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METHODOLOGIES FOR REMOVAL OF THE CORAL SUN IN OFFSHORE UNITS RESULTING FROM OIL EXPLORATION IN BRAZIL AND ITS ENVIRONMENTAL IMPACTS

Luiz Lúcio de Aragão Pedroso[1], Everton Rangel Bispo[2], José Roberto Moreira Ribeiro Gonçalves[3,*] and Fabiano Battemarco da Silva Martins[4]

[1,2,3] Centro Universitário Augusto Motta– UNISUAM, Engineering Department– Avenida Paris, 84, Zip Code: 22631-002, Bonsucesso, Municipality of Rio de Janeiro, stateof Rio de Janeiro, Brazil
[4]Universidade Santa Úrsula– USU,Centro Universitário Gama e Souza – UNIGAMA, Engineering Department – Rua Fernando Matos, nº 48, Zip Code: 22621-090, Barra da Tijuca, Municipality of Rio de Janeiro, stateof Rio de Janeiro, Brazil

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****Corresponding author:***
José Roberto Moreira Ribeiro Gonçalves

ABSTRACT

Coral Sun is an exotic invasive species that has spread over three thousand kilometers of the Brazilian coast, representing a threat to the ecosystem. Some of these bio invasive species are embedded in oil platforms on the Brazilian coast. The present study sought to evaluate the advantages and disadvantages of removing the Coral Sun in marine oil units in Brazilian waters by means of two procedures: the first using a team of divers and the second, an ROV, more specifically, a Roving Bat. The removal operation for both methods was performed in two phases; the first one consisting of an inspection by shooting around the marine unit using a high-resolution GoPro camera for identification of bioinvader niches embedded in the hull; the second phase performing proper removal of the bio-invader by a team of divers using, as tools, rotating brushes and spatulas. In the removal by the ROV,it was used the process of hydro-blasting, suggesting being more efficient and faster in a general way; however, it proved to be inefficient in certain areas. In both methods, it was evidenced the absence of concern for the environment. The entire process of removal of the Coral Sun in the two operations had all the organic material removed from the hull of the units and discarded in the sea, probably contributing to the emergence of new colonies of this bioinvader on the Brazilian coast.

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INTRODUCTION

The installed capacity of renewable energy sources identified by several agencies, including the International Energy Agency (IEA), reports a growth of 825 giga-watts by the year 2021 (IEA 2017).This proves that, even though several countries have been investing in the most diverse renewable sources, such as solar, wind, biomass, among others, the dependence on oil is still very significant for many countries (IEA, 2017). Data from the Brazilian Statistical Yearbook of Oil, Natural Gas and Biofuels, of theNational Petroleum Agency(ANP, 2017), reports that world oil production was 92,150 mb/d (million barrels/day) in 2016 versus 91,704 mb/d in 2015, with a positive percentage range of 0.49%.The United States produced 12,354 mb/d, in 2016, and 12,757, in 2015, showing a small negative percentage reduction of 3.16%. China produced, in 2016, 3,995 mb/d *versus* 4,309 mb/d, in 2015, registering a negative percentage reduction of 7.19%. Differently, Brazil produced, in 2016, 2,605 mb/d compared to 2,525 mb/d, in 2015, presenting a positive percentage increase of 3.16% (ANP, 2017). While global production showed a slight growth of 0.49% in the period 2016/2015, global consumption increased by 1.64% in the same period, from 96,558 mb/d, in 2016, to 95,003 mb/d in 2015.The United States alone consumed 19,631 mb/d, in 2016, and 19,931 mb/d, in 2015, showing a slight increase of 0.51%. Brazil, in 2016, consumed 3,018 mb/d in contrast to 3,170 mb/d, in

