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ARTIFICIAL REEFS AND HABITATS AT POZOS COLORADOS BAY, SANTA MARTA, COLOMBIA

Oscar, Delgadillo-Garzón, MoAm Monitoreos Ambientales, odelgadillo@moam.com.co
Nirith, Toro-Ballesteros, Ecopetrol S.A., nirith.toro@ecopetrol.com.co
Sergio, Candelario-Peña, Ecopetrol S.A., sergio.candelario@ecopetrol.com.co
Edwin, Guerrero-Utria, University of Magdalena, eguerrero@unimagdalena.edu.co

ABSTRACT
The substantial coastal development and unsustainable management of resources at Santa Marta region have affected natural ecosystems and current artisanal fishing activities. Under this scenario, ECOPETROL S.A. began a project for socio-environmental solutions through the utilization of artificial reefs and habitats. Materials and design for artificial reefs were proposed and legal requirements to maritime space concession for reef deployment were processed. On the other hand, artificial collectors for fish and invertebrate settlement were assembled with the local fishermen. As preliminary results, six artificial reefs of 4.5 x 4.5 x 4.5 meters were built with recycle steel pipes, as well as the obtaining of permissions and concessions. On artificial collectors, 27 fishes and 16 macroinvertebrates were recorded by means of visual census. Within this biota, important commercial, ornamental and some endangered species such as snappers, groupers, jacks, puffers, spiny lobster, shrimps and crabs were abundant and frequent on the habitats. For spiny lobster (*Panulirus argus*) 249 postlarvae and juveniles were extracted and introduced on sea cages for growing with the idea of population restocking and eventual commercial utilization. These preliminary results support the idea of artificial reef and habitat development as a potential management tool for the benefit of the environment and local communities.

Keywords: artificial reefs, artificial habitats, design, development, benefits, fishermen communities.

INTRODUCTION
Santa Marta region is considered a megadiverse area at the Caribbean of Colombia owing their particular geographic features. The biggest coastal mountain system in the world, Sierra Nevada de Santa Marta, the Tayrona National Natural Park and a large coastal lagoon, the Ciénaga Grande de Santa Marta have a strong influence on the weather, coast line conformation and the extension of the continental shelf, greatly affecting the diversity of the ecosystems and environments represented by bays, long beaches, rocky shores, coral reefs formations, seagrass beds, sand and muddy bottoms, mangrove forests, dry tropical forest and a complex hydrological system which maintain a rich biota associated to them. Also, in the area an upwelling event during the first months of the year, increase the sea productivity (INVEMAR 2000; Díaz et al., 2000, 2003; García y Díaz-Pulido 2006; Idárraga-García et al., 2011).
These environmental characteristics have promoted a significant coastal development in the last decades with port facilities for coal and hydrocarbons transportation, as well as ecotourism expansion that together with pollution, unsustainable management of resources and the effects of climate change have produced environmental degradation, reduction of fishery productivity and loss of traditional fishing grounds, affecting fishermen communities (Díaz et al., 2000; García, 2010).
Under these environmental and social requirements, ECOPETROL S.A. as a leading company on oil and gas exploration, production, transport and export in Colombia, within their policy of good neighbour, promoted a process for sustainable management of natural resources with the creation of artificial reefs (ARs) and habitats for conservation, ecotourism and mariculture, through the strengthening of technical-organizational capacity of fishermen communities. This document represents the preliminaries results up to date.

METHODS
Licences and permissions for ARs transport and deployment were processed during 2011 and 2012 after fulfilled all the documentation and studies required to the Ministry of Commerce, Industry and Tourism, Ministry of Transport, Ministry of Environment and Sustainable Development and the National Maritime Direction.
Between May and October of 2011, opportunity materials for oil transport from ECOPETROL S.A., the recycled steel pipe of 18 inches diameter and six meters long were transported from the origin site 500

km away from Santa Marta to the place of construction. Steel pipes were cleaned for hydrocarbons residuals and then oxy-cutting to reach the desired measures. High pressure welding was used to build each of the six ARs in a frame-box of 4.5 x 4.5 x 4.5 meters and a parallel base of six meters. Three of them with empty space inside the structure and the others three with crossing diagonal pipes between the main frame-box. Different pipes were drilled with circular holes of two and eight diameters. Estimated weight of the ARs range 12 to 14 tons (Figure 1).

Figure 1 – Artificial reefs designed for conservation and ecotourism at Pozos Colorados bay.

On the other hand, between June and July of 2012 artificial collectors were assembled with polyethylene ropes and plastic disks of 13.7 inches diameter. Each disk was perforated with eight holes on its surface to insert ropes as tassels of 40 cm, simulating macro algae branches; eight disks separated 20 cm one from another secured on a single vertical rope was the collector. In September 2012 at three different depths (S1: 16 m, S4: 14 m and S5: 11 m) on the proposed sites for ARs placement, two vertical lines with two collectors each one were installed and anchored with a concrete box of 100 kg proximately, and suspended on a water column with buoys attached to the line. Sea cages were constructed with polyurethane and PVC on a cylindrical shape of 1.5 m of diameter, 1 m high, a volume of 1.76 m^3 and a mesh of 3 mm (Figure 2).

Figure 2 – Artificial collectors and sea cages for settlement and growth of fishes and invertebrates at Pozos Colorados bay.

