Community Characteristics of Mangrove Species in Guimaras After an Oil Spill

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Abstract. The oil spill from M/T Solar I on August 11, 2006 off southern Guimaras, Philippines released over two million liters of Bunker C industrial fuel. Visibly affected were the highly vulnerable mangroves. Spilled oil were stranded and settled in the shores affecting mangrove trees, saplings, and wildings; and including the associated resident fauna. The effect of oil spill in mangroves can be acute, secondary, and chronic and this paper focused only the acute effects of oil on the affected mangrove flora in the affected sites in Guimaras. Specifically, the study (a) identified true mangrove species affected; (b) described the community structure; and (c) mapped the degree of oiling and areas with defoliated mangroves. The assessment was conducted on August 19 to November 18, 2006 for community structure analysis in 14 oiled sites, namely; Brgys. Dolores, Tando, Lucmayan, San Roque, La Paz (Taklong Island National Marine Reserve), Cabalagnan, Igdarapdap in Nueva Valencia; Brgys. Alegria, Sabang, Sebaste, San Isidro, Bubog in Sibunag; Igcawayan and Sebario in San Lorenzo. Two unoiled mangroves (reference sites) were also surveyed in Brgys. Getulio, Buenavista; and Lawi, Jordan. In terms of floristic composition, areas included in this assessment had 29 true mangrove species representing 14 families, or about 83% of the total number of known Philippine mangrove species. The highest floristic composition was recorded in Taklong Island National Marine Reserve (TINMR), in La Paz with 26 species. The most frequently occurring species were *Avicennia marina*, *Rhizophora apiculata*, *R. mucronata*, *R. stylosa*, and *Sonneratia alba* which occurred in 15 sites (93.8%) and they were also the dominating species with 66.66, 52.02, 27.48, 30.72, and 50.01 relative dominance respectively. Large-sized trees were found in Sebario, Igdarapdap, and Bubog with 13.31, 12.51, and 10.55 cm diameter at breast height respectively. Stand basal area ranged from 1.96 m^2 ha^{-1} in Sebaste, to 56.36 m^2 ha^{-1} in Bubog. The presence of large-sized *S. alba* in Bubog contributed greatly to its stand basal area while relatively young or generating mangroves composed the stand of the latter. Densities per plant category vary widely per site. Wilding density was highest in Dolores with 49,567 individual ha^{-1} and lowest in Tando with 700 individual ha^{-1}; sapling density was highest in Dolores with 2,900 individual ha^{-1} and lowest in San Isidro with 650 individuals ha^{-1}; and tree density was highest in TINMR with 3,983 individual ha^{-1} and lowest in Sabang with 783 individual ha^{-1}. Species diversity was highest in Sebaste (H'= 1.088) and lowest in Dolores (H' = 0.497). This high diversity is mainly attributed by the absence of the dominant species. The acute effects during the three month assessment involved the massive death of mangroves in Lucmayan, Bagatnan and Alman Sur which accounted to 0.932 ha. However, the remaining stranded oil in the mangrove area will continue to be a source of stress that cause chronic effects that are observed in a continuous and regular monitoring of the areas affected.

Keywords:
mangroves,mangrove community structure, Guimaras, oil spill

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Introduction

The term mangrove refers to the dominant intertidal plant community composed of nontaxonomically related species of woody halophytes that occur along most low-wave energy shorelines, deltas, estuaries, and embayments in the tropics and subtropics (Macnae, 1968; Lugo and Snedaker, 1974). These are highly-valuable ecosystems to sustain biodiversity in intertidal regions in tropical and sub-tropical areas (Duke, 1992; Tomlinson, 1986). Their known ecological and economic significance are well-established (Odum and Heald, 1975; Robertson and Duke, 1987; Bandaranayake, 1988;). However, they remain under constant threat from direct (i.e. conversion to fishpond, reclamation for housing and industrial use, and others) (Sasekumar *et al.*, 1994; Primavera, 1995) and indirect anthropogenic activities occurring upland (i.e., agriculture and urban run-off) and offshore (e.g. accidental oil spill) (Lewis, 1983; Duke *et al.*, 1997).

Mangrove forests are highly vulnerable to oil spills since oil settles with the tide and smothers both breathing and feeder roots including the associated residentfauna (Lai *et al.*, 1993). Mangroves can be killed or harmed by oil due to physical suffocation and toxicological or physiological impacts. Reports disagree with regard to relative contributions of each

