ICE THRUSTS AND PILES ON THE SHORES OF THE SOUTHERN
BALTIC SEA COAST (POLAND) LAGOONS

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Abstract

This paper presents some phenomena of the ice cover deformations related to the ice thrusts and piles, and to their disappearance on the shores of lagoons located along the Polish coast of the Baltic Sea. The observations were carried out at different periods, for significant thrusts of ice field and accompanying ice piles i.e., during the winters of 1976, 1993 and 2003. Measurements of the ice thickness by drilling were used to prepare the ice profiles. They allowed a presentation of spatial and temporal variations in thickness of different ice forms in the study area. We observed a relation between the length of the thrusted ice sheet and the height of the ice pile. The piles of the ice sheets thrusted closer to the basin usually attained a greater height. The ice sheets thrusted far landward were devoid of piled ice. The melting rate of the ice piled on land depended (mainly) on air temperature. At a mean air temperature of 8.5 °C the melting rate of an ice hummock amounted to 11 cm/24 hours. Frequent disintegration of ice covers and thrusting of the ice fields onto the shore is a destructive factor that enhances the abrasion of the shores.

Keywords: ice-sheet thrusts, coastal ice piles, ice hummocks, Southern Baltic Sea, Szczecin Lagoon, Vistula Lagoon.

INTRODUCTION

One of the most characteristic features of the Polish coast of the Baltic Sea is the presence of lagoons. These coastal lagoons are relatively shallow basins and their mean depths range from 2.6 m (the Vistula Lagoon) to 3.4 m (the Szczecin Lagoon, Mikulski 1964). Hence, the ice cover of these basins is characterized by a relatively long duration, reaching up to 120 days. The maximum ice thickness, especially in the Vistula Lagoon, even amounts to 70 cm (Girjatowicz, 1990). Greater ice thickness in the area of the southern Baltic Sea is only noted in the Curonian Lagoon, reaching up to 90 cm (Zorina, 1965; Sergejeva, 1983).

The fast ice is the dominant form of ice in the lagoons of the study area (Maliński, 1971; Zorina and Maliński, 1975). During the warmer periods, particularly in

<table>
<thead>
<tr>
<th>Baltic Coastal Zone No. 8</th>
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<tbody>
<tr>
<td>Institute of Biology and Environmental Protection</td>
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<tr>
<td>Pomeranian Pedagogical University</td>
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<td>Ślupsk</td>
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</tbody>
</table>

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process is the wind (Girjatowicz, 1977; Zakrzewski, 1978). A wind-driven ice field tends to thrust and pile up not only within the basin, but also on the land. These phenomena have a destructive effect on the shore and constructions on the land within the range of the ice activity, and they are characteristic of nontidal basins in the temperate climatic zone. Some examples of destructive ice impact on the shores of the coastal lagoons of the southern Baltic Sea were given by Kraus (1930), Banzhaf (1931), Lundbeck (1931), Zaimdars (1941) and Correns (1973).

Kraus (1930) and Alestalo & Häikiö (1976) paid much attention to the thrusting and piling of ice fields on the shores of sheltered basins within the Baltic Sea. According to Kraus (1930), the longest landward-thrusting ice sheet, measuring as much as 312 m, was observed in the Pärnu Bay. The ice hummocks formed there were even over 12 m a.s.l.

Alestalo & Häikiö (1976) studied similar ice phenomena, in the northeastern part of the Bay of Bothnia, in the sheltered Luodonselkä Bay. Towards the end of December 1972, with a wind speed of up to 20 m/s blowing from southwestern directions, thrusts of ice sheets of ca. 100 meters landward were observed. These thrusts were associated with hummocks reaching a relative height of 4 meters above the ground level (up to 6 m a.s.l.). Such phenomena are observed in this area fairly frequently, as evidenced by the damage and scarring of tree trunks in the coastal zone. Girjatowicz (1980, 1999, 2001) also reported observations on ice thrusts on the shores of the Szczecin Lagoon. The ice enters the flat coasts of the Szczecin Lagoon usually over a distance not exceeding 100 meters.

