BULLETIN OF MARINE SCIENCE, 67(2): 761–772, 2000

POSITION AND MONITORING OF ANTI-TRAWLING REEFS IN THE CAPE OF TRAFALGAR (GULF OF CADIZ, SW SPAIN)

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ABSTRACT

Illegal trawling was perceived in protected areas of the Gulf of Cadiz (southwest of Spain). A method of studying the nature of the seabed and identifying the paths taken by the illegal trawl ships is hereby described. So, the shape and minimum number of indispensable barriers necessary to guarantee an inoperative status for these illegal trawling vessel are defined. A new type of artificial reef is presented which is both more efficient and cost effective in terms of its construction and installation. This model has been under experimentation in the area of Cape Trafalgar, where 610 units, grouped in 11 barriers were deployed. Side-scan sonar has been used over 1.5 yrs to test the status of these barriers after their implementation. The final results of this experiment indicate that, after the first 6 mo, all illegal trawling activity had disappeared. Although the displacement of some reefs was established, these movements were not enough to reopen new trawling paths. Nevertheless, in spite of these good results, the damage to the benthic diversity is not yet resolved.

One of the major functions of artificial reefs was to create new fishing grounds or to improve existing ones. The main targets of their installation was to concentrate species to allow more efficient fishing, protect small animals and increase natural productivity.

A large number of artificial reef programs have been developed world wide in the last decades to enhance biological production, basically in Japan (Kakimoto, 1978; Yamane, 1985; Thierry, 1988), France (Simard, 1985; Lefevre and Duclerc, 1985), the United States of America (Stone et al., 1979,1991; Benefield, 1982; Muller, 1995), Portugal (Santos and Monteiro, 1997), Italy (Relini and Orsi-Relini, 1989), and Spain (Serra and Medina, 1988; Gomez-Buckley and Haroun, 1994; Moreno et al., 1994) among others.

From the economic point of view, it is more profitable and prioritary to protect any already existing productive zones before creating new ones. Hence, the protection of over-exploited coastal areas from trawl fisheries, has lead some authors to develop a new type of artificial reef specially designed to avoid the use of illegal trawl gears. Although previous experiences were carried out in USA, it is in Japan where a specific planning for deployment of protection and production artificial reefs is developed in the 80s. The first Septenal Plan (82–88), named MARINOVATION, included the installation of 14 M m^3 of artificial reefs in the Japanese coast (Simard, 1985). The reefs layed in front of Marseille in 1983 showed fish concentrations 15 to 40 times greater than in neighboring places (Bregliano and Ody, 1985). Protection reefs have also been deployed in Spain. Contributions made by Gomez Buckley and Haroun (1994), Guillen et al. (1994), Moreno et al. (1994) and Muñoz-Pérez et al. (1998), among others, could be cited. Certain studies in the Portuguese coast must not be forgotten (Santos and Monteiro, 1997).

In the last decade, great investments were made by the Andalusian regional Government (see Table 1), but many good fishing grounds like those of Conil, near Cape of Trafalgar, are yet to be protected. Accordingly, the Federal Coastal Directorate decided to approach the problem through a study to better understand the actual state this area was

Table 1. Artificial reefs installed in the southern littoral of Spain (all anti-trawling except those marked * which are production modules).

Location	Protected surface (km^2)	Number of units	Weight (tons)	Year	Budget (US$)
Conil I	3	55	3.94	1989	63,000
El Rompido I	4	125	2.4	1990	133,000
Sanlucar I	4	125	2.4	1990	133,000
Isla Cristina	15	350	3	1991	225,000
Sanlucar II	23	350	2.5	1991	195,000
Conil II *	3	30	7	1991	106,000
Sanlucar III	29.4	504	2.4	1992	320,000
Torremolinos	16.6	504	2.4	1992	320,000
Roquetas de mar	15.8	504	2.4	1992	320,000
El Rompido II	17.2	500	2.4	1994	208,000
Barbate *	0.1	312	7	1995	207,000
Torre Perdigal	14.1	327	5.4	1998	296,000
Punta Baño–Marbella	14.8	169	5.4	1998	155,000
Marbella–Cabo Pino	9.4	133	5.4	1998	132,000
Rio Lagos–Punta Torrox	3.5	115	5.4	1998	112,000
Torre Benalgabon	20	333	5.4	1998	307,000

in, to evaluate its fishing resources, and find new suggestions for a solid defense of the marine environment facing the dangerous presence of trawling ships.

