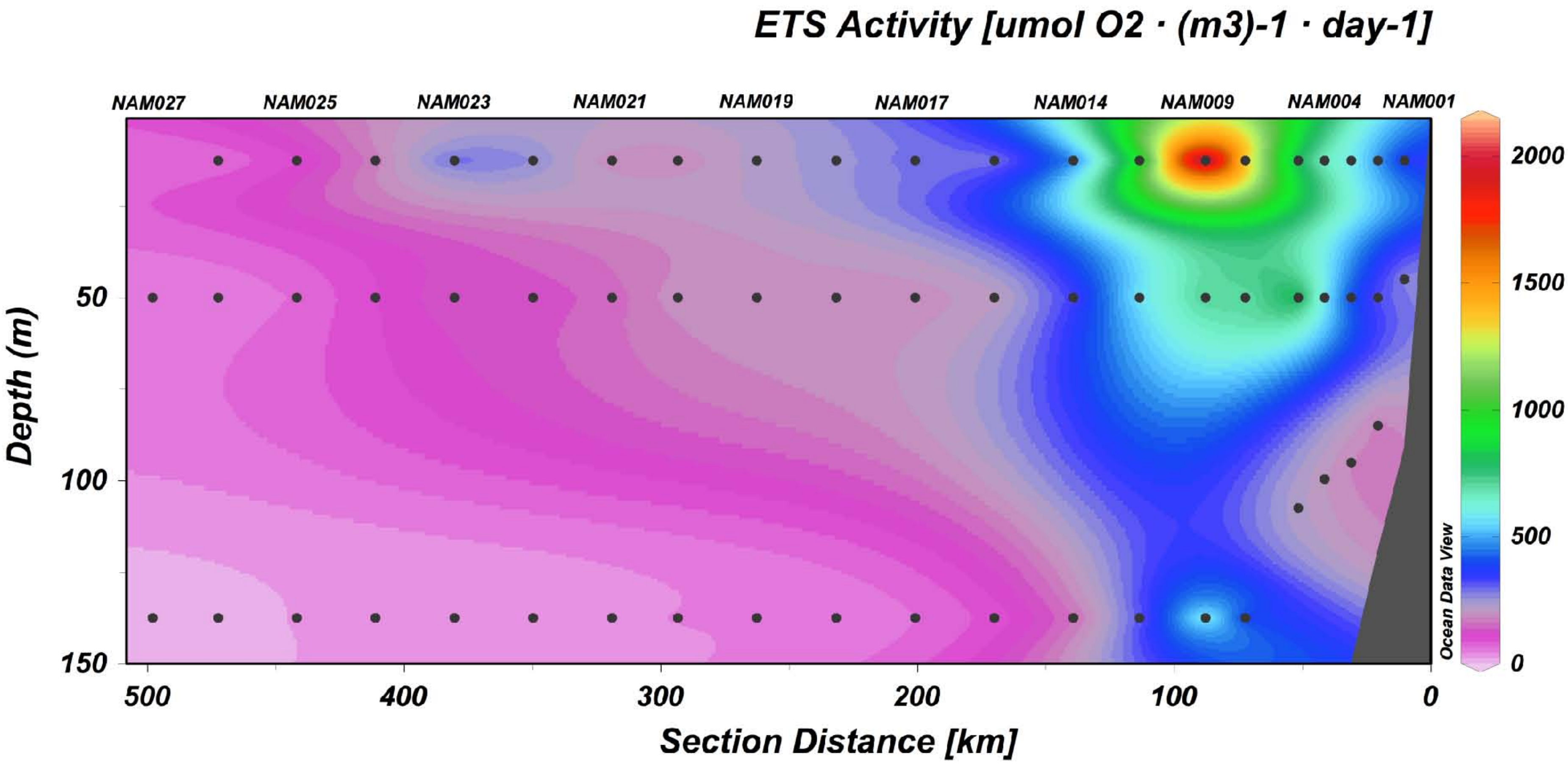


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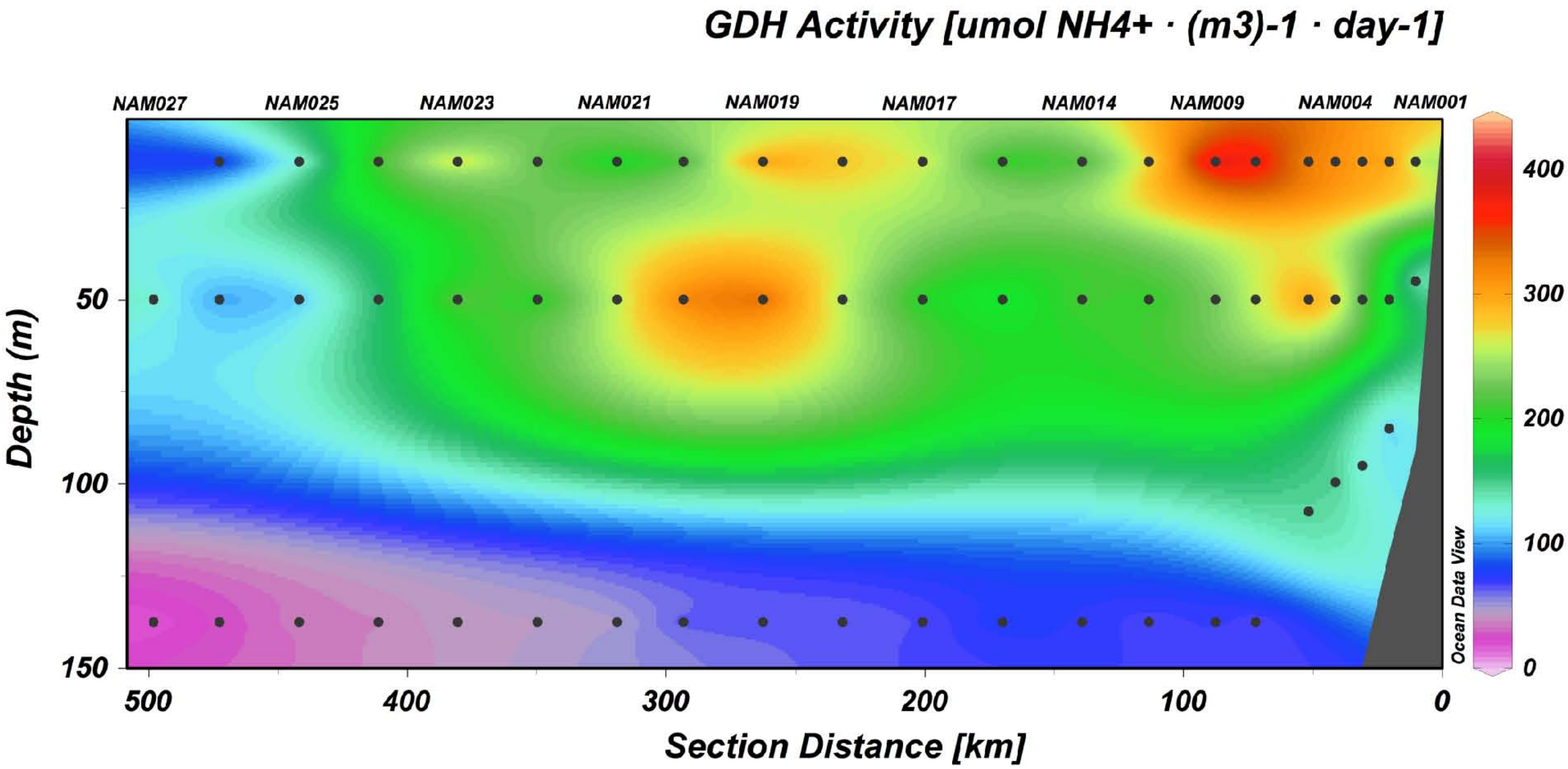


