Case study: Giardini Naxos (Italy)

Technique: Artificial reef creation

Location

The reported example for this technique is **Giardini Naxos** Bay. The Bay of Giardini (Fig. 1), is located in eastern Sicily, along the Jonian Sea, and his total length of coastline is about 5 km. Jonian coastline along Sicily island is about 200 km long whose about 30 % is affected by erosion.

The bay, which have an average orientation of 34° E morphologically regulated by a regional fault systems, stretches from Capo Taormina in the North to Capo Schisò in the South, represents an element of very great natural beauty as well as a central tourist attraction. Immediately to the South of the rocky promontory of Schisò there is a stretch of sandy beach which links directly to the Alcantara river mouth. The Western boundary is marked by the Peloritan mountains and the southern by the North-Eastern slopes of Mount Etna. The continental area behind Giadini Bay is hilly, and the hills raise gradually in height moving inland, and form, as a whole, the range of the Peloritan Mountains.

Two municipalities insist on the Giardini Bay: Taormina and Giardini Naxos. Taormina is one of the most famous seaside of the Jonian sea, known for his archeological treasure (Greek theatre), night life and famous international film festival; Giardini Naxos is the “beach” of Taormina, but it lives its own life, with its numerous hotels and resteaurants which guests more than 1 million tourists per year.

Fig. 1 - ***Location of the coastline of Giardini Bay.***

Coastal morphology and dynamics

The area of the Bay of Giardini is confined between Capo Taormina to the North and Capo Schisò to the South.

Observing the geomorphological characteristics of the two promontories and considering the geological nature of the area immediately inland, it is possible to note how the Northern area is completely "isolated" by the contiguous physiographic units (coastal sedimentary cells), while the Southern area shows a greater "permeability" with respect to sediments transported from the South.

The beach enclosed by the Bay of Giardini Naxos, as we have said, may be considered a "relict" beach or *pocket beach*, extending for about 5 km. It may be divided into several parts. These parts are characterised by the presence of a number of man-made structures realised over the years: the quay of Schisò, five sub perpendicular groynes, three sub parallel breakwaters and the quay of Saia.

Using both man-made and natural landmarks it is possible to identify the following areas (Fig. 2):

- Schisò Harbour, from the quay built onto the extension of Capo Schisò to the first sub perpendicular groyne built to the South of the lido della Sirenetta: this represents today's Giardini Naxos Harbour.
- Sirenetta, between the two southernmost sub parallel groynes: this offers a widespread sandy area where the private lidos are situated.
- Macine: between the second and third sub parallel groynes: this represents a flat rocky area, periodically free of sediment, where it is possible to see traces of the quarrying of millstones for oil-mills ("macine" in Italian).
- San Pancrazio, between the third and fourth sub perpendicular groynes: an area greatly deteriorated by the presence of the three sub parallel breakwater barriers.
- San Giovanni, between the fourth and the fifth sub perpendicular groynes, offering a stretch of beach varying in width, at the centre of which is the mouth of the torrente San Giovanni.
- Municipio ("City Hall"), between the fifth sub perpendicular groynes and the Saia quay: a barely developed stretch of beach, protected by a number of outcropping rocks
- Villagonia, which falls almost entirely within the territory of the City of Taormina, between Saia Quay and Capo Taormina: a stretch of pebbly beach, running alongside the railway line, where at present bathing is forbidden.

