Long-Term Impact of Oil Pollution on Vegetation Diversity and Structure in a Secondary Rainforest, Rivers State, Nigeria

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ABSTRACT: Phytoremediative ability of plant and natural regeneration have been documented but there is no unanimity on the rate of regeneration at an unremediated site. During studies on the long-term effects of oil pollution on soil microarthropods eco-toxicology, assessment of above-ground vegetation was undertaken. Assessment comprised, determination of Total Hydrocarbon Content (THC) values in soil, plant form (Trees, shrubs, grasses and sedges) composition and relative abundance, and the evenness and unevenness of numbers of individuals from each species, an indicator of species diversity. Studies were conducted at four habitat-types: unpolluted and polluted 1yr, 3yrs and 6yrs prior to the commencement of investigations in a secondary rainforest, Rivers State, Nigeria. Total Hydrocarbon Content (THC) of the soils was measured. Simple random sampling method based on standard procedures for ecological assessment along transects. THC values were progressively lower with time (interval between oil spill and commencement of study). In the unpolluted habitat, numbers of individuals in each species were relatively even. Trees and shrubs were abundant; grasses and sedges were very few. The habitat polluted 1yr pre-study was dominated by grasses and sedges. There was high species richness, although there was great unevenness in the abundance of species. The habitat polluted 3yrs pre-study was dominated by grasses and sedges. In the habitat polluted 6yrs pre-study, the species composition and plant forms were similar to those in the unpolluted habitat, although there was high unevenness in the abundance of species. The progressively lower THC values with time, post-pollution, were an indication of the phytoremediative ability of plants. The graminoids with rhizomes were probably less affected by oil pollution, hence the high species richness in habitats, polluted 1 and 3 years pre-study. Although in the habitat polluted 6years pre-study, the species composition and plant forms were similar to those in the unpolluted habitat, the effects on pollution were still evident in the unevenness in the abundance of species.

Key Words: Oil Spill, Plant Forms, Abundance, Diversity, Nigeria.

1. Introduction

Studies on eco-taxonomic assessment of plant species regeneration in oil-impacted habitats in the Niger Delta had focussed on remediated soils [1,2,3]. Since natural regeneration occurs as a result of phytoremediation [4,5,6], an eco-taxonomic assessment of plant species regeration was undertaken in 4 habitat types (Pristine, polluted 1year pre-study, 3years pre-study, polluted 6years pre-study) during studies on the impact of oil pollution on soil microarthropods (mesofauna) in a secondary rain forest, Rivers State[7,8,9,10].

2. Materials and Methods

2.1. Study Area

The studies were conducted at Norkpo, Kporghor and Gio in Tai Local Government Area of Rivers State Nigeria. The study area in each village was approximately 3500m^2 of secondary rainforest in Nigeria's lowland ran forest zone. It is in the centre of one of the agricultural zones in the State (Fig 1). There are two seasons: rainy (May-October) and dry (November-April). The area is characterized by species of trees, shrubs, herbs, climbers and lainers. The dominant species are in the *Loganiacae, Fabacae, Poaceae, Euphorbiacaea, Malraceae, Asteraceae, Cyperaceae*, *Convolvulaceae, Myraceae, Selliginellaceae*; these families are typical of secondary succession in fallowed bush.

2.2. Methodology

Studies were conducted at four habitats: unpolluted, polluted 1yr, 3yrs and 6yrs prior to the commencement of investigations.

2.2.1. Determination of Total Hydrocarbon Content (THC)

Since the major pollutant in three of the four habitats was petroleum, soil was collected to a depth of 10.0cm from four subplots in each habitat, for the determination of THC. Determination of THC was undertaken during dry and rainy seasons by the 1985 ASTMD 3921 (modified) method. QA/QC measures undertaken during the analysis for THC included: Solid samples were dried at room temperature and sieved through 2mm mesh; analytical grade solvent ($CHCL_3$) was used; standard BCBM crude oil was used to plot graphs; adsorbent of analytical grade anhydrous $NaSO_4$ was used to eliminate interferences; analysis was in replicate and the service of another laboratory was engaged for comparison.