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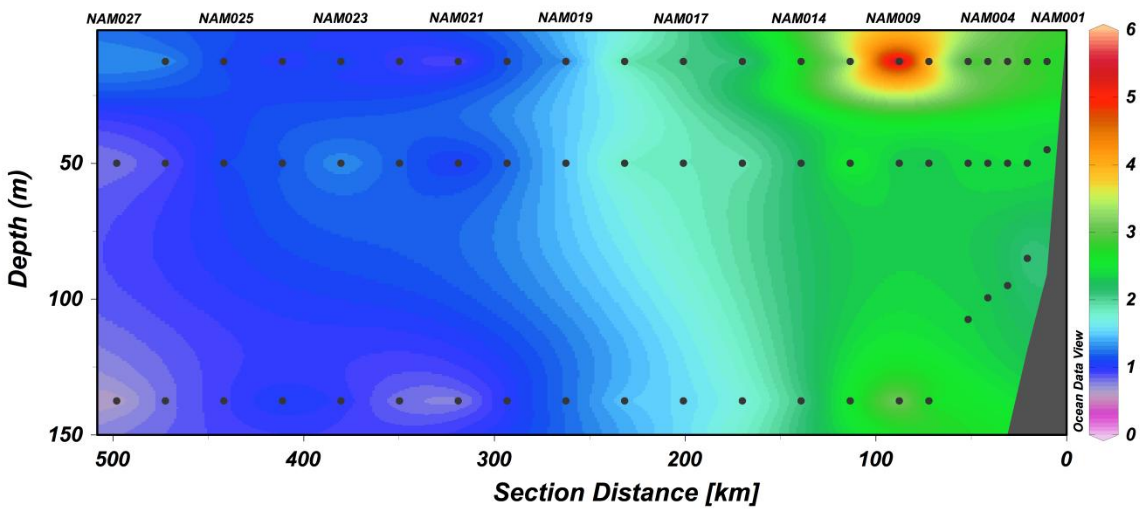
## Enzyme activities standarized by biomass

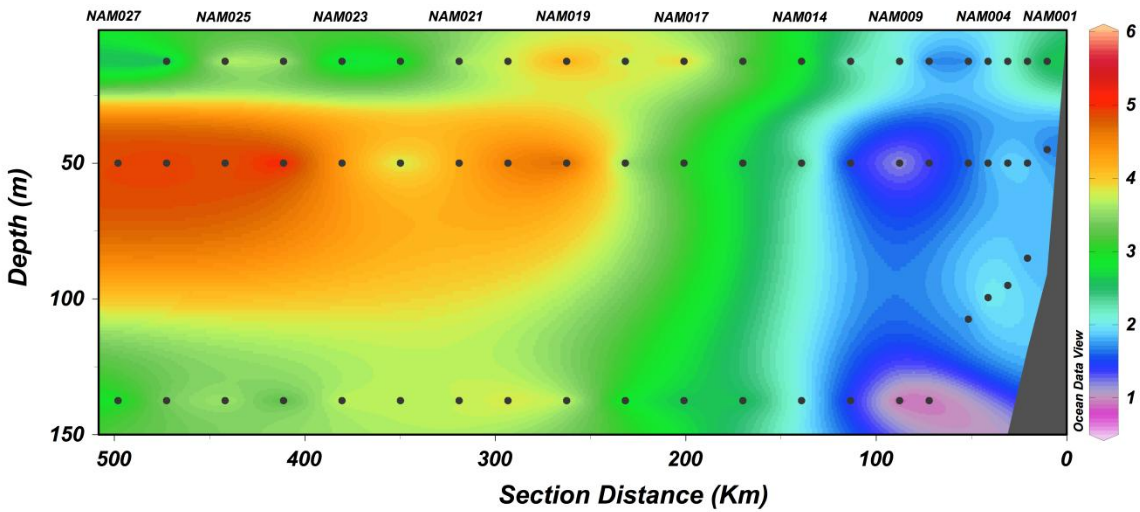
While ETS measures the respiratory activity in all the organisms, GDH is specific for heterotrophic $NH_4^+$ excretion. The difference becomes significant when these rates are standarized by biomass.

A drop in the GDH/ETS ratio would indicate the influence of the phytoplankton. This happens in the stations affected by the upwelling.

**Specific ETS [umol O2 · h-1 · mg protein-1]**

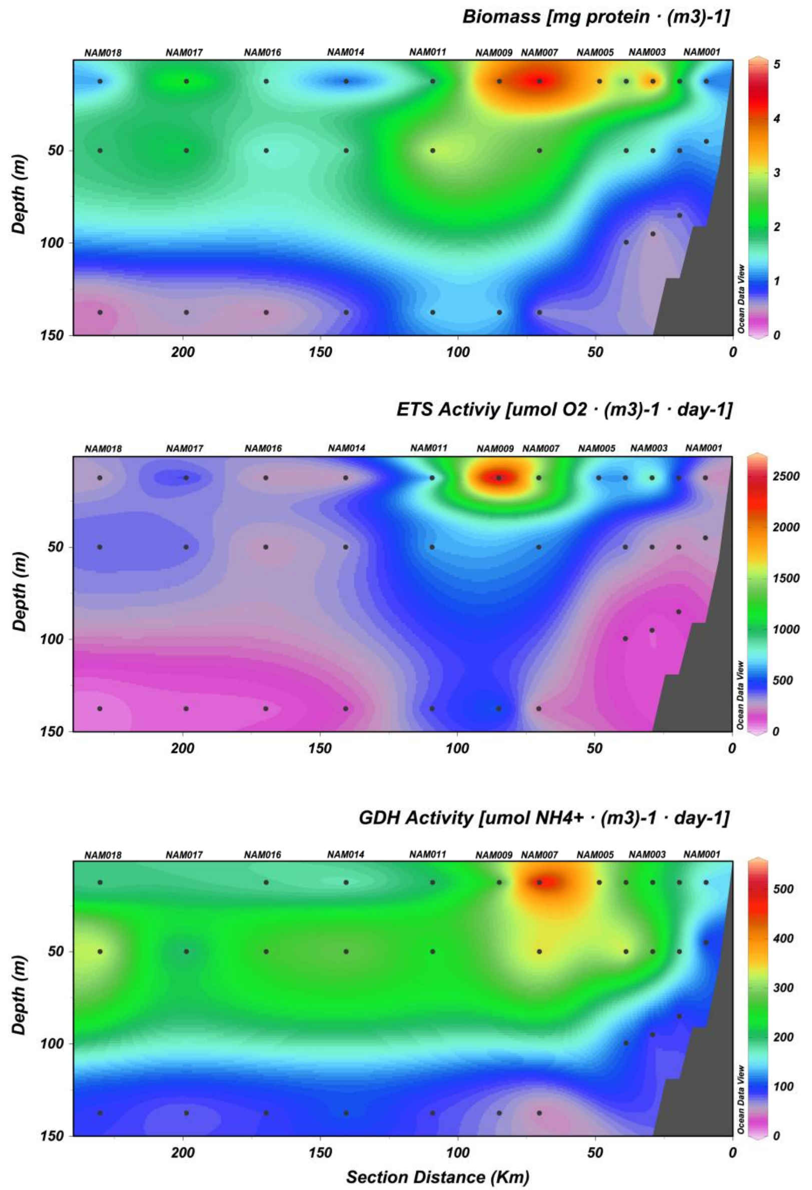



**Specific GDH [umol NH4+ · h-1 · mg protein-1]**



# SECTION 1

There is a bloom on NAM007, which causes high enzimatic rates in this area. This active metabolism seems to move offshore along the subsuperficial waters, specially for GDH.



