Inlet Induced Shoreline Changes along Holden Beach, N.C. (2000 – 2019)

A technical report for the Town of Holden Beach

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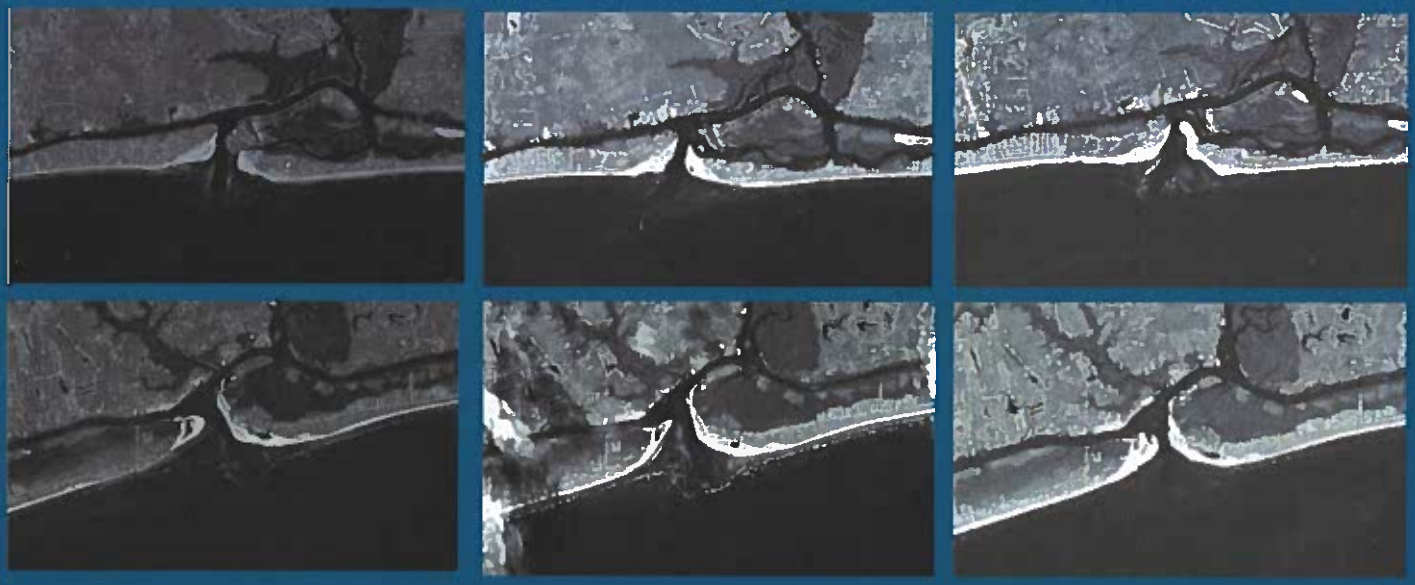

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Study Areas
Shallotte Inlet and Lockwood Folly Inlet
Brunswick County, NC

Introduction

Tidal inlets, or narrow channels of water which separate adjacent barrier-islands, are common features along the East Coast and Gulf Coasts of the United States, including along the entire length of coastal North Carolina. Along south- facing Brunswick County, there are five tidal inlets. These include Shallotte Inlet and Lockwood Folly Inlet, which are the main focus of this study. Previous investigations (e.g. Cleary and Marden, 1999; Hayes, 1980) have demonstrated that tidal inlets are morphologically active; that is, their general orientation, main channels, sandbars and smaller shoals are constantly shifting as a result of oceanographic forcing such as waves & tides, and due to changes in sediment transport patterns. These large-scale changes, which can occur on annual to decadal timescales, often have a significant influence on the adjacent barrier island shorelines, causing noticeable and measurable erosion or accretion.

The observed coastal changes are primarily attributed to a few factors, including the position and orientation of the inlet's ebb channel (the main channel where water moves out to sea during the outgoing tide), the ebb delta and associated smaller bars and channels. As the ebb channel shifts and changes orientation, it influences sediment transport patterns along the ebb delta, which in turn has a direct impact on depositional and erosional changes within, and along, the margins of the tidal inlet.
Coastal development has grown exponentially along North Carolina's barrier islands, including along Holden Beach, over the last several decades. Therefore, it is critical to understand how the adjacent tidal inlets have influenced coastal evolution in the past in order to avoid building new homes in potentially hazardous coastal zones. The main morphological changes occur most often on the flanking barrier island shoulders, commonly known as Inlet Hazard Areas, or IHAs. The IHA influence can often extend up to a few kilometers on either side of the main inlet throat. The main objective of this study is to update the Pictorial Atlas of N.C. Inlets (Cleary and Marden, 1999) for Shallotte and Lockwood Folly inlets from 2000 to 2019, with a focus on understanding shoreline change attributed to changing inlet morphologies.