The aim of this paper was to present some phenomena related to ice cover deformations. Particular attention was paid to the ice thrusts and piles, and to their disappearance on the shores of (the Baltic Sea) coastal lagoons located along the Polish coast.

MATERIALS AND METHODS

The research was mainly based on measurements of the ice drillings and ice surface features (topography), supplemented by photographic documentation. A simple measuring equipment was used to measure the ice thickness and the height of ice piles. For drilling, we used a hand-operated auger. The ice thickness and ice pile height were assessed using a measuring rod, the distances between the drillings were measured with a tape, and the azimuths with a compass.

The ice drillings were collected at a distance dependent on the differentiation of the type of ice, but usually amounted to several meters. The distance between drillings was smaller, even up to several dozens of centimeter, in piled ice. At the site of a given drilling, the depth and height of the ice surface (the pile inclusive) above the water level were measured, in addition to the ice thickness. The drillings in ice, along particular profiles, were sometimes repeated to determine the changes in ice conditions.

The ice profiles in the coastal zone, obtained and used in this paper, including the ice thrusts and piles on the land, originated from different periods. Specifically three significant cases of ice phenomena were recorded by the author on the Rów
Peninsula during the winters of 1976, 1993 and 2003. Low scale thrusts and ice piles appeared in the lagoons of Polish coast almost each year. It is necessary to note that the author carried out the ice exploration on these basins for several decades, since the early '70.

The technique of ice drillings is commonly applied in studies of ice cover morphology. In the northern part of the Baltic Sea, studies using measurements from ice drillings were principally carried out by Keinonen (1976, 1978), Kankaanpää (1997), and Leppärant (1998, 1999). On large areas, particularly on glaciers of the Arctic and Antarctic, sophisticated research techniques were tested, e.g., airborne laser profilometry, or airborne electromagnetic techniques (Wadhams, 1996). However, the advantage of the simple method of ice drillings is that it allows the most precise measurements at particular sites (Leppäranta, 1999). Such ice profiles enable proper recognition of the ice cover structure, along with all forms of deformed ice (Bruns, 1962; Derjugin and Stepanjuk, 1974).

RESULTS

Thrusting and piling of the ice on the shores

The area in which thrusted and piled ice was frequently observed corresponded to the flat coasts of the Rów Peninsula in the Szczecin Lagoon. From the seventies of 20th century up to the winter of 2002/2003, three cases of large scale landward ice thrusts at a distance exceeding 100 m were observed (Tab. 1).

<table>
<thead>
<tr>
<th>Date</th>
<th>Longest ice thrust [m]</th>
<th>Ice thickness [cm]</th>
<th>Mean diurnal air temperature [°C]</th>
<th>Direction and maximum Beaufort force</th>
<th>Maximum water level [cm]</th>
<th>Atmospheric circulation pattern by Litynski (1963, 1969)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 March 1976</td>
<td>110-120</td>
<td>21</td>
<td>5.2</td>
<td>NW 8</td>
<td>503</td>
<td>NWc</td>
</tr>
<tr>
<td>14 January 1993</td>
<td>100-110</td>
<td>13</td>
<td>7.3</td>
<td>SW 8-9</td>
<td>485</td>
<td>W0</td>
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<tr>
<td>28 January 2003</td>
<td>120</td>
<td>18</td>
<td>5.1</td>
<td>W 6-7</td>
<td>518</td>
<td>NWc</td>
</tr>
</tbody>
</table>

Table 1

Hydro-meteorological conditions during the time of the ice field thrusting towards the western shore of the Rów Peninsula in Szczecin Lagoon

Thrusted ice fields were of at least thirteen centimeters in thickness (13–21 cm). A somewhat higher than normal water level, was also a factor favoring the ice thrusts. The ice thrusts appeared most frequently during the periods of western (W) and north-western (NW) circulation with cyclonic (c) conditions (Tab. 1), which are
connected with warmer weather conditions. Hence the air temperatures during these periods exceeded 0°C. However, the major factor causing ice fields drift and thrusts was the strong wind from the western directions, of at least 7°B (Tab. 1).