# RESULTS

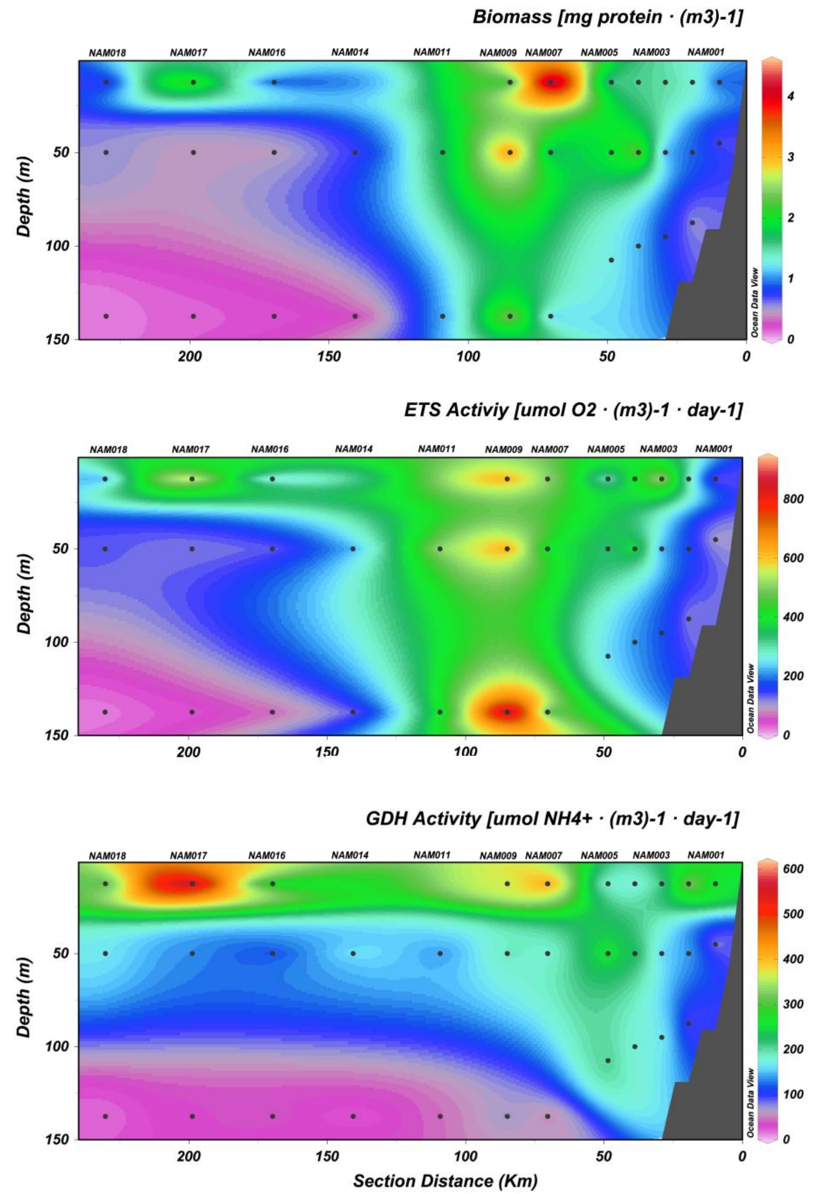
## Biomass and enzyme activities for each “short” section

### SECTION 1

There is a bloom on NAM007, which causes high enzimatic rates in this area. This active metabolism seems to move offshore along the subsuperficial waters, specially for GDH.

### SECTION 2

Biomass and ETS activity are mostly distributed in all the water column of NAM009. The latter, however, presents its maximum between 200-75 m. This not seems to affect GDH, whose higher activity is in the surface waters of NAM017 probably due to a peak of zooplankton in this region.



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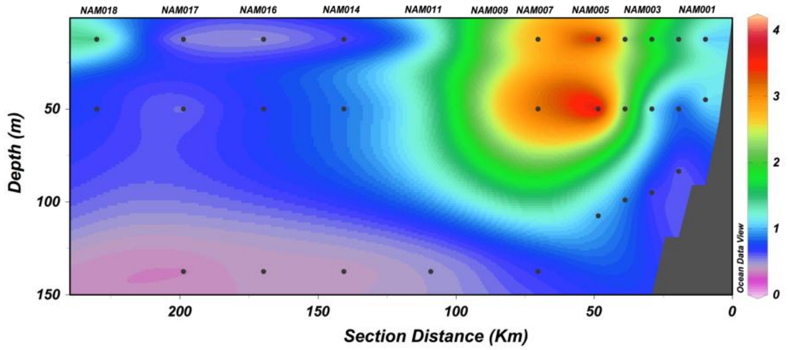
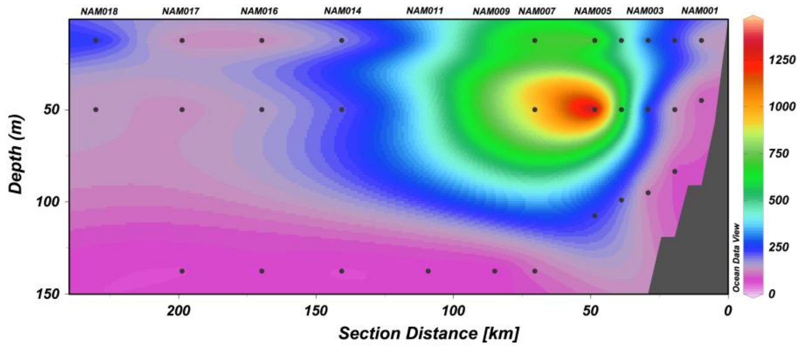
### SECTIONS 3 and 4

These two sections show a similar pattern than that found in section one. The bloom is now placed around NAM005 and it slightly extends offshore.

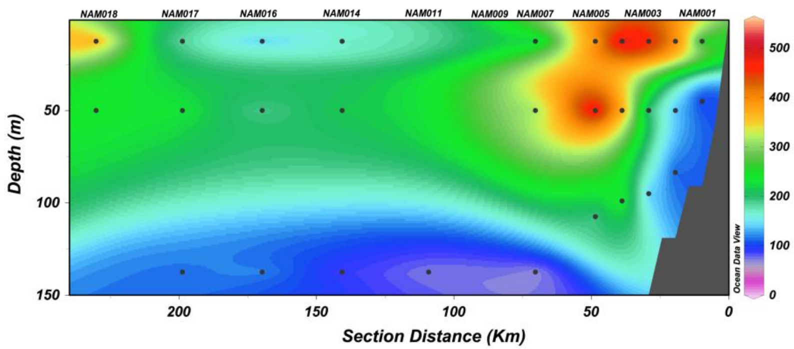
Biomass [mg protein · (m3)-1]




ETS Activiy [umol O2 · (m3)-1 · day-1]




GDH Activity [umol NH4+ · (m3)-1 · day-1]



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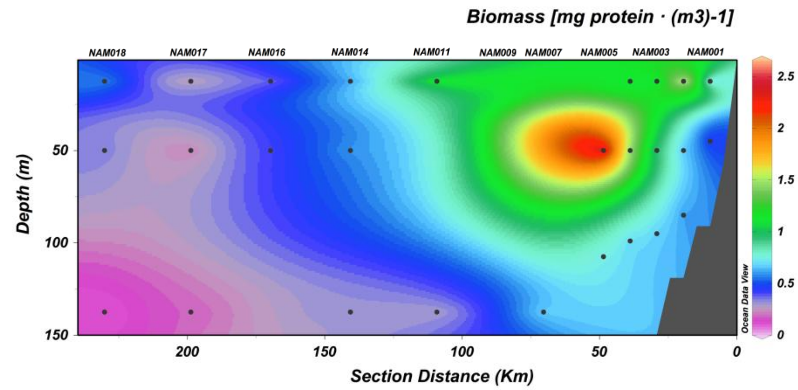
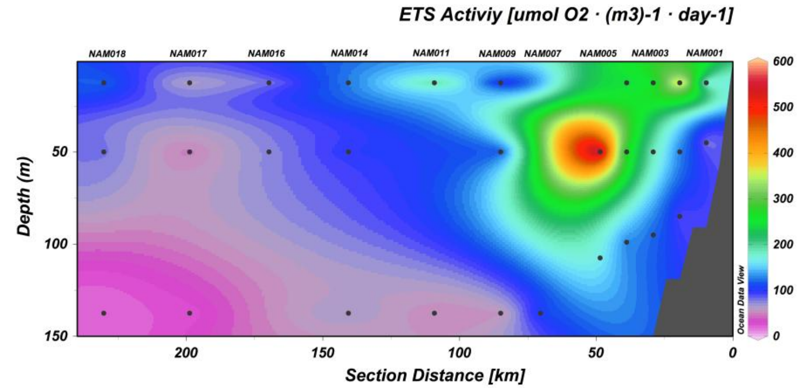
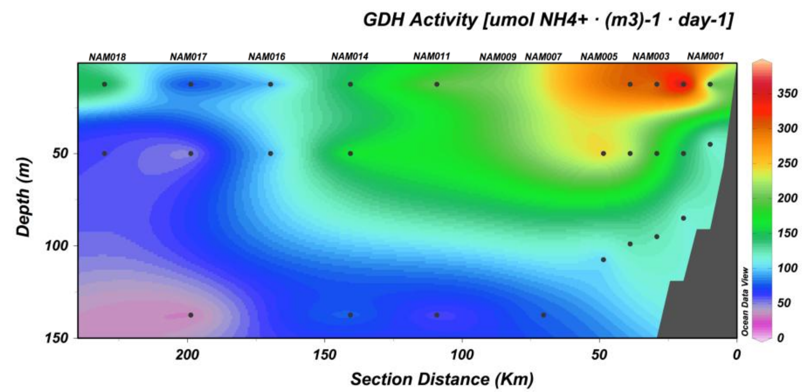


