Artificial Reef: Turning Old Ships into National Treasures

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Abstract

Global warming is a growing threat to marine ecosystems, especially coral reefs, which are extremely sensitive to climate changes such as rising temperatures and rising carbon dioxide levels. Ocean acidification and coral bleaching are alarming signs of the effects of climate change, demonstrating the urgent need for strategies to mitigate these impacts. One promising solution is the dismantling of ships to create artificial reefs, which can serve as habitats for various marine species and help in the recovery of degraded areas. These artificial reefs also open doors to the sustainable extraction of bioproducts, offering economic opportunities for Brazil in the global biotechnology market. Investing in research in this area can generate valuable discoveries for the pharmaceutical, medical, cosmetic and bioantifouling industries without biocides.

Keywords: Artificial reefs of ships, bioproducts, sustainability and marine biodiversity.

Introduction

The creation of artificial reefs from ship dismantling is a strategy aligned with the principles of sustainable development and represents an innovative solution for the reuse of out-of-service vessels. This method not only provides a way to give new uses to structures that no longer have a navigational purpose, but also contributes to the preservation of marine ecosystems. The controlled sinking process transforms the submerged parts of the vessel into new habitats for marine biodiversity, helping to mitigate coastal erosion and relieve pressure on natural reefs that face significant threats (IBAMA, 2009). Artificial reefs can play a crucial role in revitalizing degraded marine areas. According to White et al. (1990), more than 50% of oceanic fish use these artificial habitats as refuge and breeding grounds, while corals, algae and sponges also find a suitable environment for attachment. Furthermore, artificial reefs can be particularly beneficial in areas with sandy bottoms where natural settlement of organisms is limited (Arena et al., 2007). The use of decommissioned ships as artificial reefs not only revitalizes marine biodiversity but also contributes to research and sustainable extraction of bioresources. The implementation of these structures can facilitate the creation of permanent protected areas and foster the development of technologies for bioremediation and other sustainable uses of marine resources. Dismantling ships to create artificial reefs represents a vital strategy to address global warming, providing ecological and economic benefits while promoting the conservation of marine ecosystems.

General Objective

Develop and evaluate the feasibility of controlled ship dismantling to create artificial reefs, analyzing its effectiveness in revitalizing marine ecosystems and promoting biodiversity.

Specific Objectives

- To analyze the effectiveness of artificial reefs created from ships in promoting marine biodiversity compared to natural reefs.
- To assess the environmental impact of the ship-sinking process on the integrity of marine ecosystems and coastal erosion.
- To investigate the efficiency of artificial reefs in restoring degraded marine areas, particularly on sandy bottoms where the natural attachment of organisms is difficult.
- To explore the potential of artificial reefs as tools for bioremediation and sustainable extraction of marine bioresources.
- To promote the dissemination of results and the implementation of ship-dismantling practices for artificial reefs as a sustainable marine conservation strategy.

