Ecological Methods for Improving the Epibiotic Biofilter in Rocky Coastal Areas Affected by Anthropogenic Impact (Cornel Ursache, Tania Zaharia, Magda Nenciu)	"Cercetări Marine" Issue no. 43 Pages 307-319	2013

ECOLOGICAL METHODS FOR IMPROVING THE EPIBIOTIC BIOFILTER IN ROCKY COASTAL AREAS AFFECTED BY ANTHROPOGENIC IMPACT

Cornel Ursache, Tania Zaharia, Magda Nenciu

NIRDEP - National Institute for Marine Research and Development "Grigore Antipa", 300 Mamaia Blvd., 900581 Constanța, Romania, E-mail: cursache@alpha.rmri.ro

ABSTRACT

The epibiosis that develops spontaneously in the Black Sea is composed of a cluster of organisms (mono/multicellular algae, protozoa, coelenterates, bryozoans, molluscs, crustaceans etc.), which, during juvenile stages, attach themselves on existing rigid surfaces in the water mass (natural or artificial), where they run their entire life cycle. The qualitative and quantitative structure of this epibiosis varies depending on the existing environmental conditions, but generally bivalve molluscs prevail, with over 80% of the total biomass.

The protection of these mollusc species severely affected can be made solely by applying legislation measures banning mussel harvesting in littoral areas, applying ecological biotechnologies for commercial epibiotic bivalves and using recovery programs well-coordinated and substantiated scientifically.

Knowing the major ecological role of the epibiotic biofilter in cleansing marine water and the fact that during the past decades its natural restoration in major social and economic interest costal areas was insignificant, it is required to find feasible and appropriate measures to ensure a controlled, fast and efficient rehabilitation of the rocky facies clogged as a follow-up of large hydrotechnical works, as well as of the filter-feeding epibiotic organisms, highly affected by anthropogenic impact.

The method elaborated consists in creating artificial supports convenient for the fixation of filtering epibiotic bodies, to be located in rocky facies sectors affected by clogging. The use of appropriate technical means will lead to the extension of the support area of the above mentioned animals and, implicitly, will enhance significantly the water bio-cleansing capacity of the epibiotic filter formed.

The technical means used/artificial reefs for the rehabilitation of rocky bottom coastal area clogged by human activities are the following: concrete tiles, raw limestone blocks, hydrotechnical protection rigid elements - gabions - and submerged pyramid-shaped structures.

Based on the results obtained in experimental work on the sea water biofiltering capacity by epibiotic organisms, one kg of epibiotic filter-feeding juveniles, of which mussels are 90% of the reference amount, can cleanse, during a 24 hour cycle and up to 85 ÷ 90%, a volume of approx. 73 m^3 of sea water, with a phytoplankton load of approx. 18 mil. cells/liter.

This production technology of marine epibiosis on artificial supports is a purely ecological method, aimed at improving marine water quality in tourist coastal areas by means of local epibiotic biofilters.
KEYWORDS: epibiosis, biofilters, bivalves, artificial supports

AIMS AND BACKGROUND

All aquatic organisms, in fresh or marine water, living fixed on a natural hard substrate in the water (sessile organisms) and which through their own vital functions contribute to maintaining the normal quality of the aquatic environment make-up the so-called natural epibiotic filter.

The natural marine epibiotic filter includes epibiotic microphyte and macrophyte algae, as well as all invertebrates living fixed on the submerged hard substrate.

Ecological investigations have shown that epibiotic filter-feeders are more efficient in bio-cleansing the marine environment compared to the ones inhabiting the sedimentary substrate - psamobiotic filter-feeders.

The epibiotic filter-feeders growing spontaneously in the Black Sea fixate while juveniles on the existing rigid surfaces in the water mass, either natural - platforms, submerged rocks - or artificial, on which they develop their entire life cycle.

The considerable reduction of the rocky facies area led to a significant drop in the populations of filter-feeding epibiotic organisms which use it for fixation. Apart from the impact caused by the loss of the rocky facies, a major role in the alarming drop of epibiotic bio-filtering organisms have had and still have, to a smaller scale, the well-known negative effects of phytoplankton blooms causing mass mortalities among benthic organisms. We must not forget the destructive effect of natural hazards, which have become acute recently.

