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A SPLIT PLOT DESIGN ANALYSIS ON THE EFFECT OF AQUATIC SPECIES IN DETERMINING OIL SEVERITY

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ABSTRACT

The Split plot design is used to analyze the effect of factors affecting oil spill severity with TPH value as a measure of the concentration of oil spilled. The TPH value is measured from the four aquatic organisms at a particular carbon range (C-8 to C-40). The results showed that the carbon levels, organisms and the interaction between carbon levels and species causes a significant effect on the TPH value and therefore the concentration of the spill in any specie at any place. Further analysis using Duncan's multiple range test shows which species differ significantly from another and the carbon levels within the carbon range contributing to the significant effect of the carbon range.

Key Words: Split plot design, Duncan's Multiple-range test, Total petroleum Hydrocarbon (TPH), Main plot, Sub Plot.

INTRODUCTION

Oil spillage has always been a major cause of water pollution. Which has affected aquatic habitats greatly ASTDR (1999). The severity of impact typically depends on the quantity and type of oil spilt, its behavior in the marine environment, the location of the spills in terms of ambient conditions and physical characteristics of the habitat, the timing especially in relation to the season and prevalent weather conditions, the rate at which the pollutant is diluted or dissipated by natural process (this determines the geographical extent of the affected areas) and the sensitivity of the affected species to the oil spilled. The sensitivity of the affected species can be affected by the position in the aquatic habitat or by their biological makeup.

The severity of impact is measured amongst other ways in terms of level of pollution or gross contamination in an area and the level of pollution in a habitat is measured in terms of the total petroleum hydrocarbons (TPH) values at various carbon ranges.TPH is a term used for any mixture of hydrocarbons that are found in crude oil. T.P.H value is defined as the measurable amount of petroleum-based hydrocarbon in an environmental media. It is, thus, dependent on analysis of the medium in which it is found. Petroleum products have petroleum hydrocarbon ranges. The total petroleum hydrocarbon values are thus taken for a specific hydrocarbon range to determine the concentration of the product spilled in the habitat. However each state or sometimes each site within a state may change the boundaries of each range to target their specific study of interest based on the cleanup criteria, toxicity and type of product spilled.

In this study, the split plot design is used to investigate the effect of the sensitivity of the aquatic organisms in determining the severity of impact caused by oil spills. Ott, R.L and Longnecker, M. (2010), the split plot designs is an experimental design that is used when a factorial treatment structure has two levels of experimental units. In the case of the split plot design, two levels of randomization are applied to assign experimental units to treatments. Split-plot design developed by fisher (1925) is a blocked design with at least one blocking factor where the experimental unit within each block is assigned to treatment factor levels and the blocks are assigned to further treatment levels. It is a nested block design where the experimental units (sub plot) are nested within the blocks (whole plot). In the choice of what will serve as whole plots treatments of a split plot design, Dicks H.M (2006),one might consider certain types of treatments are impossible to apply to small areas (plots) and may therefore be applied to whole-plots. There may be no real interest in the main effect of one the factors, but only the interaction with the factors. Under such circumstances the factor concerned should be allocated to whole-plots. Also one of the factors may be such that its main effects are expected to be significantly large; such a factor can be allocated to whole-plots treatment. There may be more interest in one factor than another; the less important factor under such circumstances is being applied to whole-plots treatments.

However while split plot method helps us in determining if these mean treatments effects are significantly different from each other, they do not tell us which mean treatment effect is significantly different. A method that helps us in determining this is the multiple comparison methods. Multiple comparison methods are analytical methods used determining which treatments mean significantly differs from another. There are various comparison methods, however in this analysis, the Duncan's multiple test range test is used. According to Bruce Frey (2010), Duncan's multiple range test, or Duncan's test, or Duncan's new multiple range test, provides significance levels for the difference between any pair of means, regardless of whether a significant F resulted from an initial analysis of variance

MASTERIALS AND METHOD

Scope of Study

This study uses split-plot design to test if the type of aquatic organism, the location of the area, the carbon range and the interaction between the organisms and the carbon levels play a significant role in determining the T.P.H value in areas with oil spills. The aim of this study is to investigate the role that various species plays in affecting T.P.H.

