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Metal concentrations in sediments from tourist beaches of Miri City, Sarawak, Malaysia (Borneo Island)

R. Nagarajan[1], M. P. Jonathan[2†], P. D. Roy[3], L. Wai-Hwa[1], M.V. Prasanna[1], S.K. Sarkar[4] and M. Navarrete-López[5]

[1]Department of Applied Geology, School of Engineering and Science, Curtin University, CDT 250, Miri, 98009, Sarawak, Malaysia.

[2]Centro Interdisciplinario de Investigaciones y Estudios sobre Medio Ambiente y Desarrollo (CIIEMAD), Instituto Politécnico Nacional (IPN), Calle 30 de Junio de 1520, Barrio la Laguna Ticomán, Del. Gustavo A. Madero, C.P.07340, México DF., México.

[3]Instituto de Geología, Universidad Nacional Autónoma de México (UNAM), Ciudad Universitaria C.P. 04510, Coyoacan, México DF., México.

[4]Department of Marine Science, University of Calcutta, 35 Ballygunge Circular Road, Calcutta – 700 019, India.

[5]Escuela Nacional de Ciencias Biológicas, Laboratorio Central de Instrumentación, Instituto Politécnico Nacional (IPN), Prol. de Manuel M Carpio y Plan de Ayala, Col. Sto. Tomas, Del. Miguel Hidalgo, C.P.11340, México DF., México.

[†]Corresponding author. Tel.: +52 5557296000 Ext: 52707, 52708; fax: +52 5557296000
E-mail address: mpjonathan7@yahoo.com

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Abstract

43 sediment samples were collected from the beaches of Miri City, Sarawak, Malaysia to identify the enrichment of partially leached trace metals (PLTMs) from six different tourist beaches. The samples were analyzed for PLTMs Fe, Mn, Cr, Co, Cu, Ni, Pb, Sr and Zn. The concentration pattern suggest that the southern side of the study area is enriched with higher concentration of Fe (1821-6097 $\mu g\ g^{-1}$), Mn (11.57-90.22 $\mu g\ g^{-1}$), Cr (51.50-311 $\mu g\ g^{-1}$), Ni (18-51 $\mu g\ g^{-1}$), Pb (8.81-84.05 $\mu g\ g^{-1}$), Sr (25.95-140.49 $\mu g\ g^{-1}$) and Zn (12.46–35.04 $\mu g\ g^{-1}$). Compared to the eco-toxicological values, Cr > Effects range low (ERL), Lowest effect level (LEL), Severe effect level (SEL); Cu > Unpolluted sediments, ERL, LEL; Pb > Unpolluted sediments and Ni > ERL and LEL. Comparative results with other regions indicate that Co, Cr, Cu, Ni and Zn are higher, indicating an external input rather than natural process.

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Miri city is located in the northern part of Sarawak, Malaysia, which also forms part of the Borneo Island. The coastal region is enriched with fossil fuels, mainly petroleum and the city is also the birth place of oil industry for Malaysia during 1900s. The other principal industries which dominate this region are the fast growing timber processing and palm oil production. The Baram river drains in the northern part of the study area and the average discharge is 1590 m^3/s (Sandal, 1996) and, likewise the Miri river criss-crosses the city and drains in the South China Sea. The beaches in this region are often vulnerable to oil pollution due to the presence of numerous oil platforms in the offshore region as well as the cargo vessels in this part. Previous studies also indicate that the drainage effluents which drain and accumulate into the South China Sea is stamped with huge residential properties (Ho and Kumar, 2011; Ho and Quan, 2012). The movement of cargo vessels, transportation of industrial products (timber logs), and the numerous coastal developments have documented to higher level of contamination in the beaches of Miri (Minton and Peter, 2009). The annual mean rainfall in the study area varied from 2247 to 3499 mm in 1981-1990 (avg. 2715 mm), 2228 to 3265 mm for the period of 1991-2000 (avg. 2682 mm) and 2516 to 3267 mm through 2001-2010 (avg. 2916) respectively (Jabatan Meterologi, Malaysia, 2009) . The beaches in most part of this region is dominated by sandy texture with open stands of *Casuarina equisetifolia*, coarse grasses and shallow swamps running parallel to the coast in most places.

