CARBON BUDGET AND BACTERIAL GROWTH EFFICIENCY IN THE ADRIATIC SEA
A THEORETICAL MODELLING STUDY

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Introduction

Planktonic organisms are, in marine environment, the main actors of both consumption (photosinthesys) and production (respiration) of CO_2. For this reason they play a crucial role in the global carbon cycle and, therefore, in modulating the global climate.
The ratio between primary production and community respiration (GPP/R) is the main parameter considered in order to understand whether an environment is net-heterotrophic or net-autotrophic and consequently if is a source or a sink of CO_2 for the Atmosphere. The importance of the Bacterial Growth Efficiency (BGE) as index of environmental trophic conditions and its influence on the global carbon cycle has also been highlighted by several studies (Del Giorgio and Cole, 1998, Biddanda et al., 2001). On the basis of these two parameters is theoretically possible to estimate the marine metabolic balance and to quantify the marine ecosystem response to changing environmental condition.
In this work, on the basis of numerical simulations carried out with a three dimensional climatological ecosystem model (Polimene et al., 2006a), the carbon budget (by means of the GPP/R ratio, the sedimentation and boundary fluxes) for the Adriatic Sea was estimated and a theoretical scenario of carbon exchanges between four Adriatic sub-basins is offered. BGE was also estimated in order to highlight the trophic variability of the basin. GPP/R, the sedimentation fluxes, the BGE and the bacterial respiration were estimated by considering spatially (basin and sub-basins) and temporally (annually) integrated fluxes. The BGE was calculated by dividing the net bacterial production (BCP) for the total bacterial carbon uptake (C-Uptake) as suggested by Polimene et al. (2006b). The simulation was analysed after three years of perpetual year mode run (spin up) when each model state variables achieved a stable yearly repeating cycle.
The subdivision in sub-basins (Fig. 1) was made following Zavatarelli et al. (1998) who divided the Adriatic in 4 main sub basins: the shallow North (SN), the deep North (DN), the middle (M) and southern basin (S); shallow and deep north were separated on the basis of the 40-m isobath

STATIONS	MODEL	DATA
B6	118 ± 19	71 ± 11
B13	74 ± 24	53 ± 7
C4	11 ± 27	61 ± 10
C12	91 ± 41	36 ± 5

Tab. 1. Simulated and observed depth-integrated gross primary production value in the four station indicated in Fig 1. Both simulated and observed values are yearly averaged and displayed with standard deviation.

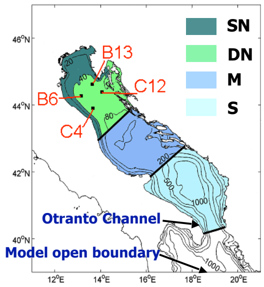

Fig. 1. The model domain and the Adriatic Sea Sub-basins. SN=Shallow North, DN=Deep North, M=middle, S=South. B3, B13, C4 and C12 are the stations in which a comparison with experimental data was performed.

R_{bact}/R			
SN	0.58	M	0.69
DN	0.68	S	0.75

Tab. 2. Bacterial respiration (R_{bact}) to community respiration (R) ratio estimated in the four sub-basins.