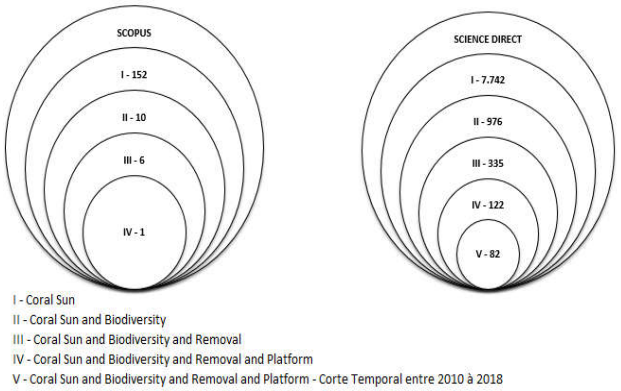
2015, representing a negative percentage reduction of -4.79%; and China consumed, in 2016, 12,381 mb/d to 11,986 mb/d in 2015, representing a percentage increase of 3.30% (ANP, 2017). The International Energy Agency (IEA 2017) estimates the growth in demand for oil could decrease by 1 mb/d (million barrels/day) until 2023, as a result of initiatives by a number of countries to replace oil with other energy sources.Driven by the Kyoto Protocol, China, for instance, has been recognizing the emergency need to improve poor air quality in its cities.Actions have been conducted by the government by means of incentives to buy electric or natural gas vehicles, more precisely for truck and bus fleets. The IEA analyses indicate the demand for diesel tends to decrease (IEA OIL, 2018). Brazil registered a negative reduction in oil consumption of 4.79%, with a production level for the same period increasing by 7.16%.Estimates suggest the price of Brent Oil, in 2018, could go from US$ 57 per barrel to US$ 63, which could boost production; for this, it will be necessary to make investments by operators in their offshore units (ANP, 2017).

In accordance with data from the Management of Surveys, Inspections, and Technical Expertise of the Brazilian Navy, in its report of March 16, 2018, there are 45 non-operating oil platform and 150 operation in the country, totaling 195 units (MARINHA DO BRASIL, 2018), with the majority of them being classified as Floating Production Storage and Offloading – FPSO, floating units for production, storage, and transfer of oil and/or gas. Some of these platforms operated in other oceans for a while and probably contributed to the introduction of an invasive exotic species in their hulls, or even in their ballast tanks, bringing the *Tubastrae*Sppbioinvader (Coral Sun) to Brazilian seas in the form of colonies, all with no natural enemies. This species is regarded as a "pest", since it reproduces rapidly, increasing its density and geographical coverage, thereby modifying the local marine fauna and flora in the Brazilian coastal regions (MANGELLI and CREED, 2012).

Studies show the accidental introduction of thebioinvader in Brazil in the 1980s, via vectors developed by human beings.There are signs the arrival of these exotic species occurred with the coming of oil platforms from other continents and via the ballast water of ships. The type was initially recorded in the *Bacia de Campos*, in the state of Rio de Janeiro, Brazil (CASTRO and PIRES, 2001; Pszczol et al., 2017; MMA, 2019). Studies conducted by non-governmental associations and official bodies, such as the Ministry of the Environment, by means of the *Instituto Brasileiro do MeioAmbiente e dos RecursosNaturaisRenováveis* – IBAMA (Brazilian Institute of the Environment and Renewable Natural Resources), also highlight the rapid expansion of this bioinvader on the CoralSun over the Brazilian coast, besides the need for removal and a procedure not yet defined. According to BAX et al. (2003), the environmental impact caused by invasive exotic species on native species can generatedamages in public health, loss of production in activities based on the marine environment and its resources, such as fishing, aquaculture, tourism, and infrastructure, in other words, besides environmental damages, it also causes negative impacts in both the economic and social spheres (Pszczol et al., 2017).

General Purpose: This study aims at analyzing two proposals for the removal of Coral Sun in offshore oil exploration units.The first one by a team of divers; and the second proposal, with the use of an ROV (Roving Bat) equipment, and, thus, examine the possible advantages and disadvantages of each proposal, and its possible side effects.

