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GIS based Infestation Biogeography of Palm Weevils, *Pachymerus cardo* in the Niger Delta, Nigeria

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Abstract

Data on Oil Palm Kernel Borer *Pachymerus cardo* were compiled from several sites in the Niger Delta at different Euclidean distances ranging from 11-127 kilometers. The monthly infestation rates and location similarity in infestation were examined with univariate non-spatial statistics and geographic information geostatistical tools. The results of the within month abundance of the weevils showed an average and peak infestation rate of (452:800) in May with a slow increase through the months of June(497:921) to peak values in August (616:1272). This dropped to 578:1206 and 525:924 in September and October respectively. No significant differences within-month mean scores for all the months ($p < 0.05$) by both the student t and Hsu pair comparisons were observed. Significant differences from univariate non-spatial statistics were however observed in site infestation distribution ($p < 0.05$) between Obiozimini, Omerelu, Ebubu, Omoku, Egbeda and the following sites namely Abuloma, Obowo, Mbieri, Isiala Ngwa, Kaiama, Old Bakana and between Egbeda and Obiozomini. A scaling of the sites using geostatistics techniques of kriging and inverse distance weighting indicated that geographic association among sites was independent of nearness or distance decay. A spatial autocorrelation analysis at a z-score of 2.98 and 95% confidence rejected the null hypothesis of the cause for the observed distribution to be random. The clustered nature of the weevil pest is attributed to the stable habitat and wide spread of the oil palm which is thriving within the same environmental variables of rainfall and humidity among the sites from where the weevils were collected.

Key words. Oil Palm, Weevil, *Pachymerus cardo,* GIS, Autocorrelation

1.0 Introduction

Pachymerus cardo (Fahraeus), a Niger Delta Palm fruit borer of the tribe Pachymerini (Coleoptera: Bruchidae:Pachymerinae) uses the Oil Palm (*Elaise guineensis)* as its main host plant and they are often times referred to as Palm bruchids. There are about seven known species of *Pachymerus*. Other genera that are in the same family with *Pachymerus* include *Caryoborus* (three species), *Speciobruchus* (four species) *Curyobruchus (*six species). Most of the aforementioned bruchids use Palms as their host plants. It was earlier reported that almost all species are South and Central American however Prevett (1966) earlier reported its presence in Palm fruits of Nigeria. Bruchids have a negative impact on palms as they feed on the palm nuts and cause a reduction on the reproductive potentials of the palms. Its feeding activities wholly affect the germinability of the palm seedlings.

Thus far no documented evidence of the spatial and temporal distribution of these weevils has been made in the Niger Delta. In other regions the mapping of the distribution of red palm weevils have been conducted with Geographic Information based techniques (Massoud *et al.,* 2011; Pontikakos *et al.,* 2013; Rui-Ting and Aziz, 2011). These GIS based techniques offer a number of scientific and management opportunities which include pest management (Sciarretta *et al.,* 2001; Papadopoulos *et al.*, 2003; Hetzroni *et al.,* 2009). Access to information on distribution or infestation rate is no longer limited to a fixed environment time or place (Wenzhong *et al.,* 2009). Because of the growth of the wireless Internet, data collectors integrated with GPS mobile devices and handheld computers is shifting the focus of research and development to the real-time mobile GIS providing real-time services based on the location of the user (Pontikakos *et al.*, 2008; Pontikakos and Kontodimas, 2010; Pontikakos *et al.*, 2010; Pontikakos *et al.*, 2012). These monitoring systems are evolving and being developed for decision support, risk assessment and optimization of pest management operations (Mahaman *et al.*, 2002; Pontikakos *et al.*, 2010; Pontikakos *et al.*, 2012). In this paper GIS based techniques are used to describe and analyse the spatial and temporal distribution of *Pachymerus cardo* (Fahraeus), a known pest of the Palm fruit.

2.0 Study Area

The study area is shown in Fig. 1.0 and spreads across three (3) states in the Niger Delta namely Imo, Rivers and Bayelsa States. A total of ten (10) sites were sampled with three (3) in Imo State; six (6) in Rivers State and one (1) in Bayelsa state. The sampling sites in Imo state are at Obowo, Isiala Ngwa and Mbieri. In Rivers State the sampling sites are located in Omoku, Egbeda, Omerelu, Old Bakana, Ebubu and Abuloma. The only site in Bayelsa is at Kaiama. The coordinates in Latitude and Longitude are included in Fig. 1.0. All the sites have luxuriant growth of the oil Palm tree (*Elaise guineensis*).

