Recovery of mangrove deforested areas from M/T Solar oil spill in Guimaras, Philippines

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ABSTRACT 299722:

On August 11, 2006 more than 2 million liters of Bunker C oil spilled in southern Guimaras Island, central Philippines. Over 200 kilometers of coastline have been affected including the traditional livelihood in the island. The immediate effects involved death of marine fauna and massive mortality of mangroves which accounted to almost one hectare and two years after the incident some albino propagules of *Rhizophora stylosa* were observed. Additionally, some species of mangroves found in heavily impacted sites exhibited significant reduction of leaf sizes. Monitoring of the deforested mangrove areas three years after the incident showed a varying recruitment-to-mortality ratio. Recruitment and settlement of seedlings was impaired in areas where dead trees are extracted mainly for firewood purposes. The harvesting of dead trees created a forest gap, exposed the area to surging waves and thus increased the hydrodynamics. On the other hand, faster recovery dynamics was observed in area where the dead trees are not harvested. The presence of logs trapped the available propagules and facilitated the colonization of new cohorts. Quantification of polyaromatic hydrocarbons (PAHs) in mangrove sediments showed higher rate of decomposition. Three years after the oil spill, the level of PAHs in sampled sites were within the safe level based on the National Oceanic and Atmospheric Administration (NOAA) standards. However, sub-lethal, long term monitoring should be carried out further to focus on the species-specific long term responses.

INTRODUCTION:

The Philippines is an archipelago of 7,107 islands located within the tropics in southeastern coast of Asia. Its coastline extends up to 36,300 km and surrounded with the waters of Celebes and Sulu Sea to the south, South China Sea in the west, and the Philippine Sea in the east coast. Being an archipelago, the water transport system played a vital role in the delivery of products and services to the islands. Inevitable circumstances and untoward incidents due to natural phenomenon, mechanical failure, and human error may result to oil pollution causing environmental problems. The M/T Solar I oil spill on August 11, 2006 in southwest coast of Guimaras, Philippines (Figure 1) released more than 2 million liters of Bunker C oil and affected over 200 kilometers of coastline including the traditional livelihood in the island. This is considered as the worst oil spill incident happened in Philippine history to date. It affected the environmentally critical coastal habitat in Guimaras including coral reefs, seagrass meadows and mangroves. Oil impacts to mangroves vary with a number of factors including the amount of oil, type and magnitude of clean-up activities, type of oil, physical and biological structure, latitude, and season (Getter et al. 1984) and were known to cause acute and long-term damage to mangrove ecosystems (Duke et al. 1997). The incident caused massive mortality of mangroves, leaving various patches of deforestation that accounted to 0.932 ha (Sadaba et al., 2009a). These deforested patches have few surviving trees in the middle portion or bordered by few survivors trees. Among the 29 species present in Guimaras, only five exhibited mortality that includes *Avicennia marina*, *Rhizophora apiculata*, *R. mucronata*, *R. stylosa*, and *Sonneratia alba* (Sadaba et al., 2009b). These species were widely distributed in the island and often found in the seaward margin to middle zone of the forest; hence they are more likely vulnerable species. Few recruits were observed in the deforested areas three years after the incident and together with the surviving trees they represent a cohort for natural recovery processes. This paper looked into the natural recovery dynamics of the deforested mangroves areas in selected sites in Guimaras. Specifically, this study determined the rate of recruitment and mortality; density of cohorts and quantified the levels of polyaromatic hydrocarbons in sediments. These are the basic demographic variables used in evaluating the capacity of mangroves habitat to recover from oil spill induced-stress and in tracing past growth dynamics and colonization rate. There has been studies documenting the recovery of mangrove impacted by oil spill but most were outside Southeast Asia with different type of spilled oil. This study will generate new knowledge as to the long term effects and persistence of Bunker C oil and the recovery of deforested mangrove areas in tropical scenario particularly the Philippines.