1. Artificial Ship Reefs: The Sunken Treasure of Marine Bioproducts

Coral structures are formed by millions of tiny polyps, which extract calcium (Ca) from seawater to create the hardened structure of calcium carbonate ($CaCO_3$) (Monteiro, 2021). These sessile organisms feed on floating waste and maintain a symbiotic relationship with algae called zooxanthellae, which live inside the cells of coral tissue. Zooxanthellae, unicellular algae, provide essential nutrients for the growth and vitality of corals, while the latter provide shelter and protection (Monteiro, 2021). Plankton, composed of zooplankton and phytoplankton, is essential to the marine food chain. Phytoplankton perform photosynthesis, while zooplankton participate in the cycling of organic matter. Silicon dioxide (SiO_2), present in phytoplankton, contributes to the formation of the skeleton of some marine organisms (Monteiro, 2021). Calcium carbonate and silicon dioxide form the structure of corals and can be used in products such as dietary supplements, cosmetics and the pharmaceutical industry (Monteiro, 2021). Marine sponges, which often colonize reefs, contain bioactive compounds with medicinal potential. These compounds, when isolated, are used in medicines and skin care products. Seaweed provides nutrients, fibers, dyes and alginate, a promising polysaccharide for bioantifouling (CPA Cardoso, 2024). Coral reefs have enormous potential to boost the country's bioeconomy, with biomolecules such as proteins, enzymes and polysaccharides that have applications in several areas and contribute to scientific research projects. Biotechnology applied to biological remediation and production of bioproducts is a tool capable of promoting improvements in environmental problems (Cardoso, 2024). According to BRASIL (2020), the world is jealous of the natural resources of the Blue Amazon. The creation of natural reserves and the defense of the sustainable use of environmental resources are relevant factors for sustainable development. Funding for research programs and projects is necessary for the production of bioproducts for the benefit of National Defense. Decommissioned ships can revitalize the ocean floor with organic bioproducts (Cardoso, 2024). Artificial reefs from ships transform the underwater environment into a majestic setting, where diving becomes a poetic experience, and the ship, now an enchanted reef, offers shelter to marine life (Cardoso, 2024). Artificial reefs created from decommissioned ships promote ecological diving and generate income for local communities. These structures provide a suitable environment for marine life to establish itself and thrive. By revitalizing the seabed and areas degraded by human actions, they contribute to species diversity and to maintaining the health of the oceans. According to IBAMA (2009), the implementation of artificial reefs aims to manage the use of fishing resources, conserve biodiversity, conduct scientific research, and protect the coastline. Protecting natural resources is a national strategy for preserving the ecosystems of the Blue Amazon, which directs the country toward global bioeconomy growth (BRASIL, 2020). Dismantling ships to create artificial reefs is an ecologically sustainable and economically viable alternative. This strategy can revitalize the ocean floor and promote the desired changes. Climate change, rising sea surface temperatures, and ocean acidification have significant impacts on the health of the oceans and all marine life (Monteiro, 2021). The creation of artificial reefs offers considerable social and environmental benefits, such as providing marine habitat for the revitalization of biodiversity, advancing scientific research, expanding bioresources, and enabling the sustainable use of the resources of the Blue Amazon (BRASIL, 2020).

2. A Sea of Sustainability: The Oceans and the Carbon Cycle

The oceans play a crucial role in absorbing atmospheric gases through the biogeochemical cycle, including nitrogen (N), oxygen (O_2), carbon dioxide (CO_2) and phosphorus (P) (Monteiro, 2021). This cycle is vital for the maintenance of marine life and for global climate regulation. The oceans act as carbon sinks, absorbing CO_2 from the atmosphere and contributing to the planet's climate control (Cardoso, 2024). Microorganisms, such as phytoplanktonic algae, use nitrogen (N) for growth and reproduction. The oceans convert nitrogen into ammonia (NH_3), which is then assimilated by plants for the synthesis of organic molecules (Monteiro, 2021). Excess nitrogen, from the excessive use of agricultural fertilizers, can cause eutrophication, resulting in the proliferation of algae that compete for dissolved oxygen in the water, leading to the asphyxiation of fish and other aquatic organisms (Monteiro, 2021). Furthermore, algal blooms can hinder waterway transportation and increase the maintenance costs of propulsion systems (Cardoso CPA, 2024). The oxygen (O_2) produced by algae during photosynthesis is essential for the respiration of living beings. According to FUNIBER (2024), the algae that inhabit coral tissues capture solar energy to convert CO_2 and water into glucose and oxygen. Oxygen production by corals is responsible for more than 50% of atmospheric oxygen (FUNIBER, 2024). The imbalance in CO_2 emissions resulting from human activities contributes to the bleaching and degradation of coral reefs. The increase in atmospheric CO_2 leads to ocean acidification, a process that harms marine organisms such as corals, mollusks, and plankton, affecting their shells and calcareous skeletons (Monteiro, 2021; FUNIBER, 2024). Acidification occurs when dissolved CO_2 reacts with bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions to form carbonic acid (H_2CO_3) (Monteiro, 2021). Ocean currents, driven by variations in sea surface temperature (SST) and salinity, play an essential role in the redistribution of nutrients and maintaining the health of marine ecosystems. The mixing of water from the depths, known as upwelling, is crucial for the transport of nutrients to the surface (FUNIBER, 2024). Changes in salinity, exacerbated by melting glaciers, can disrupt these processes, affecting nutrient availability and disrupting the trophic levels of marine ecosystems (FUNIBER, 2024). Ocean currents, such as the Gulf Stream and the Antarctic Circumpolar Current, play a key role in regulating global climate, transporting warm water to cold regions and cold water to warm regions, and helping to regulate global temperature (FUNIBER, 2024). The balance of the biogeochemical cycle is crucial for the maintenance of marine life and the health of the oceans. The creation of artificial reefs from decommissioned ships is a promising strategy to mitigate the impacts of climate change and revitalize the oceans. Sustainable measures are needed to restore the balance of biogeochemical cycles and protect marine ecosystems (Cardoso, 2024; FUNIBER, 2024).

