# SEASONAL and INTERANNUAL VARIABILITY OF GELATINOUS ZOOPLANKTON FROM BERLENGAS NATURAL RESERVE (Western Coast of Portugal)


Joana Falcão*[1,2,3]
Todd O'Brien[4]
Sónia Cotrim Marques[5]
Agostinho Antunes[1,2]
Sérgio Miguel Leandro[5]
Antonina dos Santos[1,3]

*joanfalcao@gmail.com

[1]CIIMAR – Interdisciplinary Center of Marine and Environmental Research - University of Porto, Terminal de Cruzeiros do Porto de Leixões, Av. General Norton de Matos, s/n 4450–208 Porto, Portugal; [2]FCUP - Department of Biology, Faculty of Sciences, University of Porto, Rua do Campo Alegre, s/n Edifício FC5, 4169–007, Porto, Portugal; [3]IPMA - Portuguese Sea and Atmosphere Institute, Av. Doutor Alfredo Magalhães Ramalho, 6, 1465-165 Algés, Portugal; [4]National Oceanic and Atmospheric Administration (NOAA), Silver Spring, Maryland, United States; [5]MARE - Marine and Environmental Sciences Centre, ESTM, Polytechnic Institute of Leiria, 2520-614 Peniche, Portugal.


## INTRODUCTION

Climate change may seriously affect the stability and resilience of marine ecosystems.

Jellyfish can act as critical components of ecosystems functioning and biogeochemical cycling, acting as hydroclimatic indicators. Even more, through their substantial input to total standing stock and primary production.

Gelatinous zooplankton include highly diverse representatives of several phyla of marine invertebrates. Among them, Cnidarians (Hydromedusae group and siphonophores), Ctenophores and Chordata (salps and doliolids) taxa, herein referred to as gelatinous zooplankton (GZ).

The absence of relevant monitoring programs and long-term data sets prevent an effective calculation of GZ seasonal appearance and geographical dynamics.

Coastal upwelling along western Portuguese coast shows a seasonal cycle, from April to October, with summer maxima, contributing for the high primary productivity of Berlengas Natural Reserve (BNR), as an important nursery for small pelagic fish species.

Variations in the GZ community due to environmental conditions could result in a significant effect on the abundances and fluctuations of the stocks for these pelagic species.

**OBJECTIVES**

- To describe for the first time the GZ community occurring in BNR (Western Portuguese Coast).
- To analyse the seasonal and annual distribution of the GZ community in BNR, identifying the environmental variables affecting its patterns.

## METHODS

⇒ GZ samples were collected monthly from June 2014 until December 2018 at daytime with subsurface oblique tows with a 200 µm mesh size WP2 plankton net.

⇒ Water temperature was registered *in situ*. Sea surface temperature (SST) and chlorophyll a concentration (Chl *a*) data were obtained from oceancolor.gsfc.nasa.gov/; Upwelling Index (UI) data from http://www.indicedeafloramiento.ieo.es/ and the North Atlantic Oscillation (NAO) data were obtained from https://www.cpc.ncep.noaa.gov/.

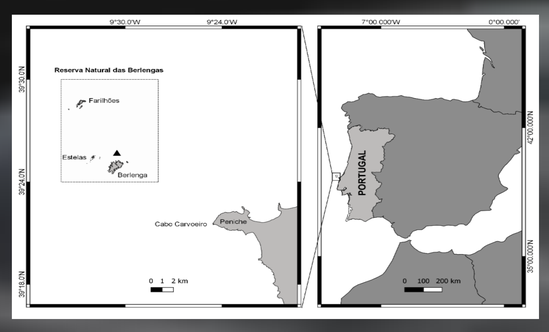


**Fig. 1.** Map of the sampling area. Berlengas Natural Reserve (BNR), showing sampling site (Δ) the Berlengas Watch. The dotted lines rectangle represents the marine protected area.

⇒ International Group for Marine Ecological Time Series (IGMETS)/ International Council for the Exploration of the Sea (ICES) Working Group on Zooplankton Ecology (WGZE) statistical methodology was accessed for satellite-retrieved salinity, Primary production - PP, windspeed, chlorophyll *a* concentrations and sea surface temperature – SST (www.st.nmfs.noaa.gov/copepod/toolkit/).

