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Baseline

Shellfish from Todos os Santos Bay, Bahia, Brazil: Treat or threat?

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ABSTRACT

This study determined the concentrations of major and trace elements in shellfish (oysters, clams and mussels) and conducted an assessment of the health risks due to the consumption of contaminated seafood. Samples were collected at 34 sites along Todos os Santos Bay, Brazil. The elements were determined by ICP OES and Hg by Direct Mercury Analysis. Relatively high concentrations of trace elements (As, Zn, Se and Cu) were found in seafood tissues. Potential daily intake of As, Co, Se, Zn and Cu associated to shellfish consumption suggested relevant non-carcinogenic risk for all studied locations. Copper was the element that posed the greatest non-carcinogenic risk, while Pb posed the highest carcinogenic risk. Health risks for humans were greatest from the consumption of mussels. Contaminated shellfish offer the greatest risk for children, subsistence fishers and subsistence shellfish consumers.

Bioaccumulation describes the net accumulation of an array of major and trace elements into the tissues of an organism as a result of an organism's total contaminant exposure across all routes. This is a complex process because of the interplay between exposure routes, environmental settings, metal speciation, and biological influences (Luoma and Rainbow, 2008). Trace and major elements, which may be toxic, accumulate in the tissues of organisms at concentrations many times higher than their concentrations in water, and may be biomagnified in the food chain to levels that cause physiological impairment at higher tropic levels and in human consumers (Kljakovic-Gaspic et al., 2007; Karouna-Renier et al., 2007).

There is a large variation in the accumulation patterns among the different contaminants accumulated by different biomonitoring species (Rainbow, 2002; Cain et al., 2004). In monitoring programs, it is desirable to use more than one biomonitor in order to increase the strength of generalized conclusions to be made along a contamination gradient, and/or over various time periods (Phillips and Rainbow, 1994). A well-chosen suite of biomonitors also provides information on the relative importance of different sources of contaminants to the biota (solution and diet).

Urban and industrial expansion in coastal zones increases the input and the mobilization of contaminants such as trace metals, which also potentially enhance the exposure of marine organisms and may affect biodiversity. Todos os Santos Bay (BTS) is located in the vicinity of Salvador, the third largest metropolitan area in Brazil, and home to the largest petrochemical complex in the southern hemisphere and as such it represents a tropical case study. The influx of domestic effluents and solid wastes, as well as several anthropogenic activities, including agriculture, industry (chemicals, petrochemicals, smelters, etc.), harbor and mining activities influence the environmental system's quality (CRA, 2008; Hatje and de Andrade, 2009; Hatje et al., 2010). As a result, relatively high concentrations of trace elements are observed in marine invertebrates (Wallner-Kersanach et al., 2000; CRA, 2004; Amado Filho et al., 2008; Hatje et al., 2009), and in sediments (CRA, 2004; Hatje et al., 2006, 2009, 2010; Barros et al., 2008). Nevertheless, published information about the metal contamination status of BTS is surprisingly scarce and limited to the northern part of the bay (Hatje et al., 2009). There is no article, up to date, in the scientific literature reporting the microbiological contamination of the BTS system.

Biomonitors, especially shellfish, have been extensively used to examine trace metal contamination in coastal systems and to reveal the bioavailability of contaminants, as exemplified by the global "mussel watch" program (e.g. Goldberg, 1975; Lauenstein et al., 1990; O'Connor, 2002). The wide use of shellfish reflects not only the high capacity of these organisms to bioaccumulate organic and inorganic contaminants and their widespread distribution, but also their importance, because shellfish represent an important source of protein for coastal communities. It has been estimated, for instance, that over 90% of human health exposure to several contaminants occurs through diet (Kim and Wolt, 2011), primarily seafood and meat (Smith and Gangolli, 2002). Segments of the human population with increased exposure risk include consumers of commercially harvested shellfish, recreational and subsistence fishers and subsistence shellfish consumers, not to mention the children whose diet is based on harvested shellfish.

Cases of trace elements contamination and poisoning due to shellfish and other foods are becoming more frequent and have

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been the object of several studies (e.g. Hatje et al., 2006; Sarkar et al., 2008; Widmeyer and Bendell-Young, 2008; García-Rico et al., 2010; Sáenz et al., 2010; Yatawara et al., 2010).

Elements such as Fe, Cu, Zn and Mn are essential to fauna and plants, as well as, for the proper functioning of the human metabolism. Nevertheless, in high concentrations essential elements can pose a serious risk to health (Tüzen, 2003). Non-essential metals (e.g. Hg, Pb and Cd) are even more problematic and much more toxic, even at low concentration levels (Förstner and Wittman, 1979). These elements have a great ability to form complexes with organic substances and can reach concentrations up to a thousand times greater in biological tissues than in the environmental matrixes (i.e. water and sediments).

Over the past 60 years, the BTS has received a large input of contaminants, which may have contaminated the biota of the region. Commercial and recreational harvesting of shellfish along BTS is extensive, and thus any potential contamination may impose a toxicological risk to human consumers. Around 170 low income fishing communities at BTS rely on harvesting shellfish as the main source of protein and income (Ibama, 2008; Soares et al., 2009). Information on metal contamination body burdens in shellfish along BTS is scarce and exists mainly in the form of restricted circulation reports (CRA, 2004, 2005). Nevertheless, these reports suggested that a problem may exist for some fish and shellfish collected along the bay. The aims of this study are: (i) to determine whether the most important species of shellfish (*Anomalocardia brasiliana* – clams; *Brachidontes exustus* – mussels; *Crassostrea rhizophorae* – oysters; *Mytella guyanensis* – mussels), in terms of biomass and people depending on them, collected along Todos os Santos Bay are contaminated by major and trace elements; (ii) to identify chemicals of concern exceeding screening values; and (iii) to estimate the potential toxicological risk to consumers of shellfish.

Thirty-four locations were sampled (Fig. 1) between 2006 and 2010. A minimum sample of 20 individuals of similar size was assembled for each location. Shellfish samples were also collected at two pristine sites, namely Camamu Bay, Bahia (Hatje et al., 2008) and Guarapoá, Bahia (Rondinelli and Barros, 2010), both located south of BTS.

Sampling procedures, pre-treatment of tissues and chemical analysis details have been described elsewhere (Santos et al., 2010). Summarizing, the digestion of bivalve tissues was performed using ultrapure HNO_3 conc. in Teflon Parr bombs. The analytes were determined by an ICP OES (VISTA PRO, Varian, Mulgrave, Australia). All samples were digested in triplicate and blanks were included in each batch analyzed. The precision and accuracy of the analytical technique were assessed by the analysis of certified oyster tissue material (NIST, SRM 1566b – National Institute of Standard and Technology, USA). The results were in agreement with the certified values, and the relative standard deviations were low (<9.3%). Average recovery efficiencies ($n = 10$) for the studied elements varied from 82.2% to 103%. The determination of total Hg was performed by direct analysis using a Milestone Direct Mercury Analyzer (DMA-80). The reference materials NIST-2711 (Montana Soil), GBW-08301 (River Sediment) and IAEA-336 (Trace Elements in Lichens) were used to evaluate the accuracy of the method. The recuperations for reference material varied from 99% to 104%, with an average precision of 4%. Principal component analyses (PCA) were performed on the biotic data which were first normalized and $\log(x + 1)$ transformed.

Species-specific carcinogenic and non-carcinogenic risks for contaminants were estimated for each sampling location. Screening values were calculated based on the shellfish consumption rate, mean child and adult body weight, oral dosage and exposure duration.

For the non-carcinogenic effect, the risk was expressed as a hazard quotient (HQ), i.e. the ratio between the exposure and the average oral daily reference dose (RfD; estimate of a daily exposure that is unlikely to bring an appreciable risk of deleterious effects during a lifetime). According to the report of US EPA (1989, 2002), the dose of exposure is equal to the chemical concentration (percentile of 95%) times the contact ratio (0.3 kg/day for adults and 0.15 kg/day for children), divided by body weight (60 kg for adults and 15 kg for children; CRA, 2005).