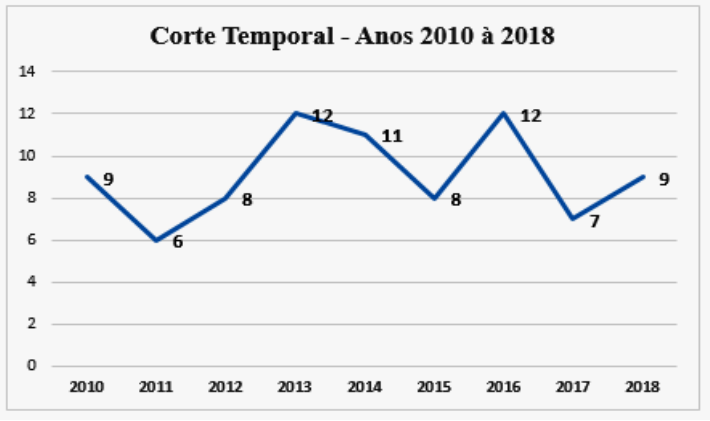
Bibliometric Review: A literature review was conducted to elaborate this study.First, in the search for sources of information in publications that were significant to this study, the *Scopus* and *Science Direct* databases were used, applying the following steps:in a first survey, *Coral Sun* was used, and 152 and 7,742 publications were identified in the *Scopus* and *Science Direct* databases; in a second survey,using *Coral SunandBiodiversity*, it was identified 10 and 976;in a third one, *Coral Sun and Biodiversity and removal* were used, and 6 and 635 publications were identified;in a fourth survey using *Coral Sun and Biodiversity and removal and platform*keywords, 1 and 122 publications were identified. From these 122 publications, a time cut was applied, between 2010 and 2018, with the purpose of identifying the most recent publications in the *Science Direct* database (Fig. 1).



Time Cut between 2010 and 2018

Figure 1. Publications in official databases (authors, 2018).

It was possible to identify, using the time cut between 2010 and 2018, in which years there was more research.It is noted that there were 12 publications in 2013 and 2016, followed by the years 2010 and 2018, respectively, with nine publications each, calling attention to this last exercise, in which there are still six months to close, arousing a curiosity about what has driven the international scientific community to publish articles in the first five months of 2018. In this context, a path is opened for future research (Fig. 2).



Time Cut – Years 2010 to 2018

Figure 2. Publications in official databases (authors, 2018)

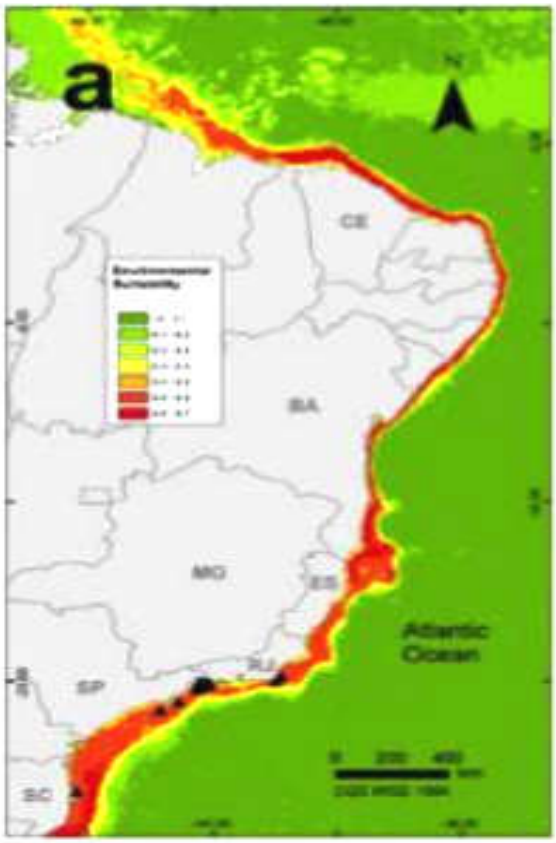


Figure 4Map of potential distribution of Tubastraea coccinea invader coral along the Brazilian coast on the basis of an ecological niche model (Carlos-Júnior et al., 2015).