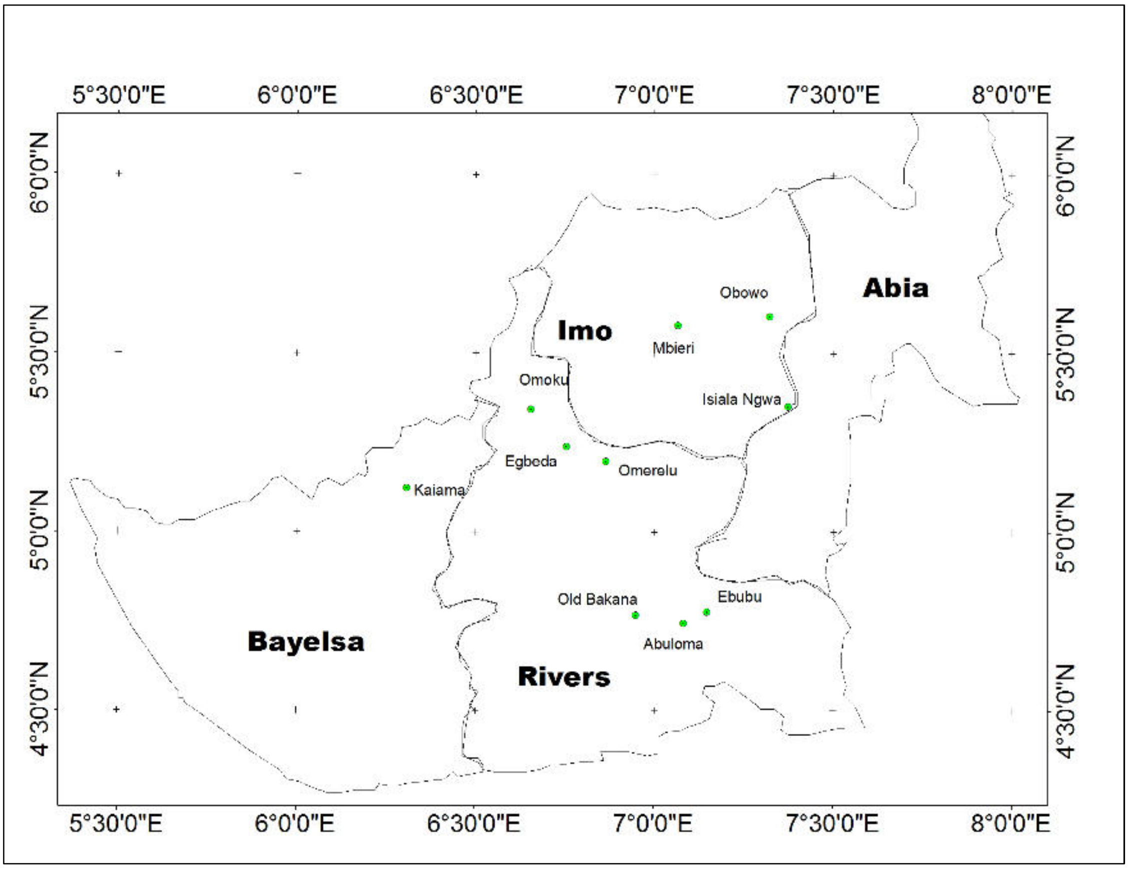

Figure 1.0 Sampling sites for *Pachymerus cardo* in Imo, Rivers and Bayelsa States

3.0 Materials and Methods

3.1 Entomology

3.1.1 Sampling Techniques

Fallen palm fruits were collected between May and October 2013 from ten sites of the Niger Delta; Omerelu, Egbeda, Ebubu, Abuloma, Omoku (all Rivers), Obowo, Isiala Ngwa and Mbieri (Imo state) and one site from Bayelsa (Kaiama). We restricted our samplings to the wild palms only and in sampling we considered variables that could influence reliability and generalization of findings; hence we focused on picking palm fruits from under the oil palms and estimating the number of *P. cardo* inside the kernels. Samplings were carried out by ten samplers per site at morning hours (8am -11am) monthly to allow enough time for palm fruits to fall. Each sampler sampled from ten palm trees with mature fruits and all samplers wore a laboratory coat, a pair of hand gloves and a mouth gauze. Each sampler also had a 3-litre capacity polyethylene transparent bag labelled per site per tree. Fallen palm fruits were kept in the polyethylene labelled bags .At least a total of two hundred fallen mature palm fruits were picked per site per sampling date. The palm fruits were conveyed from the aforementioned locations to the Post Graduate Entomology laboratory of the Department of Applied and

Environmental Biology, Rivers State University of Science and Technology, Port Harcourt. Each palm fruit was broken with the aid of a carpenter's medium hammer in order to assess the type, number of larvae, pupae and adults found inside the fruits. Examination of the broken palm fruits was done under an M7 Stereomicroscope to account for the stages of the palm borer, *P. cardo*.

Data collection was primarily based on acquiring knowledge on the pest distribution in oil palms focusing on species richness (ie the number of species) and abundance (ie overall number of individuals and occurrences).

3.2 Geographic Information System Techniques

The coordinates of the locations were extracted from satellite imagery and used to establish a point feature dataset in ArcGIS 10.2 software. The map interface was used to calculate the approximate distances between sites in order to apply in autocorrelation statistics. Due to the multimodal nature of the datasets natural breaks (discontinuous) was used to create classes by grouping clusters of similar values in determination of geographic similarity.

3.2.1 Geostatistics

The geographic distribution of monthly infestation was analyzed in GIS with Kriging which is a geostatistical interpolation procedure that generates an estimated surface from a scattered set of points with z-values. A similar comparison was made with another interpolation method such as the Inverse Distance Weighting (IDW) which estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell. The closer a point is to the center of the cell being estimated, the more influence, or weight; it has in the averaging process. Similar values were obtained with both interpolation methods.

Spatial autocorrelation in data was also explored by examining the different pairs of sample locations. By measuring the distance between two locations and plotting the squared difference between the values at the locations, an evaluation of whether the pattern expressed is clustered, dispersed, or random is made. The tool calculates the Moran's I Index value and both a z-score and p-value to evaluate the significance of that Index. The Spatial Autocorrelation (Global Moran's I) tool returns five values: the Moran's Index, Expected Index, Variance, z-score, and p-value. The methodology in ArcGIS was to convert the point data (infestation site) into a grid and spatially join to the points and use the resulting shape file to perform the autocorrelation. Using the Spatial Statistics tools of zone of indifference distance constraints starting at 1kilometer were used with increments of 10000 kilometers (to cover the maximum range of occurrence) to determine the best z –score above the 95% confidence interval.

4.0 Results

4.1 Population Densities of *Pachymerus cardo*

The within month and between site abundance of Pachymerus *cardo* throughout the months of sampling is shown in Figs. 2.0 -7.0. The results of the within month abundance of the weevils showed an average and peak infestation rate of (452:800) in May with a slow increase through the months of June(497:921) to peak values in August (616:1272). This dropped in to 578:1206 and 525:924 in September and October respectively.

