# Examining The Temporal Behavior of Swash and Backwash Waves on Shorelines of Some Selected Settlements in Bayelsa State, Nigeria

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**Abstract:** This research is aimed at examining the temporal behavior of swash and backwash on shorelines in some selected settlements in Bayelsa State in order to promote a better understanding of the causes and impact of shoreline changes on settlements along the coast. To achieve this aim therefore, the study examined the shorelines of three settlements, Agge, Koluama2 and Okpoama situated along the coastline with respect to determining the impact of the temporal behavior of swash and backwash waves on on the shore. The study utilized the instrument of stop watch to carry out in-situ measurements of wave break rate at the shore. Furthermore, Pearson correlation was used to test whether the temporal behavior of backwash is significantly related to shoreline changes in the study area. The results show that erosion is the dominant event in all the three settlements. The result further revealed a progressive increase of wave break rate from the month of April to July and becomes regressive from the month of August to December. This high rate of wave breaks in the month of April to August is as a result of the influence of the tropical maritime air mass which occurs within the period of June and July. The study also reveal that the occurrences or factors that contributes to coastal erosion in the different settlements might be the same or similar. The study recommended amongst others the execution of coastal zone management for the region.

**Key Words:** swash, backwash, temporal, erosion, shoreline

### Background of the Study

Coastlines around the world play a crucial role in safeguarding coastal communities. They hold significant economic and ecological value, serving as vital sources of livelihood and acting as a defense against coastal storms by absorbing floodwaters and dissipating wave energy. However, the combined impact of adverse natural conditions and increasing human activities has seriously compromised the ability of shorelines to fulfill these essential functions. Several studies by Oyegun et al. (2016), Udo-Akuaibit (2017), and Oyedotun et al. (2018) have documented these challenges in relation to the sustainability of coastlines. Despite many countries worldwide enacting various local environmental regulations (including coastal and marine area protection) and participating in international agreements and conventions to preserve the coastal environment, shoreline erosion remains a persistent global problem.

Due to the evident and substantial adverse effects on coastal areas and their shorelines, numerous countries worldwide have initiated efforts to address these issues through research and practical mitigation measures. For instance, concerns related to shoreline issues have been studied and addressed in various locations, including the shores of Florida along the Gulf of Mexico (Morton, 2005), the coast of Bali (Prasetya and Black, 2003), and the South Gujarat Coastline in India (Misra and Balaji, 2015).

The Gulf of Guinea along the Nigerian coast is no different when it comes to human intervention. Evident mitigation measures have been put into practice along various areas, such as the shores of Lagos Bar Beach, Lekki Island in Lagos state, Ugborodo shoreline in Warri, Delta State, and Ogulagha shores in Delta State, as documented by Etuonovbe (2006) and Nwilo et al. (2020).

Previous research efforts on the shoreline along the Bayelsa State Coast and the Niger Delta shoreline have predominantly focused on various geomorphic characteristics, including relief, slope, relative sea level rise, and tidal range (Oyegun et al., 2016). Some studies have also delved into grain size analysis of sediments (Akpofure & Tombra, 2019) and the impact of sea level rise

(Ibe, 1996). However, these studies largely neglected the temporal and spatial observation of backwash and swash wave. Consequently, there is a lack of information regarding the influence of backwash and swash along the Bayelsa State shoreline.

In certain parts of the world, shoreline erosion has been effectively addressed due to well-documented trends and causes of shoreline changes stemming from empirical studies (Prasetya and Black, 2003; Morton, 2005; Houston and Dean, 2014; Misra and Balaji, 2015). However, in Bayelsa State, there is a lack of empirical research aimed at understanding causes of shoreline changes. Consequently, the full extent of the problem remains unknown. Despite the longstanding concerns of coastal residents about their displacement due to shoreline retreat, and the encroachment on settlements to the brink of extinction, it remains unclear the role played by wave processes. This study, therefore, aims to address this knowledge gap by conducting comprehensive empirical research and analysis on the impacts of swash and backwash on shoreline changes. This study will leverage on in-situ recording of wave breaking rates in order to assess the degree and scope of changes along the Agge, Koluama2 and Okpoama shorelines of Bayelsa State.