3. Methodologies for the Implementation of Artificial Reefs

☐ Comparative Analysis of Marine Biodiversity: Conduct comparative studies to assess the diversity and abundance of species between areas with artificial and natural reefs, using quantitative and qualitative methodologies.

☐ Assessment of Changes in Water Quality and Sedimentation: Monitor environmental indicators before and after the shipwreck to measure changes in water quality, sedimentation and erosion, using sampling techniques and environmental data analysis.

☐ Colonization and Growth of Marine Organisms: Examine the colonization and growth of marine organisms in sandy bottom areas where artificial reefs have been implemented, using observation methodologies and ecological data collection.

☐ Assessment of the Capacity of Artificial Reefs to Absorb Pollutants: Study the capacity of artificial reefs to absorb pollutants and provide substrate for the growth of organisms that can be used in bioremediation and production of bioproducts, with a focus on bioengineering techniques and chemical analysis. ☐Knowledge Dissemination and Training: Develop guidelines and recommendations based on the study results and promote workshops and seminars for stakeholders and environmental managers, aiming at the dissemination of knowledge and good practices in the implementation and management of artificial reefs.

4. Life at Sea: Dismantling Unseaworthy Ships

Figure 1 shows some toxic materials found on ships, as well as the side effects associated with the contamination of these materials on marine organisms. It is crucial to remove these toxic materials and reuse the dismantled parts appropriately. Metal sheets can be used in the automotive industry, while iron can be used in civil construction, contributing to the support of structures such as walls and concrete slabs. Hull scrap is used to create artificial reefs, promoting the revitalization and restoration of marine habitats.

Elemento Químico	Toxicidade	Fontes de Contaminação	Efeitos nos Corais
Arsênio (As)	Muito tóxico	Mineração, indústrias, pesticidas	Danos ao DNA, crescimento prejudicado
Cádmio (Cd)	Tóxico	Indústrias, fertilizantes	Inibição do crescimento, branqueamento
Cobre (Cu)	Tóxico	Mineração, esgoto, tintas	Danos aos tecidos, branqueamento
Mercúrio (Hg)	Muito tóxico	Mineração, queima de carvão	Danos neurológicos, mortalidade
Zinco (Zn)	Tóxico	Indústrias, esgoto, fertilizantes	Inibição do crescimento, branqueamento

Figura 1 - Fonte: Elaboração própria, Capitã Cintia Cardoso.

4.1 Determinants of the Suitable Location to Sink the Ship

Figure 2 presents the ideal environmental variables and their thresholds to ensure effective coral growth and revitalization. These variables were adjusted to reflect conditions that favor coral health and development, taking into account the impacts of global warming. Analyzing these parameters is essential to ensure that the shipwreck site provides an environment conducive to coral colonization and growth, promoting the creation of sustainable and resilient artificial reefs.