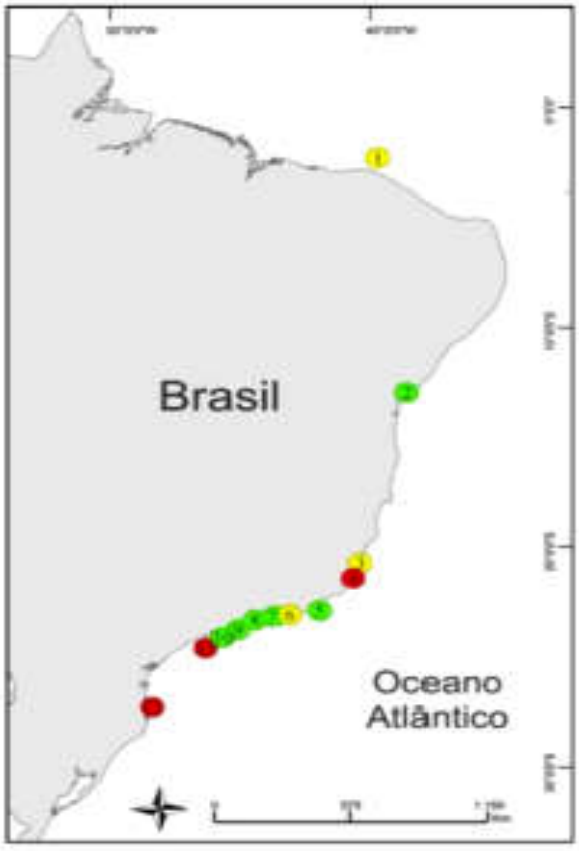


Figure 5. Occurrence map of Coral Sun in different Brazilian states (Creed et al., 2016)

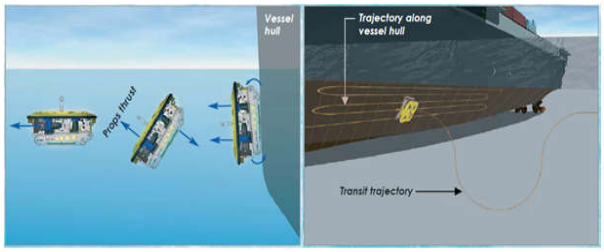


Figure 6. Free-Flying Mode and Trajectory along the vessel hull (ECA, 2018).

Moreover, publications by group in specific areas were researched in Science Direct in order to obtain content that had adherence to the research.Thirteen publications were found, which contributed to the elaboration of the theoretical framework, *Marine Pollution Bulletin* (5), *Ocean & CostalManagement* (4), *Advances in Marine Biology* (2), and *Journal of Experimental MarineBiology and Ecology* (2).

Literature Review: Studies have pointed out that, since 1980, new "pests" from the Indo-Pacific, known as *Tubastraeacoccínea* (orange) and *Tubastraeatagusensis* (yellow), have appeared in Brazil.Both popularly known as Coral Sun are exotic species embedded in oil and gas platforms in the *Bacia de Campos*,municipality of Campos dos Goytacazes, state of Rio de Janeiro, Brazil.After a decade, it contaminated the rocky coasts of *Baía da Ilha Grande*, spreading to more than 20 municipalities in more than 3,000 kilometers of the Brazilian coast (OIGMAN PSZCZOL et al., 2017; Pszczol et al., 2017; MMA, 2019). *Tubastraeacoccínea* and *T. tagusensis* are corals from the Scleractina Bourne order (DALY et al., 2003; MMA, 2018; Pszczol et al., 2017; MMA, 2019).These are species of stony corals or scleractians, which produce calcareous skeletons, ahermatypics and not reef builders; they are azooxanthellates, that is, they do not depend on symbiont algae to nourish themselves (CAIRNS, 2002; MMA, 2018; MMA, 2019). This type of coral does not belong to the Brazilian marine fauna and flora. It has rapid growth in comparison to native species of Brazil; it is hermaphrodite but can also be asexually reproduced; its larvae are planktonic and easily dispersed in a water column (MMA, 2018; MMA, 2019).Moreover, there are no species with similar morphology in Brazil, facilitating the identification of Coral Sun because of its red-orange color (MMA, 2019).

Coral Sun has great ecological tolerance, enabling it to survive in high temperature environments, even with low oxygen levels (MMA, 2019). "Exotic species, or non-native species, are those found beyond its historically known geographical range" (MANGELLI and CREED, 2012). "The displacement of exotic species occurs in maritime transport by the fouling of the ship hulls and has greatly increased by the use of ballast water from ships" (KOLIAM et al., 2013). “Evidence from the life history of Tubastraea indicates that ballast water is not the main vector of introduction. Tubastraea type presents a series of reproductive strategies, which lead to small-scale dispersion, among them, incubation and subsequent release of larvae already developed in a water column" (OIGMAN-PSZCZOL et al.,2017). Documents indicate that, in 2012, IBAMA was reported by Petrobras company that, on the oil platforms located on the coast of the state of Sergipe, Brazil, there were signs of Coral Sun (Pszczol et al., 2017).In 2013, this environmental agency conducted inspections on these platforms, corroborating that colonies were embedded in the structures of the PCM-6 and PDO-1 units, thus generating the

