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THE USE OF SIDESCAN SONAR TO DETECT LARGE BENTHIC MARINE DEBRIS IN NITERÓI HARBOR-GUANABARA BAY/SE BRAZIL

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ABSTRACT. Marine debris constitute a global concern that pollutes the world's oceans, including deep benthic habitats where little is known about the extent of the problem. SideScan Sonar systems are able to provide near-photographic high-resolution images of underwater areas, for a wide variety of objectives, including production of nautical charts and detection of underwater bathymetric features. Lately this technology has been used as a tool to detect debris on the seafloor that may be hazardous for living organisms and finally for humans. Harbor activities were the most common contributors of benthic debris. Little is known about the extent of the problem in the Guanabara Bay, Rio de Janeiro, regarding benthic debris distribution and their influence in the bottom sediment. The present study analyzes the spatial distribution and type of marine benthic debris in the area of Niterói Harbour. The study identified great amount of benthic debris, including tires, anchors, cables or linear features, sunken vessels, wooden or metal bars and pillars.

Keywords: anthropogenic marine debris; benthic habitats, marine debris, estuarine pollution, Guanabara Bay

RESUMO. Os detritos marinhos são uma preocupação global que poluem os oceanos do mundo, incluindo habitats bentônicos profundos, onde pouco se sabe sobre a extensão do problema. O sistema de sonar de varredura lateral é capaz de fornecer imagens quase fotográficas de alta resolução de áreas subaquáticas, para uma ampla variedade de objetivos, incluindo a produção de cartas náuticas e detecção de características batimétricas subaquáticas. Ultimamente, essa tecnologia tem sido usada como uma ferramenta para detectar detritos no fundo do mar que podem ser perigosos para os organismos marinhos vivos e, finalmente, para os humanos. As atividades portuárias foram as que mais contribuíram para os detritos bentônicos. Pouco se sabe sobre a extensão do problema na Baía de Guanabara em relação à distribuição de detritos bentônicos e sua influência no sedimento de fundo. O presente estudo analisa a distribuição espacial e o tipo de detritos bentônicos marinhos na área do Porto de Niterói. Na área estudada foi observada grande quantidade de detritos bentônicos, incluindo: pneus, âncoras, cabos ou feições lineares, embarcações afundadas, barras e pilares de madeira ou metal.

Palavras-chave: detritos marinhos antropogênicos; habitats bentônicos, detritos marinhos: poluição estuarina: Baía de Guanabara

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INTRODUCTION

The marine environment is becoming worldwide under increasing pressures from anthropogenic activities. Fishing, mining, pollution and other human activities cause serious damage to seabed ecosystems and reduce benthic biodiversity. Recently, the global scientific community has directed its efforts towards the study of the impacts of waste on the oceans (Galgani et al., 2015; Ryan, 2015; Thompson, 2015). Marine debris represent a widespread type of pollution in the World's Oceans, including deep benthic habitats where little is known about the extent of the problem. They have been recognized as a widespread problem, being considered at the highest political level (G7 Leader's declaration, 2015; UNEP, 2015). Only for plastic, a recent research suggested that the amount of litter globally entering in the oceans every year is between 4.8 and 12.7 million tons (Jambeck et al., 2015).

Marine debris are defined as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" (UNEP, 2009), and may be categorized according to the material type. Marine litter can be broadly categorized according to its source into land (land-borne sources) and marine-based (sea-borne sources) items. According to Spengler & Costa (2008), there are preferential places for the accumulation of marine debris, like estuaries, the shoreline and the ocean floor.

Marine litter presents many sources, circulates through different routes and eventually accumulates in litter sinks. While most of plastic marine litter floats on the sea surface, macro-litter items composed of heavy materials typically go down to the seabed, where, because of their inertia to decomposition, tend to accumulate, even in a long-term period (Cau et al., 2017). According to Spengler & Costa (2008), the debris deposited on the ocean floor are called submerged benthic marine debris, or benthic marine debris. They have become a global concern, as they pollute habitats in the most remote parts of the world's oceans (NRC, 2009). According to Watterset al. (2010), debris are introduced into the marine environment by their improper disposal, accidental loss, and by natural disasters. They can be transported long distances by ocean currents and tides and can sink and accumulate on the seafloor. As a result, marine debris have become ubiquitous in the world's oceans, from the shorelines to the deepest areas (Thompson et al., 2009).