MATERIALS AND METHODS:

Study area

The study was conducted in the deforested mangrove areas of Guimaras Island that was adversely impacted by oil spill located in the Panay Gulf central part of the Philippines (Figure 1). Over 200 kilometers of coastline in the five municipalities of the island province of Guimaras have been affected including the traditional livelihood of the people. Marine habitat and resources like coral reefs, seagrass meadows, mangroves and fisheries were impacted to varying degrees. Mangroves are considered to be highly vulnerable and most sensitive tropical habitat to oil spill based on the rankings of coastal areas in National Oceanic and Atmospheric Administration (NOAA) index (NOAA 2010). Thus they are commonly used as a tool for spill contingency planning by NOAA. The oil spill in Guimaras caused 0.932 ha mangrove deforestation three months after the incident, which was distributed to four patches in the municipality of Nueva Valencia (Sadaba et al. 2009a). This study was conducted from November 2009 to February 2011 in two deforested mangrove areas in Sitio Bagatnan, Brgy. Lapaz (SB), and in Panobolon Island (PBI) both were in the municipality of Nueva Valencia in the southern part Guimaras (Figure 1). The Bagatnan site has residents thriving nearby while Panobolon is adjacent to fishpond and no residents. Field sampling was done every two months for the first six months and every three months in the succeeding nine months period. Forest structure in both study sites are classified as fringe forest type with a muddy substrate and dominated by *Rhizophora* species. Common to both site was a death of mangroves concentrated only in the inner part (middle) of the forest stretching towards the terrestrial margin while the outer fringe remained intact and had one or two surviving trees along the seaward margin (Figure 2a-c). Areas with massive death of mangrove trees were primarily characterized by a low hydrodynamics as they are sheltered by neighboring islets thus delaying the washing off of the stranded oil. This deforested patch thus opened an area for recruitment of seedlings.

Sediment sampling for hydrocarbons

Sediments were collected twice a year for polyaromatic hydrocarbons (PAH) and total petroleum hydrocarbons (TPH). Sediment samples were collected using a tube corer and the core sample was divided into three subsamples corresponding into three depths: 0-2, 10-12, and 20-22 cm (Figure 3). Analysis was done at Oil Spill Response Program Analytical Service Laboratory (OSRP ASL) in Freshwater Aquaculture Station (FAS), University of the Philippines Visayas. For extraction, Soxhlet (EPA 3540) method of extraction for semivolatile and nonvolatile organics was employed and followed by Solid Phase Extraction (SPE) (EPA-3630). Five grams of sediment sample was thoroughly mixed with five grams anhydrous sodium sulphate (sediment/Na_2SO_4 (1:1) (w/w) and place in Soxhlet extractor. The extraction solvent (acetone/hexane (1:1) (v/v), 150 ml in volume was added in the bottom flask attached to the extractor. This extraction set up was placed on a water bath with a hotplate set at 45 ^{0}C and ran for 16-24 hrs. Upon completion of the extraction, the extracts were transferred to a drying column with 5 g of Na_2SO_4 and concentrated using rotary evaporator. When the volume of the liquid reaches approximately 0.5 ml, extracts were transferred to the concentrator tube placed in a water bath at 35^{0}C and subjected to gentle stream of clean dry nitrogen to let the solvents evaporate. The extracts were analyzed for PAH and TPH method EPA 8270-C by gas chromatography/mass spectrometry (GC/MS) Clarus 600 Perkin Elmer.

Recruitment and mortality

The species of *Rhizophora* started to grow in the deforested areas. Within the deforested areas, three 5x5m (25 m^2) permanent plots were established and the corners of the plots were marked with a PVC pipe. Seedlings and saplings inside the plot were marked and numbered with flagging device. Recruitment and mortality were scored every two to three months using the equations:

$$\mathrm{R}_{t+1} = \ln\{[\mathrm{N}_t + \mathrm{NR}_{t+1})/\mathrm{N}_t]/\ \Delta t\}$$

$$M_{t+1} = \ln\{[(N_t - D_{t+1})/N_t]/\Delta t\}$$

where R_{t+1}, specific recruitment rate for the time interval (day^{-1}); M_{t+1}, specific mortality rate for the time interval (day^{-1}); N_t, total seedling population at beginning of time interval; NR_{t+1}, number of new recruits at the end of the time interval; D_{t+1}, number of dead seedlings at the end of time interval; Δt, number of days elapsed from t days to $t+1$, and averaged during the study period and multiplied by 365 days to calculate annual specific rates (Padilla et al. 2004).

