Ballast water: A threat to the Amazon Basin

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Ballast water: A threat to the Amazon Basin

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ABSTRACT

Ballast water exchange (BWE) is the most efficient measure to control the invasion of exotic species from ships. This procedure is being used for merchant ships in national and international voyages. The ballast water (BW) salinity is the main parameter to evaluate the efficacy of the mid-ocean ballast water exchange. The vessels must report to the Port State Control (PSC), via ballast water report (BWR), where and how the mid-ocean BWE was performed. This measure allows the PSC to analyze this information before the ship arrives at the port, and to decide whether or not it should berth.

Ship BW reporting forms were collected from the Captaincy of Santana and some ships were visited near the Port of Santana, located in Macapá (Amazon River), to evaluate the BW quality onboard. We evaluated data submitted in these BWR forms and concluded that the BWE efficacy might be compromised, because data contained in these BWR indicate that some ships did not change their BW. We found mistakes in filling the BWR forms and lack of information. Moreover, these ships had discharged BW with high level of salinity, *Escherichia coli* and total coliforms into the Amazon River. We concluded that the authorities of the Amazon Region need to develop more efficient proceedings to evaluate the ballast water reporting forms and BW quality, as there is potential risk of future invasion of exotic species in Brazilian ports.

1. Introduction

The introduction of exotic species in port environments was first reported by the International Maritime Organization – IMO – in 1973 during the creation of the *International Convention for the Prevention of Pollution from Ships,* MARPOL 73/78 (Cohen and Foster, 2000). In the course of the convention, Resolution 18 for Research into the Effects of Discharge of Ballast Water containing Bacteria of Epidemic Diseases was approved, which charged IMO with the responsibility of elaborating measures of ballast water (BW) control (Cohen, 1998). Several exotic species were identified in many parts of the world (Carlton and Geller, 1993; Hallegraeff, 1992; Gollasch, 2006). Studies identified ballast water as the vector of exotic species transfer (Ruiz et al., 1997; Miller et al., 2007). The impacts caused by the organisms found in the ballast water affect the environment, the economy and human health by transferring pathogens, such as the *Vibrio cholerae* (Dobroski et al., 2009; Pereira and Brinati, 2012). In addition, these species can be found in the sediments inside BW tanks (Prange and Pereira, 2013).

Faced with this problem, the first IMO initiative was to establish Resolution A.774 (18) in 1993, following of A.868 (20), in 1997, in which it recommends ships to perform the ballast water exchange (BWE) in open ocean. In 2004, the International Convention for the Control and Management of Ships Ballast Water and Sediments (BWM Convention) took place, with the purpose of establishing guidelines for ballast water control (IMO, 2004). In 2005, Brazil established the Marine Authority Regulation for Ships Ballast Water Management of the Directorate of Ports and Coastlines, Brazilian Navy – NORMAM-20 (DPC, 2005) (De Castro et al., 2010). DPC, 2005 created the Brazilian procedures for BW management, and Brazil ratified the BW Convention in 2010.

NORMAM-20 basically considers the same procedures established by the BW Convention, adapting them to the Brazilian reality. Both consider the open mid-ocean BWE to be the most efficient model of ballast water management. However, special procedures are applied to ports of the Amazon Basin, where an additional exchange is required to reduce ballast water salinity. This should take place between the isobathic of 20 m and Macapá. In this case, the tank volume only needs to be pumped once. The same procedure

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has to be applied to the Pará River (DPC, 2005). In sum, in the Amazon River, ships need to discharge only water with low salinity <5 ppt (Santos et al., 2008).

The salinity varies between 32 and 35 ppt (parts per thousand) in port regions, but it could be higher (Doblin et al., 2010) or lower (Cohen and Foster, 2000). In open ocean, the salinity varies from 35 ppt to 37 ppt, on average (Murphy et al., 2008; Falkner et al., 2007). Thus, BWE suggests that freshwater organisms cannot survive in salt water and vice versa (Smith et al., 1999). BWE typically eliminates between 70% and 99% of the organisms originally taken into a tank while the vessel is in or near a port (Cohen, 1998).

In order to have a proof of the effectiveness of mid-ocean exchange, the ballast water salinity must be examined. This test consists in collecting a sample of the ballast water in the tank, dripping it in a refractometer and analyzing the salinity and specific weight of the sample. The result will confirm if the water collected originates from estuary, coastal or mid-ocean waters.

To guarantee this efficacy, ships need to carry out the procedures established by the BW Convention and NORMAM-20. For this, it is necessary to evaluate the BW Reporting (BWR) form filled. Basically, this verification means to use the coordinates submitted in the ballast water reporting forms. From these reports, it is possible to identify if the region of the BWE was at least 200 nautical miles from the coast and in 200 m deep waters. Since ships need to send the BWR 24 h before arriving at the port, it is possible to identify if they have exchanged BW in mid-ocean before mooring.

There are diagnostics about BWR filling problems identified in several ports in Brazil and in foreign ones. Leal Neto (2007) indicated filling problems in 919 ballast water reporting forms handed to CDRJ from May 1998 to 2002. Approximately 808 reports handed to the Port of Itajaí presented errors. Only 33.42% of the report presented data about ballast water mid-ocean exchange (Caron, 2007). This reflects the reality of ships berthing in the Brazilian ports.

