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Effects of wind speed and direction on ocean waves along Ibeno Atlantic Ocean

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Abstract

Studies on effects of wind speed and direction on ocean wave along Ibeno Atlantic ocean, south-south, Nigeria were conducted between May – October, 2016 with the aim of understanding the impact of wind speed on ocean wave along the coastline. Wind speed and wave height were measured bimonthly during spring and neap tidal phases in two stations along the coastline using standard procedure. The results analysis provides an insight to the direction of the prevailing wind on the coastline which was mostly from the North-East direction. The maximum wind speed value was observed to be 4.5 m/s in the month of October during spring tidal phase and the minimum value recorded was 1.0 m/s in the month of May during spring tidal phase and also in the months of June and July during neap tidal phase. The maximum and minimum wave height recorded was 78 cm (0.78m) in the month of August during spring tidal phase and 12 cm (0.12m) in the month of May during neap tidal phase respectively. There was a transition in stratification between high and low wind speed as observed during the study. Wind speed has a direct impact on the incoming waves from offshore as it was observed that an increase in wind speed also brings about a corresponding increase in wave breaker height. As large water mass is transported offshore, it is being interrupted by wind. As the wind blew over the sea surface, the large water mass was affected, resulting in high wave magnitude and height, which travel several kilometers before breaking at the shoaling zone. Based on findings it was concluded that wind speed and direction has a direct impact on ocean wave along the study area.

Keywords: wind speed, wind direction, ocean waves, Ibeno, Atlantic Ocean

1. Introduction

Wind blowing over the surface of the ocean generates or transfer energy that produces wave's action that can travel thousands of miles before reaching the land (onshore) (Young & Sobey, 1985; Jones & Toba) [12]. Wind waves ranges in sizes from small ripples to 30m high when directly generated and affected by local winds (Tom, 2009) [11]. A wind wave system is called Wind Sea. It has certain degree of randomness, differs in height, duration and shape with limited predictability. They can be described as a stochastic process in combination with the physics governing their generation, growth, propagation and decay as well as governing the interdependence between flow quantities such as; the water surface movements, flow velocities and water pressure.

As the wind blows, pressure and friction forces perturbed the equilibrium of the water surface and transfer energy from the air to the water forming waves. The initial formation of waves by the wind is as described according to the theory of Philips (1957) and the subsequent growth of the small waves has been modeled by Miles (1957).

The speed of all ocean waves is controlled by gravity, wavelength and water depth. Most characteristics of ocean waves depend on the relationship between their wavelength and the depth of the water. Wavelength plays vital role in determining the size of the orbits. The path of water molecules in a wind wave is circular only when the wave is travelling in deep water (Philips, 1977). Wind wave actions are mechanical waves that propagates along the interface between water and air; the restoring force is provided by gravity and is often referred to as surface gravity waves (Holthuijsen, 2007) [3].

The linear theory of surface gravity waves is the basis for deriving the physical characteristic of wind generated waves. The theory explained the wave's spectrum, local characteristics such as wave-induced orbital motion; waves induced pressure fluctuations in the ocean and wave energy together with phase velocity and propagation of wave energy (Holthuijsen, 2007, Donelan *et. al*., 1985) [3, 1].

Waves are the main source of energy that cause beach to change in size, shape and sediment type. It also moves marine debris between the beach and offshore zone. The objective of this study was to evaluate the effects of wind speed and direction on ocean waves along Ibeno Atlantic Ocean.

2. Materials and Methods

2.1 Description of Study Area

The study was at the Atlantic coastline of Ibeno which is located on the rest of the Niger Delta around Qua Iboe River Estuary which lies between latitude 04^{o} 32' 74.5'' N and longitude 07^{o} 59' 55.6'' E. The study area composes of beach materials with unconsolidated sediment which ranges from fine to sand grains at the backshore, extends to the supra-tidal foreshore with a width of 103m during low water tide. The beach has a slope of 0.60 to 0.70m during low tide from the berm edge. The area is a high energy induced environment characterized by semi-diurnal tide and meso-tidal range of 2.4m. The winds are mostly blown from the North-East and the beach morphology is a low-lying and gently sloppy beach, sloping seaward.