Figure 8. Submerged area of the FPSO XUnit (P Company, 2018)

Item	Description	Location	Item	Description	Location
1	Thruster # 01	STBD FWD (StarboardBow)	16	Connection of Sponson with Pontoon	STBD AFT (Stern Starboard)
2	Thruster # 02	STBD FWD (StarboardBow)	17	StructuralReinforcementofBracing	STBD AFT (Stern Starboard)
3	SeaChest 04S	STBD FWD (StarboardBow)	18	Welding Cross	STBD AFT (Stern Starboard)
4	SeaChest 04S	STBD FWD (StarboardBow)	19	Thruster # 05	PORT AFT (Port Stern)
5	SeaChest 011S	STBD FWD (StarboardBow)	20	Thruster # 06	PORT AFT (Port Stern)
6	Connection of Bracing with Pontoon	STBD FWD (StarboardBow)	21	SeaChest 30S	PORT AFT (Port Stern)
7	Connection of Sponson with Pontoon	STBD FWD (StarboardBow)	22	SeaChest 26P	PORT AFT (Port Stern)
8	Structural Reinforcement of Bracing	STBD FWD (StarboardBow)	23	SeaChest 23P	PORT AFT (Port Stern)
9	Welding Cross	STBD FWD (StarboardBow)	24	Connection of Bracing with Pontoon	PORT AFT (Port Stern)
10	Hydrophone	STBD MidshipStarboard– Outside	25	Connection of Sponson with Pontoon	PORT AFT (Port Stern)
11	Thruster # 03	STBD AFT	26	StructuralReinforcementofBracing	PORT AFT (Port Stern)
12	Thruster # 04	STBD AFT	27	Welding Cross	PORT AFT (Port Stern)
13	Sea Chest 04S)	STBD AFT	28	Hydrophone	PortMidship – Inside
14	SeaChest 04S	STBD AFT)	29	Hydrophone	PortMidship – Outside
15	Connection of Bracing with Pontoon	STBD AFT	30	Thruster # 07	PORT FWD (PortBow)

Figure 9 – Submerged area of the FPSO –YUnit (P Company, 2018)

VESSEL SECTION *(SEÇÃO DO NAVIO)*	LENGTH *(COMPRIMENTO)*	QUADRANTS AND NICHES *(QUADRANTE E NICHOS)*
AFT SECTION	89.6m	PORT SURFACE, STDB SURFACE, PORT BOTTOM SURFACE, CENTER BOTTOM SURFACE, STDB BOTTOM SURFACE, SIX SEA CHEST, THREE THRUSTER AND ECHO SOUNDER TRANSDUCER *(Superfície de bombordo, superfície de boreste, superfície do fundo à bombordo, superfície do fundo ao centro, superfície do fundo à boreste, seis caixas de mar, três propulsores e o transdutor da ecossonda)*
MIDSHIP-MOONPOOL SECTION	57.6m	PORT SURFACE, STDB SURFACE, PORT BOTTOM SURFACE, CENTER BOTTOM SURFACE, STDB BOTTOM SURFACE, MOONPOOL *(Superfície de bombordo, superfície de boreste, superfície do fundo à bombordo, superfície do fundo ao centro, superfície do fundo à boreste e moonpool)*
FWD SECTION	72.2m	PORT SURFACE, STDB SURFACE, PORT BOTTOM SURFACE, CENTER BOTTOM SURFACE, STDB BOTTOM SURFACE, FOUR SEA CHEST, THREE BOW THRUSTER AND ECHO SOUNDER TRANSDUCER *(Superfície de bombordo, superfície de boreste, superfície do fundo à bombordo, superfície do fundo ao centro, superfície do fundo à boreste, quatro caixas de mar, três propulsores e o transdutor da ecossonda)*

