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Analysis of effluent discharge in to natural forest in Bangladesh

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Abstract: Natural forest resources like Sundarbans mangroves in Asia including Bangladesh, India, and East Africa previously contained a much fuller range of species (Seidensticker, and Hai, 1983; Khan, 1997). In the Southeast Asian region, species diversity of mangroves was previously much higher, where approximately two-thirds of all species and 70% of the major vegetation types with 15% of terrestrial species in the Bangladesh-India-Malayan realm have already been destroyed (Ellison, 1998, 2000). Despite this designation, this natural forest resources (Sundarbans) in Bangladesh has been facing tremendous problems, including that of dieback (top-dying), shrimp farming, human destructions, deforestations, illicit fellings, miss-management of the main tree species (*Heritiera fomes*) which is affecting millions of trees (Awal, 2007). The cause of this dieback is still not well understood unknown. The present work has investigated one of the possible factors that might be causing this top-dying, namely the concentrations of various chemical elements present in the sediments, particularly heavy metals, though other chemical parameters such as the pH, salinity, moisture content of the sediment and nutrient status were also assessed. A questionnaire survey was conducted among different groups of people inside and outside of Sundarbans to explore local perceptions as to the possible causes of top dying. This confirmed the increase in top-dying prevalence (Awal, 2007). Despite various hypotheses as to the causes of this top-dying, the underlying causes are still not well understood. The present work has explored some of the possible factors involved, focusing particularly on the relationship between the amount of top-dying in different places and the concentrations of a number of chemical elements present in the soil and water, in order to test the hypothesis that chemical pollution might be responsible. Other factors such as the pH, salinity and nutrient status were also assessed. The vegetation structure was assessed in terms of tree height, bole diameter, species present, and regeneration status; and the intensity of top-dying within the plots was recorded on a rank scale. Most of the elements studied had no significant correlation with the top dying of *Heritiera fomes*. However, Sn, Exchangeable K, and soil pH were significantly related, and three elements, namely Pb, Zn, Ni, were also close to significance. Sn concentration is negatively associated with top dying. Soil pH varied significantly in the different plots. Exchangeable K was positively associated with the tree diameter whether the top dying was severe or mild (Awal, 2007).

Keywords: Shrimp Farming, Chemical Contamination, Abnormal Elemental Concentration, Chemical Contamination, Health Problems, Causal Factors, Heavy Metal Concentrations, Pollution, *Natural Resources Degradations,* Sundarbans, Top-Dying

1. Introduction

Bangladesh is literally a treasure-trove of rich and variegated natural beauty interspersed with enchanting landscape, mighty meandering rivers, exotic flora and fauna, picturesque resorts, long sunny beaches, tropical natural mangrove forests, fascinating art and architecture, ancient relics and archaeological sites and colorful tribal life. As a vacation land, Bangladesh has many facets like Sundarbans natural forest resources in Bangladesh Mosaic of Bangladesh; 2006; External Publicity Wing; Ministry of Foreign Affairs; Government of the People's Republic of Bangladesh; p: 1-145). However, the Sundarbans is the largest single mangrove forest in the world (*figure 1.0*), occupying about 6,029 km^2 in Bangladesh and the rest in India (Iftekhar & Islam, 2004). The Sundarbans supports a diverse fauna and flora (e.g. Prain, 1903; Siddiqi *et al*., 1993, Iftekhar, 2006), approximately one million people of Bangladesh and India depend on it directly for their livelihood (Iftekhar & Islam, 2004), and also it provides a critical natural habitat which helps protect the low lying country and its population from natural catastrophes such as cyclones (e.g. Blasco *et al*., 1992; Iftekhar, 2008).

It is a land of enormous economic potentials, inhabited by diligent and hard-working people who have a love for heritage. All of these together make Sundarbans a colorful mosaic of nature's splendor and bounty (Awal, 2007, 2009, 2014).

1.1. Natural Forest Resources in Bangladesh

History records that till the advent of the British in the eighteenth century; Bangladesh had an enviable position in the entire region and was known as the legendary land of affluence and prosperity. The country has almost achieved green revolution. Sub-sectors like fishery, livestock rearing, and forestry are growing by leaps and bounds. The Bay of Bengal is literally a treasure- trove of sea fish and other wealth. Bangladesh's major natural forest resource is Sundarbans. There is also bright prospect of striking oil and gas. Huge deposits of coal, limestone, peat, bitumen, hard rock, lignite's, white clay etc. have already been indentified and projects are being implemented for their harnessing for productive use(Mosaic of Bangladesh; 2006; External Publicity Wing; Ministry of Foreign Affairs; Government of the People's Republic of Bangladesh; p:1-145).

1.2. Destruction of Natural Forest

Coastal lands cover 6% of the world's land surface (Tiner, 1984). Coastal and wetlands everywhere are under threat from agricultural intensification, pollution, major engineering schemes and urban development, (UN-ESCAP 1987; 1988). Mangroves in Asia including Bangladesh, India, and East Africa previously contained a much fuller range of species (Seidensticker, and Hai, 1983; Khan, 1997). In the Southeast Asian region, species diversity of mangroves was previously much higher, where approximately two-thirds of all species and 70% of the major vegetation types with 15% of terrestrial species in the Bangladesh-India-Malayan realm have already been destroyed (Ellison, 1998, 2000). The Indo-Pacific region is known for its luxuriant mangroves. The mangrove zone of Bangladesh is about 710 km long including several tiny islands (Rahman, *et al.,* 2003). In the present day the Indo-Malayan mangroves are confined to Sundarban reserved forests, mainly in Bangladesh (figure 1.0). According to Miller *et al.* (1985, 1981), this forest had been affected by direct human destructions, human settlement and agricultural activities during and under both the Bengal Sultanate (1204-1575) and the Mughal Empire (1575-1765). At the arrival of British rule in 1765, the Sundarbans forests were double their present size and significant exhaustion of the growing stock led to dwindling by 40% - 45% between 1959 and 1983 (Chaffey *et al.,* 1985).