The negative effect of reducing the bio-cleansing capacity of the natural epibiotic biofilter is visible year by year, especially during the summer season, through the poor quality of marine littoral waters off urban areas and tourist resorts (high turbidity and high biological load).

Knowing the major ecological role of the epibiotic biofilter in cleansing marine water and the fact that during the past decades its natural restoration in major social and economic interest costal areas was insignificant, it is required to find feasible and appropriate measures to ensure a controlled, fast and efficient rehabilitation of the rocky facies clogged as a follow-up of large hydrotechnical works, as well as of the filter-feeding epibiotic organisms, highly affected by anthropogenic impact.

MATERIAL AND METHODS

The biotechnology elaborated consists in creating artificial supports convenient for the fixation of filtering epibiotic bodies, to be located in rocky facies sectors affected by clogging. The use of appropriate technical means will lead to the extension of the support area of the above mentioned animals and, implicitly, will enhance significantly the water bio-cleansing capacity of the epibiotic filter formed.

The technical means we are referring to were tested under normal use conditions in the Black Sea - open/unsheltered sea areas, subjected to the direct action of natural phenomena - waves and marine currents.

Based on the results obtained as a follow-up of technical and biotechnical tests, the most efficient marine pieces of equipment for the arrangement of an artificial reef barrier were selected, to create a natural epibiotic filter.

The marine equipment which may be used to create an artificial reef under the specific hydroclimate conditions of the Romanian Black Sea coastal area are the following:

- Raw limestone blocks;
- Concrete tiles;
- Gabions;
- Submerged pyramid-shaped structures.

Raw limestone blocks are the simplest components by means of which an artificial reef can be created to support a natural epibiotic biofilter. Stone blocks may have any shape and the maximum sizes depend on the capacity of the machinery by means of which they are placed in the water. No stone blocks with a diameter smaller than 0.50 ÷ 0.60 m a weight under 100 kg can be used, as they can become fully buried in mud or driven and moved by marine currents to the shore.

By means of raw limestone blocks, raw substrate platforms or submerged moles can be constructed, which are a proper artificial support for the fixation and growth of epibiotic organisms.

Concrete tiles, cast in type/B250 cement resistant to the marine environment, are plane surfaces which may have various shapes and sizes (Fig. 1).

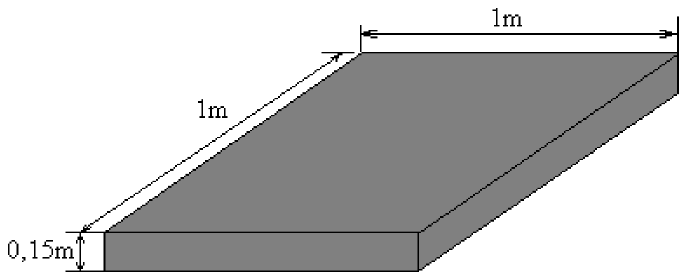

Fig. 1 - Concrete tiles

The length and width of concrete tiles can be maximum 1 m x 1 m, depending on the sea deployment technology, and their thickness cannot be smaller than 0.15 ÷0.20 m, as they could become fully buried in the sandy substrate or in the silty muds in the area.

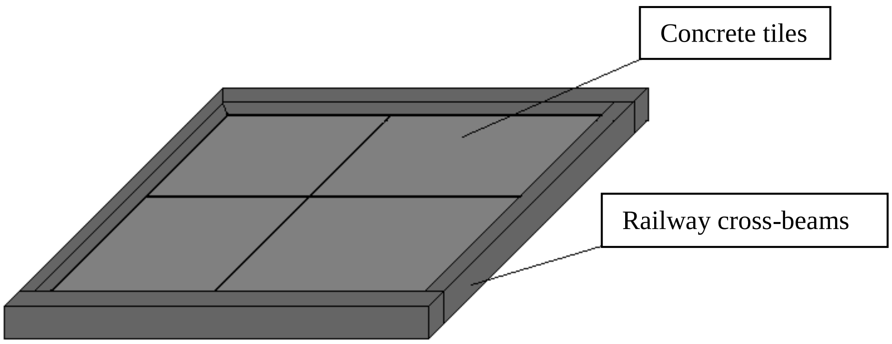

Fig. 2 - Concrete tile platforms

In order to create an efficient artificial reef, ensuring an optimal area for the fixing and growth of epibiotic organisms, platforms comprising minimum four concrete tiles covering approx. 4 m^2, arranged as a square, can be used. In order to reduce the speed of bottom currents and protect the area, this platform can be surrounded by cased reinforced concrete railway beams (Fig. 2).