RESULTS AND DISCUSSION:

Polyaromatic hydrocarbons

Polyaromatic hydrocarbons (PAHs) are ubiquitous organic environmental pollutants came from both natural and anthropogenic sources. They are neutral, nonpolar organic molecules comprised of two or more benzene rings arranged in various configurations. PAHs are of primary concerned pollutant because some compounds have been identified as carcinogenic, mutagenic, and teratogenic. Together with their alkylated homologues, they are the most hazardous compounds in oil spills. There are more than 100 compounds of PAH in petroleum with different implications to human health (IARC 1983, US EPA 1994). From these compounds, around 54 have been identified to be hazardous and 16 to 18 are given special attention because of their toxicity and potential hazard to humans. Among the PAHs that has potential human carcinogens are benzo(a)pyrene, benz(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-c,d)pyrene (IARC 1983, US EPA 1994).

In Guimaras oil spill, the total PAH (including alk-PAH) concentration in the surface sediments one month after the oil was 333 mg/g based on the study of Pahila et al., (2010a) in Taklong Island site which is proximal to Bagatnan study site. In the same study, biological samples (including oyster, squid, and fish samples) collected one month after the oil spill were found to contain PAHs and some alk-PAH compounds that includes naphthalene, acenaphthylene, fluorene, dibenzothiophene, phenanthrene, fluoranthene, pyrene, benz(a)anthracene, and chrysene but in low levels. Shellfish *Modiolus* sp. collected six months after the incident indicated a higher level of chrysene (>50 ng/g) and benzo(a)pyrene (Pahila et al. 2010a). Furthermore in the monitoring study of Pahila et al (2010b), they reported that PAHs in the surface of the sediments dropped dramatically in 2007 or one year after the incident in Taklong Island area that measures (<0.16 mg/kg) to 0.8 mg/kg) and the same trend was observed two years after the incident.

Petroleum degradation is relatively faster in tropical areas than in temperate areas because of high temperature and more frequent storms and stronger hydrodynamics that subsequently resulted to high tidal flushing of oil. Quantification of the level of total PAH in the deforested mangrove areas showed dramatic dropped from the initial levels (Figure 4). In this study, total PAH in sediment samples on January 2010 were 19.12 mg/kg for Bagatnan and 21.38 mg/kg for Panobolon. The levels continued to reduce towards the end of the study with 2.53 mg/kg for Bagatnan and 6.81 mg/kg for Panobolon. According to Volkman et al. (1992), organic rich marine sediments may contain up to 100 ppm (mg/kg) total aliphatic hydrocarbons, but concentrations higher than this are usually due to petroleum inputs.

Recruitment, mortality and density of recruits

The M/T Solar I oil spill affected the integrity of coastal habitat due to toxicity and smothering effects of the spilled to the habitat and associated fauna in the island province of Guimaras particularly mangroves. Three species of *Rhizophora* were monitored since they are the pioneering species that were recruited in the gap generated due to oil spill deforestation and therefore can serve as an indicator of the recovery dynamics. The recruitment and mortality rates showed that Bagatnan site has higher fluctuation in terms of seedlings density throughout the 15 months study period inside the permanent monitoring plot compared to Panobolon. Furthermore, the former site has higher M rate compared to the latter site, which has fairly stable M rate almost equal to R rate (Figure 5). Intra site M and R rates showed that both sites had a slightly higher M rate (4.99±1.0 for Bagatnan, 2.49±1.1 for Panobolon) relative to R rate (3.84±0.38 for Bagatnan, 2.08±0.65 for Panobolon). There are no changes in species composition in both sites as the recruits were the same species previously observed in the area. Among the three species recruited, only *R. apiculata* showed a higher R over M. The period with maximum R was observed in the months of January and March (0.51±0.13) for Bagatnan and March and May (0.35±0.01) for Panobolon. On the other hand, the period where high M occurred in the month of March (0.61±0.34) for Bagatnan and November (0.43±0.15) for Panobolon. Based on the report of Tamai and Iampa (1988), the death of propagules particularly *R. apiculata* can occur anytime of the year but the peak occurred just after seedling establishment and is more frequent from November to April. Apparently, the high M in Bagatnan could not be conclusively taken as direct evidence of population decline considering the short study period that ran only for over a year. The decline of seedling population or high M rate could be compensated in the succeeding years considering a longer period of time. The study of Padilla et al. (2004) in Ulugan Bay, Palawan (Philippines) also showed that mortality was higher than recruitment in the oil-free sites. In terms of species richness and density, the Panobolon site had an increasing number of plants inside the monitored plot and became stable towards the end of the study period while Bagatnan appeared to be highly dynamic and the density slightly declined towards the end of the study period (Figure 6). The anthropogenic activity within the deforested area can have significant effect in the differential recovery processes of the deforested areas. The photos in Figure 7 taken three years after incident showed a remarkable contrast between the two sites. The dead trees in Bagatnan (Figure 7a, b) were harvested by the nearby residents mainly for firewood. This leads to the eventual opening and highly dynamic area characterized by an increase in water dynamics and wave energy. Additionally, outrigger boats were parked in the vicinity, which in return might add further disturbance to the struggling habitat. The dead mangrove logs have they not been harvested will reduce the hydrodynamics of the deforested area and facilitates in the faster establishment of seedlings and propagule stranding. In contrast, the dead trees in Panobolon were not harvested and remained in the area (Figure 7c, d). The dead logs reduced the water movement within the opened canopy, helped in keeping propagules from drifting away and thus catalyze in the seedling establishment and recruitment.

