Proceedings of the 14th Biennial Coastal Zone Conference
New Orleans, Louisiana
July 17 to 21, 2005

HYDRODYNAMICS MODELLING APPLIED TO REACHING OPTIMAL FUNCTIONING OF THE LARGEST FRENCH ARTIFICIAL REEF SITE

Marie-Aude Pradal, LOB UMR 6535
Bertrand Millet, LOB UMR 6535
Delphine Thibault Botha, LOB, UMR 6535

Keywords: hydrodynamics, model, POM, artificial reef, currents, dispersion, GIS

INTRODUCTION

An artificial reef is made of one or more objects of natural or human origin deployed purposefully on the seafloor to influence physical, biological or socioeconomic processes related to living marine resources (Seaman, 2000). Indeed artificial reefs can be used as breakwaters to create surf spots, or as attracting devices to increase biomass and biodiversity in order to create new diving sports or new fishing sites. For that purpose the city of Marseilles launched in 2001 the largest French artificial reef deployment programme. By the end of 2006, 35000m^3 of concrete, wood and nets will be deployed then almost doubling the total volume of artificial structures submerged along the French coasts.

OPERATION "RÉCIFS PRADO 2006"

As shown on figure 1, the bay of Marseilles is subdivided into two basins north and south the Frioul Islands. The commercial harbour is located in the northern bay. The average depth of the northern basin is 70m. The southern basin limits are Prado beaches to the east and the mount Marseilleveyre, the Riou Islands and the Calanques to the south. This basin is shallower than the northern with an average depth of 40m. The southern bay is widely open to the west and south.

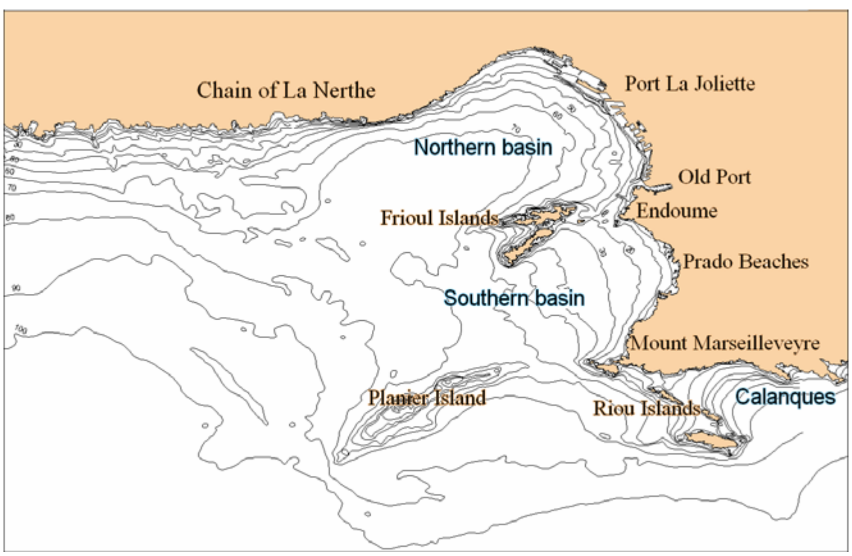

Figure 1. Geography of the Bay of Marseilles

The Fjord networks formed by the Calanques are very touristic areas with a million visitors per year. These are natural sites that should be protected; at the other end of the bay, the port of La Joliette is a highly urbanised area. Northern and southern areas of city can not be developed anymore. But in between, the southern bay is yet to be valorized and reasonably improved. Therefore, artificial reefs will be deployed in the southern bay. But where? Considering various parameters such as :
geographical (location of cable, wires, navigation routes)
ecological (location of potential areas of emission of eggs and larvae)
physical (seafloor resistance and composition) and
hydrodynamical (currents),
the city of Marseilles selected an area between the isobaths 20m and 30m such as shown on figure 2.

