SEA ICE AND ITS INFLUENCE TO COASTAL PROCESSES - BALTIC SEA, ESTONIA

Orviku, K., and Tõnisson, H.
Institute of Ecology at Tallinn University, Uus-Sadama 5, Tallinn 10120, Estonia
E-mails: kaarelorviku@gmail.com, Hannes.Tonisson@tlu.ee

Introduction
The Baltic Sea region is characterized by variable winter weather conditions. Sea ice forms near the Estonian coast almost every winter and is characterized by large temporal and spatial variability [1, 2]. In severe winters, the Baltic Sea near the Estonian coast is totally covered by pack ice, whose thickness may achieve 20 – 30 cm [5]. A combination of high sea level and prolonged strong winds from a single direction forms preconditions for catastrophic ice movement to the coast. Large accumulations of erratic boulders characterize both ancient and contemporary shore formations in the northern Baltics. These formations often consist of straight rows of boulders parallel to the shoreline. The boulders sometimes accumulate on beach ridges at elevations of a couple of meters above the sea level and tens of meters inland from the shoreline. Sea ice drifting onshore and the formation of ice hummocks is usually accompanied by transport and accumulation of sea bottom sediment to the shore. Ice lobes are capable of moving boulders over 1 m in diameter and deposit ridges of cobble and boulders. The genesis of such accumulations has been attributed mainly to drifting ice from near-shore water to the shore. Evidence of transported boulders are visible in spring at low sea-level conditions after the ice has melted [4]. The main goal of the article is to discuss the role of sea ice in shaping the accumulative shores of Estonia.

Data and methods
Due to limited access to the Estonian coast during the Soviet era, sea ice observations were sporadic and datasets were incomplete. Ice drifting was observed only in some springs by an array of different researchers and data were recorded as field reports. Coastal researchers from Institute of Ecology at Tallinn University have documented the most severe events since 1990s. Such irregular data allows us to draw very robust conclusions on the impact of drifted ice on the morphology and structure of the seashores.

Regular sea ice observations have been made at coastal stations and the data archived by the Estonian Meteorological and Hydrological Institute. These data are available from the original observation record and includes observations on coverage of pack and of drifting ice, ice thickness and other ice phenomena.

Results and discussion
The earliest descriptions and figures on the accumulation of massive sea ice and the formation of “icebergs” originate from Tallinn Bay on 3rd February, 1863 [3]. This description includes two large boulders from the sea bottom, which were transported onshore to a 3 m high ridge.

Our first studies on the structure and formation conditions of the hummocks of drifted ice on shore originate from February 1957, when 15 m-high blocks of ice were deposited on a sandy beach in Pärnu Bay [4]. In some places ice movement was particularly active and some lobes broke through
the ice mass threatening buildings. The drifted ice carried sand from the sea bottom, which upon melting in spring, left sand deposits covering the ice and inhibiting its final melting. Catastrophic sea ice drift to the beach in Pärnu was observed in the afternoon of 2 February, caused by an intense cyclone (mean wind speed 28 m/s, sea level +125 cm). Sea ice started to drift towards the coast. Records indicate ca. 10 m high ice ridges forming 150 m from the coastline. Accumulations of onshore drifting ice masses in Pärnu Bay have been recorded many times since.

The formation of icebergs is rarely observed, occurring usually during strong winter storms far from human settlements or perchance observers. However, manifestations of drifting ice are frequently evident on the seashores in spring after melting of the ice. For instance, an accumulation of near-shore bottom sediments with large boulders was recorded in 1965 at the foot of Kaugatoma cliff in Saaremaa. This accumulation looked as if the sea bottom had been levelled. A storm on 8 March with WSW winds of 16 m/s most likely caused the sea ice drifting near the Kaugatoma cliff.

Figure 1. Hummocks of drifting ice in pine forest at Paaste in March 1997.

Sea-ice heaps were formed in Tallinn near Russalka monument in 1968. Northerly winds with a mean of 15 m/s were recorded on 10 March, which could have formed the sea-ice heaps on the coast near Russalka. As a result of this storm, the accumulated ice advanced across the coastal defenses and the nearby road damaging its metal barriers. Formation of ice hummocks and their invasion on land has been observed many times in Tallinn. It is possible that Tallinn Bay is not so much a favorable site for accumulation of drifted ice blocks as an optimal location from which to observe the process. It is also possible that the heavy marine traffic in Tallinn Bay may enhance sea ice movement by dissecting the ice cover into smaller pieces and thus contributing to onshore movement of the near-shore ice in favorable wind conditions.

The formation of ice hummocks on the coast of Narva Bay has been recurrently observed. For instance, an accumulation of drifted ice blocks on Narva-Jõesuu beach was recorded in 1982. A
drift of sea ice to the coast (NW winds) with an average speed of 1 cm/s was recorded on 7 April. It can be assumed that the ice heaps on the beach of Narva-Jõesuu formed the same day.

One of the best investigated events of sea ice accumulation occurred in 1997 in Paaste village, Saaremaa (Figure 1). Although the process itself was unwitnessed, traces of the ice assault were carefully studied afterwards thanks to information given by the local inhabitants. Hummocks of ice moved about 100 m inland within a 0.5 m wide sector of the shore as a result of north-westerly winds resulting in severe damage to a pine forest. The results of the ice assault became evident in summer after the final melting of the ice: some boulders and sea bottom sediments had been transported to the damaged pine forest. North-westerly winds gusting to 19 m/s on 19 March probably caused an extreme sea ice drift to the coast of Saaremaa near Paaste. A maximum sea level 136 cm above zero was measured at that time.

The latest studies on the impact of drifting ice on the structure and development of the Estonian seashores are from spring 2011 and 2012 on the coasts of Saaremaa, Kihnu and Muhu Island as well as on the southern coast of Gulf of Finland (near Toila) and eastern coast of Gulf of Livonia (northern Latvian coast).

Conclusions
We can conclude that decomposition of sea ice and its drifting onshore is enhanced by severe storms associated with high sea levels. Despite an irregular character and limited extent of drifting ice events, their advances onshore enhance erosion of typically stabilized seashores. A complex dataset of hydrological, climatic and geomorphic characteristics should be analyzed to determine the conditions facilitating the formation of drifting ice hummocks on the shore. This is an important scientific research task for the future, the results of which can contribute to sustainable coastal zone management and safe living conditions on the coast.

Acknowledgement
This work was supported by ESF Grants No. 9191, 8549 and target financed project No SF0280009s07.

References