2.2 Sampling Stations

Two stations were selected along the Ibeno Atlantic coastline for the observation and measurement of wind speed and wave height. Station 1, marked East was about 150m away from Qua Iboe River Estuary mouth, is located at latitude 04° 32' 06.49'' N and longitude 07° 58' 56.6'' E while the second location was marked 800m away from station 1 at the end of the beach portion, is located at latitude 04° 32' 14.32'' N and longitude 07° 59' 30.0'' E (Fig. 1). All the stations selected were monitored and measurements were made respectively at 30 minutes interval for a duration of 12 hours and measurement began from 006hours to 1800hours.

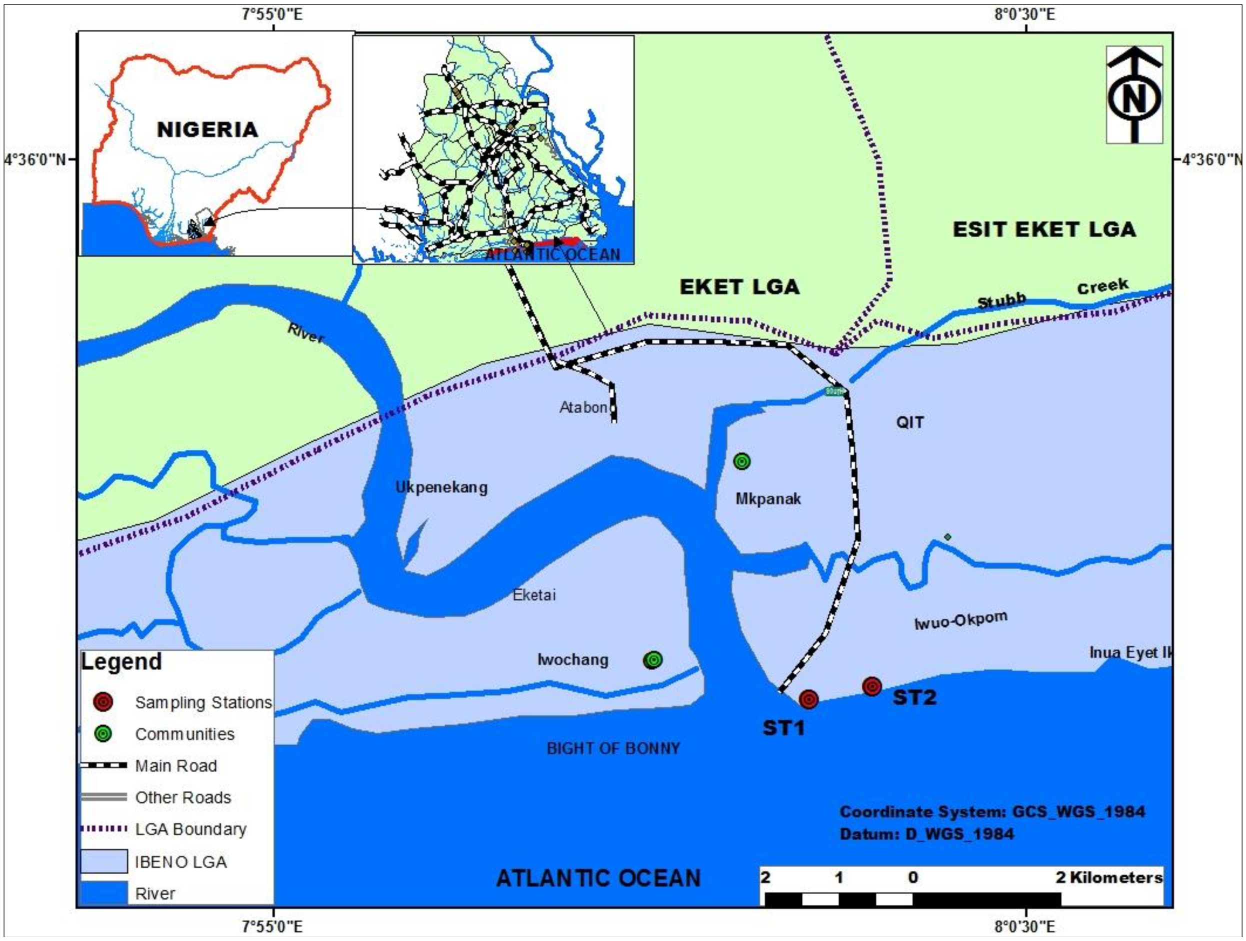

Fig 1: Map of the Study Area Showing Sampling Stations

2.3 Sampling duration

Sampling was carried out twice a month (i.e. at spring and neap tide respectively) for a period of six (6) months. Lunar calendar for the year 2016 was consulted for days of new moon, first quarter moon, full moon and third quarter moon respectively. This calendar served as a guide for selection of sampling days regarding spring and neap tide days.

2.4 Measurements of Parameters

2.4.1 Wind Speed

Wind speed was measured using a portable multifunction anemometer PCE-HVAC 2 which involved the use of a hand held meter. As soon as there was an increase in wind velocity, it's speed in m/s was recorded has displayed on the meter.

2.4.2 Wind Direction

Wind direction was observed using a wind vane. The way a weather vane is pointed by prevailing winds indicates the direction from which the wind is blowing.

2.4.3 Wave Height

Wave height was observed and measured by placing a tidal pole perpendicular to the approaching breaking wave and observing the mean water level when if corresponding with the horizon at offshore, then wave height was recorded in centimeters.

2.5 Data Analysis

Statistical package for Social Sciences (SPSS) version 20 was employed to compute Mean and standard error in the data. Also, one-way analysis of variance (ANOVA) and Least Significant Difference (LSD) test were employed to separate significant differences in mean values computed for stations while paired sample t-test was used to compare significant difference in wind speed and wave height during spring and neap tide respectively. The probability level was set at $p = 0.05$.