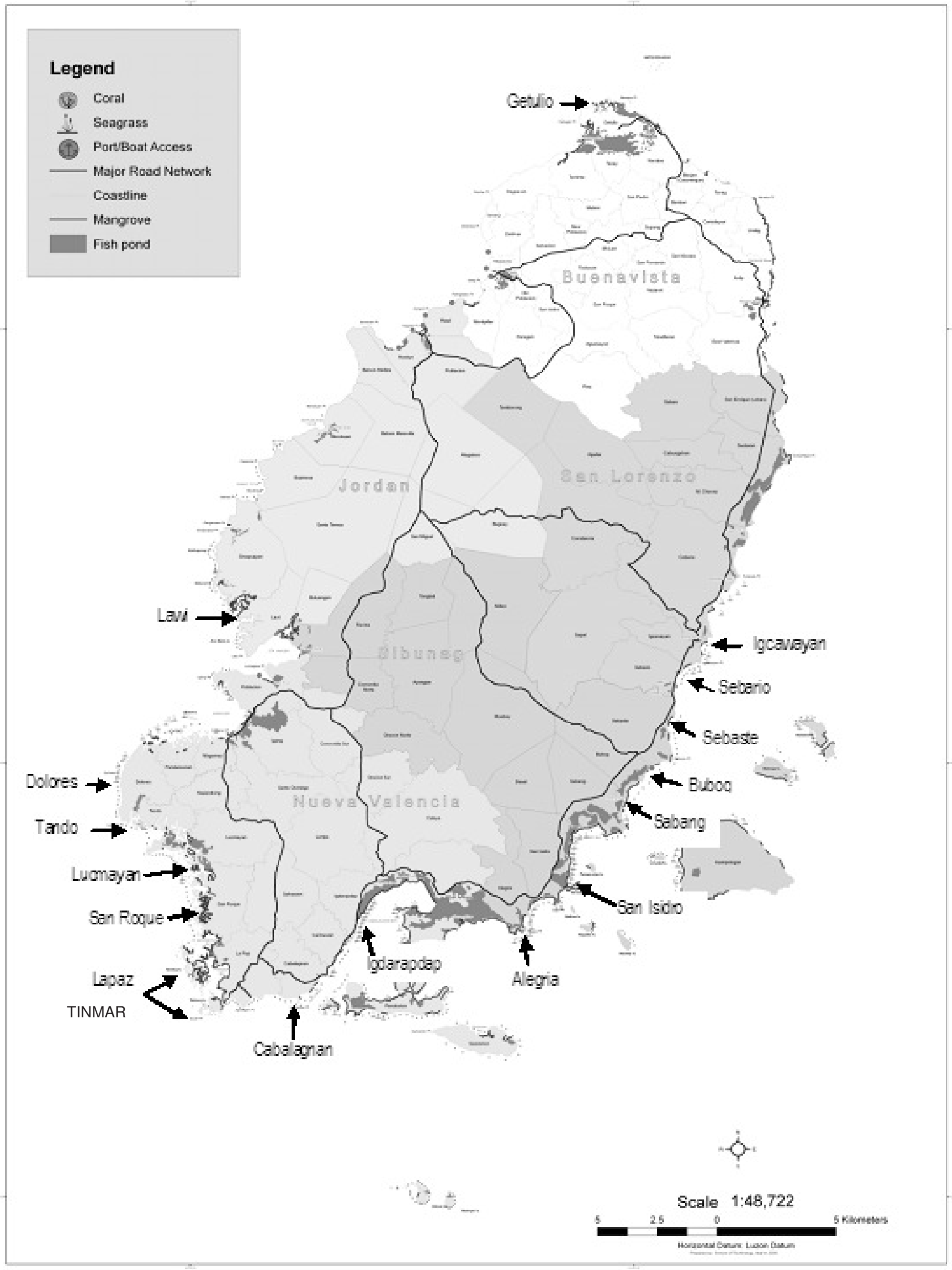

Figure 1. Map of Guimaras showing the study sites (in arrow) in five municipalities. (Map by A. Moscoso)

mechanism which may further be influenced by the type of oil, weathered state and quantity, the mangrove species, prevailing climatic and tidal conditions, and period of exposure after a spill (Cintrón *et al.*,)1981.

The M/T Solar I oil spill on August 11, 2006 off Guimaras which released more than 2 million liters of Bunker C has affected the mangroves in this part of the province including those within the Taklong Island and Tandog Island National Marine Reserve (TINMR) in Lapaz and San Roque, Nueva Valencia where the University of the Philippines Visayas Marine Biological Station is located. The effects of oil spill in mangroves can be acute, secondary, and chronic. This paper however, focused only on the acute effects of oil within three month period on the affected mangrove flora in the affected sites. Specifically, the study (a) identified true mangrove species affected; (b) described the community structure; and (c) mapped out the areas of defoliated mangroves.

Methodology

Assessment covered the period August 21 to November 18, 2006 in the M/T Solar I affected areas in Guimaras. A total of fourteen oiled sites were surveyed as follows: Brgys. Dolores, Tando, Lucmayan, San Roque, La Paz (TINMR), Cabalagnan, Igdarapdap in Nueva Valencia; Brgys. Alegria, Sabang, Sebaste, San Isidro, Bubog in Sibunag; Igcawayan and Sebario in San Lorenzo. In addition, two unoiled mangroves (reference sites) were also surveyed in Brgy. Getulio, Buenavista; and in Lawi, Jordan (Figure 1).

Mangrove community structure was done following the modified transect line plots method of English *et al (*1994) for community structure analysis. Representative plots with 100 m^2 area were established in the general forest structure. True mangrove species inside the plot were identified based on the handbook of Primavera *et al* (2004) and measurement of girth at breast height (GBH) of trees was taken approximately at 1.3 m above the ground. For trees with different growth forms and shape, the following guidelines were followed: when a system forks/branches below breast height, each branch was measured as a separate stem; when the stem branches at breast height or slightly above, measurement was taken at the breast height or just below the swelling caused by the branch; when the stem has prop roots or fluted lower trunk (*Rhizophora* species), measurement of the girth was taken 20 cm above the root collar; and, when the stem has swellings, branches, or abnormalities at the point of measurement, the girth was measured slightly above or below the irregularity. Saplings (girth less than 4 cm and height greater than 1 m) and wildings (height less than 1 m) were identified and number of individuals by species was determined by actual count. Smaller subplots (5 x 5 m) were established in the corner of the main plot if the density of saplings and wildings was uniform and evenly distributed throughout the main plot. The community structure was analyzed using ecological parameters with formulae presented below:

Height of trees was determined by approximation while height of saplings and wildings was determined using a meter stick and areas with

$$Basal\ Area\ (BA) = \frac{\pi DBH^2}{4}\ cm^2$$

$$Stand\ BA = \frac{\Sigma\ BA}{area\ of\ the\ plot}\ m^2\ ha^{-2}$$

$$Stems\ per\ ha = \frac{no.\ of\ stems\ in\ plot \times 10{,}000}{area\ of\ the\ plot}$$

$$Relative\ density = \frac{no.\ of\ individuals\ of\ a\ species}{total\ of\ no.\ individuals\ (all\ species)} \times 100$$

$$Relative\ frequency = \frac{frequency\ of\ a\ species}{\Sigma\ frequency\ of\ all\ species} \times 100$$

$$Relative\ dominance = \frac{total\ basal\ area\ of\ a\ species}{basal\ area\ of\ all\ species} \times 100$$

$$Importance\ value\ (I_v) = Relative\ frequency + Relative\ density + Relative\ dominance$$

$$Shannon\ index\ of\ diversity\ (H') = -\sum_{i=1}^{s} \left(\frac{N_i}{N}\right) \log \left(\frac{N_i}{N}\right)$$

N_i = importance value of species I

N = sum of importance values for all species

S = total number of species in the sample defoliations were estimated and mapped out using a GPS Garmin® 76S.

Results and Discussion

Species composition

The overall species composition in mangrove areas included in this assessment recorded a total of 29 true mangrove species under 14 families and 16 genera. This is about 83% of the total number of Philippine mangrove species (Primavera *et al.*, 2004). Among the 29 true mangrove species identified, *Avicennia marina, Rhizophora apiculata, R. mucronata, R. stylosa* and *Sonneratia alba* were present in all sites surveyed. *Exoecaria agallocha* occurred in 15 sites (93.8% occurrence). The three most represented families were Rhizophoraceae; with nine; and Acanthaceae and Avicenniaceae with three representative species each. Families Meliaceae, Myrsinaceae, Sonneratiaceae, Bombaceae, Combretaceae, Euphorbiaceae, Lythraceae, Myrtaceae, Arecaceae, Rubiaceae, and Sterculiaceae had either two or one species (Table 1). The species *Rhizophora x lamarckii* was recorded only in Taklong Island. This species is a hybrid of *R. apiculata* and *R. mucronata* and reported to be found only in Taklong Island and nowhere else in the Philippines. Species composition was highest in Taklong Island, La Paz, Nueva Valencia with 24 species. Brgy. Sabang, Sibunag had 25 species. Brgy. Tando and San Roque in Nueva Valencia had the least, 11 species each.