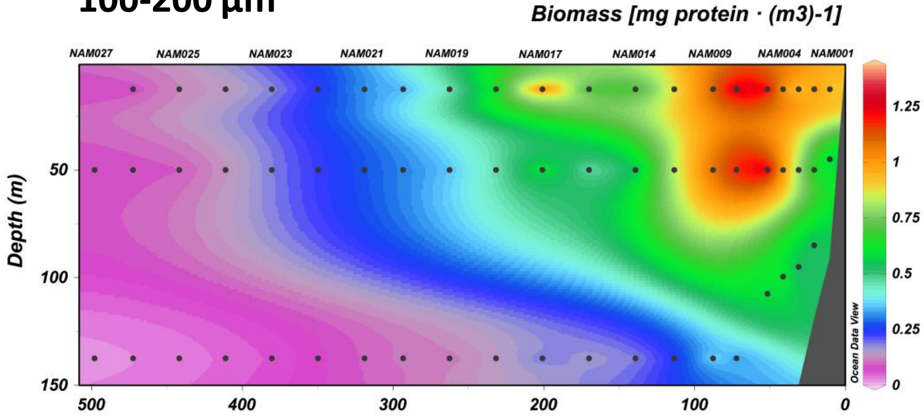



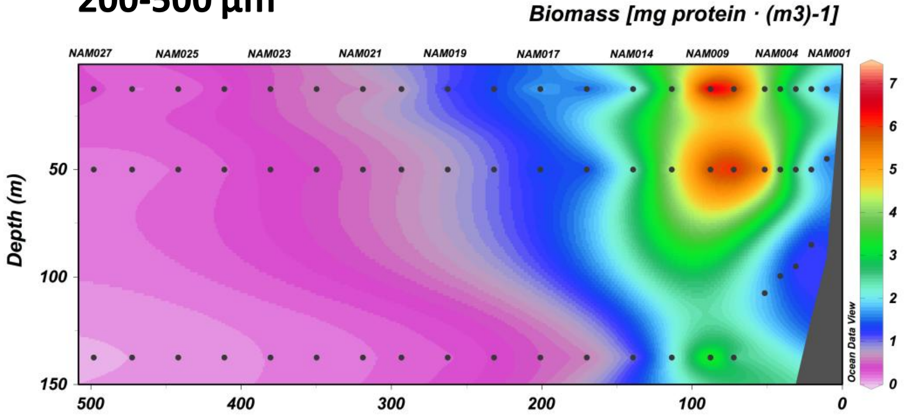
# RESULTS

## Size fraction contribution to the mean values in terms of Biomass

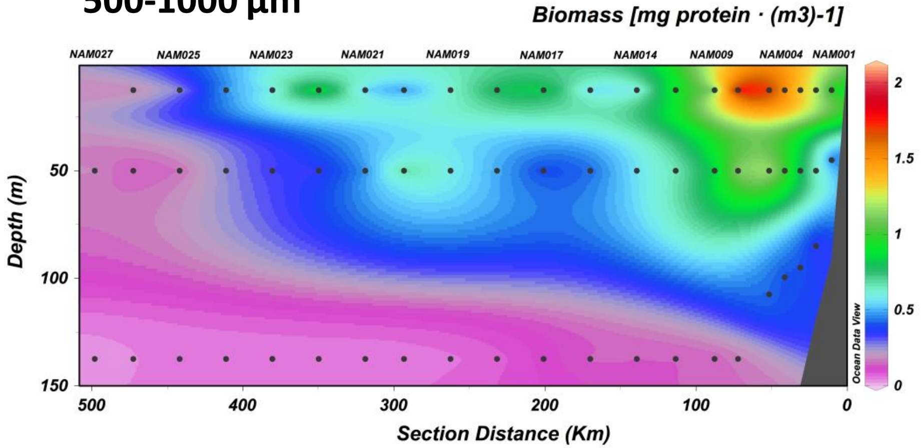
### 100-200 µm



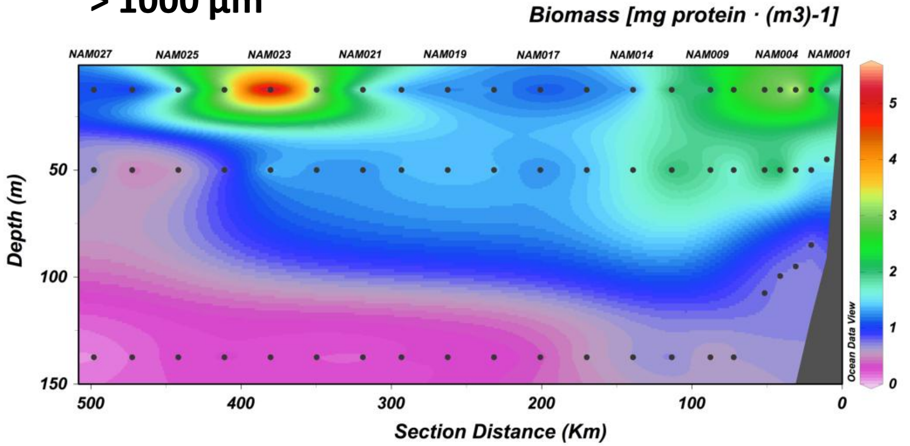

### 200-500 µm




### 500-1000 µm




### > 1000 µm

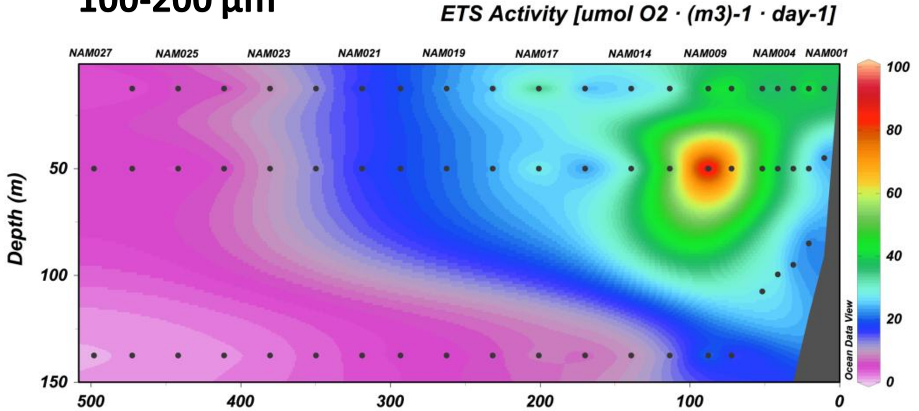



All the fractions present high values onshore. However, the lower the size fraction is, the more coupled is with the upwelling. Consequently, the mesozooplankton over 500 µm seems to dominate offshore, with maximum values on NAM023 for the highest fraction.

