10 m pr. year of dune face retreat rates at Danish coastline undulations

Nikolai Sørensen, Danish Coastal Authority, nihes@kyst.dk
Christina Weidick Kærsgaard, cwk@hjoerring.dk
Per Sørensen, Danish Coastal Authority, pso@kyst.dk

INTRODUCTION

On sandy coasts exposed to waves from an almost shore-parallel angle, coast undulations can be present. At Tversted beach in the northwestern part of Denmark (figure 1) the dune face has migrated more than 100 m seawards between 1945 and 2010. From 2010 the dune face has started moving landwards with a rate of +10 m/y for consecutive years. From 2010 to 2022 the dune face has in total migrated nearly 100 m landwards.

This narrows the dune width in certain areas, making these areas prone to erosion and flooding which worries the local community. The community which has moved closer to the sea during the period of seaward migration.

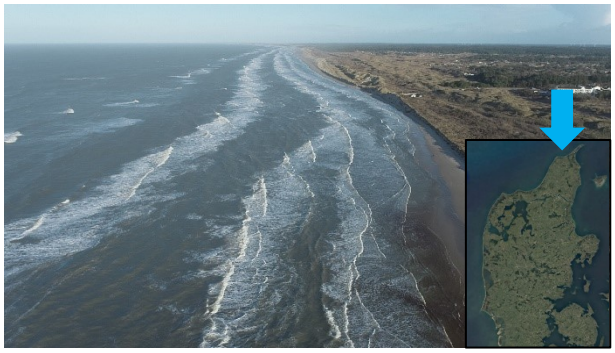

Figure 1: Aerial image (facing east) of coastline undulation and salient at Tversted beach, Denmark.

Adjacent coasts experience advance rates in the same order of magnitude as the neighboring retreat rates and even larger rates are observed for accretion periods.

This study will focus on analyzing if there is a cyclicity at the coast which will cause a seaward migration of the dune face again.

METHODOLOGY

The coast at Tversted is facing north and waves a dominantly from west which results in very skew waves hence a unidirectional longshore wave energy flux towards east (figure 2).

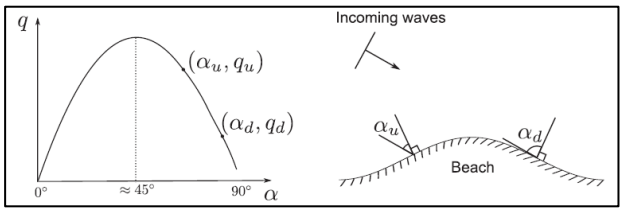

Figure 2: Instability mechanism (Kaergaard et al., 2011).

Is it hypothesized that the coastline and dune face undulations are driven by an instability mechanism described by Kaergaard et al. (2011) presented in Figure 2, and also by sand-waves migrating in the same direction as the alongshore wave energy flux with crests orientated perpendicular to shore as presented 10 km west of the area in Figure 3. Sand-wave crests and troughs could possibly cultivate coastline salients and coastline undulations, respectively.

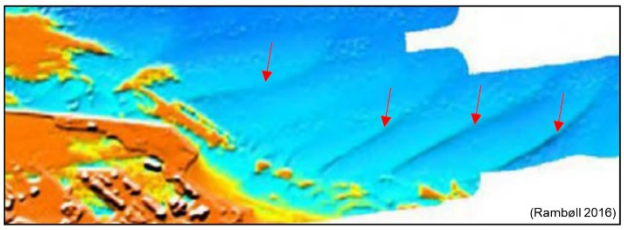

Figure 3: Bathymetry 10 km west of site. Red arrows indicate sand-wave crests (Rambøll, 2013).

Sørensen (2021) showed a correlation between the composition of the bars and the location at the coastline. Geertsen et al. (2021) analyzed the impact of the bar composition on dune retreat and found a correlation between depression of the bar system and the retreat of the dune face. It is therefore hypothesized that the compositions of the bars, coastline and dune face position are correlated.