The study also tells us how (if they are significantly different) they differ using the Duncan's multiple range test. The experiment was carried out in two cities B-Dere and Bode City on different days; therefore the city serves as replicates for the experiment. The main plot treatments is the carbon range (C8-C40) and the sub plot

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treatments are the four aquatic species that are tested; tilapia, mullets, crabs and shrimps. A statistical package SPSS is used in the analysis. We assume that other factors that affect the severity of impact of oil spill like the quantity and type of oil spilled, its behavior in the marine environment, the timing especially in relation to the season and prevalent weather conditions, the rate at which the pollutant is diluted or dissipated by natural process do not cause a significant difference in the level of pollution.

RESULTS

Research Design

The split plot design is used in the analysis of the data in this research. The main plot treatments are the carbon levels from C8 to C40. This is because the carbon range has a larger treatment level and also the experimental (aquatic species) unit can be grouped into homogenous units due to the number of carbon been tested for.

The sub-plot treatments are the aquatic species; tilapia, mullets, shrimps and crabs since the level of precision in testing if these species cause a significant effect in the levels of pollution in an area should be higher than that of the carbon range. Moreover the size of the treatment level the aquatic organisms are just 4 compared to 35 treatment levels of carbon range.

The places serve as replicates for the experiment since the experiments were carried out in 2 places oil spill; B-DERE and BODE CITY. Thus the design for this experiment is shown below in Table1

Table 1: Split Plot Design for Total Petroleum Hydrocarbon

Replication 1 B-Bere				Replication 2 Bode City				
$TPHt_v$	$TPHt_v$	…..	$TPHt_v$	$TPHt_v$	$TPHt_v$	…..	$TPHt_v$	$TPHt_v$
$TPHm_v$	$TPHm_v$	…..	$TPHm_v$	$TPHm_v$	$TPHm_v$	…..	$TPHm_v$	$TPHm_v$
$TPHc_v$	$TPHc_v$	…..	$TPHc_v$	$TPHc_v$	$TPHc_v$	…..	$TPHc_v$	$TPHc_v$
$TPHs_v$	$TPHs_v$	….	$TPHs_v$	$TPHs_v$	$TPHs_v$	…..	$TPHs_v$	$TPHs_v$
C-8	C-9	…..	C-40	C-8	C-9	…..	C-39	C-40

Where
$TPHt_v$ represents Total Petroleum Hydrocarbon Value for tilapia at a particular carbon level

$TPHm_v$ represents Total Petroleum Hydrocarbon Value for mullets at a particular carbon level

$TPHc_v$ represents Total Petroleum Hydrocarbon Value for crabs at a particular carbon level

$TPHs_v$ represents Total Petroleum Hydrocarbon Value for shrimps at a particular carbon level.
See appendix (A) for the table

Table 2: Split Plot Data Analysis

Source	Type III Sum of Squares	D F	Mean Square	F	Sig.
Places	13817.065	1	13817.065	2.813	0.103
Carbon Levels	694711.036	34	20432.678	4.160	0.000
Aquatic Species	15249.649	3	5083.216	2.988	0.034
Places*Carbonlevels	166986.937	34	4911.381	2.887	0.000
Carbon Levels*Aquatic Species	578405.205	102	5670.639	3.333	0.000
Error	178634.372	105	1701.280		
TOTAL	1647804.265	279			

Dependent Variable: TPH VALUE

Table 3: Duncan's Multiple Range Test for Carbon Range

Homogenous Subsets							
CARBON LEVELS	N	Subsets for alpha= 0.05					
		1	2	3	4	5	6
C-8	8	.0000					
C-9	8	.0988					
C-10	8	.0338					
C-11	8	.1850					
C-12	8	1.9638					
C-13	8	.5375	.5375				
C-14	8	2.1063					
C-15	8	1.9150	1.9150				
C-16	8	2.7138	2.7138				
C-17	8	5.0488	5.0488				
PRISTINE	8	7.6713	7.6713				
C-18	8	8.1188	8.1188				
PHYTANE	8	5.9825	5.9825				
C-19	8	14.0738	14.0738				
C-20	8						243.6200
C-21	8	12.4661	12.4661				
C-22	8				121.7875		
C-23	8	14.8188	14.8188				
C-24	8	22.5400	22.5400				
C-25	8	12.7463	12.7463				
C-26	8	12.4250	12.4250				
C-27	8	13.7863	13.7863				
C-28	8	14.1963	14.1963				
C-29	8			77.8100			