For the carcinogenic effects, potential cancer risk reflects the probability of an individual developing cancer over a lifetime (US EPA, 2002). Screening values were calculated based on shellfish consumption, the Cancer Slope Factor (CSF; an upper boundary risk estimate), and Risk Level (maximum acceptable lifetime risk). Because the ingestion of several contaminants occurs simultaneously, the multiple risk, i.e. the sum of an individual's risk from each contaminant, was also estimated.

All marine invertebrates accumulate trace elements in their tissues. Net accumulation of major and trace elements in biological tissues is the result of a balance between total uptake and the loss from the organism across all routes. Contamination studies in shellfish have some advantages over measurements in other compartments, firstly because they reflect metal bioavailability to biota and secondly because they also allow for the assessment of health risks associated with shellfish consumption.

Biogeographical differences in shellfish occurrence controlled by the physical (grain size, location related to tidal influence, temperature, hydrology), chemical (organic matter content, and food availability) and biological characteristics of their habitat prevented collecting samples of all of the species studied at every sampling site. Different degrees and patterns of accumulation can be observed in the tissues analyzed (Table 1). For instance, the highest Cu, Cd, Zn, Co and Se concentrations of 602, 13.7, 2976 and 68.6 μg/g dry weight, respectively, were obtained for oysters, whereas the highest Al, Cr, As, Ba, Pb, Fe and Hg concentrations were found in mussel tissues. Among the species studied, clams generally presented the lowest metal concentrations. The differences in bioaccumulation between shellfish are not surprising and should not be regarded as a shortcoming, since they reflect the influence on bioaccumulation of important differences in physiology, autecology (Phillips, 1995) and feeding guilds (e.g. suspension feeders and deposit feeders).

Biomonitors which are taxonomically closely related may preferentially accumulate different metals as well as different species of the same metal in the aquatic environment (Rainbow, 1990). Data interpretation, however, should give similar information for different species, if it is compared to what is typical for each species (Luoma and Rainbow, 2008). In addition, as metal concentrations are expressed in μg per g body weight, the growth rate and biomass of a biomonitor can influence its final metal concentration due to tissue dilution or tissue wastage (Leung et al., 2001). Nevertheless, although clams are much smaller than mussels and oysters and therefore present an increased surface area to volume ratio (which may result in enhanced weight-specific uptake rates), a negative correlation between size and concentration could not be seen in the present data. In fact, the results indicated that the ability of mussels and oysters collected at BTS to concentrate trace metals is higher than that of clams. The relatively high concentrations of metal observed may not affect shellfish directly (Han and Hung, 1990), but contaminants may cause toxicity to humans. Therefore, the potential risk of consuming mussels and oysters is relatively higher than that of consuming clams, if the ingestion frequency of all seafood items is the same. In addition, Holloman and Newman (2010) stated that when estimating the total amount of a particular item ingested, not only the portion size, but also the

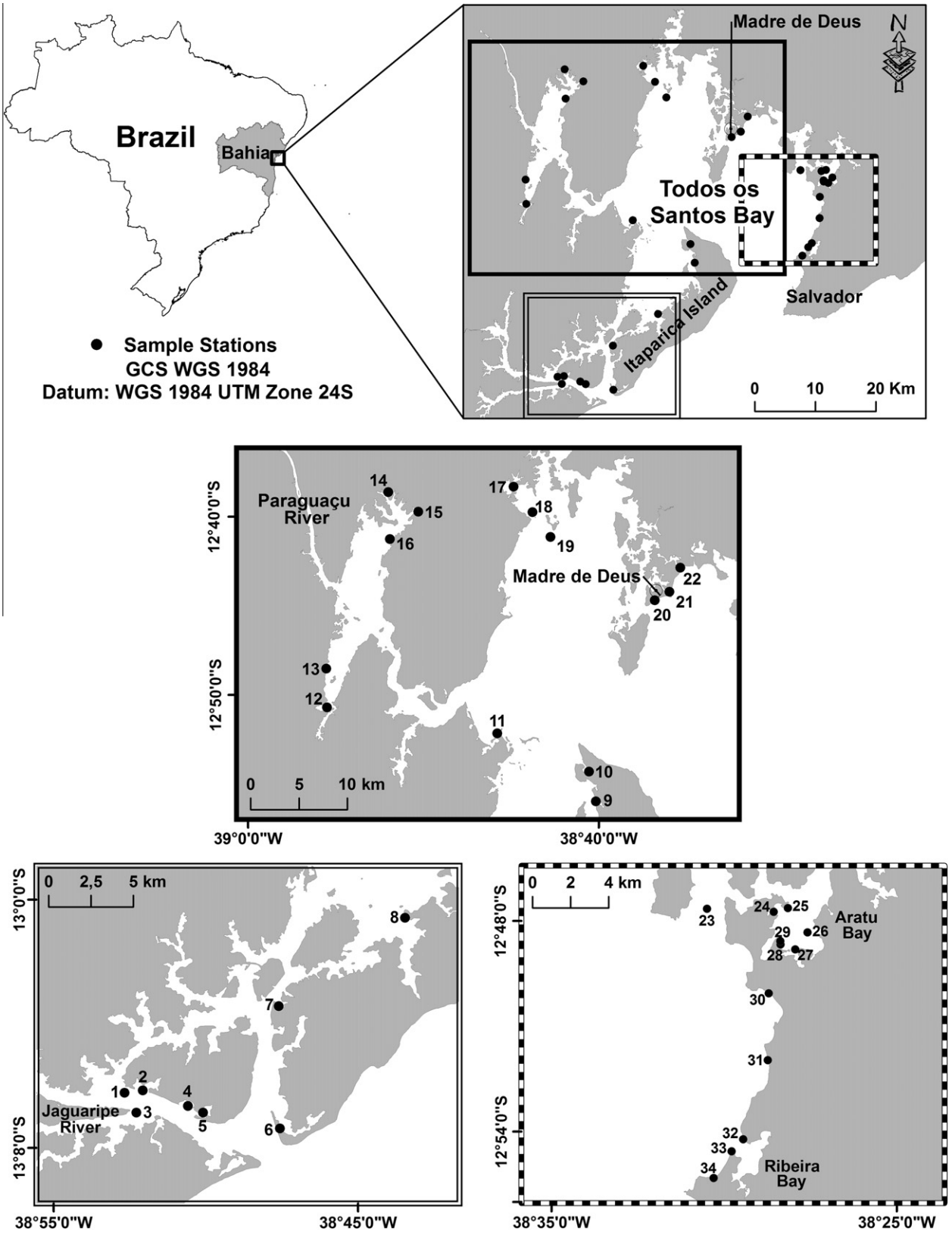

Fig. 1. Sample locations at Todos os Santos Bay, Bahia, Brazil.

number of individual portions consumed during one meal setting should be taking in account.

Table 1 shows that Zn concentrations in oysters collected in BTS were higher than those of other studied elements in various organisms. However, Zn concentrations were at the "typical Zn level" for this species (Silva et al., 2003, 2006). Concentrations of Mn and As (Table 1) were also generally high, and at least in part seem to be associated to natural sources of these elements present in BTS

Table 1
Average ($n = 3$; μg/g dry weight) ± standard deviation of concentrations of major and trace elements in shellfish samples (20 individuals pooled).