Study Area - Holden Beach

Holden Beach is a 13 km long, developed barrier island located along the low energy, south-facing shoreline of Brunswick County, North Carolina. It is bordered by Shallotte Inlet to the west, which separates Holden Beach from Ocean Isle, and Lockwood Folly Inlet to the east, which separates it from Oak Island. According to the North Carolina Department of Coastal Management, Holden Beach has some of the highest inlet-induced shoreline recession rates in southeastern North Carolina.

Methods

The tidal inlet images were either scanned and georeferenced from aerial photographs (Year 2000) or they comprise high-resolution satellite imagery (2006 to 2019), obtained courtesy of the Wilmington District, US Corps of Engineers (USACE). All of the images were initially imported into Geographic Information System (GIS) software for subsequent shoreline and tidal inlet analysis. Once the images were catalogued and correctly imported, the shorelines were digitized by following the wet/dry line from the imagery. It must be noted that the respective shoreline digitizations and subsequent analyses are best approximations, which can be subjective due to differences in, for example, water clarity, the presence of nearshore bars and tidal level. The Year 2000 shoreline was used as a baseline, against which all future shorelines were measured from. For purposes of this report, we analyzed shoreline change at two locations for each image, representing the tidal inlet throat and another location approximately 500 m from the inlet, representing the oceanfront beaches located close to the inlet.

Acknowledgments

This project would not have been possible without significant help from Spencer Roylance, remote sensing specialist at the Wilmington District of the USACE. He kindly provided the authors with both aerial and satellite imagery, in addition to professional guidance and support. We would also like to thank Colleen Reilly, an MCOP graduate student from UNCW who assisted with GIS analysis and digitizing. The template used for this report is based on Cleary and Marden's 'A Pictorial Atlas of North Carolina's Inlets' (1999), a NC Sea Grant Publication. This study was funded by the Town of Holden Beach.

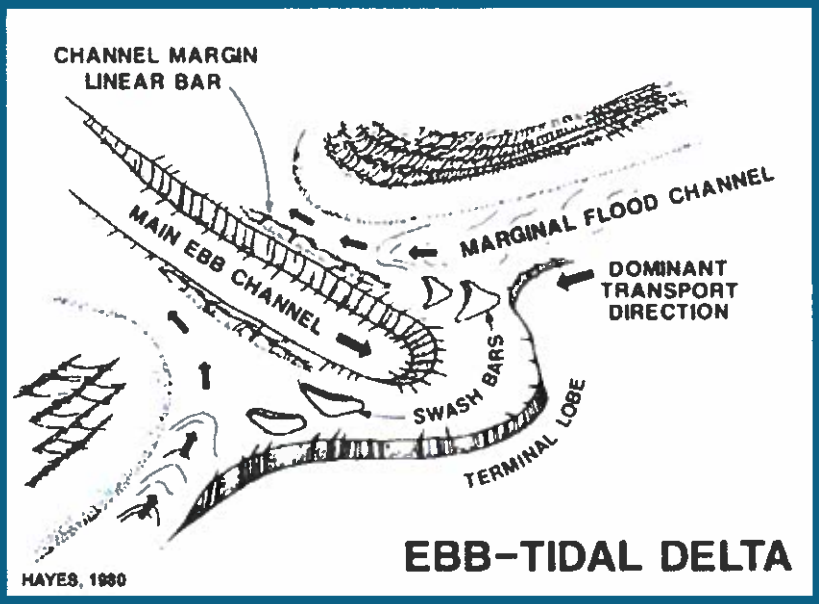
References

Cleary, W.J. and Marden, T. P., (1999). A Pictorial Atlas of North Carolina's Inlets. A NC Sea Grant Publication. 50 p.

Hayes M., 1980. General Morphology and Sediment Patterns in Tidal Inlets. Sedimentary Geology, 26, pp. 139-156.

Main Tidal Inlet Features, Processes and Definitions

(after Hayes, 1980 and Cleary and Marden, 1999)



Definitions

Accretion – accumulation of sand due to waves, currents and wind. A buildup of beach, shoreline or dune

Ebb Channel – the main, deeper tidal channel, dominated by outgoing tides located between two barrier islands.

Ebb Tidal Delta – the main sand deposit located seaward of the tidal inlet, which often protects adjacent barrier islands from the effects of storms and wave action.