According to Markert et al. (2013), the continuously human impact on the seafloor and benthic habitats demands the knowledge of clearly defined habitats to assess recent conditions and to monitor future changes. In recent years, marine scientists have been considering the use of acoustic systems, such as sidescan sonar, to assist in understanding and mapping the spatial extent of seabed habitats, which in turn improves our understanding of benthic ecosystems (Mayer, 2006). According to Zheng & Tian (2018), a SideScan Sonar system uses a sonar device that emits conical or fan-shaped pulses toward the seafloor across a wide angle perpendicular to the path of the sensor through the water. The intensity of the acoustic reflections from the seafloor of this fan-shaped beam is recorded in a series of cross-track slices, forming an image of the sea bottom within the swath of the beam. According to Li et al. (2017), in recent decades, acoustic techniques have been utilized to improve our ability to map the spatial characterization of benthic habitat in the presence of artificial structures (Kang et al., 2011). Acoustic habitat mapping has become a major tool for evaluating the status of coastal ecosystems. This technique is also commonly used in marine spatial planning, resource assessment and offshore engineering (Brown et al., 2011; Micallef et al., 2012). Moreover, according to Overmeeren et al. (2009), sidescan sonar makes use of high-frequency sound waves, yielding high resolution and producing detailed, photo-like images, in which different features are often easily recognized. Field data acquirement is straightforward and fast. If it is carried out along parallel tracks with a spacing of some tens to hundreds of meters, it can produce mosaics that fully cover large seafloor surfaces. Due to its high resolution, this technique has been used in different areas of science, such as to locate submerged archeological sites, to find the wreckage of airplanes and helicopters in the sea. Even in forensic contexts, it has been used to search for submerged bodies and forensic evidence (Schultz et al., 2013; Healy et al., 2015; Schultz & Dupras, 2018).

Guanabara Bay is one of the most polluted coastal bay in Brazil (Leal and Wagener, 1993; Kjerfve et al., 1997; Baptista Neto et al., 2006; Soares-Gomes et al., 2016; Aguiar et al., 2018). This environment receives millions of liters of untreated sewage everyday in its waters and also a large amount of all kinds of chemical substance (Rebello et al., 1986, Leal & Wagener, 1993, Carreira et al., 2002; Kehrig et al., 2003, Baptista Neto et al., 2006; Aguiar et al., 2018; Nascimento et al., 2018. The beaches of Guanabara Bay are not suitable for bathing. Garbage pollution has been neglected and is an increasing and persistent problem in the bay that affects all the beaches. This pollution has always been associated in the coastal environment with the visual aspect that inhibits tourist activities. Only from last decade this type of pollution has been studied more intensively (Baptista Neto & Fonseca, 2011; Farias, 2014; Carvalho & Baptista Neto, 2016; Bernardino & Franz, 2016; Cordeiro et al., 2017; Figueiredo & Vianna, 2018; Olivatto et al., 2019; Alves & Figueiredo, 2019).

In this study we used a side scan sonar system to map the occurrence of large benthic marine debris in Niterói Harbor, one of the most polluted sites inside Guanabara Bay.

STUDY AREA

Guanabara Bay is located in Rio de Janeiro State-Southeast Brazil, between 22°40´S and 23°00´S of latitude and 043°00´- 043°18´W longitude. It is one of the largest bays on the Brazilian coastline and has an area of approximately 384 km^2, including the island shorelines. According to Amador (1997), the coastline of the bay is 131 km long; the mean water volume is $1.87 \cdot 10^9$ m^3. The bay measures 28 km from west to east and 30 km from south to north, but the narrow entrance to Guanabara Bay is only 1.6 km wide (Kjerfve et al., 1997). This bay is considered one of the most polluted coastal environments on the Brazilian coastline (Leal and Wagener, 1993; Kjerfve et al., 1997; Baptista Neto et al., 2006; Soares-Gomes et al., 2016). In the last 100 years the catchment area around Guanabara Bay has been strongly modified by human activities, in particular deforestation and uncontrolled settlement, which increased the amounts of contaminants introduced from sewage effluents, industrial discharge, urban and agricultural runoff, atmospheric fallout, and the combined inputs from the rivers (Baptista Neto and Fonseca, 2011). There are more than 12,000 industries in the drainage basin which account for 25% of the organic pollution released to the bay. The bay also hosts two oil refineries along its shore, which process 7% of the national oil. At least 2,000 commercial ships dock in the port of Rio de Janeiro every year, making it the second biggest harbor in Brazil. The bay is also the home port to two naval bases, a shipyard, and a large number of ferries, fishing boats, and yachts (Kjerfve et al., 1997). The hydrographic basin is drained by a total of 45 rivers, 6 of them responsible for 85% of the mean annual freshwater discharge (Baptista Neto et al., 2006). The bay receives the untreated agricultural runoffs and the urban and industrial sewage from the rivers, the Rio de Janeiro metropolitan area, two harbors, refineries, thousands of industries in the surrounding basin and from the atmospheric fallout (Kjerfve et al., 1997; Baptista Neto et al., 2006; Soares-Gomes et al., 2016).