1.3. Shrimp Farming

Sundri *(Heritiera fomes)* and other important floral species in surrounding areas of Sundarbans have probably been adversely affected by the establishment of shrimp farms for shrimp cultivation (Personal observation, 1993-97; Currie, 1984). Massive extraction of wild post larvae shrimp affects the stocks of natural resources. Satellite images show the expansion of the shrimp farming industry within the wetlands of the Gulf including Sundarbans recently, which changes the mangroves, lagoons and estuaries, and results in a net loss of habitat for native and migratory birds, fishes, mollusks, crustaceans, mammals, biological diversity and aquatic resources severely (Personal observation, 1994-1998). Along with habitat changes, biodiversity is strongly impacted by the practice of catching post larval shrimp along with any other accompanying fauna, and separating out the shrimp while exterminating the other fauna by allowing the rest of the catch to die on the ground, or applying chemicals that do not harm shrimp but kill other species (Personal observation, 1993-98). Post larvae shrimp usually make up approximately 10% of the catch; leaving 90% to be exterminated (reviewed by FAO, 1982). Shrimp culture might be associated with deteriorating mangrove conditions in the western part of the Sundarbans (Chaffey, Miller and Sandom, 1985).

According to Phillips, 1994, tropical shrimp farming has a long history, dating back at least 400 years (e.g. the 'tambaks' of Indonesia, 'bheris' and 'gera' of Bangal and tidal ponds in Ecuador) the expansion of the industry over the last 15 years has been extremely rapid and its environmental impact is now the subject of grave concern (Phillips, 1994). In the Khulna District of Bangladesh, artificial shrimp farms (locally called ger) are flooded with brackish water in the dry season months for shrimp culture (Nuruzzaman, 1990). For economic reasons associated with the high price of shrimp, such partial or complete switches from rice farming to aquaculture are putting further pressure on the remaining mangroves. Thailand has lost a total of 203,000 ha, 52% of the mangrove resource, due to shrimp-culture since 1961 (Anon, 1975; Briggs, 1991). Similar events are taking place in many other areas of the world; in Indonesia, most of the 300,000 ha of land being used to culture shrimp was ex-mangrove forest and the government of that country is planning to raise this figure to more than 1 million ha. By 1985, Java had lost 70% of its mangroves, Sulawesi 49% and Sumatra 36% (Anon, 1975). A similar scenario exists in the Philippines where mangrove areas have shrunk from 448,000 ha in 1968 to 110,000 ha in 1991 and such destruction has had a devastating effect on coastal fisheries and has led to the marginalization of subsistence fisherman and the erosion of shorelines (Singh, 1988).

It is estimated that 100 organisms (Personal observation in Sundarbans as Head of East Wildlife Sanctuary from 1993 to 1998) are destroyed for every shrimp-fry collected to supply extensive shrimp ponds ('gher') in Bangladesh; as many as 80% of the people in some coastal areas of the country are engaged in aquaculture seed collection (Personal observation, 1995-97). There is growing evidence that the environmental impacts of shrimp farming play a significant role in disease outbreaks and subsequent crop loss, as a result of the overloading of the carrying capacity of the environment (Personal observation, 1995-97; Phillips *et al.,* 1994). The result of this is an accumulation of wastes in the surrounding ecosystems which may lead to severe and sometimes irreversible problems (Personal observation, 1993-98). In the Khulna District of Bangladesh, poldered rice fields (‘gher’) are flooded with brackish water in the dry season months for shrimp culture, then a rice crop is grown in the wet seasons when the field can be flushed with freshwater (e.g. Nuruzzaman,1990). In Asia large tracts of back mangrove were cleared initially for agriculture, especially rice farming (reviewed by FAO, 1981, 1982).

1.4. Effluent Discharge

Effluent discharge from intensive shrimp farming has been put at 1.29 billion cubic meters of effluent per year in Thailand (FAO Report, 1997), although it has not been assessed in Bangladesh. However, effluent discharge is a problem of Sundarbans (Personal communication Mongla Port Authority, Khulna, 1996).

A large number of industries are discharging untreated effluents directly into the river at Khulna which is carried down to the Sundarbans forests. The polluting industries are Khulna Newsprint Mill (KNM), Hardboard Mills, and some match factories, fish processing units, Goalpara power station, some Jute mills and Khulna shipyard. KNM alone continuously discharge nearly 4500 m^3/ ha of waste water containing high levels of suspended solids (300-500mg/l) and sulphur compounds (UN-ESCAP, 1987). Moreover, resuspension of dredging material for port development is a potential threat to the Sundarbans due to long lasting toxicological effects from heavy metal pollution.

1.5. Indirect Human Influence

Sundarbans plays a vital role for human survivability from cradle to grave including tangible and intangible benefits. Coastal lands include some of the most productive ecosystems and have a wide range of natural functions. Wetlands are also one of the most threatened habitats because of their vulnerability and attractiveness for ‘development’. The first global conservation convention (Ramsar Convention) focused solely on coastal lands and wetlands like Sundarbans, and this Convention has recently been strengthened and elaborated with regard to the wise use of all coastal forests such as Sundarbans.

Sundarbans protects people and resources from strong tidal surges, hurricanes, tides and from waves. Progressive reclamation of the Sundarbans over the last 150 years has resulted in the loss of substantial masses of mangrove forests.

Bangladesh is a poor country, the size of Wisconsin, bursting with a population nearly half (of the total population) of the United States. On top of rampant illiteracy, poverty, and disease, the country suffers year after year from devastating natural disasters (Emilie,R; and Sandhya, S, 2006).