The goal of this paper is to show the real experience carried out in Conil, where a system for the positioning, deployment and monitoring artificial reefs against illegal trawl fisheries was developed. Furthermore, an economic criterion for site selection is also presented.

Site Location and Zone Characteristics.

The study zone coincides with the protected area defined in the Spanish Legislation (B.O.E., 1962, 1977). It is a coastal band with a width of 6 mi, located in the Gulf of Cadiz (SW of Spain), between Cape of Roche (36°17'N) and Cape of Trafalgar (36°10'N), reaching a depth of 35 m and providing 270 km^2 areal cover (Fig. 1).

The nearshore geomorphology of the Gulf of Cadiz shows two dominating directions, NNE–SSE and WSW–ENE, giving the coast a meandrous shape which controls the direction of the currents and the dynamics of sedimentation (Gutiérrez Mas et al., 1991). The coast itself consists of alternating sandy beaches with a mild slope and rocky cliffs as, for example, those of the Cape of Trafalgar.

The circulation of water masses is determined by its proximity to the Strait of Gibraltar, the specific boundary conditions and the wind, waves, and local tidal regimes. The Mediterranean waters have substantially more density than those of the Atlantic Ocean and therefore penetrate in the intermediate and deeper layers of the latter. On the contrary, the Atlantic waters enter the Mediterranean Sea on the superficial layer, through the Strait of Gibraltar (Garcia Lafuente, 1986). By looking into the areas affected by the current, the detritus deposits become finer as the current speed from east to west diminishes (Gutiérrez Mas et al., 1991). As far as the tidal regime is concerned, a semidiurnal mesotidal character and a medium neap to spring variation, between 0.60 and 2.20 m, are noted.

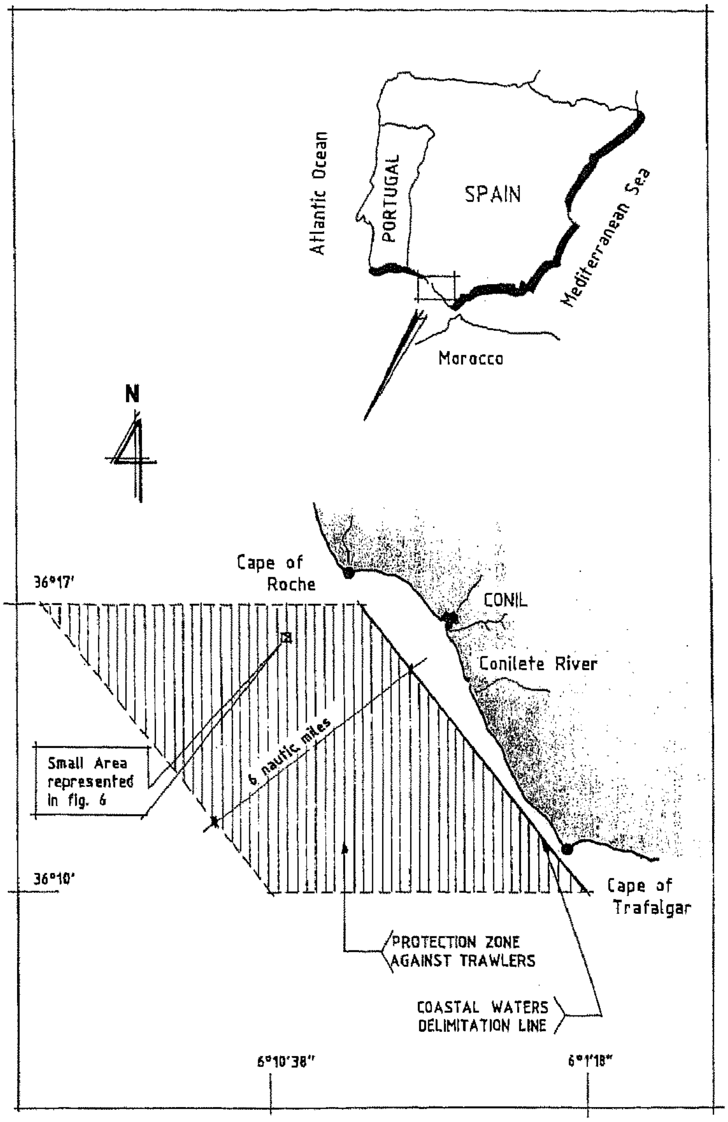

Figure 1. Location of the studied coastal stretch; includes the straight line base and the 6 nautical mile protection zone.