Impacts and recovery of mangroves

Recovery of any impacted ecosystem following a perturbation such as an oil spill is often interpreted by many to mean a return to the system in place at the time of the spill (NOAA 2010). While considerable debate exists over the definition of recovery and the point at which an ecosystem can be said to have recovered, there is broad acceptance that natural variability in ecosystem makes a return to the exact pre-spill conditions unlikely (ITOPF 2011). For instance, mangroves' specialized niche is in a unique, changeable zone, subject to sediment flow that accretes and erodes, varying amounts of fresh water, impacts from storms and hurricanes, invasion by foreign species, and predation. Thus, even if there is a precise description of ecosystem conditions just before the spill, reversion to pre-spill state remains a question (NOAA 2010). Most definitions of recovery instead focus on the re-establishment of a community of flora and fauna that is characteristic of the habitat and functioning normally in terms of biodiversity and productivity. The report of ITOPF (2011), outlined the indicative general recovery periods of various habitats in different parts of the world (Table 1). Among the different types of habitat listed, mangroves takes at least 10 years to recover. On the other hand, the review report of Burns et al. (1993) on the long term assessment of an oil spill into a coastal fringe mangrove ecosystem in Panama demonstrated that a time period of up to 20 years or longer is required for deep mud coastal habitats to recover from the toxic impact of catastrophic oil spills. This is due to the long-term persistence of oil trapped in anoxic sediments and subsequent release into the water column. Table 2 summarizes the generalized responses of mangroves to oil spills from acute

Table 1. Indicative recovery periods of various habitats

Habitat	Recovery
Plankton	Weeks/months
Sand beaches	1-2 years
Exposed rocky shores	1-3 years
Sheltered rocky shores	1-5 years
Saltmarsh	3-5 years
Mangroves	10 years and greater

ITOPF 2011

to chronic impacts. From this report, mangrove requires from 10 to 50 years to completely recover. The M/T Solar I oil spill in Guimaras impacted the mangrove forest in varying degrees from acute and lethal damages to sublethal stresses depending on the location and species specific. Oil band level reached as high as 1.2 m for trees surveyed and among the 29 species present in the island province, five species suffered mortality including *A. Marina, R. apiculata*, *R. mucronata*, *R. stylosa,* and *S. alba* (Sadaba et al. 2009b). Acute effects involved yellowing of leaves defoliation and mortality while long term effects involved appearance of albino propagules manifested in *R. stylosa* and reduction in canopy cover and leaf sizes of *R. stylosa*, *R. mucronata* and *R. apiculata* (Sadaba and Barnuevo 2010, Sadaba and Barnuevo 2011). One year after the incident, re-colonization started as manifested in the internodal counts (separate report) of the three indicator *Rhizophora* species monitored. There is no change in species diversity since the recruited seedlings were the same species previously occupying the area. The deforested areas were concentrated in the inner part of the forest dominated by *Rhizophora* species stretching towards the terrestrial margin while the outer fringe remained intact. The deforested area is located in low hydrodynamics and tidal flushing is minimal which consequently resulted to delayed oil removal through natural processes. The same observations were reported by Duke et al. (1997) in the 1968 and 1986 oil spills in Bahia Las Minas on the Caribbean coast of Panama and Getter et al. (1981) in the Gulf of Mexico and Caribbean Seas. Based on the conceptual model for evaluating the residence time of oil in mangroves forests by Jacobi and Schaeffer-Novelli (1990), after an oil spill on a mangrove coastline the oil tends to be retained by mangrove sediment and its removal is mainly in association with seaward export.