METHODOLOGY

The sidescan sonar data in the Niterói Harbor was acquired with a Tritech Starfish 452, a small, lightweight, low-cost imaging equipment, with the transducer attached on the side of the vessel through a tubular support. The acquisition software Scanline (Tritech®) receives and stores the sonar data and integrates the DGPS positioning. For navigation, we used the Hypack® 2012 software and a DGPS Hemisphere® R130 console with submetric accuracy and differential correction via L-band (communication satellite). The survey lines were planned to cover the largest possible area of the harbor, totaling nearly 32 km of sonar lines (Fig. 1). The obtained sonargrams were imported into the SonarWiz® 5 software for processing and

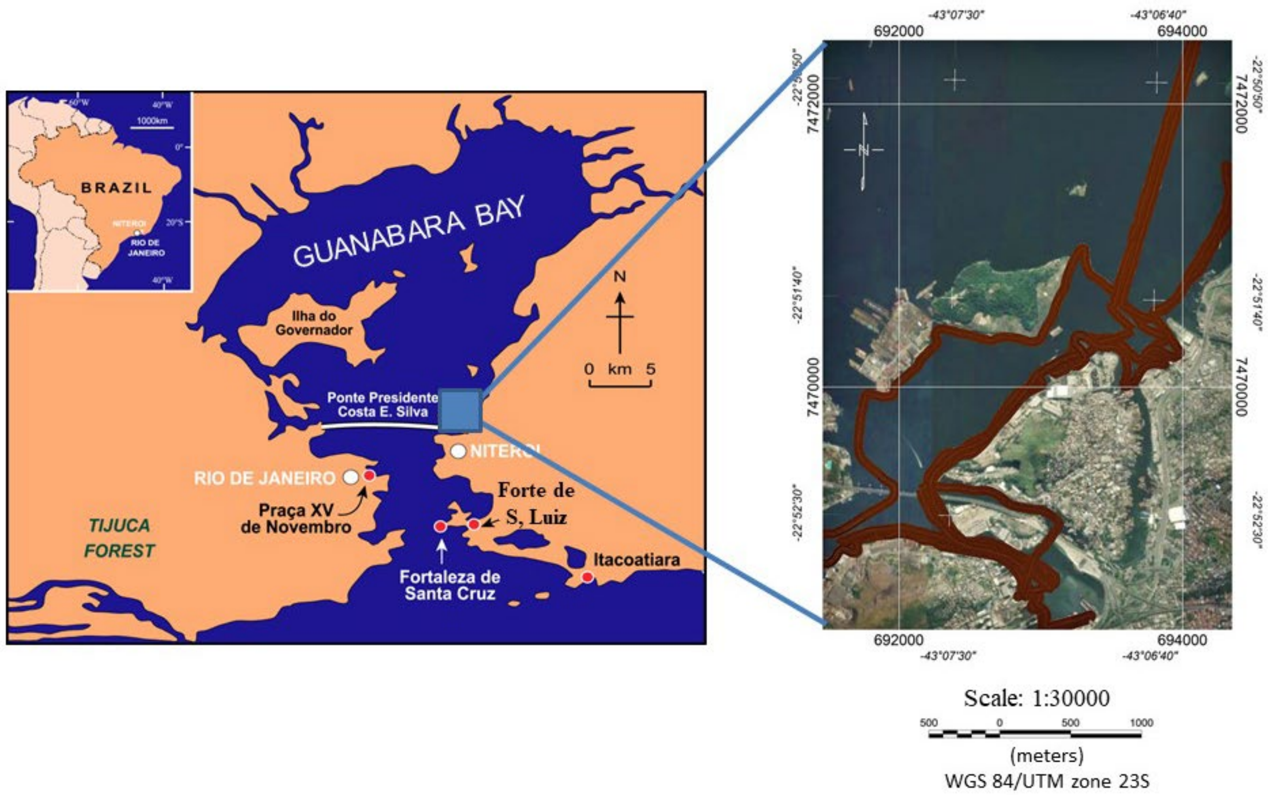

Figure 1 - Location map of study area and the survey sidescan sonar lines.

interpretation. Image processing included angle of incidence corrections, differential gain in signal intensity, changes in brightness, contrast, gamma and color palette changes. All of this improved the image quality, helping the identification of background features.