The between site infestation rates of the weevils in Fig. 8.0 show a 75 percentile value above 500 weevils per site in Egbeda, Obiozimini, Omoku, Omerelu, Abuloma, Ebubu, Obowo, Mbieri, Isiala Ngwa, except in Kaiama and Old Bakana. The highest infestation rates above 900 weevils were observed at Obiozimini (1272), Omerelu (1206), Omoku (984), Egbeda (982) and Ebubu (952).

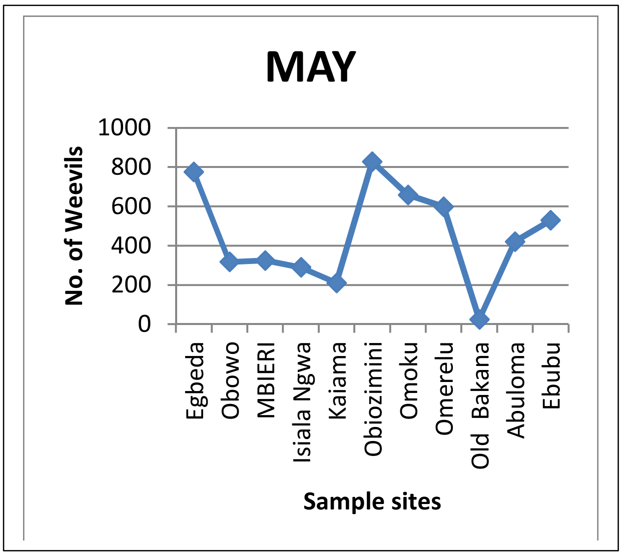

Figure 2.0 Abundance of weevils in May

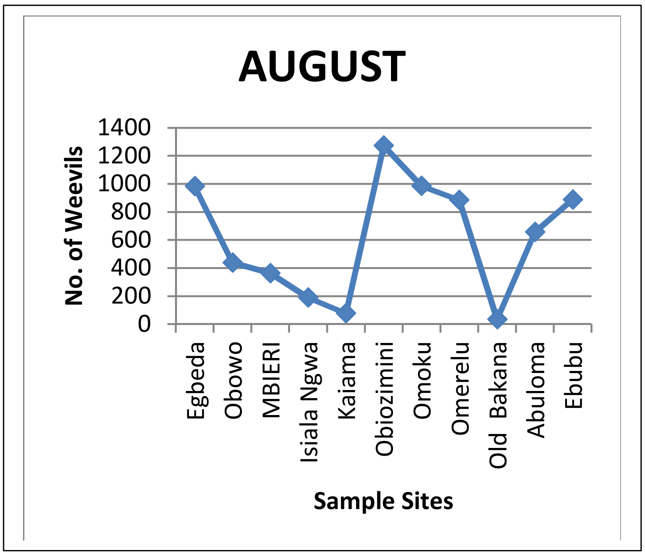

Figure 5.0 Abundance of weevils in August

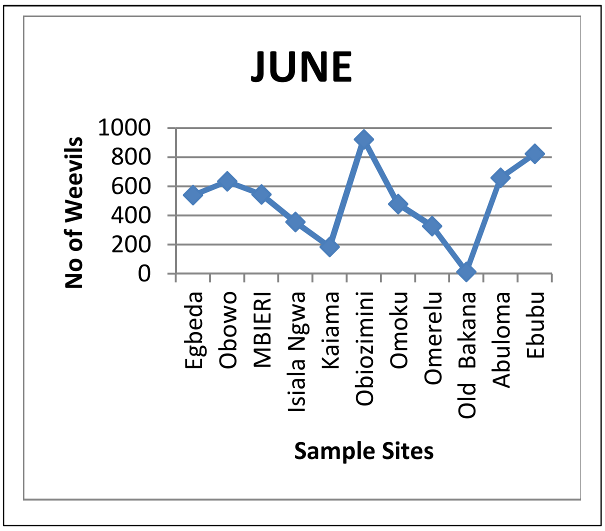

Figure 3.0 Abundance of weevils in June

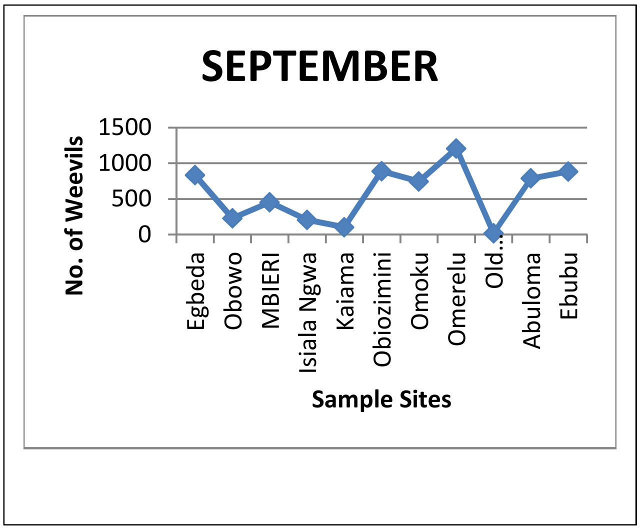

Figure 6.0 Abundance of weevils in September

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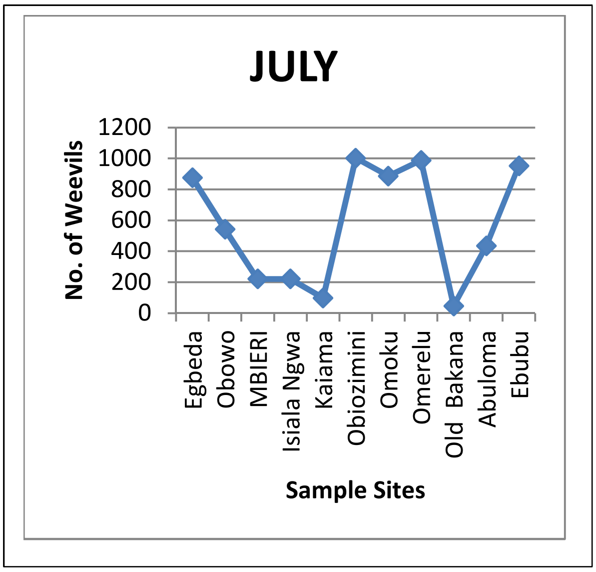