Table 2. Generalized response of mangroves to oil spill

Stage	Observed impact
Acute	
0-15 days	Deaths of birds, fish, invertebrates
15-30 days	Defoliation and death of small (<1m) mangroves
	Loss of aerial root community
Chronic	
30 days - 1 year	Defoliation and death of medium (<3m) mangroves
	Tissue damage to aerial roots
1 year - 5 years	Death of larger (>3m) mangroves
	Loss of aerial roots
	Regrowth of roots (sometimes deformed)
	Recolonization of oiled areas by new seedlings
1 year - 10 years?	Reduction in litter fall
	Reduced reproduction
	Reduced seedling survival
	Death or reduced growth of recolonizing trees?
	Increased insect damage?
10 - 50 years?	Complete recovery

CONCLUSION AND RECOMMENDATIONS:

Mangroves are resilient and recover quickly when given an opportunity and if the geomorphological and hydrological features of their habitat are not changed by human use (Martinuzzi et al. 2009). Understanding vegetation dynamics is important for conservation, restoration and sustainable exploitation purposes (Santos et al. 2012). Any information on mangrove dynamics serves as a basis for deciding whether or not human interference in the form of management or restoration is appropriate (Dahdouh-Guebas et al. 2004). It is important to be aware of natural processes and how they might have been altered, if at all, by oil spills. Otherwise the outcome of the good intentions of habitat restoration could result to further destruction of the already damaged habitat (Duke et al. 1999). In Guimaras, the recruitment and settlement of seedlings was impaired in areas where dead trees are extracted mainly for firewood purposes. The harvesting of dead trees created a forest gap, exposed the area to surging waves and thus increased the hydrodynamics. On the other hand, faster recovery dynamics was observed in area where the dead trees are not harvested. The presence of logs trapped the available propagules and facilitated the colonization of new cohorts.

Most common initiative from governing institutions in dealing with the aftermath of oil spill incident particularly in the Philippines is replanting mangroves without conducting baseline site assessment. This is mainly due to the pressure expected from them being tasked to respond to environmental disaster. In any restoration efforts, the decision in assisting the recovery of the damaged habitat such as from oil spill is based on the assumption that natural processes are inadequate in restoring the damaged habitat. Thus, before proceeding to mangrove restoration, it is therefore imperative to have knowledge of the natural processes and recovery dynamics of the impacted areas. Assessment of recruitment, mortality and growth of seedlings in the deforested and or impacted areas can serve as basic indicator. Otherwise the good intentions of helping the recovery processes could result to further destruction of the already disrupted community.