Site	Shellfish species	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Pb	Se	Sr	V	Zn
1	*M. guyanensis*	1390 ± 1.48	10.1 ± 0.25	76.9 ± 4.77	<DL	183 ± 109	2.13 ± 0.23	18.5 ± 0.31	1073 ± 1.94	0.18 ± 0.00	42.6 ± 0.88	6.34 ± 0.61	13.6 ± 6.17	58.7 ± 1.96	1.88 ± 1.04	54.9 ± 1.18
	C. rhizophorae	288 ± 3.18	5.66 ± 0.62	<DL	<DL	0.39 ± 0.02	0.33 ± 0.00	35.1 ± 0.44	315 ± 5.90	0.09 ± 0.00	24.6 ± 0.15	3.18 ± 0.00	<DL	63.3 ± 0.27	<DL	990 ± 5.63
2	*M. guyanensis*	1539 ± 14.1	12.5 ± 0.94	88.7 ± 4.69	<DL	611 ± 123	2.44 ± 0.06	10.8 ± 0.77	1421 ± 62.1	0.16 ± 0.00	52.0 ± 1.22	10.4 ± 0.50	49.6 ± 8.24	55.5 ± 1.24	6.93 ± 1.14	59.6 ± 5.17
	C. rhizophorae	202 ± 3.26	5.55 ± 0.37	<DL	<DL	152 ± 59.2	0.15 ± 0.00	28.4 ± 0.30	346 ± 8.97	0.11 ± 0.00	18.9 ± 0.31	6.43 ± 0.00	6.87 ± 1.85	61.7 ± 0.93	1.34 ± 1.28	1273 ± 13.5
3	*M. guyanensis*	1749 ± 10.4	12.1 ± 1.04	67.6 ± 2.15	<DL	212 ± 112	<DL	24.2 ± 0.36	<DL	0.21 ± 0.00	49.2 ± 1.11	6.28 ± 1.02	16.7 ± 6.93	59.5 ± 0.92	3.46 ± 1.45	50.8 ± 0.47
	C. rhizophorae	181 ± 2.20	6.67 ± 0.40	<DL	<DL	0.23 ± 0.00	<DL	29.2 ± 0.79	292 ± 9.81	<DL	22.4 ± 0.53	<DL	0.18 ± 0.00	59.1 ± 0.47	<DL	1004 ± 14.4
4	*A. brasiliana*	1414 ± 14.7	10.1 ± 0.61	1.74 ± 0.09	<DL	62.8 ± 0.28	1.57 ± 0.05	4.29 ± 0.09	1184 ± 8.29	0.12 ± 0.00	32.3 ± 0.33	4.24 ± 0.18	6.06 ± 0.58	130 ± 9.25	0.74 ± 0.03	51.5 ± 1.44
5	*A. brasiliana*	323 ± 7.91	15.6 ± 0.76	<DL	<DL	372 ± 71.9	0.62 ± 0.02	3.94 ± 0.18	299 ± 6.90	0.11 ± 0.00	21.2 ± 1.24	4.19 ± 4.19	21.1 ± 1.79	109 ± 4.39	2.87 ± 0.35	53.3 ± 2.43
6	*A. brasiliana*	1660 ± 19.1	8.83 ± 0.13	5.33 ± 0.20	<DL	6.49 ± 0.21	2.23 ± 0.03	8.84 ± 0.26	1361 ± 43.1	0.10 ± 0.01	18.3 ± 1.01	5.12 ± 0.33	3.43 ± 0.04	132 ± 4.89	1.63 ± 0.11	67.5 ± 2.62
7	C. rhizophorae	243 ± 12.7	6.05 ± 0.02	<DL	1.04 ± 0.09	9.28 ± 0.54	0.07 ± 0.02	44.8 ± 2.54	372 ± 0.00	0.16 ± 0.00	16.8 ± 1.59	5.42 ± 0.00	4.64 ± 0.07	72.8 ± 3.39	0.33 ± 0.02	918 ± 46.1
8	*M. guyanensis*	2365 ± 19.9	7.73 ± 0.62	4.19 ± 0.05	0.06 ± 0.00	0.43 ± 0.00	2.64 ± 0.06	12.1 ± 0.33	1431 ± 8.28	0.13 ± 0.00	30.7 ± 0.35	6.56 ± 0.29	2.45 ± 0.00	64.3 ± 0.97	2.47 ± 0.03	69.7 ± 1.01
	C. rhizophorae.	187 ± 9.36	2.53 ± 0.72	<DL	1.71 ± 0.14	<DL	<DL	58.8 ± 3.62	212 ± 13.1	0.15 ± 0.00	5.27 ± 0.27	<DL	3.54 ± 0.24	49.7 ± 3.19	0.15 ± 0.00	928 ± 67.1
9	*B. exustus*	1919 ± 39.9	5.53 ± 0.18	1.82 ± 0.07	1.08 ± 0.02	21.8 ± 0.18	1.95 ± 0.15	24.4 ± 0.44	1123 ± 15.3	0.15 ± 0.00	20.4 ± 0.45	7.39 ± 0.83	5.34 ± 0.18	63.6 ± 1.28	2.00 ± 0.01	43.8 ± 0.67
	M. guyanensis	2458 ± 5.58	9.22 ± 0.64	5.28 ± 0.14	0.19 ± 0.00	42.1 ± 1.52	3.13 ± 0.04	16.7 ± 0.34	1820 ± 39.8	–	45.8 ± 1.28	8.49 ± 0.31	5.71 ± 0.51	62.2 ± 1.72	3.25 ± 0.04	65.9 ± 1.13
	C. rhizophorae	669 ± 36.9	2.94 ± 0.26	<DL	1.94 ± 0.06	3.37 ± 0.24	0.39 ± 0.02	65.9 ± 1.70	460 ± 14.9	0.14 ± 0.00	26.7 ± 0.80	2.89 ± 0.00	3.17 ± 0.02	53.2 ± 1.84	0.43 ± 0.04	846 ± 10.7
10	*C. rhizophorae*	147 ± 6.29	4.08 ± 0.12	<DL	1.50 ± 0.02	11.5 ± 0.42	0.10 ± 0.00	68.6 ± 0.85	266 ± 10.9	0.08 ± 0.00	19.8 ± 0.67	3.24 ± 0.00	3.52 ± 0.67	51.8 ± 2.17	<DL	1095 ± 10.8
	M. guyanensis	1997 ± 39.8	8.51 ± 0.51	6.44 ± 0.52	0.05 ± 0.00	16.1 ± 0.54	2.03 ± 0.09	15.3 ± 0.56	1802 ± 65.8	0.13 ± 0.00	30.1 ± 1.44	7.24 ± 0.12	4.02 ± 0.27	72.5 ± 1.41	3.12 ± 0.08	59.2 ± 1.73
11	*A. brasiliana*	555 ± 9.78	8.07 ± 0.39	<DL	<DL	0.98 ± 0.06	2.57 ± 0.38	7.41 ± 0.12	396 ± 3.76	0.09 ± 0.00	30.3 ± 0.78	4.66 ± 2.68	<DL	40.6 ± 0.44	<DL	55.2 ± 0.58
12	*C. rhizophorae*	335 ± 6.60	5.88 ± 0.37	<DL	1.03 ± 0.04	0.27 ± 0.03	0.66 ± 0.01	64.1 ± 1.45	376 ± 8.31	0.10 ± 0.00	17.8 ± 0.42	2.81 ± 0.00	0.74 ± 0.30	27.1 ± 0.49	<DL	1024 ± 19.9
13	*C. rhizophorae*	864 ± 53.1	3.03 ± 0.19	<DL	0.53 ± 0.01	5.37 ± 0.39	0.22 ± 0.07	214 ± 3.41	637 ± 24.9	0.09 ± 0.00	12.4 ± 0.57	6.49 ± 0.90	<DL	47.5 ± 0.76	<DL	2976 ± 19.9
14	*C. rhizophorae*	256 ± 12.3	13.2 ± 1.15	<DL	0.49 ± 0.06	<DL	1.53	158 ± 4.63	230 ± 4.76	0.09 ± 0.00	12.3 ± 0.28	9.89 ± 0.70	68.6 ± 4.75	42.7 ± 1.07	11.0 ± 0.54	2396 ± 51.6
15	*C. rhizophorae*	278 ± 14.3	9.12 ± 0.26	<DL	<DL	755 ± 14.1	1.29 ± 0.12	147 ± 2.67	275 ± 11.8	0.07 ± 0.00	13.9 ± 0.82	5.38 ± 1.29	42.0 ± 3.03	46.0 ± 2.21	6.23 ± 0.08	2046 ± 39.2
16	*C. rhizophorae*	343 ± 8.21	4.46 ± 0.04	<DL	0.35 ± 0.03	1.54 ± 0.11	<DL	124 ± 2.01	295 ± 5.64	0.10 ± 0.00	8.45 ± 0.14	5.47 ± 0.00	<DL	34.9 ± 0.63	<DL	2121 ± 36.4
17	*M. guyanensis*	1737 ± 21.3	7.39 ± 0.42	4.76 ± 0.22	0.52 ± 0.03	0.52 ± 0.06	2.08 ± 0.09	48.6 ± 1.42	<DL	0.12 ± 0.00	126 ± 1.35	9.27 ± 1.36	<DL	39.0 ± 0.54	2.21 ± 0.06	60.8 ± 0.65
	C. rhizophorae	271 ± 4.98	5.51 ± 0.04	<DL	13.7 ± 0.18	352 ± 42.2	0.20 ± 0.04	151 ± 2.50	410 ± 4.22	0.11 ± 0.00	28.2 ± 0.21	5.73 ± 0.71	24.6 ± 3.73	45.0 ± 0.06	3.13 ± 0.30	2757 ± 36.6
18	*M. guyanensis.*	1888 ± 267	5.87 ± 0.21	4.74 ± 1.27	<DL	122 ± 41.2	2.13 ± 0.52	14.1 ± 1.02	<DL	0.12 ± 0.00	57.1 ± 5.09	8.41 ± 1.58	<DL	35.5 ± 1.40	3.05 ± 0.32	182 ± 5.39
19	*A. brasiliana*	775 ± 28.5	8.92 ± 0.53	0.64 ± 0.3	<DL	467 ± 16.9	1.02 ± 0.10	8.62 ± 0.34	522 ± 23.7	0.12 ± 0.01	29.4 ± 1.42	5.49 ± 0.32	19.4 ± 1.83	83.0 ± 2.19	3.90 ± 0.45	52.4 ± 1.93
20	*A. brasiliana*	142 ± 4.64	14.1 ± 0.27	0.59 ± 0.17	0.49 ± 0.01	8.27 ± 0.05	0.18 ± 0.03	44.8 ± 0.37	218 ± 4.53	0.21 ± 0.00	35.6 ± 0.94	6.76 ± 0.00	5.24 ± 0.06	97.1 ± 0.91	0.15 ± 0.01	64.3 ± 1.22