Figure 4.0 Abundance of weevils in July

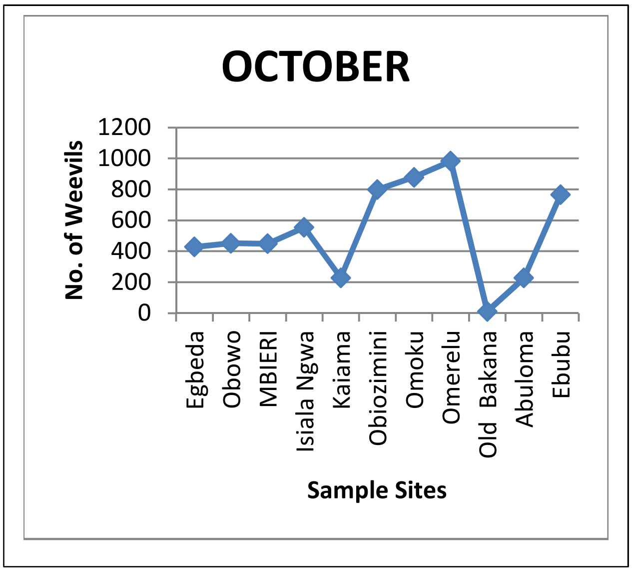

Figure 7.0 Abundance of weevils in October

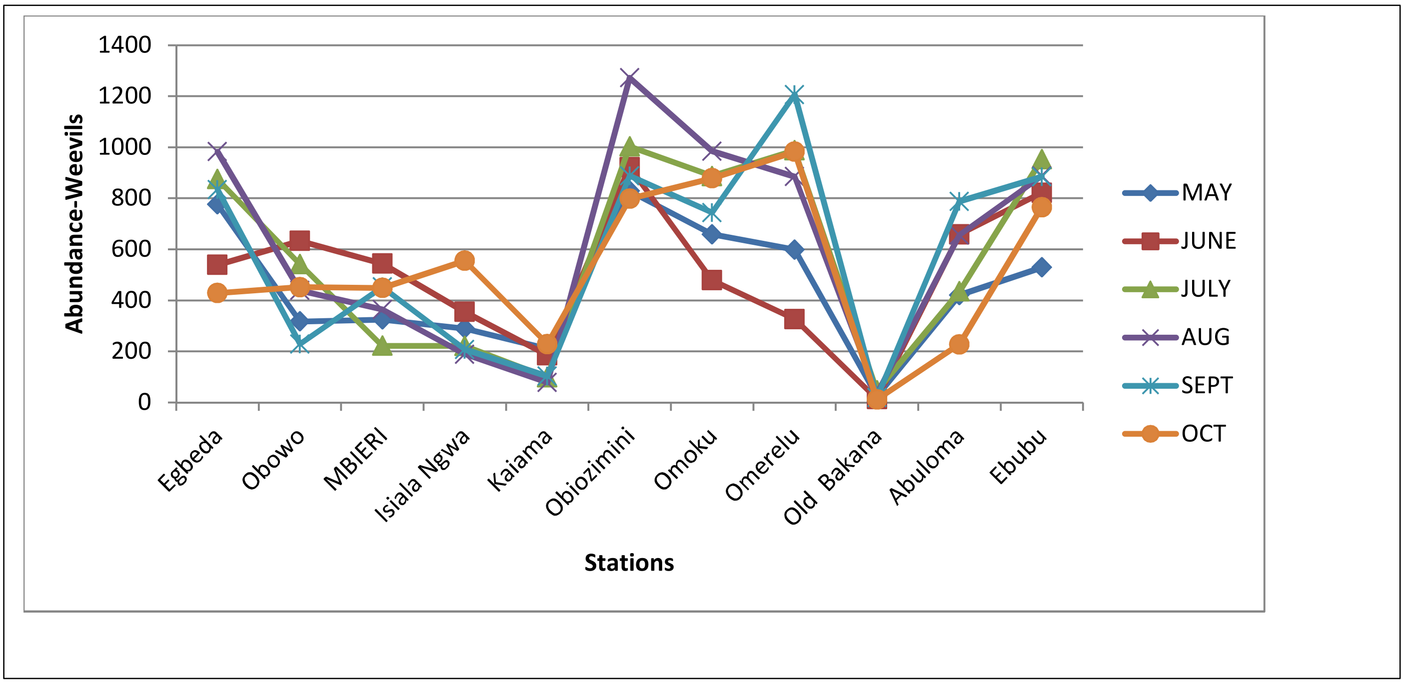

Figure 8.0 Mean abundance of weevils at sampling sites from May to October.

The graphical scatterplot for within-month variation at all the sites is shown in Fig. 9.0. The mean month scores for all the months do not show any significant differences ($p < 0.05$) by both the student and Hsu pair comparisons. The box plots however indicate greatest variation between July, August and September corresponding with the linear graphs.