The locations of the coastline and dune face on the 7 km long stretch of coast are investigated in the study by analyzing +50 years of cross-shore profile data, satellite images, orthophotos, drone imagery, images and videos from handheld cameras and Lidar mounted on a drone.

Following available data are also included in the analysis: the evolution of dune, shoreline (figure 2) and depth contour's positions, morphological changes from Digital Elevation Models (DEM), long-term coastline changes from satellite images and bar locations from images and timelapse.

RESULTS AND CONCLUSIONS

Our first analysis shows that fluctuations in the dune, shoreline and depth contour's cross-shore positions over time are prominent when analyzing individual cross-shore profiles. Very large coastline erosion and accretion rates are observed with averages of +10 m/y and +15 m/y, respectively for +15 consecutive years.

Figure 4 shows the relative shoreline position of the shoreline for 8 cross profiles, covering 7 km of coast. Profile 1400 is the most upstream profile and profile 1330 is the most downstream. Although large fluctuations are seen in the coastline position over time in each profile (figure 4) calculating the average of changes of all the profiles (red line) indicates a relatively stable coast over

space and time.

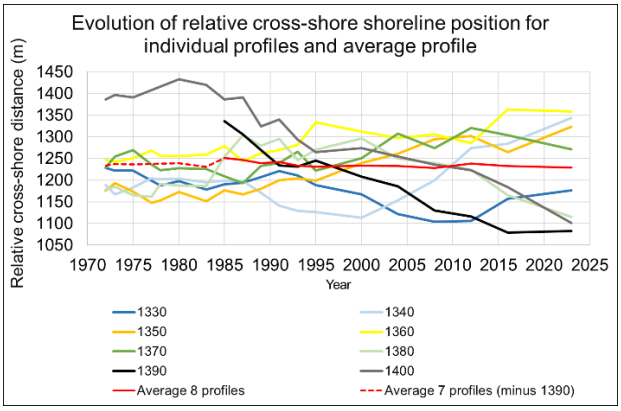

Figure 4: Evolution of coastline positions in the cross-shore domain from measured profiles.

When analyzing the coastline position in each profile it is seen, that when the upstream coastlines retreats, the next profile downstream have a coastline that advances. This transition takes place gradually between coastlines downstream. The last profile, 1330, shows a relatively stable coastline. This indicates a beach rotation or a cyclicity of the position of the coastline.

To further investigate this possible natural cyclicity of the coastline, the position of the dune face from 2010 to 2022 is analyzed. The dune face is here used as measure of the dynamics, since it is a more robust indicator of long-term trends than the coastline position, which is constantly changing due to the tide.

In figure 5 the location of the dune face in 2010, 2016 and 2022 is shown.

Figure 5: Position of dune face in 2010, 2016 and 2022.

It is noticeable that the dune face has retreated approximately 100m from 2010 to 2022 in the western part of the coast and a nearly corresponding advance of the dune face to the east.

Both in 2010 and 2022 the dune face has sinusoidal shape along the coast while it is less prominent in 2016.

The analysis shows a clear cyclicity of the coast in Tversted and a stability of the coastline and dune face position over time and space despite retreat rates of 10 m/year!

Further analysis will focus on investigating the coastline and dune face undulation's relation to bar morphology and sand-waves. Focus will also be on the cyclicity, migration rates and future locations of erosion hotspots in the area.

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REFERENCES

Kystdirektoratet et al. (1994): Kysten nordøst for Hirtshals

K. Kaergaard, J. Fredsoe & S.B. Knudsen (2011): Coastline undulations on the West Coast of Denmark: Offshore extent, relation to breaker bars and transported sediment volume.

N. H. Sørensen (2021): Hydrodynamics and morphological change in a rip current setting on the west coast of Jutland prior to, during and after high-energy events.

K. S. Geertsen, S. Hillmann, E. Quataert, R. Hoogland & B. Frederiksen (2021): Influencing the SPR for storm surge events-A cross-border XBeach application.

Rambøll Danmark a/s. (2013). Hirtshals Havn, virkning på kysten af inddæmning. DHI - The expert in WATER ENVIRONMENTS.