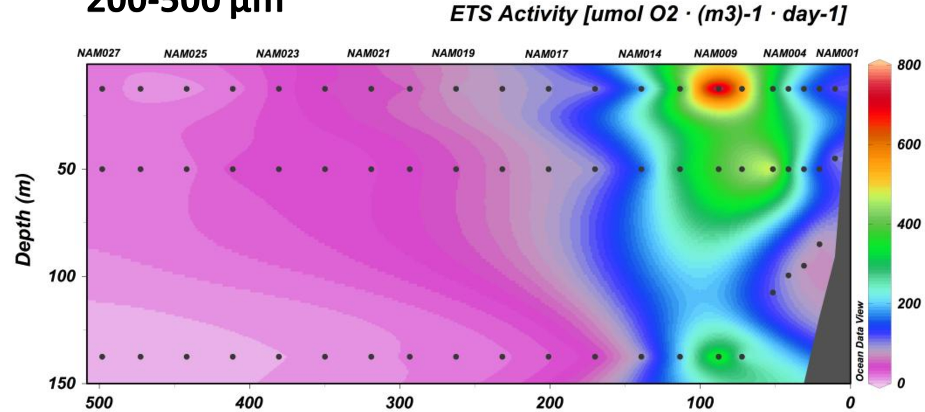
# RESULTS

## Size fraction contribution to the mean values in terms of ETS

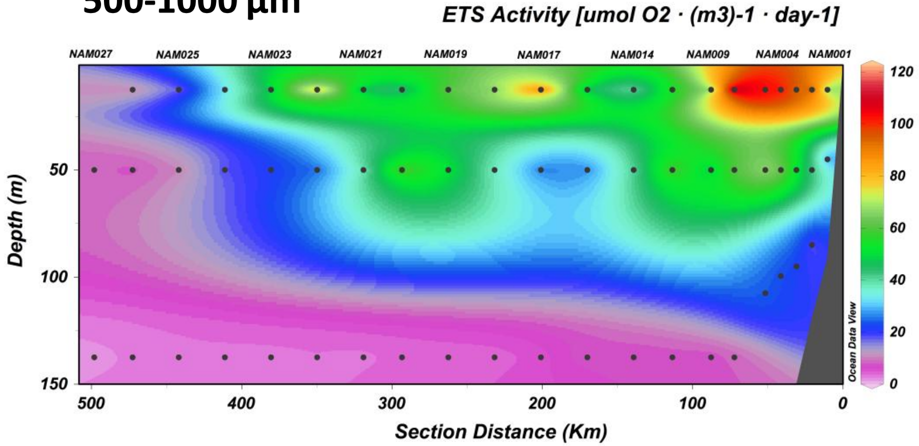
### 100-200 µm



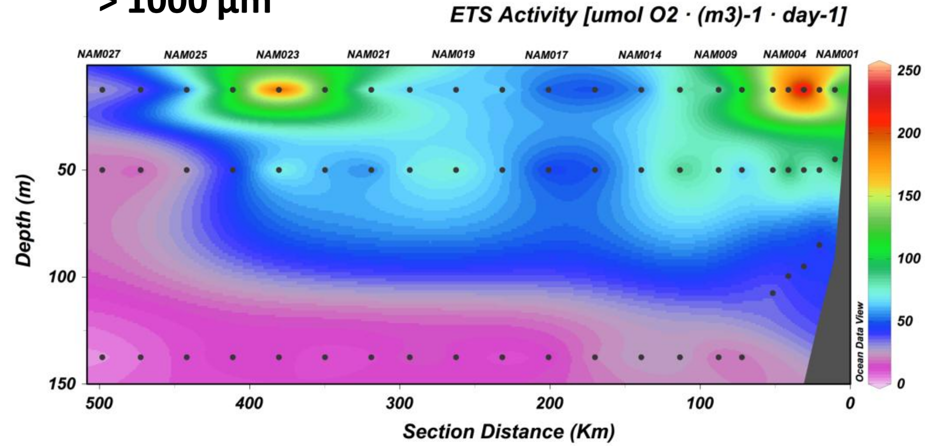

### 200-500 µm




### 500-1000 µm




### > 1000 µm

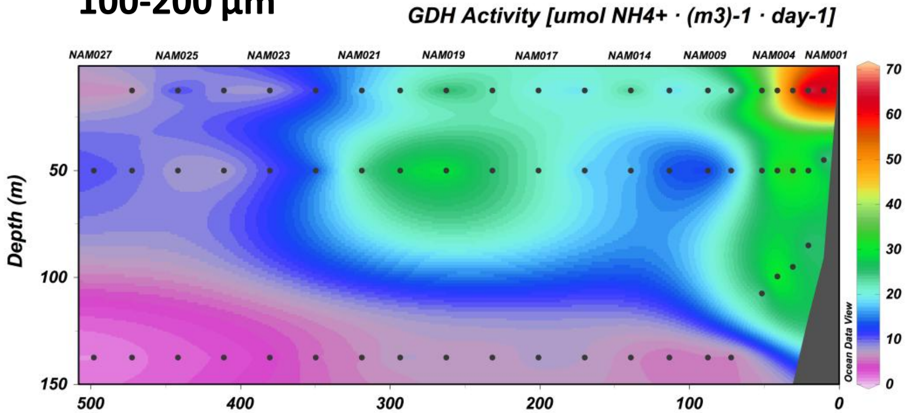



All the fractions present high values onshore. However, the lower the size fraction is, the more coupled is with the upwelling. Consequently, the mesozooplankton over 500 µm seems to dominate offshore, with maximum values on NAM023 for the highest fraction.