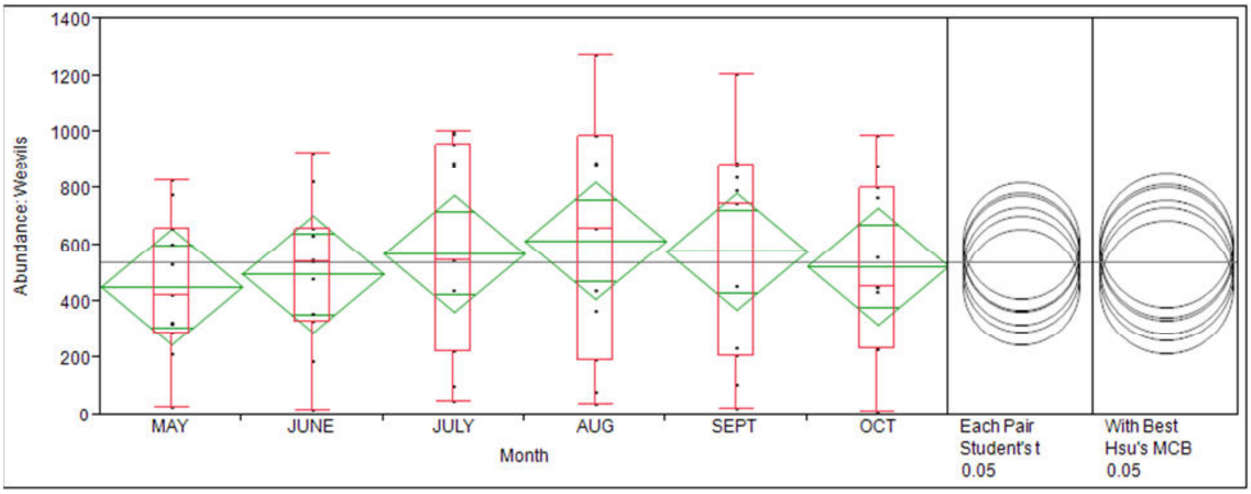

Figure 9.0 One way Analysis of Variance for Within-Month infestation

Connecting Letters Report

Level		Mean
AUG	A	615.36364
SEPT	A	577.54545
JULY	A	569.70000
OCT	A	524.93636
JUNE	A	497.66364
MAY	A	452.35455

Abs(Dif)-LSD

	AUG	SEPT	JULY	OCT	JUNE	MAY
AUG	-291.58	-253.76	-245.92	-201.15	-173.88	-128.57
SEPT	-253.76	-291.58	-283.74	-238.97	-211.70	-166.39
JULY	-245.92	-283.74	-291.58	-246.82	-219.54	-174.24
OCT	-201.15	-238.97	-246.82	-291.58	-264.31	-219.00
JUNE	-173.88	-211.70	-219.54	-264.31	-291.58	-246.27
MAY	-128.57	-166.39	-174.24	-219.00	-246.27	-291.58

Positive values show pairs of means that are significantly different.

Levels not connected by same letter are significantly different.

The graphical scatterplot for between site infestations is shown in Fig. 10.0. The mean month scores for all the sites show significant differences ($p < 0.05$) between Obiozimini, Omerelu, Ebubu, Omoku, Egbeda and the following sites namely Abuloma, Obowo, Mbieri, Isiala Ngwa, Kaiama, Old Bakana. A significant difference ($p < 0.05$) was also observed between Egbeda and Obiozomini.

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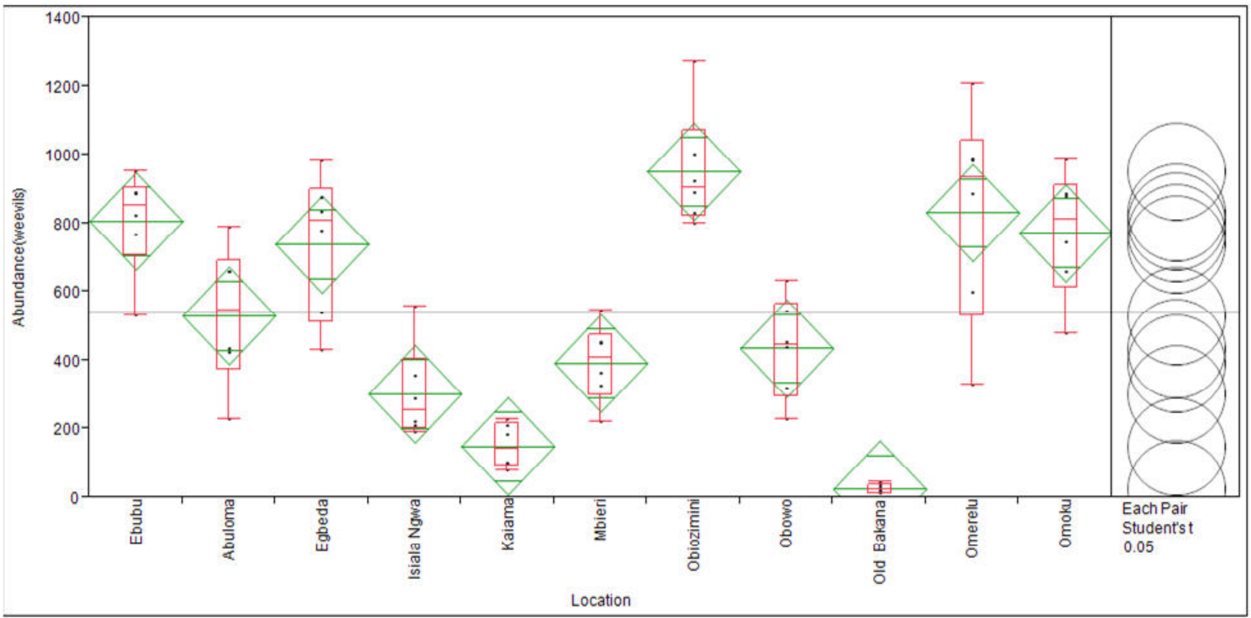

Figure 10.0 Graphical scatterplot for between site infestations

LSD Threshold Matrix

Abs(Dif)-LSD	**Obiozimini**	**Omerelu**	**Ebubu**	**Omoku**	**Egbeda**
Obiozimini	-200.74	-79.94	-55.49	-20.51	12.17
Omerelu	-79.94	-200.74	-176.29	-141.31	-108.63
Ebubu	-55.49	-176.29	-200.74	-165.76	-133.08
Omoku	-20.51	-141.31	-165.76	-200.74	-168.06
Egbeda	12.17	-108.63	-133.08	-168.06	-200.74
Abuloma	220.34	99.54	75.09	40.11	7.42
Obowo	316.12	195.32	170.87	135.89	103.21
Mbieri	358.61	237.81	213.36	178.37	145.69
Isiala Ngwa	448.42	327.62	303.17	268.19	235.51
Kaiama	600.72	479.92	455.47	420.49	387.81
Old Bakana	726.39	605.59	581.14	546.16	513.47