**Study Area**

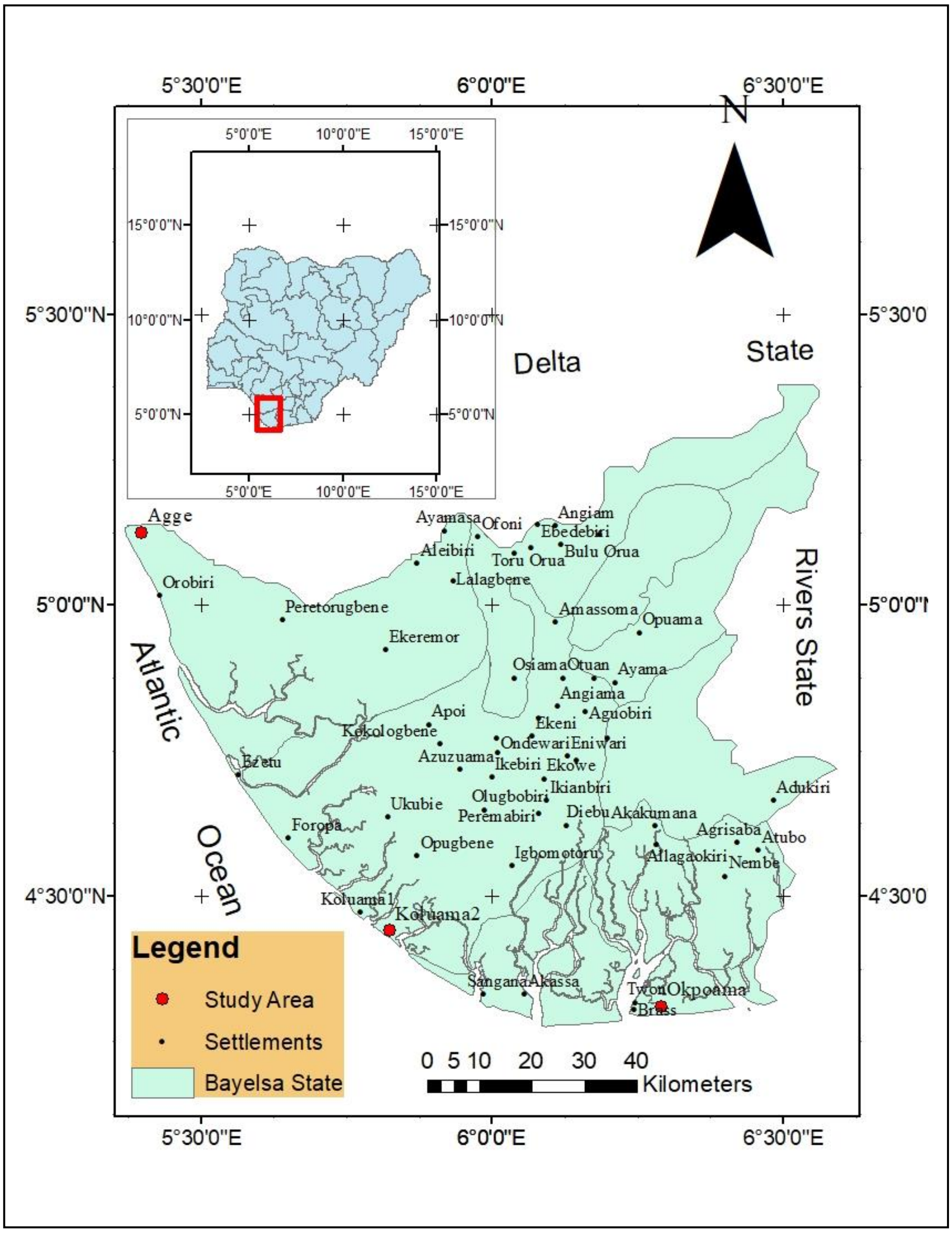


**Fig. 1.0: Bayelsa State map showing Study Areas and Settlements**

**Source: Author's Adaptation from Bayelsa State Administrative Map, 2010 and Google Earth Pro Image, 2020**

The focus of this research is on three communities within Bayelsa State: Agge in Ekeremor local government area, Koluama2 in Southern Ijaw local government area, and Okpoama in Brass local government area. These settlements, are situated between longitudes 5°30' East and 6°30' East of the Prime Meridian and latitudes 4°00' North and 5°15' North of the equator (Fig. 1.0). The geographical coordinates of these three settlements place them adjacent to the Atlantic Ocean which forms its southern, and southwestern borders. The state's proximity to water and its strategic positioning significantly influence its physical characteristics and climate. Bayelsa State encompasses a land area of 13,500 km2, as reported by Eli and Bariweni (2017). Notably, the state boasts a 185km coastline (Google Earth Image, 2021).