2.2.2. Quantitative and Qualitative Floral Analyses

Plant species identifications were based on the keys of Keay [11] and Burkill [12, 13. 14, 15, 16]. Simple random sampling method based on standard procedures for ecological assessment along transects was utilized[17]. In each habitat-type, five 20m x 20m transects were sampled. Representative plant species were identified. The frequency of distribution and abundance of the most representative species were estimated by the Kershaw[18] and Austin and Greg-Smith[19] methods, modified by Chikkahuchaiah *et al.*[20] and Bonham[21]. The diversity of each species within the family was

evaluated using the Shannon-Wiener index, modified by Shukla[22] and Kinako[23]. Species of many stands, with wide frequencies of distribution were described as very abundant (++++>) and species of fewer stands, with wide frequencies of distribution were moderately abundant (+++). The species of limited geographical distribution and few stands were termed scarce or occasional (++) and those with fewer stands as very scarce or rare (+).

$$\% \text{ Frequency of species} = \frac{\text{Number of transects in which species occurred}}{\text{Total Number of Transects}} \times 100$$

Species diversity within family Kinako's Index $D_k = S + \sqrt{\frac{1}{2N}}$

S = No of species present in transect community;

N = Number of individuals in species per transect

3. RESULTS

3.1. Total Hydrocarbon Content

Mean THC values were 10.0mg/kg at the unpolluted habitat and 630mg/kg, 260mg/kg and 125mg/kg at the habitats polluted 1yr, 3yrs and 6yrs pre-study respectively.

3.2. Above-ground Vegetation

In the unpolluted habitat, 27 species in 20 families were recorded; 3 families were dominant, with 11 abundant species and 12 very abundant species. Distribution of plant forms was: herbs (12), shrubs (7) and trees (7) (Table 1). Recorded from the habitat, polluted 1 yr pre-study were: 52 species in 26 families; 4 families were dominant, 3 species were very abundant and 6 species were abundant. The vegetation profile consisted of: herbs (28), trees (8), shrubs (100) and climbers (6) (Table 2). In the habitat polluted 3yrs pre-study, 32 species in 19 families were recorded; 2 families were dominant, 2 species were very abundant and 9 species abundant. Distribution of plants forms was: herbs (16), shrubs (8), trees (4) and climbers (3) (Table 3). The habitat polluted 6yrs pre-study recorded 22 species in 15 families; 2 families were dominant, 5 species were very abundant and 5 species were abundant. The vegetation profile consisted of: shrubs (9), trees (7], herbs (4) and climbers (2) (Table 4).

4. DISCUSSION

Total Hydrocarbon Content (THC) values were progressively lower with time (interval between oil spill and commencement of study) indicative of the phytoremediative ability of plants [22]. In the unpolluted habitat, the numbers of individuals from each species were more even, indicating higher species diversity[23]. This was reflected in the high species diversity indices obtained. The trees were abundant and shrubs flourished, providing effective ground cover. Grasses and sedges were very few, reflecting the advancing seral stage of the community [21]. The habitat polluted 1yr pre-study was dominated by grasses and sedges. Many graminoids with rhizomes were less likely to be adversely affected by oil pollution, especially those species with tall growth forms and associated deeper roots. These tolerant species contributed to the high species richness and therefore, high diversity in the habitat polluted

1yr pre study. However, the impact of the pollution was highlighted in the great unevenness in species abundance, a few were very abundant or abundant and many rare and scarce species.

The dominant plant forms in the habitat polluted 3yrs pre-study were grasses and sedges. Natural regeneration after oil pollution proceeds with germination, resulting from spatial movement of seeds. The crude oil must have killed the seeds in the seed bank. In addition, these grasses and sedges are ubiquitous, with high numbers of seeds per unit area during dispersal. They also have high dispersability potential (low seed weight, presence of pappus) and were aided by the dispersing agent, wind, thus producing high abundance[21]. In the habitat polluted 6yrs pre-study, the species composition and plant forms were similar to those found in the unpolluted habitat. However, there was high unevenness in the abundance of species reflected in low species diversity indices, attributable to the long lasting effects of crude oil pollution.

5. CONCLUSION

Although natural regeneration was near completion at 6years because the species composition and plant forms were similar to those in the unpolluted habitat, the long-lasting effects of crude oil pollution were still evident in the high unevenness in the abundance of species reflected in low species diversity indices.

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Table 1: Plant Species in Unpolluted Habitat