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level							**Mean**
Obiozimini	A						951.80000
Omerelu	A	B					831.00000
Ebubu	A	B					806.55000
Omoku	A	B					771.56667
Egbeda		B					738.88333
Abuloma			C				530.71667
Obowo			C	D			434.93333
Mbieri			C	D			392.45000
Isiala Ngwa				D	E		302.63333
Kaiama					E	F	150.33333
Old Bakana						F	24.66667

Levels not connected by same letter are significantly different.

4.1 Geographic Similarity

To assess the geographic similarity, the approximate distances between the sites shown in table 1.0 are provided as a basis for comparison of infestation rates against distances. The distances range from a minimum of 14 km between Omerelu and Egbeda and a maximum of 127 km between Kaiama and Ebubu. Based on the collections from sites across the Niger Delta, the distribution maps of monthly abundance between sites across the distances are shown in Figs. 11 – 16. The within month similarity in abundance across geographic space for the month of May (Fig. 11.0) show three groups. Similarity was evident for sites in Mbieri, Obowo and Isiala Ngwa separated by a range of 27, 29 and 43 km; while Omoku and Omerelu separated by 30km form the second group.

The third groups are sites not similar to each other and they are namely Old Bakana, Abuloma, Ebubu and Kaiama. In the month of June (Fig. 12.0) the geographic similarity in abundance was observed for Egbeda, Omoku and Mbieri separated by 17km, 53km and 54km and between Omerelu and Isiala Ngwa separated by 58km. The remaining sites at Old Bakana, Abuloma, Ebubu, Obowo and kaiama were not assocaited.

In Fig. 13.0 evidence of geographic similarity was seen in four groups namely Mbieri and Isiala-Ngwa separated by 43 km; Kaiama and Old Bakana separated by 83km; Ebubu and Omerelu separated by 56 km and Omoku and Egbeda separated by 17km. The non-associated sites were at Abuloma and Obowo. In Fig. 14.0 geographic similarity between sites were seen in three groups; Omoku, Egbeda, and Omerelu separated by 14,km, 17km and 30km; Mbieri, and Obowo separated by 29km; Kaiama and Old Bakana separated by 82km. The non-associated sites were at Ebubu, Abuloma and Isiala Ngwa.

In Fig. 15.0 four groups in September with geographic similarity are evident at Obowo and Isiala Ngwa separated by 27km; Kaiama and Old Bakana separated by 82km; Ebubu and Egbeda separated by 68km; Omoku and Abuloma separated by 82km. The non-associated sites were Omerelu and Mbieri. In Fig. 16.0 geographic similarities in October were observed between Obowo, Mbieri and Egbeda separated by 29km, 54km, 76km, kaiama and Abuloma separated by 97km; while the non-associated sites were observed for Old Bakana, Ebubu, Omerelu, and Omoku.

Table 1.0 Approximate distances in kilometers between sample sites

	Site	Obowo	Mbieri	Isiala Ngwa	Omoku	Egbeda	Omerelu	Old Bakana	Ebubu	Abuloma	Kaiama
1	Obowo	0	29	27	80	76	70	101	94	100	125
2	Mbieri	29	0	43	53	54	48	92	90	93	99
3	Isiala Ngwa	27	43	0	80	70	58	81	70	77	123
4	Omoku	80	53	80	0	17	30	73	84	82	46
5	Egbeda	76	54	70	17	0	14	57	68	66	51
6	Omerelu	70	48	58	30	14	0	50	56	55	64
7	Old Bakana	101	92	81	73	57	50	0	23	17	82
8	Ebubu	94	90	70	84	68	56	23	0	11	127
9	Abuloma	100	93	77	82	66	55	17	11	0	97
10	Kaiama	125	99	123	46	51	64	82	127	97	0