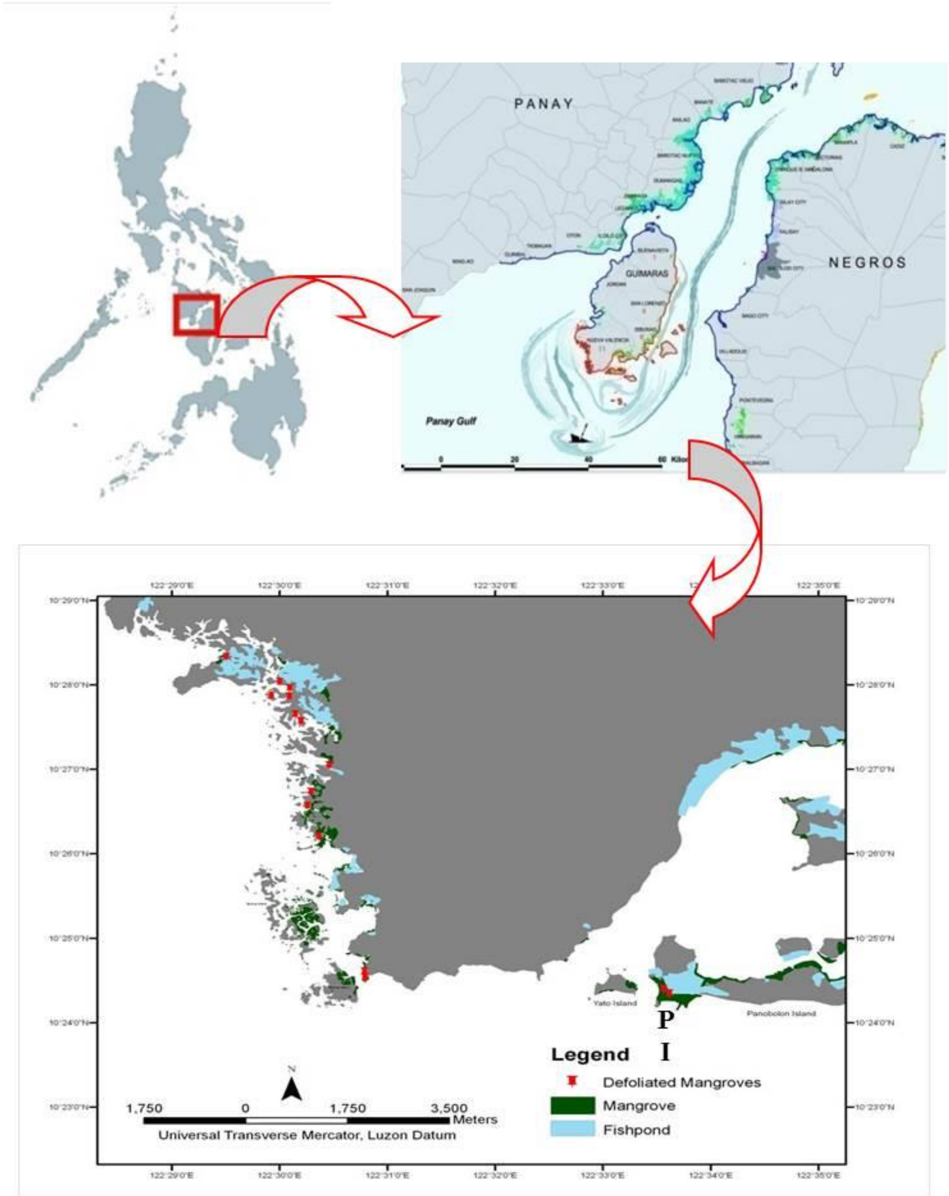

Figure 1. Map of study sites (red). PI – Panobolon Island; SB - Sitio Bagatnan (Map by WWF Philippines and A. Moscoso)

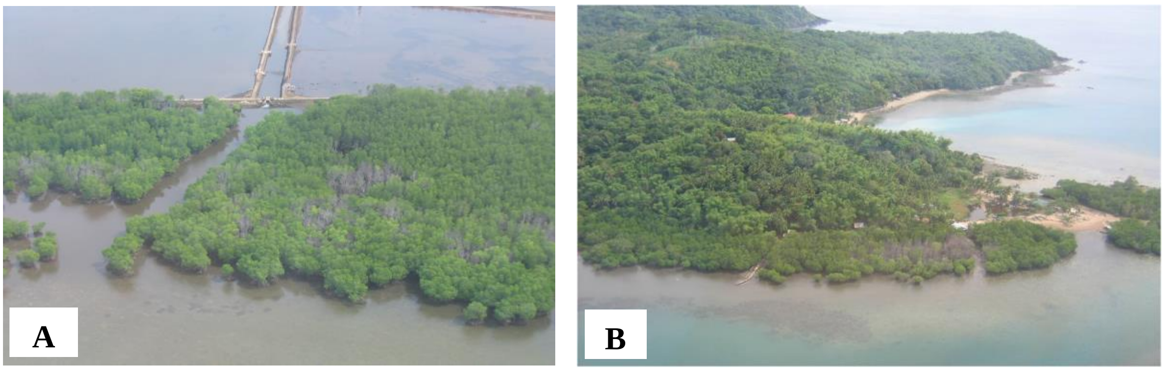

Figure 2. Aerial photographs of dead mangrove areas in (a.) Panobolon Is., and (b.) Sitio Bagatnan. Photos by K. Stanzel

Figure 3. Collection of soil samples for hydrocarbon analysis. Samples were taken up to 22 cm and subdivided into 3 depths: 0-2cm, 10-12 and 20-22.