3. Result

3.1 Wind Speed Variation at spring and Neap Tide

Variation was observed in wind speed during the different tidal phase and month of study. Maximum wind speed of 3.6 m/s at the hour of 16:30hrs and a minimum wind speed of 1.0 m/s at 8:30hrs during the tidal cycle of spring tidal phase was recorded for the month of May and a maximum wind speed of 3.4 m/s at the hour of 14:30hrs and minimum wind speed of 1.1 m/s at 9:30hrs during neap tidal phase was recorded during the same month. In the month of June a maximum wind speed of 4.4 m/s was recorded at the hour of 15:30hrs and a minimum wind speed of 1.1 m/s at 8:00hrs during spring tidal phase and a maximum wind speed of 4.2 m/s and minimum wind speed of 1.0 m/s was recorded at neap tidal phase at 15:30hrs and 7:00hrs respectively. A maximum wind speed of 4.1 m/s and minimum value of 1.1 m/s was recorded in the month of July at 16:30hrs and 7:00hrs for spring tidal phase while during the neap tidal phase a maximum and minimum wind speed value of 3.6 m/s and 1.0 m/s at the hour of 16:00 and 7:00hrs respectively was recorded. In the month of August a maximum and minimum wind speed value of 4.4 m/s and 1.3 m/s at the hour of 15:30 and 7:30hrs respectively was recorded for spring tidal phase while a maximum and minimum wind speed value of 4.4 m/s and 1.2 m/s was recorded during the neap tidal phase at the hour of 17:30hrs and 7:00hrs respectively. In September, maximum and minimum wind speed value recorded was 4.4 m/s and 1.1 m/s at the hour of 17:30hrs and 8:00hrs for spring tidal phase while during the neap tidal phase the maximum and minimum wind speed value recorded was 4.2 m/s and 1.1 m/s at the hour of 16:30hrs and 7:30hrs respectively. Variation in wind speed during spring and neap tide was also observed in the month of October with maximum wind speed value of 4.5 m/s and 4.2 m/s at the hour of 16:00hrs for spring and neap tidal phase while a minimum wind speed value of 1.2 m/s was recorded for spring and neap tidal phase at the hour of 7:30hrs (Table 1). Fig. 2 and Fig. 3 show the mean variation in wind speed during spring and neap tidal phases. The trend depict that wind speed was more predominant during the month of August in both spring and neap tidal phases.

