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Approaches to derive phytoplankton functional types and size classes. Validation along a gradient of trophic status in Eastern Atlantic

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Abstract

In recent years PFT (Phytoplankton Functional Types) and PSC (Phytoplankton Size Class) distributions on a global scale have received increasing attention, due to the different roles PFTs play in biogeochemical cycles and to the strong effect that any change in the balance between groups would have upon marine ecosystems, especially in the context of Earth's changing climate.

Whereas remote sensing of ocean colour is a widely-accepted tool to evaluate phytoplankton chlorophyll-a (Chla) concentration, its application to estimate PFTs is still an area of active ongoing research. Likewise, HPLC is used to measure phytoplankton pigment assemblage; however, its use to distinguish PFT is also matter of on-going research. Hence, quantification of PFT or PSC either by remote sensing or from HPLC photosynthetic pigments needs *in situ* validation.

A previous developed model (Brewin *et al* 2010) was applied to *in situ* data along a trophic gradient, with oligotrophic (Horseshoe seamounts), mesotrophic (Azores islands) and eutrophic (upwelled Portuguese coast) areas, sampled from 2006 to 2010, as well as to AMT data for the same region. Intracellular Chla per cell, for each size class, was computed from the cell enumeration results (microscopic counts and Flow Cytometry) and Chla concentration for that size class given by the application of the model. Finally, a map of cell abundance was obtained, from a remote sensing MODIS composite image of Chla.

Objective

The main goal of the present work is **to produce a cell abundance map from remote sensing Chla**, **on the Eastern North Atlantic region**, which will be extremely valuable for biogeochemical models, and will allow a better estimation of carbon production and sequestration in the ocean.

Methodology

The present work gathers data from several cruises performed by the work team from 2005 to 2010 as well as data from the Atlantic Meridional Transect (AMT) cruises 2-19, collected from 1996 – 2009, gently provided by the British Oceanographic Data Centre (BODC), (concerning results of photosynthetic pigments and cell enumeration from flow cytometry).

Photosynthetic pigments were analysed by HPLC (Mendes et al 2011 and references herein). Microscopic cell counts were performed on Azores and Cascais NR05 cruises following Utermőhl technique. For Pico and Nanoplankton cell counting, samples from POS384 and HM09 cruises were analysed by Flow Cytometry (Tarran *et al*, 2006).

The relative contribution to each phytoplankton taxonomical class to the overall Chla was calculated by means of Chemtax software. For each region, a particular set of classes and ratios was chosen, according to previous published literature for the region and to the results obtained by cell enumeration.

The model developed by Brewin et al 2010, which calculates the fractional contributions of the three phytoplankton size classes (Micro, Nano and Pico) to the total Chla was applied to the whole in situ data. The fractions of the Chla concentration associated with each size class were inferred from the relative concentration of seven diagnostic pigments (Vidussi et al 2001 and Uitz et al 2006), and then multiplied by the *in situ* Chla concentration to derive size-specific concentrations.

A ratio of Chla per cell, for each size class, was computed from the cell enumeration results (microscopic counts and Flow Cytometry) and Chla concentration for that size class given by the application of Brewin's model.

A cell abundance map for the region was estimated from remote sensing Chla as follows: a MODIS AQUA May 2009 monthly L3 composite was used, from which the Chla concentration of each size class was estimated using the three-component model, parameterized to our dataset. The Chla for each size class was then divided by the mean Chla per unit cell for each size class (according to the ratios plotted in Fig 6)

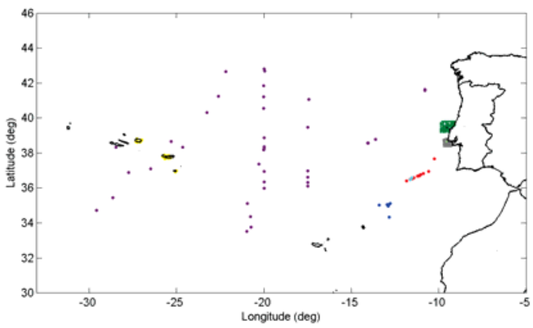


Figure 1 – Map of sampling stations. Blue – Ampere Seamount; Black - Seine Seamount; Light Blue – Gettysburg Seamount; Light Green – Cascais fixed point; Grey – Cascais spatial grid (NR05) Green - Nazaré 2006, Nazaré 2010 and Pelagia 2006; Red – Gorringe Seamount; Yellow – Azores; Purple – AMT cruises.