Gabions are rigid structures for the protection of hydrotechnical works (protection dams, highwalls, pillars etc.) adapted from the constructive and operational point of view to provide for a hard substrate for epibiotic organisms.

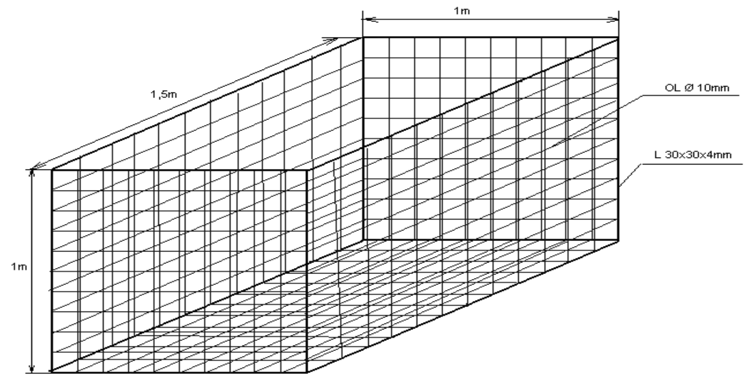

Fig. 3 - Metal frame for gabions

A gabion comprises a parallelepipedic-shaped metal frame encased in a Ol Ø 10 mm wire grid, filled with rocks, and has the following technical specifications:

- height .... = 1.00 m;
- length.. = 1.50 m;
- width... = 1.00 m
- crushed stone for filling……….. = 1.50 m^3
- substrate area covered……….. = 1.50 m^2
- area for the growth and fixation of epibiotic filter-feeders……..... ≈ 6.50 m^2

Table 1 - Amounts list for the construction of a gabion

Ref. no.	Material	Sizes - mm -	Length -m-	Weight -kg-	Pcs.	Total weight/kg
1.	Laminated profile	30x30x4	1.50	3.02	4	12.06
2.	Laminated profile	30x30x4	1.00	2.01	8	16.08
3.	Reinforcing steel	10	1.50	0.93	27	25.11
4.	Reinforcing steel	10	1.00	0.62	78	48.36
TOTAL			-	-	-	101.61
7.	Crushed stone	-		200.00		200.00

After deployment and emplacement on the marine substrate, crushed stone blocks or concrete pieces resistant to marine corrosion are introduced.

Submerged pyramid-shaped structures. A pyramid-shaped submerged structure used for epibiotic filter-feeders is a rigid construction made of two distinct sub-assemblies:

- Metal frame made of Ø = 11/2" laminated steel tubes/bars;
- Collector network made of Ø = 10÷16 mm recovered textiles.

The rigid frame was made of welded laminated steel bars/tubes according to the execution details in the shape and sizes given in Fig. 4 and Table 2. On this pyramid frame made of steel bars Ø = 10 ÷ 16 mm recovered ropes were tied horizontally and vertically, in the shape of a net with mesh size of approx. a = 0.3 m.