Inlet – the main body of water which separates adjacent barrier islands. Water, sediment and nutrients flow in (flood) our out (ebb) of the inlet depending on the tidal phase.

Marginal Flood Channel – main channel where water flows into the inlet and inland, often located along the margin of the barrier island. Commonly associated with erosional processes.

Shoreline – an approximation of the high tide line, or commonly the wet/dry line in aerial and satellite imagery.

Shallotte Inlet

Historical Context (1949 – 1996)

An analysis of aerial photographs from 1949 to 1996 (Cleary and Marden, 1999) reveal that the position of Shallotte Inlet has remained relatively stable, with minor westward movement. However, significant changes to the adjacent inlet 'shoulders', including erosion and accretion, have occurred due to the shifting inlet ebb channel. When the main ebb channel is orientated southeast, towards Holden Beach, accretion takes place along Holden Beach's western margin. In this scenario, the neighboring eastern margin of Ocean Isle experiences erosion.

Prior to 1960, the main inlet channel was skewed towards the southwest, resulting in significant erosion along Holden Beach due to the flood channel being positioned along the Holden Beach shoulder. In 1962, the position of the main ebb channel was almost due south, which resulted in accretion of both Ocean Isle and Holden Beach shoulders, representing an ideal scenario for both beach communities. From 1974 to 1996, there has been an accretionary trend along the western section of Holden Beach, mainly due to the southeasterly orientation of the ebb channel. The oceanfront area in close proximity to the inlet (within 600 meters) eroded 146 meters between 1938 and 1949; from 1949 to 1996 there was up to 240 meters of accretion.

Contemporary Context (2000 to 2019)

Inlet Induced Shoreline Change

There have been significant changes in shoreline position along the western Holden Beach inlet shoulder since 2000. These changes are primarily attributed to the position and orientation of the main ebb channel, which influences the shape of the offshore ebb delta and associated flood channel. As shown by Cleary and Marden (1999), when the main ebb channel 'hugs' the Holden Beach shoulder, there tends to be a tendency towards erosion on the far southwest section of Holden Beach. As the ebb channel turns more southward and shore normal, shoreline accretion takes place on the southwest section of the Holden Beach shoulder. However, the opposite appears to be true further in towards the inlet throat; there is an accretionary trend towards the mainland when the ebb channel is orientated towards the southeast and the Holden Beach shoulder.

The main ebb channel slowly shifted from a southeast position in 2000 to a southward, shore normal orientation, in 2011. The imagery from 2015 shows that the seaward section of the ebb channel had a more southwest orientation.

Interestingly, the most recent image from 2019 appears to show the development of a second channel, with a more southeasterly alignment towards Holden Beach. It will be interesting to see which channel becomes the more dominant ebb channel over the next few years. The new channel orientation will eventually determine the shoreline changes along the western section of Holden Beach.

Net Shoreline Change (2000 to 2019)

An analysis of the wet/dry shoreline using standard digitizing methods (bottom image this page) shows that the influence of Shallotte Inlet extends approximately 700 meters eastward, shown by the confluence of all the profiles. An examination of net shoreline change was conducted along two sections of Holden Beach: i) the 'inlet throat', representing the closest distance between Holden Beach and Ocean Isle and ii) approximately 500 m east from the southwest tip of Holden Beach, referred to as 'shorefront'. The digitized shoreline from 2000 has been used as the baseline, from which all measurements are based off.

2000 to 2006

A comparison of shorelines from 2000 to 2006 shows that there was significant erosion, up to 125 meters, within the inlet throat, representing a 'widening' of the main inlet channel. In contrast, the oceanfront shoreline accreted by up to 107 m.

2000 to 2011

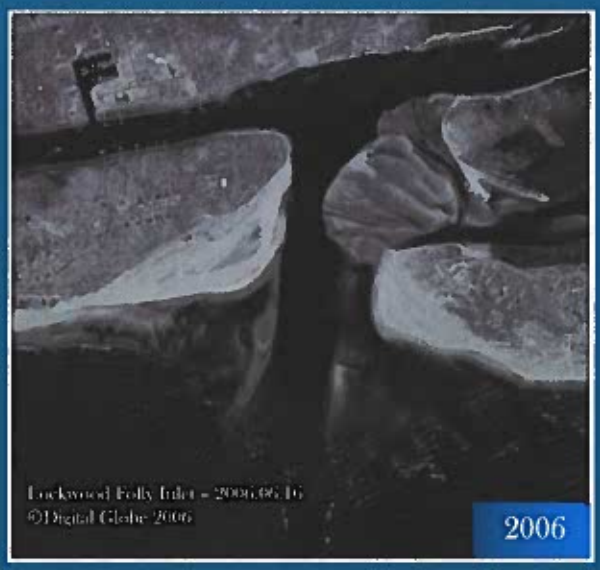
A similar pattern of inlet throat erosion and shorefront accretion continued in 2011 compared to 2000. Shoreline measurements indicate up to 125 meters of erosion along the inlet throat and 120 meters of shorefront accretion compared to 2000.

