Influence of Salt Works' Hyper-Saline Waste-Brine on Distribution of Mangrove Crabs (Decapoda) within the Gongoni-Kurawa Intertidal Area, Kenya

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Abstract

Evaporation is one of the oldest methods employed in sea salt production, a process that involves pumping seas water into a series of ponds where solar evaporation concentrates it into brine, and precipitates the salt; which is then harvested manually. Lack of baseline information on the effect of the discharged brine at the Gongoni-Kurawa region caused the need to determine its impact on the marine ecosystem. The objective of this study was to identify the effect of brine on mangrove crab species diversity and distribution. The impact of the discharged hyper-saline waste-brine waters on the mangrove crabs along the intertidal habitats bordering two of the biggest salt works; Krystalline and Kurawa salt industries was investigated in this study. Sampling was done during both spring and neap season in the year 2015 between the month of February to June using 1m^2 quadrats, and crabs collected from the quadrats used to estimate the densities. A total of 34 mangrove crab species were recorded, with abundances significantly higher ($p>0.05$) within the inlets' habitats as compared to the outlets (discharge-point) habitats. Six species were most dominant and occurred in all of the transect samples and they were *Machrophthalmus grandidieri*, *Uca chlorophthalmus*, *Terebralia palustris*, *Machrophthalmus latreillei*, *Uca tetragonon* and *Amaea acuminata*. Higher species diversity and evenness were recorded in inlet habitats at Kurawa compared to the outlets. The inlet habitats reported higher Maximum Shannon-Wiener diversity, whereas outlets recorded lower diversity, with Marereni recording considerably lower Hmax, at 0.95. Species distribution showed a significant reduction of the genera *Uca* and *M. grandidieri* ($p<0.05$) at Marereni outlet habitats, but an increase in *U. vocans* at the inlet habitats. Similarly, there was a higher abundance of genera *Uca*, *M. ovalina*, *M. grandidieri*, *M. latreillei*, *Amaea acuminata* and *Cerithidea decollata* ($p<0.05$) during the spring tide period while the abundances of *U. vocans* dropped during the same period. This asymmetric distribution between inlets and outlets was explained by significant variations in salinity as well as site specific salinity gradients at the two study sites; Marereni and Kurawa in north coast, Kenya. Suggestions for improving salt production and quality while minimizing adverse environmental effects were recommended.

Keywords: Inter-tidal habitats, Salinity, Waste-brine, Crab

INTRODUCTION

Waste-brine discharge is one of the most significant environmental issues associated with solar sea salt production due to the presence of highly potent salt concentration and residual chemicals, (Danoun, 2007; Dawoud, 2012) including chemicals used during the 'cleaning' of the salt after harvesting. In many salt industries, and especially within the Developing and Least Developing Countries (LDCs), majority of salt industries discharge (Ochiewo, 2004) the untreated waste-brine back into the mangrove habitats along the coast with little regard to the likely impacts of these toxic concentrates on the environment and the associated flora and fauna. In Kenya, along the Gongoni-Kurawa coastal stretch in the north of Malindi, the operations of the numerous salt works are no different (Ochiewo, 2004), and the impacts of the discharges on the marine environment, although little documented, cannot be understated. The impacts can be deduced from the numerous conflicts between the salt industries and the local communities, who have highlighted the issues such as the salination of underground freshwater, mortality of both juvenile fish and adult fish species and crustaceans during weeks when the salt works discharge their brine, and when the mangroves habitats get flooded with the waste brine.

Furthermore, the mangrove areas form important nursery and feeding grounds for many offshore marine fish species as well as habitats for a variety of terrestrial birds which depend on the abundance of the marine flora and fauna in these habitats (Cohen, 2010). Consequently, any impacts on the mangrove ecosystems and coastal habitats go beyond localized species depletions (Cohen, 2010; Cooley & Heberger, 2013), to wide ecosystem impacts on the associated flora and fauna of inshore environments (Kumar & Khan, 2013), as well as both the small-scale inshore- and offshore- industrial fisheries which are closely linked to the habitats, including the bottom trawl shrimp fisheries of the adjacent Malindi-Ungwana Bay. Therefore, the little benefits derived by the locals from employment in the salt works and the scanty fisheries within the inlet reservoirs, cannot compensate for the likely wider impacts of the waste-brine discharge into the intertidal ecosystems. Evidently, the lack of baseline studies and documented information on the impacts of these salt works remains the biggest hindrance to the design of environmentally sound and sustainable salt works management systems, as well as establishment of key environmental audit guidelines for these expansive industries. The few studies conducted within the salt works only assessed the socio-economic impacts of the salt works on the local communities (Ochiewo, 2004). Therefore, a comprehensive assessment of the salt works in relation to impacts on the mangrove ecosystems and the associated flora and fauna, as well as to the overall impacts on the environment, is long overdue. Therefore, the present study aimed to assess the impacts of the hyper saline waste-brine discharge on the environment using mangrove crabs as the key macro-invertebrates indicators. crabs are among benthic macro-invertebrates that are impacted by the physical, chemical, and biological conditions of the environments due to their limited ability to escape pollution (Ngo-Massou *et al.,* 2012), and therefore, present very good indicators of the quality of the aquatic environments (Rader & Reed, (2005). Furthermore, they exhibit stress related to the effects of both short and long term pollution events, and they may also show the cumulative impacts of pollution.