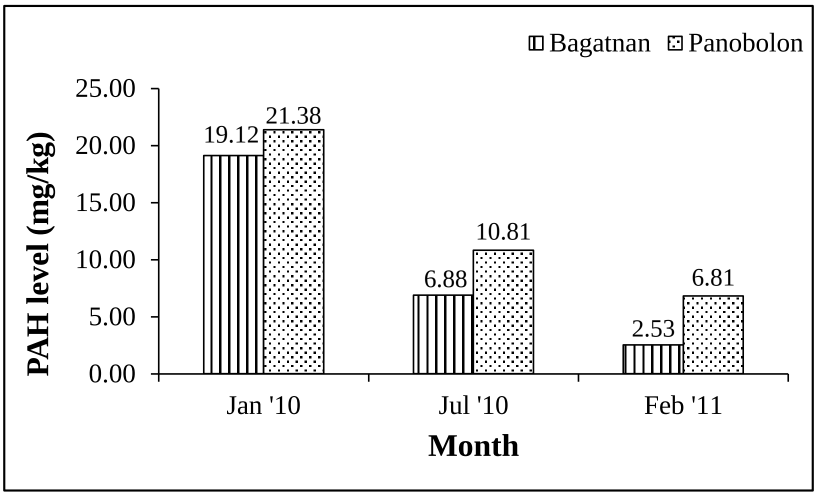

Figure 4. Levels of polyaromatic hydrocarbons in sediments (mg/kg)

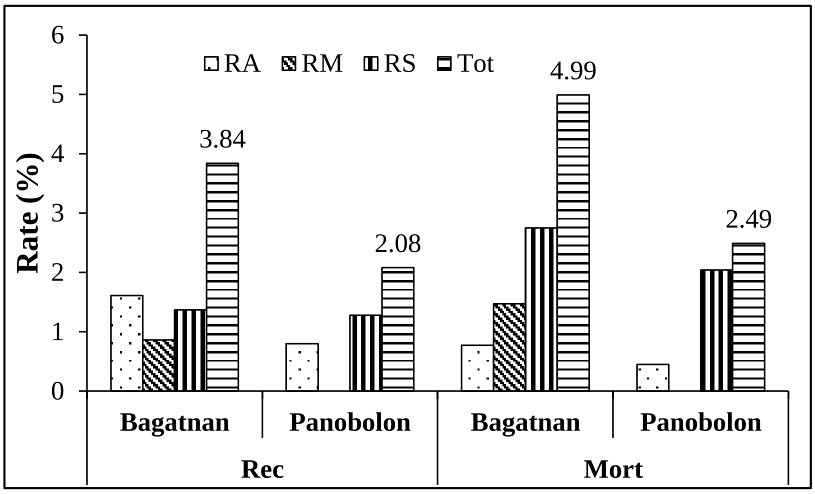

Figure 5. Rate of recruitment and mortality (%) in Bagatnan and Panobolon. (RA – *R. apiculata, RM – R. mucronata, RS – R. stylosa,* Tot – total, Rec – recruitment, Mort – mortality)