Methods

After the first stage of data collection, the study continued onto the implementation of a series of campaigns in search of specific data and samples. Among the information collected previously, a geophysical research campaign (Geomytsa, 1991) and marine biospheric study (C.I.S., 1993) must be highlighted. The analysis of samples and registries and their interpretation lead us to propose, compose and finally to carry out the implementation of an artificial protective reef project.

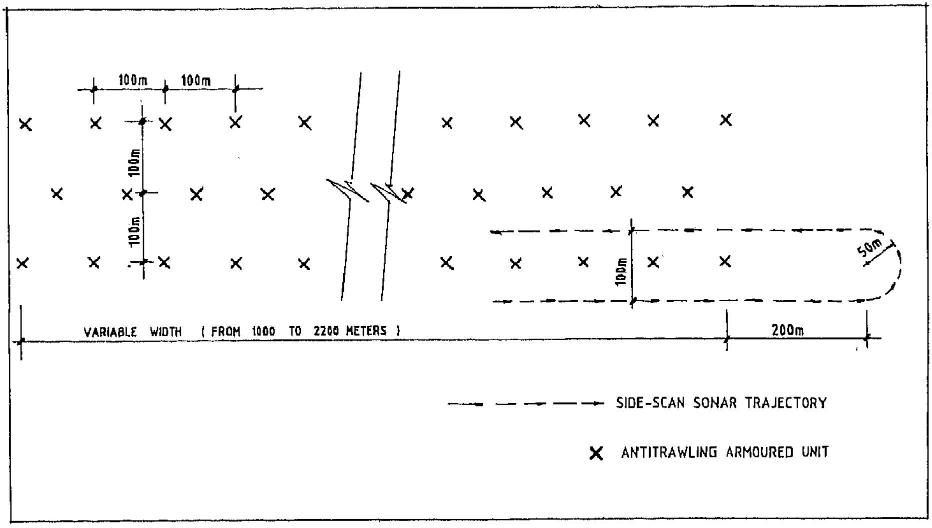

Figure 2. Disposition of artificial reefs in quincunxes (variable width) with the side-scan sonar follow up trajectories.

RECONNAISSANCE AND IDENTIFICATION OF THE SEABED

Positioning and Bathymetry.—A Differential Global Position System (DGPS) was used to position the echosounder boat in order to guarantee that the mapping error would be of no more than a 2 m radius (Español et al., 1997). After having made perpendicular transections of the coastal area (445 lines with 50 m gaps between them), the confirmation was then performed by using three longitudinal profiles which reflected upon the contour lines of 15, 20 and 30 m depth. For the identification of the superficial texture of sediments on the floor, a USP-Rox Ann system was put into use. The sonar signals as well as those coming from the seabed identification equipment were received and integrated with the use of a specific software. A primary cartography set was made up, where the bathymetry and the different types of the seabed were charted. This information was used to establish the sampling stations, immersion points and test fishing sites.

Identification of the Trailing Paths.—Once the analysis of the bathymetric, sedimentological and biological data were performed, the trailing paths could be determined. The trawling paths are identified as sandy zones having enough length to be trawled in and without rock formations that may interfere with dragging nets. The thorough knowledge of their location would facilitate the exact definition of the amount, site and placement of a precise group of reefs in a way that guarantees an end to the use of trawl gear. Contrarily, the artificial reefs set without a comprehensive knowledge of all the possibilities the zone has to offer, once GPS positioned by the illegal fishermen, allow them to dexterously dodge bad spots. The standard trawling ship has a gross tonnage of less than 36 Moorson tons with an average of 22. Lengthwise, the range varies from 10 to 15 m and the power of its engine averages 180 hp. The mouth opening on the typical trawling net can be anywhere between 15 to 20 m and the navigational speed, taking the trawler at the bottom into consideration, is 3 to 4 kt.

The data expressed before permit to determine that, in order for a path to be economically profitable for the poacher, its length must be superior to 1500 m. A detailed description of the data compiled and the method developed may be consulted in the report by Tecnología Ambiental (1996).

Design of the Artificial Reef

As a protective system to counteract the action of any trawling devices, 611 dissuasive modules, grouped in 11 barrier units, were designed, built and installed. These barriers were placed at a distance between them which was enough to make the trawling task difficult. This way, raising and lowering the net each time an obstacle appeared, results in wasted effort, regardless of whether the exact locations of these barriers are known.