3.2 Wave Height Variation at spring and Neap Tide

At Ibeno coastline the wind and wave measurement during the study period shows that the study coastline is strongly affected by the two coastal processes. Wind direction and speed determine the magnitude of the wave strength. As the wind blow over the surface of the sea it generates a maximum wave height of 56 cm and a minimum wave height of 14 cm at the hour of 14:30hrs and 7:00hrs during the tidal cycle of spring tidal phase for the month of May and a maximum wave height of 56 cm and a minimum wave height of 12 cm at the hour of 15:00hrs and 7:00hrs during the same month during neap tidal phase. In the month of June a maximum and minimum wave height of 72 cm and 18 cm was recorded at the hour of 15:30hrs and 7:00hrs at spring tidal phase and a maximum and minimum wave height of 70 cm and 16 cm was recorded at neap tidal phase at 15:00hrs and 7:00hrs respectively. A maximum and minimum wave height of 69 cm and 16 cm was recorded at 15:00hrs and 7:00hrs for spring tidal phase while 59 cm and 18 cm was recorded in the month of July at 15:00hrs and 7:00hrs as the maximum and minimum wave height during neap tidal phase respectively. In the month of August a maximum and minimum wave height of 78 cm and 26 cm was recorded at 15:30hrs and 7:00hrs for spring tidal phase while 76 cm and 24 cm was recorded at 15:30hrs and 7:00hrs for neap tidal phase respectively. In September maximum and minimum wave height recorded was 76 cm and 18 cm at the hour of 15:30hrs and 7:00hrs for spring tidal phase while during the neap tide phase the maximum and minimum wave height recorded was 74 cm and 16 cm at 15:30hrs and 7:00hrs respectively. Similar trend was observed in the month of October with maximum and minimum wave height recorded at the 15:00hrs and 7:00hrs for spring and neap tidal phase respectively (Table 2). Fig. 4 and Fig. 5 show the mean variation in wave height during spring and neap tidal phases. The trend reveal that wave height was more predominant during the month of August in both spring and neap tidal phases.

Table 1: Wind Speed (m/s) Measurement for six months (May, 2016 – October, 2016) at spring and Neap Tide along Ibeno Atlantic Ocean