The total number of true mangrove species recorded in this study is higher than those reported by Babaran *et al.* (1995) for the Province of Guimaras. A similar trend was also found among the total number of mangroves per municipality. The difference could possibly be attributed to differences in sampling sites between the two studies. In addition, the list of Babaran *et al.* (1995) had *Sonneratia caseolaris* as having the highest percentage occurrence of 80% but this species is commonly found in low-salinity areas (Primavera *et al.*, 2004) not typical of sites in Guimaras. This, in marked contrast with the common occurrence of *S. alba* as one of the most common species found in this study is reflective of the high-salinity condition prevalent in mangroves of Guimaras. *Bruguiera parviflora* was also not found in this study compared with the report of Babaran *et al.* (1995). Instead, this study recorded *Bruguiera cylindrica* at thirteen sites. *B. parviflora* is also known to occur in low-salinity areas (Primavera *et al.*, 2004).

Diversity index (Figure 2) was highest in Sebaste, Sibunag (H'= 1.088) followed by Lawi, Jordan (un-oiled) (H'= 0.907), Sabang, Sibunag (H'= 0.899), Bubog, Sibunag (H'= 0.881), and lowest in Dolores, Nueva. Valencia (H'=0.497). The various species recorded occurred in a fairly even distribution in all sites. Species evenness was highest in Sebaste, Sibunag with 0.884 and lowest in Dolores, Valencia with 0.711. In terms of floristic composition, Guimaras has more diverse floristic composition than the east coast of Samar which has 22 species (Mendoza and Alura, 2001); Danjugan Island, Cauayan, Negros Occidental with 14 species (King *et al.*, 2001); northern forest of Florida with 3 species (Dawes *et al.*, 1999) and south-western coast of Sri Lanka with 20 species (Jayatissa *et al.*, 2002). It is comparatively similar with Davao Gulf which has 30 species (Flores, 2003) and Cogtong Bay, Bohol with 33 species including mangrove associates (Yao, 1999). A simple listing or enumeration of species numbers, however, could not discount the fact that richness or variety of Guimaras mangroves could have been high if not for the conversions into fishponds. As the true value of mangrove ecosystems was recognized only recently (Primavera, 2004), the absence of a true taxonomic inventory prior to the destruction fails in the exact estimation of how many species actually existed before the advent of aquaculture and how many were actually lost to extinction. Considering the natural distribution patterns of mangroves (Tomlinson, 1986; Primavera *et al.*, 2004), most of the *3* sacrificed3 species were those occurring mainly in high-diversity zone of the upper and middle tidal flat, and which are more vulnerable to be converted to other purposes; thus, disappearing the fastest (Ashton and Macintosh, 2002).

Diameter at breast height and average height

Comparisons of structural characteristics of mangroves in 16 barangays surveyed were based on the following: mean diameter at breast height (DBH) in centimeters; stand basal area (m^2/ha); density of wildings (seedlings), saplings, and trees; species diversity; species evenness and average height (Table 2). The DBH of mangrove species expressed in centimeter (cm) is categorized into three class sizes namely: small, 0.5 to d"2.5 cm, medium, 2.5 to d"10 cm, and, large, >10 cm. Large-sized trees were found in Sebario, Igdarapdap and Bubog at an average of 13.31, 12.51, and, 10.55 cm, respectively. The other sites surveyed were composed of medium-sized ones including those in the unoiled areas (Getulio, Buenavista; and Lawi, Jordan). Comparison with common sites such as Getulio, San Roque and Taklong Island sampled by Babaran *et al.*, (1995) showed smaller DBHs of 8.01, 7.22, and 7.85 cm, respectively. The smaller DBH in Getulio and San Roque could be reflective of the continued pressure from anthropogenic activities such as firewood gathering which resulted in the removal of large-sized trees; while the reduction in Taklong Island could probably be the result of the increase in density of trees brought about by protection afforded by the declaration of the area as part of the marine reserve. Mean height of trees range from 4.8 m in Lucmayan to 6.6 m in Igdarapdap.

Stand Basal Area

For the 16 stations, the computed stand basal area ranged from 1.96 m^2/ha in Sebaste, to 56.36 m^2/ha in Bubog (Table 3). The low stand basal area in Sebaste is largely due to the absence of large-sized trees, and the occurrence of relatively-young small-medium sized trees, a characteristic of a generating mangrove forest type. In contrast, the presence of large-sized *S. alba* trees in Bubog contributed greatly to its high stand basal area. After twelve years since the work of Babaran *et al.*, (1995), the mangroves in Getulio, San Roque and Taklong Island appeared to have increased in terms of stand basal areas at 24.14 m^2 ha^{-1}, 29.91 m^2 ha^{-1}, and 22.72 m^2 ha^{-1}, respectively. The observed improvement of mangroves in Taklong Island could be a benefit derived from the non-harvest of trees in the marine reserve. The large mean DBH in all sites in Guimaras is comparable with the mangrove trees located in Dolores, eastern coast of Samar Island, Philippines with basal area of 22.78$\pm$7.9 m^2 ha^{-1}. It is however, larger than that of Guiuan, eastern Samar which has a basal 5.7$\pm$3.3 m^2 only, and those in Liloan, Cebu in central Philippines that has 0.73 m^2 basal area (Dacles *et al.*, 1995). The small basal areas in Guiuan and Liloan, Cebu is due to excessive harvesting as well as having smaller mangrove areas compared to other important coastal sites studied (Dacles *et al.*, 1995; Mendoza and Alura, 2001).

