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Presence and Composition of Planktons' Organisms in Ships Ballast Water Discharged in Al-Mukalla Harbor, Gulf of Aden

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Authors' contributions

This work was carried out in collaboration between all authors. Author MSA designed the study, wrote the protocol and wrote the draft of the manuscript. Author NOAH managed the analyses of the study and the literature searches. Authors MSA and NAKA performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

This was the first study in Yemen, and Gulf of Aden aims to investigate the marine organisms in ballast water and sediments, and gives baseline information defines the zooplankton, phytoplankton and invertebrates, associated fuel tankers. Samples from Ballast water were taken from three ships that arrived at Mukalla Port, the Hadhramout coast from ports of Hamriyah port, U.A.E; ports of Taheri, Iran; and Bosaso Somalia (MT: Gulf Petroleum III, MT: Prime Royal, and M T: Breu) respectively. The marine organisms in samples were presented by three taxonomic groups, phytoplankton, zooplankton and benthos. Fifty-eight taxa were identified within this study; which consisted of 17 phytoplankton, 18 zooplanktons and 23 Benthos. The highest density of phytoplankton was 21 Ind/L, with the occurrence of 17 species found in ballast water, while 22 Ind/50cc of 2 species in sediment samples of the tanker Beru, and fewer densities were in Gulf Petroleum and Prim Royal. The most common phytoplankton observed were *Coscinodiscus granii,*

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Coscinodiscus jonesianus and *Thalassiosira eccentric*. The low Zooplankton density was 13 Ind/L with an occurrence of 18 species found in Prim Royal tanker. Copepods were the most dominant zooplankton among the three tankers. *Paracalanus parvus* had the highest value of dominance followed by *Calanopia parathompsoni*, *Acrocalanus gracilis* and *Paracalanus denudatus* had the lowest occurrence over three tankers. Seven taxa of Dinoflagellates were identified; two of them *Ceratium fusus* and *polykrikos* sp. are known to be harmful species.

Keywords: Ballast water; fuel tankers; Gulf of Aden; phytoplankton; zooplankton.

1. INTRODUCTION

Ballast water discharged by ship into marine environment has become an official concern to national maritime authorities worldwide and globally to International Maritime Organization. Seawater and the associated sediments taken up by aquatic vessels as ballasting mechanism are recognised recently as an essential vector for spread marine organisms across natural biogeography borders [1,2,3,4]. These waters, usually have a large quantity and diversity of marine plankton and benthos [5,4] dominant by many species of phytoplankton, zooplankton, invertebrates [6], cysts and spores of diatoms and Dinoflagellates resting stages in sediment [7,8,9] and many fish stages [5,10].

A number of studies demonstrated that several taxa were able to survive in ballast tanks during the marine journeys. Diatoms and Dinoflagellates are resting stages may have the ability to survive in the new environment and cause serious harm to human health, ecosystems or economy [5,1,11,12,13].

Detailed studies have conducted on ships ballast water in the neighbours' ports in the Indian Ocean. Shapoori and Gholami [14] investigated the effect of a ballast water treatment system on survivorship of marine plankton in Persian Gulf, Senanayake et al. [15] confirm occurrence wide taxa of live phytoplankton and dead zooplankton in ballast water of ships visiting Colombo harbour in Sri Lanka; Gollasch et al. [12] assess the survival of tropical organisms in ballast water from Singapore and Sri Lanka during a cruise to the north sea.

Yemen has several essential ports and strategic Terminals in the Gulf of Aden and the Red Sea. The Terminals serving large crude oil tankers and LNG carriers, such Ras Isa, Al-Shehir and Rudoom terminals, and Balhaf LNG plant harbour which are existed, discharged points of ballast waters. There is no data available about discharge points or volumes of deballasting waters in these terminals, so that no incoming vessels subjected to inspected or surveyed ballast water organisms. Neither scientific study has not been conducted nor published data on the ballast water in ships entering Yemeni harbours. Very few have been done according to the national strategy for management ships ballast water, which declared by Yemeni prime minister in 2012 [16].

It should be noted that in the area of coastal and marine resources, a regional strategic plan of International Maritime Organization (Convention on the Control and Management of Ships' Ballast Water and Sediments) has been established to minimise the transfer of harmful aquatic organisms and build capacity in the region. However, Yemen has remained far from complying with or exploiting its right under this convention, as well as delayed by their ratification.

Al-Mukalla harbour is the third largest port in Yemen, and of economic importance due to a strategic location on the southern coast of Arabian Peninsula. Due to growing demand for petroleum products which resulted in increasing the number of fuel tankers entering Al-Mukalla harbour for transfer operations (Ship to Ship), therefore the discharge rate of ballast water into marine environment increased.