Time / Hrs	**Spring (May) 06/05/2016**	**Neap (May) 13/05/2016**	**Spring (June) 20/06/2016**	**Neap (June) 27/06/2016**	**Spring (July) 19/07/2016**	**Neap (July) 27/07/2016**	**Spring (Aug.) 18/08/2016**	**Neap (Aug.) 25/08/2016**	**Spring (Sep.) 16/09/2016**	**Neap (Sep.) 23/09/2016**	**Spring (Oct.) 01/10/2016**	**Neap (Oct.) 22/10/2016**
0700	1.3	1.6	1.6	1.0	1.1	1.0	1.6	1.2	1.6	1.3	1.4	1.3
0730	1.1	1.3	1.4	1.2	1.5	1.2	1.3	1.6	1.4	1.1	1.2	1.2
0800	1.7	1.2	1.1	1.3	1.6	1.4	1.5	1.7	1.1	1.7	1.8	1.7
0830	1.0	1.4	1.8	1.9	1.2	1.6	1.8	2.1	1.8	1.0	1.8	1.9
0900	1.5	1.6	2.0	2.1	1.7	1.6	2.4	2.1	2.0	1.5	1.6	1.4
0930	1.8	1.1	2.3	2.4	1.6	1.4	2.6	2.2	2.3	1.8	2.3	2.2
1000	2.0	1.4	1.5	2.2	2.2	1.5	2.7	2.3	1.5	2.0	2.1	2.5
1030	2.4	1.4	3.1	2.5	2.4	1.6	3.3	2.6	3.1	2.4	3.0	1.6
1100	1.2	1.3	2.8	1.6	1.4	1.3	2.6	2.7	2.8	1.2	2.8	1.5
1130	2.2	1.5	3.0	1.5	2.1	1.6	3.2	2.8	3.0	2.2	2.8	2.2
1200	3.3	1.9	2.4	2.2	3.2	2.1	2.8	2.6	2.4	3.3	2.8	2.6
1230	2.2	2.3	1.2	2.6	2.6	2.8	3.2	2.8	1.2	2.2	3.0	2.9
1300	2.3	2.2	3.2	2.9	2.6	3.0	3.3	2.9	2.9	3.0	1.6	1.6
1330	2.9	3.0	4.0	2.8	2.7	3.4	4.2	2.8	2.8	3.2	1.4	3.2
1400	2.0	3.1	3.8	3.2	2.6	3.3	3.8	3.4	3.4	3.1	1.7	4.0
1430	1.8	3.4	2.2	2.4	2.8	2.4	2.7	2.8	2.8	3.4	1.8	3.8
1500	1.6	2.5	3.0	2.5	2.6	2.8	3.2	2.6	2.6	2.5	2.0	2.2
1530	1.3	3.2	4.4	4.2	2.3	3.2	4.4	4.2	4.2	3.2	2.3	3.0
1600	2.1	3.1	2.6	3.3	3.4	3.6	2.8	3.2	3.2	3.1	4.5	4.2
1630	3.6	2.4	3.2	2.9	4.1	2.6	3.3	2.9	2.9	4.2	3.1	2.6
1700	2.8	2.6	2.4	3.7	2.8	2.4	2.2	3.6	3.6	2.6	2.8	3.2
1730	2.8	3.0	2.8	4.0	2.6	3.2	2.6	4.4	4.4	3.0	3.0	2.4
1800	2.8	2.8	3.0	3.1	2.4	2.6	3.3	3.6	3.6	2.8	2.7	2.8

Table 2: Wave Height (cm) Measurement for six months (May, 2016 – October, 2016) at Spring and Neap Tide along Ibeno Atlantic Ocean

Time/ Hrs	Spring (May) 06/05/2016	Neap (May) 13/05/2016	Spring (June) 20/06/2016	Neap (June) 27/06/2016	Spring (July) 19/07/2016	Neap (July) 27/07/2016	Spring (Aug.) 18/08/2016	Neap (Aug.) 25/08/2016	Spring (Sept.) 16/09/2016	Neap (Sept.) 23/09/2016	Spring (Oct.) 01/10/2016	Neap (Oct.) 22/10/2016
0700	14	12	18	16	16	18	26	24	18	16	20	18
0730	20	20	22	22	24	26	28	26	20	22	22	20
0800	23	26	25	23	27	28	28	23	23	25	23	23
0830	29	25	24	22	29	31	29	22	29	24	22	22
0900	33	28	23	30	36	28	29	30	33	23	30	30
0930	36	33	28	31	38	36	38	31	36	28	31	31
1000	38	33	37	31	38	37	39	34	12	37	31	31
1030	46	34	47	35	48	38	47	37	20	47	35	35
1100	42	36	50	43	44	36	51	44	26	20	24	43
1130	47	39	56	40	49	42	58	42	25	20	26	40
1200	48	40	65	40	46	41	66	43	28	23	23	40
1230	49	40	71	48	47	44	73	49	33	22	32	39
1300	50	39	73	54	50	37	76	58	53	30	30	36
1330	40	39	71	61	42	39	73	64	56	31	31	34
1400	50	45	69	65	53	48	69	67	49	31	34	38
1430	56	51	60	67	66	58	64	69	46	35	37	44
1500	48	56	62	70	69	59	69	74	74	69	66	56
1530	47	49	72	64	62	55	78	76	76	74	45	41
1600	47	40	69	69	56	48	69	72	71	69	47	44
1630	40	38	65	63	56	47	68	66	74	68	47	44
1700	44	37	66	60	41	35	64	65	74	64	44	42
1730	41	39	64	60	48	46	67	69	42	67	42	38
1800	40	36	64	64	44	39	63	67	65	63	41	35