	C. rhizophorae	86.5 ± 5.53	7.88 ± 0.01	<DL	2.43 ± 0.15	12.4 ± 0.82	<DL	237 ± 11.6	152 ± 6.73	0.13 ± 0.00	11.1 ± 0.69	5.90 ± 0.00	4.42 ± 0.42	65.6 ± 3.11	0.04 ± 0.00	1566 ± 67.4
21	*A. brasiliana*	305 ± 6.97	4.46 ± 0.34	<DL	0.53 ± 0.00	<DL	0.14 ± 0.00	5.90 ± 0.02	310 ± 6.11	0.07 ± 0.00	109 ± 3.42	6.20 ± 0.48	2.94 ± 0.07	73.3 ± 0.87	0.21 ± 0.01	58.0 ± 0.64
	C. rhizophorae	191 ± 10.2	4.58 ± 0.02	<DL	1.25 ± 0.05	8.66 ± 0.52	0.10 ± 0.09	114 ± 6.66	248 ± 20.1	0.07 ± 0.00	15.6 ± 0.63	3.39 ± 1.92	4.83 ± 0.33	57.8 ± 4.62	0.12 ± 0.00	2399 ± 107
22	*A. brasiliana*	305 ± 5.50	5.92 ± 0.16	<DL	0.30 ± 0.00	4.51 ± 0.39	0.27 ± 0.00	4.48 ± 0.07	274 ± 1.33	0.08 ± 0.00	64.4 ± 4.87	3.09 ± 0.00	5.63 ± 0.27	62.9 ± 0.97	0.22 ± 0.02	68.5 ± 0.61
23	*A. brasiliana*	780 ± 27.4	2.86 ± 0.63	4.34 ± 0.31	0.59 ± 0.10	0.81 ± 0.56	0.89 ± 0.08	48.7 ± 4.28	700 ± 40.0	0.05 ± 0.00	209 ± 20.6	5.41 ± 1.59	2.11 ± 1.41	101 ± 6.21	0.93 ± 0.05	79.4 ± 5.57
	C. rhizophorae	394 ± 17.2	<DL	0.03 ± 0.00	1.79 ± 0.02	<DL	0.15 ± 0.00	586 ± 15.1	298 ± 10.1	0.04 ± 0.00	21.8 ± 2.07	2.41 ± 1.07	3.59 ± 0.18	80.4 ± 3.44	0.22 ± 0.02	1600 ± 30.6
	B. exustus	1923 ± 43.9	1.31 ± 0.57	6.12 ± 0.22	0.59 ± 0.04	1.43 ± 0.00	2.36 ± 0.14	53.3 ± 0.61	1448 ± 53.6	0.04 ± 0.00	118 ± 0.87	6.08 ± 1.91	3.45 ± 0.38	185 ± 3.67	2.97 ± 0.02	56.2 ± 1.74
24	*B. exustus*	1589 ± 13.6	<DL	18.6 ± 1.41	0.33 ± 0.01	<DL	1.64 ± 0.03	26.9 ± 0.44	1314 ± 9.82	0.03 ± 0.00	119 ± 2.54	6.67 ± 0.26	2.62 ± 0.11	228 ± 8.17	2.66 ± 0.06	54.0 ± 1.12
	C. rhizophorae	229 ± 3.71	0.79 ± 0.00	0.32 ± 0.00	1.88 ± 0.01	<DL	0.08 ± 0.06	248 ± 1.43	209 ± 3.03	–	13.6 ± 0.25	3.23 ± 0.7	2.81 ± 0.77	63.8 ± 0.16	0.16 ± 0.08	1300 ± 15.3
	A. brasiliana	610 ± 10.7	1.35 ± 0.38	4.86 ± 0.30	0.35 ± 0.02	<DL	0.51 ± 0.02	7.05 ± 0.21	605 ± 8.23	0.03 ± 0.00	110 ± 6.42	3.43 ± 0.36	2.52 ± 0.14	74.2 ± 2.20	0.59 ± 0.03	64.9 ± 2.82
25	*A. brasiliana*	835 ± 12.3	5.36 ± 0.52	6.15 ± 1.23	0.27 ± 0.01	<DL	0.97 ± 0.05	7.73 ± 0.21	749 ± 8.76	0.04 ± 0.00	35.2 ± 0.17	4.82 ± 0.00	1.93 ± 0.42	86.5 ± 1.54	1.35 ± 0.05	82.2 ± 2.58
	C. rhizophorae	178 ± 15.1	1.50 ± 0.00	1.13 ± 1.09	2.74 ± 0.18	<DL	0.18 ± 0.15	521 ± 30.8	200 ± 8.65	0.04 ± 0.00	13.8 ± 0.64	<DL	3.94 ± 0.23	73.7 ± 4.15	0.18 ± 0.06	1445 ± 82.2
26	*M. guyanensis*	1791 ± 30.4	1.44 ± 0.00	9.20 ± 0.62	0.56 ± 0.01	0.60 ± 0.19	2.23 ± 0.03	64.1 ± 1.10	1339 ± 15.1	0.03 ± 0.00	94.7 ± 3.12	4.45 ± 0.18	3.59 ± 0.04	95.8 ± 4.58	2.74 ± 0.06	63.4 ± 1.41
	C. rhizophorae	332 ± 11.2	<DL	0.25 ± 0.00	2.25 ± 0.02	<DL	0.14 ± 0.01	602 ± 9.15	266 ± 5.96	0.04 ± 0.00	12.2 ± 0.55	1.31 ± 0.41	3.54 ± 0.26	67.1 ± 1.68	0.21 ± 0.05	1713 ± 25.7
	A. brasiliana	834 ± 20.6	3.37 ± 0.14	3.75 ± 0.24	0.74 ± 0.07	1.19 ± 0.10	0.90 ± 0.08	10.9 ± 0.87	765 ± 24.7	0.05 ± 0.00	316 ± 8.34	6.60 ± 3.07	2.21 ± 0.18	77.4 ± 3.64	1.19 ± 0.04	72.3 ± 5.16
27	*C. rhizophorae*	269 ± 10.1	1.09 ± 0.00	<DL	1.26 ± 0.05	<DL	0.02 ± 0.00	259 ± 8.48	287 ± 5.60	0.05 ± 0.00	16.8 ± 0.31	3.75 ± 2.40	3.59 ± 0.12	95.8 ± 3.03	0.11 ± 0.00	1720 ± 48.6
	M. guyanensis	1428 ± 5.16	3.35 ± 0.43	3.44 ± 0.22	0.04 ± 0.00	<DL	1.09 ± 0.06	102 ± 8.88	1065 ± 4.26	0.08 ± 0.00	37.5 ± 0.44	7.13 ± 0.39	2.20 ± 0.35	91.1 ± 18.2	1.77 ± 0.06	67.2 ± 1.71
28	*B. exustus.*	1330 ± 33.9	1.64 ± 0.00	6.52 ± 0.62	0.46 ± 0.01	<DL	1.12 ± 0.01	51.2 ± 0.73	886 ± 34.9	0.03 ± 0.00	46.5 ± 2.77	5.81 ± 0.44	2.16 ± 0.14	40.1 ± 1.19	1.62 ± 0.03	45.0 ± 0.57
	C. rhizophorae	313 ± 6.41	<DL	0.33 ± 0.27	2.33 ± 0.02	<DL	0.11 ± 0.04	396 ± 3.69	287 ± 3.53	0.04 ± 0.00	18.8 ± 0.58	5.19 ± 0.63	3.33 ± 0.15	92.2 ± 0.60	0.18 ± 0.03	1109 ± 14.9
	A. brasiliana	763 ± 28.4	<DL	2.11 ± 0.20	0.56 ± 0.01	<DL	0.68 ± 0.04	5.69 ± 0.01	673 ± 16.8	0.03 ± 0.00	117 ± 3.68	5.71 ± 0.04	3.58 ± 0.71	71.9 ± 1.35	0.84 ± 0.02	68.8 ± 0.44
29	*C. rhizophorae*	297 ± 10.1	<DL	0.08 ± 0.01	2.60 ± 0.09	<DL	0.05 ± 0.00	444 ± 12.8	288 ± 8.25	0.04 ± 0.00	14.1 ± 0.89	5.39 ± 0.00	2.98 ± 0.12	62.9 ± 1.82	0.36 ± 0.01	1432 ± 23.1
30	*A. brasiliana*	669 ± 39.4	3.58 ± 0.32	0.73 ± 0.05	0.05 ± 0.00	27.5 ± 1.11	0.58 ± 0.05	9.55 ± 0.19	508 ± 32.2	0.07 ± 0.00	11.8 ± 0.72	4.26 ± 0.00	4.73 ± 0.50	82.3 ± 4.82	0.78 ± 0.07	59.3 ± 2.56
31	*A. brasiliana*	404 ± 33.2	5.46 ± 0.23	<DL	0.08 ± 0.04	9.73 ± 0.84	0.37 ± 0.13	2.72 ± 0.03	309 ± 30.8	0.07 ± 0.00	27.8 ± 0.14	3.17 ± 1.52	2.78 ± 0.24	56.3 ± 0.19	0.25 ± 0.04	46.9 ± 0.01
32	*A. brasiliana*	215 ± 15.8	7.77 ± 0.27	<DL	0.14 ± 0.01	<DL	0.46 ± 0.05	1.03 ± 0.03	205 ± 15.6	0.07 ± 0.00	52.8 ± 3.09	<DL	1.73 ± 0.00	55.3 ± 3.45	0.06 ± 0.00	54.7 ± 4.36
33	*A. brasiliana*	73.5 ± 5.61	6.83 ± 0.57	<DL	0.42 ± 0.03	16.6 ± 0.34	0.02 ± 0.01	3.61 ± 0.28	122 ± 5.51	0.06 ± 0.00	86.2 ± 4.54	2.53 ± 0.01	2.74 ± 0.35	77.7 ± 4.01	<DL	69.7 ± 3.54
34	*A. brasiliana*	504 ± 7.93	11.2 ± 0.23	0.14 ± 0.03	0.09 ± 0.01	15.5 ± 0.03	0.44 ± 0.04	5.38 ± 0.18	416 ± 5.02	0.13 ± 0.00	6.56 ± 0.40	3.89 ± 2.97	4.48 ± 0.11	76.9 ± 0.63	0.49 ± 0.03	73.6 ± 1.38
	M. guyanensis	778 ± 20.1	23.1 ± 1.21	0.53 ± 0.02	1.42 ± 0.06	26.0 ± 0.99	1.38 ± 0.04	35.7 ± 0.85	518 ± 14.6	0.35 ± 0.00	3520 ± 25.4	19.4 ± 0.23	9.57 ± 0.55	84.4 ± 1.97	1.43 ± 0.01	141 ± 5.69