Recently, Miri is also focusing on development of tourism in this region and is also occupied by natural parks, exotic coral reefs, beaches and during 2011 nearly 3,795,373 visitors has visited Sarawak State alone (Sarawak Tourism Quick Facts, 2011). The city is also dominated by narrow beaches for nearly 25 km in the southern part of the Baram delta region facing the South China Sea, where the waves are relatively small and low in energy predominantly in micro-tidal range (Lambiase et al., 2002). Geologically, tertiary sandstone reservoirs dominate the region (Johnson et al., 1989).

The present study attempts in documenting a baseline data related to the concentration pattern of partially leached trace metals (PLTMs) in sediments from the tourist beaches due to the growing tourist activities in the Miri City.

Sediment sample collection in the inter-tidal region of the beaches was done during 2011 based on the tourist population history visiting the particular locations. Surface sediment samples (N = 43) were collected from 6 tourist beaches, viz Lutong Beach (LB) (n = 9), Park Everly Beach (PE) (n = 4), Tanjong Lobang Beach (TL) (n = 8), Esplanade Beach (EP) (n = 9), Hawaii Beach (HB) (n = 8) and Bungai Beach (BU) (n = 5) respectively (Fig. 1a-f). The modified EPA 3051A method was used with autoclave digestion in determining the concentration of PLTMS of Fe, Mn, Co, Cr, Cu, Ni, Pb, Sr and Zn (Navarrete-López et al., 2012). 0.5 g of sediment sample was digested for nearly 40 minutes with HNO_3 + HCl (9:3 ratio) acid mixture in a PFA [Poly(tetrafluoroethylene)] vessel at 119 ±1.5°C and the final solution was made upto 50 ml after filtration. The solution was directly introduced in the ICP-OES (*Varian 720 ES*) to measure PLTMs: Fe, Mn, Co, Cu, Ni, Sr, Zn, whereas, Cr, Pb were measured by AASGF (*Varian Spectra AA220 G7A110*). The reagents used in the present analysis were of analytical grade (J.T. Baker). The precision of the analysis was done using Standard Reference Material (SRM No.691029) Loam Soil B (soil sample) and it was run after every 5th samples and the accuracy level was within the acceptable limits. Statistica (Version 8) was used to generate the correlation matrix for the PLTMs in order to identify the relationship between the metals.

The concentration pattern of PLMTs along the beaches of Miri City is presented in figure 2a-i. Likewise, in order to verify the existence of common source involving the PLTMs, correlation matrix results are presented in the text version and the comparison of the analyzed elements with that of eco-toxicological values are presented in table 1 respectively.

General distribution pattern of PLTMs indicate that mostly the beaches in the southern part (EB, HB, BB) is enriched by majority of metals (except Co, Cu) which might be due to the long shore currents transporting the materials to the southern part as this coastal region is actively eroded throughout the year (Cheong, 2000; James, 1984). The above inference is also supported by the huge cargo ship traffic, Miri River (draining in the coastal region), smaller channels (> 15) that brings in domestic, industrial and agricultural effluents into the coastal beaches. Our results also indicate that the concentration pattern of PLTMs in the study area varies depending on the nature of input through the local channels that drains in the region. The concentration pattern of PLTMs indicates higher values of Fe in EP (avg. 3030 μg g^{-1}), HB (avg. 4408 μg g^{-1}) and BB (avg. 3625 μg g^{-1}) and Mn in EP (avg. 26.25 μg g^{-1}), HB (avg. 52.94 μg g^{-1}) and BB (avg. 34.89 μg g^{-1}) respectively. The use Fe in construction, transportation industries indicates that it is easily in contact with either fresh or marine water and as it is chemically reactive, the process of corrosion is very high, which in turn accumulates in the sediments. Moreover, naturally Fe leaches from the clastic sediments also contributing Fe content to beach sediments which is common phenomenon of the beaches of Miri particularly, in Tanjong Labung and Bungai beaches. The presence of electrical, pigment, ceramics and fertilizer plants indicates the use of Mn in higher level and the discharges from these will also increase the concentration level (eg. Kabata-Pendia and Pendias, 2001).