However, the problem of BWR compliance is not exclusive of Brazil. The analysis of 53,503 ballast water reporting forms handed to the USA Coast Guard from 2004 to 2005 to identify the ballast water collection and discharge points showed that approximately 18,250 vessels discharge ballast water within 200 nautical miles (Ruiz et al., 1997). Miller et al. (2007) shows that BWR compliance for overseas arrivals during 2006 to 2007 was 83.5% and for coastwise arrivals was 77.8%.

From the 20.9 million of cubic meter (Mm^3) of ballast water discharged in California from July 2008 and June 2010, 88% were properly managed through the legal methods of ballast water exchange abiding by the laws of California. Approximately 2.5 Mm^3 of irregular ballast water were discharged in Californian waters in this period (Dobroski et al., 2011, 2013).

Brown (2012) compared the BWR delivered by ships at the ports of California and found a reduction in noncompliant between 2012 and 2011. The main errors identified were change in the wrong location, no change, change location unknown, incorrect geography and not intentional non-management. BWR filling, there could be a potential confusion between BWE near 50 nm from shore and 50 nm from any land mass.

Thus, the only way to identify these BWR problems is an evaluation of filling. For this, in Brazil, the first barrier to break is the free access to ballast water reporting forms handed by all ships to the ports. Secondly, a reliable analysis system is needed in order to identify ships that did not carry out the ballast water mid-ocean change. Considering the 33 ports on the Brazilian coast, the analysis of the BWR forms is vital to guarantee the execution of BW mid-ocean change.

In order to evaluate the execution of these principles in Brazil, ships BW reports were collected from the Santana Port Authority and those ships were visited near the Port of Santana, located in Macapá (Amazon River), to evaluate the BW quality onboard. The BW discharge in the Amazon region needs to meet the Resolution of the National Environment Council – CONAMA number 357 of 2005 that established criteria about the water classification and standard regarding effluent discharge in the Brazilian water. Considering these aspects, we analyzed the reports between July, 2012 and January, 2013 and noticed that some BWR indicate errors in filling, exchange location unknown, exchange in wrong location, blank spaces and others mistakes. Two ships had informed that BW change was on land.

The BW quality was evaluated, for which nine quality variables of ballast water were used (temperature, salinity, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), total coliform (TC), *Escherichia coli* (EC)). These waters contained live microorganisms, as well as high salinity, and could not thus be discharged in the Amazon ports of destination, since they did not comply with National and International Laws. It was found that when performing the second change of ballast water, some ships are loaded with waters from the Amazon River port area of Santana/ AP upriver to other regions of the Amazon Basin. We concluded that the authorities of the Amazon Region need to develop more efficient proceedings to evaluate the ballast water reporting forms, as there is potential risk of future invasion of exotic species in Brazilian ports.

2. Material and methods

2.1. Port of Santana

The Port of Santana is located on the Amazon River, Santana channel, 18 km away from Macapá, capital of the State of Amapá, Brazil. The geographical coordinates of the location of the port are: Latitude: 0° 4′N – Longitude: 51°10′W.

The Port of Santana organized jurisdiction is a polygon composed of the following points: A: 0°03′00″ S e 51°12′30″W; B: 0°04′06″ S e 51°12′30″ W; C: 0°04′06″ S e 51°06′46″ W; D: 0°03′00″ S e 51° 06′46″ W. The public port is composed of two piers being – Pier A: 200 m long, 12 m deep and a berth for Panamax ships. Pier B: 150 m long, 11 m deep, and a berth, serves oversea and cabotage navigation. There are two private terminals: Tocantins: 270 m long and 12 m-deep berth, operates in the exportation of ore; Texaco: with 120 m quay and 10 m deep, operating petrol byproducts. The main cargo handling are chromite, manganese, wood, eucalyptus and pine chips, biomass, iron ore and cellulose.

2.2. Evaluation of ballast water reporting forms

We collected reports handed by the ships to the Santana Port Authority in Amapá (Amazon Region) in the period between July 2012 and January 2013. We identified ships last port of call and compared the coordinates indicated as the place of change versus the route from the last port of call to the port of Santana.

We identified ships characteristic such as full load capacity of Deadweight Tonnage – DWT and their ballast water tanks capacity. The tanks that changed ballast water before berthing in the Port of Santana were identified. We checked the information about physicochemical parameters of the ballast water, such as specific weight, temperature and salinity. After that, the values of specific weight were converted into salinity, considering the temperature informed in the reports. The model proposed by (Reid, 2006) was used in this conversion. The ballast water exchange method was identified for all ships that declared it.

Then, we identified ships that did not conduct the ballast water change procedures according to DPC (2005) rules. It provides that every vessel entering the Amazon River has to make a second ballast water change in the region comprehended between the isobathic of 20 m and Macapá.

After that, we made an analytic form to verify if the coordinates and dates informed were true. First, we searched www.marinetraffic.com for the real average speed of each vessel. Using Earth Point® (www.earthpoint.com), we could plot all the coordinates from the forms on Google Earth® and then measure the distance between those change points. Once the dates of those changes were on the BW report, we could estimate the speed of each vessel to travel these points and compare it with the real average speed.

Note that this speed is underestimated, because the form only gives us the day on which the change occurred, not its exact time. We thus used the maximum time period between those days. If a vessel changed a tank at coordinate A on day one and changed the other tank at coordinate B on day two, we used a period of 48 h (00:00 of first day to 23:59 of the second one). Then we compared those two velocities and verified if it was possible or not to travel those distances in that period.