This study aims to investigate the organisms in ballast water and sediment-associated in fuel tankers entering Al-Mukalla and obtaining the first baseline information to define marine taxa (Zooplankton, phytoplankton, Invertebrates and vertebrates) entering with shipping into Yemeni marine environment.

2. MATERIALS AND METHODS

This study focused primarily on Fuel tankers, which discharged the ballast water in the Anchorage area (E 49°06’187, N 14°30'201) of Al-Mukalla harbour during the period of June to July 2016, during ship transfer operations (ship

to ship) (Fig. 1). Sampling was conducted on the deck of three fuel tankers originated from three different ports sources, MT: Prime Royal, MT: Gulf Petroleum III and MT: Breu. A total of three ballast water and three sediment samples obtained from each tanker (Table 1).

Temperature and Salinity recorded directly from the port side and starboarded side by the sensor system of the ballast tankers.

For plankton sampling, electrical pump with 1-inch diameter tube was lowering gradually from deck manhole for suction ballast water from the subsurface, middle and 2 meters above the tank bottom, this mechanism target the vertical distribution of zoo-phytoplankton in the water column of the tank.

One sample was taken from randomly chosen to ballast tank by filtering about 350 litres of ballast water pumping through 35 µm plankton net. 1 liter of residual water in the conical end of the plankton net kept in plastic bottle fixed in 4% formaldehyde solution and kept in an ice box for further identification of species in the laboratory.

Sediments in ballast tank are likely to contain many diverse marine organisms more than ballast water. One sample was randomly chosen from every tanker ballast tank by lowering steel grab sampler. 50 mL of settled ballast tank sediment transferred into a plastic bottle and add 4% formaldehyde solution for fixation for further laboratory analysis [17]. For ease examination and distinguish between recently living from dead organism's sediment, sub-sample of 10 mL were stained with 10 mL Rose Bengal for 24 hours (prepared by added 1 g of Rose Bengal to 1liter of distilled water). This method is commonly used in meiofauna studies [18,19].

The taxonomic identification has relied on special and general keys and guides for plankton and benthos of the Indian Ocean and the Indo-Pacific region [20,21,22,23,24]; using dissecting binocular zoom 40X, model Wagtech, United Kingdom. All organisms have identified, to a group of species or genus.

Fig. 1. Al Mukalla harbor, yellow circle show the harbour, the red is the Anchorage area

Table 1. Shows the vessels names involved in this study and sampling dates, origin of ballasting

Vessel name	Vessel type	Sampling date	BW origin	Voyage time
Breu	Fuel Tanker	03.6.2016	Bosaso Somalia N 11.17.213 E049.10.398	4 Days
Gulf Petroleum III	Fuel Tanker	13.7.2016	Hamriyah,U.A.E N25.28.211 E055.28.529	9 Days
Prime Royal	Fuel Tanker	24.06.2016	Taheri, N27.39.279 E052.21.046	13 Days

3. RESULTS

The highest temperature value of 29°C was at MT: Prime Royal and the lowest value (26°C) were at MT: Breu. The highest value of Salinity (40.1‰) was recorded at MT: Prime Royal while the lowest value (36.4‰) was recorded at MT: Breu origin the ballast water from Somalia (Table 2).

3.1 Phytoplankton

A total of 17 species of 10 genera of phytoplankton were recorded in overall samples collected during this study. The dominant species *Coscinodiscus granii* represented 12.50%, *Coscinodiscus jonesianus* 10.71% and *Thalassiosira eccentric* 8.93% (Table 3).

Ten species belonging to 6 genera identified in Breu, composed of 7 species of diatoms and 3 species of Dinoflagellates, with phytoplankton density of 21 Ind/L while the most dominant species were *Coscinodiscus granii* and *Thalassiosira eccentric* represented of 28.57% and 14.29, respectively (Table 3).

In Gulf Petroleum III, 11 species of 7 genera identified from ballast water samples. Diatoms were the most dominance group, comprising of 11 species followed by Dinoflagellates with 2 species with density of 18 Ind/L, the most dominant species were *Coscinodiscus jonesianus* represent 22.22% and 16.67% for *Ceratium* sp. (Table 3).

Prim Royal has the highest occurrence of 14 species belonging to 9 genera of phytoplankton, with fewer species dominance than Breu and Gulf Petroleum III.