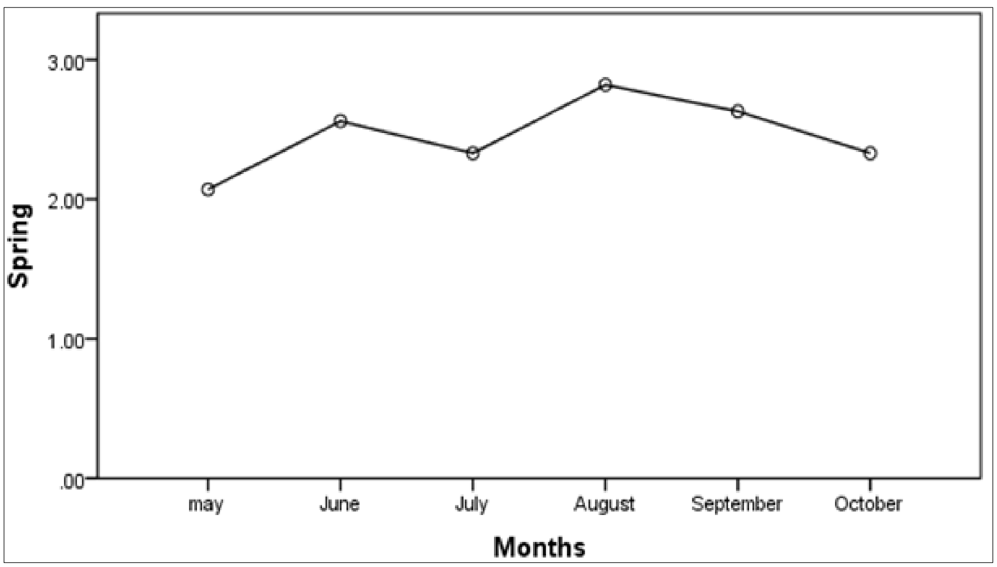

Fig 2: Mean Wind Speed Variation at Spring Tide during the Study Period (May – October, 2016)

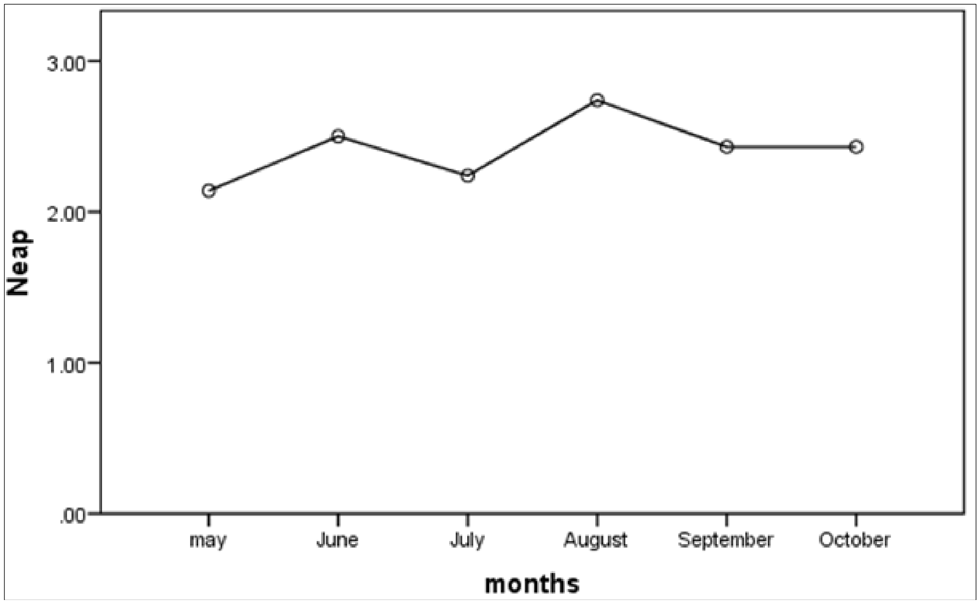

Fig 3: Mean Wind Speed Variation at Neap Tide during the Study Period (May – October, 2016)