Bayelsa State's geographical surface gently slopes from the north to the south towards the ocean. Bayelsa State boasts a roughly 185km shoreline along which numerous rivers, including the Ramos, Dodo, Pennington, Digatoru, Middleton, Koluama, Fishtown, Sangana Nun, Brass, St. Nicholas, and Santa Barbara, run into the Atlantic Ocean. (Ojile, 2007). According to Oyegun (1999), Bayelsa State's climate can be classified as a humid semi-hot equatorial Koppen-Gieger climate of the Af type. The state's weather is caused by two tropical air masses: a moist tropical maritime air mass and a dry and dust-filled tropical continental air mass (Oyegun, 1999).

## Conceptual Review

### Concept of Swash and Backwash

When a wave gets to the coast, the wave energy is divided into: swash and backwash. The swash and backwash motions breaking waves carry sediment across the foreshore, representing one of the most important mechanisms for sediment transport in the beach environment (Bin Arrifin, 2017). However, there may be a significant difference between the amount of sediment carried up the beach and carried off the beach depending upon the wave conditions, the slope of the beach, and sediment permeability (Davis &Fitzgerald, 2004).

Longshore drift has been found to have an impact on shorelines (Tsoukala et al., 2015). Longshore drift is the term for the movement of items along the shoreline brought on by wave action. Longshore drift happens when waves break obliquely towards the beach (Bunnett&Okunrotife, 2013). Materials are carried at an oblique angle by the swash waves up and along the beach. Materials are returned to the beach at an angle by the backwash waves. Longshore drift is the combined outcome of these two motions (Bunnett&Okunrotife, 2013). This mechanism connects erosion and deposition by gradually moving items along the shore. Building out to sea, such as groynes or walls, can prevent the removal of materials by longshore drift. To prevent deposition at the entrance to the Lagos port, walls have been constructed. Nearly the entire coast of West Africa is affected by longshore drift, particularly the shores of Senegal and Mauritania (Burnnet & Okunrotife, 2013).

A study of decadal shoreline changes in the central Pacific region, where sea level has risen faster than the global average since 1950, was sparked by Le Cozannet et al. (2013) research. There is consistency between significant coastline alterations and cyclonic and seasonal waves, according to a modelling study of waves produced by historical cyclonic and seasonal events in French Polynesia since 1970. The study contends that, although being impacted by increased sea level rise rates, waves are the primary driver of shoreline dynamics on relatively underdeveloped atolls.

Boye (2015) sought to pinpoint the patterns of shoreline alterations along Ghana's coast. The elements under consideration include sea-level rise, wave impact, river sediment supply, coastal material resistance, and human impact. Additionally used were hydrodynamic datasets, regional geological maps, multitemporal spatial datasets, and randomly chosen field measurements. The categories of short-term (1974–2005) and long-term (1895–2005) change were used to analyse shoreline trends. It was also found that the primary drivers of the trends in shoreline change observed in the study area are the physical processes of wave action, which are altered by the specific features along the coastlines and made worse by human impact.

## Theoretical Framework

### Systems

Chorley and Kennedy (1971) classified systems into four types: morphological systems, cascading systems, process response systems, and control systems. Morphological systems represent static relationships, illustrating links between elements. Cascading systems involve links through which energy is transferred from one element to another. Process response systems focus on studying the effects of linked elements on each other, emphasizing causal interrelationships. This may include examining how a variable, X, affects another variable, Y. In geomorphology, a natural system that is formed by the combination of at least one morphological and one cascading system. It therefore shows how form and geomorphological process are relate (Allaby, 2013). Langton (1972) identified two sub-types of process response systems: simple-action systems and feedback systems. Simple-action systems are unidirectional; a stimulus in X produces a response in Y, which may then act as a stimulus for another variable, Z. This causal chain is essentially a reiteration of the cause-and-effect relationship. The feedback system can be either direct – where A influences B, and B influences A in return – or indirect, with the impulse of A returning through a chain of other variables.

Lalande and Baumeister (2015) introduced the concept of systems as intricate entities comprising interacting components. This perspective has inspired systems scientists in both the natural and social sciences to investigate the interactions among these parts, aiming for a more profound comprehension of the complexities of reality. Building upon this notion, Arnold and Wade (2015) offer a more specific definition, characterizing a system as "groups or combinations of interrelated, interdependent, or interacting elements forming collective entities." In essence, a system can be understood as a compilation of interrelated parts collaborating as a cohesive whole to achieve a shared objective. An example of this is evident in the various components within a school organization, working collectively to facilitate its overall functioning (Bozkus, 2014).