Density

The estimated densities (Table 4) of the various age classes of mangroves in the 16 barangays were not uniform. Wilding density was highest in Dolores at 49,567 wildings ha^{-1}; and lowest in Tando at 700 wildings ha^{-1}. Density of saplings was least in San Isidro (650 saplings ha^{-1}) and highest in Dolores (2,900 saplings ha^{-1}). Recorded tree density was highest in La Paz at 3,982 trees ha^{-1}; and lowest in Sabang, with only 783 trees ha^{-1}. Stems per hectare (total density of trees, saplings and widings) were highest in Dolores at 53,467 plants ha^{-1} and lowest in Alegria at 2,933 plants ha^{-1}. A comparison with sites surveyed in 1995 (Babaran *et al*, 1995) showed an increase in density (such as) from 709 to 2,127 trees ha^{-1} in Taklong Island; 1233 to 1384 trees ha^{-1} in Getulio; and, 733 to 1850 trees ha^{-1} in San Roque. The mean tree density of 1605 trees per hectare for Guimaras is lower than that in Borongan, Samar (3,300$\pm$656 trees ha^{-1}) and in Dolores, Samar (1,780$\pm$349 trees ha^{-1}) but higher than the 1,575$\pm$296 trees ha^{-1} in Matarinao Bay (Mendoza and Alura, 2001).

Importance Value

The importance value is a significant parameter that describes the community structure of mangrove stands since it shows which among the species predominate(s) in a given area. The value refers to the sum of relative frequency of a species, the relative density, and relative dominance (Table 5). An overall

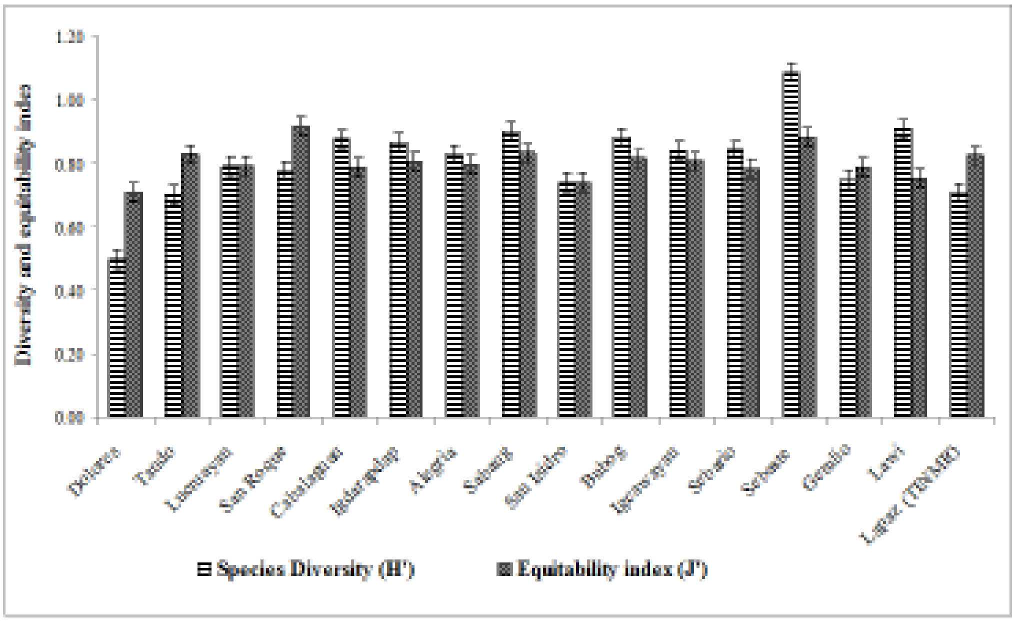

Figure 2. Shannon index of diversity (H') and equitability index of mangroves sampling sites (± s.d.). August 18 to November 19, 2006.

Table 1. Overall list of mangrove species in Guimaras, Philippines. August 18 to November 19, 2006.

Municipality		Nueva Valencia									Sibunag						San Lorenzo		
Site Number/Barangay Number		1	2	3	4	5					6	7	8	9	10	11	12	13	14
						LAPAZ													
Family	Species	DOLORES	TANDO	LUCMAYAN	SAN ROQUE	Taklong Is.	Tandog Is.	Bagatnan-Pototan	Alman Sur	Tuguisan	CABALAGNAN	IGDARAPDAP	ALEGRIA	SAN ISIDRO	SABANG	BUBOG	SEBASTE	SEBARIO	IGCAWAYAN
1. Acanthaceae	*1. Acanthus ebracteatus*	X				X		X	X	X			X		X				
	2. Ac. Ilicifolius	X				X		X	X	X			X		X				
	3. Ac. volubilis					X		X	X	X					X				
2. Avicenniaceae	*4. Avicennia marina*	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
	5. Av. officinalis			X				X			X	X			X				X
	6. Av. rumphiana	X		X		X		X	X	X	X	X	X	X	X	X	X	X	X
3. Bombaceae	*7. Camptostemon philippinensis*					X					X					X	X	X	X
4. Combretaceae	*8. Lumnitzera littorea*	X	X	X	X										X		X		X
	9. L. racemosa	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X
5. Euphorbiaceae	*10. Excoecaria agallocha*	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
6.Lythraceae	*11. Pemphis acidula*		X	X	X	X	X												X
7. Meliaceae	*12. Xylocarpus granatum*	X		X		X						X	X		X		X	X	X
	13. X. moluccensis			X		X		X		X		X	X	X	X		X		
8. Myrsinaceae	*14. Aegiceras corniculatum*			X				X						X	X	X	X	X	X
	15. Ae. floridum	X		X	X	X	X			X					X	X		X	X
9. Myrtaceae	*16. Osbornia octodonta*				X	X	X	X		X	X	X		X	X	X	X	X	X
10. Arecaceae	*17. Nypa fruticans*	X	X		X	X		X	X	X	X	X		X	X		X	X	X
11. Rhizophoraceae	*18. Bruguiera cylindrica*	X	X	X		X	X	X			X	X	X		X	X	X	X	X
	19. B. gymnorrhiza	X		X			X						X	X	X		X	X	
	20. Ceriops decandra	X		X		X	X	X		X	X	X	X	X	X	X	X	X	X
	21. C. tagal					X		X					X	X	X	X		X	X
	22. Rhizophora apiculata	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	23. R. x lamarckii					X													
	24. R. mucronata	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	25. R. stylosa	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
12. Rubiaceae	*26. Scyphiphora hydrophyllacea*					X	X	X		X		X			X		X	X	X
13. Sonneratiaceae	*27. Sonneratia alba*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	28. S. ovata																		
14. Sterculiaceae	*29. Heritiera littoralis*			X		X		X	X		X	X	X	X	X	X	X	X	X
Total Number of Species		**17**	**11**	**19**	**11**	**24**	**14**	**21**	**13**	**17**	**15**	**17**	**17**	**16**	**25**	**14**	**20**	**19**	**22**
Total Number of Families		**9**	**7**	**9**	**9**	**13**	**7**	**12**	**8**	**11**	**9**	**10**	**8**	**10**	**12**	**9**	**12**	**12**	**12**

* found outside sampling sites

Table 2. Structural characteristics of mangrove species in all surveyed sites in Guimaras, Philippines. August 18 to November 19, 2006.