Lastly, all the BWR form filling problems were computed and were separated between correct and wrong filling per ship.

2.3. BW biological evaluation

Physical and chemical analysis were performed through a Multi Analysis probe of brand YSI, model 5556MPS (Burkholder et al., 2007), that instantly gave results for several water quality parameters, such as pH, DO, TDS, water temperature, electrical conductivity and others (Laboratory of Chemistry and Environmental Sanitation CCAM/UNIFAP). The sampling system followed standards established by the Ballast Water Management Convention directives and used in the studies by Gollasch and David (2010) with the sampling techniques they proposed.

Ballast water samples from inspected vessels and from the Amazon River were used to verify and to analyze their hydrochemistry, besides its characterization and adequacy to the CONAMA Resolution 357 05 (Class-2, from Water Quality Brazilian Resolution). A total of 44 ballast water samples and 1 from the Amazon River were analyzed to be used as a reference to the experience.

The physicochemical BW parameters analyzed were: temperature (ToC), TDS (g/l), salinity (Sal. ppt), Dissolved oxygen (DO g/l) and hydrogen ionic (pH), measured at the moment of the sampling of ship by using the multi analysis probe.

Those experience data were compared to those found in the Simplified Environmental Form (RAS, 2012) of CDSA, elaborated for obtaining environmental licensing through relevant state entities for the port extension works.

Microbiological analyses for determining possible invader species were conducted to determine total coliforms and *E. coli* using the chromogenic substrate method (APHA, 1985).

3. Results

47 ballast water ship forms were received regarding ships that moored at the Santana port, State of Amapá. Specifically in Santana port, chromite, manganese, wood, eucalyptus and pine scraps, biomass, iron ore and pulp is transported. From those forms, it was not possible to determine the cargo moved by ships, but it was possible to determine the kind of ships operating in that region. Bulk carrier ships were predominant at the sample (72.34%), tanker ships represented (12.77%), general cargo and multipurpose ships (8.52%), full container, liquefied petroleum gas – LPG and woodchips carrier ships (6.39%). This region is also a producer of oil products that are loaded at the Santana port. A large share of those products are exported to other countries and are used for Brazil internal supply. From the analysis of ballast water forms, those ships discharged 527.808 m^3 of ballast water into the Amazon River.

The distribution of origins of ballast water transported by ships that use the Santana port is predominantly from Brazilian waters (19%), considering only the sample obtained from forms. This is due to the stimulus to cabotage in Brazil in recent years.

The IMO provides that ships have to conduct BWE using three methods (Dilution (1), Flow Through (2) or Empty/Refill (3)). The distribution regarding the BWE method used by ships are 36% (2) and 64% (3).

Since ships that use Amazon ports are obliged to perform BWE alongside Macapá city, we correlated declared volumes between the first and the second BWE. Fig. 1 shows onboard volumes indicated by ships at the first and the second BWE. This was correlated with information presented in the BWR form that contained the declaration about each of these ships BWE.

In function of the forms collected, we observed that some ships did not conduct the first and/or the second BWE. 0 means that BWR forms did not inform the volume relative to those BWE. We observed that some ships that conducted the first BWE and declared some volume did not perform BWE in the same proportion the second time. This is because some ships did not need to discharge all the ballast water of the ship when they arrive at the port. The comparison between values of the first and the second BWE for the same ships did not follow the same behavior, according to the BWR information.

3.1. Forms filling

All the ballast operation coordinates were plotted from Google Earth® by using the website http://www.earthpoint.us/ExcelToKml.aspx. The objective of this evaluation was to identify if the information presented in the BWR forms matched reality. From 47 ship BWRs analyzed, 2 ships were identified that informed a wrong coordinate of oceanic exchange. Ship 2 informed the following coordinate (00°34′N 050°35′W). This coordinate shows that the place of change was Itaubal -AP, Brazil 7.6 km inland. Ship 34 informed the coordinate (26°08, 0′N 002°08, 0′W) which indicates its location in the Sahara Desert, 870 km inland. Another ascertainment by conducting this verification is that 11 ships conducted ballast water change within less than 200 miles from the coast and 6 ships conducted BWE less than 50 miles away from the coast.

Likewise, we confronted dates informed in the BWR forms of when they performed oceanic exchange with the ship average speed to identify their correct location on the respective dates. Results show that 14 ships presented incompatible dates to their real speed of cruise. This suggests that dates or locations informed in the forms were randomly attributed during navigation and did not represent the truth of when and where the ballast water exchange effectively occurred.