Table I – Characterization of the cruises

Cruises/Data sets	Lat -Long (west), decimal degrees	Trophic status	Date	Nº of stations	Observations	Flow Cytometry /Cell counts
POS384 Horseshoe seamounts: Seine, Ampere, Gettysburg	33.47- 36. 69 11.55 – 14.38	Oligotrophic	8-25 May 2009	15	Profiles up to 150m	FC
HM09 Gorringe Seamount	36º-37º 10º-12º	Oligotrophic	2-6 June 2009	14	Profiles up to 100m	FC
Azores 2008/2009	36.93- 38.81 25.03 – 27.34	Mesotrophic	May-June 2008 April-July 2009	27 27	Surface, 15 and 30m	CC
Nazare Canyon June-July 2006	39.20 -39.80 9.08 – 9.90	Upwelled coast	22 June – 5 July 2006	92	Surface	
Nazare Canyon 2010	39.34 -39.71 9.09 – 9.80		6-18 March 2010	71	Profiles up to 50m	
Pelagia (Nazare Canyon)	Fixed point 39.61 9.29		10-11 September 2006	1 (24h cycle)	5, 50 m & DCM	
Cascais NR05, spatial grid	38º - 39º 9º -10º	On the influence of Tagus river	29 August-6 September 2006	78	Surface, and DCM samples	CC
Cascais, NR05, fixed point	Fixed point 38.68 9.4		4-5 September 2006	1 (24 h cycle)	Surface and DCM samples	
AMT 2,3,4,6,8,10,12,13,14,15,18,19	33º - 43º 10º- 30º	Oligotrophic	1996-2009	74	Profiles up to 150m	FC (AMT13,18 and 15)

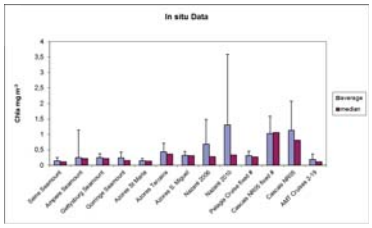
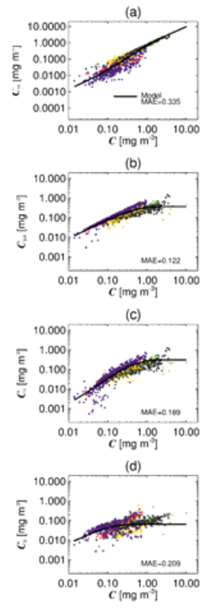


Figure 2 – Chla Averages, standard deviation and medians are plotted for the various cruises. The highest concentrations (8-10 mg m^{-3}) were found over Nazaré canyon (Nazaré 2010 cruise), in July, during an upwelling event.



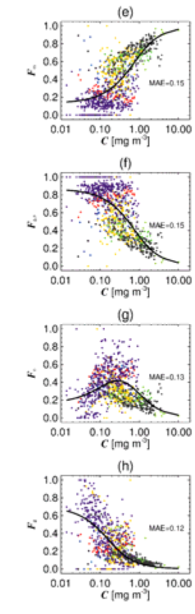


Figure 3 – (a-d) shows the three component model plotted against Chla values. (e-h) shows the size-specific fractional contributions of microplancton (F_m), Nano+Picoplancton ($F_{n,p}$), Nanoplancton (F_n), and Picoplancton (F_p), plotted calculated according to the model as a function of total Chla. (ME: mean error). Colours represent different cruises (see legend Figure 1).

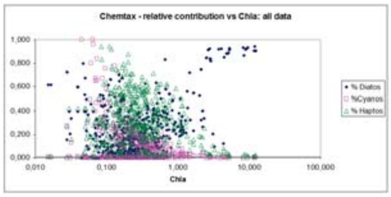


Figure 4 – Relative contribution of Diatoms, Haptophytes and Cyanobacteria, as estimated by Chemtax, applied to all cruises (except AMT).

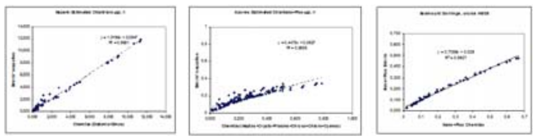


Figure 5 – Estimated Chla for the different size-classes, comparison of results from Brewin's model and Chemtax, for Eutrophic (Nazaré), Mesotrophic (Azores) and Oligotrophic (Seamounts) areas.

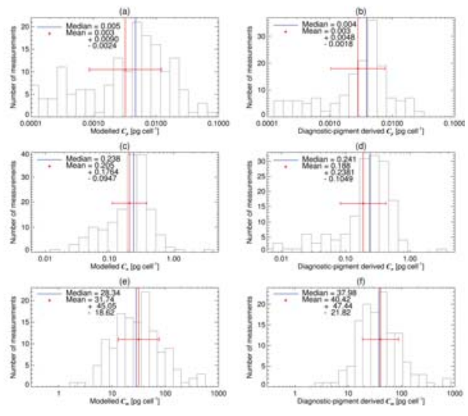


Figure 6 - Ratio Chla/Cell for Pico, Nano and Microplankton, estimated from cell enumeration results and size class Chla concentration given by the application of Brewin's model (a,c,e), and using Chla derived from diagnostic pigments for each size class (b,d,f). Mean and mean absolute deviation as well as median values are displayed.