The major portion of the land is low with a maximum height of 10 m above mean sea level (Alam, 1990). Every year, tornados strike at peoples, buildings, plants and wildlife in the coastal belt at the beginning and end of autumn season. Although less obvious than habitat loss, the indirect effects of agriculture on mangroves, though the diversion of freshwater by agriculture irrigation schemes, or run–off of agricultural chemical residues into mangroves, have also been significant factors associated with deteriorating mangrove conditions in the Indus Delta and in the western part of the Sundarbans (Chaffey, Miller and Sandom, 1985). Although very little information is available, there is great concern in Asia regarding environmental impacts from agricultural pesticides, some of which are known to be highly toxic to shrimp (Phillips, 1994), as well as concern about the consumption of aquaculture products which can expose consumes to high levels of contaminants (Pullin, 1993). Bangladesh experiences many kinds of pollution (Emilie,R; and Sandhya, S, 2006), and this is likely to affect ecosystems as well as human health. Bangladesh is the one of the most densely populated countries (World Fact book, July 2006). Bangladesh is facing many problems including environmental pollution, high population density and poverty, these problems being interlinked with each other. These unique coastal tropical forests are among the most threatened habitats in the world. They may be disappearing more quickly than inland tropical rainforests, and so far, with little public notice. The Sundarbans provide critical habitat for a diverse marine and terrestrial flora and fauna, and 3.5 million people depend on Sundarbans forests and waterways for their survival (Anon, 1986; Chaffey *et a*l, 1985). Enrichment and illicit removal of timber and firewood from the forests are the major forest conservation problems in Sundarbans. Approximately 2.5 million people live in small villages surrounding the Sundarbans, while number of people within 20 km of the Sundarban boundary was 3.14 million (Islam, 1993). The annual average destruction of forest land in the country was 8000 ha in 1980 and subsequently it increased to 38000 ha in 1981-90 according to FAO (1993). But probably the rate of destruction of forest is more severe than the official statistics as it is very difficult to estimate the real picture (Awal, 2007}. Deforestation affects one eighth of the country’s land areas (Awal, 2007). Approximately 100,000 to 200,000 people work inside the Sundarbans for at least 6 months, while the number of people entering the forest in a year could be as high as 3,000,000 (Hussain and Karim, 1994). Of these, about 25,000 people work in fish drying and 60,000 – 90,000 people in shrimp post-larvae collection inside the Sundarbans (FAO, 1994). About one million people are engaged in shrimp larval collection in the rivers and creeks around the outside of the Sundarbans (Chantarasri, 1994).

The Sundarbans, like other tidal forests, is tolerant of natural disturbances such as the cyclones and tidal waves of the Bay of Bangle, but it is highly vulnerable to human disturbances (Seidensticker, 1983). Most of the abuses found in professional forestry management elsewhere have been observed here as well, such as excessive cutting of stocks in the auctioned area and connivance between purchasers and forestry staff to cut wider areas than sanctioned (Bari, 1993). 157 major oil spills in tropical seas between 1974 and 1990 (Burns *et al.,* 1993). Deep mud coastal habitats may take 20 years or more to recover from the toxic effects of such oil spills (Phillips, 1994).

2. Methodology

In this section the various field and laboratory methods used in this study will be discussed as below:

2.1. Field Sampling Methods

The Sundarbans Reserved Forest is located at the south west corner of the Ganges River Delta close to the Bay of Bengal, mainly on the sea-shore line, river banks, channels, and small creeks *(figure 1.0).* The location of the Sundarbans within Bangladesh has been shown in *Figure 3.0.*

Figure 3.0. *Photograph of part of the Sundarbans coastal area, near compartment number 26, where the trees have been cut down to be replaced by a fishing village.*

2.1.1. Site Selection and Location of the Study Area

General reconnaissance of possible sites was made by visiting all the possible regional areas before categorizing and selecting plots for sampling. It was decided to sample from the Chandpai area which is the mostly human accessible and ecologically polluted area (in *Figure 2.0).* Three compartments from this regional area (range), namely numbers 26, 28 and 31, were selected because they were believed to represent a range of severity of top-dying disease, based on relevant maps, documents, literature, consultations with forest professionals, and surrounding peoples. The location of these compartments within the Chandpai area, and the location of this area in the wider Sundarbans is shown in *Figure 2.0.* Among the three compartments, compartment number 26 was selected as an area highly affected by top-dying, where most of the trees were affected severely. Compartment 26 had pronounced human activities, and also in places is undergoing rapid housing development involving extensive construction activities due to the presence nearby of the Range HQ office in Chandpai (in *figure 2.0).* Compartment number 28 was selected as a moderately affected area. This compartment has various human activities including boat making grounds, football-playing grounds, and cattle-grazing fields, all types of major soil erosion, a moderate amount of construction activities and the presence of communities of fishermen (*figure 3.0).* Compartment number 31 was chosen as being relatively little affected by top-dying disease.

Of the three chosen compartments, the nearest compartment to Mongla port is compartment 31, with comparatively modest human activities, but which nonetheless involve clear-cutting of natural vegetation, replanting with other species rather than mangrove or other native species, all types of soil erosion, and construction activities present. Within each of the three compartments, detailed observations of the regeneration and sampling of soil and water took place within three 20 m x 20 m plots, chosen to reflect a range of top-dying intensities (High, medium and Low for that area). The sampling was conducted in a randomized block design, in that a plot was sited within a particular top-dying intensity block, but the precise location of that plot was randomized so as not to bias the detailed data collection. Thus in total nine plots were sampled, representing a range of top-dying intensities.

Intensive field data collection was made among these nine selected plots (*in Figure 2.0).* Observations were performed from observation towers during low and high tides, also traversing the forest floor and vegetation on foot, as well as using a speed boat, trawlers, country-boats, and a launch as required to gain access.