MATERIALS AND METHODS

Study Area

The study was conducted at two areas in Gongoni-Kurawa area, north coast of Kenya adjacent to the salt works as shown in the Fig. below, namely: Marereni and Kurawa. These are home to some of the biggest salt works, mangrove and benthic macro-invertebrates such as crabs of along this coast. Marereni is an area that is populated with people and whose geographical coordinates are 2° 52' 9" South, 40° 8' 44" East, whereas Kurawa is a semi-populated area with latitude and longitude coordinates of 2°41'41.28"S and 40°9'35.58"E.

Fig. 1: Map showing the sites for data collection, Marereni and Kurawa along Malindi-Ungwana Bay, in North Coast Kenya.

Data Collection

Assessments were conducted for a total of five months between February and June of the year 2015 in the two sampling stations: Marereni and Kurawa. At the two stations, crab samples were collected at both neap and spring tide. Crab sampling was done using a 1m² (1m x 1m) wooden quadrat at each site (outlet and inlet area) at the littoral zones. In order to give a representative data 10 replicate sampling locations were randomly chosen at a distance of 0-10m horizontally along the water channels that flows into the ocean and then 0-10m vertically to identify the species type, density, richness and diversity. The crab samples were hand-picked while some were scoped. The crabs were washed through a sieve, sorted and identified to species level according to Richmond, (2011) in situ and others packed in zipped paper bags and labelled depending on the site collected; and preserved in iced cooler box and taken to a laboratory for further identification according to Richmond (2011). At the laboratory the crabs were removed and counted and the number recorded based on the species type. The crab size was also determined by measuring the carapace length using a vainer calliper to the nearest 0.1centimetres. Only the record of the four most abundant crab species in both the sites was used to determine the size frequency distribution of the crabs.

Data Analysis

Data analysis was carried out based on the random sample collected during the study. Means, Standard Errors and tables were used for descriptive statistics. Data analysis was based on species level in order to provide greater resolution of selectivity and potential overlap among sites. Logistic regression was used to estimate coefficients (parameter estimates), standard error of the coefficients, z-values and p-values. These sets of parameter estimates, gave nonparallel lines for the response values. The taxa richness (for higher classification level), Shannon-Wiener diversity index -, and dominance index were used in order to reduce the multivariate (multi-taxa) complexity of the data into a single (or small number of indices) that were evaluated for each sample. Size distribution by species was established from