Associated to the verification of given coordinates in the ballast water forms, other verifications were conducted regarding the filling of the necessary information to identify if the ship conducted BWE. Our investigation showed the following errors: information about BW exchange; incompatible ship speed (ships could not travel the filled points in the filled dates); Earth exchange coordinates; ships did not inform where the BW discharge occurred; incompatible dates (the dates in the first form are not compatible with the ones in the second); discharge ballast water without exchanging; incomplete BW reporting; exchange nearer than 50 nautical miles from the coast; without first BWR; without second BWR; total BW capacity changed (isolate case); information of the total BW capacity ship (isolate case); unreadable form (isolate case); incoherent BW report and less than 95% of the tank

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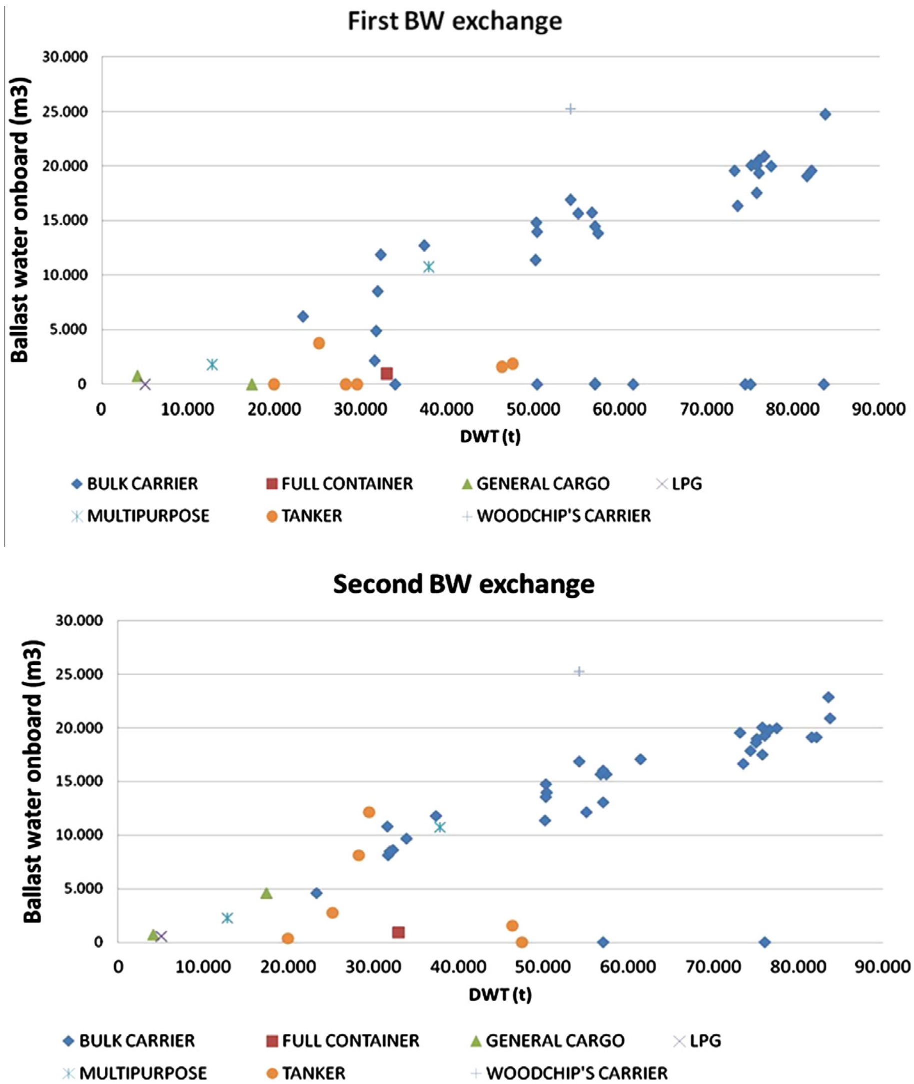

Fig. 1. Relation between ballast water collected at the first and second BW exchange × DWT of ships. Total values of ballast water onboard equal to zero means that the ship did not change ballast water.

exchanged; ship did not conduct first BWE; BW report completely empty; incompatible BWR.

Therefore, Fig. 2 presents the frequency of major errors identified in BWR forms and Fig. 3 identified errors committed by each ship in filling BWR forms.

3.2. Characterization of ballast water discharged into the Amazon River

The 47 ships that presented ballast water forms were inspected and ballast water samples were collected. However, only 44 ship samples were collected. Samples were collected together with ships crews. Some were conducted from manholes and others collected directly during the overflow of tanks. Samples of the Amazon River water were also collected to verify and to analyze its chemical characteristics and adequacy to CONAMA Resolution 357/05. A total of 45 samples, out of which 44 samples are ballast water and 1 sample is Amazon River water, were collected. An analysis of water quality was performed *in loco* on the banks of the Amazon River on Sept./11/2012 to verify the compliance to Resolution 357/05. Table 1 presents the results from the Sept./11/2012 analysis.

From the water sample from the Amazon River in the Santana region, we verified that TDS, salinity, DO and pH values are within the established values, but those for *E. coli* and total coliforms are out of the established standard ranges of CONAMA Resolution 357/05. This river is classified as Freshwater Class 2 and the classification into classes will rely on the use that can be adapted to the Amazon River at the reading of the CONAMA Resolution.

Reference parameters were compared to the result of the analysis of ballast water collected inside ship tanks (Fig. 4). The general disposition of results is presented in the form of a graphic matrix to all physicochemical and microbiologic parameters.

Based on the graphic matrix, collinear and non collinear variables were selected. For example, an almost linear correlation can be verified between salinity and electric conductivity or concentration of dissolved total solids. Based on this visualization, we highlighted the comparative analysis of salinity, temperature, *E. coli* and faecal coliforms for being important variables for risk analysis of transference of exotic species (Gollasch, 2006).