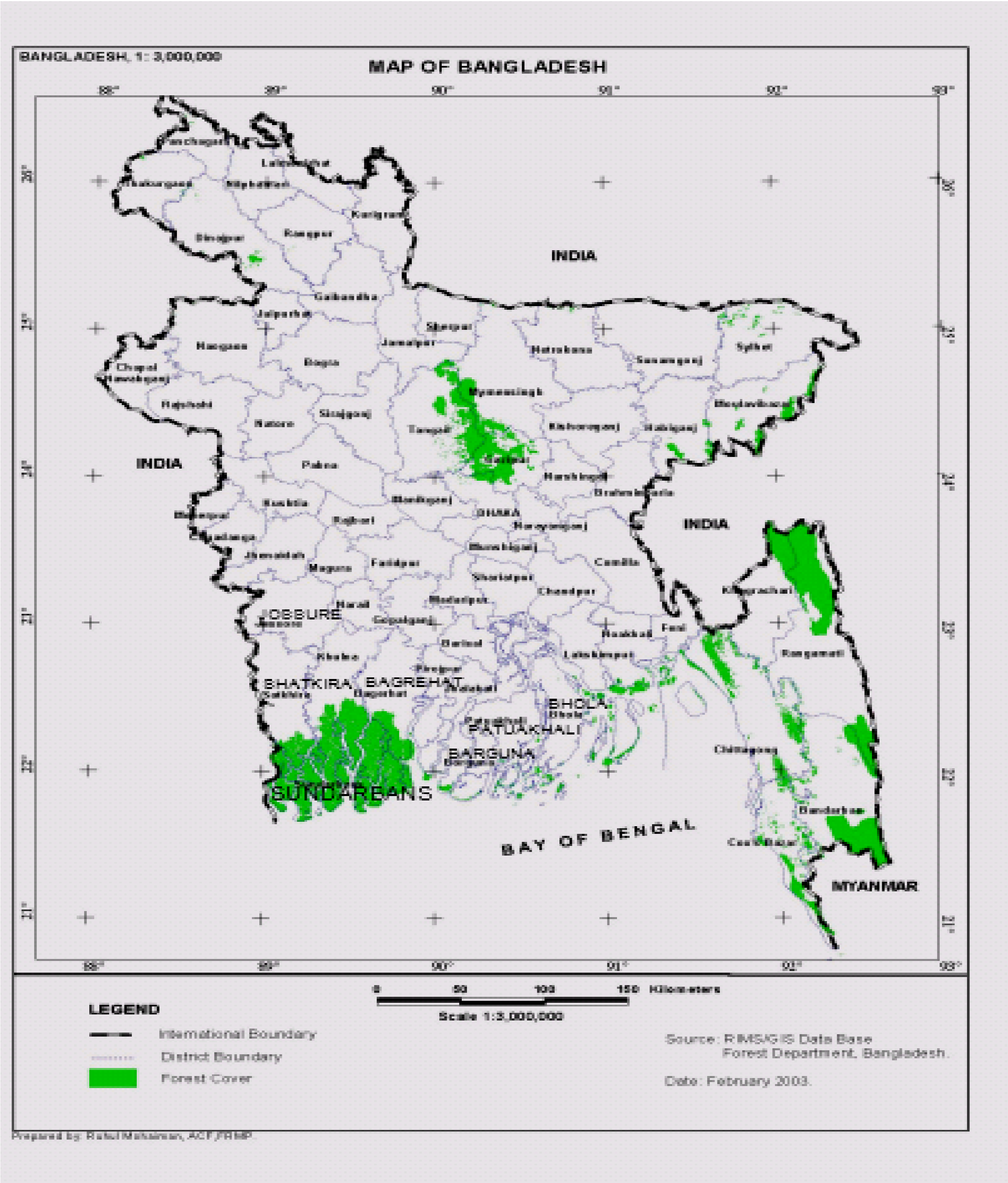

Figure 1.0. *Map showing the administrative districts of Bangladesh, including the location of the Sundarbans (the shaded area in the south-west of the country)*