RESULTS AND DISCUSSIONS

Niterói harbour is the main facility that supports the oil and gas operators in Rio de Janeiro State. This area of study has a complex and shallow morphology, with strong interventions and anthropic modifications, besides being considered one of the most polluted of the Guanabara Bay (Baptista Neto et al., 2005; Vilela et al., 2004). According with Melli et al. (2017), debris accumulation on the sea bed occurs in areas of a complex geomorphology and under favorable hydrodynamic conditions (Galgani et al., 2000; Watters et al., 2010). Once settled on the seabed, the debris may alter the surrounding habitats by providing a previously absent hard substrate, potentially covering large portions of the settled communities (Saldanha et al., 2003), preventing gas exchange, causing chemical and physical pollution (Brown and Macfadyen, 2007). According to Strafella et al. (2015), anthropogenic debris in the sea is a greatly underestimated component of marine pollution due to the limited geographic extensions of the study areas that make difficult to have a comprehensive understanding of the problem. Most of the studies of marine debris were conducted on beaches using item counts along transects due to the easy accessibility of the data. The sea surface was surveyed using the ship-based observation technique to quantify and locate the floating debris. However, the seafloor is much less widely investigated, due to some sampling difficulties, as inaccessibility, and the high cost of sampling in the seafloor. Souza et al. (2009) highlighted the importance of acoustic techniques in the environmental monitoring. The sidescan sonar has been applied in different kind of studies, such as Mosher et al. (1997), that use it to monitor one of the most active dumping area of dredging material on the west coast of Canada. Dias et al. (2019) used the same technique to evaluate the environmental impact on the continental shelf of Rio de Janeiro after accumulated dredge disposal material from the harbor.

The benthic marine debris were quantified on side scan sonar transects conducted in the Niterói Harbor. The total length of these transects has an area of 32 km. The use of sidescan sonar allowed the identification of a large amount of anthropogenic debris widespread throughout the study area. These anthropogenic debris are derived mainly from harbor activities and after escaping management procedures, reaching the environment. The identified debris were marked one by one and separated into seven categories: anchors, tires, bars of wood or metal, cables and lines, shipwrecks, surface vessels and, finally, stacking pillars (Figs. 2, 3, 4, 5). In total, besides inumerous tires, it was also possible to identify in the area 18 lost anchors, 16 cables or linear features (which could be dragging at the bottom), 6 sunken vessels, 21 wooden or metal bars and 21 pillars.

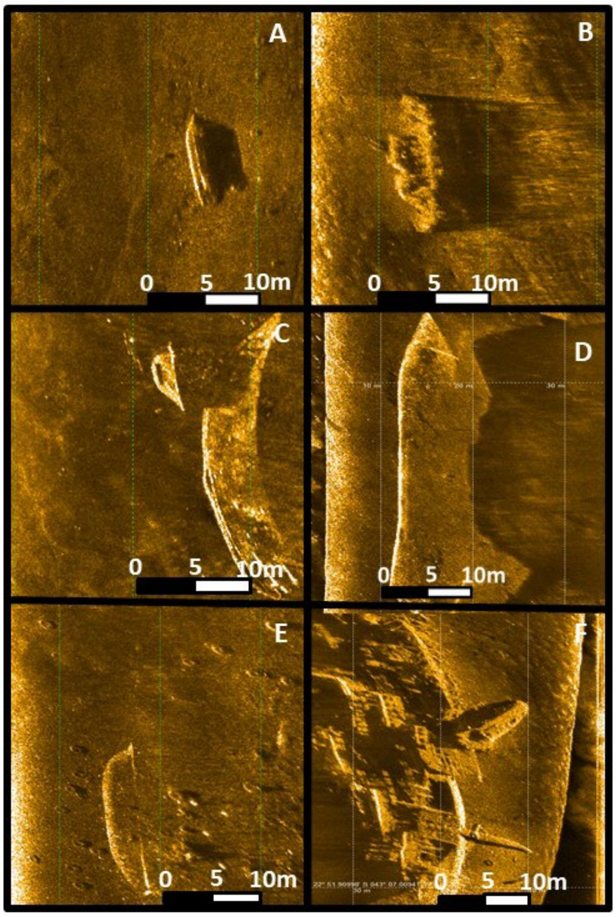

Figure 2 - The occurrence of sunken vessels and tire (A and E) in the bottom sediment.