Figura 2

Variáveis Ambientais	Unidades	Mínimo	Ideal	Máximo
Correntes Marinhas	m/s	0.2	0.3 - 0.5	0.7
Altura das Ondas	m	0.8	1.0	1.5
TSM	°C	22-24	25-29	30
Salinidade	ppt	32	33	36
Oxigênio Dissolvido	mg/1	5.8	6.5	7.2
Turbidez	NTU	3.5	4.0	5.0
Dióxido de carbono	ppm	380	400	420
Alcalinidade	mg/1	110	120	130
Ressurgências	-	não	x	x
Fitoplâncton	células/1	4500	5000	5500
Ph	-	7.8	8.0 - 8.4	8.4
Pesticidas Agrícolas	%	x	x	28
Isobatimétricas	m	23	30-40	47
Coordenadas Geográficas	Lat - Baixa	-	28°N - 28°S	-
Isotermas	°	19	22-28	30
Temperatura do Ar	°	24	26-30	32
Nutrientes	Baixos níveis de Nitrogênio (N) e Fósforo (P)			
Luz Solar	Fotossíntese Zooxantelas, microalgas simbióticas			
Metais Pesados	Concentrações mínimas para evitar toxicidade			
Sedimentação	Baixa para evitar sufocamento dos corais			
Ondas	Altura, Frequência e Direção			
Vento	Velocidade e Intensidade			
Licenças	Autorização para a criação de Reserva Ambiental			
Distância da Costa	Atualização e Marcação na Carta Náutica			

Figura 2 Fonte: Elaboração própria, Capitã Cintia Cardoso.

4.2 Submerging Method: Turning the Ship into an Air Factory

The procedure for submerging a ship in a controlled and safe manner requires precise calculations of the volume of water displaced, the density of the water and the forces involved in the descent process. These calculations are essential to ensure that the ship settles stably on the seabed, without causing environmental damage, and include:

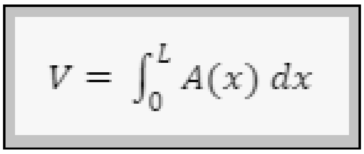
1 Volume Calculation (Figure 4): The volume of the ship is crucial to determine the water displacement, it is calculated by the formula V = L x W x H where V is the volume, L is the length, W is the width and H is the height of the ship. 2 Water Density (Figure 4): Using the volume V and the density of the water (D), the displacement of the water (D) is calculated using the expression: D = V x D.

3 Cross-Sectional Area (Figure 3): The cross-sectional area ((A(x)) of the ship along its length (L) is considered, allowing for greater precision, detailed analysis of the mass distribution and behavior during submersion.

4 Rotational Inertia (Figure 5): Inertia affects the stability of the ship when sinking, and is calculated taking into account the distance (y) of an area element (dA) to the axis of rotation, essential to avoid unwanted rolling.

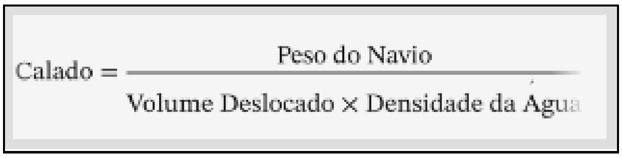
5 Buoyancy Force (Figure 6): The buoyancy force (F_b) is determined by the density of the water (V), displaced volume (V) and acceleration of gravity (g).

These calculations and considerations were learned during my preparation for the Amateur Captain test of the Brazilian Navy, and are essential to ensure that the sinking is safe and that the ship sits stably on the seabed, minimizing environmental impacts.



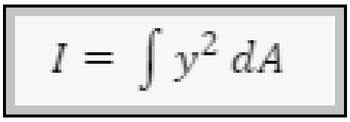
$$V = \int_0^L A(x)\, dx$$

Figura 3



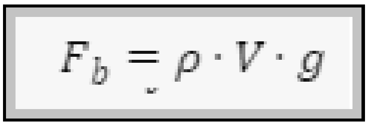
$$\text{Calado} = \frac{\text{Peso do Navio}}{\text{Volume Deslocado} \times \text{Densidade da Água}}$$

Figura 4



$$I = \int y^2\, dA$$

Figura 5



$$F_b = \rho \cdot V \cdot g$$

Figura 6

"May the seas welcome the sunken ships, transforming them into enchanted reefs."