(*continued on next page*)

Table 1 (*continued*)

Site	Shellfish species	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Pb	Se	Sr	V	Zn
Camamu	*B. exustus*	776 ± 11.6	6.26 ± 0.11	1.12 ± 0.08	<DL	19.3 ± 0.28	0.73 ± 0.02	25.8 ± 0.14	484 ± 5.59	0.15 ± 0.00	2.80 ± 0.10	<DL	3.74 ± 0.10	56.0 ± 0.30	0.77 ± 0.06	42.7 ± 0.82
	C. rhizophorae	939 ± 57.2	11.5 ± 1.01	2.09 ± 0.18	0.02 ± 0.00	<DL	0.70 ± 0.05	71.8 ± 5.91	644 ± 47.7	0.09 ± 0.00	21.1 ± 0.20	4.12 ± 0.00	4.06 ± 0.20	72.1 ± 6.25	0.78 ± 0.06	901 ± 73.1
	M. guyanensis	2175 ± 32.9	11.7 ± 0.35	53.4 ± 2.07	<DL	0.66 ± 0.02	2.32 ± 0.04	6.03 ± 0.39	1516 ± 44.8	0.11 ± 0.00	92.5 ± 2.26	2.59 ± 0.10	3.80 ± 0.27	60.3 ± 1.85	2.47 ± 0.07	61.7 ± 2.62
Boipeba	*C. rhizophorae*	262 ± 6.61	4.28 ± 0.58	<DL	<DL	0.28 ± 0.01	0.05 ± 0.00	13.7 ± 0.34	306 ± 3.40	0.10 ± 0.00	5.48 ± 0.09	4.22 ± 0.00	<DL	33.8 ± 1.00	<DL	1671 ± 30.4

<DL = below detection limit.

(Barros et al., 2008; Hatje et al., 2010). That seems to be the case for As concentrations found in clams and mussels collected in the relatively well preserved Jaguaripe estuary, where there is considerable water exchange with the Atlantic ocean (Fig. 1), and the sediments are more than 90% composed of sand (Hatje et al., 2010). In the marine environment, As is often found in high concentrations in organic forms (up to 50 μg/g; wet weight basis). The highest As concentrations were recorded in samples from the Salvador area (mussels: 23.1 μg/g), which is similar to levels observed in contaminated areas on the East coast of China (Fung et al., 2004) and in the McMurdo Sound (Negri et al., 2006). Arsenobetaine, which is the principal As form in fish, shellfish and crustaceans is considered nontoxic. Nevertheless, since As levels were above the recommended limits for shellfish as food in Brazil (1 μg/g; wet weight basis; ANVISA/Portaria no. 685), speciation studies are needed to evaluate As toxicity in seafood tissues.

Concentrations of Cu in oysters, mussels and clams at several locations were above typical values (Bryan et al., 1985; Gault et al., 1983; Cantillo, 1998) and acceptable levels promulgated by the US Food and Drug Administration (USFDA) and by the Brazilian Agency ANVISA. Levels of Cu in oyster samples ranged from 21.5 to 602 μg/g, at Aratu Bay. This area is under the influence of a number of Cu based industrial activities and extensive port facilities. The highest levels in clams (48.7 μg/g) and in mussels (*Mytella guayanensis*, 102 μg/g; *Brachidontes exustus*, 53.6 μg/g) were also observed in the same area. Concentrations of Cu in the present study were higher than those reported in the older literature for BTS (Wallner-Kersanach et al., 1994; CRA, 2004), but are in agreement with those reported by Amado Filho et al. (2008).

