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Operation RECIFS PRADO : a model for management of the Marseille coast

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Abstract: In 2000, the City of Marseille launched the "PRADO REEFS" program involving the construction and submersion of underwater ecological habitats designed to repopulate, in a few years, previously unproductive seabeds. It was a national, European and mediterraneanscale pilot project; in fact, nearly 30,000 m^3 of reefs have been submerged at depths of 25–30 m, over an area of 200 ha, off the coast of Marseille.

The "PRADO REEFS" project is a true sustainable development project, an example of what a community can do to protect and enhance its environment and support its socioeconomic activities.

Keywords: *artificial reef, Marseille, restoration*

I. Introduction

The rehabilitation of the soft sea-bottom of Prado Bay is an important operation in territory restoration, one that fits in with a program for sustainable management of the Marseille coast (Fig. 1). The aim of this project is to increase natural resources and ensure the permanence of human activity on the coast.

With this program, the city of Marseille has decided to act in a global and coordinated fashion, by initiating a voluntary approach in favour of the Management Plan for the Roadstead of Marseille (known by its French acronym PGRM - Plan de Gestion de la Rade de Marseille).

This restoration policy and management plan consists mainly in reaching an adequate balance between:

– natural environments that must be preserved due to their exceptional value in terms of ecology and scenery,
– sites that have become definitively "artificial" to satisfy the needs of maritime activities (such as ports).

Between these two extremes are intermediary urban spaces, such as Prado Bay and the Frioul archipelago, sites with ecological and economic potential that have heretofore been neglected, but which now could be developed and enhanced.

The dual advantage of restoring former marine productive zones that have disappeared (such as dead seagrass bed matter of Posidonia oceanica that points to the rise by several metres of the lower limit of the living one) is that it directly benefits users of the sea, particularly fishers, and relieves pressure on the sensitive and threatened natural zones that have been damaged by overuse.

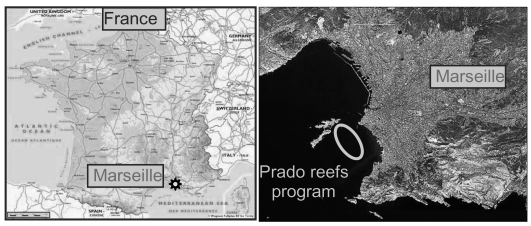

Fig. 1. Localisation of Marseille and Prado program

II. General principles

The main goal of the artificial reef immersion project is to increase the diversity and stability of marine resources in the soft bottom of

Prado Bay.

The basic idea is to provide new hard-substrate undersea habitats, immersed between 25 and 30 m below the surface, which are adapted to the ecological needs (maximum of habitats diversity) of a greater number of marine organisms. With a massive input of rock-like habitat, the productivity and biological diversity of the current sandy bottom will increase considerably, along with the value for both ecology and fishing activities [3] [9].

Diverse research projects carried out in the Mediterranean over the past two decades are now considered to be sufficiently conclusive [2] [5] [7], providing support for the Marseille project to adopt a very ambitious qualitative and quantitative objective from the start. This has made the project more significant at the national level: the immersion of nearly 30,000 cubic metres of reef, for a total investment of 6 million euros (40% from Europe [european founds for fishery], 30% from the Mediterranean Rhone and Corsican Water Agency, 20% from the city of Marseille and 10% from the Regional Council in Provence, Alps and Côte d'Azur). This objective was met in 2008 with the immersion of the last of the 400 artificial reefs (table 1).

From the start, the city of Marseille has built its project on the active collaboration of all partners, brought together onto a Scientific and Technical Monitoring Committee that reunites State institutions, scientific and expert groups, and stakeholder representatives [8]. Its essential mission is to discuss and validate each big step in the project, at the scientific, technical and administrative levels [3] [9] [11] [4] [6]. Over the past ten years (2000–2010), the committee has held 10 plenary meetings at Marseille City Hall.

From the very start of project development, the involvement of professional fishers has resulted in active participation of the Local committee of Maritime Fishers [8], transfer of European financing on structural funds destined for fishing, the application of a **ban on all forms of fishing** during the consultation period until December 31, 2012 in the regulated fishing zone, and their **willingness to undertake self-surveillance** of reef zones and sustainable and reasoned management of the halieutic resource.

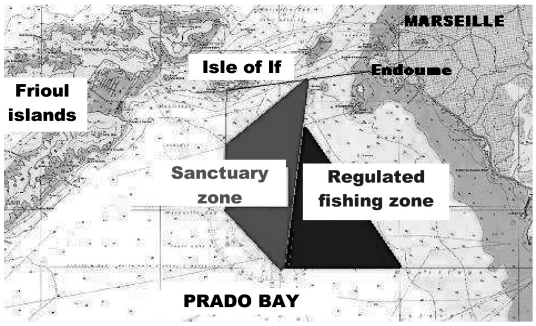

Fig. 2 The Prado reefs area

III. Anticipated organisation

In agreement with the main partners involved, it was finally decided to limit the sector of immersion to two zones: **a sanctuary zone** of 100 ha, in which all uses are forbidden outside of surface navigation and **a regulated zone** of 100 ha, in which fishing will not be allowed during the transition period until December 2012 (Fig. 2). This delay will be used to develop management of this zone with all stakeholders.