Underscoring the importance of systems in education, John (2010) underscores their critical role in shaping human resources. The notion of a production function in education, as elucidated by John (2010), establishes a connection between input quantities, intervening factors, and the creation of a distinct quality of outcome.
Chorley and Kennedy (1971), process response definition of system is the most relevant to the objective of this study, given the emphasis it places on the effects of linked elements. Although John (2010), and Arnold and Wade (2015), like Chorley and Kennedy (1971), says system is a group or combination of interrelated, interdependent, or interacting elements forming collective entities, there is no description of form and geomorphologic processes that relate in their definition.

In geomorphology, a natural system is formed by the combination of at least one morphological and one cascading system. As a result, process response system will play an important role in showing the relationship between form and processes. Chorley and Kennedy's (1971) definition is therefore more relevant

**Process-response systems**

According to Chorley and Kennedy (1971) Process-response systems examine causal relationships among various processes.

Chorley &Kennedy (1971) description of systems as process response systems are the most relevant to the objectives of this study, given the fact that it comprises a system of energy flow connected to a system of form in such a way that system operations can modify the system form, which in turn modifies the system operations, while the control system, controls or regulate the system. A geomorphic system reacts to an imposition of a disturbance or change in driving force (a perturbation) by changing one or more of its constituent parts. An example occurs in a beach system, where costal processes may also affect the balance between wave energy and sediment supply. Any change in this balance is manifested in the shoreline. A steady state is achieved if the supply of sediment and wave energy remain constant. Should any of these constituents parts alter, the shoreline will shift in location. For instance, Storms may intensify wave energy, and fine-grained beach sand may be pushed offshore to create cobble beaches or pebble beaches provided sediment supply is steady (Nelson, 2018) As such, interventions in a system may affect the way the system operate, bringing about a range of consequences. Furthermore, a system will be affected when seasonal winds influence waves energy resulting to beaches experiencing different impact such as erosion or accretion at different seasons.

**Methods and Materials**

The study adopted a quantitative research design. The nature of data required, include data on wave breaking rate at the shore. The data-sets used were collected from both primary and secondary sources. The primary instrument deployed for data collection is a stopwatch.
Wave data collected were analyzed to determine swash and backwash rates since they are the most reliable means to evaluate destructive and constructive waves along the shoreline. Constructive and destructive waves were determined by the use of stop watch to carry out in-situ measurements of the break rate of waves. Constructive wave which swash is more powerful than the backwash, was determined by the use of stop watch to measuring wave breaks at the rate of 10 waves or less per minute. Destructive waves whose backwash is more powerful than the swash, was determined by measuring wave breaks at the rate of 10 waves or more per minute (Bunnett & Okunrotifa, 2013). Average values were computed for wave break rates for each settlement, where records were taken on shore at the beginning of any particular month, at the middle of the same month and at the end of the same month. All types of computations for the analysis of data was done using Microsoft office excel.

**Result and Discussion**

**Table 1.0: Breaking Rate of Waves Analysis**

| SETTLEMENT | MEAN WAVE BREAKING RATE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
| Agge | 14 | 14 | 14 | 15 | 17 | 15 | 17 | 12 | 11 | 11 | 12 | 12 |
| Koluama2 | 13 | 13 | 12 | 15 | 14 | 16 | 17 | 10 | 10 | 11 | 12 | 13 |
| Okpoama | 11 | 10 | 10 | 12 | 11 | 12 | 16 | 8 | 8 | 8 | 7 | 9 |

**Fig 2.0: Breaking Rate of Waves (Swash & Backwash)**

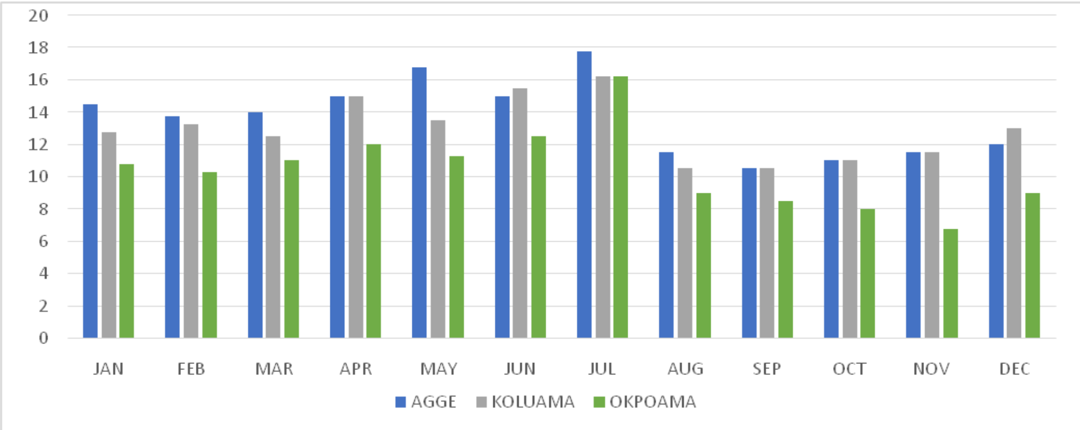


Table 1.0 shows the breaking rate of waves (Swash and Backwash) along shorelines in the study. The field measurements obtained in table 1.0 in the month of January, February, and March show that the mean wave breaking rate is at a rate of 10 waves or more per minute for all the settlements under study.