Concentrations of Cd in oysters are relatively high and above recommended limits for shellfish in Brazil (1 μg/g; wet weight basis; ANVISA/Portaria no. 685), at several locations (Table 1). The highest concentrations were observed in the Subaé estuary, which is subject to Cd, As, Pb and Zn contamination due to an inactive lead smelter which operated in the region for over 30 years (Hatje et al., 2006) and which continues to be an important source of contamination to the river and estuarine areas. Relatively high Cd concentrations were also observed in the Aratu Bay and harbor areas that are subject to a series of anthropogenic activities. Cadmium concentrations obtained in this study are similar to values reported for BTS in previous studies (Wallner-Kersanach et al., 1994; CRA, 2004).

The shellfish species studied, generally, showed low accumulated body concentrations of Hg, with values obtained from all sites ranging from <0.03 to 0.35 μg/g. Highest values of Hg were recorded (0.35 μg/g) in mussel samples (*M. guyanensis*) from the Ribeira Bay, which may be explained by a chlor-alkali industry, which was located in this region and was responsible for the emission of 2–4 kg of mercury chloride over its 12 years of operation (CRA, 2004).

Concentrations of major and trace elements at the control sites (Camamu and Guarapoá), which are similar environments compared to BTS (i.e. presence of mangroves, estuaries, and similar granulometry), but well preserved and subject to limited human influences (Hatje et al., 2008), were generally lower than those obtained for BTS (Table 1). When compared to the World Mussel Watch database (Cantillo, 1998) and typical values for uncontaminated areas (Silva et al., 2003, 2006; Luoma and Rainbow, 2008), both Camamu Bay and Guarapoá can be considered as low impacted sites.

There were large differences among stations in the accumulated concentrations of trace elements in shellfish. Given that accumulated concentrations are integrated records of bioavailability for each element studied (Phillips and Rainbow, 1994), bioavailability varied significantly along BTS and among the

elements studied, reflecting proximity to sources of contaminants (industries, sewage, agriculture, etc.), hydrodynamics, organic matter content and sediment granulometry. To a certain degree, the levels of Cr, V, Mn and Zn were similar at all sampling sites, and no clear spatial patterns were obtained. The bioavailability of Cr, Hg, Se and V in the BTS was generally low, whereas that of As, Al, Cu, Fe, Pb, Mn and Zn was higher.

Because of the distribution pattern of each species studied, the statistical analysis (PCA) of the oyster and clam datasets was performed separately. The number of sites with mussel occurrence did not justify the use of PCA analysis.

For oysters, the first two principal components explained, respectively, 62.2% and 20.8% of the total variance (Fig. 2). The first PC of the oyster ordination mainly correlated positively to Co and V. The second PC positively correlated to As, and negatively correlated to Zn, Cu, and Cd. The third PC, although corresponding to only 4.6% of the total variance of the data, presented a significant correlation to Cr, Fe and Mn. In BTS the latter are mainly associated to natural sources. Lead, on the other hand, was also negatively correlated to PC3, although high concentrations of Pb from anthropogenic sources, including atmospheric deposition, can be found all over BTS (Hatje et al., 2009). Based on PC1 and PC2, it is possible to group together the results for oysters from Aratu Bay, where there is a series of industries and harbors which largely introduce Zn, Cu and Cd (CRA, 2004). Based on sediments data, this area has been identified as one of the most contaminated in the BTS (Hatje and de Andrade, 2009). PC2 separated samples which presented high As concentrations, but in the cases of Camamu, Boipeba, Jaguaripe, Itaparica and, at least part of the Paraguaçu area, the As concentrations seem to be mainly associated to natural sources (Hatje et al., 2010), which may explain why the results for these areas were distinct from the results for Aratu Bay. Based on metal concentrations in oyster tissues, the PCA analysis indicated that the Jaguaripe, Itaparica and Paraguaçu areas (Fig. 1) are more similar to each other than other parts of BTS, and that they also suffer less anthropogenic impact from the studied elements.

The PCA results for clam samples are presented in Fig. 3. The first two PCs corresponded to 78.3% of the total variance, while the third PC corresponded to 9.3%. The distribution pattern observed for clam samples was less clear than the one observed for oysters, but nevertheless corroborated the results obtained for oysters, with PC1 also separating the sites of the contaminated Aratu Bay. Arsenic and Co concentrations were positively correlated with PC1 whereas Mn was negatively correlated with the same PC. PC1 distinguished contaminated sites in the Aratu Bay, Madre de Deus and Salvador areas from the Jaguaripe, Itaparica and Subaé sites

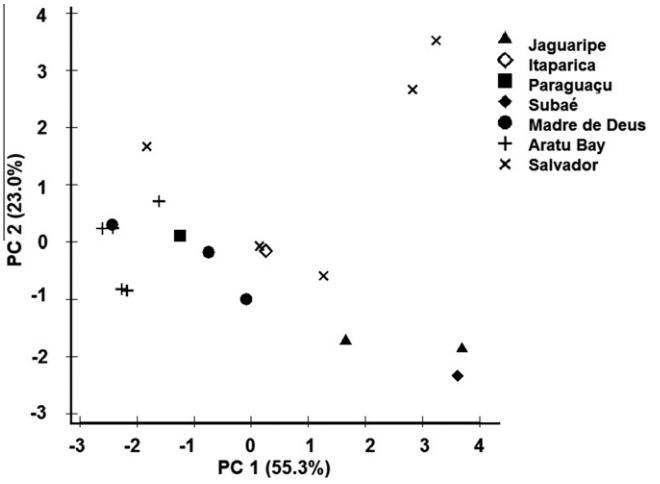

Fig. 3. Results of PCA analysis for trace metals in clams.

(Fig. 1). The latter presented high As concentrations, but As concentrations in Jaguaripe, as explained above, seem to be from natural sources, while in the Subaé estuary an old Pb smelter is the main As source (CRA, 2004; Hatje et al., 2006, 2010). PC2 was significantly correlated to V and negatively correlated to Pb, which is widely distributed in the sediments of BTS (Hatje and de Andrade, 2009).

Differences in the accumulation patterns for oysters, clams and mussels are intimately associated to the habitats of these invertebrates and also to their physiology, trace element intake routes and feeding guilds. Clams were collected in unconsolidated sediments (sand–mud sediments), on tidal flats exposed at low tide and they feed on suspended particulate material and on sediments (Rodrigues et al., 2010). Due to their low commercial value, the majority of the clams harvested are consumed by local fishers and by their families (CRA, 2005). Oysters, on the other hand, are typically collected in mangrove roots, and are exposed to water contamination which, in general, presents much lower metal concentrations than those found in sediments. However, oysters feed on very fine suspended matter, generally, rich in organic matter and trace elements. Oysters are consumed raw or cooked and have a high commercial value, so they do not represent an important seafood item for the subsistence fishers and subsistence shellfish consumers. Mussels, on the other hand, are consumed both by local populations (i.e. subsistence fishers and subsistence shellfish consumers) and are also sold to restaurants and local markets.

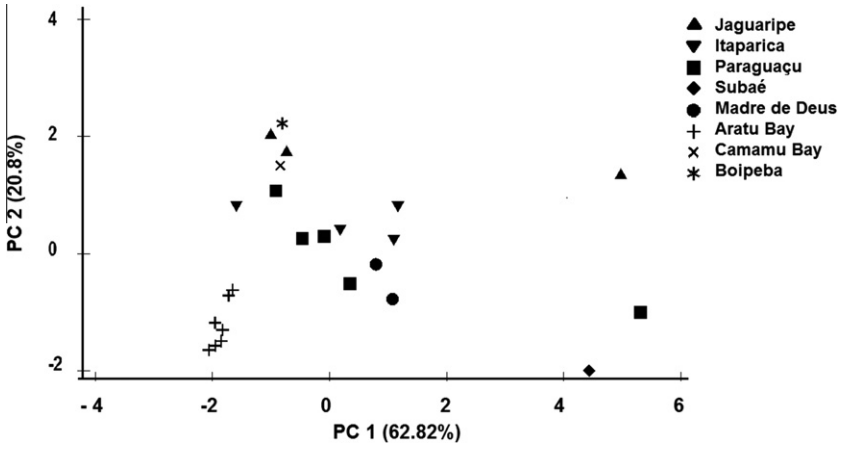

Fig. 2. Results of PCA analysis for trace metals in oysters.