Sites	Average height			Mean DBH	SBA	Stems Ha^{-1}	Density (n ha^{-1})			Speci
	Trees (m)	Saplings (m)	Wildings cm)	(cm)	(m^2 ha^{-1})	(n ha^{-1})	Trees	Saplings	Wildings	Divers
Dolores	3.7	1.9	52.4	4.17	3.82	53 467	49 567	2 900	1 000	0.5
Tando	6.3	1.9	67.4	8.49	26.40	4 433	700	1 278	2 456	0.7
Lucmayan	4.8	2.4	38.0	6.8	20.55	6 711	1 800	2 786	2 129	0.7
San Roque	5.6	2.1	45.6	7.22	29.91	15 500	1 283	983	1 850	0.7
Cabalagnan	6.3	3.6	59.5	9.01	35.32	15 500	12 617	1 350	1 533	0.8
Igdarapdap	6.6	1.9	79.7	12.51	43.19	2 850	800	900	1 150	0.8
Alegria	5.6	2.8	29.4	8.49	28.68	2 933	800	678	1 456	0.8
Sabang	4.8	1.9	29.4	7.45	14.01	5 200	1 850	2 500	850	0.9
San Isidro	5.0	2.1	63.7	8.32	18.02	3 300	1 867	650	783	0.7
Bubog	6.2	1.6	55.3	10.55	56.37	4 583	1 333	1 883	1 367	0.8
Igcawayan	5.1	1.8	55.4	9.99	33.20	7 125	4 725	925	1 475	0.8
Sebario	6.3	1.8	78.5	13.31	36.82	5 800	1 867	2 700	1 233	0.8
Sebaste	4.9	2.2	48.7	9.59	1.96	3 633	1 067	1 288	1 283	1.0
Getulio	6.0	2.0	36.3	8.01	24.14	3 217	1 067	767	1 383	0.7
Lawi	5.2	2.0	36.3	9.37	27.87	5 900	2 233	1 917	1 750	0.9
Lapaz (TINMR)	6.5	2.4	68.7	9.43	47.28	9 820	3 332	2 291	3 982	0.7

Table 3. Stand basal area (m^2 ha^{-1}) of mangrove species in all sites in Guimaras. August 18 to November 19, 2006

Municipality	Nueva Valencia								Sibunag				San Lorenzo	
Site number	1	2	3	4	5	6	7	8	9	10	11	12	3	14
Species	DOLORES	TANDO	LUCMAYAN	SAN ROQUE	LAPAZ (TINMR)	CABALAGNAN	IGDARAPDAP	ALEGRIA	SAN ISIDRO	SABANG	BUBOG	SEBASTE	SEBARIO	IGCAWAYAN
Aegiceras corniculatum									0.001	0.17	0.05	0.03	0.01	
Ae. floridum				2.40	0.83								0.02	
Avicennia marina	2.27	6.08	8.87	2.90	6.18	3.86	5.19	9.13	1.80	1.90	0.30	0.48	1.25	4.39
Av. officinalis						1.78								
Av. rumphiana			5.13		0.23	12.90	5.02	3.21	0.01	0.67	8.98	0.05	0.69	2.37
Bruguiera cylindrica						0.09	0.02	0.01				0.001	0.05	0.002
B. gymnorrhiza								1.75			0.05	0.004	0.02	
Camptostemon philippinensis												0.001		0.82
Ceriops decandra			0.04			0.72	0.01	0.05	0.03	0.05	0.02	0.15	0.14	0.01
C. tagal					0.07			0.08	0.11		1.41			
Excoecaria agallocha					0.43	0.52						0.02		
Heritiera littoralis						2.26						0.002		
Lumnitzera littorea														
L. racemosa		1.50	0.85		0.01	3.94	0.03			0.25	3.78			
Osbornia octodonta				0.51	0.11	0.26				0.24	0.001	0.05		
Pemphis acidula					0.31									
Rhizophora apiculata	1.21	0.46	0.18	4.87	5.79	0.61	10.43	10.77	12.70	6.91	2.87	0.09	0.02	0.01
R. mucronata	0.14	0.06	0.03	0.90	6.50	0.01		0.02				0.17	27.55	3.52
R. stylosa	0.18	2.51	0.40	0.75	6.59	0.04	1.30		0.06	0.55	4.26	0.43	0.14	4.95
Scyphiphora hydrophyllacea					0.02		0.60					0.11		
Sonneratia alba	0.03	15.80	5.04	17.58	16.11	8.31	19.79	3.65	3.31	3.26	34.64	0.35	6.87	17.13
Xylocarpus granatum			0.003				0.77					0.01	0.06	0.01
X. moluccensis							0.03	0.01				0.01		0.005
Total	**3.83**	**26.41**	**20.54**	**29.91**	**43.18**	**35.30**	**43.19**	**28.68**	**18.02**	**14.00**	**56.36**	**1.96**	**36.82**	**33.22**