inspection report number 01R/2013/SE (IBAMA, 2012). Also according to this agency, in the year 2013, Petrobras requested authorization to manage and control the Coral Sun, as it appeared embedded in a suspension buoy of a riser in the field of Congro, in the Bacia de Campos, state of Rio de Janeiro, Brazil. In this specific case, the removal was unsuccessful.Sammarco et al. (2015) report a wall called Coral Sun T was found at the Nuclear Power Plant in Taiwan, and, according to Ho et al. (2016), this type of encrustation brings risk to the structures of the Plant. Coutinho et al. (2013) also consider that the manual removal of a species may cause enough stress for the colonies to release reproductive structures, given that the method commonly used comes from the manual use of tip and hammer (Creed et al., 2017; MMA, 2019). An essential factor to be observed is the low tolerance for low salinity environments, which are fatal for its survival. The Coral Sun tends to die in only two hours when inserted in fresh water, while in closed environments with sea water, it can survive for 14 days. When inserted in vinegar, its survival drops to 15 minutes (Moreira, et al., 2014; Mantelatto et al., 2015; Creed et al., 2015; MMA, 2019).

Invader Exotic Species: For the Convention on Biological Diversity – CBD, "exotic species" are those outside their natural habitat.Recognized as threats to the ecosystem, they have a high competitive advantage because of the partial or total absence of natural enemies and, for this reason, they find a favorable environment to proliferate (MMA, 2018).

Coral Sun on the Brazilian Coast: Some studies suggest that at least 20 municipalities along 3,000 km of the Brazilian coastal region have records of T. coccínea and T. tagusensis. Creed et al. (2016), when conducting surveys based on distribution modeling and niche, verified the Brazilian coast has a high environmental condition for adaptability (RIUL et al., 2013; CARLOS-JÚNIOR et al., 2015 (Fig. 4).Also according to Creed et al. (2016), there is evidence of the existence of this bioinvader on the Brazilian coast in different states, as depicted in Figures 4 and 5.In the Figures below, it can be seen, respectively, the Tubastraeacoccíneaspecies in the red circles; in the yellow ones, the T. tagusensisspecies; and, in the green circles, the T. coccinea and T. tagusensis species. The Brazilianstatesthathadtheirincidencesprovenwere: 1 - Acaraú (stateof Ceará); 2 - BTS (stateof Bahia); 3 - Vitória (stateof Espírito Santo); 4 - Guarapari (stateof Espírito Santo); 5 - Região dos Lagos (stateof Rio de Janeiro); 6 - Cagarras (stateof Rio de Janeiro); 7 - SepetibaBay (stateof Rio de Janeiro); 8 –Baía da Ilha Grande (stateof Rio de Janeiro); 9 - Ilhabela (stateof São Paulo); 10 - Alcatrazes (stateof São Paulo); 11 - Laje de Santos (stateof São Paulo); 12 - Arvoredo (stateof Santa Catarina). Potential effects in these regions are the increased capture of zooplankton (Birkeland, 1977), which may reduce the supply of these organisms, native suspensive species; changes in local biogeochemical cycles; and loss of environmental, tourism and fishing values (Schuhmann et al., 2013).

Brazilian Law: On December 29, 1994, by Decree No. 1,354, Brazil created the National Program of Biological Diversity (Pronabio).On August 22, 2002,by Decree No. 4,339, Pronabio started coordinating the implementation of the principles and guidelines of the National Biodiversity Policy by means of a

partnership with the Government and Civil Society; but, on May 21, 2003, Decree No. 4,703 amended Pronabio, and repealed Decree 1,354/1944, creating the National Commission for Biodiversity (MMA, 2018). The Ministry of the Environment enacted Ordinance No. 94, on April 9, 2016, with the purpose of providing technical advice in the preparation of the Plan for Control and Monitoring of Bioinvasion of Coral Sun, called "Coral Sun Plan".This ordinance defines strategies to mitigate negative impacts; however, it does not regulate by law the systematic combat of this bioinvader (MMA, 2016). The Public Ministry of the state of Rio de Janeiro (MPF/RJ),in 2017, issued an injunction from a public civil suit filed by the Federal Public Ministry in the municipality of Angra dos Reis, state of Rio de Janeiro, Brazil.The injunction stipulated Petrobras, Transpetro, EstaleiroBrasfels, Vale (Terminal IlhaGuaíba TIG), and Technip to adopt effective measures to control the Coral Sun.These companies would be given up to 60 days to present an inspection report on the terminals, ships, and platforms, and Petrobras should submit, within 90 days, a complete diagnosis, besides an eradication schedule for this species for a maximum period of two years. Furthermore, it was established that all vessels and platforms that need to pass through the region, and have any relation with oil exploration, should undergo inspections. In the event of non-compliance, there would be a daily fine of R$ 50,000.00 (MPF/RJ, 2017). Brazil still has no specific legislation on bioinvader species, such as Coral Sun; althoughthe Chamber of Deputies has considered Bill No. 7.129/2017, of Congressman Alexandre Leite, since 2017, aiming at regulating the slaughter and control of invader exotic species (CÂMARA, 2017).