	Species	% F	SD	Family	Habits	Remark
1	*Bridella ferruginea* Benth	80	4.35	Euphorbiaceae	Shrub	+++
2	*Pteridium equilinium* Linn	60	3.41	Dennstaediaceae	Herb	+++
3	*Anthocleista voigelii* Planch	60	3.41	Loganiaceae	Tree	+++
5	*Cnetis ferruginea* Dc.	60	3.41	Connaraceae	Shrub	+++
6	*Rauvolfia vomitoria* Afzel	80	4.35	Apocynaceae	Tree	++++
7	*Alchornea cordifolia* (Schum Thonn) Mull-Arg	100	5.32	Euphorbiaceae	Shrub	+++++
8	*Elaeis guineensis* Jacq.	80	4.35	Arecaceae	Tree	++++
9	*Anthocleista nobilis* G.Don	60	3.41	Loganiaceae	Tree	+++
10	*Scleria verrucosa* Willd	60	3.41	Cyperaceae	Herb	+++
11	*Panicum maximum* Jacq	80	4.35	Poaceae	Herb	++++
12	*Baphia nitida* Lodd	40	2.50	Fabaccae-papi	Shrub	++
13	*Maesobortrya barteri (*Baill.) Hutch	60	3.41	Euphorbiaceae	Shrub	+++
14	*Barteria nigritiana* Hook F.	80	4.35	Passifloraceae	Shrub	++++
15	*Anthocleista djalonesis* A. Chev	40	2.50	Loganiaceae	Tree	++
16	*Conyza summatrensis* (Retz.) Walker	100	5.32	Asteraceae	Herb	
17	*Melastomastrum capitatum (*Vahl.*)* A & R. Fern	100	5.32	Melastomataceae	Herb	+++++

18	*Chromolaena odorata* (Linn.) R.M. King & Robinson	100	5.32	Asteraccae	Herb	+++++
19	*Smilax anceps* Willd	60	3.41	Smilacaceae	Climber	+++
20	*Icacina trichantha* Oliv	60	3.41	Icacinaceae	Herb	+++
21	*Costus lucanusianus* J. Braun & .K.Schum	80	4.35	Costaceae	Herb	++++
22	*Tetracera alnifolia* Willd	60	3.41	Dilleriecae	Climber	+++
23	*Anthonotha macrophylla* P. Beauv	80	4.35	Fabaceae-caesal	Shrub	++++
24	*Anchormanes difformis* (BL) Engl.	60	3.41	Araceae	Herb	+++
25	*Selaginella myosurus* (Sw) Alston	80	4.35	Selaginellaceae	Herb climber	++++
26	*Nehrolepis biserrata* (Sw) Schott	80	4.35	Davalliacea	Herbaceous Epiphyte	++++
27	*Palisota hirsuta (Thunb.)* K. Schum.	60	3.41	Commelinaceae	Herb	+++

+ (15-19) very scarce
++ (20-49) scarce
+++ (50-79) Abundant
++++> (80-α) very abundant
NA – Not available
SD- Species diversity (within family)
% F – percentage frequency

Table 2: Plant Species in Habitat Polluted Approximately 1-Year Pre-Study

	Species	% F	SD	Family	Habits	Remark
1	*Bambusa valgaris* Schrad	100	5.32	Poaceae	Tree	+++++
2	*Milletia aboensis* (Hook .f.) Bak	20	1.71	Fabaceae papilio	Shrub	+
3	*Uirena lobata* Linn.	20	1.71	Malvaceae	Herb	+
4	*Chromolaena odorata* (Linn.) R.M. King & Robinson	80	4.35	Asteraceae	Herb	++++
5	*Kyllinga erecta* Schumach	40	2.50	Cyperaceae	Herb	++
6	*Melastomastrum capitatum* (Vahl.) A&R. Fern	100	5.32	Melastomataceae	Herb	+++++
7	*Costus lucanusianus* J. Braun & K. Schum	20	1.71	Costaceae	Herb	+
8	*Alchornea cordifoli*a (Schum & Thonn.) Mull-Arg	100	5.32	Euphorbiaceae	Shrub	+++++
9	*Smilax anceps* Willd	20	1.71	Similacaceae	Climber	+
10	*Malvastrum coram andelianum* (Linn.) Garcke	20	1.71	Malvaceae	Herb	+
11	*Centrosema pubescens* Benth	20	1.71	Fabaceae	Climber	+
12	*Triumfetta cordifolia* A. Rich	20	1.71	Tiliaceae	Herb	+
13	*Elaeis guineensis* Jacq.	80	4.35	Arecaeceae	Tree	++++
14	*Psidium guajava* Linn.	80	4.35	Myrtaceae	Shrub	++++
15	*Anthonotha macrophylla* P. Beauv.	20	1.71	Fabacea-caesal	Shrub	+
16	*Seleria naumamana* Boeck	40	2.50	Cyperaceae	Herb	++
17	*Harrungana madagascariensis* Lam ex. Poir	80	4.35	Guttiferea	Shrub	++++
18	*Lonchocarpus sericeus* (Poir) HB & K.	20	1.71	Fabaceae-papi	Climber	+
19	*Anthocleista nobilis* G. Don	40	2.50	Loganiaceae	Tree	++
20	*Salaginella myosurus* (Sw) Alston.	80	4.35	Selaginellaceae	Herbaceous climber	++++
21	*Barteria nigritiana* Hook .F	40	2.50	Passifloraceae	Shrub	++
22	*Scopria duclis* Linn.	40	2.50	Serophulariaceae	Climber	++
23	*Baphia nitida* Lodd	20	1.71	Fabaceae-papilio	Shrub	+
24	*Cleistopholis patens* (Benth.) Engl & Diels.	20	1.71	Annonaceae	Tree	+
25	*Rauvolfia vomitoria* Afzel	20	1.71	Apocynaceae	Tree	+