2000 to 2015

Compared to 2011, there was a tendency for the inlet throat to accrete by approximately 35 m, although compared to 2000, the erosion was still 64 meters. In contrast, there was minimal change along the shorefront position compared to 2011, with a net accretion of 122 meters compared to 2000.

2000 to 2019

Compared to 2000, 2019 represents the greatest amount of erosion along the inlet throat, up to 202 meters. The shorefront accreted an additional 40 meters compared to 2015, or up to 163 meters compared to the 2000 baseline.



Lockwood Folly Inlet

Historical Context (1938 – 1996)

According to Cleary and Marden (1999), early maps from the 16th and 17th centuries indicate that Lockwood Folly Inlet has remained more or less in the same position as presently, with a maximum excursion of about two kilometers east towards Long Beach. The presence of peat outcrops and tree stumps on the eastern section of Holden Beach suggests that the inlet has not migrated westwards in at least a few centuries. From 1938 to 1996, the midpoint of the inlet has migrated approximately 150 meters to the east. There have been significant coastal changes along the adjacent shorelines due to the changing orientation of the main ebb channel, which directly influences the shape and position of the seaward ebb delta. When the main ebb-channel is orientated to the southeast (i.e. away from Holden Beach), the main flood channel is often located adjacent to the eastern margin of Holden Beach, promoting erosion. When the main ebb channel has a more southern orientation, erosion along Holden Beach stops, followed by an accretionary trend. Erosion of Holden Beach's downdrift eastern shoulder was common from the 1930s through to the 1970s, after which accretion was the dominant pattern. As the channel shifted southwards, accretion was the dominant pattern from 1974 to 1986. After 1986, the channel once again resumed its southeast orientation, resulting in widespread erosion. Average shoreline erosion rates since 1938 near the inlet have been estimated to be 1.5 meters per year.

Contemporary Context (2000 to 2019)

Inlet-Induced Shoreline Change

As with neighboring Shallotte Inlet, there have been significant changes in shoreline position along this easterly located Holden Beach inlet since 2000. These changes are also primarily attributed to the position and orientation of the main outgoing ebb channel, which influences the shape of the offshore ebb delta and associated flood channel. As shown by Cleary and Marden (1999), when the main ebb channel is aligned southwest, towards Holden Beach, there is a tendency towards accretion on Holden Beach and erosion on the opposite Oak Island side, due to the location of the marginal flood channel. In contrast, as the ebb channel becomes aligned southward, there is significant accretion on the oceanfront section of Holden Beach, coupled with a narrowing of the inlet throat located landward. This was the case in 2006 and 2011 as the main ebb channel maintained a southerly, shore-normal

orientation. In 2015 and 2019 the satellite imagery shows that the main ebb channel continued to rotate clockwise towards the southwest. In this position, there was continued accretion on Holden Beach's oceanfront side of the inlet shoulder, coupled with inlet throat erosion. In 2019, the main southwesterly orientation of the main inlet channel continues, maintaining generally the same form as in 2015.

Net Shoreline Change (2000 to 2019)

An analysis of the wet/dry shoreline using standard digitizing methods (bottom image this page) shows that the influence of Lockwood Folly Inlet extends approximately 700 meters westward. An examination of net shoreline change along two sections of Holden Beach, defined as: i) the' inlet throat', representing the central part of the main inlet between Holden Beach and Oak Island and: ii) approximately 500 m west from the southeast tip of Holden Beach, referred to as 'shorefront'. The digitized shoreline from 2000 has been used as the baseline, from which all measurements are based off.

2000 to 2006/2011

A comparison of shorelines from 2000 to 2006 and 2011 shows that there was approximately 50 meters of accretion along the inlet throat and close to 70 m of accretion along the 'shorefront'. The digitized shorelines for 2006 and 2011 were similar, attributed to the southerly orientation of the main ebb channel.

2000 to 2015/2019

In 2015 and 2019, as the inlet channel was orientated more towards the southwest, there was notable accretion on the shorefront beach, with over 100 meters of oceanfront build-up in 2015 and 120 meters in 2019 compared to 2000. Along the inlet throat, there was an erosional tendency compared to 2006 and 2011, with the inlet shoreline returning more or less back to its original 2000 position.