PLTM Co indicates higher values in TL (avg. 37.46 µg g^{-1}) and EP (avg. 20.40 µg g^{-1}) than other beaches. Likewise, Cr indicate that all the beaches [avg. (in µg g^{-1}) LB: 85.33; PE: 100.25; TL: 140.13; EP: 82.83; HB: 253.75; BB: 95.00] in this region are above the permissible limits (except ERM). The higher concentration of the above metals is mainly due to the electroplating, antifouling paints (in ships), leather tanning, varnishes, wood (use of preservatives), automobile industries, magnetic & sludges and the deforested agricultural fields in the upland region (eg. Alloway 1995; Maata and Singh 2008; Maján et al., 2001; Nicholson et al., 2003; Nriagu and Pacyna 1988). PLTM Ni indicates higher values in the beaches of LB (avg. 18.78 µg g^{-1}), PB (avg. 23.50 µg g^{-1}), EP (33.89 µg g^{-1}), HB (40.63 µg g^{-1}) and BB (30.80 µg g^{-1}) than ERL and LEL values. Higher values of PLTM Pb are also reported from LB (avg. 19.67), HB (avg. 18.61 µg g^{-1}), which are well below the eco-toxicological values. Some peak values of 84 and 42 µg g^{-1} (in EP & BB) PLTM Pb is mainly due to the local vehicular traffic, effluents and also due to the proximity of the sampling point. PLTM Zn in the study area varies depending on site, as high (PE: 28.31; EB: 27.50; BB: 24.00 µg g^{-1}) and low values (LB: 17.93; TL: 19.89; HB: 18.66 µg g^{-1}) are observed in the beach sediments and they are within the permissible limits. Anyhow, the anthropogenic input of Zn cannot be neglected as it is used in various industries for alloys, chemical production and in steel components. With reference to PLTM Sr, the southern region dominates with higher averages in EB (91.25 µg g^{-1}), HB (51.06 µg g^{-1}), BB (84.80 µg g^{-1}) and even though there is no specific values for comparison the use of Sr in paints, glass, television sets cannot be ruled out. The higher concentrations could also be due to the mobile nature of Sr in the deforested region and is also leached down from the calcareous beds which are subsequently transported by the smaller channels (eg. Brent and Harding, 1995). The rapid development of Miri city compared with steady increase of population result in enrichment of both inorganic and organic pollutants which are detrimental for the living organisms. The carbonate rich regions could have the easily mobile elements absorbed, and subsequently the bioavailability to organisms also increases naturally (eg. Belzile et al., 1989; Li et al., 2001). The concentration pattern of the PLTMs is also closely related to the hydrodynamic condition of the coastal region due to the southern currents.

The comparative results for the beach sediments with that of other selected beaches and bay regions around the World suggest a four-fold increase of Co, Cr, Cu; two-fold increase of Ni, Pb and Zn in the study area indicating that mostly the elements are anthropogenic due to the increased human activities in the region (Table 1). This is also due to the non-proper planning and uncontrolled discharge of contaminated industrial sewage and domestic sludge into the drains which gets accumulated in time and then drains into the open ocean during monsoon seasons.

The above inference is very well supported by their individual association Fe *vs* Mn (r^2 = 0.90), its scavenging capacity which is observed by the correlation of Fe *vs* Ni (r^2 = 0.79), Mn *vs* Ni (r^2 = 0.76) and Sr *vs* Fe (r^2 = 0.48), Mn (r^2 = 0.42, Ni (r^2 = 0.44) indicating that they are mainly from external input (eg. Gao et al., 2002; Jain and Sharma 2006). The association of Sr could be related to natural and anthropogenic source which is dominated by the geologically calcareous rocks in this region. The separate association of Cu *vs* Zn (r^2 = 0.72) clearly suggests that they are from external sources.

Even though various control measures are adopted, the human activities still impact the coastal beach quality and there is an urgent need to protect the beaches of Miri in Sarawak, Malaysia before it goes out of control.

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Table 1

Table 1 Comparison of elemental concentration with that of eco-toxicological values used for evaluating aquatic environments.