3.2 Zooplankton

A total of 15 zooplankton species and 3 larval stages of Gastropods and Crustacean had identified in the study samples collected from the three tankers. The most dominant species were *Paracalanus parvus,* and *Calanopia parathompsoni* comprised 12.73% and 10.91%, respectively (Table 4).

Fourteen zooplankton species belonging to 8 genera recorded in the ballast water samples collected from Breu, consisted of 12 copepod species, one Crustacean larvae and one Nauplius of Cirripedia. *Euphausia* sp., *Paracalanus parvus*, and *Acartia* sp. were the most dominant zooplankton species while the species of *Microsetella rosea and Paracalanus denudatus* were absent from the tankers Gulf Petroleum III and Prim Royal and present in low percentage of 7.69% and 1.82% respectively in Breu (Table 4).

Out of 11 zooplankton species, 9 species of copepods, one veligers larva and one Crustacean larva identified in the ballast sample from Gulf Petroleum III. The Copepod species of *Acartia* sp*, Calanopia* sp*, Oncaeaclevei* and *Temora turbinate* were the dominant the same Tanker zooplankton samples.

On the other hand, Prim Royal had fewer (7) species richness of zooplankton with dominance of *Calanopia parathompsoni* and *Paracalanus parvus* which represent 30.77% and 15.38% respectively (Table 4).

The density of zooplankton species was 26 individual per litre in the sample of Breu, while Prim Royal had a lower average density of 13 individual per litre.

3.3 Benthos

A total of 3 sediments samples collected from every tanker have analysed. Diatom, Dinoflagellates, Copepod, Foraminifera, Bivalves, cysts and Gastropods found as most of the marine taxa recorded in this study. A total of 23 species belonging to 22 genera identified in the ballast sediments over 3 tankers, among which, 10 identified to the species level and one veligers larva (Table 5).

Four different Dinoflagellates of *Noctiluca scintillans, Ellobiopsis* sp*., polykrikos* sp and *Scrippsiella* sp. were found in the sediments samples, representing 29.54% of total species occurrences in the three tankers, while ten foraminifer's species combined of 11.94% of overall species.

Table 2. Salinity and temperature of ballast water and their origin ports

Vessel name	Temp.°C	Sal ‰	BW Origin
Breu	26	36.4	Bosaso Somalia
Gulf Petroleum III	27	38.1	Hamriyah, U.A.E
Prime Royal	29	40.1	Taheri,

Table 3. The densities and occurrence of phytoplankton species present in three fuel tankers

Phytoplankton	Breu		Gulf petroleum III		Prim royal		Total dominance
Species	**Density per L**	**Percentage %**	**Density per L**	**Percentage %**	**Density per L**	**Percentage%**	**species%**
Coscinodiscus Jonesianus	1	4.76	4	22.22	1	5.88	10.71
Coscinodiscus granii	6	28.57	1	5.56	0	0.00	12.50
Coscinodiscus centralis	0	0.00	2	11.11	2	11.76	7.14
Coscinodiscus sp	2	9.52	0	0.00	1	5.88	5.36
*Ceratium fusus**	2*	9.52	0	0.00	1*	5.88	5.36
Ceratium sp*	1*	4.76	3*	16.67	1*	5.88	8.93
Navicula sp	0	0.00	0	0.00	1	5.88	1.79
Nitzschia longissima	0	0.00	1	5.56	2	11.76	5.36
Nitzschia sp	2	9.52	1	5.56	0	0.00	5.36
Peridinium sp *	2*	9.52	1*	5.56	0	0.00	5.36
Pleurosigma sp	0	0.00	0	0.00	2	0.00	3.57
Rhizosolenia cochlea	1	4.76	1	5.56	1	11.76	5.36
Rhizosolenia alata	0	0.00	2	11.11	1	5.88	5.36
Scrippsiella sp *	0	0.00	0	0.00	1*	5.88	1.79
Thalassiosira ccentric	3	14.29	1	5.56	1	5.88	8.93
Thalassiosira oestrupii	1	4.76	0	0.00	1	5.88	3.57
Thalassionema nitzschioides	0	0.00	1	5.56	1	5.88	3.57
Total = 17 Species	21	100%	18	100%	17	100%	100%

** Dinoflagellate species*

Table 4. The densities and occurrence of zooplankton species present in three fuel tankers