## CONCLUSIONS

⇒ **Not all time-series trends were statistically significant over the five years sampling period. Notably, the decreasing trend of in situ temperature was related with the decreasing abundance trend of most of the GZ species.**

⇒ **The relationship between climate variability, represented by NAO index, and GZ abundance in BNR had a reduced influence (with the exception of the negative correlation with M. kochii) in inducing significant changes in the local GZ population, already well adapted to the magnitude of environmental fluctuations.**

⇒ **The gelatinous species are always present in BNR waters. Their abundance is characterized by short time-scale periods of increasing dominance, indicative of local variability. This pattern supports the idea that local environment is more important than the regional scale on GZ composition and these local conditions drive the occurrence of these abundance peaks, typical of GZ complex lifecycles.**

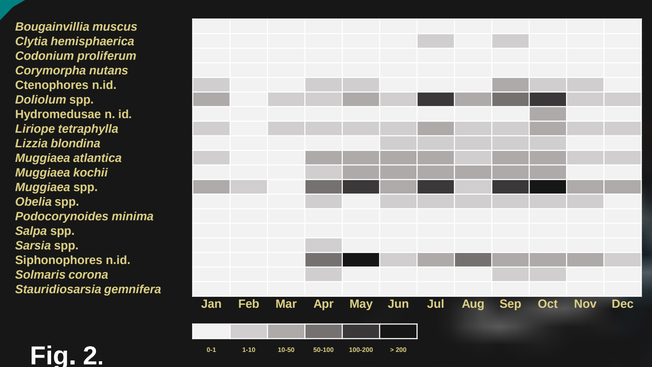


**Fig. 2.** Heat map with the GZ species mean monthly abundance (ind m$^{-3}$) in BNR between 2014 and 2018.

⇒ **Siphonophores** were the most abundant (> 200 ind m$^{-3}$) during late spring, summer and autumn; mainly represented by two species *M. atlantica* and *M. kochii*.

⇒ **Hydromedusae** showed a greater diversity of species, with 11 taxa identified with *Liriope tetraphylla* as the most representative taxon, occurring regularly in all sampled months with mean monthly abundance up to 50 ind m$^{-3}$.

⇒ **Thaliacea** mainly represented by *Doliolum* spp., regularly present in the sampling period, with mean monthly abundances of 100-200 ind m$^{-3}$ during Autumn.

⇒ **Ctenophores** with only one taxon (*Ctenophora* spp.) reached mean monthly abundances up to 50 ind m$^{-3}$ in September.

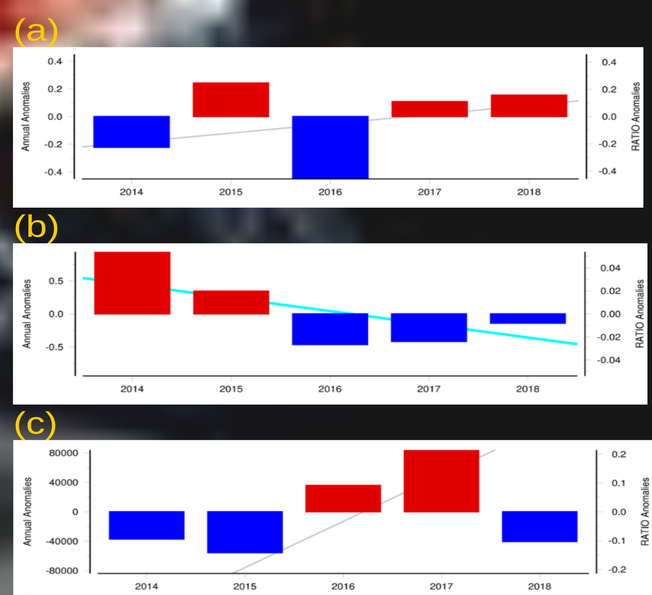


**Fig. 4.** Annual anomalies with shifts between phases of high (red) or low (blue) values in the NAO (a), SST (b), and UI (c) monthly time-series. Note to the trend lines behind the bars: thin grey, non significant trend ($p > 0,05$); solid blue, significant trend ($p < 0,01$).

⇒ **NAO** index was characterized by marked interannual variations. Mainly negative in 2014 and 2016 and shifting to positive values afterwards.

⇒ **UI** annual anomalies displayed negative values for three years of the entire period studied, namely 2014, 2015 and 2018.

⇒ **SST** annual anomalies showed negative values from 2016 onwards presenting a significant downward trend in the period studied. Although an inversion of this trend was observed in the last 3 years analysed.