Elements/ Areas	Extraction Type	Fe	Mn	Co	Cr	Cu	Ni	Pb	Sr	Zn
Present study										
Lutong Beach (LB) (avg.)	$HCl:HNO_3$	1888	12.83	12.64	85.33	28.81	18.78	12.88	62.00	17.93
Park Everly Beach (PE) (avg.)	$HCl:HNO_3$	2948	19.95	17.35	100.25	71.31	23.50	11.65	67.25	28.31
Tanjong Lobang Beach (TL) (avg.)	$HCl:HNO_3$	1771	12.65	37.46	140.13	31.66	14.71	10.48	28.00	19.89
Esplande Beach (EP) (avg.)	$HCl:HNO_3$	3030	26.35	20.40	82.83	43.34	33.89	19.67	91.25	27.50
Hawaii Beach (HB) (avg.)	$HCl:HNO_3$	4408	52.94	16.26	253.75	32.24	40.63	18.61	51.06	18.66
Bungai Beach (BB) (avg.)	$HCl:HNO_3$	3625	34.89	14.69	95.00	43.76	30.80	14.04	84.80	24.00
Other Beaches & Bays										
[1]Chennai Beach, India (avg.)	$HCl:HNO_3$	442	46.84	5.05	14.10	4.05	9.17	19.77	-	9.89
[2]Gulf of Mannar, India (avg.)	HOAc	255	108	3.00	5.4	-	3.1	6.3	-	16.6
[3]Acapulco Beach, Mexico (avg.)	HCl	6549	90.47	-	17.86	6.33	3.41	3.73	-	19.04
[4]Tokyo Bay, Japan	HF	3770	1098		77.3	53.47	32.63	50.68	-	322
[5]Gulf of Aqaba (Red Sea)	HF	40-2840	53-655	21-56	15-186	7-27	19-76	83-225	-	31-260
[6]Hangzhou Bay, China (avg.)	HF	3833	85	16.85	79.76	31.11	40.32	23.04	144.11	97.54
[7]Langkawi Island, Malaysia (avg.)	HNO_3	-	-	42.67	9.67	6.00	26.67	63.67	-	34.67
Eco-toxicological values										
[8]Unpolluted Sediments		-	770	-	-	33	52	19	-	95
[9]ERL		-	-	-	81	34	20.9	46.7	-	150
[10]ERM		-	-	-	370	270	51.6	218	-	410
[11]LEL		-	460	-	26	16	16	31	-	120
[12]SEL		-	1110	-	110	110	75	250	-	820

All values are expressed in ($\mu g\ g^{-1}$); [1]Santhiya et al., 2011; [2]Jonathan and Ram-Mohan, 2003; [3]Jonathan et al., 2011; [4]Fukushima et al., 1992; [5]Abu-Hilal, 1987; [6]Shengfa et al., 2012; [7]Razi-Idris et al., 2009; [8]Unpolluted sediments (Salomons and Förstner 1984); [9]ERL – Effects range low (Long et al., 1995); [10]ERM – Effects range medium (Long et al., 1995); [11]LEL - Lowest effect level (USEPA, 2001); [12]SEL - Severe effect level (USEPA, 2001).