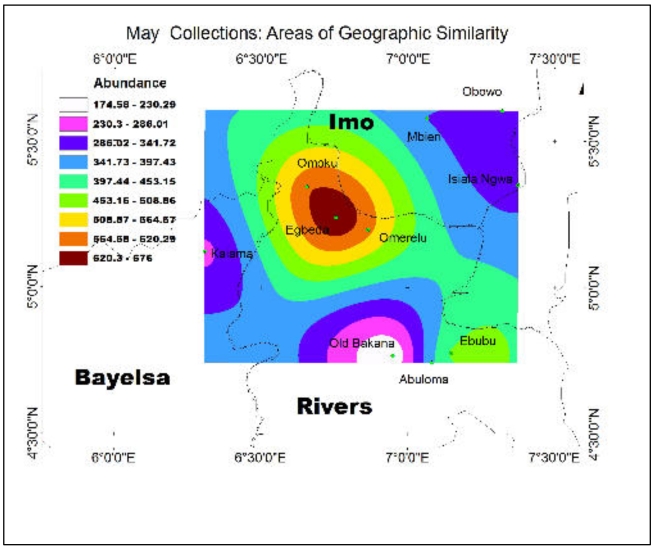

Figure 11.0 Geographic Similarity of infestation in May

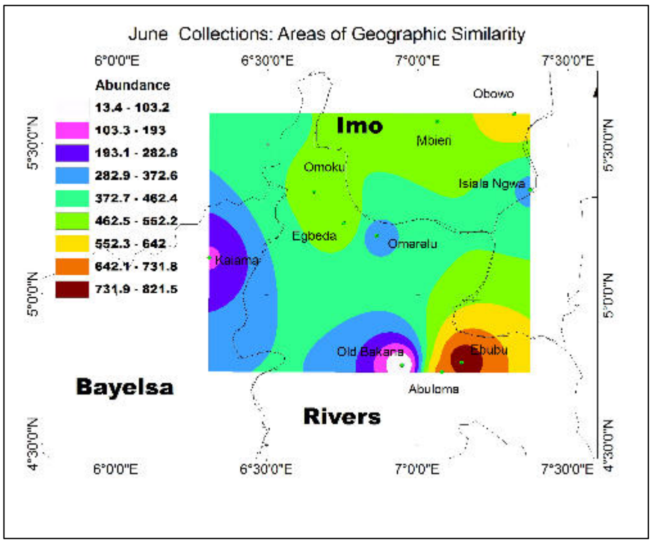

Figure 12.0 Geographic Similarity of infestation in June

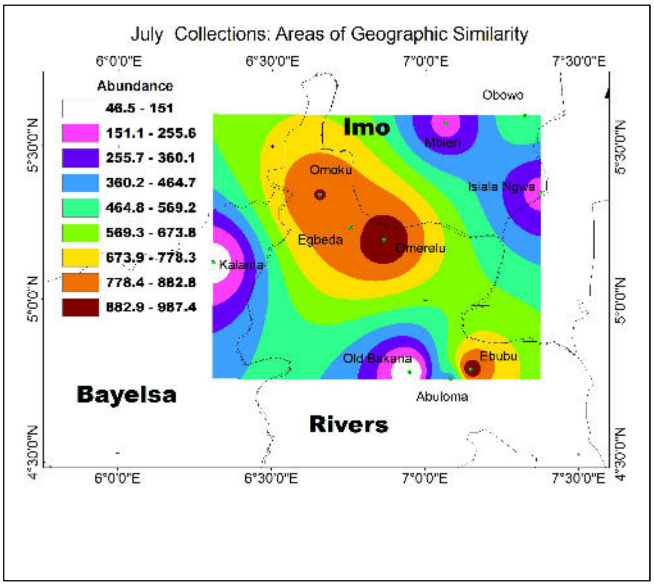

Figure 13.0 Geographic Similarity of infestation in July

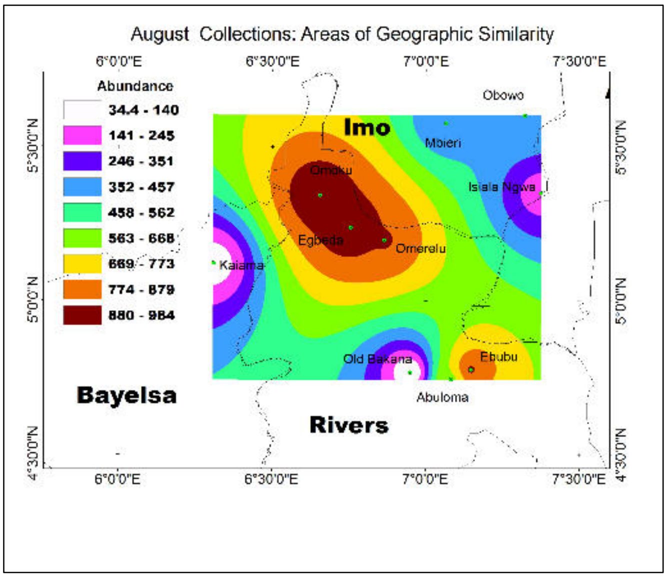

Figure 14.0 Geographic Similarity of infestation in August

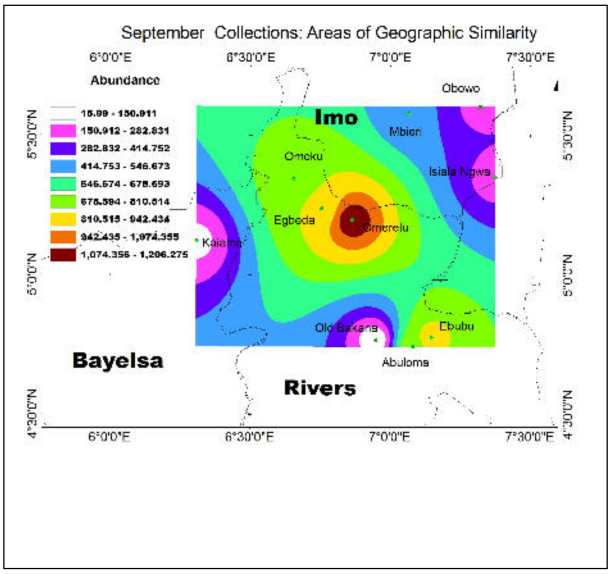

Figure 15.0 Geographic Similarity of infestation

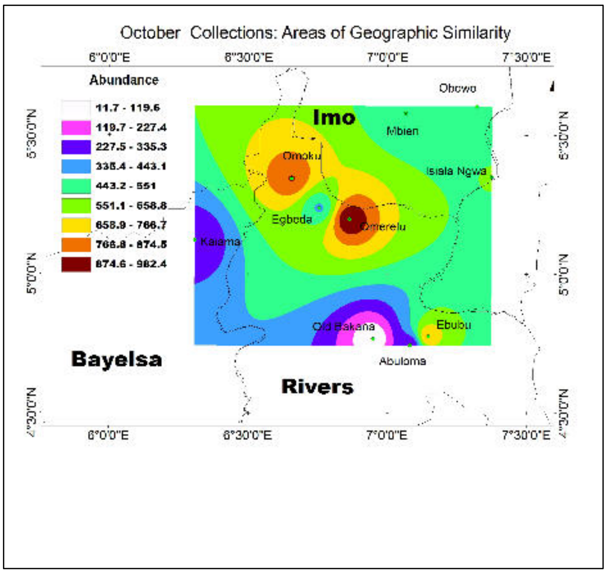

Figure 16.0 Geographic Similarity of infestation

5.0 Discussion

The study has shown evidence of similarity in monthly average infestation of the weevils within each site implying the prevalence of similar environmental conditions within each of the 11 sites. The ANOVA univariate statistics also show that the infestation percentages at the various sites were significantly different ($p < 0.05$). In applying geostatistical methods by scaling the data to the same natural breaks, the geographic similarity of sites produced associations where the threshold of the Euclidean distances did not maximize the similarity values. This means that both the environmental and geographical distances had no negative effect on the frequency of the infestation records. This is corroborated in Fig. 17.0 by the high autocorrelation z-score of 2.96 above 95% confidence interval. With a z-score of 2.85, there is less than 1% likelihood that this distribution pattern across the sites could be the result of random chance thereby rejecting the null hypothesis of random cause for the distribution of the weevils.