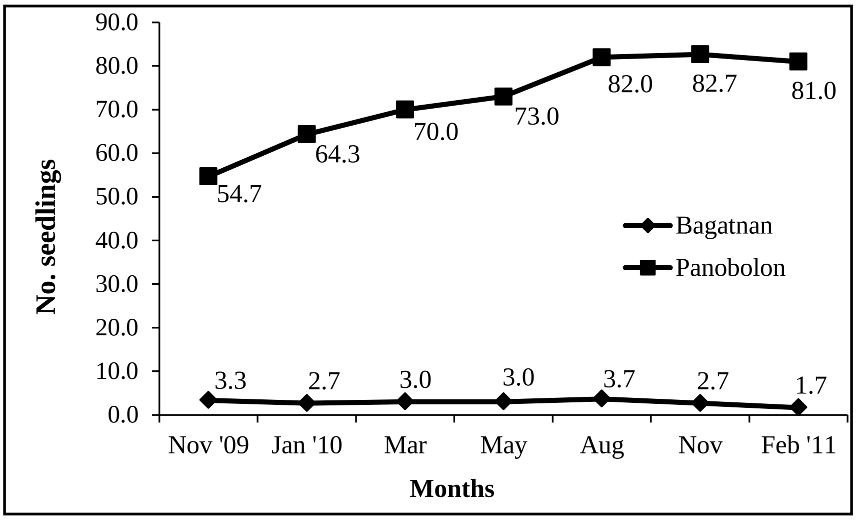

Figure 6. Average seedlings richness inside the established permanent monitoring plot (area = 25 m^2).

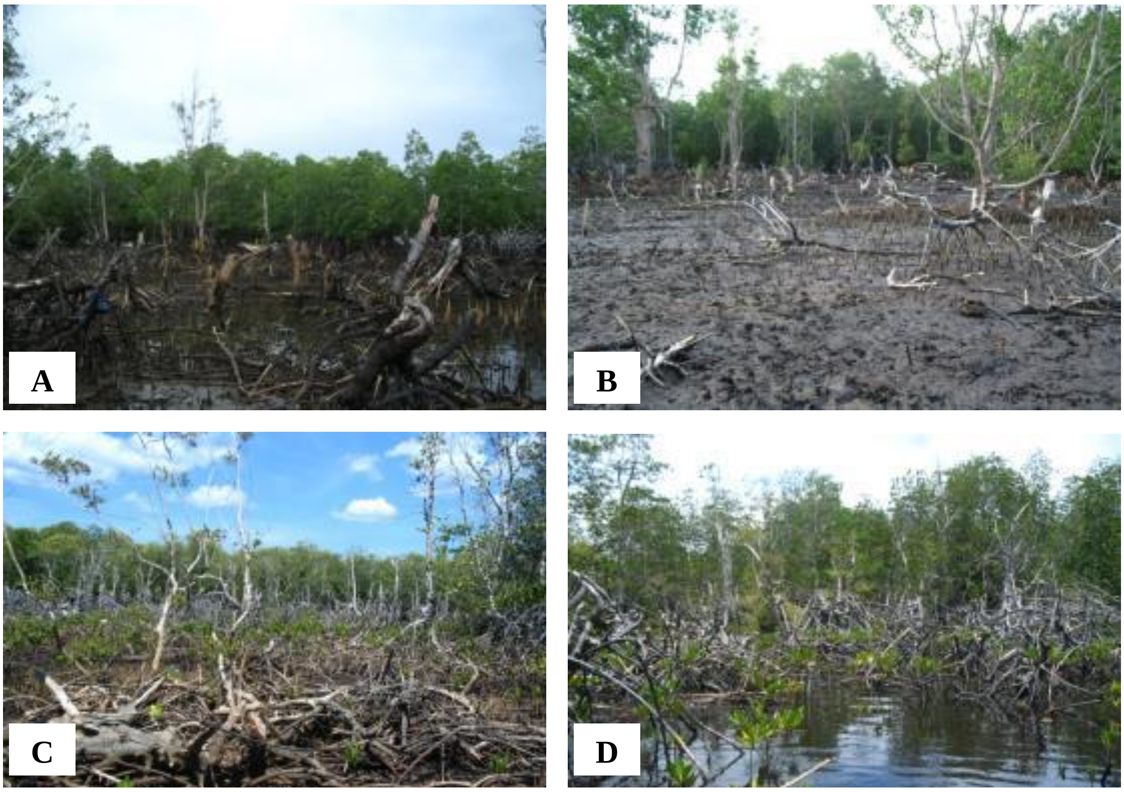

Figure 7. Photos of deforested areas in Bagatnan and Panobolon three years after the oil spill. The photod in A and B is in Bagatnan deforested area, while the photos in C and D in Panobolon.

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