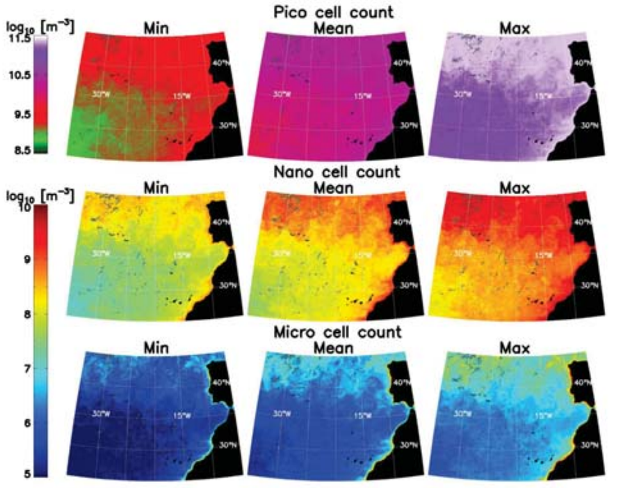


Figure 7 – Cell abundance estimation from remote sensing Chla. A MODIS AQUA May 2009 monthly L3 composite was used. Chla for each size class was estimated from the three-component model, and divided by the mean chl-a per unit cell (see figure 6) obtained from combining information from the model, microscopic cell counts and Flow Cytometry.

The distribution of the three size classes clearly presents higher cell concentrations in the northern part of the area, above latitude 40º, and along the Portuguese and Morocco coasts.

Table II – Ratios Chla/cell or DivChla/Cell from the literature

Taxons	Chla or DivChla pg cell-1	Authors
Picoeukarytes		
Prasinophyte Ostreococcus	0.04	Six et al. 2008, L&O: 255-265
Prochlorophytes (DivChla)	0.23 x 10^{-3} 0.2 – 3 x 10^{-3}	Grob et al. 2007, Biogeosciences: 837-852
	0.1-7 x 10^{-3}	Veldhuis & Kraay 2004, DSR: 507-530
	0.1-1 x 10^{-3}	Bouman et al 2006, Science : 918-921
Cocolithophores		
Emiliana huxleyi	0.075-0.1	Ra et al. 2010, Marine Chemistry:130-7
Emiliana huxleyi	0.049-0.283	Saunders, 1991
Prymnesiophytes		
Pavlova lutheri	0.156-0.288	Saunders, 1991, MsThesis, PML, unp
Cryptophyceae		
Hemiselmis aff virescens	0.032-0.194	Saunders, 1991, MsThesis, PML, unp
Chrsomonas salina	0.30-1.131	"
Diatoms		
Thalassiosira weissflogii	2.70-5.21	Saunders, 1991, MsThesis, PML, unp
Skeletonema costatum	0.14	Harrison et al, 1977, Mar Bio: 19-31
Thalassiosira gravida	0.65	"
Chaetoceros debilis	5.7	"
Cylindrotheca closterium	0.045	Ruivo et al. 2011, JPR: 1012-1022
Thalassiosira pseudonana	0.35	Hitchcock 1982, JPR : 363-377
Coscinodiscus wailesii	2.37 x 10^{3}	"
Dinoflagellates		
Amphidinium carterae	7.265	Ruivo et al. 2011, JPR: 1012-1022
Scripsiella trochoidea	9.76 - 11.18	Saunders, 1991, MsThesis, PML, unp
Gymnodinium instriatum	122.5 ± 7.3	Park et al 2002, MEPS : 281-292
Akashiwo sanguinea	54	"
Cachonia pygmeya	3.2	Hitchcock 1982, JPR : 363-377
Gymnodinium nelsoni	307	"

Conclusions

- The application of Brewin et al 2010 model to in situ data of Eastern North Atlantic successfully displayed the spatial distribution of phytoplankton size-classes in the area, furthermore, the comparison with Chemtax results for PFTs correctly matched the model size-classes relative abundance.
- The values obtained for Pico and Nanoplankton for the ratio Chla/Cell are consistent with the literature, but the mean value for Microplankton is higher than the available values measured in cultures (see Table 2). However, when we applied Menden-Deuer & Lessard 2000 Carbon:volume relationships for local species of Diatoms and Dinoflagellates, and then the respective Carbon: Chla ratio given by Sathyendranath et al 2003, values in the order of 10-50 pg Chla $cell^{-1}$ for Diatoms *Lauderia annulata* and 5-25 for *Detonula pumila,* are found; whereas for Dinoflagellates, species like *Ceratium furca* would have a ratio of 60-185 and *Dinophysis* 75-220 pg Chla $cell^{-1}$.

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