Prado Bay has many positive features for type of project: easy access and surveillance; **protection afforded by the Frioul archipelago against waves from the open sea; the existence of nearly permanent marine currents** that change direction depending on the dominant winds (mistrals, eastern winds) ; proximity of a **vast Posidonia bed** and significant natural rocky zones that guarantee rapid colonisation by local submarine flora and fauna; the possibility of **restoring former plant bed zones** that have disappeared and which form vast flat bottoms that are favourable to reef installation [6]; the existence of ferry way (Marseille-South developed zone) that enables a **sanctuary for marine fauna** to be included in this zone without engendering new constraints.

IV. Description of reef architecture

The objective is to provide marine plant and animal life with the features of hard substrates, a range of ecological habitats that are as large and diversified as possible (dimensions

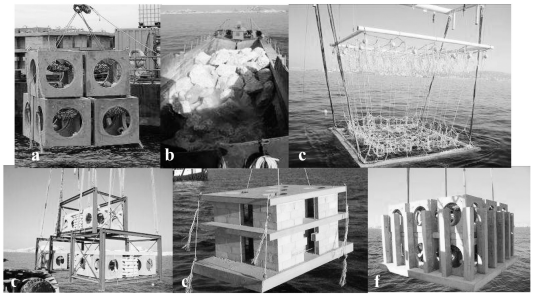

Photo 1. The different types of artificial reefs used in the PRADO REEFS operation in Marseilles
a : pile of concrete cubes, b : pile of stone Cubes, c : floating rope, d : metal basket, e : chicane, f : fakir basket

of cavities between a few decimetres and a few millimetres) to provide food sources and shelter to all stages of biological cycles of the different species (Photo 1).

Ecological optimisation of these structures that are organised on land, essentially focuses on the interior three-dimensional complexity and uniformity, obtained with the materials used in their fabrication (concrete, steel, synthetic cords for guard lines) and the interior packing using units of different sizes and functions (1.7m^3 concrete cubes, blocks, oyster shell nets, octopus pots).

Project studies have led to three overall types of reefs being retained (large volume "basket" models, piles of concrete cubes, quarry rocks) and two types of guard lines ("high" floating ropes, which are independent units of two floors and "low" floating ropes, that are always combined in four groups; there are three specific models : the metal basket reef, the chicane reef and the piles of concrete cubes) (Photos 1).

Biological effectiveness is provided by the system known as "chaotic piles" which has proven to be valuable in the Mediterranean. But the legal obligation to plan for the eventual possibility of reef removal (due to the temporary nature of territory acquisition in the public maritime domain) has led to significant constraints. As well, studies have been done on the design of large-volume units (58 to 306 m^3) (Table 2) that are solid and stable on the bottom, that are easy to manufacture and immerse (as well as to remove).

V. Plan for implantation

The general objective is to favour the distribution of a large number of reef units (surface effect) rather than a great concentration in the form of a few big piles, and to facilitate accessibility by mobile fauna to all lower parts of the reef units, as well as communication among the reefs using linkages.

Two overall types of unit grouping were thus adopted, enabling optimal occupation of all available surfaces (220 ha) : the villages (6 triangles of 300 m on each side, made of 51 to 57 units) and linkages (8 segments of 300 m in length made up of 9 units).

Reef density in the Prado area is 0.014 m^3 per m^2 of plot. In Europe, the program with the biggest volume of submersed reefs is found in Portugal, with 102 000 m^3 scattered over

Table 1. Number and volume of the different models used

Types of reef	Number	Total volume (m^3)	Percentage %	
			Number	Volume
Piles:	245	10 000	34	36
- Concrete Cubes (CCP)	202	3 100	28	11
- Stone Cubes (SCP)	43	6 900	6	25
Modules:	142	8 585	20	31
- Metal Basket Reef (MBR)	21	4 880	3	18
- Fakir Basket Reef (FBR)	21	1 705	3	6
- Chicane Reef (CR)	100	2 000	14	7
Ropes:	337	9 025	46	33
- Low (LR)	323 (x4)	5 500	44	20
- High (HR)	14	3 525	2	13
TOTAL	724	27 610	100	100

Table 2. Data on the weight and volume of the reefs

Module or pile	Volume (m^3)	Weight (tons)	Total volume and weight
Pile of 6 Concrete Cubes (CCP) + low ropes (LR)	volume of one cube = 1.7 m^3 pile of 6 cubes+ LR = 25 m^3	1 block = 0.750 t 4.5 t + link	202 CCP = 5 050 m^3 (= 1 000 t) 43 SCP = 6 880 m^3 for 21 500 tons
Stone Cube Pile (SCP)	160 m^3	500 t	
Metal Basket Reef (MBR) + low ropes (LR)	1 element = 45 m^3 MBR = set of 3 piled elements + LR = 266 m^3	16 t 48 t	21 MBR = 5 580 m^3 for 1 000 tons
Fakir Basket Reef (FBR)	75 m^3	48 t	21 FBR = 1 575 m^3 for 1 000 tons
Chicane Reef (CR) + low ropes (LR)	50 m^3	15 t	100 CR = 5 000 m^3 for 1 500 tons
High rope (HR)	252 m^3	Ballast = 6 m^3 of concrete = 14 t	14 HR = 3 525 m^3 for 200 tons of ballast
TOTAL			26 610 m^3 26 200 tons