In the eastern part of the Szczecin Lagoon, the wind velocity reaches its highest values. This phenomenon is favored by extent of the lagoon which follows the parallel of latitude. The western wind is particularly strong in this area, which intensifies the processes of ice cover deformation and contributes to the water level rise. A good example of such anemometric conditions accompanied by the ice thrusts and piles is the situation recorded on the 1st of March 1976. At 14:30 GMT of this day, a squall blowing from the north-west with the velocity of 30 m/s occurred. The strength of the wind was high enough to sweep the ice debris from the ice cover and deposit them on the shore. It was accompanied by an occasional, intense snow fall, limiting the visibility to several dozens of meters. The squall, observed by the author, lasted for several minutes, and resulted in initiation of the ice field drift and in consequence the ice thrusting and piling on the northern shore of the Rów Peninsula. On the major irregularities of the coastal line, the ice piles, with the ice sheets thrusting onto the land between them, were formed at a distance up to 110-120 m from the shore. The width of these thrusted ice sheets onto the land amounted from a few to several dozens of meters.

On January 14th of 1993, a gale of 8-9°B blew during the night (from 13th to 14th January) from the south-west direction. The hitherto occurring solid ice cover was disintegrated by the wind. A drifting ice field thrusted only in the central, low-lying part of the Rów Peninsula, at a distance of 100-170 m landward (Tab. 1). In the remaining areas, ice hummocks of a height up to 4 m were formed along the shore with thrusted, rafted ice sheets in front of them. The cause of insignificant ice thrusts and high numbers of ice piles (mostly formed at a certain distance seaward the coastal line) was the relatively low water level in the lagoon (Tab. 1). While thrusting on to relatively steep shores, the lowered ice field was breaking down and piling up. Some of the ice sheets dipping into the bottom sediments and coastal scarps were broken and rafted. The other sheets cut the soil and plant clumps and moved them, resulting in changes in the coastal line. A low lying, in comparison to the shore, ice field stripped the coastal zone bottom sediments and piles from sediments and brown ice were formed during thrusting. Such brown piles composed of alternating layers of ice debris and bottom sediments resembled rather to sediment clamps, than to ice piles.

The observations of ice thrusts and piles during the winter of 2003 began on 27th of February and continued on March 4th, 12th, 18th, 27th, April 1st and 9th. Subject of the measurements were mainly the morphometry of these forms, and the dynamics of changes in ice thickness and height of ice piles.

The ice field thrusted and piled there (probably) on 28th of January 2003. A possible occurrence of the landward ice field thrust on this day is evidenced by the meteorological situation and ice conditions observed at that period in the Szczecin Lagoon. On this day, a strong western wind (7°B) blew in the early morning, resulting in eastward oriented ice field drift. Prior to that day, a solid ice of ca. 20 cm in thickness occurred in this area. The distant landward penetration of ice was enhanced
by a high water level which exceeded by more than a dozen of centimeters the mean water level (Tab. 1). We must notice that increased water levels, elevated ice cover and flooded areas particularly reduce the thrusting ice friction. Such areas, usually reed covered, do not constitute an important obstacle against a thrusting ice field (Figs 1 and 2).

![Ice hummock](image)

**Fig. 1.** A thrusted ice sheet and the windward side of an ice hummock in the northwestern part of the Rów Peninsula (Szczecin Lagoon, 18 March 2003).

The thrusts of ice field and ice piles in the interior of the Rów Peninsula during the winter of 2003 are shown in Figs 1 and 3. Figure 1 shows the ice field thrusts on a distance of ca. 100 m from the shore (the second distinct thrust from the north in Fig. 3). On both sides of this thrust the ice piles were formed closer to the shore. Here, the terrain ruggedness, and especially sand bars and willow trees, prevented the ice field thrusting, which was piled instead.

