Installing green artificial reefs: a sustainable challenge

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Abstract. Green Artificial Reefs (GARs) are marine structures to exploit sea resources in a sustainable way (produce food resources, improve the tourism, etc.). They should be installed on the seabed, process that is not usually easy. Therefore, their installation process should be clearly defined. The aim of this paper is to propose several methods for installing a group of green artificial reefs designed in the PROARR research project. Two of these methodologies are conventional: a bulkcarrier and a special service workboat. The other technique is innovative: an autonomous vehicle. All of them offer different results in terms of maneuverability, positioning, precision and cost. This study will compare these four methods of installing green artificial reefs to improve the knowledge about this type of sustainable way of exploiting the marine resources.

Keywords. Green artificial reef, food, transport, installation

1. Introduction

Artificial reefs (AR) offer a refuge for different marine species [1,2]. It allows that marine animals can develop their reproduction, increasing the biodiversity of a particular sea location. AR are successful fish attractants and an significant fishery management facility [3] in areas where some species were decreased. It generates that a AR had a great social interest [4]. In addition, AR can be used to rehabilitate reef flats degraded [5], to increase the employment of an area, to improve tourism [2] or to give other uses to offshore wind [6].

The destruction of the marine habitat is one of the main causes of the decline in biodiversity and fishery resources.

The introduction of ARs into the ecosystem can be a tool to protect or restore these habitats and their declining biodiversity. However, the deployment (meaning its design, production and installation) of ARs must occur in terms of the necessary sustainability, understanding this in aspects such as; the use of materials and the processes that take place and, finally, in terms of the ecosystem created.

Sustainability in the deployment phases (materials and processes) by incorporating materials under the principle of applying the circular economy (CE) criteria, minimizing the participation of non-renewable resources and the production of technical waste. Processes, so that activities in the development of supply chains, production and distribution of ARs are carried out minimizing energy consumption and GHG emissions.

The search for sustainability finally leads to [7,8] introducing the concept of ARs of the green GAR type framed within the controlled use of natural resources, typical of the EC and reduction in energy consumption and emissions. All this means reducing the size of the economic system to acceptable proportions for the biosphere [9].

The objective of the present paper is to suggest several methods for installing a group of green artificial reefs designed in the PROARR research project [10]. Two of these methodologies are conventional: a bulkcarrier and a special service workboat. Being, the other technique innovative: autonomous vehicle. All of them offer different results in terms of manoeuvrability, positioning,

precision and cost. This study will compare these methods of installing green artificial reefs to improve the knowledge about this type of sustainable way of exploiting the marine resources.

2. Methodology

A. Introduction

Several methods of installing a green artificial reef can be considered:

1) Conventional methods:
   - 1.1) Bulk carrier.
   - 1.2) Special service workboat.
2) Innovative methods:
   - 2.1) A barge with an autonomous vehicle.

Small vessels usually offer lifting equipment appropriate for loading and unloading at ports and piers unequipped with cranes. The diverse cargo techniques affect the number of green artificial reef units that can be stowed.

The bulk carrier has cargo holds enhanced by its relatively high draft (5.45 m) [1]. It has a long of 81 m [1]. In addition, the special service workboat has a self-propulsion system, on-deck storage and an auxiliary crane. It is shortest than the previous one, with 24 m and its draft is 2.3 m [1].

B. Calculation of costs

The total cost of installing and transporting ($C_{i\&T}$) a green artificial reef is composed by the cost of transport the unit ($C_{TRANSPORT}$) and the cost of installing the green artificial reef ($C_{INSTALLING}$).

$$C_{i\&T} = C_T + C_I \qquad (1)$$

The **cost of transport** is composed by:
- $C_{T_{onshore}}$: Cost of the onshore transport.
- $C_{T_{offshore}}$: Cost of the offshore transport.

$$C_T = C_{T_{onshore}} + C_{T_{offshore}} \qquad (2)$$

The **cost of installing** is composed by:
- $C_{I_{onshore}}$: Cost of the onshore installation.
- $C_{I_{offshore}}$: Cost of the offshore installation.

$$C_I = C_{I_{onshore}} + C_{I_{offshore}} \qquad (3)$$

On the other hand, the cost of the onshore transport is basically, the transport of the green artificial reef units on road from the manufacturing facilities to the port. In addition, the cost of the offshore transport is the maritime transport from a particular port to the location of installing the units at sea.

Moreover, the cost of the onshore installation comprises the loading of the units in the vessel selected in the port; and the cost of the offshore installation includes other two costs: the cost of positioning the AR unit at sea and the cost of descent the units from the surface of the water to the seabed at its final position.

Fig. 1 shows the general procedure of installing and transport the AR units to their final position at sea.

Fig. 1. General view. Source: Own elaboration.

3. Case study

A. AR unit

The AR considered in this study is a GAR (Green Artificial Reef) [1], where the traditional materials (cement, sand, gravel and frames) were replaced in a percentage by waste (oyster and mussel shells and eucalyptus vegetable fibers). It has been defined in the PROARR research project (Recycled Artificial Reef Project).
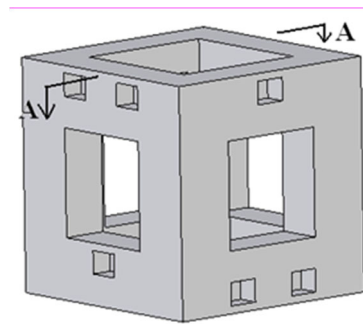

Fig. 2. AR Unit design

AR dimensions are 1.5 m x 1.5 m at the base, and 1.5 m height. The total weight is 5.2 ton.