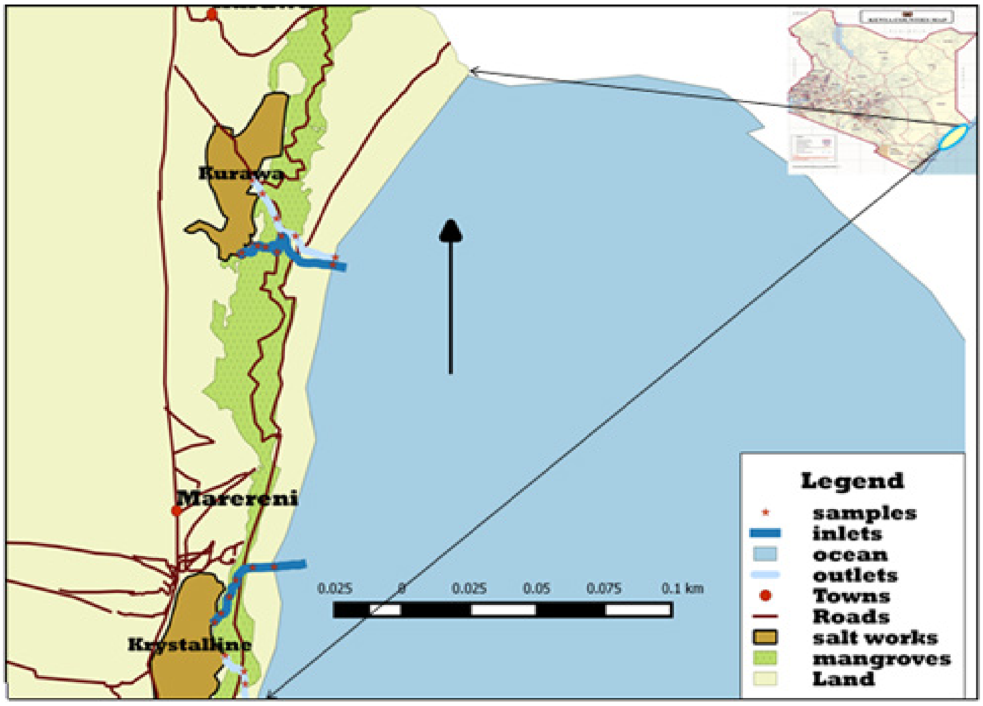


Fig. 1: Map showing the sites for data collection, Marereni and Kurawa along Malindi-Ungwana Bay, in North Coast Kenya.

the sampled catch using standard length measurements. Macro invertebrates species composition data was used to determine species abundance between the two sampling station; of Kurawa and Marereni.

RESULTS

Distribution of Crabs

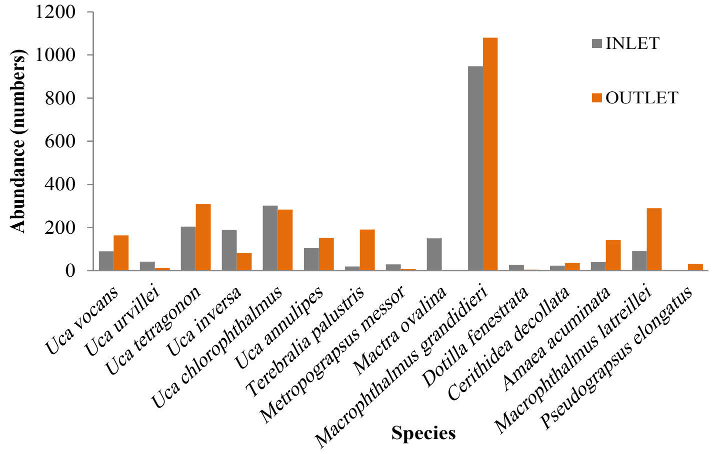
A total number of 34 crab species of 17 families were captured at Marereni and Kurawa (Table 1). A total of 10 specific species were present at both the inlet and outlet both in Kurawa and Marereni. Marereni and Kurawa inlet with 24 species recorded the highest while Kurawa outlet with 19 species recorded the least. Marereni outlet recorded 21 species. Species from family Littorinidae, Macrophthalmidae, Mactridae, Ellobiidae and Grapsidae were not recorded in Kurawa outlet compared to Marereni.

Table 1: Families and macro-invertebrate species obtained at Marereni and Kuruwa area (Inlet and Outlet) with + showing presence

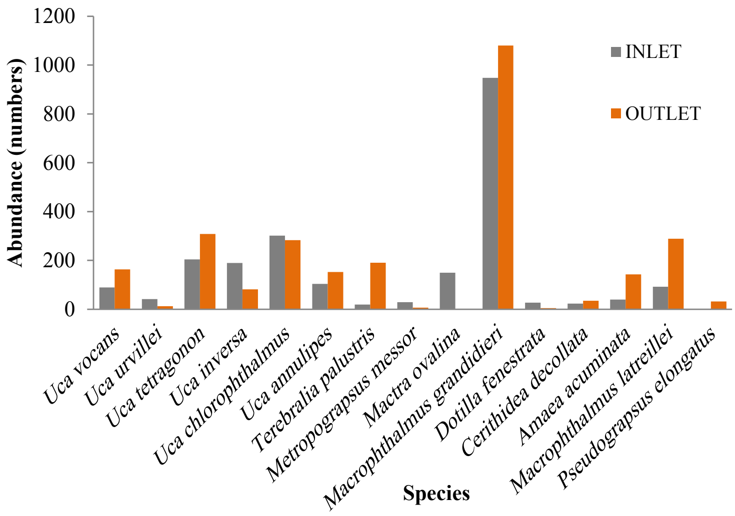
Family	Species	Marereni		Kurawa	
		Inlet	Outlet	Inlet	Outlet
	Alpheus sp	+		+	+
Epitoniidae	*Amaea acuminata*	+	+	+	+
Cerithiidae	*Rhinoclavissinensis*			+	+
	Cerithedea decollata		+		
	Diola lauta	+		+	
Diogenidae	*Clibanarius virescens*			+	+
	Diogenes avarus		+		
Dotillidae	*Dotilla fenestrate*	+	+	+	+
Grapsidae	*Metopograpsus messor*		+	+	+
	Llyograpsus paludicola	+	+		
Lucinidae	*Anodontia edentula*	+			
Gecarcinidae	*Cardisoma carnifex*	+			+
Potamididae	*Terebralia palustris*	+	+	+	+
	Cerithidea decollata	+		+	
Sesarmidae	*Sesarmops impressus*		+	+	+
	Chiromantes eulimene	+	+	+	+
	Neosarmatium meinerti	+	+	+	
Littorinidae	*Littoraria scabra*	+	+		
	Littoraria undulate	+	+		
	Littoraria glabrata			+	
Macrophthalmidae	*Macrophthalmus latreillei*	+		+	
	Macrophthalmus grandidieri	+	+	+	+
Mactridae	*Mactra ovalina*		+	+	
Ellobiidae	*Melampus sp*	+		+	
Varunidae	*Pseudograpsus elongate*	+	+		+
Portunidae	*Scylla serrate*	+	+	+	+
Ocypodidae	*Uca annulipes*	+	+		+
	Uca chlorophthalmus	+	+	+	+
	Ocypode ceratophthalmus			+	
	Uca inversa	+	+	+	+
	Uca tetragonon	+	+	+	+
	Uca urvillei	+	+	+	+
	Uca vocans	+	+	+	+

