DEVELOPMENT OF A NOVEL TOOL TO PREDICT DIFFERENT WATER QUALITY SCENARIOS WITHIN A MARINE PROTECTED AREA (MPA) IN THE MALTESE ISLANDS: THE 2D SHYFEM-BFM MODEL

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Abstract
Effective operational marine conservation and management is thwarted by a lack of financial and human resources. A coupled 2D hydrodynamic (SHYFEM) and ecological (BFM) model was developed in the current study as a Decision Support System (DSS) to spearhead good governance of a Marine Protected Area (MPA) in Dwejra (Maltese Islands) in the Central Mediterranean. Two scenarios were considered – one with the current levels of nutrient runoff from land and one in which such levels are increased as a result of a greater human activity within the area. Although the developed numerical modeling platform needs to be refined and to be run for a longer time-frame, its output suggests that it is a promising tool to assist in the operational management of an MPA.

Keywords: Models, Nutrients, Diatoms, Dinoflagellates, South-Central Mediterranean

Introduction
One of the most frequent and impacting vectors of changes in the environmental status of coastal areas is the input of dissolved nutrients, from both point and diffused sources.The simultaneous occurrence of high nutrient loads, high water temperatures and low hydrodynamic flushing of water bodies may lead to dystrophic and anoxic events, with cascade effects on the entire marine ecosystem. Understanding and predicting the mechanisms leading to such events is therefore of fundamental importance for a proper management of the marine environment within marine areas of high conservation value, such as MPAs. The operational monitoring of the relevant water parameters is frequently thwarted by prohibitive demands on costs and manpower.

Materials and Methods
In this context, we developed an integrated numerical platform that is able to provide, operationally, an evaluation of the Current Environmental Status (CES) of the Dwejra MPA on the island of Gozo (Maltese Islands, lon=14° 11'17"; lat=36°03'14"). This system is based on a coupled 2D hydrodynamic and ecosystem model and constitutes a pilot case of a Decision Support System (DSS) formulated to support the governance of an MPA's coastal waters, capable of forecasting different water quality scenarios arising under different nutrient loads. In particular, an ecological model (BFM - Vichi et al. 2007) and a shallow water finite element hydrodynamic model (SHYFEM – Umgiesser et al., 2004) have been coupled to each other (Cucco et al., 2012) and applied to reproduce the main hydrodynamic and biogeochemical processes affecting the water quality features within the Dwejra MPA in Gozo. Both hydrodynamic and biogeochemical flux models run operationally to predict, on a daily basis, the changes in both hydrodynamic and biogeochemical variables. The hydrodynamic and biogeochemical model domain covers the coastal waters of the Malta archipelago in their entirety (up to a distance of 20 km from the coast) by means of an unstructured grid, with a spatial resolution varying between a few km for offshore areas to a few hundred meters for the more coastal areas around the Dwejra site. Boundary conditions for the hydrodynamic module were provided by the ROSARIO sub-regional oceanographic prediction system (ROSARIO, 2006), whereas boundary conditions for the biogeochemical module were downloaded from MyOcean Web data services (MyOcean, 2012). Responses of ammonium, diatoms, dinoflagellates, carnivorous and omnivorous zooplankton to varying input of nitrates to the aquatic system in question were monitored. About 110 boathouses, frequented by approximately 220 persons annually, mainly during the spring and summer periods, are located around the periphery of the same lagoon. The nutrient loads produced by the boathouses were estimated by means of the so-called "*equivalent population*" procedure. This method is based on an estimation of the nutrients concentration of the sewages generated by anthropogenic activities. Considering the boathouse agglomerate as a 'camping' activity, for which 1 EI corresponds to 2 physical persons frequenting the area, an equivalent population of about 110 EI was adopted to represent the current scenario. Adopting the same table of conversion from EI to nutrients loads adopted in Italy, the wastewaters produced daily by each EI is characterized by a BOD_5 at 20° C equal to 60g of oxygen (Art.74 of Law 152/06 of the Italian Ministry of the Environment). A set of 2 simulation scenarios have been carried out for the 1st July-1st September period (when boathouse occupation levels are highest). Such an exercise involved varying the value of EI in the area, to represent a corresponding increase in the number of boathouses in the area, from the current number of 110 boathouses to 160, in order to explore the water quality consequences of a more permissive environmental policy in future.

Results and Discussion
According to the output of the developed numerical platform, a scenario where nutrient (nitrate and phosphate) input to the coastal area is increased (as a result of the increase in boathouses in the area) is also characterized by a corresponding increase in ammonium levels, which increase by approximately 30%, and in dinoflagellate populations, whose annual blooming at this time of year in the Mediterranean (e.g. Daly Yahia-Kefi et al., 2005) is further accentuated. Diatom populations, already depressed at this time of year in the Mediterranean (e.g. Daly Yahia-Kefi et al., 2005), do not exhibit any significant increases in their abundances in the EI160 scenario, as do both omnivorous and carnivorous zooplankton classes. The fact that no cascade effect of the surge in nutrients up different trophic levels within the pelagic food web at Dwejra was observed might be due to the intense hydrodynamic flushing and advection that the Dwejra area is generally subjected to, which in turn results in low nutrient residence times within the lagoon. Such observations are further confirmed through the results of a third simulation (assuming an EI value of 210), run over the 1st June-30th September period.

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