The screening risk assessment was based on conservative assumptions, i.e. maximum ingestion rates of shellfish and the threshold concentration limits established in the legislation. It was assumed that 100% of the metal concentrations present (Table 1) were in a toxic form. The only exception was As, for which only 10% of the obtained concentration was used, since in general terms, only that fraction represents the most toxic forms, e.g. As(III) and As(V) (FDA, 2003). The mean seafood consumption rate used in this study (0.3 kg/day for adults and 0.15 kg/day for children) was relatively high. In this way, the probability of the occurrence of adverse impacts, when the risk is not detected is reduced in order to protect human health, especially for populations for which shellfish is the main source of protein.

Several studies, however, have used a much lower consumption rate (e.g. US EPA, 2000; Falcó et al., 2006; Silver et al., 2007). If the consumption rates reported in the literature were used in this study, the risks associated with seafood consumption by the subsistence fishers and the subsistence shellfish consumers would be underestimated.

Figs. 4 and 5 present the hazard quotient (HQ) calculated for non-carcinogenic risk for adults and children, respectively. The health risk calculated for each location is related to the accumulation capacity of the biological species collected at each sampling site. The comparison of health risks among locations is not an easy task, due to the fact that the shellfish studied occur in different habitats. The daily reference dose (RfD; estimate of daily exposure which is unlikely to bring an appreciable risk of deleterious effects during a lifetime) and the Cancer Slope Factor (CSF; an upper boundary risk estimate) used are presented in Table 2.

The non-carcinogenic risk was classified as: not significant (HQ < 1), low (1 < HQ < 9.9), moderate (10 < HQ < 19.9), high (20 < HQ < 99.9), or critical (⩽100). Only the moderate, high and critical risks are presented in Figs. 4 and 5. As expected, the estimated risks for children were superior to the risks for adults. The non-carcinogenic risk assessment indicated that As, Zn and Cu were the most critical elements. Significant risks were observed for As at Jaguaripe, Salinas das Margaridas, and in the Subaé estuary (Fig. 1). The risks associated with Zn were a reflection of the high Zn concentrations in oyster tissues. The oyster's ability to concentrate Zn is well known and it is associated to the organism's physiology. At the sites where oysters were not collected the risk for Zn was not significant, indicating that oyster ingestion is an important Zn transfer route for humans, especially children.

The element that posed the greatest risk was Cu. Relevant risks were detected at all of the studied stations except Jaguaripe and Itaparica Island. Copper apart, Se, Co and As are the elements of greatest concern (Figs. 4 and 5). The non-carcinogenic risk was also calculated for the different species (Table 3). The results showed that clams bring more risks to both children and adults due to the accumulation of As, Co and Se, and also to children due to Fe, Mn and Pb. In the case of oysters, As, Cd, Co, Cu, Se and Zn cause concern for both children and adults. For the two species of mussels analyzed, it was observed that As, Cu and Pb are important sources of risk. Mussels were the species that posed the highest risk for the greatest number of elements studied, both in children and in adults.

The carcinogenic screening risk evaluation was only performed for As, Cd and Pb, since these are the elements which present the

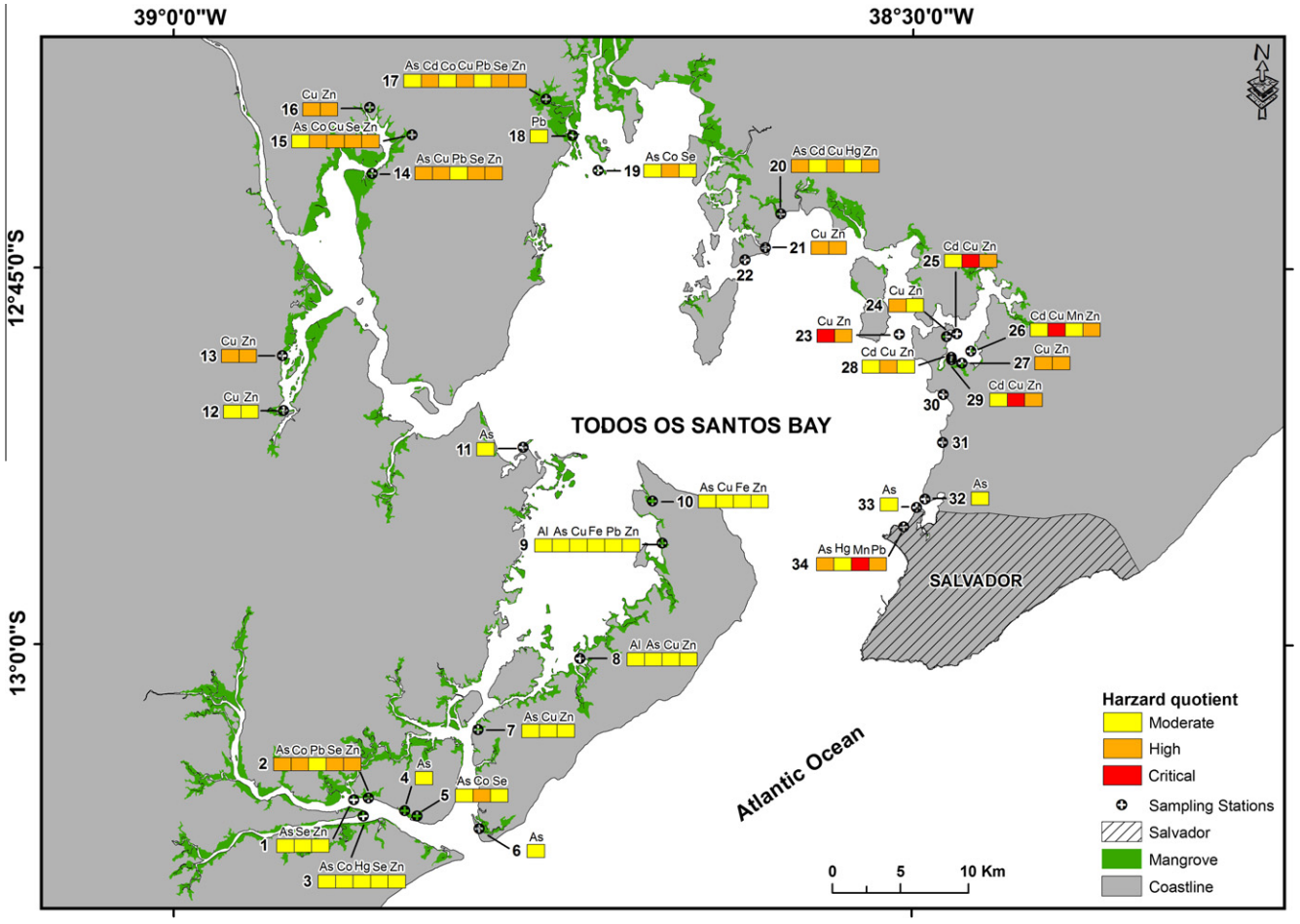

Fig. 4. Hazard quotient (HQ) calculated for adults, for different elements, at studied locations.