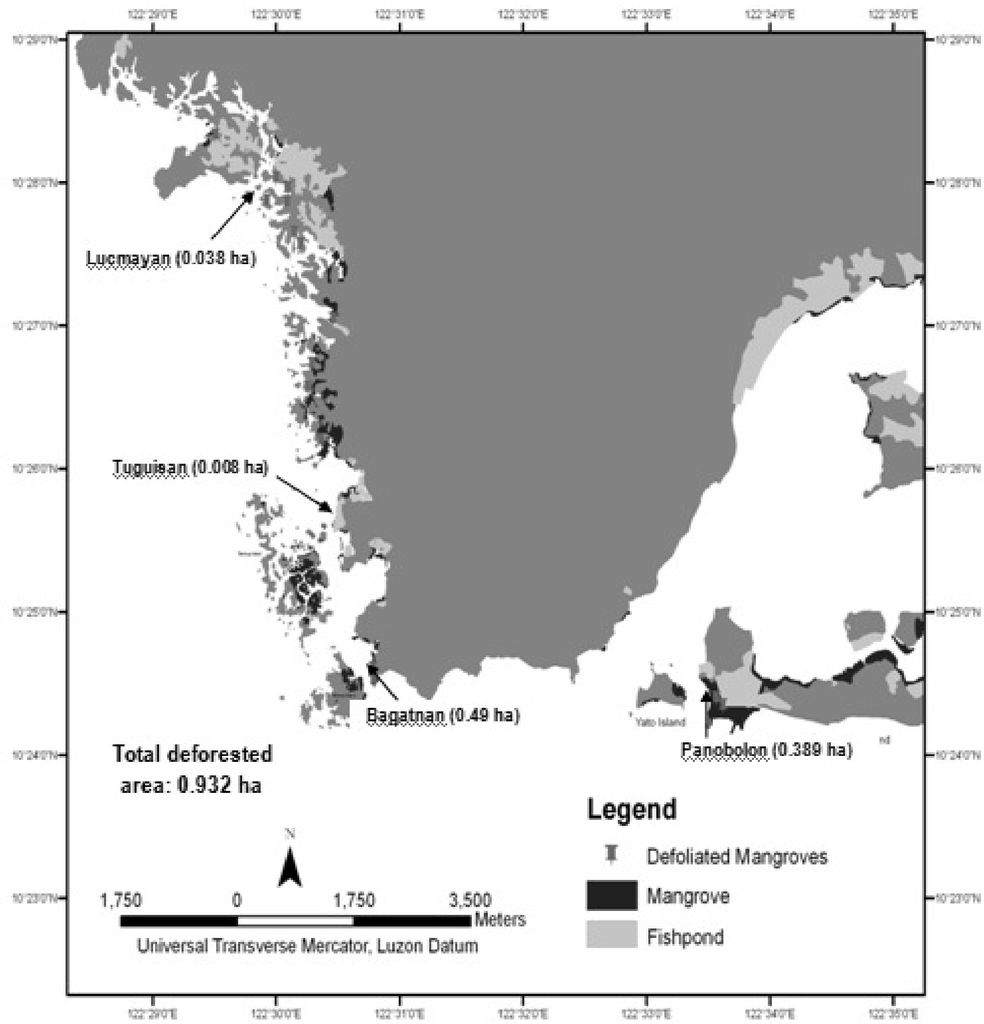

Figure 3. Areas (in hectare) with mangrove mortality within three months after oil spill in southern Guimaras. August 18 to November 19, 2006. (Map by A. Moscoso)

ranked based on the analysis of pooled values, showed that the top five species were *A. marina* (66.66), *R. apiculata* (52.02), *S. alba* (50.01), *R. stylosa* (30.72) and *R. mucronata* (27.48) (Table 6). The high importance values for these species could be attributed to combined factors of protection and high anthropogenic impacts observed in Guimaras mangroves, leaving mostly the individuals which are adapted for growth and proliferation in the low intertidal range. These species usually occur in high-salinity areas, consistent with the prevailing conditions found in the island. On the other hand, when only the list of the most important species is analyzed, three groups were formed. These are the *Avicennia*-dominated, *Rhizophora*-dominated, and *S. alba*-dominated areas. The *Avicennia* species dominated sites were Alegria, Dolores, Cabalagnan, and Lawi; the *Rhizophora* species dominated sites were Lapaz, Lucmayan, Sabang, San Isidro, Sebario, Sebaste, and Bubog; while the *S. alba* dominated species were Igcawayan, Igdarapdap, San Roque, and Tando.

Deforested areas

Areas with dead/defoliated mangroves occurred sporadically or in patches only. They were those in low energy areas where tidal flushing is minimal thus delaying oil removal through natural processes. Among sites surveyed, total area of deforested mangrove accounted to 0.932 hectares (Figure 3). Largest deforested patch was observed in Sitio Bagatnan, Lapaz with 0.490 ha. The site in Panobolon had 0.389 ha, Sitio Dungkaan, Lucmayan had 0.038, and Sitio Tuguisan, Lapaz had 0.008. Other sites including Taklong Island, Tandog Island, and San Roque had also deforested patches, however small enough to create gap canopy within the forest stand. This observed deforestation is an indicative of a highly impacted area. Hence, the municipality of Nueva Valencia where all the deforested areas found could be considered as the worst impacted area among the five municipalities. From among the species that were found inside the sampling plots, only five species

Table 4. Tree, sapling, wilding density (n ha^{-1}) of mangrove species in all sampling sites in Guimaras (August 18 to November 19, 2006)

Municipality	Nueva Valencia																			
Site number	1			2			3			4			5			6			7	
Site/Barangay	DOLORES			TANDO			LUCMAYAN			SAN ROQUE			LAPAZ (TINMR)			CABALAGNAN				
Species	Tree	Sapling	Wilding	Tree	Sapling	Wilding	Tree	Sapling	Wilding	Tree	Sapling	Wilding	Tree	Sapling	Wilding	Tree	Sapling	Wilding	Tree	Sapling
Aegiceras corniculatum																				
Ae. floridum										200	17	150	190	41	63					
Avicennia marina	633	1400	49167	544	78	111	1171	1129	1443	567	483	283	350	306	573	200	217	367	333	200
Av. officinalis																50				
Av. rumphiana							286						24			283	67	11667	50	
Bruguiera cylindrica																17				83
B. gymnorrhiza																				
Camptostemon philippinensis																				
Ceriops decandra							14		14					2		150	467	50		17
C. tagal													28	72	17					
Excoecaria agallocha						67							32	1		33				
Heritiera littoralis																83				
Lumnitzera littorea																				
L. racemosa				211	100	200	114	957	243				5	5		150	17		17	
Osbornia octodonta										50		17	8		12	50				
Pemphis acidula													23	1	8					
Rhizophora apiculata	267	367	333	111	156	11	314	14		267	117	67	1016	184	522	33	33	33	450	233
R. mucronata	33	1033	67	11	111		14		14	250	250	383	1358	1348	617		183	67		17
R. stylosa	67	33		333	556	211	14	571	14	117	83	283	463	294	1392		233	317	50	33
Scyphiphora hydrophyllacea													2		2				17	50
Sonneratia alba		67		1244	278	100	200	86	71	400	33	100	484	38	125	483	133	117	217	83
Xylocarpus granatum								14							2				17	50
X. moluccensis								14												133
Total	**1000**	**2900**	**49567**	**2454**	**1279**	**700**	**2127**	**2785**	**1799**	**1851**	**983**	**1283**	**3983**	**2292**	**3333**	**1532**	**1350**	**12618**	**1151**	**899**
Stems ha^{-1}		**53467**			**4433**			**6711**			**4117**			**9608**			**15500**			**2851**