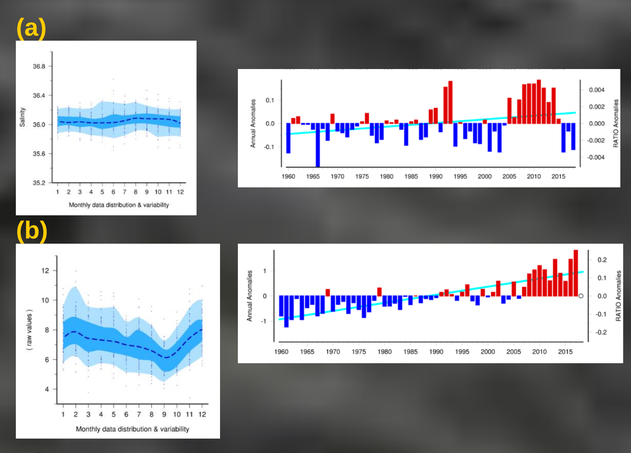


**Fig. 6.** Satellite-retrieved monthly distribution and variability of (a) Salinity and (b) Windspeed (m s$^{-1}$) in Berlengas Watch sampling station, over the period 2014-2018 (left-hand column; blue shadow area). Annual anomalies are indicated in the right-hand column (red positive, blue negative).

## RESULTS

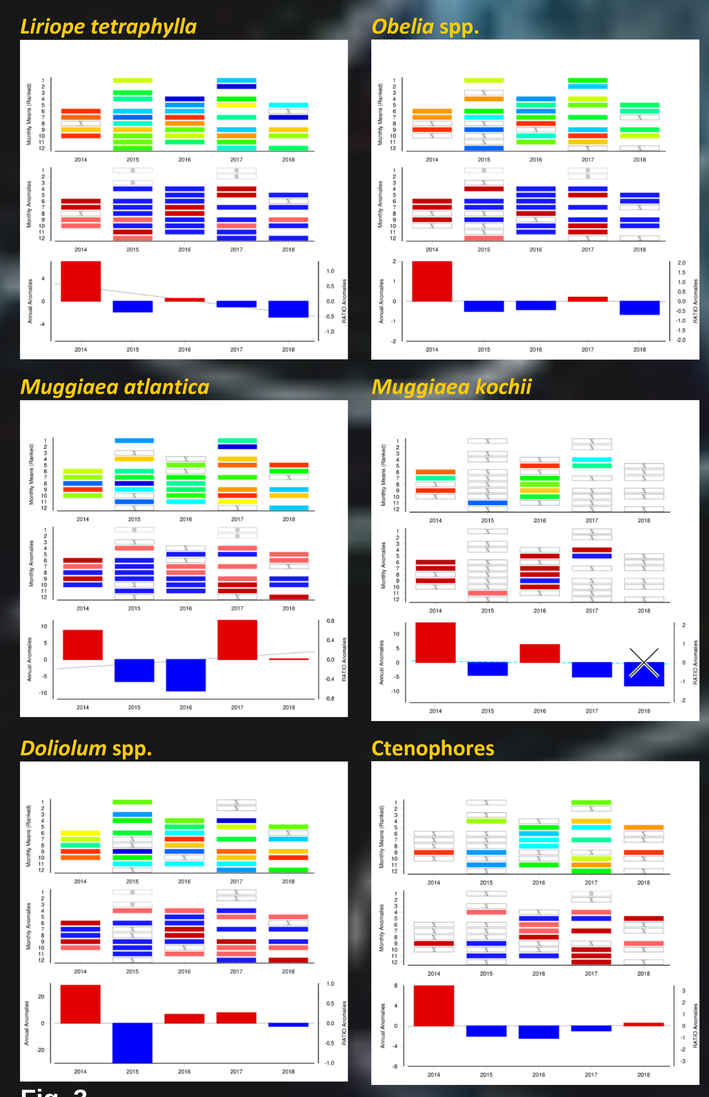


**Fig. 3.** Monthly means (MM) (ind m$^{-3}$), Monthly anomalies (MA) and Annual Anomalies (AA) with RATIO Anomalies (RAT) of the most abundant GZ species. Open white boxes with "X" are months where the species was completely absent.
MA= MM - Monthly Climatology (MC); AA = Annual Mean (AM) - Annual Climatology (AC); RAT – AA = AA/ Annual Climatology (AC); MC and AC – average of all data from this month or year in the current time window, respectively.

Decreasing (ind m$^{-3}$)

⇒ *Liriope tetraphylla* annual anomalies revel a downward trend.

⇒ *M. atlantica* occurred more frequently than the congeneric *M. kochii*.

⇒ *M. kochii* was only recorded once in 2015, twice in 2017, with no records in 2018.

⇒ *Doliolum* spp. showed a cyclical tendency with unusual low abundances throughout 2015. A drop in the doliolids abundance is present during the study period.