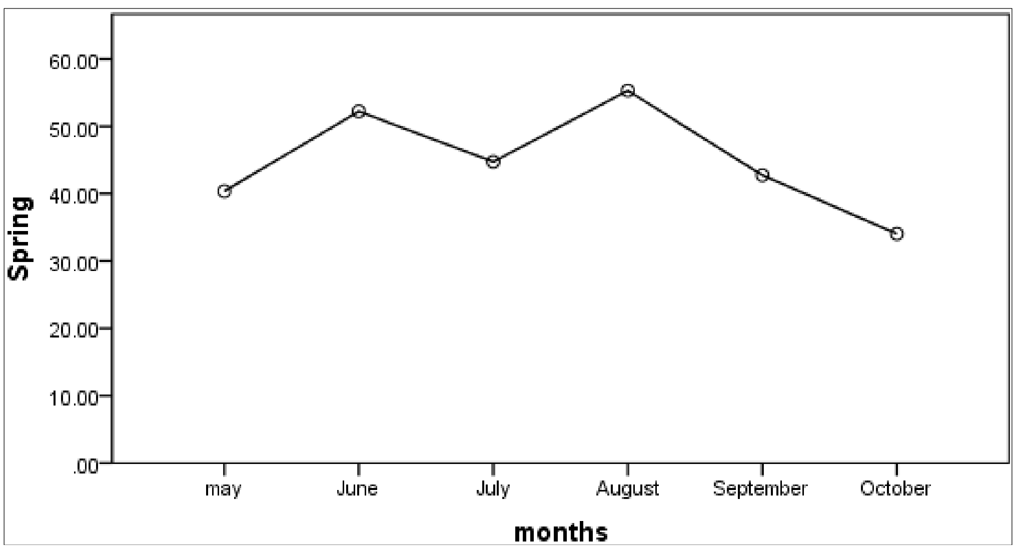

Fig 4: Mean Wave Height Variation at Spring Tide during the Study Period (May – October, 2016)

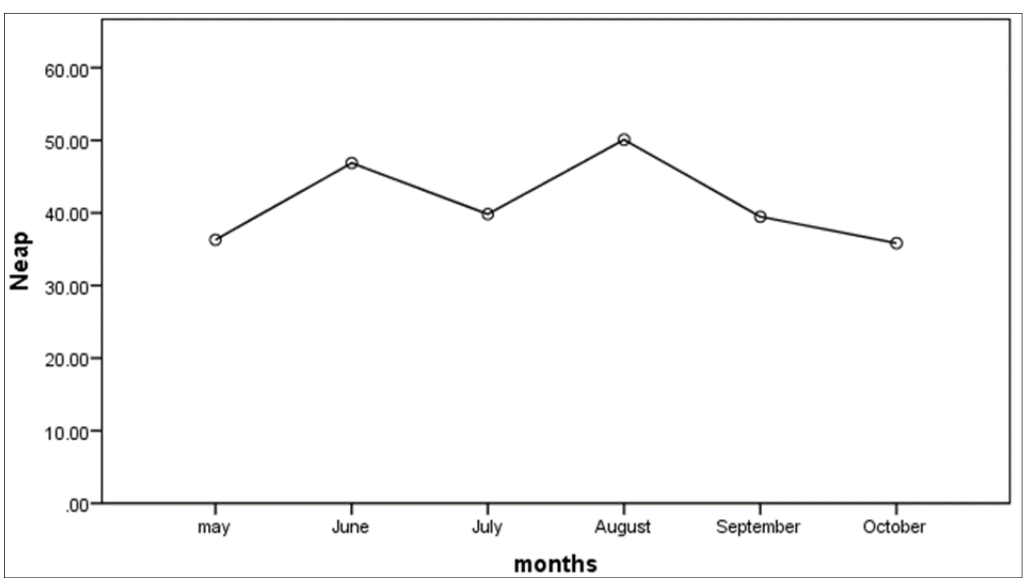

Fig 5: Mean Wave Height Variation at Neap Tide during the Study Period (May – October, 2016)