26	*Marattia fraxinea* Sm	40	2.50	Marattiaceae	Herb	++
27	*Heterotis rotundifolia* (Sm) Jac.	20	1.71	Melastomataceae	Herb	+
28	*Kiylplinga pumila* Michx	60	3.41	Cyperaceae	Herb	+++
29	*Dioda samentosa* Sw	60	3.41	Rubiaceae	Herb	+++
30	*Asystasia gagentica* (Linn.) T. Anders	20	1.71	Acanthaecae	Herb	+
31	*Panicum maximum* Jacq.	20	1.71	Poaceae	Herb	+
32	*Digitaria horizontalis* Willd	40	2.50	Poaceae	Herb	++
33	*Hibiscus surattensis* Linn.	20	1.71	Malvaceae	Herb	+
34	*Anthonontha obanensis* Bak. F.	40	2.50	Fabaceae-Caesal	Shrub	++
35	*Rhynchospora corymbosa* (Linn.) Britt	20	1.71	Cyperaceae	Herb	+
36	*Adenia lobata* (Jacq.) Engl.	20	1.71	Passifloraceae	Climber	+
37	*Eragrostis tenella* (L.) Roem & Schutt	20	1.71	Poaceae	Herb	+
38	*Ipomoea involucrata* P. Beauv.	40	2.50	Convolvulaceae	Climber	++
39	*Spigella anthelmia* Linn	20	1.71	Loganiaceae	Herb	+
40	*Agyratum conyzoides* Linn.	20	1.71	Asteraceae	Herb	+
41	*Mariscus alternifolius* Vahl	20	1.71	Cyperaceae	Herb	+
42	*Mariscus flabelliformis* Kunth.	40	2.50	Cyperaceae	Herb	++
43	*Alchornea laxiflora* (Benth) Pax & K. Hoffm.	20	1.71	Euphorbiaceae	Shrub	+
44	*Ficus sur* Forssk	40	2.50	Moraceae	Herb	++
45	*Musanga cecropoides* R. Br.	20	1.71	Cecropiaceae	Tree	+
46	*Scleria verrucosa* Willd	20	1.71	Cyperaceae	Herb	+
47	*Raphia hookeri* Mann & Wendle	40	2.50	Arecaccae	Tree	++
48	*Pteriduim aquillinum* Linn.	20	1.71	Dennstaediaceae	Herb	+
49	*Kyllinga bulbosa* Beauv.	80	4.35	Cyperaceae	Herb	++++
50	*Emilia praetermissa* Milne-Redhead	40	2.50	Asteraceae	Herb	++
51	*Cyperus haspan* Linn	40	2.50	Cyperaceae	Herb	++
52	*Manniophyton fulvum* Mull-Arg	20	1.71	Euphorbiaceae	Shrub	+

Table 3: Plant Species in Habitat Polluted Approximately 3-Years Pre-Study

	Species	% F	SD	Family	Habit	Remark
1	*Newbouldia laevis* Seem	20	1.71	Bignoniaceae	Shrub	+
2	*Melochia melissifolia* Mollis K-Schum	60	3.41	Sterculiaceae	Herb	+++
3	*Panicum maximum* Jacq	100	5.32	Poaceae	Herb	+++++
4	*Chromolaena odorata* (Linn.) R.M King & Robinson	100	5.32	Asteraceae	Herb	++++
5	*Psidium guajava* Linn	60	3.41	Myrtaceae	Shrub	+++
6	*Alchornea cordifolia* (Schum. & Thonn. Mull-Arg.)	80	4.35	Euphorbiaceae	Shrub	++++
7	*Kyllinga erecta* Schumach	40	2.50	Cyperaceae	Herb	++
8	*Anthocleista vogelii* Planch	40	2.50	Loganiaceae	Tree	++
9	*Combretum zenkeri* Engl & Diels	20	1.71	Combretaceae	Climber	+
10	*Pteridium aquillinum* Linn	60	3.41	Dennstaediaceae	Herb	+++
11	*Urena lobata* Linn	60	3.41	Malvaceae	Herb	+++
12	*Ipomoea involucrata* P. Beauv.	60	3.41	Convolvulaceae	Climber	+++
13	*Pentaciethra macrophylla* Benth	20	1.71	Fabaceae-mimo	Tree	+
14	*Cnetis ferruginea* Dc	60	3.41	Connaraceae	Shrub	+++
15	*Digitaria horizontalis* Willd	40	2.50	Poaceae	Herb	++
16	*Elaeis guineensis* Jacq.	40	2.50	Arecaceae	Tree	++
17	*Milletia aboensis* (Hook. f.) Bak	40	2.50	Fabaceae-papi	Shrub	++
18	*Anthonotha macrophylla* P. Beauv.	40	2.50	Fabaceae-caesal	Shrub	++
19	*Desmodium scorporius* (Sw) Desv.	40	2.50	Fabaceae-papi	Herb	++
20	*Harrungana madagascariensis* Lam ex. Poir	20	1.71	Guttiferea	Shrub	+