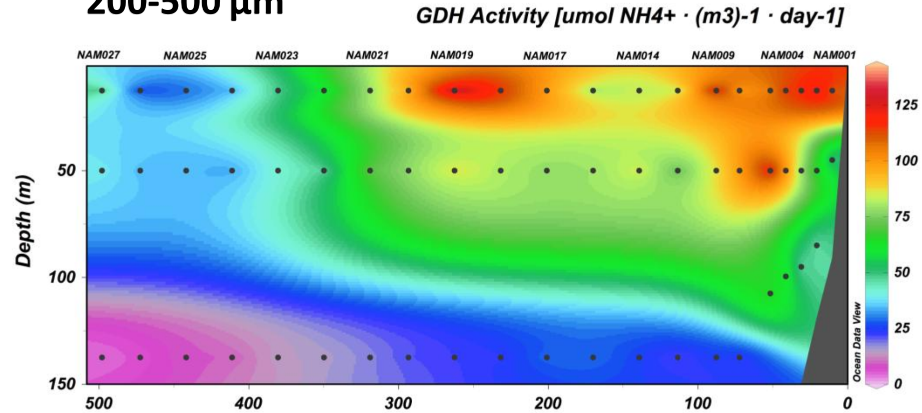
# RESULTS

## Size fraction contribution to the mean values in terms of GDH

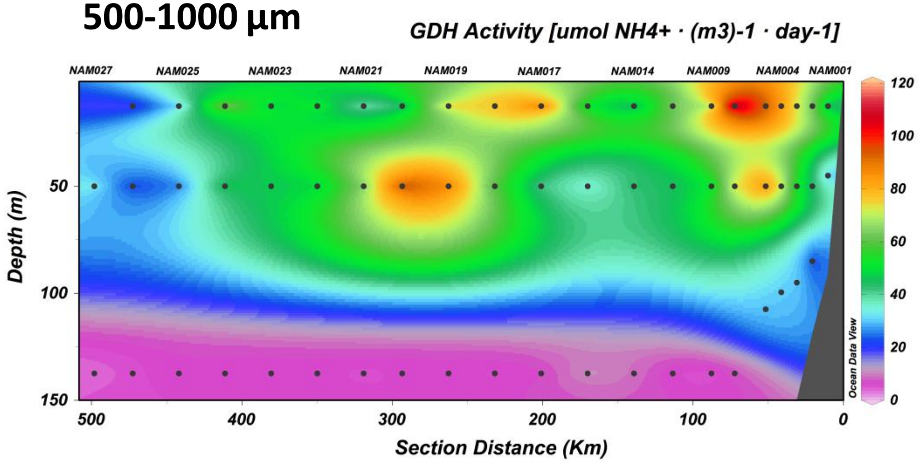
### 100-200 µm



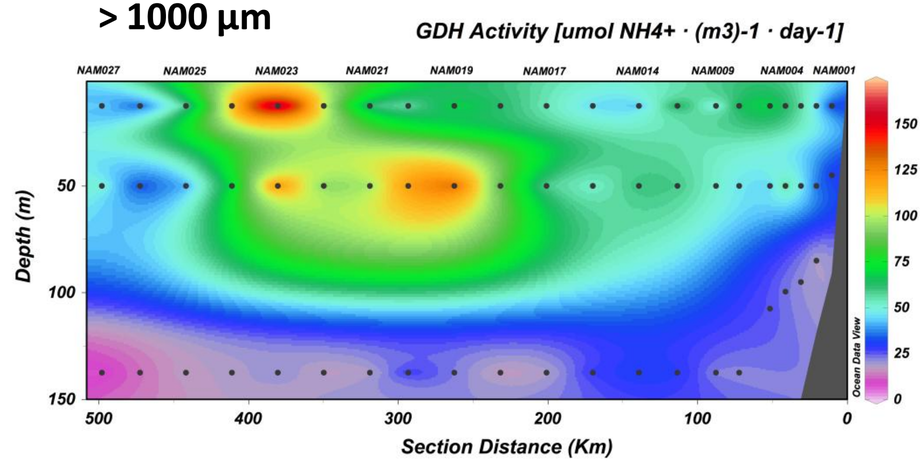

### 200-500 µm




### 500-1000 µm




### > 1000 µm

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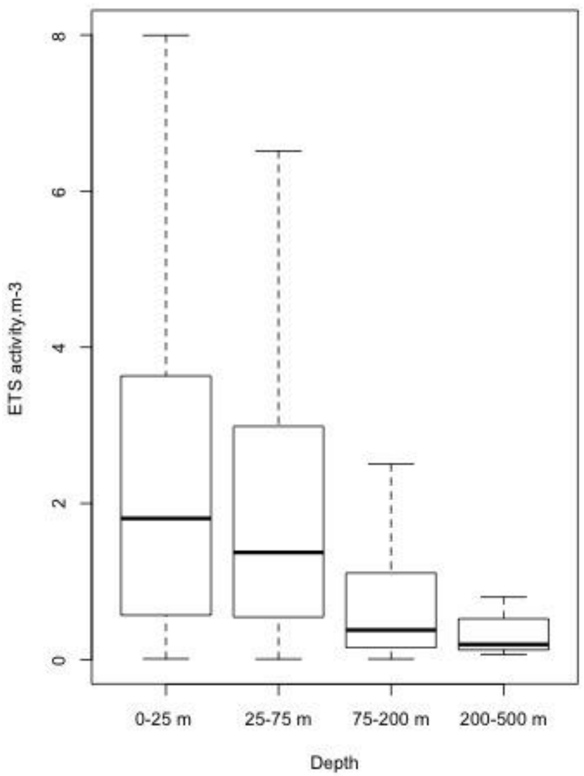
# RESULTS

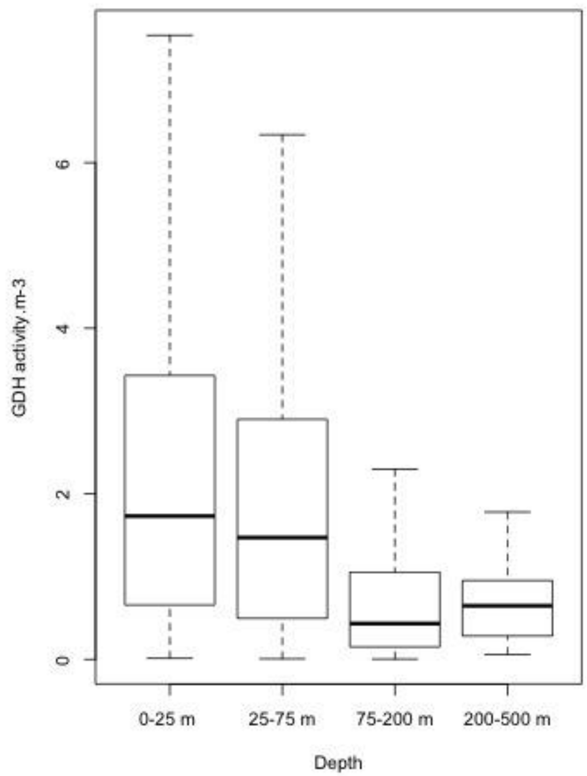
## What does the statisctics say?

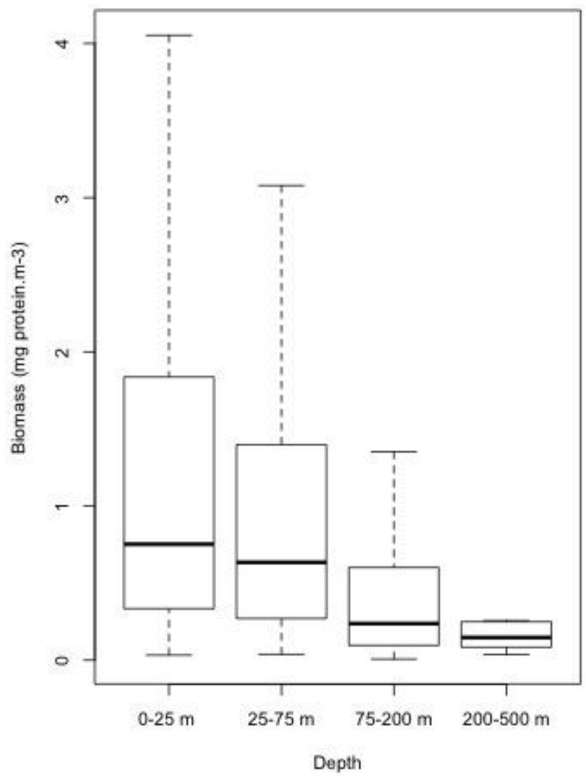
1. **Are there significant differences in ETS, GDH and Biomass between <u>DEPTHS</u>?**

✓ ***YES!!***

(Kruskal-Wallis test, p<0.001)



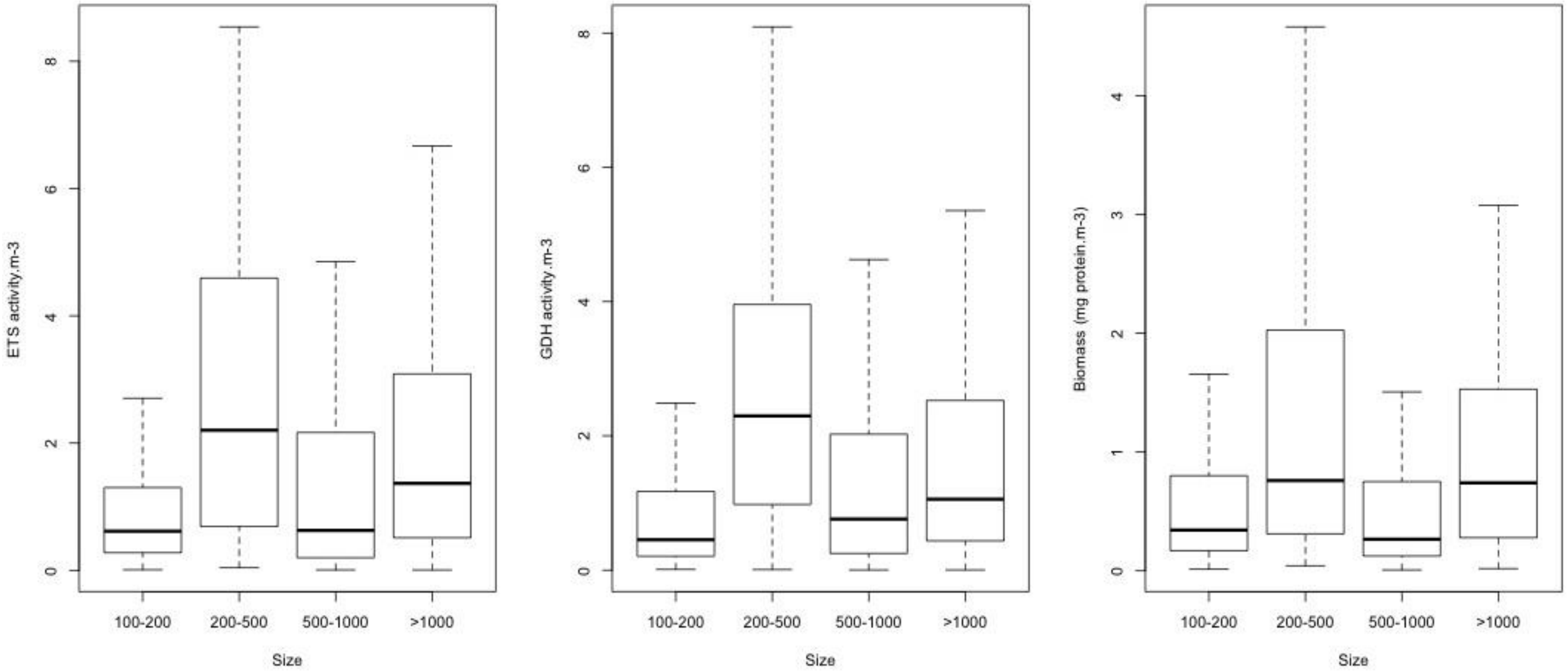



2. Are there significant differences in ETS, GDH and Biomass between **SIZE FRACTIONS**?

✓ ***YES!!***

(Kruskal-Wallis test, p<0.001)