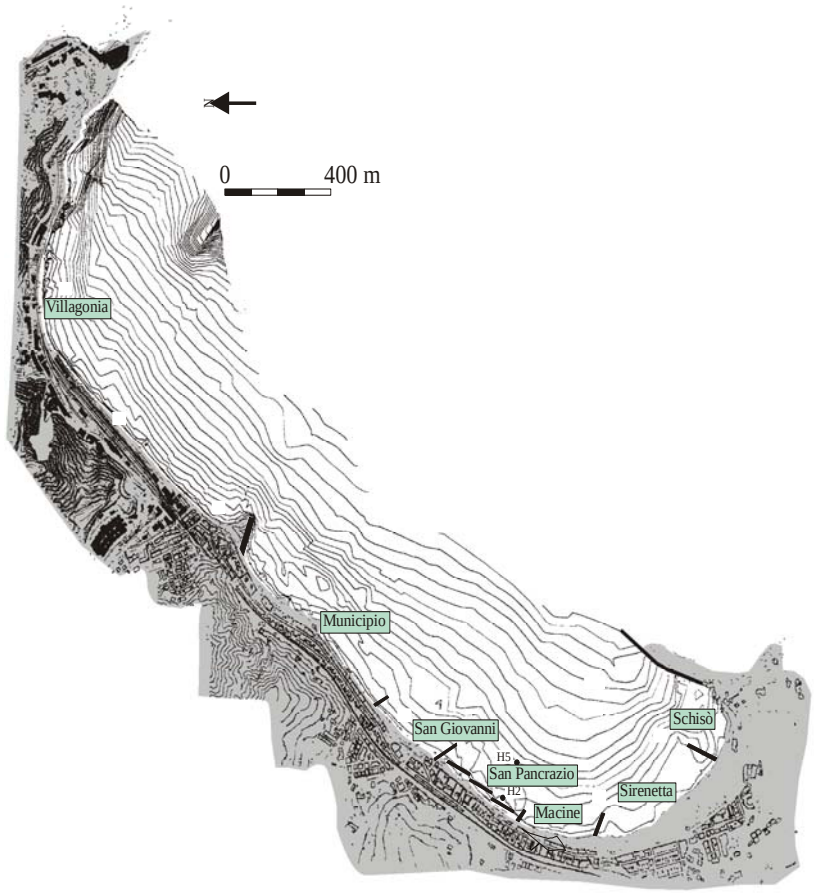

Fig. 2 – ***Location of local sites.***

The elaboration of the bathymetric map, realized in summer 2000, of the Bay of Giardini (Fig. 3) shows a fairly articulated trend in the isobaths to a depth of – 15m., with a general increase in gradient proceeding Northwards. Beyond the isobaths closest to the coast (-1 and –2), in fact, a general distension may be noted, that is an increase in the interdistances between isobaths present at depths between –2 and –14 m. This distension is more marked in the area of the Sirenetta and decreases progressively in the Macine, San Pancrazio and San Giovanni areas.

Locally, especially in the areas closest to the shoreline, anomalies may be noted due to the protections along the coast, in fact in the Sirenetta area, under the total protection of the harbour quay, a wide area of sedimentation can be seen which, in our memory, has sometimes managed to emerge, while in the sector immediately adjacent to the Macine, it is possible to observe a steeper gradient of the coast, without a corresponding steepness in the more distal areas. The regularisation of the distension may be made to coincide with the –5 m isobath which maintains a practically constant distance (about 150 m) from the shoreline and marks a more internal area (inland) which is less regular and an external area (seawards) with constant and regular distances between isobaths.