21	*Anthocleista nobilis* G. Don	20	1.71	Loganiacceae	Tree	+
22	*Desmoduim triflorum* (Linn.) DC	40	2.50	Fabaceae-papi	Herb	++
23	*Triumfetta eriophlebia* Hook .f.	20	1.71	Tiliaceae	He	+
24	*Baphia nitida* Lodd	20		Fabaceae-papilio	Shrub	+
25	*Lonchucanpus sericeus* HB & K	20	1.71	Fabacare-papito	Climber	+
26	*Anadelphia afzeliana* (Rendle) stapf	40	2.50	Poaceae	Herb	++
27	*Costus afer* K. Gawl	40	2.50	Costaceae	Herb	++
28	*Sporobolus pyramidalis* P.Beauv.	60	3.41	Poaceae	Herb	+++
29	*Diplazium sammatii* (Kuhn)C. Chr.	40	2.50	Athyriaccae	Herb	++
30	*Cyperus haspan* Linn.	80	4.35	Cyperaceae	Herb	+++
31	*Anchormanes difformis* (Bl.) Engl.	40	2.50	Araccae	Herb	++
32	*Aspilla africana (Pers)* C.D Adams	60	3.41	Asteraceae	Herb	+++

Table 4: Plant Species in Habitat Polluted Approximately 6-Years Pre-Study

	Species	% F	SD	Family		Remark
1	*Anthocleista djalonesis A.* Chev.	40	2.50	Loganiaceae	Tree	++
2	*Panicum maximum* Jacq.	80	4.35	Poaceae	Herb	++++
3	*Elaeis guineensis* Jacq.	80	4.35	Arecaceae	Tree	++++
4	*Chromolaena odorata* (Linn.) R.M. King & Robinson	100	5.35	Asteraceae	Herb	+++++
5	*Harrungana madagas cariensis* Lam ex. Poir	60	3.41	Guttiferea	Shrub	+++
6	*Pteridium aquillinum* Linn.	60	3.41	Dennstaediaceae	Herb	+++
7	*Anthonotha macrophylla P.* Beauv.	80	4.35	Fabaceae-caesal.	Tree	++++
8	*Icacina tricantha* Oliv	80	4.35	Icacinaceae	Herb	++++
9	*Manihot esculenta* Cranzt	40	2.50	Euphorbiaceae	Shrub	++
10	*Anthocleista vogelii* Planch	40	2.50	Loganiaceae	Tree	++
11	*Barteria nigritiana* Hook .f.	40	2.50	Passifloraceae	Shrub	++
12	*Milletia aboensis* (Hook. f.) Bak.	40	2.50	Fabaceae-papilio	Shrub	++
13	*Cnetis ferruginea* DC.	40	2.50	Connaraceae	Shrub	++

14	*Rauvolfia vomitoria* Afzel	60	3.41	Apocynaceae	Tree	+++
15	*Alchornea cordifolia (Schum & Thonn)* Mull-Arg	60	3.41	Euphorbiaceae	Shrub	+++
16	*Anthocleista nobilis* G. Don	60	3.41	Loganiaceae	Tree	+++
17	*Anthonotha obanensis* Bak. F	40	2.50	Fabaceae-caesal	Shrub	++
18	*Mangifera indica* Linn	20	1.71	Anacardiaceae	Tree	+
19	*Psidium guajava* Linn	20	1.71	Myrtaceae	Shrub	+
20	*Ipomoea involucrata P.* Beauv	40	2.50	Convolvulaceae	Climber	++
21	*Anacardium occidentale* Linn.	20	1.71	Anacardiaceae	Shrub	+
22	*Landolphia dulcis* (R.Br.) Pichon	40	2.50	Apocynaceae	Climber	++