The comparison between these categories shows that the majority of seafloor debris is made of tires found all around the study area, with more than 346 tires identified.

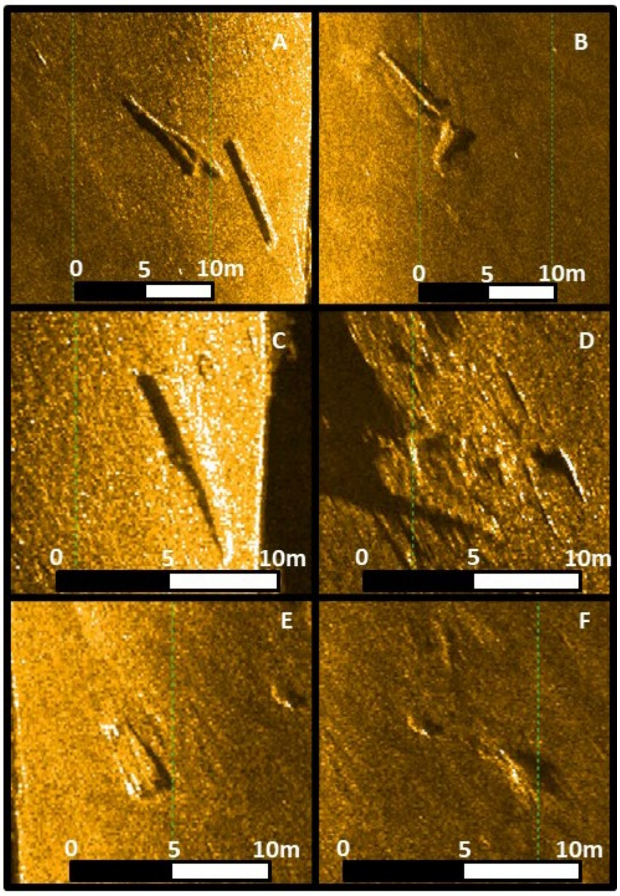

Figure 3 - Wooden or metal bars debris on the seabed.

However, in one site, named a "sea of tires", it was impossible to count the number of tires (Fig. 6). The occurrence of the tires in this area showed a tendency. The tires are found close to the margins and also mainly around the mooring areas of vessels, which is a similar pattern observed by Villena (2015), that associated the large deposit of tires in mooring and anchoring to the fishing and tourist activity in Enseada dos Anjos in Arraial do Cabo-RJ. The tires are used for mooring and as a protection for boats. This tendency in harbor areas has occurred for many years. Veiga et al (2016) suggest a wide range of uses and designs, such as boat and quayside fenders, floating breakwaters, revetment work and artificial reefs. In Guanabara Bay, boat owners place tires as fenders around their hulls to avoid damage during docking at the harbor or against another boat, as it can be seen in Figure 7. Not only boats use this device, but also moorings, that often use much larger tires due to the size of the ships they