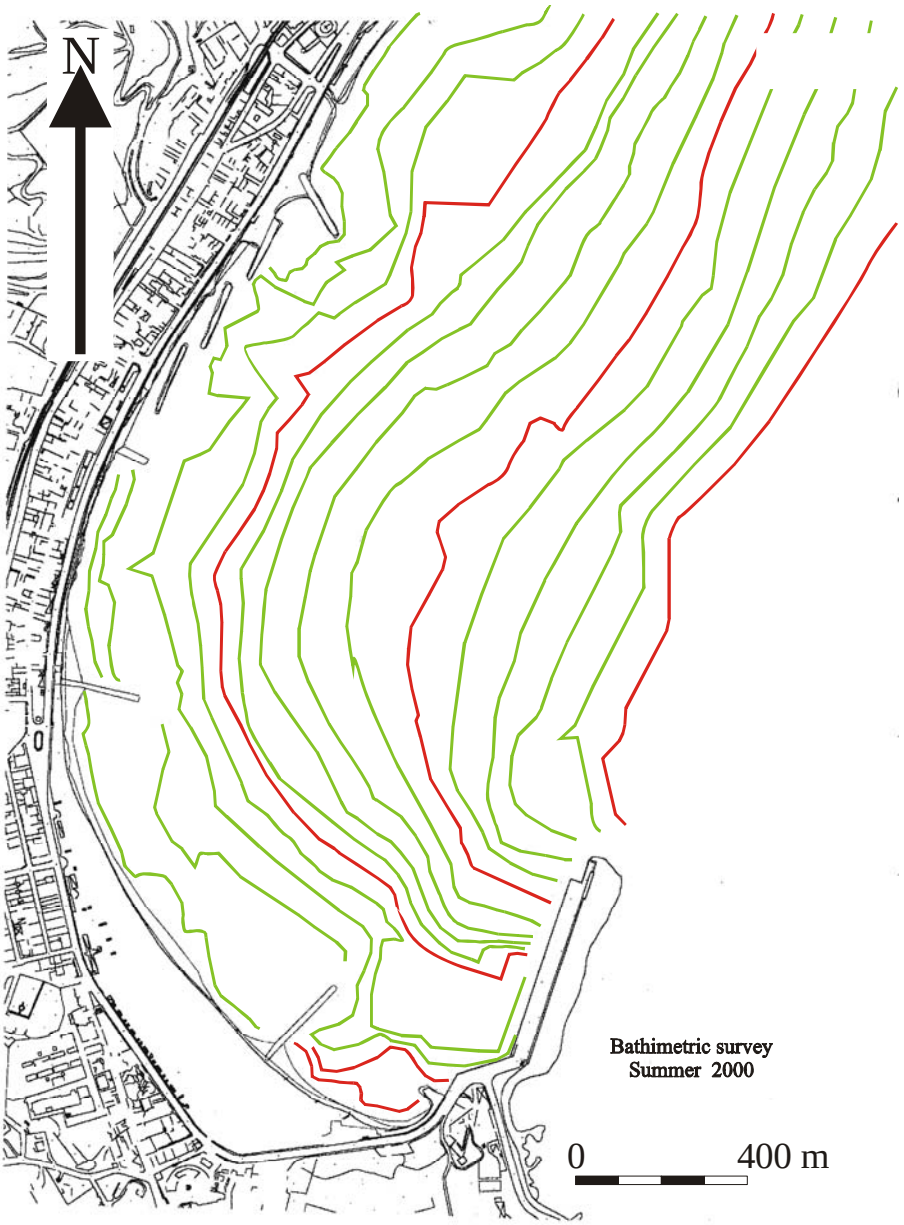

Fig. 3 – ***Bathymetric survey (2000)***

Considering the orography of the area, the site proves to be well protected from North winds and to a lesser degree from North-East winds, being sheltered from these by the promontory of Capo Taormina. However the area proves to be exposed to South-Easterly and Easterly winds; the former are slightly broken by the promontory of Capo Schisò, while the latter sweep into the Bay of Giardini without meeting with the slightest impediment. Considering the orientation of the coastline between Capo Taormina and Capo Schisò, which is about 45° N, the dominant East and North-East winds tend to generate Southward littoral currents within the bay, while the South-Westerly winds, dominating to a lesser degree, generate Northward currents.

The measurements used in order to examine the wind regime were those carried out between 1959 and 1991 at the Catania – Fontanarossa Airport Observatory [1].

The direction is indicated with reference to the eight points of the compass with the name of the cardinal point from which the wind is blowing (N, NE, E, SE, S, SW, W, NW); the speed is attributed to the direction noted at the time of observation and, when measured as less than 2 knots, the mode observed is classified as “calm”.

The measurement of the wind is carried out at least every six hours (7 a.m., 1 p.m. and 7 p.m. or 8 a.m., 2 p.m. and 7 p.m.) so that the frequency of the different modes of wind is expressed on the basis of the effective number of observations (for example, if three readings are taken per day, the total number of frequencies in a year is 1095, that is 3 readings for 365 days).

Since for the shoreline North of Catania it is the long-term evolution that is interesting, average annual values of wind speed were considered, registering for each direction of origin the frequencies of occurrence and the speed expressed in knots.

There are no specific studies of the area, while the entire coastline of Sicily is considered a patchwork of pieces which show a differential movement related to the local tectonic activity.

About underwashing activity we can say that in general in the bay of Giardini it was evident in the last decades a sediment shifting towards South. In the past, the dynamic equilibrium of the beach was determined by the alternative driving forces due, respectively, to the SE winds which moved northward the sediments of the beaches (emerged and submerged) and to the NE winds which moved the sediments southward. The never ended construction of the Schisò Harbours has stopped the northward movement of the material, limiting the transport of the sediments only southward.

[1] under the management of the ANAV (National Flying Assistance Company), situated at 16 m. a.s.l., latitude North 37° 28’ and longitude (Monte Mario) 2°37’ E. The data, published in the ISTAT (Italian Institute of Statistics) Weather Report, indicate for each principal direction of the wind rose the frequency of occurrence, the average speed calculated for each month of the year and the frequency of calms.