Each barrier is made up of modules planted in three staggered parallel rows and separated by a distance of 100 m. The modules in the center row are placed in the median points of the gaps left by the superior and inferior rows (Fig. 2). For later identification, each unit must be marked with its corresponding tag number, using indelible red paint. The weight of these modules has been functionally established at 6000 kg according to the strength imposed by the greater trawling ships

Upon designing and building the reefs, the recommendations given in the Jornadas sobre Arrecifes Artificiales y Reservas Marinas (Alicante, Spain, 1992) were followed. The use of concrete to avoid contamination is noteworthy. Earlier projects of artificial reef construction designed structures made with opportunity materials such as tires, fiber-cement or asbestos pipes, car bodies, etc. The toxicity of their constituent materials might be prejudicial to the environment. May it be added that dissuasive metallic elements are also employed against the trawling nets. Each module deployed is equipped with a ring made of galvanized steel cable which facilitates both the installation as well as the possible refloating.

Location and Positioning of Modules.—The placing of these modules was executed with the use of a bridged crane and an anchor-tripped hook. Upon placing these modules, certain unacceptable errors, which manifested themselves as a difference of more than 15 m between the theoretical and the real position, were found. Being that this would mean having an opening wide enough for a trawling vessel to pass through, these modules were brought back afloat by the use of large air balloons allowing to proceed with the exact positioning on a succeeding immersion.

Exploration with Side Scan Sonar.—A side-scan sonar, towed behind the vessel, was employed in order to effectively check and monitor the placement of these modules. At a frequency of 325 kHz, a perspective of the seafloor was provided. The exploration track lines were designed parallel to those of the anchoring lines traced out for the reef modules (Fig. 2). The units were then detected by the side-scan sonar after combing the area twice, in opposite directions, thus eliminating any possible errors related to dubious positioning of the sonar's tow fish by averaging both locations.

Figure 3 shows the disposition of the tow fish through longitudinal and transversal views, and the variability of the shadow casted by the reef unit as a function of their position (vertical, laid, inclined, etc.).

Monitoring.—Periodic checks must take place in order to verify the exact positioning of the reefs. The objective is to discover any movement of these modules, caused by the effect of trawling nets, sedimentary transportation of sand, etc. In this particular case, a complete review of the seafloor was made after a 1.5 yr period.

Test fishing, Immersions and Repopulation of Fingerlings

To be able to evaluate the existing fishing resources in the area, several fishing campaigns were performed using different types of fishing gear as well as crafts sponsored by knowledgeable fishermen from that area. With the objective of obtaining information on the fauna of the ocean bottom, the scientific trawling device proposed by Harmelin Vivien (1981) was put into use. Furthermore, several in situ diving immersions were carried out above all in sites chosen for extraction of samples. Divers specialized in marine biology took photographs and videotape, and verified the precise state and nature of the bottom.

The environmental implementation was completed through the repopulation of certain species, as for example: giltheads, flounder and sea bass fingerlings, having released over 30,000 units of each. A substantial percentage of these specimens were tagged for future identification and follow up tasks.