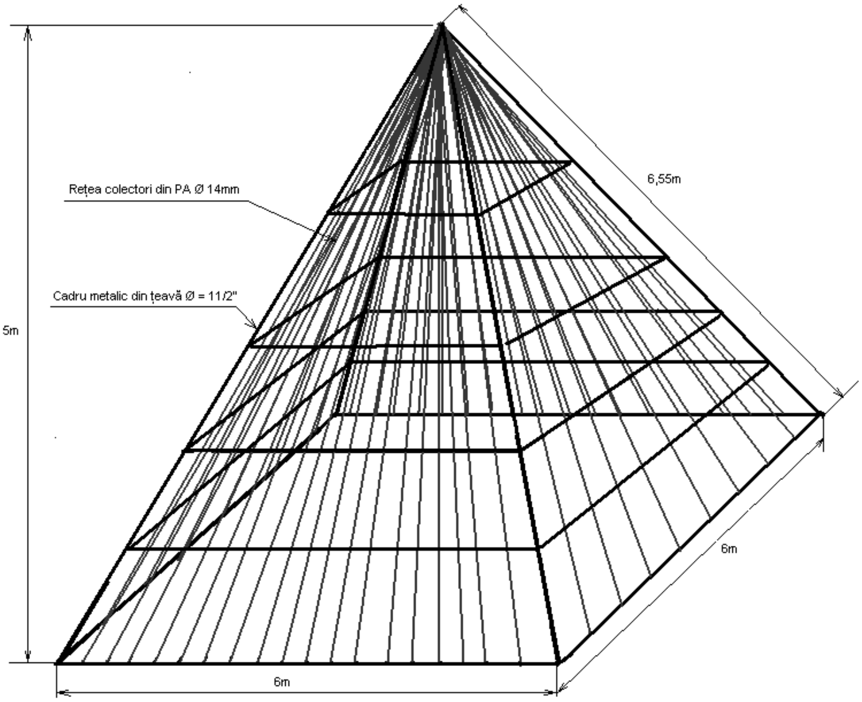

Fig. 4 - Submerged pyramid-shaped structure

The technical specifications of a pyramid-shaped submerged structure are the following:

- maximum height .... = 5 m;
- substrate area covered ………... = 36 m^2;
- total area covered by epibiotic filter-feeders ………………..... ≈ 70 m^2;
- total weight.. ≈ 400 kg.

The fixation of the pyramid-shaped structure on the hard sedimentary substrate is made with two concrete anchors/sinkers, weighing approx. 300 kg.

Table 1 - Amounts list for the construction of a pyramid-shaped structure

Ref. no.	Material	Diameter	Length -m-	Weight -kg-	Pcs.	Total weight/kg
1.	OL tubing	1.1/2"	6	20.10	4	80.40
2.	OL tubing	1.1/2"	6.5	21.77	4	87.08
3.	OL tubing	1.1/2"	4	13.40	4	53.60
4.	OL tubing	1.1/2"	3	10.05	4	40.20
5.	OL tubing	1.1/2"	2	6.70	4	26.80
6.	OL tubing	1.1/2"	1	3.35	4	13.40
TOTAL		1.1/2"	-	-	-	301.48
7.	Anchors	-	1x1x1	300.00	2	600.00
8.	Rope	10 ÷ 16 mm	100.00	100.00	-	100.00

RESULTS AND DISCUSSION

Operating parameters of the technical means

The technical means were deployed/arranged between the 6 - 10 m isobaths and were tested for one year under open sea conditions, being subjected to the direct action of natural phenomena - waves and marine currents.

According to the findings of autonomous divers who checked the shape, size and position of the technical means, the following conclusions on the operating parameters of the technical means resulted:

- All tested technical means maintained the initial position and they were not moved by marine currents from the deployment area;
- During testing, the submerged structures maintained their functional geometry and no mechanical distortions of the strength elements were reported;
- The stones used to fill the gabions were an ideal support for epibiotic filter-feeders;
- Concrete tiles and raw limestone blocks were an ideal support for the fixation and growth of bivalves;
- From the biological point of view, the artificial collectors fixed on the pyramid structures were the proper support for the fixation of juvenile mussels.

Based on the positive results obtained, it is estimated that the technical means hereby presented are appropriate for creating an artificial reef barrier in the Black Sea, which can withstand a sea choppiness degree of maximum 7 (Hwave = 6 ; Smarine currents = 1.5-2 m/s).

Biological yield of the technical means

In the Romanian coastal zone of the Black Sea, epibiotic organisms breed at different rates almost throughout the entire year. This is supported by the constant presence in the water of a variable amount of larvae. During certain moments, however, the periodical enhancement of breeding results in the occurrence in the water mass of extremely numerous larvae generations.

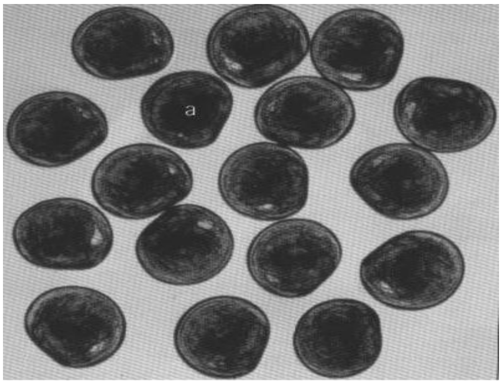

Fig. 5 - *Mytilus galloprovincialis* larvae (Helm *et al.*, 2004)

Three moments of maximum larvae abundance were reported, corresponding to three intense breeding periods of adults, namely in May, July and September.