Figure 3 shows the map of the ice field thrust and of more distinct ice piles (ice hummocks) in the north-western part of the Rów Peninsula during the winter of 2003. Two distinct ice thrusts are visible on the map. The first, longer thrust is present on the northern side, while the second, which was shorter, has already been mentioned above. The edges of the thrusted ice sheets were rounded, because of the increased friction and breaking of ice, especially in its front part.
Fig. 2. Cut and pressed reed after an earlier thrusted and melted ice field on a flat shore of the Vistula Lagoon during winter of 1999 (Tolkmicko, 9 April 1999).

Fig. 3. A thrusted ice field associated with ice hummocks in the northwestern part of the Rów Peninsula (Szczecin Lagoon, winter 2003).
The edges of thrusted and piled ice had a parabolic shape (Fig. 3). The shape of the high piles (ice hummocks) resembled a parabolic dune, with a depressed windward slope (Fig. 4) and a uniformly steeply inclined leeward slope (Fig. 1).

Fig. 4. The windward side of an ice hummock in the northwestern part of the Rów Peninsula. The increasing steepness of the side towards the summit of the hummock is visible in the background of the photograph (Szczecin Lagoon, 18 March 2003).

In some cases the ice hummocks did not occur along the edges of the thrusted ice sheets, but behind them. This may indicate that the thrusting of the ice sheet preceded the hummocking of the ice, the latter phenomenon occurring at a shorter distance from the water basin. No ice piles were observed on long thrusts of the ice sheets. The ice thrusts became progressively shorter towards the south, and no ice piles were observed in this part of the study area (Fig. 3). The most intense phenomena of ice field deformation occurred in the northwestern part of the Rów Peninsula and simultaneously the longest landward thrusts of ice sheet (up to ca. 120 m) were observed in this area. The longest landward ice sheet thrusts did not possess piled forms. The shorter the landward ice sheet thrust, the more ice was piled up (higher hummocks) were observed. Where the piling resulted depended on the local conditions, mainly the corrugation of the coast (sand bars, depressions) or willows growing there.

On the relatively flat shores devoid of obstacles, the ice sheets may thrust far landward without being piled. An advancing ice sheet rather easily crosses over small corrugations of the shores. Changes in the level of the ice sheet correspond to
the topography of the land surface (Fig. 5). Figure 5 shows rafted and undulated ice sheets in the coastal zone of the Rów Peninsula northwestern part on 12th March 2003. Rafted ice sheets occurred on a distance of ca. 85 m from the shore. Further eastward, only a single ice sheet extending up to 100 m landward occurred and it remained present from the first thrusting (Fig. 5).

**Fig. 5.** The cross-section of thrusted and piled ice sheets on the shore of the Szczecin Lagoon in the northwestern part of Rów Peninsula (12 March 2003).

The results of the present study enable us to differentiate 4 schemes of mutual relations between the land ice thrusts and piles, which are regarded as typical:

1. a thrusted ice sheet occurs without ice pile (Figs 3 and 5)
2. an ice pile occurs on the edge of a thrusted ice sheet (Figs 3 and 11)
3. the ice pile occurs behind the edge of a thrust ice sheet, i.e. between the shore of a basin and the edge of an ice sheet (Fig. 3)
4. the ice pile occurs on the shore without a landward thrusted ice sheet.

The division presented here may become more detailed when more than one pile is considered and when they occur behind and (or) on the edge of the thrusted ice sheet. Other dividing criteria to be considered in such a scheme are:

- single and rafted ice sheets
- their occurrence behind the ice piles and (or) in front of the ice piles.