Table 4. ***cont'd***

Municipality	Sibunag												San Lorenzo						Buenavista		
Site number	9			10			11			12			13			14			15		
Site/Barangay	SAN ISIDRO			SABANG			BUBOG			SEBASTE			SEBARIO			IGCAWAYAN					
Species	Tree	Sapling	Wilding	Tree	Sapling	Wilding	Tree	Sapling	Wilding	Tree	Sapling	Wilding	Tree	Sapling	Wilding	Tree	Sapling	Wilding	Tree	Sapling	
Aegiceras corniculatum			17		250	138	17	50	67		17			33	133				42	100	
Ae. floridum														67							
Avicennia marina	133	350	217	100	300	688	17		100	133	133	17	33	33		875	500	1725	617	375	7
Av. officinalis																			17		
Av. rumphiana		17	133	25	25	25	467	100	450	83	50	167	33		33	75	75	225			
Bruguiera cylindrica										17			33				25				
B. gymnorrhiza					13		17		67		17			167							
Camptostemon philippinensis												17				25					
Ceriops decandra	17		17		125	113		100	33	67	200	267	33	667	100		25	75			
C. tagal	17	200	17			13	17		33												
Excoecaria agallocha										50	33									8	
Heritiera littoralis																					
Lumnitzera littorea											17										
L. racemosa				13	375		200	17	50												
Osbornia octodonta				38	50	38			50	217		67									
Pemphis acidula																					
Rhizophora apiculata	583	67	700	400	350	563	250	117	183	50		17		100	133		25	75	308	100	1
R. mucronata			33		13			17	17	150	33	167	967	333	1300	125	75	150		58	9
R. stylosa			700	13	850	213	150	1483	283	283	700	233		1267	167	275	125	2425	75	83	5
Scyphiphora hydrophyllacea			17							83	33	17									
Sonneratia alba	33	17		263	150	63	233			133			100	33		100	25	25	325	42	6
Xylocarpus granatum										17	17		33				25				
X. moluccensis			17								33	100					25	25			8
Total	**783**	**651**	**1868**	**852**	**2501**	**1854**	**1368**	**1884**	**1333**	**1283**	**1283**	**1069**	**1232**	**2700**	**1866**	**1475**	**925**	**4725**	**1384**	**766**	**10**
Stems ha^{-1}		**3302**			**5207**			**4585**			**3635**			**5798**			**7125**			**3217**	

Table 5. Relative density, relative frequency, and relative dominance of mangrove species in all sampling sites (August 18 to November 19, 2006)

Municipality	Nueva Valencia																			
Site number	1			2			3			4			5			6			7	
Site/Barangay	DOLORES			TANDO			LUCMAYAN			SAN ROQUE			LAPAZ (TINMR)			CABALAGNAN				
Species	Rel. Den.	Rel. Freq.	Rel. Dom.	Rel. Den.	Rel. Freq.	Rel. Dom.	Rel. Den.	Rel. Freq.	Rel. Dom.	Rel. Den.	Rel. Freq.	Rel. Dom.	Rel. Den.	Rel. Freq.	Rel. Dom.	Rel. Den.	Rel. Freq.	Rel. Dom.	Rel. Den.	Rel. Freq.
Aegiceras corniculatum																				
Ae. floridum										8.91	12.90	8.02								
Avicennia marina	95.76	27.27	59.36	16.54	21.87	23.04	55.74	21.05	14.57	32.39	9.68	9.68	19.12	15.28	17.18	5.05	17.24	10.92	22.22	13.33
Av. officinalis													2.75	4.07	2.13	0.32	6.90	5.05		
Av. rumphiana							4.26	17.47	8.42				0.33	3.87	0.92	77.44	10.34	36.52	1.75	10.00
Bruguiera cylindrica																0.11	3.45	0.25	2.92	6.67
B. gymnorrhiza																				
Camptostemon philippinensis																				
Ceriops decandra							0.43	6.95	0.06				0.27	0.60	0.002	4.40	10.34	2.03	2.34	6.67
C. tagal													15.69	3.33	0.52					
Excoecaria agallocha				1.50	3.13	0.01							1.55	1.22	0.52	0.21	6.90	1.47		
Heritiera littoralis																0.54	3.45	6.40		
Lumnitzera littorea																			0.58	3.33
L. racemosa				11.53	3.13	5.67	19.57	14.11	1.40				0.04	1.19	0.05	1.07	3.45	11.16		
Osbornia octodonta										1.62	3.23	1.72	0.17	0.91	0.12	0.32	3.45	0.74		
Pemphis acidula													0.60	0.94	0.52					
Rhizophora apiculata	1.81	27.27	31.74	6.27	18.75	1.74	4.89	12.00	66.55	10.93	19.35	16.29	29.62	17.97	17.44	0.64	6.90	1.74	40.35	20.00
R. mucronata	2.12	18.18	3.53	2.76	12.50	0.21	0.43	3.58	0.04	21.46	16.13	3.02	21.29	18.31	12.06	1.61	6.90	23.21	0.58	3.33
R. stylosa	0.19	9.09	4.61	24.81	18.75	9.49	8.94	3.58	0.66	11.74	19.35	2.49	7.86	11.37	10.88	3.54	3.45	0.12	2.92	6.67
Scyphiphora hydrophyllacea													0.08	0.60	0.08				4.68	3.33
Sonneratia alba	0.12	18.18	0.75	36.59	21.88	59.83	5.32	14.11	8.28	12.96	19.35	58.78	0.04	19.75	37.54	4.73	17.24	0.38	10.53	20.00
Xylocarpus granatum							0.21	3.58	0.01				0.59	0.60	0.0003				4.09	3.33
X. moluccensis							0.21	3.58	0.004										7.02	3.33
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 5. ***cont'd.***