Concerning the metamorphosis stages structure, mussel larvae populations encountered in the plankton are represented by four main types: trocophore larvae, "straight hinge" veligers, umbonal (immediately after the resorption of the larval velum) and, finally, pediveliger (characterized by the presence of the asymmetrical shell and well developed foot), able to fixate.

Epibiotic organisms comprise all marine invertebrates which, during juvenile stages, fixate on hard natural supports (rock, submerged rocky platforms) and carry-out their entire life cycle. They can also settle and live on artificial supports, with a certain degree of ruggedness and coarse surface.

The following marine invertebrates are included among epibiotic filter-feeders: bivalve molluscs, colonial briozoans, cirriped crustaceans. Epibiotic biofilters may also include seasonal macrophyte algae temporary fixated on the supports, which, by using the mineral nutrients dissolved in the water in their metabolism, help reduce its eutrophication level.

Psamobiotic organisms settle during post-larval stages and continue living on/in the marine sedimentary substrate. Among the well-known psamobiotic biofilters are included mainly the bivalve species typical for the sedimentary substrate.

However, psamobiotic invertebrates have a smaller contribution to bio-cleansing the sedimentary substrate, by the partial consumption of the detritus in/on this type of substrate.

The amounts of epibiotic and psamobiotic filter-feeders which can be obtained on artificial reefs deployed in the water depend mainly on the annual breeding capacities of the organisms and their breeding cycle evolution, under the direct influence of changing marine environment conditions.

Biological yield of submerged tiles and blocks

In areas with rocky substrate, the rate of settlement of new mussel generations, where juvenile individuals fixate on the preexisting colony, thus being forced to face natural selection, is a priori reduced by the limitation of space available for fixation.

Fig. 6 - Limestone blocks nine months after immersion

On the arranged artificial reefs - concrete tiles and limestone blocks - deployed at 10 m water depths, the settlement of mussel populations recorded a special dynamics - during a single year, densities ranging between 795 ÷ 1,023 individuals/m^2, with lengths ranging between 2.1 ÷ 26 mm were recorded.

Table 3 - Size class distribution of mussels settled on artificial concrete tiles and limestone blocks, nine months after immersion

Ref. no.	Size classes -mm-	Concrete tiles		Limestone blocks	
		ind./m^2	%	ind./m^2	%
1.	below 4	269	26.30	189	23.77
2.	4 - 8	148	14.47	84	10.57
3.	8 - 12	160	15.64	59	7.42
4.	12 - 16	39	3.81	116	14.59
5.	16 - 20	79	7.72	87	10.94
6.	20 - 22	167	16.32	80	10.06
7.	22 - 24	83	8.11	39	4.91
8.	24 - 26	78	7.62	141	17.74
	Total	**1,023**	**100**	**795**	**100**

The numerical prevalence of the size class below 4 mm within mussel populations fixated on artificial rocky substrate deployed in the sea at the 10 m isobaths (concrete tiles and limestone blocks) is striking, 23.77 ÷ 26.30%, and represents a continuity in the settlement of individuals in the class, being the natural follow-up of the last quantitative outburst of larvae in September.

The different values per surface unit, both in this size class and the 4-8 mm size class, reveal a homogenous development trend. The next classes, 12 mm and 16 mm, are subject, however, to a heterogeneity trend, due to the nature of the substrate: the grainy surface of the concrete tile favors fixation and maintenance of individuals on the substrate up to a certain size, within the limits of two classes, while the more pronounced rugosities of limestone blocks have a collective action on juveniles overcoming the critical size (3.81% for the 12 -16 mm size class on concrete tiles and 14.59% on raw limestone substrate, of one fraction of population from the same larvae generation).

The following size classes do not show any substantial differences, up to the final two classes, 22 - 24 mm and 24 - 26 mm, which, aggregated, have a clearly favorable offset for the limestone substrate. These classes, resulting probably from the larvae settled in spring, have the maximum size mussel juveniles reach during one biological cycle.