Species Abundance

A total of fifteen most dominant crab species was captured at the two sampling sites Fig. 1. Kurawa posted nine species compared to five at Marereni. At Kurawa *Macrophthalmus grandidieri* with 1080 number of crabs was the most dominant in both the stations while *Mactra ovalina* and *Pseudograpsus elongatus* with no representation in the outlet and inlet respectively had the least crabs (Fig. 2a). At Marereni, *M. grandidieri* and *Mactra ovalina* with 639 and no crabs was the highest and the lowest respectively (Fig. 2b).



(a)



(b)

Fig. 2 : Dominant crab species at Kurawa (a) and Marereni (b) as from February to July 2015

Size-frequency Distribution

Generally *M. grandidieri*, *U. tetragonon*, *U. chlorophthalmus* and *M. latreillei* recorded the largest number in samples in every station as *U. tetragonon* recorded the least count.

In Kurawa inlet most recorded crabs were under the class interval 1-1.5 (cm); *M. grandidieri* 423, *U. chlorophthalmus* 115, *M. latreillei* 32 and *U. tetragonon* 67 number of species, while *U. tetragonon* recorded the least number under the class intervals 0-0.5 and 2.0-2.5 cm (Fig. 2).

At Kurawa outlet most of the crabs recorded were under the class interval 0.5-1.0 and 1.0-1.5 (cm). The crab *M. grandidieri*

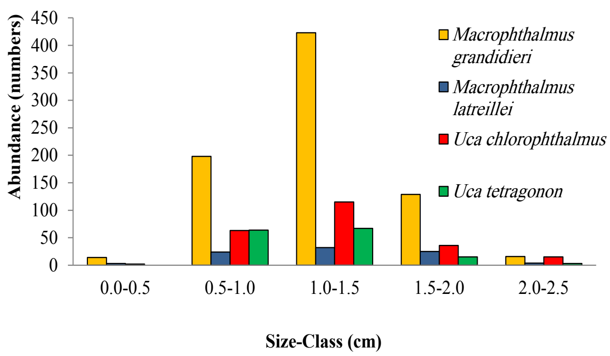


Fig. 3: The size distribution in centimetres of the four most captured crab species in Kurawa inlet.

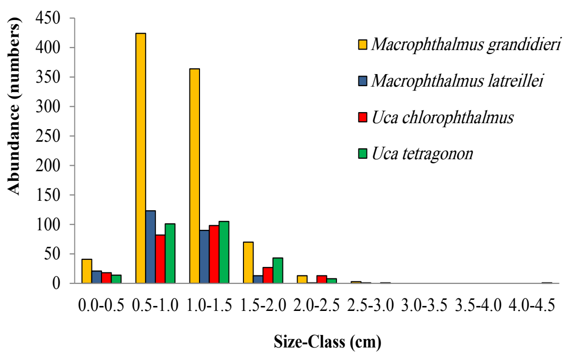


Fig. 4: The size distribution in centimetres of the four most captured crabs species in Kurawa outlet.

recorded the largest number 423 and 364 in the two class intervals respectively (Fig. 4).The lowest number of all species was recorded under the class interval 3.0-3.5 cm and above; which constituted only 0.5% in the frequency distribution.

At Marereni inlet, most crabs were caught under the class interval 0-2.5 (cm) with *M. grandidieri* crab specie having the highest record; 433. Very few numbers of specie *U. chlorophthamus* about 1% were recorded under class intervals above 0-2.5cm (Fig. 5).