5. The Treasure of the Blue Chest: A Fight Against Biopiracy

5.1 The Importance of Biotechnology to Boost the Brazilian Bioeconomy

Biotechnology is often seen as the key to unlocking the potential of the bioeconomy in Brazil, a country endowed with rich biodiversity and vast natural resources. However, Brazilian bioresources appear to be underutilized, with no clear strategy to maximize their economic and sustainable potential. Cardoso (2024) highlights that Brazil still lacks productive autonomy in the extraction of alginate, a polysaccharide extracted from seaweed that is widely used in the food industry and promising in applications such as biocide-free bio-antifouling. Despite the abundance of this resource in the Blue Amazon, Brazil continues to import large quantities of bioproducts that could be produced domestically, highlighting a significant gap in the country's capacity to transform its natural resources into high value-added products. Protecting natural resources is essential to ensure the sustainability of the Brazilian bioeconomy. According to the Brazilian government, it is imperative to join forces to protect these resources, enact laws in the penal code to combat biopiracy, and ensure the security of the Blue Amazon (BRASIL, 2020). The lack of effective regulation and monitoring puts marine biodiversity and, consequently, the basis of the bioeconomy at risk. According to Monteiro (2021), marine resources are under constant threat due to overexploitation, coral bleaching, microplastics, and other contaminants. These challenges highlight the urgent need for sustainable practices to ensure the continued exploitation of marine resources without causing ecosystem collapses. Phytoremediation in marine farming is one of the most viable solutions to meet the demand for food and maintain the sustainable exploitation of marine resources. As described by Capitã C. (2024), phytoremediation is the process of treating water with natural or genetically modified plants (GMPs), which absorb nutrients such as nitrogen and phosphorus, thus reducing aquatic pollution. These techniques are crucial to mitigating environmental impacts, including the damage caused by oil spills in water bodies. For biotechnology to fulfill its transformative potential in the Brazilian bioeconomy, it is necessary to invest in productive autonomy, protection of natural resources, and sustainable practices. Only through an integrated and coordinated approach, based on principles of sustainability and technological innovation, will it be possible to leverage Brazil's position in the global market and guarantee a sustainable future for future generations.

Final Thoughts: Strategies to Combat Global Warming

The oceans, vital for the biodiversity and sustainability of the planet, are suffering significant damage due to industrial, agricultural and urban development. Pollution and contamination resulting from human actions threaten the health of marine ecosystems and the viability of sustainable use of their waters. The saturation of the oceans with pollutants and excess CO_2 have devastating consequences. Extreme weather events, such as hurricanes, floods and severe droughts, are directly linked to rising CO_2 levels. Air pollution, the formation of acid rain and the greenhouse effect contribute to global warming, affecting all marine life and leading to the extinction of several species. To combat global warming and protect the oceans, it is vital to adopt integrated strategies that include reducing CO_2 emissions, promoting clean energy, bioremediation and restoring coral reefs. Coral reefs play a key role as natural barriers against storms and are home to around 25% of all marine life, including 65% of fish. Restoring areas affected by bleaching and degradation caused by human actions is crucial, since corals provide food, medicine and sustain life on Earth. The creation of artificial reefs for ships and environmental protection areas are important measures to preserve marine ecosystems and ensure a more sustainable future. Brazilian legislation provides support for these actions through instruments such as Law No. 6,938 of August 31, 1981, which instituted the National Environmental Policy, and Law No. 9,433 of 1997, which established the National Water Resources Policy. In addition, Law No. 7,511 of 1986 changed the boundaries of Permanent Protection Areas (APPs), and CONAMA Resolution No. 357 of 2005, which establishes the classification of water bodies and environmental guidelines for their classification, reinforces the need to protect aquatic environments. Only coordinated actions and strict compliance with these laws can reverse the damage caused and ensure a healthy and balanced planet for future generations.

To the Creator of the Universe

You taught me the lesson of the waves, each retreat was an effort for my advancement. You are the seas, the wind, the earth and the stars. You are the lighthouse, the light that never goes out!

"Para o Mundo mudar e respirar puro ar, do mar temos que cuidar."

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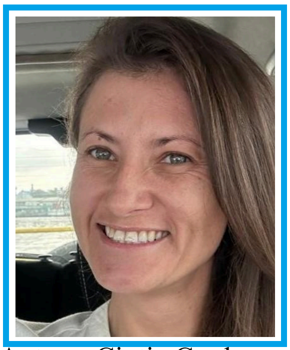

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