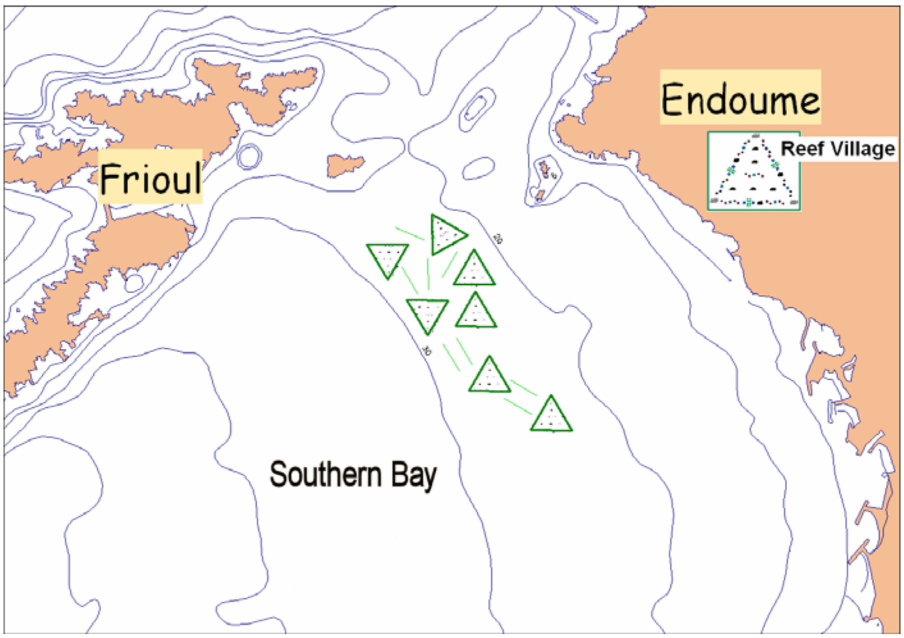

Figure 2. Deployment area in the southern bay

The 35000m^3 of concrete blocks are organised following the shape of 300m triangles, called “villages”. The seven villages are connected to each other by reefs arranged in lines in order to facilitate and enhance the colonization by offering shelter for in between movement.

OPTIMIZATION OF THE DEPLOYMENT

The success, or failure, of reef colonization depends mostly on the success, or failure, of benthic recruitment. Indeed, no larvae recruitment on the reefs means no organism growth, no production and no harvest. According to specialists (Vigliola, 1998) the main factor controlling recruitment is not the natatory speed but hydrodynamics. So the trajectory of main larvae can be assessed based on currents. Therefore, with an extensive knowledge of hydrodynamics of the bay we will be able to point out areas with a potentially high level of success or failure. The main aim of my PhD work is to describe the hydrodynamics and particle dispersion of the southern bay, based on the widely used Princeton Ocean Model (POM).

HYDRODYNAMICS AND DISPERSION MODELLING, TOOLS AND RESULTS

The model POM is a 3D circulation and dispersion model. This model uses a sigma coordinate; the vertical coordinate is scaled on the water column depth. The horizontal time differencing is explicit whereas the vertical differencing is implicit. POM is a free surface model and uses a split time step (Blumberg and Mellor, 1987). Open boundaries are free and radiative. Circulation is only driven by local winds and bottom topography. The mesh grid extension is 29kmX35km (figure 1), the cell resolution is 100m. The grid has been geo-referenced: every cell is associated to its latitude and longitude coordinates. Local wind is given by the wind rose established especially for this study at the centre of the bay according to wind measurements at Frioul Islands over 22 years (1976-1998). The rose at Frioul (figure 3) shows two main northern winds called Mistral (320° and 340°) and two main southern winds (230° and 160°)

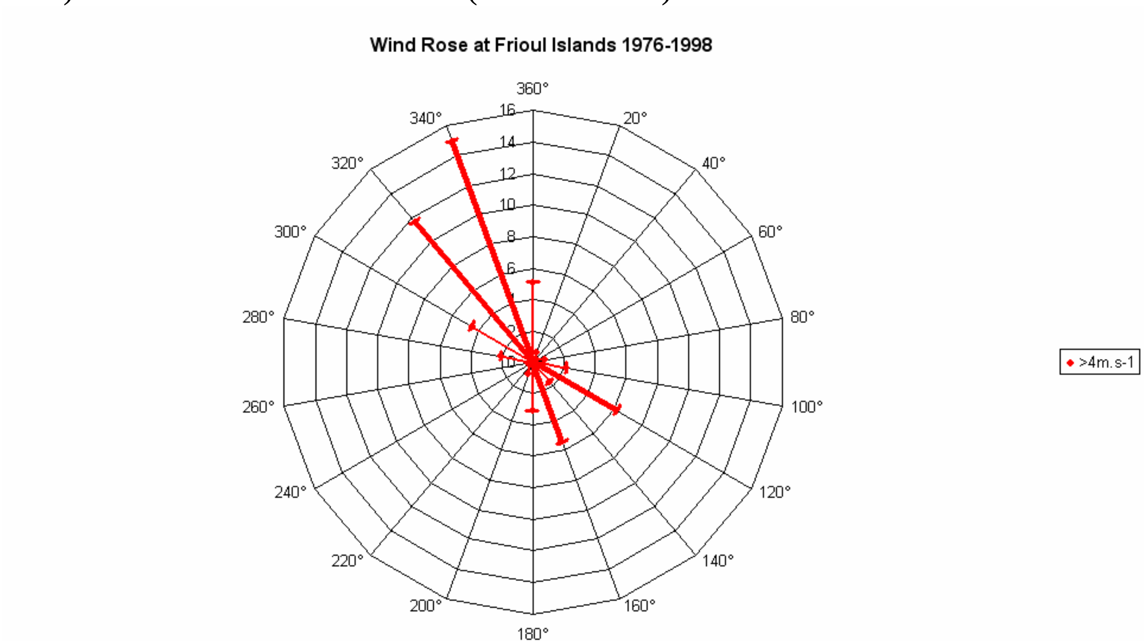

Figure 3. Wind rose at the middle of the bay. MeteoFrance data

The model was validated using a three month long time series of current data and can then be used to simulate 3D currents as well as dispersion fields generated by each wind direction. Surface and bottom currents around the area of deployment are shown on figure 4 and 5 respectively, this established the current typology according to prevailing winds.