Due to the presence of coastal obstacles, the piling of ice on the shores is more frequent than the landward thrusts of ice sheets. The ice piles most frequently occur on the coastline, including protective constructions of harbors (Figs 6 and 7). Figure 7 shows the cross-section of rafted ice and of a grounded ice pile at the southeastern protective constructions of the Krynica Morska (Vistula Lagoon) harbor. During the piling process, the ice was also pushed onto the harbor pier. The process of ice piling observed by the author in the Vistula Lagoon on the 2nd of March 1999 lasted for several dozens of seconds and resulted from a strong SW wind. The disintegration of the solid ice cover progressed eastward. On 2nd of March the western part of the Vistula Lagoon was already ice free. The edge of the ice cover with numerous raftings occurred in the vicinity of Krynica Morska. The ice cover persisted on this day further towards the east (e.g. in Frombork, Nowa Pasłęka).
As a result of ice field thrusting, deep erosion of bottom sediments and cutting (together with the sediment) of clumps of plants inhabiting the coastal zone were frequently observed. The sediment is well recognizable later on, particularly in melting ice hummocks (Fig. 8). After melting of the hummocks, small dikes of the sediment remain, mainly composed of sand, silt, plant remains and shells. These accumulation forms are unstable and are very rapidly destroyed when they are exposed to waves, particularly during high water. After melting of the ice, vegetation clumps cut off along with the sediment (Fig. 9) are more resistant to wave action, hence they distinctly change the topography of the shores.
Fig. 8. Sediments on a melting ice pile on the northwestern shores of the Rów Peninsula (Szczecin Lagoon, 27 March 2003).

Fig. 9. The vegetation clumps cut off and moved together with the sediment on the shore of the Vistula Lagoon (Tolkmicko, 9 April 1999)
Melting of thrusts and ice piles on the shores

The process of the ice cover melting takes place on the water surface of a given basin. The ice cover and floating ice disappear first; high ice hummocks grounded on shoals and in the coastal zone are the last to disappear. The ice pushed out and piled on the land persists for a longer period. The thin forms of ice disappear first, followed by rafted forms and finally by high ice hummocks. Such ice hummocks melting on land usually disappear in March and April (Figs 10 and 11). A good example showing changes in ice sheet thickness (Fig. 11) and in landward ice piles (Fig. 11, 12) are hydro-meteorological conditions during the winter of 2002/03. Figure 11 illustrated changes in the thickness of the landward thrusted ice sheet and variations in height of an ice hummock in the northwestern part of the Row Peninsula from 27th Feb. to 1st April 2003. After relatively fast melting of the ice cover within the Szczecin Lagoon, only the melting ice sheet associated with piled forms on the land remained. The ice hummock remained for the longest time and disappeared probably on 6th of April. The region was inaccessible during this period due to high water level (flooded areas).

Fig. 10. The windward side of a melting ice hummock in the northwestern part of the Row Peninsula (Szczecin Lagoon, 1 April 2003)
Fig. 11. The cross-sections of melting thrust and piled ice in the northwestern part of the Rów Peninsula (Szczecin Lagoon, winter 2003).

Fig. 12. Plot of mean air temperature (T) in selected periods and their extreme diurnal mean values versus the height of an ice hummock (H) formed in the northwestern part of the Rów Peninsula (Szczecin Lagoon, winter 2003).
The disappearance of the ice hummock formed on land ca. 30 m from the shore in the northwestern part of Rów Peninsula (53°49.712' N, 14°34.264' E) in the period of 28\textsuperscript{th} Jan. to 6\textsuperscript{th} April 2003 is shown in Figure 12. It has been formed there, similarly to the ice field thrust, probably on 28\textsuperscript{th} Jan. 2003 when a very strong wind (6–7°B) was blowing from westerly directions (Table 1). The height of the hummock at that time amounted to ca. 4 meters above the mean water level. During the period when air temperatures below freezing dominated, its rate of disappearance was small and amounted to ca. 2 cm/24 hours. The mean air temperatures in the first two observation periods (28 Jan.–27 Feb. and 27 Feb.–4 March) ranged between -1.5\degree and -2.0\degree C, and the extreme diurnal mean values, during the observation period, varied within the range of -7.0 to 3.0\degree C (Fig. 12). The rate of disappearance of the ice hummock distinctly increased in the period when air temperatures above freezing prevailed. The ice hummock melted the most rapidly (11 cm/24 hours) by the turn of March and April, when the mean air temperature (the period of 27\textsuperscript{th} March–1\textsuperscript{st} April) amounted 8.5\degree C, while the highest mean air temperature for 24 hours even exceeded 10\degree C (Fig. 12). The ice hummock finally disappeared probably on 6\textsuperscript{th} April, still exceeding the mean water level by 1–1.5 m. On this day the water level in this area rose up to ca. 0.5 m above the land surface. At a high water level associated with waves, the hydrostatic equilibrium of the ice hummock was disturbed and it rapidly disintegrated. Eventually an aggregation of floating ice brash, intensely melting on the water surface remained there.