3.2.1. Salinity

Fig. 5 shows the results of salinity obtained in the ballast water sampling of visited ships. We verified that 23 ships presented

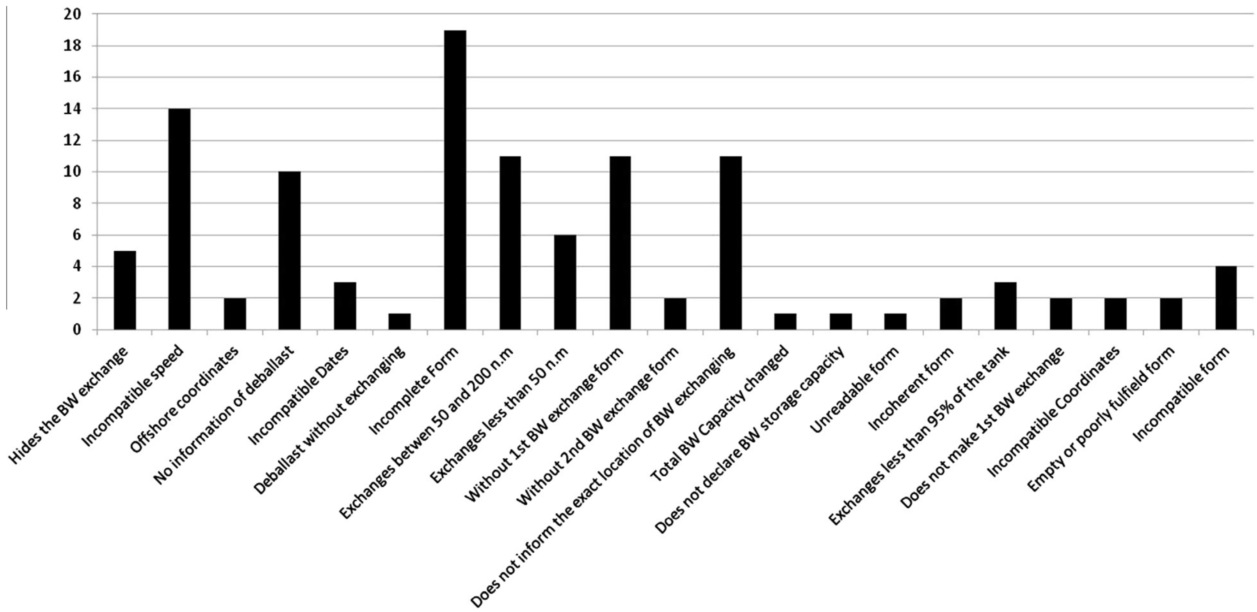

Fig. 2. Characteristics of major errors identified in ballast water forms: absolute numbers.

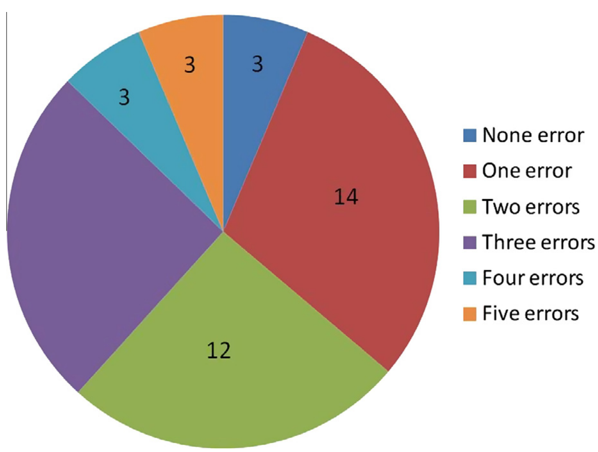

Fig. 3. Errors identified in each ship in form filling.

Table 1
Results of analysis of water from the Amazon River collected on Sept./11/2012.

Temperature (°C)	TDS (g/l)	Salinity (ppt)	OD (g/l)	pH	*E. coli*	Total coliforms
29.61	0.0041	0.03	5.36	7.86	436	2419.6

values within that established by the resolution for freshwater (<0.5 ppt), while the other 21 presented higher values, which can mean that changes were not conducted inside the percentage of 95% of the tanks water volume, as established by NORMAM-20. However, samples 21 and 43 presented extreme values or atypical in relation to the average salinity = 1.66% observed in general sampling.

3.2.2. Temperature of ballast water

The behavior of temperature (°C) for all the ships visited is shown in Fig. 6. Some extreme values were observed, such as samples 3 and 24, which are next to the maximum amount provided by law (40 °C). According to §4 of article 34 of chapter IV of CONAMA Resolution 357/05, the maximum temperature for effluent discharge, in case of ballast water, is 40 °C. The average temperature observed in the research was 28.37 °C. Results show that in this aspect, ballast water discharged by ships were within the established standards.

3.2.3. Microbiologic analysis

Fig. 7 presents a graph for total coliforms in function of the number of samples. We observed that levels of bacteria concentration of total coliforms are not necessarily originated from sewage – pathogenic, but can derive from soil or natural water, etc. Several samples, such as 1, 2, 11, 13, 24, 28, 34, 36, 38, 41 and 42 presented high values, in the order of 2500 MPN/100 mL, which shows there is intense activity of bacteria in ballast water. Similarly to *E. coli*, this microbiologic parameter can be interpreted as a potential hydro-sanitary indicator or potential threat of invasive species.