Figure 1

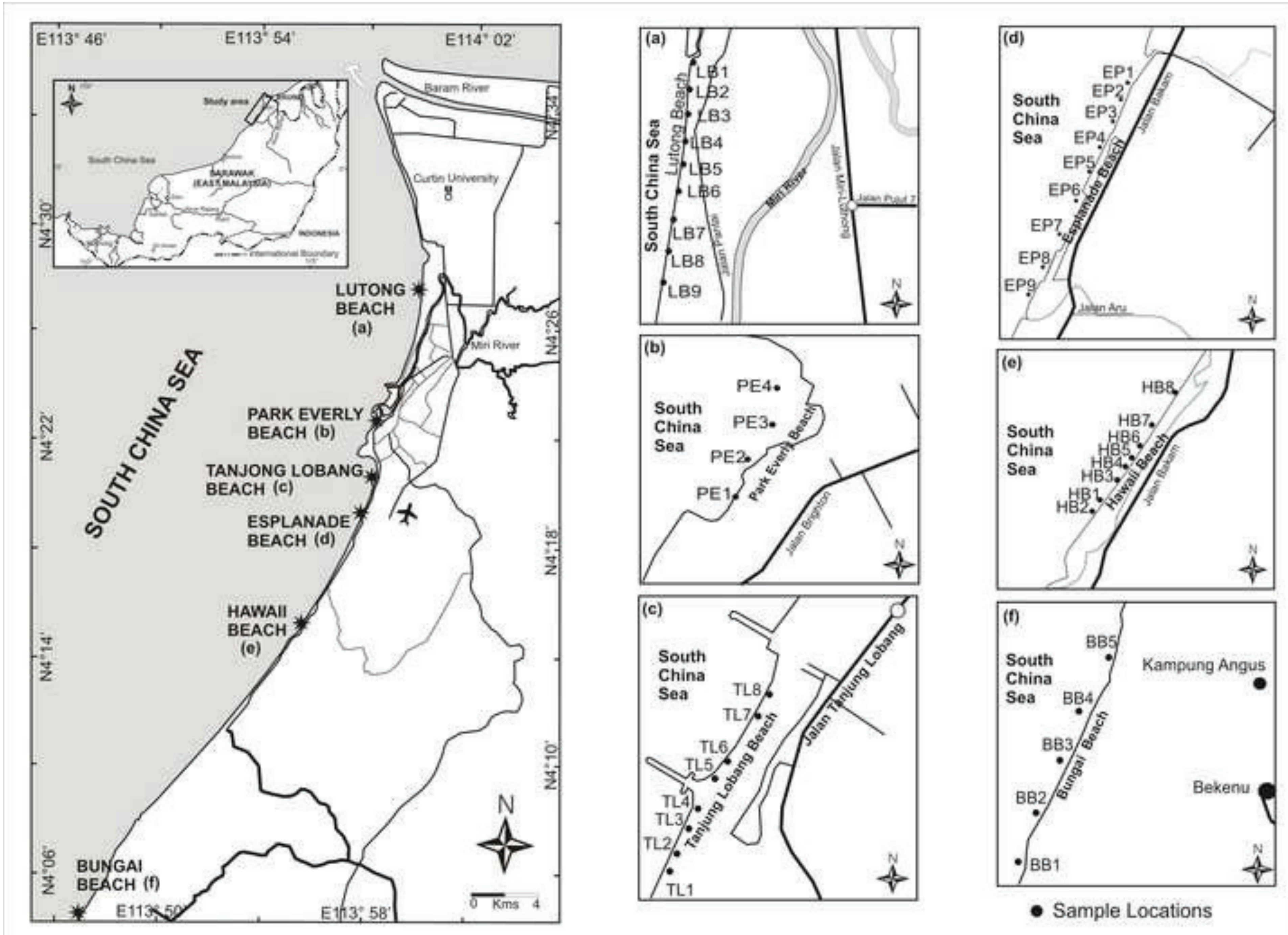
E113° 46'
E113° 54'
E114° 02'
Baram River
Curtin University
LUTONG BEACH (a)
Miri River
PARK EVERLY BEACH (b)
TANJONG LOBANG BEACH (c)
ESPLANADE BEACH (d)
HAWAII BEACH (e)
BUNGAI BEACH (f)
SOUTH CHINA SEA
N4°30'
N4°22'
N4°14'
N4°06'
N4°34'
N4°26'
N4°18'
N4°10'
E113° 58'
0 Kms 4
N
(a)
South China Sea
Lutong Beach
LB1
LB2
LB3
LB4
LB5
LB6
LB7
LB8
LB9
Miri River
Jalan Miri-Lutong
(b)
South China Sea
PE1
PE2
PE3
PE4
Park Everly Beach
(c)
South China Sea
TL1
TL2
TL3
TL4
TL5
TL6
TL7
TL8
Tanjung Lobang Beach
Jalan Tanjung Lobang
(d)
South China Sea
EP1
EP2
EP3
EP4
EP5
EP6
EP7
EP8
EP9
Esplanade Beach
(e)
South China Sea
HB1
HB2
HB3
HB4
HB5
HB6
HB7
HB8
Hawaii Beach
(f)
South China Sea
BB1
BB2
BB3
BB4
BB5
Bungai Beach
Kampung Angus
Bekenu
Sample Locations

Figure 2
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