DISCUSSION

The phenomena related to ice dynamics in the coastal lagoons of the southern Baltic Sea shores are mainly observed at the initial and terminal stages of the ice season. The landward thrusting of ice, its rafting and piling can be observed until the occurrence of strong winds, which strengthen the floating ice fields. These phenomena, however, are more frequently observed after the disintegration of solidified ice cover.

The thrusting of ice sheets onto the land and the ice piling resulted from strong winds, chiefly during the period of the ice cover disintegration. The wind often accelerate the fast ice cover disintegration, forcing its movement. Such ice motion results in ice rafting and piling within the area of the basin, and also in ice thrusting onto the shore. The thrusting and ice piling on the banks of lagoons may appear not only during the disintegration of ice cover, but also before its solidification. During the ice cover formation, floating ice fields can be pushed onto the land by strong winds. However, in the study basins, such phenomena are rarely observed and mainly occur on the western banks of the lagoons. These phenomena are caused by winds blowing from the eastern directions which dominate during the periods of ice cover formation. The distances of the landward ice thrusting depend not only on the type, thickness or resistance of the ice, but also on the local conditions. On low flat shores, deprived of obstacles, ice thrusts distances exceeding 100 m were observed.

A landward thrusted ice field mainly has a destructive impact. The victims of destruction are weakly founded hydrotechnical constructions, trees, and natural and artificial coastal protective constructions. The deep erosion of the sediment with
vegetation clumps results in shore withdrawal. This phenomenon is particularly intense along the western shores of the Row Peninsula (Szczecin Lagoon). The trunks of trees lying in the water provide evidence of changes in coastline position. The landward thrusted ice may also enhance accumulation of the sediment, mainly redeposited there from the coastal zone. The coastal sediments, and also vegetation clumps or trunks of trees can be transported over distances exceeding 100 m from the shore. The striping of the sediments and their redeposition by the ice sheet front may also contribute to the leveling of the shores. Ice hummocks influence the topography of the shore zone. High hummocks, which in coastal lagoons may reach up to 10 m, can leave imprints in the ground. These structures, up to a few dozens of centimeters in depth, can be filled in with the sediments originating from melted ice hummocks. Such “nests” (casts) of melted sediments frequently occur in the shape of lenses filled in by sediments with a disturbed structure. Similar ice phenomena and shore processes related to ice dynamics occur on the open seacoast. On the beaches of the southern Baltic Sea, especially after harsh winters, different forms of abrasion and accumulation were observed. These were mainly gullies, melting depressions and sand dikes (e.g., Gizejewski and Rudowski 1972, 1995). Sand dikes, reaching up to 1m, can result from pushing of sand by a thrusting ice field, but also from melting of ice piles (Kraus, 1930; Reinhard, 1955; Gizejewski and Rudowski, 1972). These are, however, unstable forms which usually disappear after the first storm. More intense coastal processes related to ice dynamics occur in the seas and oceans of the polar zone, where they can be observed almost all the year round. The prevailing perennial and glacier ice can cause processes with long-persisting results (e.g. Nichols, 1961; Hume & Schalk, 1964; Kovacs, 1983; Marsz, 1987).