About weathering, it is interesting to note the action of the discharge of the pluvial water trough tubes located along the promenade (seawalk) which give rise an eroding action concentrated on the emerged beaches. This action, concentrated in the few points of the water discharge, cause the erosion of part of the beaches.

Fig. 4 – ***White waste water tube.***

At the beginning of 60's of the 20th century, urbanization and anthropization of the bay area has essentially reduced the amount of river sediments reaching Giardini's beach, causing the deficit of sediment output feeding the foreshore and beaches.

The main objective has been performed is the stabilisation of the coast, particularly in recreational beaches where tourist facilities are placed.

Purposes of artificial reef creation and expected results (protection vs. recreation)

Usually in steel or concrete material, once taken in place, an artificial reef acts in the same way that naturally occurring rock outcroppings do in providing hard substrate necessary in the basic formation of a live-bottom reef community.

Designed reef habitat units of various shapes and sizes are currently being tested at many nearshore and offshore locations. These designs incorporate standard construction materials such as steel, concrete and some heavy-duty plastics.
Many materials such as concrete pipe, concrete pilings, steel highway bridges and a variety of other bulky structures are often re-utilised as substrate in the construction of artificial reefs.

Basic principles

Reef breakwaters are coast-parallel, long or short submerged structures built, with the objective of reducing wave action on the beaches by forcing wave breaking over the reef breakwater.
Building an artificial reef could providing a natural habitat for marine biodiversity , and an opportunities for recreational activities.
Emerged offshore breakwaters are protective structures of a rigid type but with active replenishing effects; they have the function of damping down the energy of the waves and therefore of creating on their landward side an area of “shadow” or “calm waters”. These measures too are not without their risks: there is the risk of downdrift erosion; of the formation of banks of fine-grained sediments and therefore with the phenomena of clouding; and the relative problems, for the environment and for exploitation, of stagnation of the waters between the barrier and the shore, with a corresponding risk of pollution and eutrophisation, and of deterioration of the landscape. All of these risks can be avoided, or significantly reduced, if the barriers are of the submerged type.
The emergent barrier, moreover, although suitable in theory for preventing erosive processes already under way, must be rejected for its very high negative impact on the landscape. It would indeed make it possible to achieve the functional objectives (of protecting houses and the road) but it would do so destroying in a virtually permanent way all the attractiveness of the beach for tourists and holiday-makers; it would also increase the use of stone material, adding to the impact on the environment “transferred” to the quarry areas and those deriving from its transport, with a considerable increase in costs.
The submerged barrier acts as a physical operator, dissipating and damping down the energy of the wave movement, respecting the shape of the local shoreline in its pre-erosive form and protecting the addition of granular material suitable for reconstructing the emerged and submerged beach.
The presence of such a barrier is a physical encouragement for the profile of the beach to reform with a generally more gentle gradient than that naturally assumed; it also leads granulometric fractions, which otherwise would have been lost out at sea, to become stable in water. It does not

create any negative visual impact on the coastal landscape, and it may constitute an ideal habitat for local marine fauna.

Expected benefits

For Giardini Naxos Bay expected benefits can be quantified as follow:

- protection of the shore
- enlargement of the beach
- regulation of sedimentation
- dissipation of wave energy
- allow deposition of drift material behind the breakwater

Environmental benefits

Those are related here for benefits on erosion control, modifying the slope of the shoreface and thus acting over the incident wave trains by diminishing their energy (especially in stormy periods).

Social and economical benefits

The welfare of an island like Sicily, whose economy depends largely on the tourist industry, depends to a great extent on the quality of the beaches.

The aim is to remove the causes of deterioration and/or erosion in coastal areas, by means of “the restoration of the natural conditions which have led to the formation of the shoreline, with particular reference also to building activities inland, to the recovery and restitution to their natural state of the wet and dry river courses and to the restoration of the solid littoral transport; particular attention is to be paid also to the effects on an increase in tourist potential, the recovery of state property and the protection of private and public goods from sea storms”.

In the last ten years there has been a continuous positive trend of presences of tourists, either in hotels or in extra hotel structures (Tab. 1and 2).