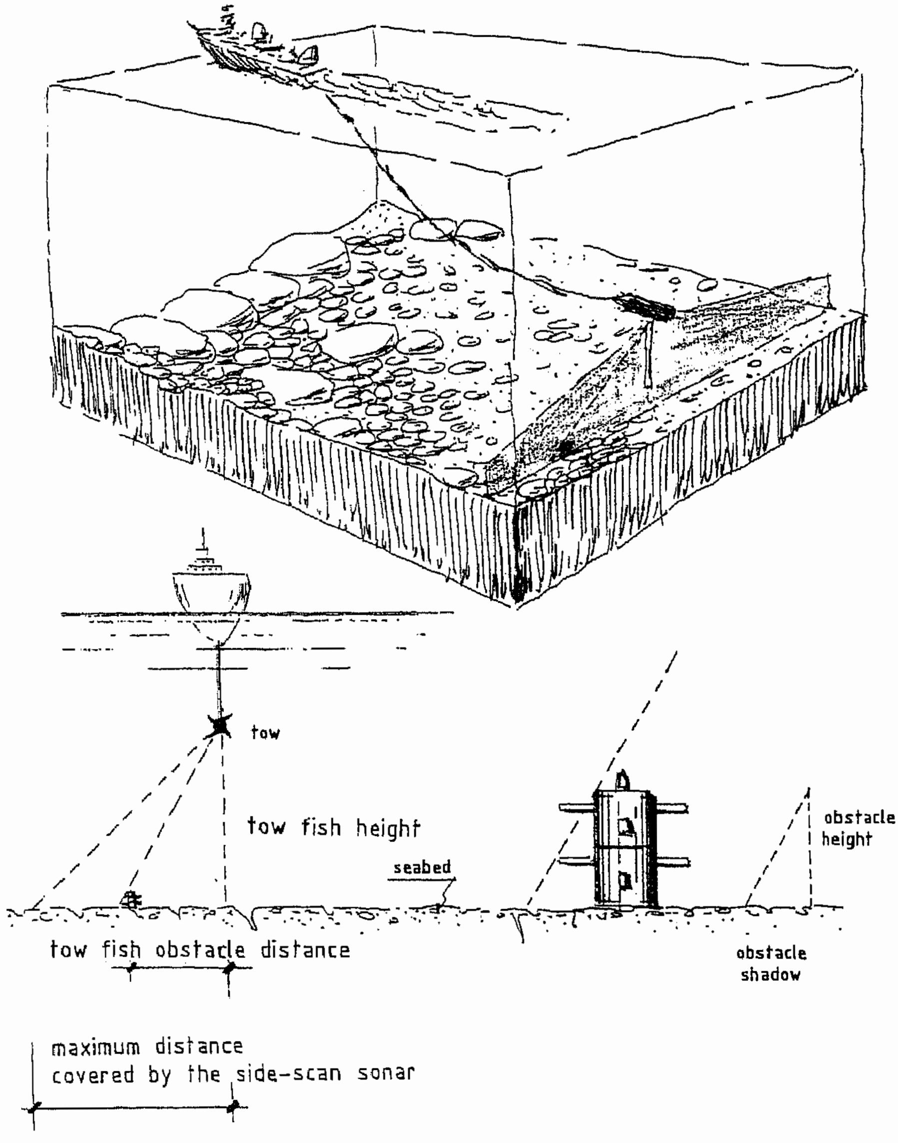

Figure 3. Longitudinal and transversal views of the side-scan sonar tow-fish.

Results and Discussion

Characteristics of the Seabed and Identification of the Trawling Paths.— The reconnaissance of the ocean bottom in the protected area gave a primary image of its morphology sediment characteristics. These results show alternating fine and very fine sand sites with the presence of rocky formations (Fig. 4).

The actual definition of the trawling paths was made after having analyzed all the bathymetric, sediment and biomass data from the seabed and having studied and designed the