Roving Bat: The Roving Bat – ROV (unmanned vehicle) can reach a particular target in free-flying mode.When launched into the sea, the equipment reaches its goal with no human interference, leaning completely or even rolling from side to side, completely adhering to any vertical surface.It has the dimensions of 1105 x 1085 x 646, in millimeters, which also includes transponder and lifting buoy. This type of equipment can be easily adapted and configured with several sensors to detect and eliminate any suspicious device (Fig. 6). The main applications of Roving Bats are in the inspection of underwater hulls of ships, hydraulic dams, and submerged structures in general, executing thickness measurement via ultrasonic sensor (UT probe) of non-destructive measurement system, commonly used to validate the conformity of vessels. It can also do the cleaning, using cavitation cleaning technology (high pressure steam from cavitation bubbles), which, when directed to the hull, can remove any and all organisms, eliminating all biological growth, without significant impacts on the hull (ECA, 2018).

METHODOLOGY

The following two methodologies were selected for this study:firstly, a bibliometric review (Costa 2010) was used, in which the data were from the Scopus and Science Direct databases, with the goal of identifying relevant publications consistent with the theme;secondly, an exploratory field research was conducted with companies that provide underwater services in hulls of vessels, more specifically performing visual inspections and recording in identifying and removing the Coral Sun.P Company that performs the identification and removal services was identified, either by divers or using the ROV.

Moreover, two other companies were evaluated, the so-called X and Y, as clients of P Company.Together, the three companies provided some data, keeping their identities confidential as their requested.

Filming Identification Process: A pair of divers inspected the outer area of the unit hull to detect and quantify the Coral Sun, using a GoPro 5 HERO Black high-resolution underwater video camera, and three days of work were required due to sea conditions. The shooting process was done by coupling the camera to the 2704 x 1520, 2.7K Roving Bat, through a linear field of vision of 30 frames per second, being monitored by an ROV operator supervised by an expert biologist. This process allowed evaluating the entire length of the vessel in only one day of work. Shooting covered the sea box grid, pipelines, and the moonpool.

Coral Sun Removal Method: The International Maritime Organization (IMO), published, in 2011, the MEPC Resolution.207(67), recommending guidelines for controlling bioinvaders(Coral Sun) encrusted in ship hulls. The criterion adopted worldwide is the application of the following three methods: I) chemical control; II) physical control; and III) biological control (Thresher and Kuris, 2004). In Brazil, in accordance with the document of the Environmental Ministry (MMA, in Portuguese) (2018), entitled "Public Consultation – Diagnosis on the Invasion of Coral Sun (Tubastraea spp.) in Brazil", there are five ways to remove this organism: manual, mechanical removal, ROV operation, surface treatment, and encapsulation technologies.According to that, for the removal of Coral Sun from offshore units, all options were examined, considering time, cost, and safety in the operation. Among them, two types of removal were selected: I) manual/mechanical with divers; and II) ROV. For both options, the unit anchored at sea is considered, not being taken into consideration units beyond this condition, as required by clients.

Removal with Divers

P Company Case: Based on the exploratory research on the survey of companies that perform this activity under study in Brazil, P Company was chosen, located at the municipality of Macaé, state of Rio de Janeiro, Brazil, which was willing to collaborate providing some data. In order to carry out a diving intervention, it must first follow the criteria of the Maritime Authority for Underwater Activities Standard - NORMAM - NR 15, which requires the use of a sign (equipment to transport divers from the vessel to the bottom of the sea) with at least two men inside this equipment and a third diver located on the surface, as a safety measure, in order that, if necessary, intervention can be taken in the event of an emergency.