Fig. 8 shows the results for *E. coli,* the allowed values for which, according to the Resolution for freshwater, is 200 thermotolerant coliforms per 100 mL of sample (MPN/100 mL). In five events, *E. coli* values were higher or next to 2000 (MPN/100 mL of sample). These cases were 13, 24, 25, 35 and 43. Samples 13, 23, 24, 35 and 43 are observed to be at the top of all the extreme values analyzed. The rest of the samples were concentrated between zero and next to 500 MPN/100 mL, which is not negligible from the sanitary point of view (Cunha et al., 2004). The concentration of *E. coli* is a genuinely sanitary indication and, thus, strongly associated to sanitary problems and risks to public health in those environments (Cunha et al., 2004, 2012; Pinheiro et al., 2008; Silveira Jr., 2012).

4. Discussion

4.1. Ballast water reporting investigation

Ballast water reporting form is the most practical instrument for a first verification of BWE. However, a correct verification of information provided by ships is necessary. The reliability of information is extremely necessary to guarantee the correct management and control of ballast water. The analysis of BWR forms showed that forms delivered by ships to local maritime authorities have a series of filling errors. We identified that 19 out of 47 forms

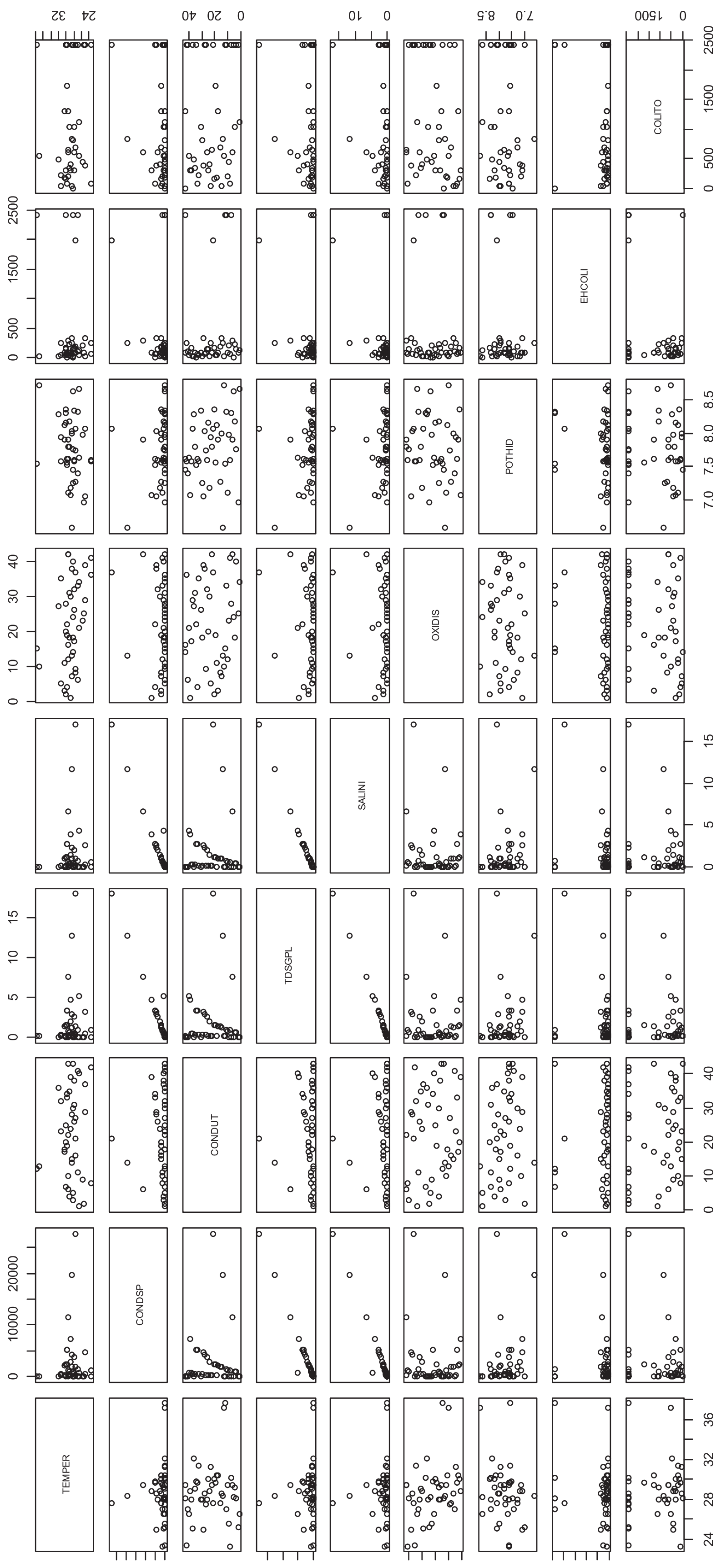

Fig. 4. Group of variables analyzed (ballast water quality). 9 parameters were evaluated and compared to identify the correlation between them.