According to the situation above, it can be concluded that the growth rate reaches, in individuals younger than 10 months, an accumulation of 20 ÷ 26 mm at densities ranging between 795 ÷ 1,023 ind./m^2 and biomasses of 11,253 ÷ 10,475 g/m^2.

Biological yield of gabions

By their construction and deployment technology, gabions are hydrotechnical protection elements located in barren areas, with massive detritus deposit areas and silty muds, which make-up a protection dam, creating thus a considerable surface of hard artificial substrate, where bio-filtering epibiotic organisms can settle and grow.

The settlement and growth rate of epibiotic organisms is similar to the one determined for limestone blocks, approx. 795 ÷ 1,023 ind./m^2, with lengths ranging between 2.1 ÷ 26 mm. The fixated biomass cannot be estimated accurately due to the inner areas from where sampling cannot be made, yet we can assess that it is proportionally larger as the stone filling the metal frame is larger in size.

Fig. 7 - Gabions nine months after immersion

Biological yield of submerged pyramid structures

By their shape, size, nature of materials and emplacement on the marine substrate, submerged pyramid-shaped structures are aimed for the settlement and growth of epibiotic filter-feeders in the water column between the 6 and 10 m isobaths.

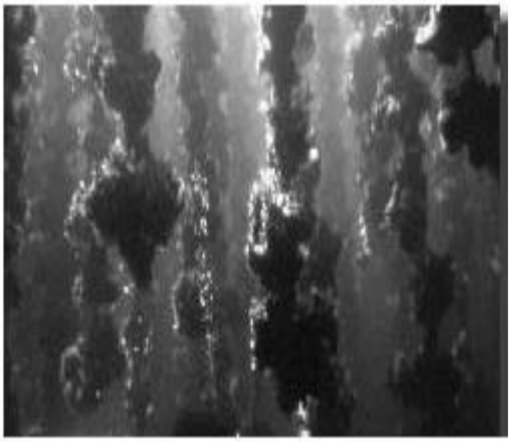

Fig. 8 - Pyramid-shaped structures nine months after immersion

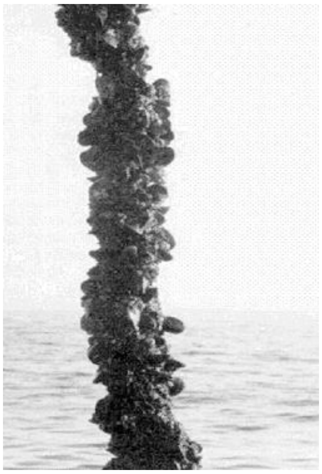

Fig. 9 - Artificial collector nine months after immersion

Three months after immersion (March - May), the qualitative - quantitative balance of epibiotic organisms on the artificial surface of the submerged structures is given in Fig. 10.

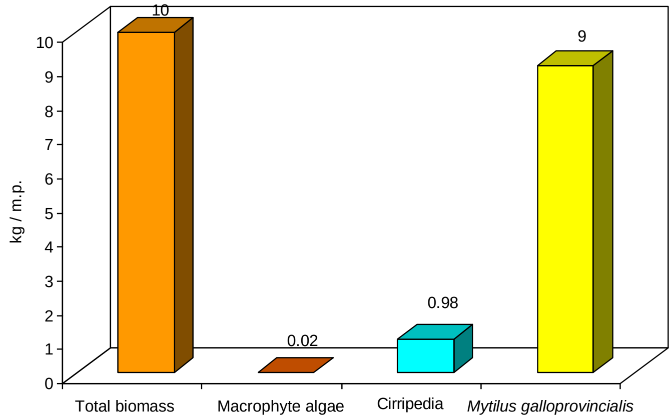

Fig. 10 - Total fixation on the submerged pyramid-shaped structures, on living organism groups (biomass), three months after deployment (March-May)

The mean biomass of living epibiotic organisms in June is approx. 10 kg/m^2 of external surface of one submerged pyramid-shaped structure.

The largest biomasses occurred on the 10 m isobath, 12.7 kg /m^2, and they drop along with the decrease of the reference isobath - 7.7 kg/m^2 at 6 m.

Mussels reach the highest biomasses, approx. 90% of the total, the biomasses of cirripeds are more modest, approx. 9.8%, while seasonal algae cover approx. 0.2% of the total biomass only on the 6 m isobath.