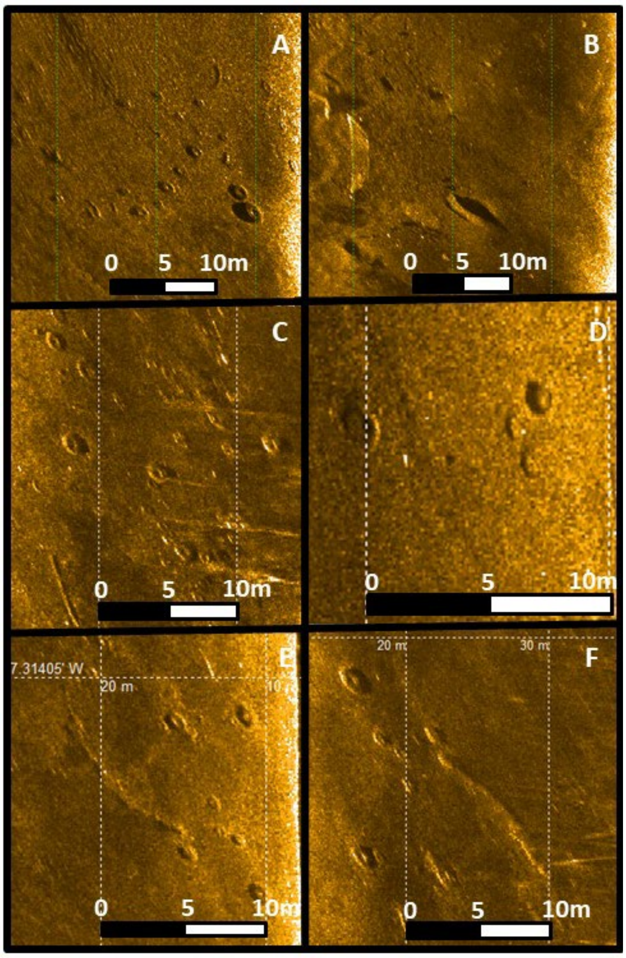

Figure 4 - The occurrence of tires in the bottom sediment.

shelter (Fig. 7) boats. The low cost of using these tires is due to the fact that they are discarded from vehicles after being worn and torn. In addition to the low cost, they are easy to obtain and there is not much caution regarding their use. Therefore, many tires end up falling by accident, generating the large concentrations that can be seen in Figure 6. A considerable example of how the negligent handling of this feature along with the precariousness of the boats is in Figure 6. In Figure 8 it is possible to observe a great number of tires on the bottom which is so large that it makes extremely difficult to quantify how many are there. All of them are associated with an area of mooring small fishing boats. According to Faverney et al. (2010), millions of tires are produced each year around the world, and waste tires raise a huge disposal problem. The disposal of this large number of scrap tires becomes problematic, as scrap tires are non-biodegradable, non-compactible. Moreover, they float to the surface in landfills (Selbes et al., 2015).

The longevity, resistance, and shape of tires have been exploited for many marine constructions, which are using tires in several applications: breakwaters (onshore and offshore), retaining walls in harbours and estuaries, and artificial reefs for fishery enhancement. Underwater, tires are protected from ultraviolet degradation and are in a neutral, stable chemical environment, which may limit leaching. However, we cannot consider coastal estuarine system as a stable chemical environment, especially in Guanabara Bay. Two extensive artificial reef research (Stanton et al., 1985; Berger, 1993) list some 60 tire breakwater papers and over 200 references to tire reefs, and describe tire reefs from North America, the Caribbean, Europe, the Middle East, Asia/Pacific, and Australia. Later, Fabi et al. (2011) elaborated an overview on artificial reefs in Europe. According to the available references, France was the first European country to carry out experiments on artificial reefs, starting earlier in 1968 with some pilot reefs made of waste materials (car bodies). In the Black Sea, the artificial reef construction begun in the 1970s. Four reefs using tires and concrete modules have so far been placed: one, along the Rumanian coast, one in Turkish waters and two in the Ukrainian coastal zone (Zaitsev et al., 2002). In United Kingdom, the Poole Bay artificial reef (central-southern coast of England) was implemented in 1998 by the immersion of concrete modules and tires.

Most papers concerning tire artificial reefs concentrate on fish populations and catches. However, when considering their potential environmental impact on the marine environment, the growth of organisms on the tires surface may be more revealing than the mobile fauna, as their exposure to any chemical release is greater. Tires are manufactured from a wide range of chemical compounds (natural rubber, synthetic polymers, carbon black, high aromatic oils, sulphur, zinc oxide, heavy metals,