In compliance with the above-mentioned rule, it is necessary to use a minimum team of eight professionals, in addition to equipment, such as compressors, volume tanks, oxygen and compressed air bottles, winches, and hyperbaric decompression chamber. The intervention took place in aunit called **X**, from 4 to 20 June 2017. A team composed of four dive supervisors, nine divers, and one coordinator worked in this operation. Th following areas were first inspected: Sea Chest, Thrusters, Bracing Sponson, Hydrophone, and Pontoon, totaling 30 items, according to (Fig. 8). At first, a team of two divers, holding a high-resolution GoPro 5 HERO camera, dive into the sea following a dive plan in the above areas, starting

shooting around the bow, stern, port, and midship, at 20-minute dive intervals because of sea conditions.Shooting time occurred within three days. After shooting and identifying the sources of Coral Sun, from the third day on, the manual removal of the colonies located in the starboard bow, midship starboard – external, and at different points of the stern was initiated.The removal process used was to scrape the species off the hull without encapsulating them nor collecting them from the sea.As reported by one of the coordinators, this is a normal practice adopted because they do not know any legislation that makes the removal of Coral Sun out of the sea mandatory.

Removal with*Roving Bat*

P Company Case: In the second exploratory research, the same P Company was used, but with a ROV type Roving Bat for inspection and pre-cleaning, by shooting with a GoPro 5 HERO Black camera, installed in the Roving Bat, following an inspection plan pre-established by the client of the **Y** unit. The intervention occurred in the three sections of the unit (Fig. 9). The operation was carried out in the unit named **Y**, in the periods from 24 to 30 November 2017 and from 10 to 20 December 2017.A team composed of oneproject manager, two ROV technicians, two biologists, and one team of divers worked on this operation.Large areas were cleaned by hydroblasting, remotely driven by the ROV operator; nevertheless, for particular hull areas, such as thrusters and sea chests, divers were needed using hand tools, such as a hand brush, spatula and chisels, and all material removed from the hull from the areas was discarded into the sea, just as in the **X** unit.

RESULTS AND DISCUSSION

The presence of bioinvader colonies in various areas of the X and Y units was found in both cases. The units did not report the quantity. New hull inspections were carried out after removal and no trace was found. By comparing the two Coral Sun removal processes, using the Roving Bat for inspection and removal, the equipment showed high performance in identification and removal aspects, all except in some areas, where diver intervention was required. Generally speaking, however, the use of the ROV proved to be satisfactory, mainly because of the non-use of human workforce on site, replaced by equipment. This technological aspect has demonstrated to be fundamental given that, for the use of divers, there is a need to submerge to the surface from time to time due to the risks of the activity to human health. Moreover, it is necessary to consider the adverse meteoceanographic conditions, such as the possibility of electric shocks caused by contact with the structures of the vessel, due to the possibility of strong underwater currents and risks of embolism because of the need for filming over long periods and subsequent removal. The Roving Bat proved operational efficiency only in flat areas and where the Coral Sun had low rooting.When evaluating the performance of the equipment in places with thrusters and sea boxes, low operational efficiency was found, requiring the complementary participation of divers to facilitate the removal by means of manual tools, such as a hand brush, spatula and a chisel. Based on the observations of the methods applied, in both cases, all the organic material removed from the hull of the units was discarded into the sea, which is likely to contribute to the emergence of new colonies of this bioinvader on the Brazilian coast.

Conclusion

This study concludes the Roving Bat appears as a technological innovation for the removal of the Coral Sun housed in the hulls of ships and platform structures.This method has proven to be efficient in flat and continuous areas; however, it has shown little efficiency in certain areas, such as the sea chest and thrusters. Generally, the use of the equipment avoids the intervention of divers, eliminating the risk of loss of human life, reducing the periodof activities, besides the cost in the operation of removal of the Coral Sun. Given the lack of specific Brazilian legislation on the topic, operating companies, together with their clients, do not consider themselves forced to adopt a safer and more efficient methods from the environmental point of view,which refers to the need to promote legislative action to preserve the marine environment from possible environmental impacts caused by the permanence or removal of the coral sun. When the environmental issue is evaluated because it is a very important issue, it is crucial to develop removal methods that do not lead to an environmental imbalance due to the inadvertent disposal of Coral-Sun in the marine environment, especially if its high proliferation capacity is considered. In this way, this study opens horizons for new researches, in the sense of generating alternatives and promoting the elaboration of procedures, legislation and protocols to be followed by all the navigation and oil exploration companies regarding the removal of the Coral sun in Brazil.

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