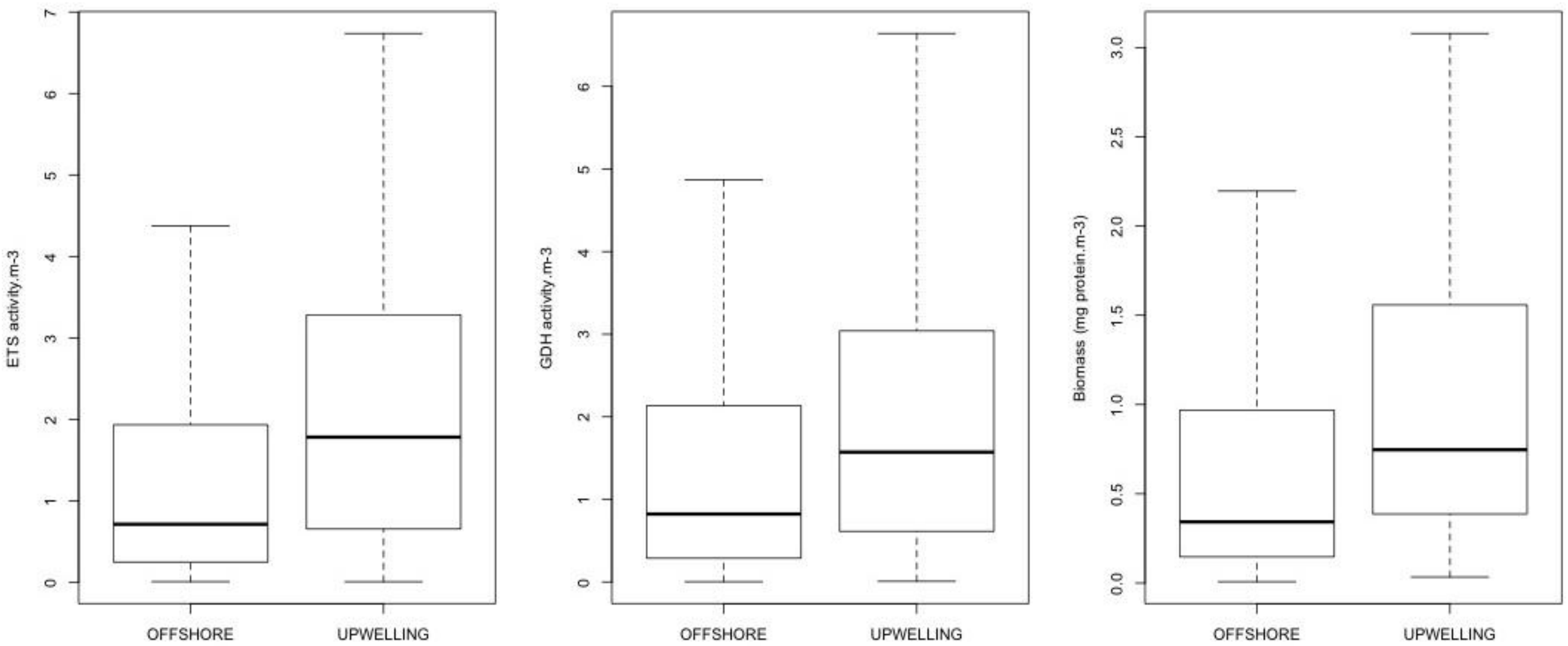
# RESULTS

## What does the statisctics say?

**3. Are there significant differences in ETS, GDH and Biomass between UPWELLED and OFFSHORE WATERS?**

✓ ***YES!!***

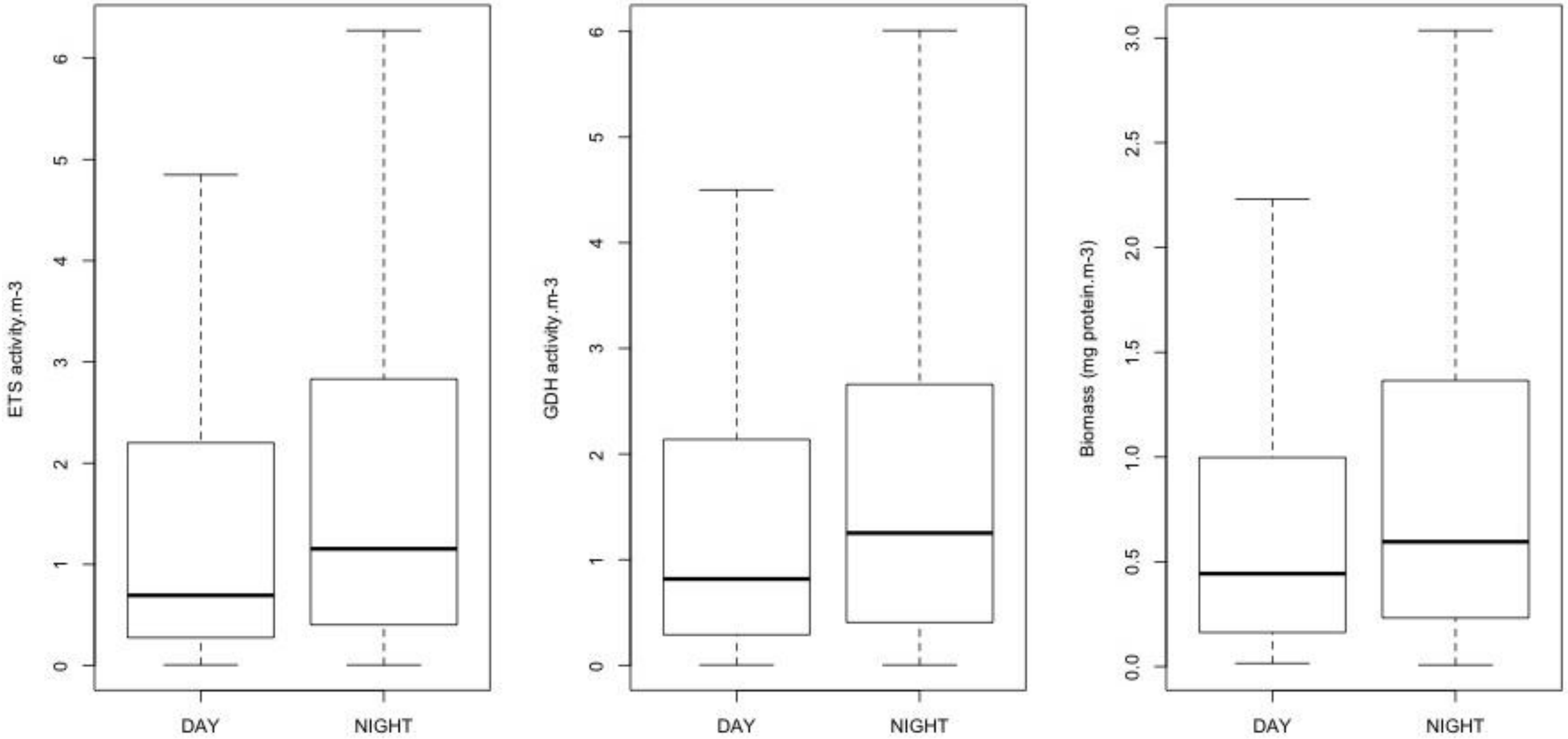
(Mann-Whitney test, $p<0.001$)



**4. Are there significant differences in ETS, GDH and Biomass between DAY/NIGHT SAMPLING?**

✗ **NO!!**

(Mann-Whitney test, p>0.001)