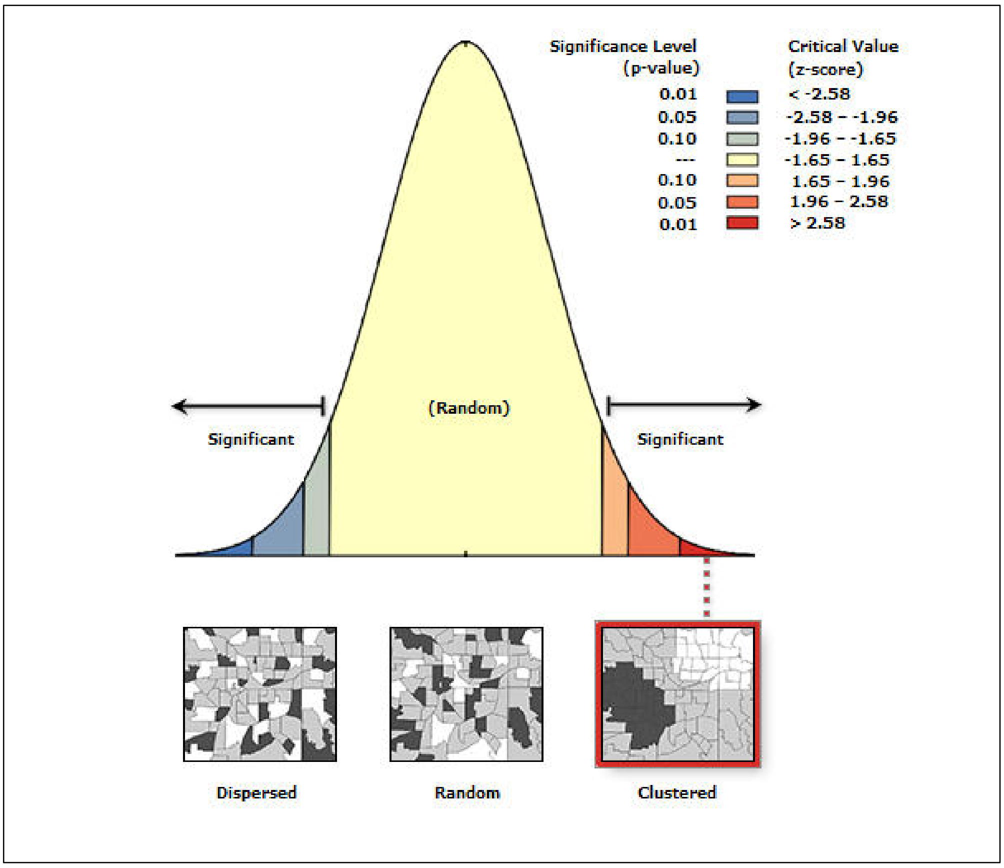

Figure 17.0 Spatial Autocorrelation of weevil distribution

However the documentation of spatial autocorrelation in the distribution ranges of the weevils does not provide much information about the mechanisms that generate these patterns. Basically, patterns of spatial autocorrelation in species' distributions reflect the combined effects of dispersal processes and spatial autocorrelation in the environment (Sokal and Oden, 1978; Legendre, 1993; Lichstein *et al.* 2002; Miller and Franklin, 2002). Distinguishing between these two effects and evaluating the relative importance of each mechanism was beyond the scope of this study.

These results are however consistent with previous studies showing that patterns of species distribution are characterized by strong spatial autocorrelation (Rushton *et al*., 2004; Heikkinen *et al.* 2004; Karst *et al.,* 2005; Luoto *et al.* 2005; Sanderson *et al.,* 2005; Betts *et al.* 2006; Segurado *et al.,* 2006). The clustering of weevils within the same geographic space indicate the lack of mass effect of environmental constraints in geographic space since the humidity and rainfall values within these sites are same with 247 days of 1200 -2,700mm of rainfall and an average of 85% humidity starting from March to November (Adefolalu, 1983; Okonkwo and Mbajiorgu, 2010; Adejuwon, 2011). In these sites where collections were made as in most parts of the Niger Delta, fallen seeds of the Oil Palms are observed to be attacked during the rainy seasons when percentage moisture content is high to aid the growth and development of the larvae of *P. cardo*. Rilley and Simmons (1966) reported that *P. cardo* will not develop in kernels with moisture content below 8%.

The study therefore shows the lack of decay in infestation similarity with increasing geographical distance. Whatever the explanation, it appears that exponential distance decay of similarity is not a universal property in weevil communities. Clearly, weevil vagility is not the main determinant of the similarity among sites of collection with distance. One possible explanation for the similarity of weevils infestation across the large distances may be the entire landscape which is saturated of oil palm. This has led to the homogeneity in infestation regardless of distance with its effects attenuated by the ecological stability of these habitats.

In summary the study demonstrate that the biogeography of the weevil species does not follow simple rules of distance decay, as it is not always the key determinant of similarity. Rather limitations of distribution would depend on the fringes of oil Palm tree habitat range.

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