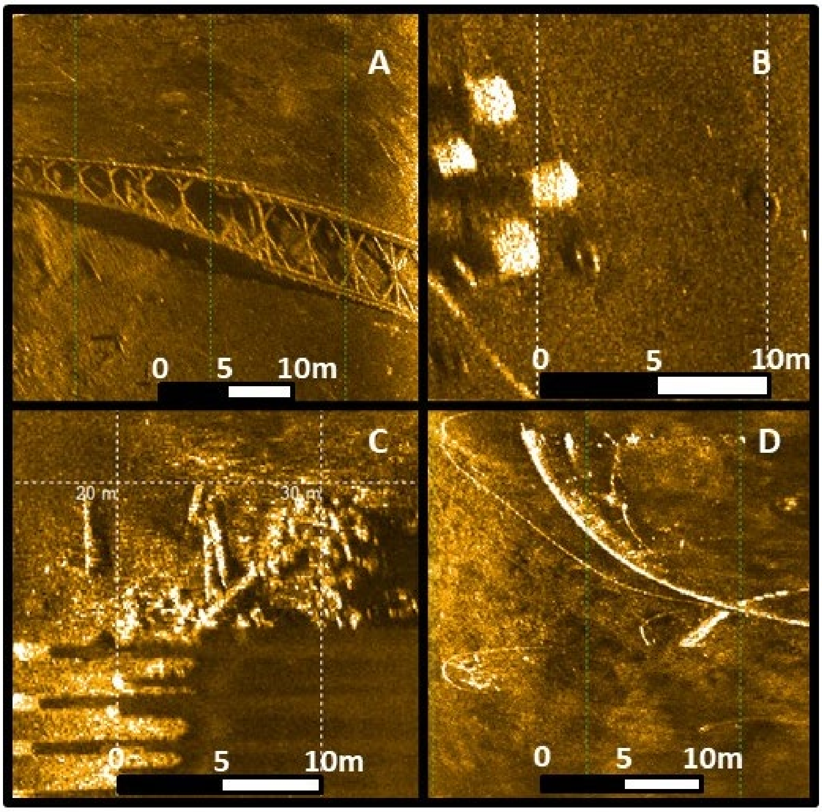

Figure 5 - The occurrence of different debris related to the harbor activities in the bottom sediment.

organic peroxides), which vary depending on type, manufacturer, date of production and country of origin. Sienkiewicz et al. (2017) highlights that scrap tires are a growing environmental problem because they are not biodegradable, and their components cannot readily be recovered. When the waste tires are disposed of at dump sites, they can also cause serious human health, environmental and atmospheric problems.

One of the major concerns about tires in the sea is the leaching of tire constituents over time and subsequent potential harmful impacts on the environment (Selbes et al., 2015). The inorganic constituents in the leachate may include some heavy metals and sulfur, while the organics are expected to consist of PAHs used in the rubber (Wik and Dave, 2005). Previous works have focused on the leaching of selected PAHs, heavy metals and their ecotoxicological effects. In general, zinc and some PAHs (benzothiazole, butylated hydroxianisole, 2-methylnapthalene, fluorine, phenanthrene, etc.) have been detected frequently in the leachates of tires (Wik and Dave, 2005; Li et al., 2010; Llompart et al., 2013).There is little published information about the leaching of compounds either in fresh or seawater (Collins et al., 2002). Several studies showed that water extracts of tires are toxic to different aquatic organisms, for example, bacteria (Day et al., 1993), crustaceans (Goudey and Barton, 1992; Gualtieri et al., 2005; Wik and Dave, 2005) and fish (Goudey and Barton, 1992; Day et al., 1993). Heavy metal bioavailability in the bottom sediment from Niterói Harbor, carried out by Baptista Neto et al. (2005) and Vilela et al. (2004), showed high concentrations and bioavailability in the sediment. They also showed high levels of deformed benthic foraminifera in the area.

CONCLUSIONS

Side scan sonar images are extremely efficient to identify and quantify antropogenic macro benthic debris on the seabed and to generate distribution maps, allowing the location of highly