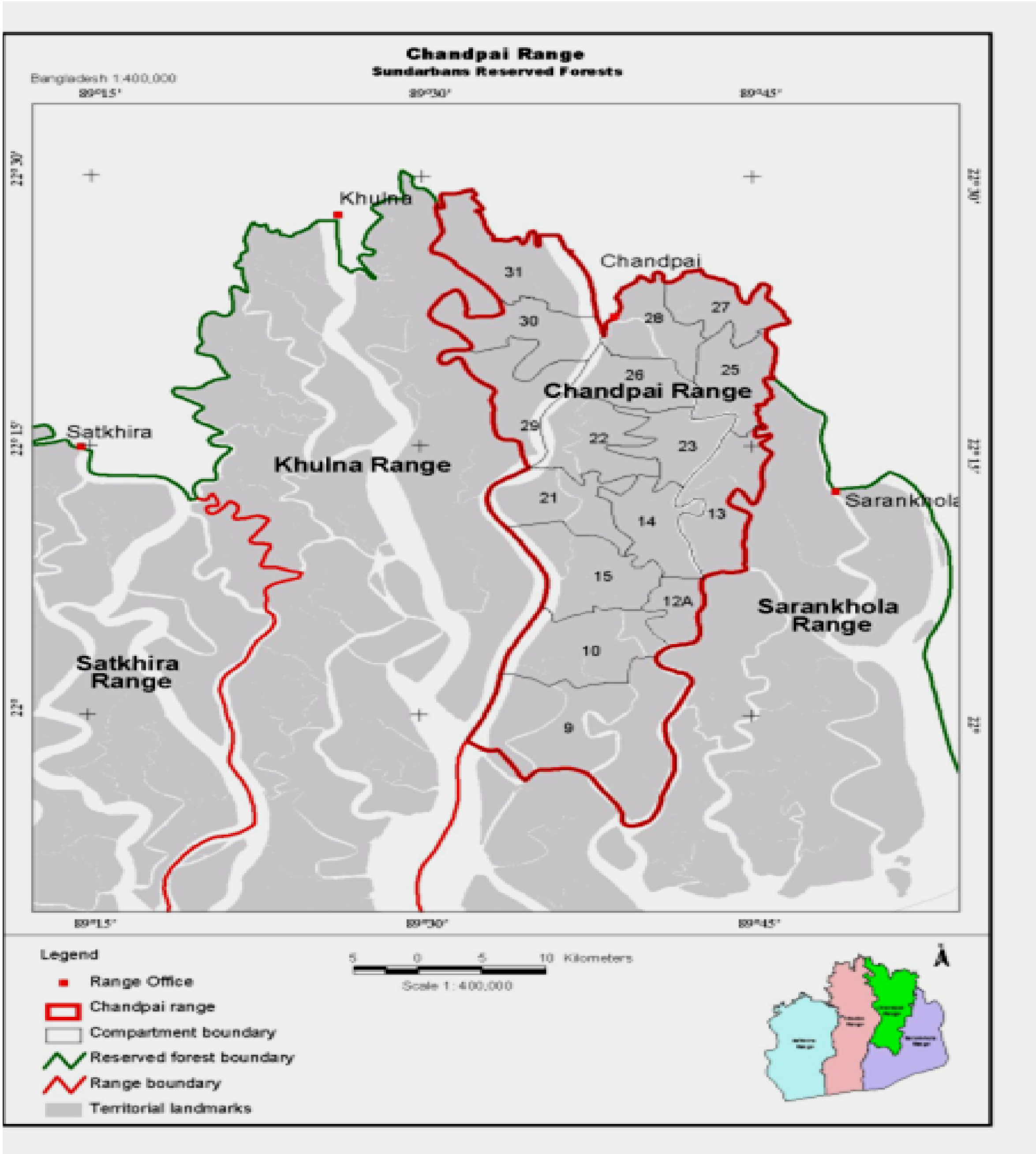

Figure 2.0. *Map showing the location of the numbered compartments within the Chandpai area, and the position of this area relative to other parts of the Sundarbans in Bangladesh (darker shaded area).*

Table 1.0. *Mean (±1 S.E.) and extreme heavy-metal elemental concentrations (ppb) in Sundarbans, together with comparisons with values from other published sources. An asterisk denotes a value below the limits of detection. Comparable data could not be found for all elements.*

Element	**Values from this study**				**Values reported elsewhere**
	Minimum	**Mean**	**S.E.**	**Maximum**	**(Data refer to sediments unless otherwise stated; number within brackets indicates source in footnote)**
Al	0.89	16332.44	854.17	37570.00	420 – 585 (soil,[1]); 8089000 – 46100000 ([1]); 500 (spring and well water,[2])
As	*	4.56	0.24	10.06	3150 – 6830 ([7])
B	0.55	19.20	2.14	103.80	2600 (spring and well water,[2])
Ba	0.59	52.41	2.37	141.80	300 (spring and well water,[2]); 141 (coastal soils,[5])
Bi	*	0.40	0.02	0.74	
Cd	0.15	0.55	0.03	1.62	0.52 – 0.92 (soil,[1]); 300 – 13520 ([1]); 43 – 147 ([4]); 0.8 (coastal soils,[5]); 11 – 65 ([7])
Co	5.93	31.31	5.65	143.60	0 – 7.9 (ocean water,[3]); 3800 – 26000 ([1]); 10.6 (coastal soils,[5]); 5540 – 15500 ([7])
Cr	3.11	15.72	3.39	114.90	7 (spring and well water,[2]); 1480 – 8560 ([4]); 41.2 (coastal soils,[5]); 12.8

Element	Values from this study				Values reported elsewhere
	Minimum	Mean	S.E.	Maximum	(Data refer to sediments unless otherwise stated; number within brackets indicates source in footnote)
					(water,[6]); 33200 ([6]); 19500 – 46100 ([7])
Cu	1.85	10.52	1.71	43.76	12.2 – 16.6 (soil,[1]); 12940 – 85600 ([1]); 22 (spring and well water,[2]); 22 – 37.2 (ocean water,[3]); 2270 – 14730 ([4]); 23.1 (coastal soils,[5]); 3.8 (water,[6]); 18200 ([6]); 6950 – 31600 ([7])
Fe	25.82	173891.10	9883.85	248200.00	634 – 820 (soil,[1]); 8080000 – 52000000 ([1]); 63 (spring and well water,[2]); 6.2 – 131.5 (ocean water,[3]); 38.5 (water,[6]); 7110000 ([6])
Hg	*	6.41	1.47	83.30	66 – 180 ([4]); 1.8 (water,[6]); 6320 ([6])
Mn	0.70	436.80	14.69	697.00	4980 – 438000 ([1]); 25 (spring and well water,[2]); 1.8 – 40.8 (ocean water,[3]); 3738 (coastal soils,[5]); 7.4 (water,[6]); 412000 ([6])
Mo	0.20	1.62	0.46	26.15	24 (spring and well water,[2])
Ni	7.58	76.08	18.84	1127.00	10800 – 37400 ([1]); 3 (spring and well water,[2]); 0 – 12.1 (ocean water,[3]); 24.5 (coastal soils,[5]); 15900 – 44600 ([7])
Pb	0.32	19.30	0.98	34.19	1.0 – 1.76 (soil,[1]); 1460 – 10400 ([1]); 2 (spring and well water,[2]); 3440 – 15590 ([4]); 74.0 (coastal soils,[5]); 2.3 (water,[6]); 12800 ([6]); 8046 – 15700 ([7])
Rb	0.18	36.37	1.65	76.94	
Sb	*	0.09	0.05	2.93	30 – 94 ([7])
Sc	*	6.05	0.37	8.98	
Se	*	0.17	0.05	1.43	
Sn	*	0.61	0.16	9.68	219 – 654 ([7])
Sr	0.18	27.77	0.89	44.17	2200 (spring and well water,[2])
Ti	4.61	475.39	26.26	1350.00	72 – 341 ([7])
V	0.09	32.93	1.14	51.65	13 (spring and well water,[2]); 18500 – 46900 ([7])
Y	0.03	6.60	0.34	16.69	
Zn	2.30	73.60	2.23	112.50	35.0 – 56.2 (soil,[1]); 120 - 62200 ([1]); 2.4 – 20 (ocean water,[3]); 72.5 (water,[6]); 43200 ([6]); 24300 – 76000 ([7])

[1] Balasubramanian, 1999. [2] Bond, R G & Straub, C P (eds), 1973 [3] Braganca & Sanzgiri, 1980. [4] IUCN Reports 1987. [5] McGrath & Loveland (1992). [6] Sarkar, S.K. et al. 2003 (Premonsoon data from the mouth of the Ganga estuary near Gangasagar used). [7] Zöckler, C & Bunting, G 2006.