4. Discussion

Wind direction has a direct impact on the incoming waves from offshore. As large water mass is transported offshore, it is being interrupted by wind. As the wind blow over the sea surface, the large water mass will be affected thereby leading to high wave magnitude and height that will travel several kilometres before it breaks at the shoaling zone. When the wind blows over smooth water surface, there are small frictional effects. This creates first, cats' paws and then ripples on the water. As the wind increases, the ripples get larger until they soon become large enough to be pushed along by the wind. However, the movements of these wavelets is slower than the wind, and the pushing of the wind on them causes an increase in size until they become steep enough to break. Increasing wind strength increases the wave size and the number of breaking waves increases simply because of the wind making steeper and steeper waves that are too high for their wavelength. This synchronizes with the result of the present study. This result however, is consistent with earlier assertion reported by (lyons 1994; Ibe, 1998; Olaniyan & Afiesimama, 2002; Edafienene, *et al*. 2010) [6, 4, 8, 2].

On a perfectly calm sea, the wind has practically no grip. As it slides over the water surface film, it makes move. As the water moves, it forms eddies and small ripples. Ironically, these ripples do not travel exactly in the direction of the wind but as two sets of parallel ripples at angles 70 – 80^o to the wind direction. The ripples make the water surface rough, giving the wind a better grip. The ripples grow to wavelets and start to travel in the direction of the wind. As the wind speed increases, the wavelets become high enough to interact with the air flow and the surface starts to look rough. The wind becomes turbulent just above the surface and starts transferring energy to the waves. Strong winds are more turbulent and makes waves more easily.

The rougher the water becomes, the easier it is for the wind to transfer its energy for the waves to become steep and choppy. Further away from the shore, the water surface is not only stirred by the wind but also by waves arriving with the wind. These waves influence the motion of the water particles such that opposing movements gradually cancel out, whereas synchronizing movements are enhanced. The waves start to become more rounded and harmonious depending on duration and distance.

Wind, earthquake, volcanic eruption and landslide generates wave while tides are as a result of gravitational attraction of the moon and sun. Winds are by far the most common causes of observed ocean waves (lyons, 1994) [6]. As the impact of wave became strong as a result of wind speed and direction, the beach face morphology was disrupted and sediments lost their strength. Some were suspended before being move to the beach face. As such, only fine grain materials were able to get to the beach. Wave breaker height has a direct effect on beach gradient and impact on sediment distribution and sedimentation. The higher the wave breaker height, the higher the long-shore current on sediment distribution and transportation.

Wind direction is reported by the direction from which it originates. For instance, a northerly wind blows from the north to the south. Wind direction is usually reported in cardinal directions or in azimuth degrees. The wind direction at the study area was particularly observed from the North and East.

However, the result of this study shows that wind speed has a direct impact on ocean waves. The mean variation of wind speed and wave height during the study period shows an interesting trend which depicts that the higher the wind speed, the higher the wave breaker height. This assertion agrees with the findings of Edafienene, *et al*. (2010) [2].

5. Conclusion

From the results of findings, it was concluded that wind speed and direction has tremendous effects on ocean waves. It was observed that an increase in wind speed also brings about a corresponding increase in wave breaker height. Wind speed and wave height was higher in the summer months reaching its peak in the month of August which could be attributed to the dry and hot summer wind during this period. Wind speed and direction affected the wave's breaker height, the higher the wave breaker height, the higher the long-shore current magnitude on sediment distribution and deposition. The direction of wind during the study was observed to blow mostly from the North-East direction. Upon the basis of these findings, it is concluded that wind speed and direction has a direct effects on ocean waves.

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