CONCLUSIONS AND OBSERVATIONS

The results of research carried out on the ice deformation phenomena presented in this paper permit the following conclusions:
- phenomena related to deformation of the ice cover on the coastal lagoons develop during the initial and terminal stages of its development;
- in the initial stage of ice cover development, the ice fields pushed by eastern wind, thrust and (or) pile mainly on western shores of the lagoons;
- following the ice cover disintegration these phenomena are more frequently observed on eastern shores of the lagoons;
- the length of landward ice thrusts depends not only from hydro-meteorological factors (ice thickness, wind velocity, water level), but also from morphology of the coastal zone;
- the thicker ice fields when compared to the thinner ones thrust further landward and form higher ice piles;
- a higher water level and raised ice fields favor the landward ice thrusting;
- low water level is rarely accompanied by the landward ice thrusts, more frequent are ice piles, usually at a certain distant from the coastal line.
- an ice field thrusting onto a rugged (sand bars, depressions) shore or a coast with obstacles (trees, coastal installations) is deformed from its front; rafted and piled ice is formed more frequently than thrusts under such conditions;
- the landward ice field thrusting exceeding 100 m from the coastal line is more frequent on flat shores;
- deformed sheet ice on land (ice thrusts and hummocks) persists for a much longer period than such an ice cover developed on water does;
- the deformation processes of ice cover have a strong impact on the lower coastal zone and on the shore zone;
- ice deformation processes can be an important factor of shore destruction in the lagoon basins;
- materials (deposits and vegetation clumps) piled and redeposited by thrusted ice cover and ice hummocks released during the ice melting can locally contribute to the sediment accumulation in the shore zone.

REFERENCES


NASUNIĘCIA I SPIĘTRZENIA LODOWE NA BRZEGACH ZALEWÓW POLSKIEGO WYBRZEŻA BAŁTYKU

Streszczenie


Na podstawie przeprowadzonych badań można przedstawić następujące wnioski i spostrzeżenia:
- zjawiska lodowe związane z deformacją pokrywy lodowej na zalewach występują w początkowej i końcowej fazie rozwoju pokrywy lodowej,
- w początkowej fazie tworzenia się pokrywy lodowej pchane wiatrem wschodnim pola lodowe nasuwają i (lub) piętrzą się przeważnie na zachodnich brzegach zalewów,
- po rozpadzie pokrywy lodowej zjawiska te znacznie częściej obserwowane są na wschodnich brzegach zalewów,
- długość nasunięć lodowych na brzeg zależy nie tylko od czynników hydrologiczno-meteorologicznych (m. in. grubość lodu, siła wiatru, poziom wody), ale także od rzeźby powierzchni strefy brzegowej,
- grubse pola lodowe w porównaniu z cieńszymi nasuwają się dalej w głąb lądu oraz mogą formować się z nich wyższe spiętrzenia lodowe,
wyższy poziom wody i podniesione pole lodowe sprzyja nasuwaniu się lodu na brzeg,
przy niskim poziomie wody rzadziej nasuwają się pola lodowe na ląd, natomiast częściej występują spiętrzenia lodowe, przeważnie przed linią brzegową,
nabrzeżach nierównych (wały piasku, zagłębień) i z przeszkodami (drzewa, umocnienia brzegowe) nasuwające się pola lodowe od czoła ulega deformacji i częściej tworzy się tam lód nawarstwiony i spiętrzony, niż nasunięty,
nabrzeżach płaskich częściej zachodzi nasuwanie się pola lodowego w głąb lądu nawet na odległość ponad 100 m od brzegu,
zdeformowana pokrywa lodowa (nasunięcia i zwalny) na lądzie występują przez dłuższy okres niż taka pokrywa zalegająca na wodzie,
procesy deformacji pokrywy lodowej oddziaływują silnie na dno strefy brzegowej oraz na brzeg,
procesy deformacji lodu mogą być istotnym czynnikiem niszczącym brzegi zalewów,
zdzierany i przemieszczany materiał przez nasuwające się tafle lodowe oraz wytapiające się osady ze zwalów lodowych mogą być czynnikiem lokalnie budującym – podnoszącym grunt na lądzie w strefie brzegowej.