For the month of April, May, June and July wave break records show that wave breaks at rate of 10 waves or more per minute.

In the month of August, Okpoama settlement recorded wave break of 8 waves per minute. Records from the other two studied settlements of Agge, and Koluama II, all have wave break records of 10 minutes and more per minute.

For the month of September, Okpoama settlement recorded respectively wave break records of 9 waves per minute and 8 waves per minute. The other settlements, Agge, and Koluama 2 have records showing 10 waves or more per minute.

In the month of October, the wave break rate measurements for Okpoama was respectively 6 waves per minute, and 8 waves per minute. Measurements for Agge, and Koluama2 show records of 10 waves or more per minute.

For the month of November, Okpoama settlement respectively show wave break records at a rate of 8 waves per minute and 6 waves per minute. Wave breaking records for Agge and Koluama2 show records of 10 waves or more per minute.
For the month of December, Okpoama settlement show wave breaking at a rate of 9 waves per minute. Agge and Koluama 2, show wave break measurements of 10 waves or more per minute.

Results from Figure 2.0 also reveal that there is a progressive increase on the rate of wave break at the shore of the settlement under study. The wave breaks progressively increased from the month of April to July and witness a regression from the month of August to December.

Further analysis was conducted to test whether the temporal behavior of backwash is significantly related to shoreline changes in the study area.

Results from Pearson correlation shows a strong positive correlation at a 0.01 probability level in terms of the fact that backwash actually cause shoreline change in the study area (Table 2.0)

**Table2.0: Pearsons Correlation Analysis**

Correlations[b]

| | | Agge | | Koluama | | | Okpoama |
|---|---|---|---|---|---|---|---|
| Agge | Pearson Correlation | 1 | | .864** | | | .897** |
| | Sig. (2-tailed) | | | .000 | | | .000 |
| Koluama | Pearson Correlation | .864** | | 1 | | | .874** |
| | Sig. (2-tailed) | .000 | | | | | .000 |
| Okpoama | Pearson Correlation | .897** | | .874** | | | 1 |
| | Sig. (2-tailed) | .000 | | .000 | | | |

**. Correlation is significant at the 0.01 level (2-tailed).

b. Listwise N=12

Findings from table 1.0 effects of waves breaking rates at the shores of Agge, Koluama II, and Okpoama.
Results from table 1.0 also reveal a progressive increase of wave break rate from the month of April to July and becomes regressive from the month of August to December. This trend implies that erosion is at its peak during seasonal period of the month of April to July. This phase coincides with the June/July period when the marine tropical air mass blows from the high pressure region over the south Atlantic. The high rate of wave breaks in the months of April to August may be as a result of the influence of the tropical maritime air mass.

Based on results from table 1.0, the shorelines of all the settlements under study can be categorized as high energy coasts, based on the classification of energy input in the coasts, which shows that wave break rates at a rates of 10 waves or more occurring per minute all through the year and thust revealing a strong backwash. This indicates that erosion will be dominant all through the year in the area. This result is consistent with Davis's (1973) findings, who asserted that high energy coast are susceptible to erosion due to the fact that they are unprotected and have shallow offshore topography and are subject to waves with the highest energy.

Results from Pearson correlation shows a strong positive correlation at a 0.01 probability level in terms of the fact that backwash actually cause shoreline change in the study area. This shows that the occurrences or factors that contributes to coastal erosion in the different settlements might be the same or similar.

## Conclusion

Breaking rates of waves at the shores of the three settlements was measured. Results show that erosion is the dominant event in all the three settlements. The result further revealed a progressive increase of wave break rate from the month of April to July and becomes regressive from the month of August to December. This trend implies that erosion is at its peak during the seasonal period of the month of April to July. This high rate of wave breaks in the month of April to August is as a result of the influence of the tropical maritime air mass which occurs within the period of June July. The study also reveal that the occurrences or factors that contributes to coastal erosion in the different settlements might be the same or similar.

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