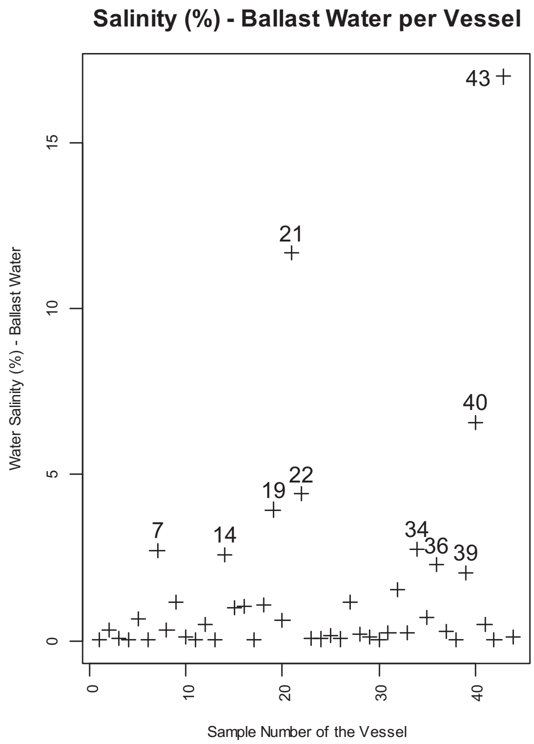

Fig. 5. Salinity of ballast water by sample – fresh/brackish: 0 < range < 16%.

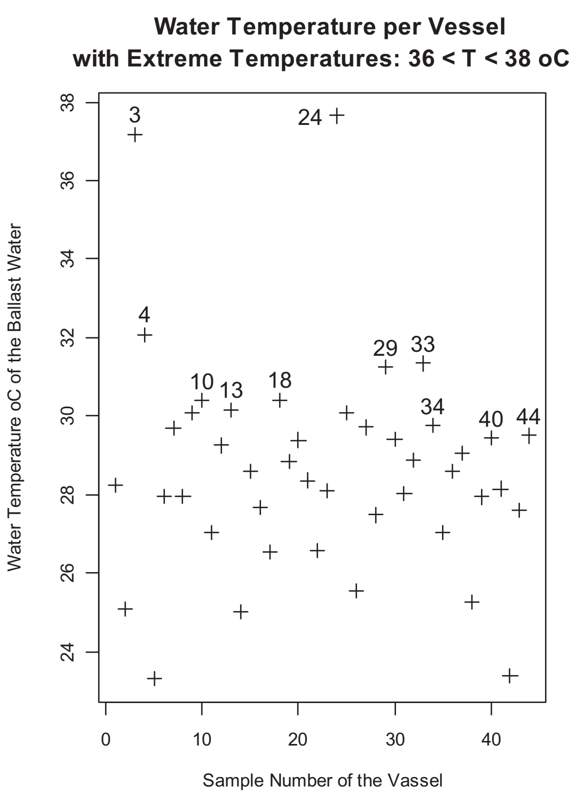

Fig. 6. Temperature of ballast water with extreme temperatures: 36 < 38 °C.

were not completely filled and presented errors regarding environmental conditions from where ballast water was collected, such as salinity, temperature and place depth.

From the total (47 BWR), 14 (≈29.78%) ships presented speeds incompatible with the dates informed to start and to complete

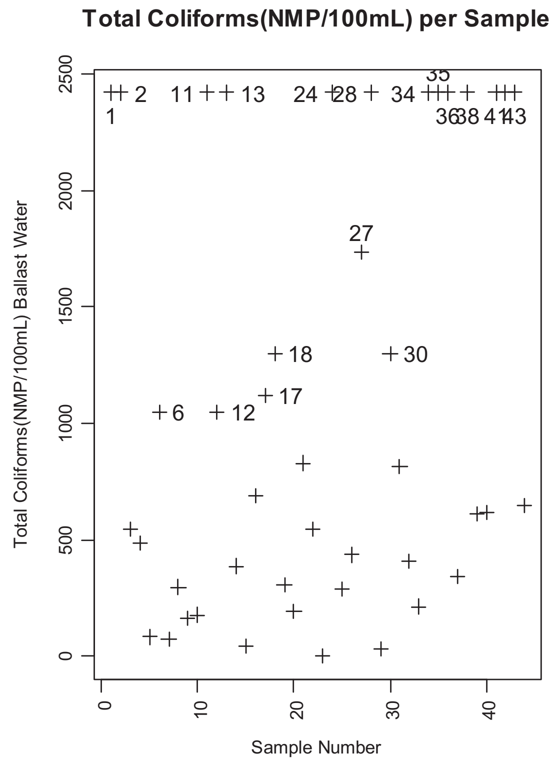

Fig. 7. *E. coli* × sampled ships.

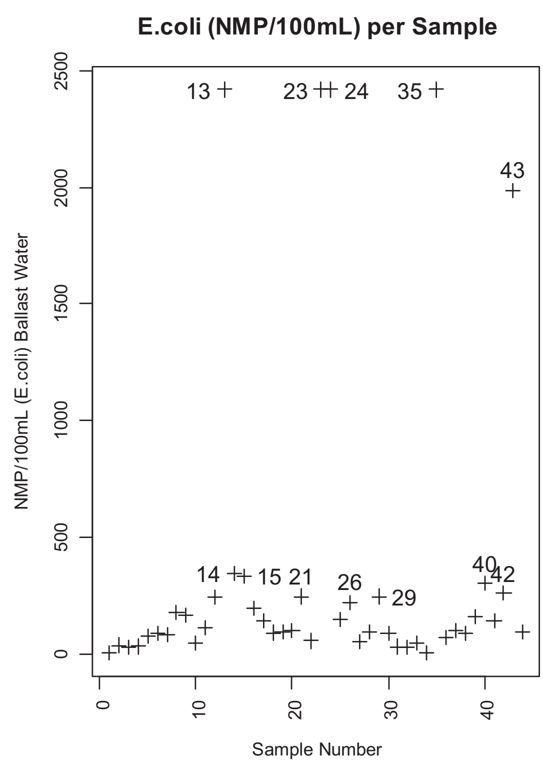

Fig. 8. Variation of MPN/100 of total coliforms sample × sampled ships.