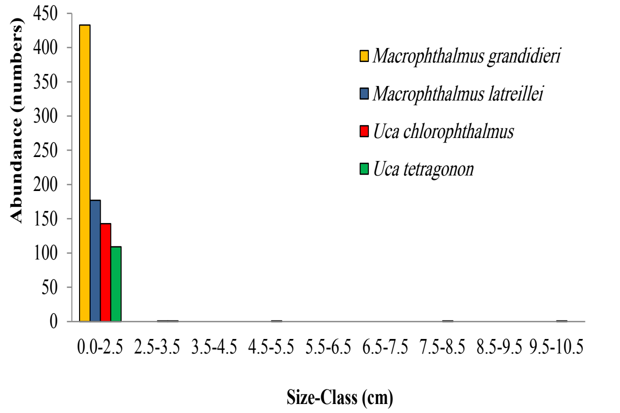


Fig. 5: The size distribution in centimetres of the four most captured macro invertebrate species in Marereni inlet.

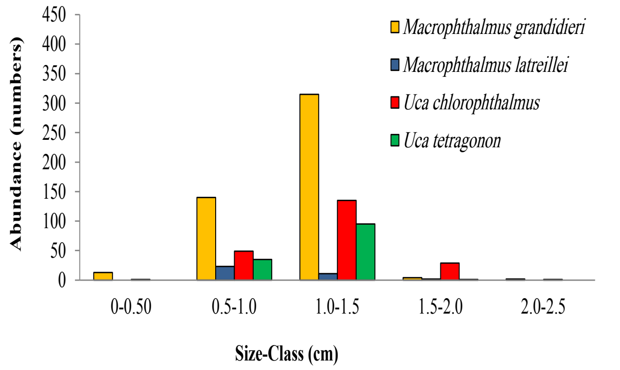


Fig. 6: The size distribution in centimetres of the four most captured macro invertebrate species in Marereni outlet.

In Marereni outlet, largest number of crabs was caught in the class interval 1.0-1.5 cm consisting of 315 *M. grandidieri*, 135 *U. chlorophthalmus* and 95 *U. tetragonon* (Fig. 8). A total of 13 crabs was caught under class interval of 0-0.5 cm while 3 crabs, two *M. grandidieri* and single *Uca chlorophthalmus* were recorded under the class interval of 2.0-2.5 cm.

Diversity Index

Table 2 : Response information used in the nominal logistic regression based on the 16 most abundant crab specie samples in the Kurawa-Marereni area of Malindi.

Diversity Index	Kurawa		Marereni	
	Inlet	Outlet	Inlet	Outlet
Shannon-Wiener	0.8912	0.8462	0.9785	1.0262
Maximum Diversity	1.1461	1.1461	1.0414	0.9542
Evenness	0.7776	0.7383	0.9396	1.0754

Logistic Regression

A total of 34 crab species were identified and enumerated in the Kurawa-Marereni area of Malindi but only 16 species with a total count of more than 200 were used in the logistic regression analysis. The most abundant species was *M. grandidieri* followed by *U. chlorophthalmus*, *T. palustris*, *U. tetragonon* and *A. acuminata*. The most suitable predictors of the species abundance were found to be the site (with two levels; Kurawa and Marereni), station (with two levels; inlet and outlet) and the tides (Neap and spring).

The first set of estimated logits, labelled Logit (1), are the parameter estimates of the change in logits of *U. urvillei* relative to the reference species (*U. vocans*). The p-values of <0.0005 for station, indicate that there is sufficient evidence that a change in station from inlet to outlet affected the occurrence of *U. urvillei* as compared to *U. vocans*. The negative coefficient (-3.61) for station indicates there tend to be less *U. urvillei* at the outlet as compared to the inlet. The estimated odds ratio of 0.03 implies that the odds of occurrence of *U. urvillei* at the outlet, is only 3% as compared to the inlet when site and tides are held constant (Table 3).

The p-value for site (<0.0005) indicate that there is sufficient evidence to conclude that a change in site from Kurawa to Marereni affected the occurrence of *U. urvillei* as compared to *U. vocans*. The positive coefficient (1.20) for site indicates there tend to be more *U. urvillei* at Marereni as compared to Kurawa.

The estimated odds ratio of 3.3 implies that the odds of occurrence of *U. urvillei* at Marereni is about 3 times higher than Kurawa when site and tide are held constant.

The p-value for tides (0.263) indicates that there is insufficient evidence to conclude that a change in tide cycle from neap to spring affected the occurrence of *U. urvillei* as compared to *U. vocans*. The positive coefficient (0.18288) for tides indicates there tend to be more *U. urvillei* at spring tides as compared to neap tides. The estimated odds ratio of 1.2 implies that the odd of occurrence of *U. urvillei* at spring tides is almost equal neap tides when site and station are held constant.