Municipality	Sibunag												San Lorenzo						Buenavista	
Site number	9			10			11			12			13			14			15	
Site/Barangay	SAN ISIDRO			SABANG			BUBOG			SEBASTE			SEBARIO			IGCAWAYAN				
Species	Rel. Den.	Rel. Freq.	Rel. Dom.	Rel. Den.	Rel. Freq.	Rel. Dom.	Rel. Den.	Rel. Freq.	Rel. Dom.	Rel. Den.	Rel. Freq.	Rel. Dom.	Rel. Den.	Rel. Freq.	Rel. Dom.	Rel. Den.	Rel. Freq.	Rel. Dom.	Rel. Den.	Rel. Freq.
Aegiceras corniculatum	0.51	4.86	0.01	7.45	8.11	13.48	1.81	5.82	13.48	0.46	4.17	1.70	2.87	11.17	0.03				4.40	6.67
Ae. floridum													1.15	5.50	0.04					
Avicennia marina	21.21	19.14	9.97	20.91	18.92	5.79	3.64	3.00	5.79	7.80	8.33	24.43	1.15	5.50	3.40	43.97	15.79	13.22	53.11	26.67
Av. officinalis																			0.52	4.53
Av. rumphiana	4.55	9.43	0.06	1.44	8.11	0.27	22.18	17.65	0.27	8.26	8.33	2.48	1.15	5.50	1.88	5.32	10.53	7.14		
Bruguiera cylindrica										0.46	4.17	0.07	0.57	5.50	0.14	0.35	5.26	0.01		
B. gymnorrhiza				0.24	2.70	0.02	1.82	3.00	0.02	0.46	4.17	0.22	2.87	11.17	0.05					
Camptostemon philippinensis										0.46	4.17	0.06				0.35	5.26	2.47		
Ceriops decandra	1.01	4.86	0.14	4.57	8.11	0.36	2.91	5.82	0.36	14.68	8.33	7.68	13.79	11.17	0.37	1.42	5.26	0.02		
C. tagal	7.07	9.43	0.61	0.24	2.70	0.003	1.09	5.82	0.003											
Excoecaria agallocha										2.29	4.17	1.11							0.26	2.13
Heritiera littoralis										0.46	4.17	0.08							16.84	13.33
Lumnitzera littorea																			4.66	11.20
L. racemosa				7.45	8.11	1.81	5.82	5.82	1.81											
Osbornia octodonta				2.40	5.41	1.77	1.09	5.82	1.77	7.80	4.17	2.55								
Pemphis acidula																				
Rhizophora apiculata	40.91	28.57	70.51	25.24	10.81	49.29	12.00	11.82	49.29	1.83	4.17	4.69	4.02	11.17	0.05	1.42	5.26	0.02		
R. mucronata	1.01	4.86	0.02	0.24	2.70	0.03	0.73	5.82	0.03	9.63	4.17	8.68	44.83	11.17	74.83	3.90	15.79	10.60		
R. stylosa	21.21	4.86	0.31	20.67	10.81	3.89	41.82	17.65	3.89	33.49	8.33	21.76	24.71	5.50	0.39	40.07	10.53	14.90	6.48	13.33
Scyphiphora hydrophyllacea										3.67	8.33	5.71								
Sonneratia alba	2.02	9.43	18.37	9.13	13.51	23.27	5.09	11.82	23.27	3.67	8.33	18.02	2.30	11.17	18.66	2.13	15.79	51.60	13.47	20.00
Xylocarpus granatum										0.92	4.17	0.33	0.57	5.50	0.16	0.35	5.26	0.02		
X. moluccensis	0.51	4.86	0.01							3.67	8.33	0.43				0.71	5.26	0.01	0.26	2.13
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 6. Importance values of mangrove species in all sampling sites (August 18 to November 19, 2006)

Municipality	Nueva Valencia								Sibunag				San Lorenzo	
Site number	1	2	3	4		6	7	8	9	10	11	12	3	14
Species	DOLORES	TANDO	LUCMAYAN	SAN ROQUE	LAPAZ (TINMR)	CABALAGNAN	IGDARAPDAP	ALEGRIA	SAN ISIDRO	SABANG	BUBOG	SEBASTE	SEBARIO	IGCAWAYAN
Aegiceras corniculatum									5.38	29.04	21.11	6.33	14.07	
Ae. floridum				29.83									6.69	
Avicennia marina	182.39	61.45	91.36	51.75	51.58	33.21	47.57	100.67	50.32	45.62	12.43	40.56	10.05	72.98
Av. officinalis					8.95	12.27								
Av. rumphiana			30.15		5.12	124.30	23.37	18.84	14.04	9.82	40.10	19.07	8.53	22.99
Bruguiera cylindrica						3.81	9.64	8.45				4.70	6.21	5.62
B. gymnorrhiza								17.57		2.96	4.84	4.85	14.09	0.00
Camptostemon philippinensis												4.69	0.00	8.08
Ceriops decandra			7.44		0.87	16.77	9.02	10.12	6.01	13.04	9.09	30.69	25.33	6.70
C. tagal					19.54	0.00		9.08	17.11	2.94	6.91			
Excoecaria agallocha		4.64			3.29	8.58						7.57		
Heritiera littoralis						10.39						4.71		
Lumnitzera littorea							3.99							
L. racemosa		20.33	35.08		1.28	15.68				17.37	13.45			
Osbornia octodonta				6.57	1.20	4.51				9.58	8.68	14.52		
Pemphis acidula					2.06									
Rhizophora apiculata	60.82	26.76	83.44	46.57	65.03	9.28	84.49	74.90	139.99	85.34	73.11	10.69	15.24	6.70
R. mucronata	23.83	15.47	4.05	40.61	51.66	31.72	3.91	23.25	5.89	2.97	6.58	22.48	130.83	30.29
R. stylosa	13.89	53.05	13.18	33.58	30.11	7.11	12.59	3.84	26.38	35.37	63.36	63.58	30.60	65.50
Scyphiphora hydrophyllacea					0.76		9.40					17.71		
Sonneratia alba	19.05	118.30	27.71	91.09	57.33	22.35	76.35	29.17	29.82	45.91	40.18	30.02	32.13	69.52
Xylocarpus granatum			3.80		1.19		9.21					5.42	6.23	5.63
X. moluccensis			3.79				10.42	3.85	5.38			12.43		5.98
Total	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**

showed mortality- *A. marina*, *R. apiculata*, *R. stylosa*, *R. mucronata*, and *S. alba*. The high vulnerability of *Rhizophora* species is attributed to the architecture of the plant where support of trees is mainly provided by the aerial roots with minimal ground roots. Thus, coating of exposed roots leads to suffocation as well as suffer from the toxic effects of oil. However, few dead trees of *Osbornia octodonta* and *Aegiceras floridum* were also found outside of the plots in Sitio Bagatnan-Pototan in Lapaz occurring at the upper intertidal levels pointing to the extent of oiling in certain areas.

Conclusion

The forest structure of mangrove in Guimaras is not pristine and considered to be secondary to tertiary forest types. It has been subjected to varying degrees of anthropogenic activities by the nearby settlers and the M/T Solar I oil spill compounded the human-induced stress on mangroves. Oil on mangroves can have acute or chronic/sublethal effects but distinction may sometimes be unclear. The most visible signs of mangrove stress following the oil spill were observed within the first two weeks of the spill; these included chlorosis or yellowing of leaves, defoliation, and death of trees, saplings and wildings. The effect of oil spill in mangroves can persist for several decades and recovery usually does not usually imply restoration to the original pre-oil spill conditions. Thus, "recovery" can only be determined through a long term monitoring program.

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