# KLEIBER´S COEFFICIENT

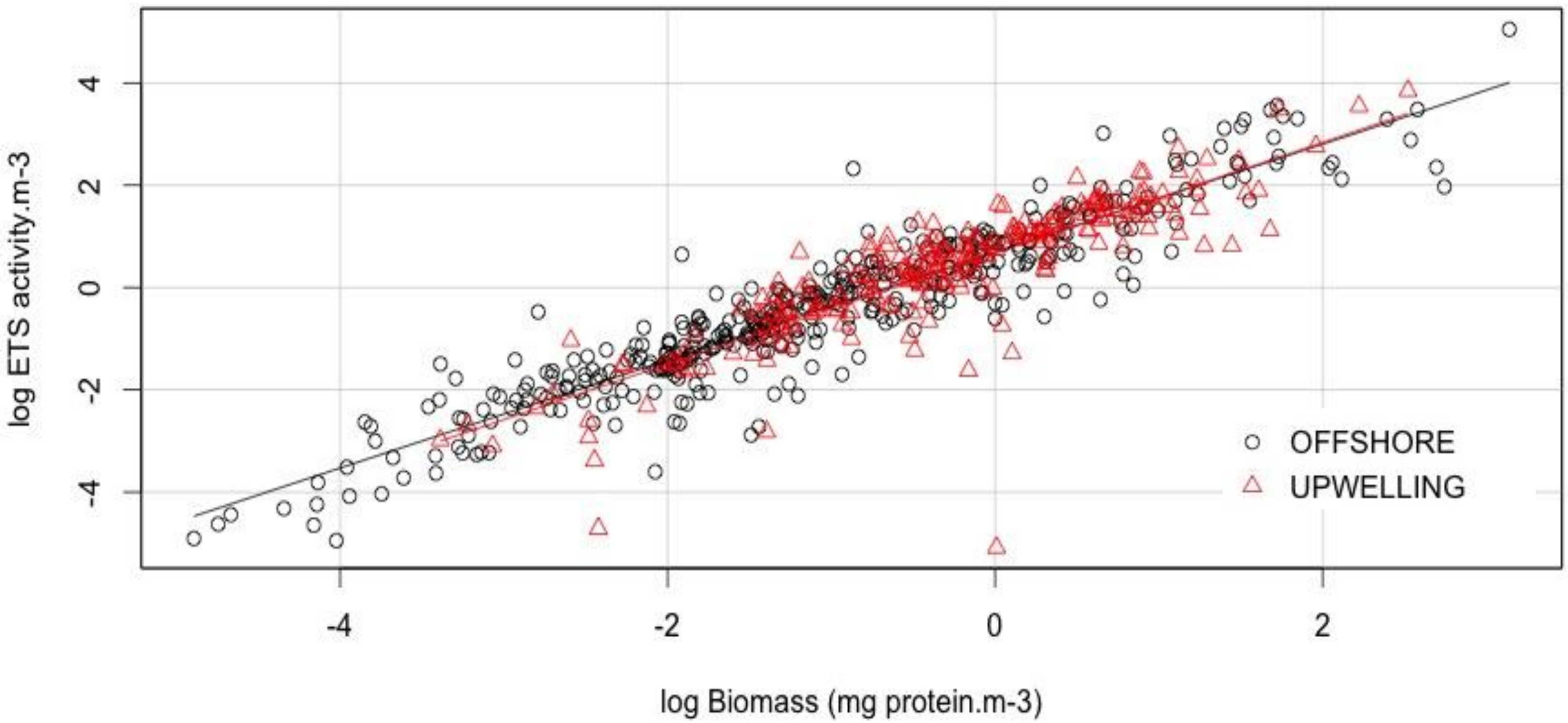
For many years it has been accepted the paradigm of the Kleiber´s law, which stablish a exponential relationship between biomass and metabolic rates with a coefficient "*b*" close to 0.75.

**Metabolic rate = $aW^b$ (W=biomass)**

Several zooplankton studies show different ratios close to or greater than 0.75 in optimal feeding conditions, and below 0.75 when the organisms are found in oligotrophic areas or poor feeding (Gómez *et al*., 2008; Herrera *et al*., 2011; Martínez, 2007; Packard and Gómez, 2008).

**In this study, the coefficients "*b*" are greater than 0.75 for ETS and GDH activities in both upwelling and offshore areas.**

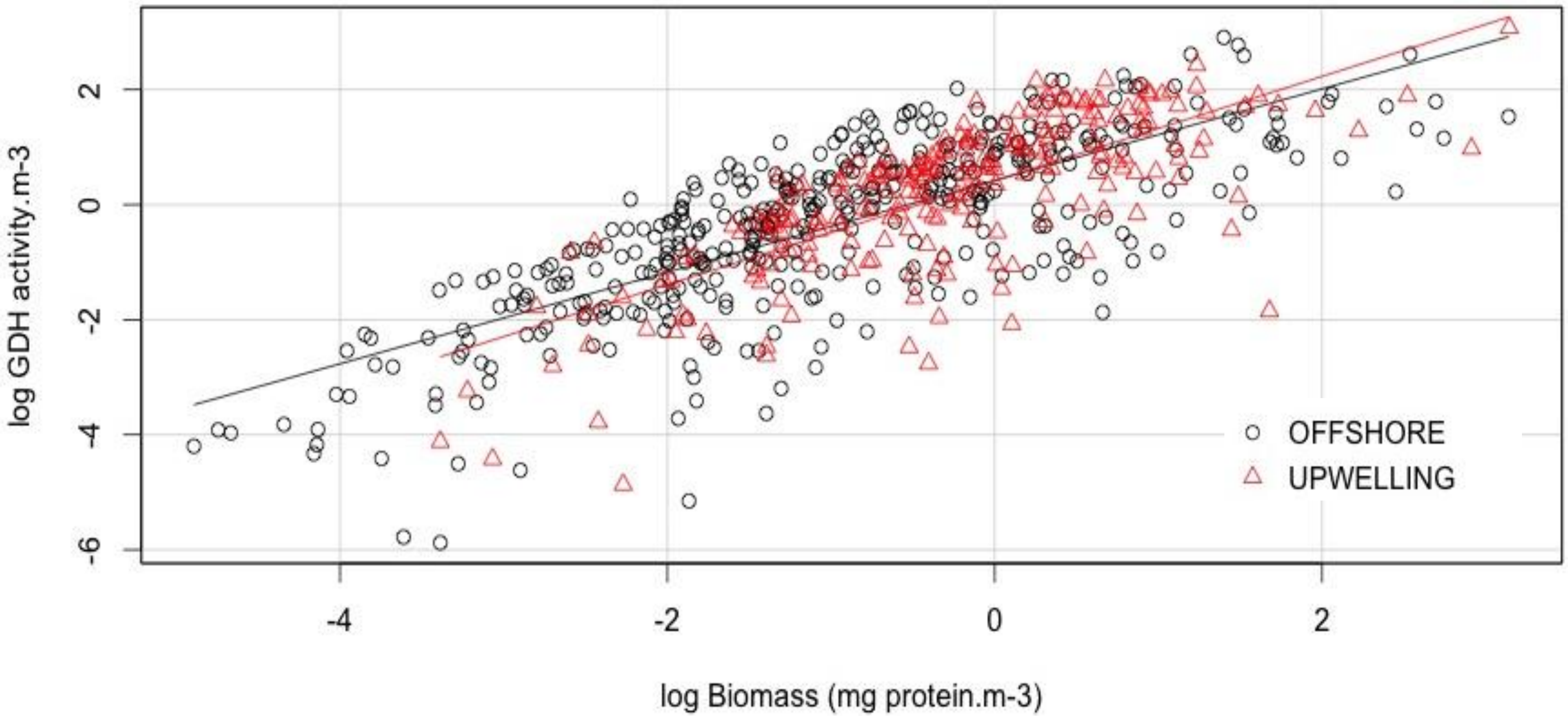
# ETS *vs* Biomass




**OFFSHORE** log ETS = 1.05 log W + 0.68

**UPWELLING** log ETS = 1.08 log W + 0.67

# GDH *vs* Biomass




**OFFSHORE** log GDH = 0.81 log W + 0.45

**UPWELLING** log GDH = 0.93 log W + 0.44

# SUMMARY

1. The peak value for biomass in terms of protein is placed between NAM007 and NAM009, with a global average of 4.15 mg protein · $(m^3)^{-1}$. The maximum values for ETS and GDH activities are presented in the same area (3126 µmol O2 · $(m^3)^{-1}$ · $day^{-1}$ and 466 µmol $NH_4^+$ · $(m^3)^{-1}$ · $day^{-1}$, respectively).

1. ETS measures respiratory activities in all the organisms, while GDH is specific for zooplankton. Consequently, the presence of phytoplankton will affect both rates unevenly when they are standarized by protein.

1. Size fractions below 500 µm are mostly coupled to the upwelled waters. However, the distribution of the upper fractions is more sparse along the surface waters of the section.

1. There are significant differences in ETS and GDH rates when compared between sizes, depths and offshore-upwelled waters. However, the time of the day in which the stations were sampled does not affect their values.

1. The Kleiber's coefficient "b" for both ETS and GDH is higher than 0.75 in the Northern Benguela upwelling system.

We thank to IOW, in particular to Dr. Postel for giving us the opportunity of being part of the Succession Cruise. We also want to mention all the scientific crew, with whom it was a pleasure to work, specially to B. Bergen and I. Schuffenhauer for those good memories and to the zooplankton group (included M. Zettler and U. Hehl) for the “thousands” of Multinet-hauls they provided us daily!

Hope see you all soon…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