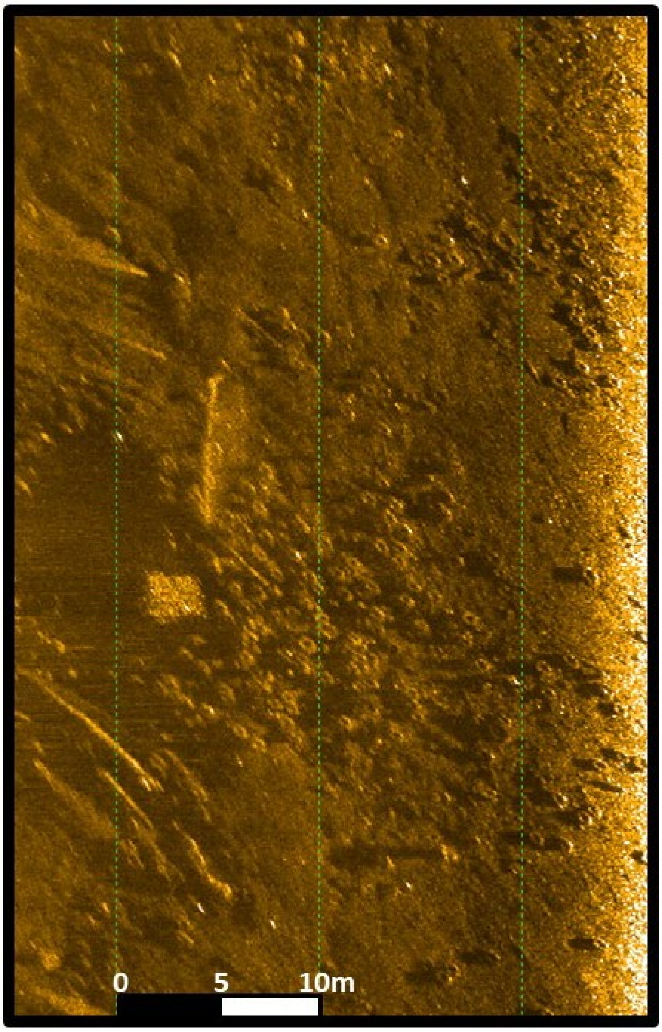

Figure 6 - The occurrence of “Sea of Tires” in the bottom sediment of the Harbor area.

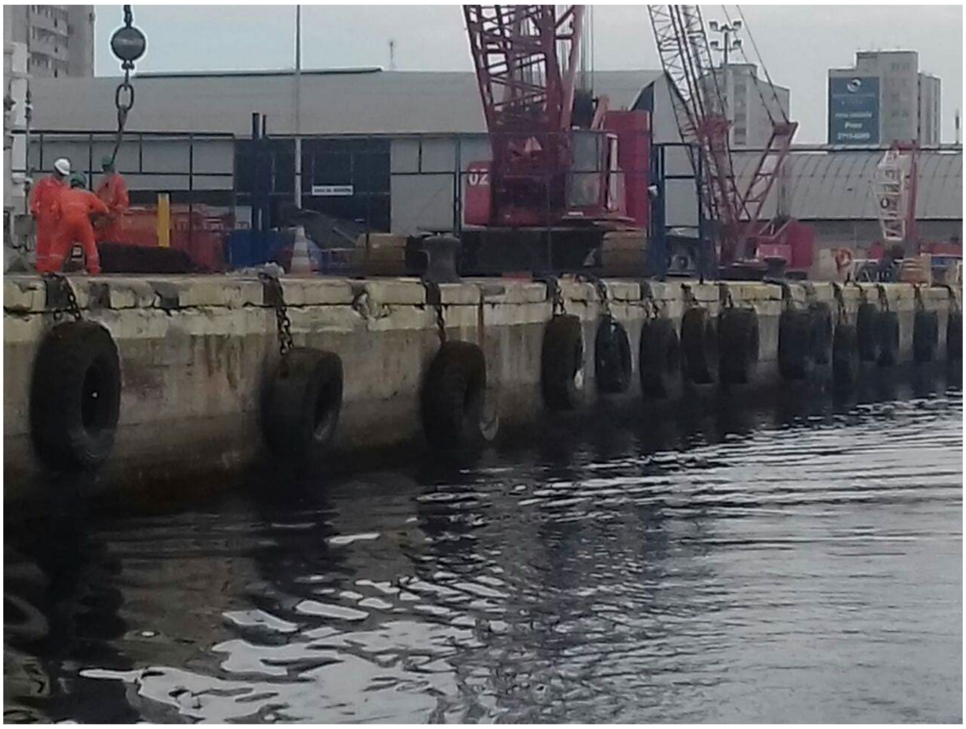

Figure 7 - Picture of the tires used as boat fenders in the harbor.

Figure 8 - Location of the “Sea of Tires” in the bottom sediment of the Harbor area.

impacted sites near the Niterói Habor inside Guanabara Bay.

Pollution by debris, mainly by tires, is very expressive, with around 346 of them identified, in a small location named "Sea of Tires". The areal distribution of tires is associated with the mooring sites of vessels with different sizes and types.
In face of the quantity, this pollution was considered very significant, since rubber has an indefinite decomposition time in nature and because of its potential source of heavy metals, microplastic particles and organic compounds, and its ecotoxicologial effects.

To reduce this type of contamination, it was considered necessary not only efforts for environmental education with harbor workers, but also work aimed at removing these residues, besides, of course, improving the ways of fixing these tires or perhaps replacing them, with other protection mechanisms.

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