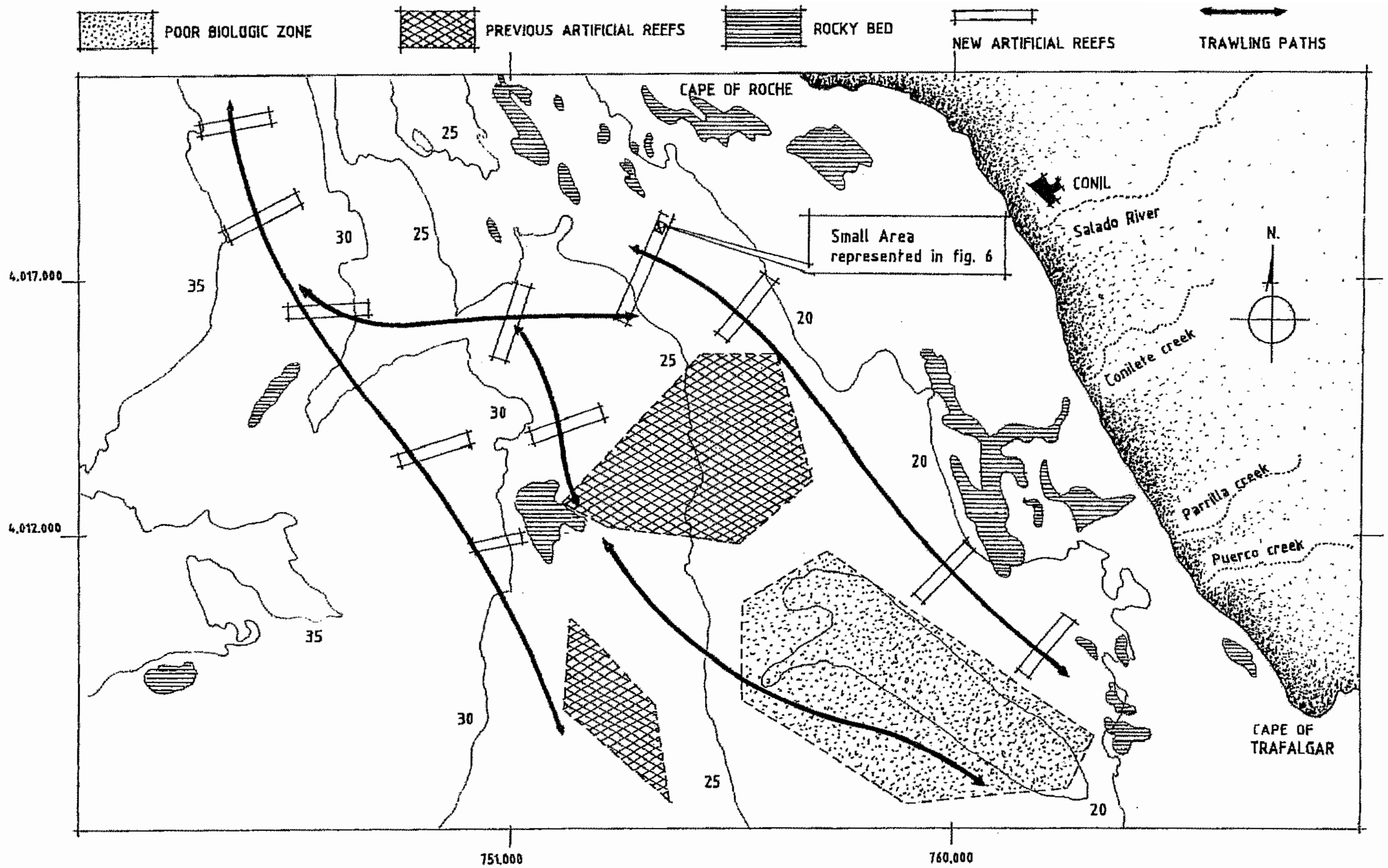

Figure 4. Sea bottom map showing rocky and sandy areas, the trawling paths and the artificial reef barriers.

correct typology of the modules. A synthesis chart with the bottom typology and the routes followed by poaching vessels can be found in Figure 4.

Three main paths can be identified as they trace slightly parallel lines to the coast, along the isobaths at 20, 25 and 30 m in depth and separated among them at distances of between 3000 and 4000 m. The outmost line has a longitude of over 15 km, the inner line approximately of 13 km and the intermediate is bisected by an older artificial reef field and divided in two strips of 4900 and 9000 m, respectively. This last path goes through a sandy area exposed to strong currents and scarce biological resources, according to data collected in situ and a survey done among the local fishermen. Therefore, protection is not needed in this area. Still, a fourth path in the vicinity of the town of Conil, direction E-W and being situated transversally to the others, allows trawling ships to pass from one path to another with no need of lifting their gear.

DESIGN OF THE MODULE.—The reefs designed, built and situated on the seabed of the protected area, consist of two concrete pipe tubes of 1.20 m outer diameter and 2.2 m in height (Fig. 5). The interior is filled solid with concrete made of sea water resistant cement and a perimetral reinforcing steel. Because there is no toxicity in any of these materials, there is no risk of contamination to the marine environment. The total weight of each of these units is of approximately 6 t and are pierced by four metallic transversal beams which formed two crosses, quite adequate for making the anchoring job easier and catching illegal fishnets.

Among the advantages of the module unit, its simple design as much as the minimum construction time required may be highlighted. A more imposing deterring effect, due to an increase in the length of the elements in relation with the diameter of the central nucleus, is observed. The symmetric design permits the execution of its mission in whichever position it takes on the seafloor. Furthermore, a higher attachment capability is perceived being that the base material employed, concrete, has a similar texture to that of a rock, ideal for the attachment of sessile organisms to its surface.

SITUATION AND PLACEMENT OF MODULES.—Having seen the itineraries which are followed by illegal fishing vessels (Fig. 4), the reefs were placed transversely in relation to these paths, and separated by a distance not not in excess of 1500 m. This distance was deduced by the time a trawling ship takes to drop the nets and gather them back up. It is assumed that this task can not be profitably carried out in inferior tracts, without risking loss of the net through hooking on to module spikes. Positioning of protective artificial reefs is not a novelty. The unique aspect of this study is to define the minimum number of units and their exact position which guarantee an end to illegal trawling operations.

A total amount of 611 units, distributed in 11 groups or barriers, were deployed. Each group consisted of three lines of modules, planted with a 100 m gap between each module as well as row of modules (Fig. 2). The total width of each group ranged between 1500 and 2250 m.

The use of side-scan sonar, after the placement of reefs, enabled the accurate verification of the real position of the modules as opposed to theoretical expectations. Displacements supexceeding 15 m were not admitted and corrected immediately by refloatation and repositioning.