Tab. 1 - ***Presence of Italian and Foreign tourists in the years1990 – 2001 in hotels.***

Years	It.arrivals	It. presences	For. Arriv.	For. presences	Total arriv.	Total presences
1990	57795	229931	51538	311504	109333	541435
1991	59991	229188	59541	351622	119532	580810
1992	56659	205448	48400	246292	105059	451740
1993	60184	223932	32750	181289	92934	405221
1994	73317	262121	57643	286410	130960	548531
1995	81513	310055	84567	381924	166080	691979
1996	91002	379314	96184	483196	187186	862510
1997	92126	360773	102296	479922	194422	840695
1998	88885	347011	104512	467874	193397	814885
1999	88393	352975	102237	483730	190630	836705
2000	85387	338909	109227	509756	194614	848665
2001	96295	372635	126646	565302	222941	937937

Tab. 2 - ***Presence of Italian and Foreign tourists in the years1990 – 2001 in extra hotel structures.***

Years	It.arrivals	It. presences	For. Arriv.	For. presences	Total arriv.	Total presences
1990	429	1934	249	1004	678	2938
1991	289	1123	427	2615	716	3738
1992	194	994	121	444	315	1438
1993	187	1019	66	1004	253	2023
1994	277	1367	70	359	347	1726
1995	252	1257	210	1157	462	2414
1996	326	1288	247	1438	573	2726
1997	270	1255	209	1161	479	2416
1998	282	1483	287	1611	569	3094
1999	239	1243	367	2422	606	3665
2000	3858	17289	4745	35558	8603	52847
2001	5225	19757	7768	55835	12993	75592

Technical and financial benefits

About technical benefits the intervention of the reef creation with the beach nourishment is focused to get a width accretion of the beach of about 50 m for about 850 m for Sicilian case. At the end of the intervention there will be an unique public beach instead of many little stretch of beaches interrupted by groynes.

Designing artificial reef scheme step-by-step

To get a clear, integrated and complete idea of the entire protection intervention, it may be useful to go back over each stage of the realisation of a coastal defence construction, including also the moments prior to planning, those of execution (even if only in synthesis) and those of management. Basically it is possible to summarize the "order of procedures" as follows:

- defining the objectives of the project (non-technical as well as strictly technical);
- establishing the surrounding conditions and the limits imposed in planning;
- carrying out preliminary studies (determining the state of the coastal environment);
- defining all the possible planning options in conformity with the already defined objectives, surrounding conditions and limits;
- examining the various options and if possible ways to optimize them (with the help of models)
- comparing the options prior to making a choice (on the basis of a "costs-benefits" analysis involving such aspects as seaside tourism and sea-bathing, the landscape, as well as social and environmental considerations);
- executive planning of the works to be carried out and drawing up of a maintenance program (with the help of models)
- building (monitoring the building activity step by step); implementing the completed work and subsequently managing it (by this we intend enjoyment of the protected good associated with monitoring and maintenance of the protection works, in conformity with the pre-established parameters)

The adequate sediment characteristics were determined, about granulometry, using the JAMES 1975 ratios, while the compositional compatibility was determined using the mineralogical analysis, performed counting 300 grains of sand under the binocular microscope, and comparing the data from the source of material and the sand present on the beach. Finally also the chromatic compatibility was determined using the Mansell's table.

The adequate sediment source for beach nourishment was found in two parts of the southern sector of the Bay.

Potentially, if all the sediment trapped in the south part of the bay should be available to be taken, there should be about 1.000.000 cm^3 of material. All this material is not available because part of this sediments are now used to bring on land the boats.

In the submerged area of the port there is about 100.000 cm³ of material available to be dredged and placed on the beach.
Another source of material for about 70.000 cm³ is present to the north of the dam of the port in correspondence with the isobaths of – 10 and – 12 m.

Selecting the adequate artificial reef techniques

Establishing environmental mitigation strategies

In the area the intervention itself is a mitigation strategy.
A prefabricated erosion prevention (P.E.P.) reef was installed during the summer months of 1992 and 1993, at the Town of **Palm Beach** in Palm Beach County, Florida. The reef was constructed at the Midtown segment of the Palm Beach Shore Protection Project. The structure consists of 330 interlocking wedge-shaped concrete modules placed approximately 76 m (250 ft) offshore, in 2.9 m (9.4 ft) of water. The total length of the structure is 1,273 m (4,176 ft), including a 66-m (216-ft) gap near the north end for a submerged cable easement. The purpose of the structure is to reduce incident wave energy, allowing accretion of sediment in the lee of the structure.

P.E.P. reef module	
Length.	12 ft
Width	15 ft.
Height	6
Concrete	5000P.S.I. Reinforced
Approx. ..... Weight	50,000 Ibs.