Table 3: Nominal logistic regression results showing the probability and odds ratio of different crab species with U. vocans as the reference even.

Predictor	Coef	SE Coef	Z	p-value	Odds Ratio	95% CI	
						Lower	Upper
Logit 1: (U. urvillei/U. vocans)							
Constant	-0.96219	0.07530	-12.78	<0.0005			
Outlet	-3.60498	0.21146	-17.05	<0.0005	0.03	0.02	0.04
Marereni	1.20202	0.13566	8.86	<0.0005	3.33	2.55	4.34
Spring	0.18288	0.16333	1.12	0.263	1.20	0.87	1.65
Logit 2: (U. tetragonon/U. vocans)							
Constant	0.41962	0.04533	9.26	<0.0005			
Outlet	-0.26164	0.05027	-5.20	<0.0005	0.77	0.70	0.85
Marereni	1.59419	0.07726	20.63	<0.0005	4.92	4.23	5.73
Spring	1.62580	0.06452	25.20	<0.0005	5.08	4.48	5.77
Logit 3: (U. inversa/U. vocans)							
Constant	-0.00679	0.05124	-0.13	0.895			
Outlet	-2.13681	0.06255	-34.16	<0.0005	0.12	0.10	0.13
Marereni	1.30951	0.08532	15.35	<0.0005	3.70	3.13	4.38
Spring	2.47296	0.07161	34.53	<0.0005	11.86	10.30	13.64
Logit 4: (U. chlorophthalmus/U. vocans)							
Constant	0.54079	0.04381	12.34	<0.0005			
Outlet	-0.31533	0.04833	-6.53	<0.0005	0.73	0.66	0.80
Marereni	1.66802	0.07584	21.99	<0.0005	5.30	4.57	6.15
Spring	2.18751	0.06294	34.76	<0.0005	8.91	7.88	10.08
Logit 5: (U. annulipes/U. vocans)							
Constant	0.40732	0.04919	8.28	<0.0005			
Outlet	-0.78605	0.05810	-13.53	<0.0005	0.46	0.41	0.51
Marereni	0.85807	0.08903	9.64	<0.0005	2.36	1.98	2.81
Spring	-0.62971	0.09882	-6.37	<0.0005	0.53	0.44	0.65
Logit 6: (T. palustris/U. vocans)							
Constant	0.60076	0.04608	13.04	<0.0005			
Outlet	0.63521	0.05091	12.48	<0.0005	1.89	1.71	2.09
Marereni	1.26588	0.07690	16.46	<0.0005	3.55	3.05	4.12
Spring	-0.59512	0.07213	-8.25	<0.0005	0.55	0.48	0.64
Logit 7: (S. impressus/U. vocans)							
Constant	-7.99744	0.35593	-22.47	<0.0005			
Outlet	3.71150	0.29465	12.60	<0.0005	40.92	22.97	72.89
Marereni	6.17567	0.21990	28.08	<0.0005	480.91	312.52	740.01
Spring	-2.53461	0.29751	-8.52	<0.0005	0.08	0.04	0.14
Logit 8: (P. elongatus/U. vocans)							
Constant	-2.17558	0.12415	-17.52	<0.0005			
Outlet	2.14976	0.12776	16.83	<0.0005	8.58	6.68	11.02
Marereni	-0.43898	0.14061	-3.12	0.002	0.64	0.49	0.85
Spring	-9998.80	4746.06	-2.11	0.035	0.00	0.00	0.00

All the species showed evidence of differences from *U. vocans* between site, station and tide cycle except *D. fenestrata* between tide cycles. The odds ratio against *U. vocans* was highest for *S. impressus* between sites (480), *M. ovalina* between tide cycles (172) and *D. fenestrata* between stations (44).

Table 3: (Continued.)Nominal logistic regression results showing the probability and odds ratio of different crab species with U. vocans as the reference even.