When exposed to southern winds, surface current direction is northwest (320°), the average speed is 40cm.s^{-1}. At the bottom gyres appear south of Endoume and close to Mount Marseilleveyre. Main bottom current direction is south east (140°) with an average speed of 10cm.s^{-1}. Downwelling appear at the east of Frioul Island while upwelling appear at the Prado beaches.

When exposed to Mistral winds, surface current direction is southeast (160°). Their speed can reach 50 or 60cm.s^{-1} locally. At the bottom gyres also appear close to Endoume and Marseilleyre Mount. East of Frioul Islands, upwelling can now be observed.
It is interesting to point out that in the area of deployment, currents, both at the surface and at the bottom, can go exactly in opposite directions (depending on the type of wind: northern or southern), gyres are maintained but centered on different locations, with changing widths depending on wind direction (120° or 160°, 320° or 340°).

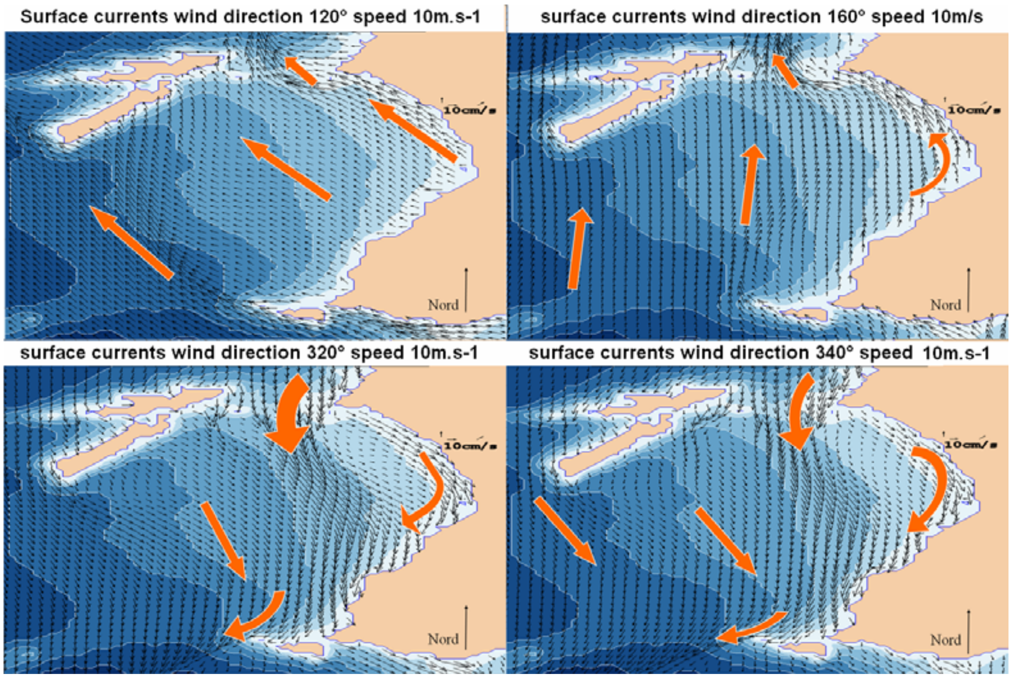

Figure 4. Surface currents generated by 10m/s 120°, 160°, 320°, 340° winds

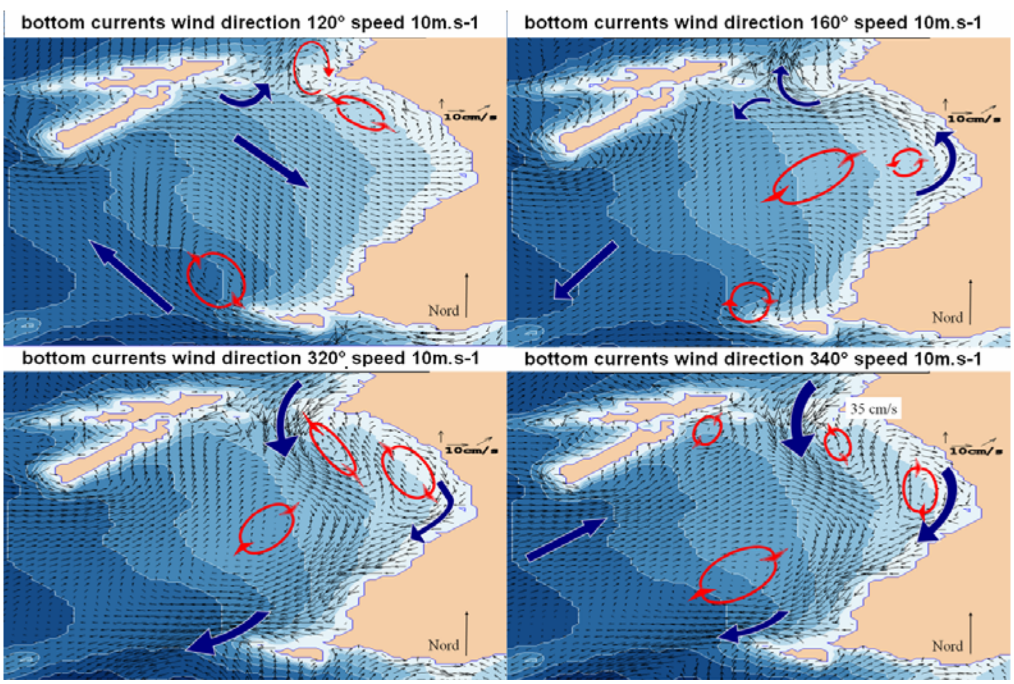

Figure 5. Bottom currents generated by 10m/s 120°, 160°, 320°, 340° winds

A further step is, knowing currents and the location of larva, to calculate the dispersion plumes of larvae coming from different areas in the bay. For instance, figure 6 shows the dispersion plume of larva initially in the seagrass area after a 12 hour long exposure to 10m.s^{-1} 340° winds.

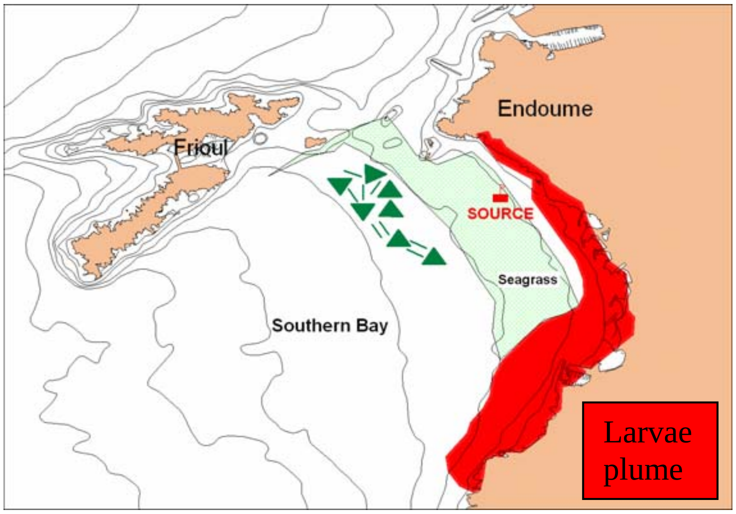

Figure 6. Larvae dispersion plume after exposure to 10m/s Mistral winds for 12 hours