Zooplankton	Breu		Gulf petroleum III		Prim royal		Total dominance
Species	**Density per L**	**Percentage %**	**Density per L**	**Percentage %**	**Density per L**	**Percentage %**	**species %**
Acartiasp	3	11.54	2	12.50	0	0.00	9.09
Acrocalanus gracilis	1	3.85	0	0.00	0	0.00	1.82
*Calanopia minor**	1	3.85	1	6.25	0	0.00	3.64
Calanopia parathompsoni	1	3.85	1	6.25	4	30.77	10.91
Calanopiasp	1	3.85	2	12.50	2	15.38	9.09
Crustacean larvae	3	11.5	2	12.50	0	0.00	9.09
*Eucalanus crassus**	1	3.85	1	6.25	2	15.38	7.27
Euphausia sp	5	19.23	0	0.00	0	0.00	9.09
Euconchoecia sp	0	0.00	0	0.00	1	7.69	1.82
Macrosetella sp	1	3.85	1	6.25	0	0.00	3.64
Microsetella rosea	2	7.69	0	0.00	0	0.00	3.64
Nauplius of Cirripedia	1	3.85	0	0.00	0	0.00	1.82
Oncaeaclevei	0	0.00	2	12.50	0	0.00	3.64
Paracalanus parvus	4	14.81	1	6.25	2	15.38	12.73
Paracalanus sp	1	3.85	0	0.00	1	7.69	3.64
Paracalanus denudatus	1	3.85	0	0.00	0	0.00	1.82
Temora turbinate	0	0.00	2	12.50	1	7.69	5.45
veliger larva Gastropoda	0	0.00	1	6.25	0	0.00	1.82
Total = 18 Species	26	100	16	100	13	100	100

** Alien species*

Table 5. The densities and occurrence of benthos recorded in three fuel tankers

Benthos	Breu		Gulf petroleum III		Prim royal		Total dominance
Species	**Density Ind/50cc**	**Percentage %**	**Density Ind/50cc**	**Percentage %**	**Density Ind/50cc**	**Percentage %**	**Species %**
Amphstigena radiate +	1	1.43	1	1.41	0	0.00	1.14
Amphistegin alessonii +	1	1.43	0	0.00	0	0.00	0.57
Assilina ammonoides +	0	0.00	1	1.41	0	0.00	0.57
Coscinodiscus oculus	9	12.86	15	21.13	7	20.00	17.61
Ditylum brightwelli	4	5.71	2	2.82	1	2.86	3.98
Dunaliella sp	0	0.00	0	0.00	3	8.57	1.70
Elphidium sp+	1	1.43	2	2.82	0	0.00	1.70
*Ellobiopsis sp**	5	7.14	10	14.08	3	8.57	10.23
Eutreptiella sp	2	2.86	1	1.41	0	0.00	1.70
Limacina sp	2	2.86	4	5.63	1	2.86	3.98
Marsipella sp+	1	1.43	1	1.41	0	0.00	1.14
Neorotalia calcar+	0	0.00	1	1.41	0	0.00	0.57
*Noctiluca scintillans**	13	18.57	6	8.45	2	5.71	11.93
Omalogyra sp	6	8.57	2	2.82	1	2.86	5.11
Pararotalianipponica +	0	0.00	2	2.82	0	0.00	1.14
*Poly krikos sp**	5	7.14	1	1.41	4	11.43	5.68
Quinqueloculinamultsp+	1	1.43	0	0.00	3	8.57	2.27
*ScrippsiellaSp**	1	1.43	0	0.00	2	5.71	1.70
Soritessp +	3	4.29	1	1.41	0	0.00	2.27
Triloculinatrigonula+	0	0.00	1	1.41	0	0.00	0.57
Tortanussp	2	2.86	0	0.00	0	0.00	1.14
Timocleasp	9	12.86	14	19.72	7	20.00	17.05
veliger larva Gastropoda	4	5.710	6	8.45	1	2.86	6.25
Total = 23 Species	70	100	71	100	35	100	100

*+ Foraminifera *Dinoflagellates*

The most dominance species over three tankers were *Coscinodiscus oculus* 17.61%, *Timoclea* sp. 17.0% and *Noctiluca scintillans* 11.93%, while the less dominant were foraminifera group of *Amphistegina lessonii*, *Assilina ammonoides*, *Neorotalia calcar* and *Triloculina trigonula* have the same percentage of 0.57%.

Coscinodiscus oculus and *Timocleasp,* find is the most dominance species in the tankers Prim Royal and Gulf Petroleum III, while *Noctiluca scintillans* have high density and dominant in Breu. The high density recorded in Gulf Petroleum III was 71 individual per 50cc of sediment (Table 5) and medium in Breu, while Prim Royal has less.