Two researchers recorded fishes and macroinvertebrates composition and abundance through erratic visual census of 30 minutes on five regular time intervals of six minutes each one (Bortone et al., 2000; Delgadillo et al., 2004). The collectors were extracted with a synthetic net of 1.5 meters diameter and two

meters long to enclose the entire collector and avoid the loss of biological material. On surface, the collectors were introduced to plastic tanks filled with water and carried to the beach for evaluation of the biota. Spiny lobsters found were separated on single plastics bowls with water to determine abundance and measurements of cephalous thorax, and then introduced to the sea cages for rising (Figure 2). The other biota was preserved and stored for posterior taxonomic and ecological analysis.

RESULTS AND DISCUSSION

In the course of 2012 each institution progressively delivered their corresponding licence and permission, until obtain the final document for the concession of the marine area and authorization for ARs placement in January of 2013.

On the collectors, a total of 27 fishes and 16 macroinvertebrates were recorded with a relative abundance of 100.7 and 62.2 individuals respectively (Table 1). Highest richness and abundance were observed in S1 and S5 respectively. Abundant species on descendent order were *Chloroscombrus chrysurus*, *Panulirus argus*, *Stenopus hispidus*, *Chaetodipterus faber* and *Canthigaster rostrata*. Also, a group of commercial, ornamental and endangered species were found on the habitats (Table 1).

Table 1 – Composition and relative abundance of fishes and macroinvertebrates on artificial collectors at Pozos Colorados bay (F: Frequency of occurrence; * endangered species; + important commercial species; - ornamental species; x seen outside visual census).

Stations	S1	S4	S5	F	Total
Fishes species					
Aluterus sp. -	0.2			6.6	0.2
Anisotremus virginicus			3.6	13.3	3.6
Apogon maculatus -		0.2		6.6	0.2
Balistes capriscus	1.8			33.3	1.8
Canthigaster rostrata -	4.2	4.2	4	73.3	12.4
Caranx crysos +			8.2	13.3	8.2
Caranx latus +	0.1			6.6	0.1
Chaetodipterus faber +	1.3	3	13.9	40	18.2
Chloroscombrus chrysurus		6.8	15.8	33.3	22.6
Coryphopterus sp. -	0.6	0.1		13.3	0.7
Diplectrum bivittatum	1.2	0.3	0.4	53.3	1.9
Familia Blennidae	0.1			6.6	0.1
Gobiosoma cf. *robustum* -		0.1		6.6	0.1
Histrio histrio			0.2	6.6	0.2
Hypoplectrus cf. *chlorurus* -		0.1		6.6	0.1
Lutjanus analis *+	0.4		0.1	13.3	0.5
Lutjanus synagris +	2	3.1	1.1	66.6	6.2
Monacanthus sp. -			x	6.6	0
Mycteroperca bonaci +	0.2	2.1		40	2.3
Mycteroperca phenax +	0.6			20	0.6
Ocyurus chrysurus +	1.8	2.1	1.4	60	5.3
Ophistosgnatus sp. -	0.1			6.6	0.1
Opisthonema oglinum +			2	6.6	2
Pterois volitans	0.1			6.6	0.1
Starksia sp.			0.1	6.6	0.1
Stephanolepis setifer -	0.9	0.2	0.6	53.3	1.7
Thalassoma bifasciatum	3.5	3.2	4.7	80	11.4
Total	**19.1**	**25.5**	**56.1**		**100.7**
Macroinvertebrates species					
Phylum Annelida					

Hermodice sp.	2.1	0.9		20	3
Phylum Mollusca					
Aplysia sp. -	0.1	0.1	0.2	26.6	0.4
Strombus sp. +	0.6	0.2		13.3	0.8
Phylum Arthropoda/Subphylum Crustacea					
Brachycarpus biunguiculatus	0.3			6.6	0.3
Callinectes sapidus *+	1.2	0.9	0.3	46.6	2.4
Callinectes similis +			0.2	6.6	0.2
Charybdis helleri	0.1	0.2	0.2	20	0.5
Dardanus sp.	0.2			6.6	0.2
Familia Grapsidae			0.1	6.6	0.1
Infraorden Brachyura	0.1			6.6	0.1
Orden Stomatopoda	0.1			6.6	0.1
Panulirus argus *+	5.3	5.8	14.1	80	25.2
Stenopus hispidus -	3.5	12.1	5.5	80	21.1
Stenorhynchus seticornis -	0.7	3.6	3.3	53.3	7.6
Phylum Echinodermata					
Clase Ophiuroidea		0.1		6.6	0.1
Luidia sp.	0.1			6.6	0.1
Total	**14.4**	**23.9**	**23.9**		**62.2**

The settlement of *P. argus* was very important with a total abundance of 249 juveniles and postlarvae. Average individual per collector was 32.5 ± 5.9 (S1), 21.2 ± 6.8 (S5) and 8.5 ± 3.5 (S4) which were extracted at days 50, 63 and 73 respectively.

Differences in abundance between habitats can be the influence of hard substrata close to S5 compared to the others collectors, but not for richness, that was higher on S1, probably by the effect of less predators and competition. The trend of reduction on *P. argus* settlement was related with extraction time, that must be on a monthly basis and after the new moon. However, the range of individuals per collector was relatively high, compared with other Caribbean regions. These preliminary results supports the idea of artificial reef as a potential tools for conservation and ecotourism, and artificial habitats as mariculture alternative for replenishment and restoration of endangered species, as well as pilot commercial utilization, seeking the benefits of local communities and the environment.

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