Despite the short distance between the source and the reefs, if the larvae emission occurs at the bottom while Mistral blows, larvae plume will spread southward along the coast and won't be able to reach the target. In that case, the benthic recruitment should fail. So geographically close structure are not necessary hydrodynamically connected.

CONCLUSION AND PERSPECTIVES

Based on the local wind rose, the modelling of currents and dispersion results in a comprehensive set of georeferenced (GIS) maps of currents and particle plumes. These maps should help and understand why a village efficiency might be higher than it's neighbour's since currents and diffusion show very large spatial and temporal variability, even at small scales. These results will be accessible for the City of Marseilles in order to compare simulated success to observed colonization on site.

REFERENCES

Seaman, 2000, Artificial Reef Evaluation: With Application to Natural Marine Habitats CRC Press

Vigliola L., 1998, Contrôle et régulation du recrutement des Sparidae (Poissons, Téléostéens) en Méditerranée : importance des processus pré- et post-installation benthique PhD thesis

Blumberg, A. F. and G. L. Mellor, A description of a three-dimensional coastal ocean circulation model. Three-Dimensional Coastal ocean Models, edited by N. Heaps, 208 pp., American Geophysical Union., 1987

Proceedings of the 14th Biennial Coastal Zone Conference
New Orleans, Louisiana
July 17 to 21, 2005

Marie-Aude Pradal, PhD candidate
Laboratoire d'Océanographie et de Biogéochimie UMR 6535
Centre d'Océanologie de Marseille Campus de Luminy Case 901
13288 Marseille Cedex 9 France
Phone : +33.4.91.82.93.32
Email : pradal@com.univ-mrs.fr