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C-30	8	19.8888	19.8888				
C-31	8	24.2913	24.2913				
C-32	8					163.3250	
C-33	8	42.2863	42.2863	42.2863			
C-34	8	31.2988	31.2988	31.2988			
C-35	8	29.5638	29.5638				
C-36	8	40.6188	40.6188	40.6188			
C-37	8	36.2050	36.2050	36.2050			
C-38	8	25.7325	25.7325				
C-39	8		51.7200	51.7200			
C-40	8	42.7450	42.7450	42.7450			

Duncan[a,b]

Means for groups in homogenous subsets are displayed above
Based on observed mean
The error term is Mean Square (Error) = 1701.280

a. Uses harmonic mean sample size = 8.0
b. Alpha = 0.05

Table 4: Significance Table for Multiple Comparisons of Carbon Range

Comparisons	Significance
C-20, C-22,C-29,C-32,C-39 VS All other levels	Significant
C-8,C-9,C-10,C-11,C-12,C-14,C-20,C-22,C-29,C32 VS All other levels	Significant
C-29,C-33,C-34,C-36,C-37,C-39 VS All other levels	Significant
C-20 VS All other levels	Significant
C-22 VS All other levels	Significant
C-32 VS All other levels	Significant

Table 5: Duncan's Multiple Range Test for Aquatic Species

Aquatic Species	N	Subset for alpha = 0.05	
		1	2
Tilapia	70	37.1113	
Mullets	70	38.6970	
Shrimps	70		19.9351
Crabs	70	30.5789	30.5789

Duncan[a,b] Homogenous Subsets

Means for groups in homogenous subsets are displayed above
Based on observed means
The error term is Mean Square (Error) = 1701.280

a. Uses harmonic mean sample size =70.0
b. Alpha = 0.05

Table 6: Significance Table for Multiple Comparisons of Aquatic Species

Comparisons (A VS B)	Tilapia	Mullets	Shrimps	Crabs
Tilapia	No Significance	No Significance	Significant	No Significance
Mullets	No Significance	No Significance	Significant	No Significance
Shrimps	Significant	Significant	No Significance	No Significance
Crabs	No Significance	No Significance	No Significance	No Significance

Where A represents treatment in rows and B represent treatment in column.