Results and Discussion

The model used in this work has been validated in a previous paper for the major biogeochemical bulk properties (Polimene et al., 2006). Here we further validate simulations against observed primary production data (Tab. 1).
The Adriatic simulated yearly GPP/R value is lower than 1 (data not shown), implying that the Adriatic is a source of CO_2 for the atmosphere. On the other hand the GPP/R value presents a high variability when calculated in the different sub-basins (Fig. 2). Only the shallow north sub-basin has a GPP/R>1 while deep north sub-basin is at equilibrium and the middle and the southern ones present an excess of respiration. Starting from the mass conservation, considering a southward net transport (mainly due to the Western Adriatic Coastal Current, see Fig. 2) and the sedimentation fluxes in each sub-basin, we found that the surplus of carbon produced in the shallow north (100% in Fig. 2) would be theoretically sufficient to explain the GPP/R value in the central basin and to match all the sedimentation fluxes, but not to explain the GPP/R value less than 1 in the southern basin. As shown in Fig. 2 only the 12% of the surplus of carbon produced in the SN would reach the southern sub-basin, while the 92% would be required to mach the excess of respiration. This implies that allochthonous organic carbon is respired in this sub-basin. We supposed that the input of Dissolved Organic Carbon (DOC), mainly associated to the Levantine Waters ingression trough the Otranto channel, increasing the bacterial respiration, could be responsible of the GPP/R value in the southern sub-basin. This idea is supported by the fact that the simulated value of the bacterial respiration to community respiration ratio (Tab. 2) increases from the north to the south where it reaches the value of 0.75, meaning that bacteria are the principal contributor to the community respiration in that zone.
The model considers the open boundary (see Fig. 1) as a DOC input/output on the basis of the value of the velocity normal to the open boundary prescribed by the hydrodynamic sub-model. When this velocity is >0, then a fixed DOC concentration (dependent on the depth) is transported inside the model domain; when the velocity is <0, the DOC amount simulated on the boundary is transported outside the model domain. On the basis of model simulation the yearly DOC flux at the open boundary is positive implying an input of allochthonous DOC.
Sensitivity experiment carried out by taking off the ingression of DOC at the open boundary showed a value of GPP/R equal to 1 for the southern basin while left unaltered the GPP/R in the others sub-basins.
The simulated values of BGE for each sub-basin are shown in Tab. 2. Highest BGE values are simulated in the SN sub-basin where the highest GPP/R value and the highest sedimentation fluxes were also simulated. In order to correctly understand these data, it should be stressed that the BGE computation is made on the basis of sub-basin and annual integrated fluxes (BCP and C-Uptake) and then should be considered as a sub-basin yearly mean values. Considering this temporal and spatial scale (on the basis of the BGE values) the Adriatic Sea ranges from an oligotrophic (the SN) to ultra-oligotrophic (the other sub-basins) regime. On the other hand values of BGE typical of meso-eutrophic coastal areas (0.4, data not shown) were simulated in the north-western coastal area indicating the presence of a strong trophic gradient at the sub-regional (local) scale.

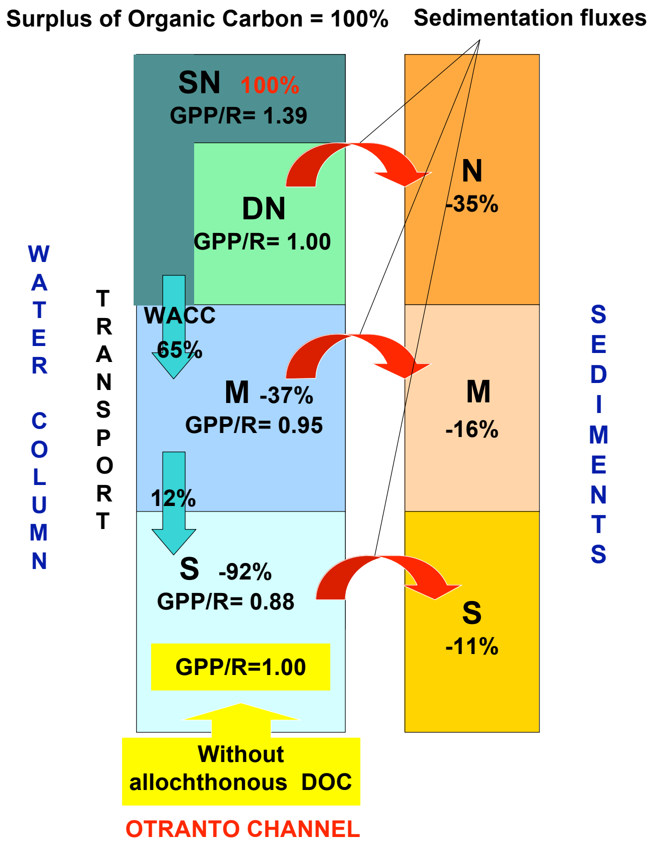

Fig. 2. Adriatic Sea carbon budget simulated scenario. WACC= Western Adriatic Coastal Current. Red arrows indicate sedimentation fluxes in each sub-basin while blue arrows indicate a net southward transport of organic carbon.

SUB-BASINS	SN	DN	M	S
BGE	0.15	0.07	0.06	0.04

Tab. 3. BGE simulated in the four Adriatic sub-basins.

Conclusions

The analysis of numerical simulation suggests the following conclusions:
1)The Adriatic sea is net-autotrophic only in the shallow northern basin. At the basin and at the yearly scale, is a net-eterotrophic and oligotrophic system.
2)The GPP/R ratio in the southern sub-basin is affected by allochthonous DOC introduced by means of the Levantine Intermediate Waters.
3)The high BGE value simulated in the north-western coastal area implies the presence of an high trophic variability at the sub-regional scale level.

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