Predictor	Coef	SE Coef	Z	p-value	Odds Ratio	95% CI	
						Lower	Upper
Logit 9: (M. messor/U. vocans)							
Constant	-1.25172	0.08442	-14.83	<0.0005			
Outlet	-2.24273	0.15176	-14.78	<0.0005	0.11	0.08	0.14
Marereni	0.43433	0.18813	2.31	0.021	1.54	1.07	2.23
Spring	-0.61441	0.25115	-2.45	0.014	0.54	0.33	0.88
Logit 10: (M. ovalina/U. vocans)							
Constant	-1.19818	0.08268	-14.49	<0.0005			
Outlet	-4.97077	0.12078	-41.16	<0.0005	0.01	0.01	0.01
Marereni	-1.45208	0.13482	-10.77	<0.0005	0.23	0.18	0.30
Spring	5.14769	0.09633	53.44	<0.0005	172.03	142.44	207.78
Logit 11: (M. latreillei/U. vocans)							
Constant	0.79768	0.04384	18.20	<0.0005			
Outlet	-0.64202	0.04943	-12.99	<0.0005	0.53	0.48	0.58
Marereni	1.84998	0.07665	24.14	<0.0005	6.36	5.47	7.39
Spring	1.06248	0.06534	16.26	<0.0005	2.89	2.55	3.29
Logit12:(M. grandidieri/U. vocans)							
Constant	2.64972	0.03905	67.85	<0.0005			
Outlet	-0.60249	0.04413	-13.65	<0.0005	0.55	0.50	0.60
Marereni	1.32654	0.07333	18.09	<0.0005	3.77	3.26	4.35
Spring	1.78184	0.06025	29.57	<0.0005	5.94	5.28	6.69
Logit 13: (D. fenestrata/U. vocans)							
Constant	-3.71402	0.12394	-29.97	<0.0005			
Outlet	1.60102	0.11487	13.94	<0.0005	4.96	3.96	6.21
Marereni	3.77995	0.10328	36.60	<0.0005	43.81	35.78	53.64
Spring	-0.02540	0.10810	-0.23	0.814	0.97	0.79	1.20
Logit 14: (C. decollata/U. vocans)							
Constant	-0.55714	0.05011	-11.12	<0.0005			
Outlet	-0.74764	0.05259	-14.22	<0.0005	0.47	0.43	0.52
Marereni	3.05420	0.07859	38.86	<0.0005	21.20	18.18	24.74
Spring	2.18144	0.06663	32.74	<0.0005	8.86	7.77	10.09
Logit 15: (A. acuminata/U. vocans)							
Constant	-0.95301	0.05728	-16.64	<0.0005			
Outlet	1.39259	0.06063	22.97	<0.0005	4.03	3.57	4.53
Marereni	2.15333	0.07692	27.99	<0.0005	8.61	7.41	10.02
Spring	1.07519	0.06568	16.37	<0.0005	2.93	2.58	3.33

The Log-Likelihood from the maximum likelihood iterations with G-statistic (the test statistic for testing the null hypothesis that all the coefficients associated with predictors equal 0 versus them not all being zero) was 48.4 with a p-value of <0.0005, indicating that at a = 0.05, there is sufficient evidence for at least one coefficient being different from 0 (Table 4).

Pearson and deviance goodness-of-fit tests gave p-values 0.730 and 0.640 respectively, indicating that there is evidence to suggest the model fits the data. If the p-value is less than selected a-level, the test would indicate that the model does not fit the data.

Table 4: *The Log-Likelihood and Goodness of Fit test for the nominal logistic regression model of the crab species.*

Log-Likelihood = -201176.098			
Test that all slopes are zero: G = 48399.994			
DF = 45			
p-value = <0.0005			
Goodness of Fit Test:			
Method	**Chi-Square**	**DF**	**p-value**
Pearson	5.97083E+14	270	0.730
Deviance	1.84772E+05	270	0.640

DISCUSSION

Distribution and Diversity

This study provided a starting point for the distribution, abundance and diversity of benthic fauna of mangroves in Kurawa-Marereni area. The distribution of crabs showed relationships to salinity and degree of tidal in unration. The dominant species shifted throughout the study period. These observed differences among the crabs may have been related to changes in water quality which affect the environment causing change. The effect of the brine waste discharge in water quality of the water channels in Kurawa and Marereni were also evident in the crab communities, which exhibited reduced species numbers and individuals per species per site based on the logistic regression test done. Such species can therefore be used as indicators of salt intrusion since they can tolerate the hyper-saline water. This is in line with Danoun (2007), who reported that changes in the salinity can play two opposite roles on the marine organisms' existence; it can be of benefit for some of these organisms such as shellfish and at the same time can have an adverse impact on other species. Decrease in the abundance of majority of crabs in this study associated with tides at different stations showed indeed how the brine discharge seasonal alters the abundance of the crabs, since salinity levels change with tidal flows. This was similar to what Savenije of 2006 found.

The change of the salinity levels could probably be caused by brine waste discharge, which has been found to be associated with reduction in the density of less tolerant species (Von Medeazza, 2005), and increase in the density of more tolerant species. Literature (Cohen, 2010; Hossain *et al.,* 2015), also documents that the coastal areas, salinity can be viewed as the major factor limiting species distributions as these vary significantly in relation to the level of salinity.