A picture of a small area of the seabed, taken by side scan sonar, is presented in Figure 6. Theoretical locations of the armored units, as compared with their real positions immediately following their immersion and the exact locations of the modules 1.5 yrs later, can be observed. The displacement of 66 units, 11% of the total, at distances of up to 90 m

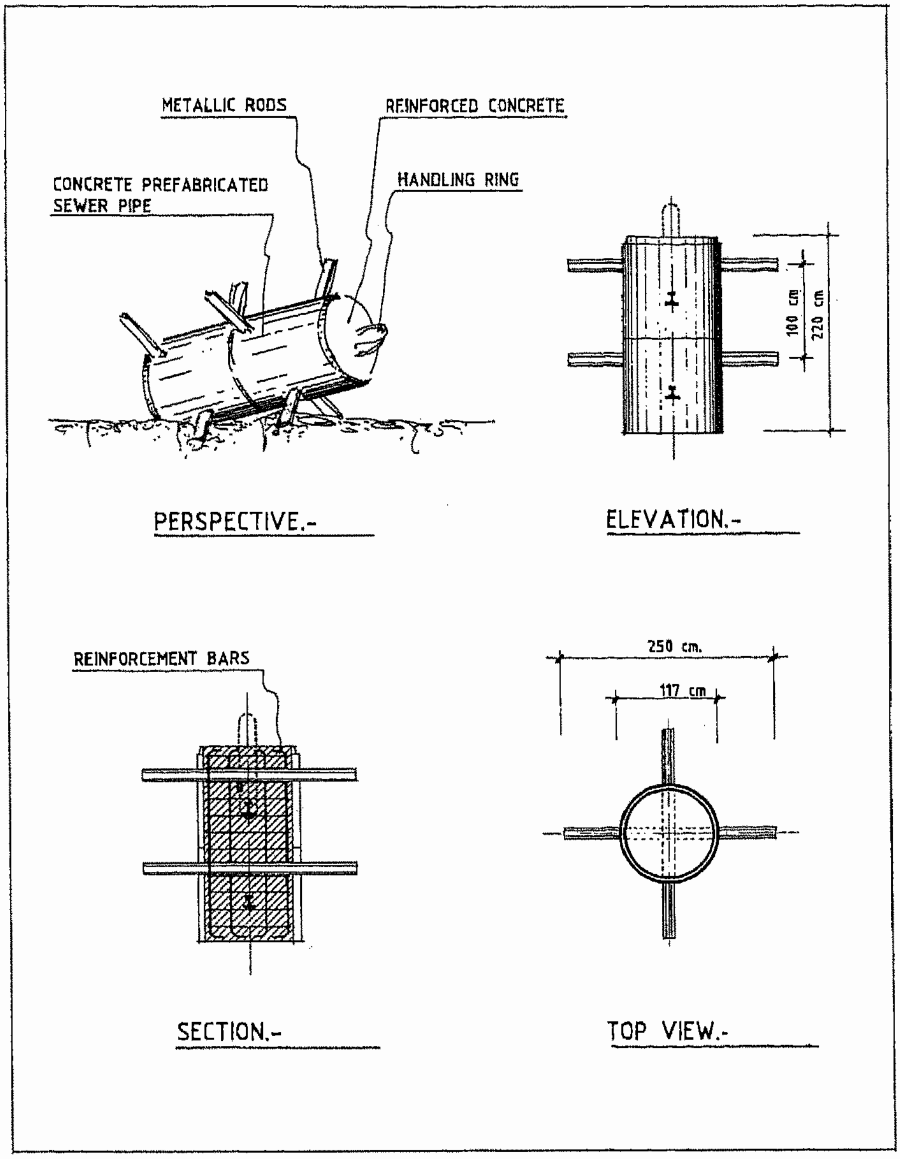

Figure 5. Scheme of the artificial module unit where top, section and elevation views may be observed. Reinforced steels and metallic beams are also represented.

away from its initial position, confirms the passing of illegal trawling vessels through this zone. Remains of nets and other attached paraphernalia also confirm this fact.

Subsequently, through the use of the side scan sonar, long term supervision of the module was necessary. This technique has proven to be distinctly useful, also, in the identification process of any unit, which may have strayed, and in keeping straight rows of module, therefore enhancing the functionality of each reef.