Table 3. Ground cover of the reefs

Type of reef	Number of reefs	Ground cover of one reef (m^2)	Total ground cover (m^2)	Percentage of ground cover (%)
Pile of Concrete Cubes	202	6.25	1 262.5	0.063
Pile of Stone Cubes	43	50	2 150	0.108
Metal Basket Reef	21	15	315	0.016
Fakir Basket Reef	21	25	525	0.026
Chicane Reef	100	9,6	960	0.048
High Ropes	14	36	504	0.025
		TOTAL	5 716.5 m^2	0.286 %

50 km^2. But, in terms of volume for the same surface, the Prado reefs are 7 times denser than the Portuguese reefs.

In regard to ground cover, the Prado reefs cover only 0.35% of the 200 ha of the plot. The highest reef cover is the pile of stone cubes (Table 3).

VI. Monitoring and development programme

The territory acquisition decree anticipates initial scientific reef monitoring over a period of 10 years, based on the measurements and observations carried out over the different "stage zero studies".

Monitoring is based on the use of two complementary methods: experimental fishing (by professional fishers and supervised by an expert in halieutics) and direct population inventories using a visual reporting technique in undersea diving. Control monitoring of reef stability and wear will also be carried out during diving expeditions.

The stakeholders in the project have hoped to go further than the compulsory monitoring program. An operation of this scope is an opportunity to develop a research program aimed at a better understanding of ecosystem function in "artificial reefs" and its relationship to the environment. The scientific community and its partners have therefore been solicited to suggest other types of monitoring of the zone.

The marine science centre in Marseille and the Subaquatic Environment and Biology Commission of Department Committee 13 of the French Federation of Undersea Studies and Sports have therefore suggested additional

means of monitoring: organic matter, plankton communities, genetic origins of populations, biological surveillance. Other means of scientific monitoring are being discussed with new partners.

A socioeconomic study will evaluate the impact of these reefs on activities and uses, in particular the economic spin-offs for professional fishing. The study will use surveys and analysis of specific indicators.

The involvement of professional fishers is essential, as it will enable monitoring of their catches over a set period to compare them with the period before the reefs were set up.

VII. Regulations and management

Fishing, diving and anchoring are forbidden throughout the zone until December 31, 2012 to allow species and food chains to establish themselves naturally.

During this period, **consultation** with stakeholders helps to define the modes of use over the regulated zone (south zone, outside the channel). The north zone (inside the navigation channel) is destinated to be a sanctuary where all activities are forbidden. The existence of two differently managed zones may assist in evaluating a conservation zone and population evolution.

VIII. Promoting the operation

The highly attractive nature of the images so far obtained, and the educational potential of these artificial reefs, make them ideal for communication and raising awareness about the marine environment and sustainable development. Several initiatives of this type are being developed, both for the general public and for schools :

– one of the "**concrete cube pile**" reefs was not submerged. It is exhibited near the beaches of the Prado. Decorated under scientific supervision, it gives passersby an idea of the size of the reef and of the contrast between the concrete at the time of submersion and the surface colonised by marine organisms several months later;

– in collaboration with National Education and the "Centre Pédagogique de la Mer", a municipal structure to teach the public about the marine environment, several primary school classes **sponsor** a reef village every year. These classes are provided with technical information, photos, and accurate scientific data about the sponsored village. Each class makes a clay plaque which is placed in the underwater village by a scientist diver. At the end of the year, the classes get together for a day to show each other their work (an ABC, a song, an electronic circuit reef, scale model, etc.) and to meet the institutional and scientific partners involved in the operation;

– to help circulate information and messages, a **set of tools** is being designed and updated : teaching pack, exhibition, internet site, teaching booklet, leaflet for the general public, etc.. Some of these will be put together to form a teaching pack, available for classroom use and for anyone interested in artificial reefs, even those outside the sponsorship programme;

– conferences have been arranged to present the operation and information about what is happening on the reefs. Held once or twice a month, they provide an opportunity to learn about the marine environment and the need to preserve it.

– the Marseille experience is **promoted** along the coast in France and abroad.

IX. Conclusion

From the moment of conception to the immersion of the last reef, the immersion of nearly 30,000 m^3 of artificial reefs in Marseille has taken 10 years. The city of Marseille and its partners (state, local skateholders, fishermen, scientists, marine users) have mobilised and involved themselves in carrying the operation PRADO REEFS successfully to term, the first project of this scope in France. The artificial reefs are an excellent tool for sustainable management of the coast and coastal activities. Spearheaded by the Plan de Gestion de la Rade de Marseille [Management plan for the Marseille coast], a program of integrated coastal zone management, this unifying project should open the way for other restoration zones to support small coastal fishing endeavours, restore irretrievably degraded zones or make certain sites more accessible for scuba diving.

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