

Foredune erosion along southern shores of Lake Michigan during 2013-2020 high lake levels

From January 18, 2013 (175.16 m a.s.l.) to September 8, 2020 (177.82 m a.s.l.), Lake Michigan-Huron experienced its fastest and highest rise (2.67 m) since 1860 when instrumental measurements began. Extensive foredunes that developed since the last high lake levels in 1997 began eroding at fast rates. This study focuses on coastal morphodynamics along the 800 m coast within central Indiana Dunes State Park on Lake Michigan's southern shores from January 2018 to January 2021. Throughout 2018, the easternmost foredunes exhibited the most erosion, totaling 4.25 m of linear loss. The central foredunes lost 2.16 m, and the westernmost foredunes lost only 1.79 m in width. An estimated 18.3 cubic meters of sand per 1 meter of coast was eroded from the foredunes and transferred to the backshore and foreshore. The lake levels were 6 - 42 cm higher in 2019 than in 2018 and amount of foredune erosion in 2019 was significantly higher than in 2018. The easternmost foredunes recorded a 9.5 m shortening, the central foredunes lost 1.84 m, and the westernmost foredunes lost only 0.6 m in width. A total of 27.51 m³ of sand per linear meter of coast was removed from the foredunes and transferred to the dry or submerged part of the beach. Lack of shelf ice along the shore, still rising lake levels, and convective storms triggering meteotsunamis changed the foredune erosion pattern in 2020. Erosion became most vigorous in the downdrift central and western study areas. From January through September 2021 Lake Michigan levels were 19 cm higher than in 2019. The total volume of eroded foredune sand (64.42 m³/m) in 2020 was more than double that of 2019 and almost quadruple that of 2018. Along the 200 m of coast in the central study area, the foredunes were completely eroded, losing 13.2 m in width. The foredunes in the western study area suffered extensive (11.2 m) erosion and were reduced to a total width of 6.8 m. Significant (7.8 m) erosion in the eastern study area reduced the foredunes to 8.85 m in width. After foredune erosion events, the beach rapidly recovered and maintained its width as the shoreline migrated landward.

Severe foredune erosion, in terms of total linear dune loss and total volume of eroded sand, occurred unevenly over the three-year period, both temporally, during a single storm, a season, a year, or three years, and spatially, in the eastern, central, and western study areas. Late autumn storms accounted for most foredune erosion in 2018 and 2019.

On many occasions following these severe erosion events the dry portion of the beach, the backshore, accreted and absorbed significant sand amounts removed from the foredunes. The remaining sand was transferred to the foreshore, where it changed the sand bar morphology and lead to their coalescence and flattening.

Keywords: foredune, beach, sand bars, erosion, Lake Michigan, meteotsunami