Assessing and monitoring the environmental and social indicators for artificial reef creation schemes

Over recent years several stretches of the coast of Giardini have been victims of an intense erosive activity, caused and aggravated by a series of man-made constructions: within the hydrographical basin (check dams); along the coast (subparallel breakwater barriers); or directly at sea (harbour quays).
The seafront has withdrawn considerably, with the result that important stretches of the coastal road have been damaged. These stretches of road have been replaced and temporarily protected with breakwater barriers and shoreline defences, which in turn have had a very negative environmental

impact because, while protecting a few dozen metres of coastline, they have accelerated the erosion of neighbouring areas.
The erosive process is also favoured by a general reduction in transported solid load, due to a series of factors (some of them common to most of the shorelines of Italy).

Impact on shoreline stability

Comparing the maps of 1938, 1967, 1972 and 1984 for Giardini case, it is possible to define an area, stretching from south of the Sirina torrent as far as Capo Schisò, where the increase in urbanisation, seafront building and the new hard protection structures, have together led to the erosion of the Northern sector (San Pancrazio) and the progressive advancement of the beach in the area protected by the harbour structure.
For example, in the years between 1967 and 1972, the beach was decreased about 5 meters each year, along Northern sector of Sirina area.
In the more Northern part, the seawall erected to protect the railway line initially led to a severe erosive phenomenon, later stabilising naturally, probably because of the characteristics of the seabed. In fact the beach at first found a new balance along the direction of the foot of the roadbed supporting the railway line, but then it became more stable thanks to the presence of natural rocks which created more protected areas.

Impact on natural habitats

The agriculture is almost absent in Giardini area, only some little cultivation of gardens for a very limited production of vegetables is still present.
In the paste the whole territory was covered by cultivation of citrus fruits (lemons, oranges) from where the name of the town derives: Giardini indicates the place where the citrus fruits are cultivated.
The last extensive cultivation of citrus fruits was present in the area of Recanati, in the south of the municipal territory, where the cultivation were replaced by private houses and hotels in late ’70.
Woods are completely absent.
The fishery fleet is constituted by less than hundred little boats used for local fishing, above all in the spring – summer time.

Impact on coastal fauna

Very rare, we think that the reef barrier should give calmer water for nursery and it should favour the grooving of fishes and mussels.

Social perception

Giardini's town area is of about 5.4 km².

The 60% of this area is urbanized. The remaining 40% is constituted by marginal lands rich in slopes of hills and drains.

The town of Giardini Naxos is placed almost in the middle between Catania and Messina (the two greater cities of Sicily).

In Giardini Naxos take place also an important and very beautiful rail station.

The tourism is the most important incoming source (Giardini Naxos area hold 34 hotels and a lot of recreation places).

It should be carefully considered the possibility to realize to ports in the area.

For the development of the bay it is of primary importance the soft protection of the beach and the reconstruction of an sustainable panorama (a long golden beach without groins and breakwaters), then it is necessary to include in the system a port structures.

It should be also possible to realize two ports, in the north area a tourist one and in the south area a commercial one (where also the cruise boat can dock), but in this case there is the need of a synergetic development which should include the dialogue between the municipalities of Giardini – Naxos and of Taormina. Here there is the conflict.

Both on the base of questionnaires previously performed and on the observation of the people, the social perception is very positive.

Impact on water quality

There is not a special water management policy. The sewerage is collected and treated.

The groundwater of the Alcantara river basin give drinking water to the area.

Impact on water turbidity

About the sediment management, until a couple of years ago, the municipality, in June, took the sand in filled in the port of Schisò (in the south of the bay) and displaced it along the beaches of the bay.

The sand was stable for two – three months and with the first storms of September – October was eroded and slowly moved again toward the port.

From this year the Municipality decide a more radical intervention with the possibility to have a more stable beach.

At the end of the intervention, after one week the turbidity was absent (pictures available).

Impact on pollutant concentration

None water pollution is recorded about Giardini case.

Budgeting artificial reef schemes

Feasibility costs

About 3.500.000 € are the established costs for Giardini case.

Environmental mitigation costs

No environmental mitigation cost has been registered for Giardini Naxos' defence work.

Investment and engineering costs

About 250.000 € are invested in Giardini Naxos' project.

Maintenance and monitoring costs

Costs for the maintenance and monitoring the defence work at Giardini Bay is about of 100.000 €.

Limitations

The intervention can be performed only after a study of the area and it has given a very good result also because it was placed inside a very closed bay.