B. Location selected

The location selected to analyze the different types of methodologies for installing the AR units is the Galicia region, located in the North-West of Spain, in the Iberian Peninsula. It is composed by four areas (see Fig. 3): Rías Altas, Costa Ártabra, Costa da Morte and Rías Baixas.

Fig. 3. Main areas studied. Source: Own elaboration using Google Earth.

Each of these areas is composed by several Estuaries, each of them associated to a particular boarding port, as is shown.

Table I. Galician Estuaries considered and their respective boarding ports.

AREA	ESTUARY	BOARDING PORT (Hj)
Rías Altas	Ribadeo	Ribadeo
	Foz	Foz
	Viveiro	Celeiro

	Barqueiro	Barqueiro
	Ortigueira	Cariño
	Cedeira	Cedeira
Costa Ártabra	Ferrol	Lorbé/Mugardos
	Ares	Lorbé/Sada
	Betanzos	Lorbé/Sada
	O Burgo	Lorbé/Oza
Costa da Morte	Corme/Laxe	Corme
	Camariñas	Muxía
	Corcubión	Corcubión/Brens
	Muros	Muros
	Noia	O Freixo/Muros
Rías Baixas	Arousa	Vilanova de Arousa/Ribeira
	Pontevedra	Portonovo
	Aldán	Cangas
	Vigo	Cangas

Ribadeo	17	6367
Foz	4	1630
Celeiro	52	18508
Barqueiro	21	7473
Cariño	14	5144
Cedeira	35	12380
Lorbé/Mugardos	92	33123
Lorbé/Sada	28	10274
Lorbé/Sada	49	17423
Lorbé/Oza	11	4916
Corme	41	14906
Muxía	35	12459
Corcubión/Brens	45	16103
Muros	122	42686
O Freixo/Muros	122	42686
Vilanova de Arousa/Ribeira	412	138754
Portonovo	343	115685
Cangas	70	26659
Cangas	183	63768

4. Results

Firstly, results for time and costs for the installation method 1.1. are shown in table II.

Table II. Time and cost results for method 1.1.

BOARDING PORT (Hj)	TOTAL TIME (days)	TOTAL COST (€)
Ribadeo	5	45226
Foz	1	9674
Celeiro	15	134685
Barqueiro	6	53961
Cariño	4	36262
Cedeira	10	89844
Lorbé/Mugardos	20	181449
Lorbé/Sada	8	72575
Lorbé/Sada	11	96412
Lorbé/Oza	3	29227
Corme	12	107924
Muxía	10	89996
Corcubión/Brens	13	116838
Muros	26	239788
O Freixo/Muros	26	239788
Vilanova de Arousa/Ribeira	59	538863
Portonovo	50	449120
Cangas	20	183447
Cangas	40	359310

Moreover, results for time and costs for the installation method 1.2. are shown in table III.

Table III. Time and cost results for method 1.2.

BOARDING PORT (Hj)	TOTAL TIME (days)	TOTAL COST (€)

Finally, results for time and costs for the installation method 1.3. are shown in table IV.

Table IV. Time and cost results for method 1.3.

BOARDING PORT (Hj)	N. UNITS (ARj)	TOTAL TIME (days)	TOTAL COST (€)
Ribadeo	180	9	35249
Foz	180	9	41530
Celeiro	180	9	41465
Barqueiro	180	9	41168
Cariño	180	9	41327
Cedeira	180	9	41305
Lorbé/Mugardos	240	12	57044
Lorbé/Sada	180	9	41870
Lorbé/Sada	240	12	55492
Lorbé/Oza	180	9	43114
Corme	180	9	41504
Muxía	180	9	41448
Corcubión/Brens	180	9	41485
Muros	240	12	55894
O Freixo/Muros	240	12	55894
Vilanova de Arousa/Ribeira	360	18	84308
Portonovo	360	18	83931
Cangas	180	10	45312
Cangas	240	12	56269

Of the three methodologies analysed for the positioning of the reef complex (barge and drone, service work boat and mini bulkcarrier), the one that offers a reduced positioning time and greater versatility is that of the barge and the drone, because they are capable of operate at any depth. Draft limitations in some of the estuaries make it impossible to use large vessels to transport the AR units. Also, this method presents reasonable time operation and cost does not skyrocket compared to the other two.

5. Conclusion

This work has proposed several methods for installing a group of green artificial reefs designed in the PROARR research project. Two of these methodologies were conventional: a bulkcarrier and a special service workboat. The other technique was innovative: an autonomous vehicle.

All of them offer different results in terms of manoeuvrability, positioning, precision and cost. The barge+drone is the best method in terms of time operation, draft and versatility. Draft limitations in some of the estuaries make it impossible to use large vessels to transport the AR units.

The estuaries with more number of AR units are Vilanova de Arousa/Ribeira and Portonovo, with a total of 360 AR units, which represents a total time of 18 days, being their costs 84,308 € and 83,931 € respectively.

This study will establish a first step in overall analysis of the installation process of green artificial reefs in the Galician shore, which will make a sustainable way of exploiting the marine resources.

Acknowledgement

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