Water salinity changes also have an influence in the population density of the crabs, causing higher population growth rate. Marine animals inclusive of the crabs are adapted to keep their body salts at a constant level, so that they don't interfere with the metabolism within cells, but significant changes in salinity can cause problems for some and also can negatively affect their growth and reproduction, and ultimately, their survival; which was same with what was found in this study (Orr *et., al* 2005; Doney *et., al* 2012), hence recording different numbers of species at the outlets compared to the inlets. This explains how some of the crabs in this study were able to cope with large salinity fluctuations while others tolerated a narrow range of salinities, hence conquering with the fact that brine constitutes a hyper-saline layer that sinks towards the seabed and due to its greater density imposes great impact on the benthos (Von Medeazza, 2005).

Diversity values in the study area ranged from 0.7383-1.1461. These values suggested that the mangroves ecosystem under which the crabs were examined in this study were heavily polluted and the crab community was under stress due to either natural or anthropogenic factors. This explains perhaps the effect of the present brine discharged from the salt industries along the water channels that affects the crabs' diversity. Lower value of the diversity index is generally interpreted as characteristic of a less assorted population in terms of species as compared to a high value which describes high variety of species in a population. The low value also described a polluted condition in this case, a poor water quality state over time, where depending on the species few (more) tolerant genera dominate the community. Higher values were recorded in normal sea waters (inlets) where few or more specie dominate depending of the tolerant ability.

Maximum diversity recorded in this study at the inlets might be due to more favourable environmental factors, such as low salinity which play a vital role in faunal distribution (El wahab & Hamada, 2012; Kumar & Khan, 2013). The Shannon Wiener's diversity index for the crab species captured in this study was higher in Marereni outlet 1.026 than Marereni inlet 0.979, a case that was different in Kurawa. The diversity value in Kurawa was high in the inlet 0.891 as compared to the outlet 0.846. There was no major difference in terms of species diversity between the two stations (Kurawa outlet/Kurawa inlet). This explains that there are more varied species in Marereni outlet compared to the inlet which could be probably due to the presence of waste brine discharged from the salt industry, thus bringing about the existence of species that can only tolerate high levels of salinity compared to those at the inlet station. A different scenario was observed in Kurawa. Effects of brine on estuarine system have high levels of dissolved solids which allow the formation of a density gradient, especially in low energy systems such as bayous; oil and chlorides are incorporated into sediments near brine discharges (Cooley & Heberger, 2013). This condition severely depressed the abundance and richness of benthic in-fauna

(Ruso *et al.,* 2007). In addition Bryant (1990) documented that the ranges of crab species diversity were greater in Oklahoma streams than in salt Creeks.

Crab Size Distribution

Based on the four most recorded mangrove crabs species, the present study shows that there was significant difference in size in the capture of *M. grandidieri*, *M. latreillei*, *U. chlorophthalmus* and *U. tetragonon*. There was no major difference in size of *M. latreillei* captured. Most small sized crabs of large numbers were recorded at the outlets whereas small sizes of few numbers were recorded at the inlets in all sites. This could be probably due to the presence of the hyper-saline water which could be affecting the growth size of the crabs, thus causing existence of more small sized crabs at the polluted sites and less number of small sized crabs at the unpolluted sites. This is well explained by Conde *et al.,* (2000); although crabs recognitions or adjustments to polluted areas seemed to be high, some differences in size have been seen among populations at different water salinities levels. Studies have also shown that crabs found in hyper-saline lagoons appear to mature at a smaller size than those in fresher riverine areas (Zimmerman *et al*., 2002).

CONCLUSION AND RECOMMENDATION

Based on the objectives, results from this study and available literature, it is concluded that the hyper-saline waste-brine discharge affects the mangrove crab species in several ways: Crab diversity was higher in the inlet (less polluted) as compared to the outlet (more polluted) site. Few numbers of small-sized crab species; *M. grandidieri*, *U. chlorophthalmus*, *U. tetragonon* and M. latreillei, was found at the outlets as those observed at the inlets indicting effect of brine on their growth. Brine discharge seasonally alters the abundance of crabs. There was increase in abundance of crab species; *U. urvillei*, *U. tetragonon*, *U. chlorophthalmus*, *U. inversa*, *M. grandidieri*, *M. latreillei*, *M. ovaina*, *A. acuminata* and *C. decollata* compared to *U. vocans* during spring tide as compared to neap due to their physiological adaptation to high salinity levels. It can therefore be concluded that variation in species diversity, dominance and richness were as a result of spatio-temporal change of water quality. Therefore monitoring of the status and conditions of the crabs in this region was recommended, using the [Before-After Control-Impact] Monitoring]. This information will be helpful to advice the salt works managers of what levels of the brine discharge is affecting the aquatic resources specially the crabs and to what extent.

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