BWE. This means that, considering the ships speed registered along with IMO, the ship could not have covered the informed distance during the execution of BWE when the speed is correlated to the geographic ship position.

Moreover, 2 ships informed that they performed BWE at inland coordinates, one of them in the middle of the Sahara Desert; 11 others did not present any coordinate of ballast water origin, showing that there was no verification of the information in BWR forms. A similar situation was presented by (Caron Junior, 2007), in which he presented a record of a ship that had deballasted 450 km inland. There are some other important numbers to notice that are direct violations against DPC, 2005: 6 ships exchanged their tanks near 50 nautical miles from the coast, 3 BWE did so less than 95% of the tank capacity, 2 did not conduct their first BWE.

The results suggest that ballast water control by ballast water BWR forms delivered in the Amazon region is not reliable. Otherwise, those ships would not be authorized to deballast inside the Amazon River at the Santana port. Those events suggest that an automated system should be developed to verify the geographic position of oceanic change and the amount of ballast water onboard of ships (Pereira et al., 2013a,b). Hence, those events could be minimized and maritime and port authorities could count on higher reliability regarding the information on ballast water presented (Pereira et al., 2013a,b).

On the other hand, those forms were already an indication that physical, chemical and biological parameters of ballast water of ships could present unsatisfactory results. Physical chemical analysis of ballast water of ships presented results that matched observations of forms regarding salinity and temperature. Salinity for freshwater could be determined as (<5 ppt), brackish as (5 < salinity < 30 ppt) and saltwater as (>30 ppt), according to CONAMA Resolution 357/2005. The discharge of freshwater into the Amazon River is so voluminous and constant that marine saltwater could not penetrate its mouth, making that estuary processes happen at an adjacent continental platform. The salinity plume (<34 ppt) of that river reached distances regarding the mouth that vary from 100 to 500 km into deep sea (Molleri, 2008). The observation of at least 3 cases of salinity higher than 5 ppt shows that water with high salinity is being discharged into Amazonian rivers. This suggests that ships did not conduct the second ballast water exchange or, if they did, it was not effective.

Temperature is one of the most important characteristics to a water body because it can affects its chemical and physical characteristics, such as solubility of gases, density, water viscosity and, the most important, reaction speeds (Cunha et al., 2011). Temperature also has a significant effect over chemical reactions and biologic activity in water. For example, reaction speeds increase twice at every 10 °C of temperature increase. The temperature controls maximum concentration of dissolved oxygen in water (DO), being extremely important for aerobic and facultative processes (Apha, 1985). Ballast water discharged by ships was within those established by Resolution CONAMA 357/2005. However, temperature is one of the most important factors that affect surviving rates of microorganisms in ballast water (Rigby et al., 2004; Quilez-Badia et al., 2008).

The results of microbiologic analysis were useful to determine that BW collected at the second BWE presents a great variation in values out of those established by CONAMA Resolution 357/05 for *E. coli* and total coliforms. This fact poses an environmental threat due to the presence of ballast water in the port zone of the Amazon Basin.

The regional and global importance of the Amazon region, since its basin covers a large territory that extends to several Brazilian states, thus considering the growth and development of Amazon port routes, more and more makes of efficient management a legitimate environmental demand. Thus, there is the need to represent and to estimate significant risks and environmental impacts and their consequences to tropical ecosystems (Cunha et al., 2012).

Therefore, it is necessary for ships that navigate Amazon waters to be followed up by much stricter inspection and supervision. This activity should cover 100% of the vessels, since each one is a potential risk, similarly to the navigation control of the Great Lakes, exerted by Canadian and US authorities (Oliveira, 2008).

5. Conclusion

By analyzing the BWR forms, we concluded that the BWE efficacy of ships berthing in the port of Santana in the Amazon region could be compromised. From the BWR forms, we identified failures in filling major necessary information for a correct evaluation of the origin of ballast water. Another critical point was identifying forms that did not present any information regarding BWE performance.

Errors in BWE geographic position described in forms show that some commanders do not have any concern about informing the correct geographic position of where the ship conducted BWE. Those BWR form filling errors had already been reported in the Brazilian and in the international literature.

This shows that, although there is an international effort to control the problem of exotic species transferences by using treatment systems onboard of ships, it is necessary to improve the evaluation of information given by ships to guarantee the efficiency of BWE.

These analyses are a strong indicative that BWE did not occur and that saltwater and freshwater from other regions is being discharged into the Amazon River, compromising native biota (Uliano-Silva et al., 2013). Regarding the sanitary aspect, ships were observed to discharge BW with higher levels of *E. coli* than that allowed for the Amazon region. Ships presented high values, in the order of 2500 MPN/100 mL, which shows that there is intense bacteria activity in ballast water. This corroborates the signs that ballast water is a vector to introduce and to transfer pathogenic species.

The results of this investigation show that Brazilian maritime authorities should intensify the supervision of BWR and BW quality discharged in Amazonian rivers to prevent the transference of pathogenic species to that region.

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