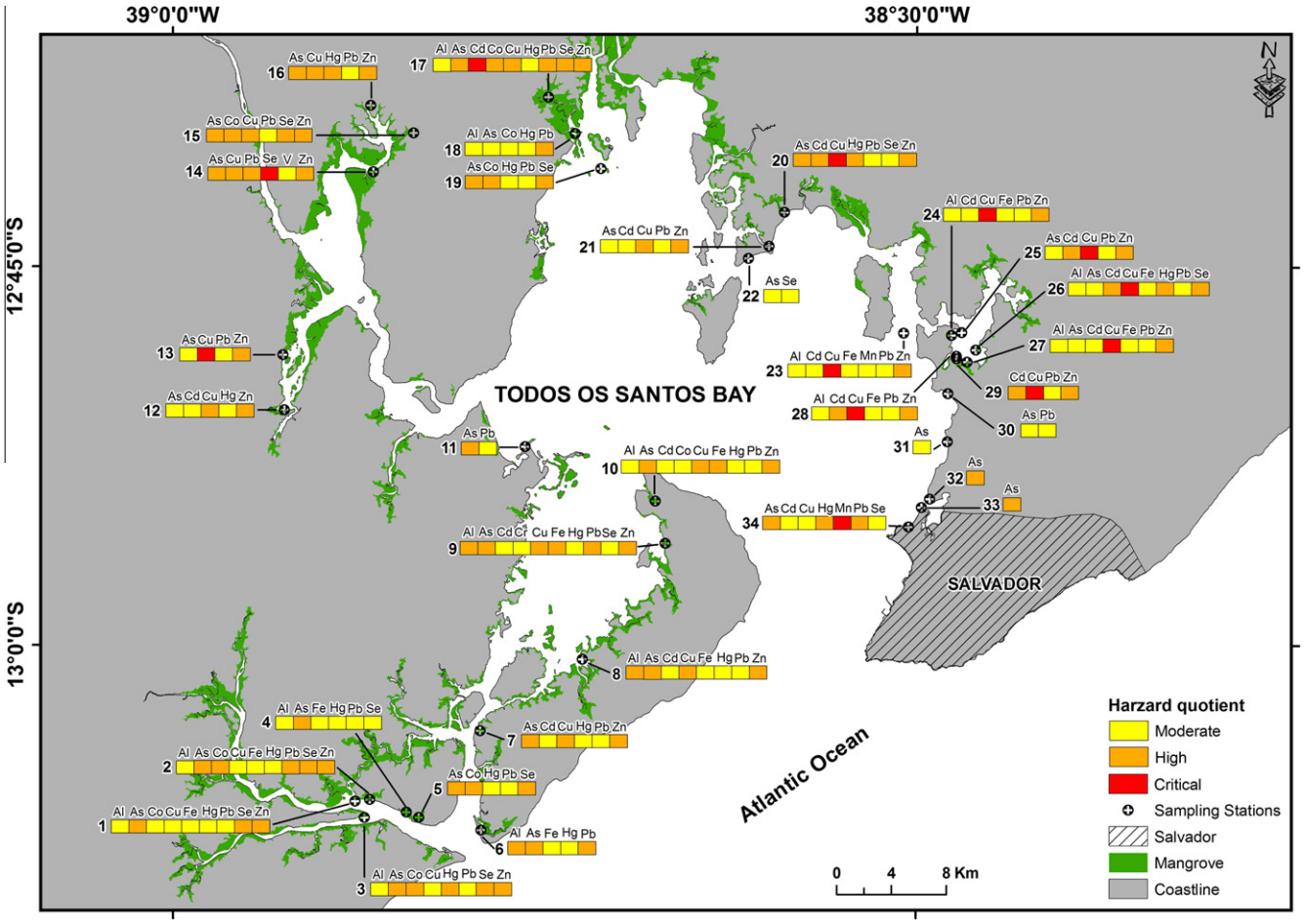

Fig. 5. Hazard quotient (HQ) calculated for child, for different elements, at studied locations.

greatest probability of causing cancer (Stewart and Kleihues, 2003). There is no certainty about the cancer risks associated with the ingestion of shellfish contaminated with Cu.

The risks for children were higher than for adults, as with the pattern observed for non-carcinogenic risks. This is mainly due to the lower body weight of children. Among the elements studied, Pb posed the greatest carcinogenic risk due to shellfish consumption (Carcinogenic risk of 5 and 10, respectively, for adults and children), which conflicts with the findings of the CRA (2005), which identified Cd as the most important source of concern (associated with fish consumption). Although Pb was the element that posed the greatest risks, the Pb concentration found in the BTS samples is lower than that in previous studies undertaken in the area (Gonçalves, 2006; Amado Filho et al., 2008).

In relation to the sampling sites, all stations presented risks above acceptable levels and also above the values reported by the CRA (2005). Carcinogenic risks for each species are shown in Table 4. Mussel samples presented the highest risks, possibly because this organism lives in fine sediments in mangrove areas, where high metal concentrations usually occur (Förstner and Wittman, 1979).

To summarize there could be implications for subsistence fishers and subsistence shellfish consumers who have high shellfish consumption rates because of exposure to trace elements associated with seafood. Estimated health risks were greatest from the consumption of mussels. Contaminated shellfish pose the greatest risk to children, suggesting that mussels from contaminated areas in the BTS, such as the Subaé estuary and Aratu Bay should be consumed with moderation. The general population and tourists who have low or only occasional shellfish ingestion are, potentially, at low risk of metal exposure. Studies on trophic transfer are necessary to understand the fate of metal burdens along the food chain. Moreover many benthic predators (i.e. fish) are also consumed by humans.

Table 2
Reference daily dose (RfD) and Cancer Slope Factor used for risk estimates.

	Reference dose (RfD) mg/kg/day	Reference	Cancer Slope Factor (CSF)	Reference
Al	1	ATSDR		
As	0.0003	CRA	1.5	CRA
Ba	0.2	ATSDR		
Cd	0.001	CRA	0.38	CRA
Co	0.1	ATSDR		
Cr	0.003	CRA		
Cu	0.02	CRA		
Fe	0.8	CRA		
Hg	0.0001	CRA		
Mn	0.14	CRA		
Pb	0.0036	CRA	0.0085	CRA
Se	0.005	ATSDR		
Sr	2	ATSDR		
V	0.01	ATSDR		
Zn	0.3	CRA		CRA

CRA (2005) and ATSDR (2009).

Table 3
Noncarcinogenic risks (Hazard Quotient- HQ) for child and adult for each studied element.

		Al	As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Pb	Se	Sr	V	Zn
Clams: *Anomalocardia brasiliana*	Adult	7.25	24.00	0.14	3.25	20.50	3.80	11.35	7.57	7.10	8.04	9.21	19.74	0.33	1.56	1.33
	Child	14.51	48.00	0.29	6.50	41.00	7.60	22.69	15.13	14.20	16.08	18.42	39.48	0.65	3.13	2.66
Oyster: *Crassostrea rhizophorae*	Adult	3.28	16.19	0.02	21.92	25.66	2.21	145.69	2.86	7.53	0.95	9.49	44.66	0.23	3.71	45.65
	Child	6.55	32.38	0.05	43.84	51.32	4.42	291.38	5.72	15.05	1.90	18.97	89.32	0.46	7.42	91.30
Mussels: *Brachidontes exustus*	Adult	9.61	10.30	0.40	5.03	1.08	3.80	13.22	8.88	7.50	4.24	10.11	5.02	0.55	1.45	0.93
	Child	19.22	20.60	0.81	10.07	2.16	7.59	26.44	17.77	15.00	8.49	20.23	10.04	1.10	2.91	1.86
Mussels: *Mytella guyanensis*	Adult	12.06	29.67	2.07	5.81	21.57	4.85	20.76	11.34	14.35	65.11	20.69	36.44	0.23	2.60	2.69
	Child	24.12	59.33	4.14	11.62	43.15	9.70	41.53	22.67	28.70	130.21	41.39	72.88	0.47	5.20	5.38

Not significant	HQ < 1	Low	1 < HQ < 9.9	Moderate	10 < HQ < 19.9	High	20 < HQ < 99.9	Critical	HQ > 100

Table 4
Adult and child carcinogenic risks for different shellfish.

		As	Cd	Pb
Clams: *Anomalocardia brasiliana*	Adult	0005	0009	4
	Child	0.01	0.02	8
Oyster: *Crassostrea rhizophorae*	Adult	0003	0.06	4
	Child	0006	0.1	8
Mussels: *Brachidontes exustus*	Adult	0002	0.01	4
	Child	0004	0.03	9
Mussels: *Mytella guyanensis*	Adult	0006	0.02	9
	Child	0.01	0.03	18

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