As far as the efficacy of the artificial reefs is concerned, the main objective, dissuasion of illegal trawlers, has been reached. Following a period of 6 mo after their placement and

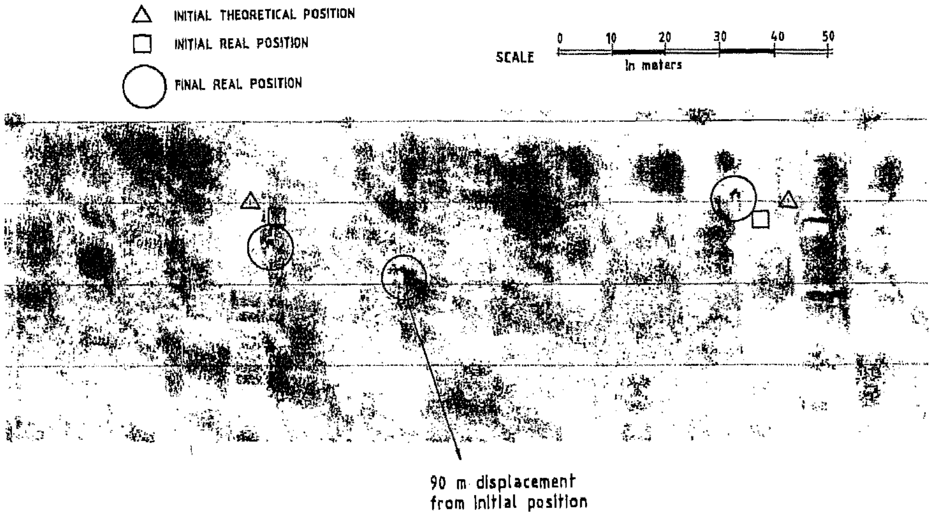

Figure 6. Side-scan sonar photograph of a small area of the ocean floor showing the position of the artificial reef units at the end of the monitoring period of 1.5 yrs after their placement. Also theoretical and real initial positions have been marked in order to compare the accuracy of the location system and the displacements due to the illegal trawling operations.

up until the present, no formal reports of trawling have been made. Nevertheless, the data of captures in the harbor of Conil do not yet indicate a recovery of piscatorial abundance in the area. The near disappearance of mollusks, for example, is to be denoted (Table 2).

BUDGET.—This project was financed by central government (15%) and European funds (85%). Total budget (Spanish taxes not included) was US$650,000 with a cost per concrete unit of US$1060 (cost of materials, construction, placement of the 610 units, control of the position and monitoring studies included).

CONCLUSIONS

A project—destined for the protection of a coastal zone adjacent to the Cape of Trafalgar (Gulf of Cadiz, SW Spain) from illegal trawl fisheries through the placements of dissuasive artificial reefs—has been put into effect.

The precise and thorough knowledge of the routes followed by illegal trawling vessels, lead to the establishment of an a priori location for the barriers destined to eradicate illegal activities involving the least amount of dissuasive reefs possible. The sea floor reconnaissance campaigns carried out facilitated the identification of the paths taken by trawlers. Once their longitudes, tracking and exact width were known, the positioning of deterring barriers was established.

The use of the side scan sonar permitted the verification of the exact positions of the submerged modules as well as to effectively carry out the subsequent monitoring. The latter includes the identification of any units, which had to be resituated because of their displacement, with the objective of maintaining the reef in optimal functioning order.

An artificial reef, 6 t in weight, constituted of prefabricated tubes filled with concrete and pierced by metallic rods forming two crosses, has been designed, built and placed. Its

Table 2. Production and market value of fishery in the harbor of Conil (1995–1998).

Year	Fish		Crustacean		Mollusk		Total	
	tons	US$	tons	US$	tons	US$	tons	US$
1995	318.6	1,589,000	3.4	16,000	483.8	2,384,000	805.8	3,989,000
1996	534.0	2,620,000	10.1	21,000	181.8	845,000	725.9	3,486,000
1997	586.7	2,950,000	5.9	19,000	27.2	116,000	619.8	3,085,000
1998	505.7	2,520,000	1.8	14,000	0.1	600	507.6	2,534,000

main characteristics are: resistance, a high production return, easy manipulation, minimal placement time, and reduced marine transport costs.

As no denunciation of trawling operations was made from 6 mo after the deployment of the artificial reefs, the main objective of deterring illegal trawlers has been reached.

At the moment, the data on captures in the harbor of Conil have not increased yet. In particular, mollusks have disappeared almost completely. In order to evaluate the rehabilitation of the zone would be of utmost convenience to make periodic follow up studies.

Acknowledgments

Contribution of the Coastal Directorate, presently belonging to the Spanish Ministry of Environment, and the Federal and Andalusian Fish Departments are acknowledged. Authors would also like to thank the Fishermen Associations of Conil and Barbate for their support and collaboration throughout the data collection. This paper was partially funded by the CICYT (Mar 98/0796).

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DATE SUBMITTED: December 7, 1999. DATE ACCEPTED: May 3, 2000.

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