Fieldwork was performed in October, 2003 to March, 2004. Locations of sampling points were determined using a Global Positioning System with a precision of 5-10 m. For one typical plot, in compartment 31, the altitude was recorded as 4.4 m above sea level.

2.1.2. Vegetation Recording Methods in the Field

Within each of the nine 20mx20m plots, each adult tree was assessed for three parameters. The diameter at 1 m height was recorded (in cm) by using a tree diameter-measuring tape or slide calipers depending on girth. The tree height to the top of the crown was determined mainly by ocular estimation but some heights were checked by using Clinometers at a set distance of 20 m to test the accuracy of such ocular estimations.

Finally, the status of the tree in respect of the amount of top-dying was assessed by using a four point qualitative scale of intensity, namely; not affected, little affected, moderately affected or highly affected by top-dying. This was later expressed as a semi-quantitative or rank scale of 0 to 3 respectively, so that a median rank value could be calculated and used as an index of top-dying intensity in that plot. After that, the total number of seedlings (individuals of the tree species <1 m tall), and saplings (young trees >1 m tall with a diameter of trunk of < 10 cm), were counted within the plots. Care was taken to ensure that trees, saplings and seedlings were not counted more than once or missed in the counting process. After recording, adult trees were marked with white chalk to segregate those marked trees from other trees, seedlings and saplings; red paints were applied to all seedlings and saplings as they were recorded.

2.1.3. Soil and Water Sampling Methods

As stated above, from the three selected compartments, a total of nine plots of 20m x 20m were selected. From each of these plots, seven soil samples were collected; one from the centre of the plot, four (one each) from all the corners, and two from the middle sides of the plot. Therefore a total of 63 soil samples were taken. Also nine water samples were collected from nearby rivers, creeks or channels, one from the area of each of the sampled plots. Soil samples were collected from 0-30 cm soil depth by using a stainless steel spatula and steel cylinder (*d*=5.25 cm), and all soil samples were kept in sealed plastic bags. Water samples were collected directly in pre-cleaned plastic-containers. Marking and labelling was performed with a detailed description of the selected sampling site on both the soil-containing plastic bags and water containers, and preserved in portable coolers until arrival at the laboratory at Dhaka University for initial chemical analysis. This field sampling method followed the W.H.O, U.K, and E.P.A systems of standard laboratory and field sampling principles, rules and regulations. Rainfall for the area during sample collection was not notably different from the respective monthly averages for the Sundarbans of recent years (shown in *Table 2.0* for reference); there was no heavy intensity of rainfall within one month before sampling.

Table 2.0. *Showing previous monthly average rainfall data.*

Year	1996	1997	1998	1999	2000	2002
Location	Mongla (mm)	Mongla (mm)	Mongla (mm)	Mongla (mm)	Mongla (mm)	Mongla (mm)

January	2	19	29	1	24	13
February	25	35	65	0	9	5
March	24	102	149	0	15	32
April	89	94	91	25	134	74
May	119	241	234	202	288	206
June	453	204	229	262	309	952
July	385	486	304	435	356	389
August	357	422	471	466	209	441
September	133	334	553	568	327	492
October	274	40	110	321	224	62
November	1	4	207	12	5	89
December	25	13	0	0	0	0

Any evidence of changes was recorded, sometimes obtained through asking local people and forestry staff, or from personal observations. In particular, any soil erosion and diversion of the river's position or of new channels and creeks observed during the data collection period were recorded, as were signs of siltation changes.

2.1.4. Questionnaire Survey of Local People

In order to establish the views of local people about the incidence and causes of top-dying, a questionnaire was prepared for asking peoples either individually or in groups. This survey was done among people living or working in the 17 Sub-Districts of Sundarbans, making a distinction between those living within and outside of Sundarbans. They were asked whether they had seen the top-dying disease of *Heritiera fomes* (Sundri) in Sudarbans for a long time, either through living within the Sundarbans or through visiting Sundarbans for their daily work, for their professional work such as forestry officials, for fishing or for collecting wood as wood cutters, for seasonal honey collection, or other purposes. Groups were made up among targeted people in all locations and from all categories mentioned above, based on age, profession, and also for their sharp memory. In this way, 50 questionnaires were filled up through interview, mostly of groups and sometimes of individual people. The justification of selection of people for the questionnaire survey was that the targeted people were familiar with the top-dying problem in Sundarbans, and are related through their professions with Sundarbans directly and indirectly. The questionnaire started by establishing that the respondents were familiar with top-dying, and went on to seek their views and information on what changes they had observed and whether they had noticed possible causes. This was possible because, most of the interviewees are living within the Sundarbans for their daily activities. So, this survey was performed to receive their indigenous response and knowledge towards top dying and its present conditions, and their ideas about what leads to top-dying, as well as questions about tree regeneration and human health in Sundarbans (Awal, 2014).

2.1.5. Statistical Analysis

Initial statistical analysis of quantitative data, particularly of the elemental concentrations, consisted of calculation of arithmetic means, standard deviations and standard error values for each variable separately. Data on the severity of top-dying for each tree in a plot, which had been recorded as ‘ not affected’, ‘mildly affected’, ‘moderately affected’, and ‘highly affected’, were converted into a four-point scale (0-3), so that they could be summed and an average (median) could be determined for each plot, thus producing an index based on ranked data. Comparisons of the strength of relationship between two variables were assessed by correlation: the Pearson's product-moment correlation coefficient where both variables were fully quantitative or the Spearman's rank correlation coefficient where the top-dying index was one of the variables. In the case of the Spearman's coefficient, the probability of the outcome was determined by using the approximation to a t-statistic appropriate to these tests (Sokal and Rohlf, 1981). Occasionally, a Pearson's correlation coefficient was calculated where top-dying was one of the variables, in order to check on the extent of the difference between the rank and quantitative versions for these data. Data on frequencies of seedlings or saplings in each of the plots and compartments were tested by $\aleph^2$ contingency table analysis to determine whether there was an association between the selected plot type (severely, moderately or little affected by top-dying) and the three chosen compartments. A similar consideration of the different compartments as comprising one factor, and the plot type as a second, was used to test the pattern of elemental concentrations and other variables by a 2-factor analysis of variance test with replication. This allows an assessment of the significance, not only of the two factors separately but also of the interaction term linking the two factors. It should be noted that the plot type was not a strictly controlled factor, since the three categories of top-dying intensity were relative to each other within any one compartment and might not have been exactly equivalent between the three categories; interpretation of the results from these tests therefore needs to bear this in mind. MINITAB Release 14 Statistical Software has been used for windows on CD-ROM, 2004 edition for all data analysis, both statistical and graphical, except for those produced automatically by the Excel package attached to the ICPMS.