⇒ Ctenophores recorded the greatest abundances in 2014 and 2018, despite the few occurrences in these years.

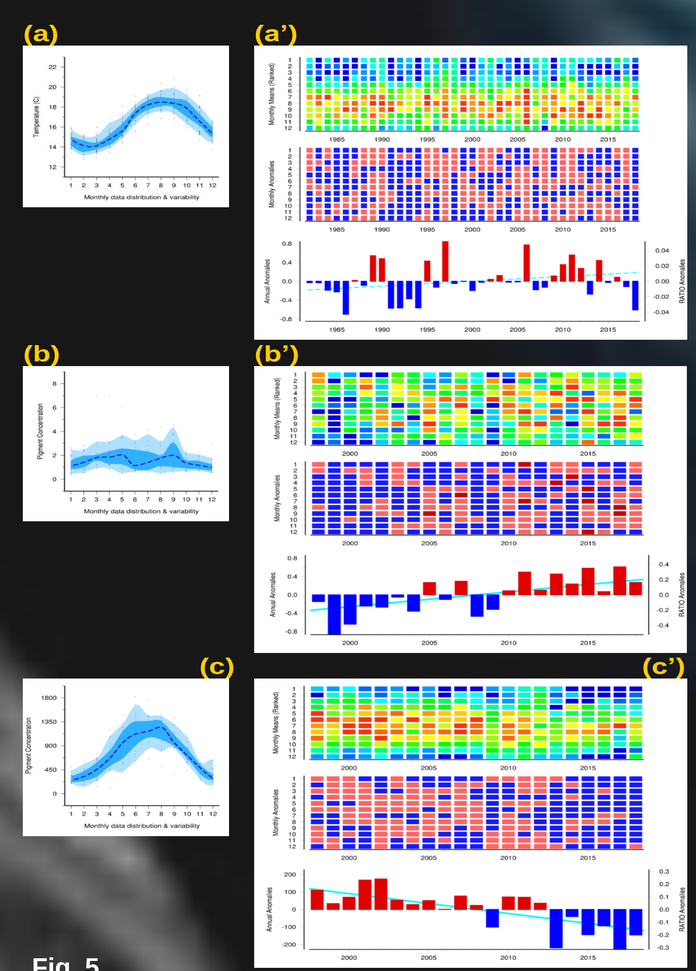


**Fig. 5.** Left-hand panels show satellite-retrieved average monthly (a) Sea Surface Temperature (SST, °C; blue shadow area); (b) chlorophyll a concentration (Chl *a*, µg L–1; blue shadow area) and (c) Primary Production (PP, mg-C/m$^2$/day; blue shadow area) for BNR coastal upwelling system.
Right-hand panels show (a') SST; (b') Chl *a* and (c') PP. Pixel contour plots at top and middle right show monthly average (full color) and anomalies (red positive, blue negative). Bar graphs (right hand bottom) show annual average anomalies.

⇒ **SST** despite the upward trend over the past 60 years, in the five-year of the study period, local temperatures have been decreasing.

⇒ **Chl *a***
- have its maximum in March, May and September in all years analysed, resembling the usual seasonality of phytoplankton growth in temperate regions;
- display a consistent significative increase over the past 20 years.

⇒ **PP**
- showed a decreasing trend since 1998.
- PP satellite-derived measurements for BNR surrounding area correlated negatively with Chl *a* for the last twenty years ($r = -0.9533$; $p < 0.05$).

⇒ **Salinity**
- remained constant at around 36.0 throughout all year in BNR;
- annual anomalies for the region revealed a significative increase over the last sixty years, however within the 5 years study, the salinity annual anomalies showed a descending trend.

⇒ **Northerly winds**
- steadily weakened during the upwelling season (April-September);
- annual anomalies presented since the 1960s an increasing trend.


**ACKNOWLEDGEMENTS**

The research was financial supported by the Portuguese Foundation for Science and Technology through a PhD grant awarded to Joana Falcão Maia (SFRH/BD/140876/2018), the strategic project UIDB/MAR/04292/2020 granted to MARE – Marine and Environmental Sciences Centre and the project JELLYFISHERIES (PTDC/MAR-BIO/0440/2014, POCI-01-0145-FEDER-016772), through the Integrated Programme of SR&TD "Smart Valorization of Endogenous Marine Biological Resources Under a Changing Climate" (Centro-01-0145-FEDER-000018), co-funded by Centro 2020 Programme, Portugal 2020, European Union through the European Regional Development Fund (FEDER).