4. DISCUSSION

There are no detailed studies have conducted on ships ballast water visiting Yemeni ports, this is the first baseline study define and detailed the marine organisms in ballast water and sediment associated tankers entering Al-Mukalla harbor. Based on the information obtained during the sampling year 2016, most fuel tankers entering port of Al-Mukalla claim to have STS operations.

As a result, about half of these tankers originated from United Arab Emirates, Iran and Somalia, are rent by local merchants as receiving tankers to transport fuel from big vessels which unable to entering Al-Mukalla berth. These tankers during commenced STS operation gradually discharged their ballast water into the marine environment in the anchorage area.

The tankers come from Somalia to Al Mukalla port are transport fuel to Bosaso port, usually travelling for 4 days than those come from other ports, such voyage periods has been shown to affect the survival number of planktonic species in ballast water [5,25]. Our study also shows a strong negative linear relationship between species density with voyage time, this was obviously reflected the high density and species composition in Breu which take 4 days from Bosaso port to Mukalla, whilst density and species composition in other two tankers of Gulf Petroleum III and Prim Royal respectively gradually decreased. Previous studies from neighbour ports [26,15,14] reported the same findings of effect voyage time.

Despite the limited sampling during this study, 58 of marine organisms compromise of 17 phytoplankton's, 18 zooplanktons species and 23 benthos taxa over the three tankers were identified, these findings almost similar to earlier studies in the Indian ocean [26,27,12,15,14] and north Atlantic as concerning benthos [28].

Our results showed that the total mean density of phytoplankton was higher in the Breu than other two tankers, species composition dominated by *Coscinodiscus granii, Coscinodiscus jonesianus, Ceratium* sp. and *Thalassiosira eccentric* over the three tankers. This result is similar to the findings of Gollasch et al. [12] in the Indian Ocean, Senanayake et al. [15] in Colombo harbor Sri Lankan, and Shapoori and Gholami [14] from Kharg island Iran.

Most of the zooplankton species identified in the ballast samples from the three tankers were copepods species. *Paracalanus parvus, Microsetella rosea* and *Acartia* sp. were most dominant species in Breu, these three zooplankton species, known as most copepods survives in ballast water, as thoroughly investigated by Gollasch et al. [12] during cruise from the Indian Ocean to the North Sea.

We found that zooplankton species *Euphausia* spp. (recorded in Bereu which transport fuel to Somalia) was not identified in earlier studies i.e. Chu et al. [26]; Dickman and Zhang [27]; Gollasch et al. [12]; Senanayake et al. [15] and Shapoori and Gholami [14]. This Euphausiids species, although considered as a wide distributed in Indian Ocean [29], however, possibly to associate short cruise ships ballast waters as found in Breu Ballast sediments.

Dinoflagellates were the most interesting taxa observed in this study, seven taxa compromise of two species and five genera were present in phytoplankton and most of them in sediment samples. *Noctiluca scintillans* was the most frequent Dinoflagellates' species recorded in the Breu sediment samples; other species found of *Ceratium fusus* and *polykrikos* sp. are known to be harmful species [30,28].

It seems that the species found in the current ballast waters are not considered alien species because they have already been recorded in the coast of Hadhramout [31] and in the neighboring coasts [32]: Somalia [33,34] and the Arabian Gulf [35]. Furthermore, the balance water in these tankers lies within the geographical area of the Gulf of Aden, which reduces the likelihood of considering marine organisms as alien [36]. In

addition, Ali et al. [31] confirm that zooplankton of Hadhramout coast not differ significantly from the situation observed in most of the northern Arabian Sea regions [35,37]. Especially, one of the tankers investigated was tracked from one of the ports of the Gulf of Aden - Bosaso at Somalia coast.

Latter comments can be partially generalized to the results of phytoplankton, where it is noted that some genera and species discovered here are also present and registered in the coast of Hadhramout and the Gulf of Aden earlier [38] and cannot considered alien to the Gulf environment. However, some mentioned in the current study genera and its species (Coscinodiscus, Ceratium, Pleurosigma, Scrippsiella, and Thalassiosira) were not confirmed so far due to the lack of studies, so that the benthos taxa.

5. CONCLUSION

This study confirms that the ballast water and sediment are an essential source to transport organisms from one region to another. Our study also detected the risks of introducing harmful and possible alien species into the port of Al-Mukalla, and that would be a concern due to gradually increase of ballast water discharge in Yemeni oil and LNG export facilities such as Al-Shehir Terminal, Ras Isa, Aden export oil Harbor and Balhaf LNG plant. Yemeni Governmental Authorities should establish regulatory guidance on the deballasting operations on above-mentioned export terminals.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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