3. Results

These results are indicated as follows: if one number (all values in ppb) is given it is a mean, otherwise if a range is given they are the minimum and maximum; the number is followed by the type of material from which the data come, with no text indicating it is from sediments (the most common material reported in the literature); finally, the number in brackets indicates the numbered reference source, the sources being indicated in the legend. Besides attempting to establish whether the element concentrations are elevated or not, it is valuable to explore whether there is any marked spatial (as opposed to random) variation in the concentrations found.

4. Discussion

Shrimp cultivation is a serious problem for the heavy metal contamination in the water, soil, plant, fishes, animals etc. Coastal lands cover 6% of the world's land surface (Tiner, 1984). Coastal and wetlands everywhere are under threat from shrimp-cultivation, agricultural intensification, pollution, major engineering schemes and urban development (UN-ESCAP 1987; 1988). The Indo-Pacific region is known for its luxuriant mangroves. The distribution of mangroves in the Indo-West Pacific bio-geographical region has been outlined in Macnae (1968). However, the mangroves in half of these countries, as well as those of other regions, have since been destroyed through various pollution problems and population pressure (Peters et al., 1985). The country's food security and public health will be in danger if the water and wetlands are destroyed at the present rate (Awal,2009).Unplanned natural resources management and environmental contamination in Sundarbans are fast destroying the surface, vegetation, water, and underground fresh water sources (Awal, 2014). The primary source of fresh water for fishes, trees, human's health in Bangladesh was vital but due to heavy-metal contaminations in soil, water, faulty-vegetation management and deforestations of trees, top-dying disease and other diseases and health problems, irrigation for food production, industrialization, and public health, while industrial pollution and poor sanitation are making surface water unusable (Awal, 2007). The health of vegetation including natural flora & fauna, drinking water, soil are largely depends on uncontaminated groundwater,(Awal, 2009). Water related diseases are responsible for 80 percent of all deaths in the developing world (Awal, 2014).Data were summarized by calculating means and standard errors, and by noting minimum and maximum values, for comparison with other data reported in the literature. The spatial variability in the data was assessed by calculating two-factor analyses of variance with replication, where the factors used were the broad-scale variation between compartments, the smaller-scale variation between plots within the same compartment, and the interaction between these two sources of variation. The concentrations of the various trace metals determined by ICP-MS from our Sundarbans soils are given in Table 1.0. For completeness, the minimum and maximum values are given, as well as the mean and the standard error, in order to facilitate comparisons with other published information and to indicate the extent of variability between the different samples in the results. It is clear that due to destruction of natural resources and contaminations of soil, water for some elements the variability is considerable; for example, nickel has a maximum value many times larger than the mean, while for iron the mean and maximum are more similar but the minimum is substantially smaller.

In order to try and establish whether these values are elevated compared to other data, comparison values are included in *(Table:1.0)* from results published in the literature concerning the Bay of Bengal region. In order to assess this, an analysis of variance has been performed for each element separately, testing for location by using the compartment from which the samples were taken as one factor, and the plot number within each compartment as a second factor, testing also for interaction between these two sources of variation. The results of these analyses are presented in Table 1.0, showing only those elements which showed at least one F-value at or near significance. Most of the elements tested do not show any significant variation related to any of these factors, and may therefore be considered to be relatively uniform or non-consistently variable in their concentrations, at least across the compartments studied here. There were no elements that proved significant when comparing between plots, nor in the interaction term, although antimony had a close result for the plot term ($p = 0.06$). However, a few elements did give significant results comparing between compartments, namely bismuth, scandium, strontium and vanadium. In all four cases, the lowest recorded concentrations were from compartment number 28; in all cases except for strontium, the compartment where the highest elemental concentrations were recorded was number 26 (compartment 31 being the highest for strontium). Interestingly, a similar analysis of concentrations (not presented separately here) also showed significant differences between compartments for sodium and phosphorus, with compartment 28 again having the lowest recorded concentrations.

In particular, the metal values from sediments are likely to be much higher than those from soils, and indeed one author (Balasubramanian, reported by Swaminathan, 2000) found sediment values to be often at least one thousand times higher than values for equivalent soils. The concentration values for the various trace metals recorded in Table 1.0 are believed to be amongst the first published for soils from the Sundarbans, and as such provide baseline data for comparison with other future studies in the area. It has therefore not been possible in many instances to find appropriate comparators from the literature in order to help assess whether the data show elevated concentrations from those expected in such soils. The comparatives information from the literature presented in Table 1.0 is all from the same general region, but includes values from water (from ocean, springs or wells), from coastal soils (but not within the main mangrove areas), and particularly from mangrove sediments, as well as a few from mangrove soils. All comments based on these other sources must therefore be judged on the basis of the differences between the materials in the results likely to be obtained. A further complicating factor in interpreting these results is the high degree of variability in concentrations between different samples shown by many elements, as indicated in *Table 1.0* by the high standard error values and by the results highlighted for some elements in *Table 1.0.*

For most of the elements tabulated there are either no comparisons in the literature, or the results from our study do not appear particularly elevated compared to other results. Perhaps surprisingly, given the problems that have been identified with elevated concentrations of arsenic (As) in groundwater in Bangladesh (e.g. Nickson *et al*., 1998;

Chowdhury *et al*., 2000), this element was not notably high in the soils studied here. However, there were other metals which may be elevated in their concentrations. Two results appeared particularly elevated, namely those for mercury (Hg) and for nickel (Ni). In considering the result for mercury, it is recognized that the ICP-MS method of testing the soils is not the most appropriate one for obtaining an accurate determination of mercury concentration because of the potential for cross-contamination of samples from earlier ones due to retention of the element within the instrument. The problem was reduced by the use of gold-wash solution rather than nitric acid in preparation of the calibration standards. Nonetheless, the elevated concentrations of mercury in these mangrove soils can only be considered as an indication until confirmation of these values by further work involving a different analytical procedure can be completed.