Appendix A

Total Petroleum Hydrocarbon Values for Aquatic Species

	Replication 1		B-Bere		Replication 2		Bodo City		Total
Carbon Levels	Tilapia	Mullet	Shrimp	Crab	Tilapia	Mullet	Shrimp	Crab	
C-8	0	0	0	0	0	0	0	0	0
C-9	0	0	0	0	0	0	0.79	0	0.79
C-10	0	0.09	0	0	0	0.13	0.05	0	0.27
C-11	0.38	0.05	0.01	0.14	0.08	0.08	0.55	0.19	1.48
C-12	0.69	0.29	0.01	0.32	0.03	0.42	13.9	0.05	15.71
C-13	0.06	1.13	0.02	1.11	0.14	1.66	0.12	0.06	4.3
C-14	2.45	1.67	0.04	5.96	3.08	2.44	0.64	0.57	16.85
C-15	1.31	1.32	0.12	3.19	4.83	1.94	0.35	2.26	15.32
C-16	0.52	3.08	0.24	3.93	2.64	7.04	1.98	2.28	21.71
C-17	6.92	9.97	0.24	3.94	2.66	14.6	0	2.06	40.39
PRISTINE	2.04	10.9	0.24	26.5	1.12	15.9	0	4.67	61.37
C-18	13.5	11.8	0.43	7.87	2.18	17.2	10.2	1.77	64.95
PHYTANE	4.45	7.87	1.00	3.97	3.37	7.86	15.1	4.24	47.86
C-19	16.1	21.6	0.6	12.7	4.99	31.6	10.7	14.3	112.59
C-20	33.4	363	7.76	94.2	515	531	15.6	389	1948.96
C-21	18.8	15.6	1.369	11.6	8.34	22.9	8.82	12.3	99.729
C-22	21	192	20	19.9	206	281.9	67.5	166	974.3
C-23	29.8	19	0.7	4.68	9.26	27.9	8.91	18.3	118.55
C-24	16.2	10.9	2.83	17.1	6.55	16.4	104	6.34	180.32
C-25	44.5	8.99	1.49	7.26	5.12	13.2	9.41	12	101.97
C-26	21.9	5.76	3.3	26.6	9.6	8.44	8.3	15.5	99.4
C-27	40.8	6.76	2.16	23.9	9.28	9.6	2.49	15.3	110.29
C-28	38.9	10.3	1.05	26.4	12.6	15.1	2.39	6.83	113.57
C-29	189	73.3	6.38	197	35.2	107	7.27	7.33	622.48
C-30	14.8	27.2	3.29	36.4	13.6	39.9	0.42	23.5	159.11
C-31	45.5	22.4	4.89	33.5	16.4	32.8	0.24	38.6	194.33
C-32	59.2	38.6	272	76.9	26.8	56.5	718	58.6	1306.6
C-33	47.9	60.9	3.01	17.3	78.6	89.3	3.48	45.8	346.29
C-34	33.7	31.5	3.87	20.1	66.3	46.1	6.92	41.9	250.39
C-35	21.4	13.1	2.62	41.5	102	19.1	0.29	36.5	236.51
C-36	101	49	7.06	30.3	36.8	71.8	1.49	27.5	324.95
C-37	46.4	17.5	4.41	52.8	95.8	25.6	2.23	44.9	289.64
C-38	36.2	23.3	2.55	20	56.6	34.1	1.81	31.3	205.86
C-39	81.5	26.5	5.13	54.5	116	38.8	1.83	89.5	413.76
C-40	58.7	14.3	6.13	42.6	97.8	20.8	4.73	96.9	341.96
Total	**1049.02**	**1099.68**	**364.949**	**924.17**	**1548.77**	**1609.11**	**1030.51**	**1216.35**	8842.559

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DISCUSSION

Data regarding the effects of the factors on oil spill severity are summarized in Table 4.2. The results showed that at the carbon range, the aquatic species and the interaction between the carbon levels and the aquatic species showed significance difference. The replication however showed no significance effect on the TPH value. This is due to the fact that the two places of oil spill from Ogoni kingdom may have the same ambient condition and physical characteristics. It is also due to the fact that the same oil was spilled in these two places.

In using Duncan's Range test to analyze the significant factors, the following results are obtained;

The result summarized in Table 4.31 for the carbon range showed that at α= 0.05, the following carbon levels in the carbon range have no significant difference between them C-8 to C-19,C-21, C-23 to C-28,C-30,C-31 and C-33 to C-38 and C-40. Thus from the table they are in one homogenous subsets. Likewise for the second homogenous subset in which there is no significant difference between carbon levels in it there is the following carbon levels;C-13, C-15 to c-19,C-21,C-23 to C-28,C-30,C-31,C-33 to C-40. The third homogenous subset has the following carbon levels with no significance within them; C-29, C-33, C-34, C-36, C-37,C-39,C-40. The fourth homogenous subset has C-22, the fifth homogenous has just C-32 and the sixth homogenous groups C-20.

However, there is significance effect between homogenous groups. This implies that C-22 differs significantly from all other levels of the carbon range. Likewise C-32 differs from all other levels. Also C-20 differs significantly from other levels. Some carbon levels falls in two or more groups. This pattern follows for other homogenous groups. The choice of the carbon range is thus an important factor to consider when testing for TPH value of organisms in oil spill area.

The result summarized in Table 4.32 shows that for the aquatic species there is no significance difference between tilapia, mullets and crabs, but there was a significant difference between shrimp vs tilapia and mullets. We also noticed that there was no significant difference between shrimps and crabs. We could attribute no significant difference between tilapia and mullets to their biological similarities as they both belong to the same phylum and class. Another reason is by the virtue of their position these fishes usually at the sea surface may have come in contact with the oil spilled on the surface or because the water is shallow, this could also explain why there is no significance difference between them and crabs. They however differ from shrimps. Also there is no significance difference between crabs and shrimps which may be a due to their belonging to the same phylum, subphylum, class and order.

The mean shows a pattern for the TPH value at shrimps < crabs < tilapia < mullets. The mean level shows that mullets have the highest TPH value and is therefore the most affected by the oil spill.

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