In relation to the value of the biomass in June of approx. 10 kg/m^2 and the area of the pyramid-shaped structure, it is estimated that the value of the fixated epibiotic biomass is approx. 700 kg.

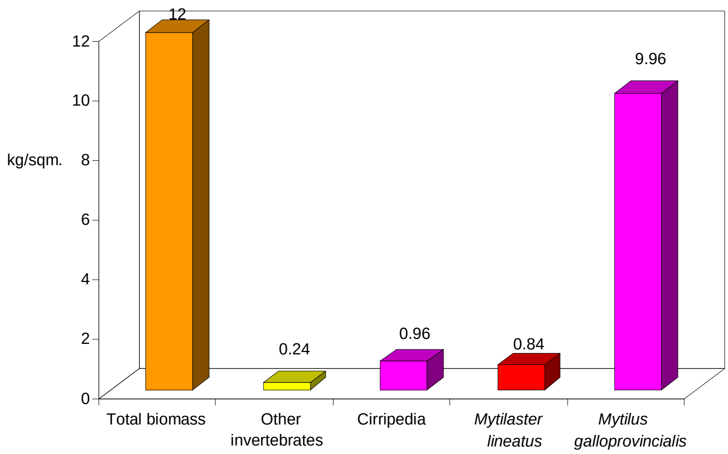

Fig. 11 - Total fixation on the submerged pyramid-shaped structures, on living organism groups (biomass), seven months after deployment (March-October)

In October, the mean biomass of living epibiotic organisms settled on the outer surface of one submerged pyramid-shaped structure is of approx. 12 kg/m^2.

Higher densities occur also on the 10 isobath, approx. 14.7 kg/m^2, and they drop once the reference isobath drops - 8.5 g/m^2 at 6 m.

Among epibiotic organisms settled on the surface of one submerged pyramid structure, mussels are prevalent, with a 83% density, followed by cirripeds and the small epibiotic bivalve *Mytilaster lineatus*, making-up 7% of the biomass. Seasonal algae are 2% and are encountered only on the 6 m isobath.

Extrapolating the mean biomass value of 12 kg/m^2 of artificial support to the total surface of pyramid-shaped structure (69.87m^2), it results that, for the mentioned period, the total biomass of epibiotic organisms on one submerged pyramid-shaped structure is approx. 838.544 kg.

CONCLUSIONS

The slow and insignificant recovery process of the natural biofilter in the coastal area of the Romanian Black Sea littoral calls for the elaboration of ecological methods aimed at increasing the populations of filter-feeding epibiotic organisms, capable to speed-up the marine environment quality restoration in the tourist - leisure areas of the coast.

In order to improve the quality of the marine environment in coastal areas affected by anthropogenic imapct, it is recommended to constucct epibiotic and psamobiotic bio-filter barriers, in the entire water column, including on the affected sedimentary substrate.

Based on the results obtained as a follow-up of technical and biotechnical tests, the most efficient marine facilities for the arrangement of an artificial reef barrier were selected, to create a natural epibiotic filter. Under the specific hydroclimate conditions of the Romanian Black Sea coastal area, the following structures are recommended: raw limestone blocks; concrete tiles; gabions; submerged pyramid-shaped structures.

The amount and fixation manner of epibiotic organisms depends on the water depth where the technical means are deployed. It was found that they prefer surface areas (1-10 m), where light penetration is higher and the food is more abundant.

The biomass fixated on artificial collectors is conditional upon the breeding period of bivalve molluscs, which depends on a cluster of physical-chemical factors influencing directly the biological cycle. If one of these factors is lacking or is diminished due to natural causes, then the entire biological fixation and growth cycle suffers both in time and in intensity.

Under the abiotic and biotic conditions of the Romanian Black Sea coast, on the technical means deployed in the sea, during one annual biological cycle of approx. 10 months, mean biomasses ranging between 8.5 ÷ 14.7 kg/m^2 were fixated.

These ecological methods aim at improving the marine environment quality in tourist coastal areas, by means of autochtonous biofilters. The methods can be adopted and capitalized by the general manager of the coastal zone, local administrations, as well as economic operators in tourism, interested in providing for an appropriate quality of marine water during the summer season.

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