There is likely to be considerable geographic variation in the extent of pollution problems in the different parts of the Sundarbans, associated both with the proximity to local polluting sources such as Mongla port and with the extent to which the area is influenced by the Ganges river, which is strongly polluted (Sarkar *et al*., 2003). This was indeed found *(Table 1.0)* as there were significant differences between different areas in the Sundarbans with regard to at least some of the elements studied, and others were probably not significant only because of the large amount of variability between different samples within individual compartments. It is therefore perhaps not surprising that the values reported by Zöckler and Bunting (2006) were lower than ours, since their study was in the east of Bangladesh away from the Ganges and other main sources of pollutants. Also, the choice of sites in the present work emphasised areas likely to be polluted because they were near to human activity and hence more accessible. Even so, and allowing for the fact that sediment data is the only comparator medium, the data from the literature suggest that the Sundarbans is not yet as polluted as some other mangroves from the region, such as in Pakistan (e.g. IUCN, 1987).

Clearly, further work is required to confirm and extend the results reported here. The indications of potentially elevated heavy metal concentrations is a matter of concern, and a higher general pollution load is likely to contribute to the increase in top-dying observed in the Sundarbans (Rahman, 2003; Chaffey, *et al*.,1985; Chowdhuy,1984; Gibson; 1975). A likely mechanism of influence might be that greater concentrations of the trace-metals weaken the resistance of the tree to attack by pathogenic fungi. The relationship between individual trace metals and the amount of top-dying will be explored further in a separate article. It is also worth noting that local residents and those who work in the Sundarbans quite frequently reported health problems, of which problems of the skin were the most common (data from a questionnaire, included in Awal, 2007). It is possible that the high concentration of nickel (Awal, 2007), which can cause skin conditions, is leading to such complaints. Such health issues are therefore also a cause of concern and need further confirmation and elaboration.

5. Conclusion

Shrimp culture is the major problem of ecological problems in Sundarbans (Awal, 2007, 2009, 2014).Duet to illicit cutting of trees, deforestations, chemical fertilizer and all types of artificial activities within natural forest like Sundarbans is the interrelation of chemical pollution in Sundarbans (Awal, 2007).The overall conclusions from the results presented in this section are that the selection of sites has not produced clear statistical differences in the amount of top-dying evident; probably because of the way the data were collected. However, it is believed that there is notable variation between plots and compartments, and certainly this seems to be reflected in the ability of the trees to regenerate. However, the link between top-dying and the size of the trees is not clear, with tree height and diameter not being directly related consistently to amount of top-dying, although moisture content of soil was inversely related. Since the great majority of trees present in all plots is the species *Heritiera fomes*, this means that the comments above are essentially referring to the response of this species rather than that of any others. So that, the Sundri, by contrast, prefers largely fresh water in which it resembles the mesophytes, but the species is adapted to the wet swampy condition of the Sundarbans by virtue of its leaves having partly xerophytic adaptations and plentiful pneumatophores which help cope with the saline swamps of the Sundarbans.The vegetations need sound ecological balanced to survive but due to deforestations, illicit fellings, hunman destruction are responsible for the heavy metal contaminations in soil, water and vegetation(Awal, 2007, 2009, 2014).

Comparing figures in the *table 1.0*, it would suggest that about two thirds of the elements have concentrations which are elevated compare to other reference sources in the Sundarbans. This would be consistent with the evidence that heavy metals were having an influence on top-dying intensity (Awal, 2007, 2009, 2014). The elements Pb, Sn, and Zn were highlighted earlier in this discussion, and although not all of them quite reached statistical significance (Awal, 2007), the positive trend linking two of them to top-dying suggests a likely mechanism of influence, namely that greater concentration of the heavy-metal weaken the resistance of the tree to attack by the pathogenic fungi (Awal, 2007, 2009, 20014). This might well be a process that other elements contribute to as well (Awal, 2007, 2009, 2014), but has not been picked out by the analysis as showing a link because of the variability between samples inherent in the data (Awal, 2007). In this respect, the anomaly of the negative relationship indicated for Sn is harder to explain (Awal, 2007), but a possible process might be an antagonistic response of Sn and another element (Awal, 2007), so that when Sn is less abundant the other element can have a stronger (deleterious) effect on the trees (Awal, 2007), thus allowing more top-dying to occur (Awal, 2007). A further point is that variations in soil pH from site to site (shown to be significant) will also have a marked effect on the bio-availability of some of these heavy metals (Awal, 2007), and thus perhaps influence top-dying (Awal, 2007).We should protect natural resources such as Sundarbans in Bangladesh (Awal, 2009), because the future of Sundarbans is as directly dependent on the health of her wetlands, as is the future flora and fauna. Considering the limitations of the current planning process in Bangladesh, it is possible that within a few short decades, as water tables fall, rivers run dry and lakes shrivel, water–riots will become the order of the day. It may also be the case that wars on the subcontinent will more likely be fought over water than oil. And until uncontrolled development is restricted, the threat of floods and droughts due to loss of mangrove systems will continue to be present (Sahgal, 1991). Coastal lands include some of the most productive of ecosystems with a wide range of natural functions, but are also one of the most threatened habitats because of their vulnerability and attractiveness for 'development'. The first global conservation convention, the Ramsar Convention, focused solely on coastal lands and wetlands, and it has recently been strengthened and elaborated with regard to the wise use of all coastal areas such as Sundarbans.

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