

Evaluation of past and present sea holly (*Eryngium maritimum*) habitats on Polish coastal dunes

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Abstract

Studies based on morphometric measurements and population assessment of plants on the dunes of the Polish coast of the Baltic Sea carried out since 1997 indicate that sea holly (*Eryngium maritimum*) is now an especially rare species in the area. Sea holly, a perennial plant of the pioneer habitats covering coastal dunes, is under legal protection on the Polish coast, but its habitats are slowly vanishing due to storms and human impact.

Key words: dune habitats, *Eryngium maritimum*, Polish coastal dunes.

Introduction

On many fragments of the Polish coast, dunes are threatened by storm surges; in effect, the dunes are retreating and sometimes are completely destroyed (Łabuz 2005). Another hazardous factor influencing dune habitats is human impact, particularly tourism, coastal protection measures, and forestry (Piotrowska, Stasiak 1984; Piotrowska 1995). All of the natural coastal plant habitats in Poland are threatened (Herbich, Warzocha 1999). Abrasion and human impact are completely destroying the foredunes and partly yellow dunes. At present, great numbers of first dune ridges in Poland are covered by pine forest (*Empetro nigri-Pinetum*), affecting the distribution of dune plants. Also sea holly (*Eryngium maritimum*), a perennial plant of pioneer habitats covering coastal dunes, is endangered and protected by Polish law since 1957 (Ćwikliński 1979).

In 1978 an inventory of the whole coast was carried out to assess the distribution of the sea holly. The inventory recorded about 100 specimens of sea holly per one kilometer of coast (Ćwikliński 1979). Later reports indicated the extinction of its habitats due to forestry, the development of tourism and devastation of the coast (Piotrowska, Stasiak 1984; Piotrowska 1995; Piotrowska 1997; Piotrowska 2002). Those results have been confirmed by research on the dynamics and the pace of degradation and retreat of the Polish Baltic coast (Łabuz 2005; <http://polishdunes.szc.pl>).

The main aim of this work was to survey and describe the condition of Polish coastal dunes and its vegetation with emphasis on sea holly (*Eryngium maritimum*).

Methods

This work was conducted over several years, as it was not possible to check the plant ranges and dune dynamics along the whole coast in one year. Therefore the data on sea holly (*Eryngium maritimum*) distribution are not complete. On the Eastern part of the Polish coast, the investigations were conducted in 2002 and 2004, in the middle part between 2002 and 2006, and on the Western part from 1997 to 2007. The field study included estimation of (i) dune relief changes, (ii) vegetation dynamics, (iii) human or animal influences, (iv) storm surge impact and (v) wind impact.

The relief measurements were taken several times during the year, particularly, but whenever possible, after every major manifestation of the factors impacting the dunes. Relief changes were measured with geodesic devices across the coastal profile in selected sites along the coast, also sometimes in fixed plots (5 × 5 m). Other field studies concentrated on the determination of dune morphodynamics, which provided comprehensive information on relief changes and the condition of the entire environment along the dune coast.

Another important element of this study was defining plant habitats along profiles, including along the coast (especially on the first dune ridge). The dominating plant species for different stages of succession (after Kornaś, 1959; Piotrowska, Gos 1995) such as pioneer habitats (*Elymo-Ammophiletum*), psammophilous sward (*Helichryso-Jasionetum*) and pine forest (*Empetro nigri-Pinetum*) were marked along profiles (see also Fig. 1). Lines were used to mark their presence and ranges. Also, a simplified method of phytosociological plots was used. In the plots the projective cover and plants sociality were determined using a method described by Braun-Blanquet (Pawłowski 1977). Plot size was 5 × 5 m.

The presence of sea holly was marked separately along profiles and in the plots. Also sea holly was searched for on the dunes and marked on topographical maps (scale 1:10 000).

To describe the habitat conditions of sea holly on the examined profiles, the ranges of pioneer grass communities were determined, as well as those of psammophilous sward, mosses cover and pine forests.

The Polish coast is 464 km long. It is divided according to the distance markers applied by the Maritime Office (established for coastal protection). According scale, the border with Russia on the Vistula Spit is the point described as 0 km, and the border with Germany at 428 km. The Hel Peninsula has a separate classification, with 72 km of coast. The scale is applied for the delineation of endangered areas, and in monitoring of coastal phenomena. In this paper, the sites of Sea Holly habitats and drawn profiles were recorded according to the scale used in Poland (see also Fig. 2).

Results and discussion

Habitats of the Polish coastal dunes

The climate of the Polish coast is mild with marine influences. In an Eastern direction, the continental influence increases causing a temperature decrease, and changes in wind and storm surge directions. Very strong northerly as well as westerly winds cause development of the coast and new dunes. In autumn-winter, these winds are responsible for the biggest storm surges with water levels up to 2 m higher than the mean.

Dune coasts constitute about 80 % of the Polish coast. At present, Polish coastal dunes constitute coasts of various types. Dyke foredunes are located on sandspits or the coastal

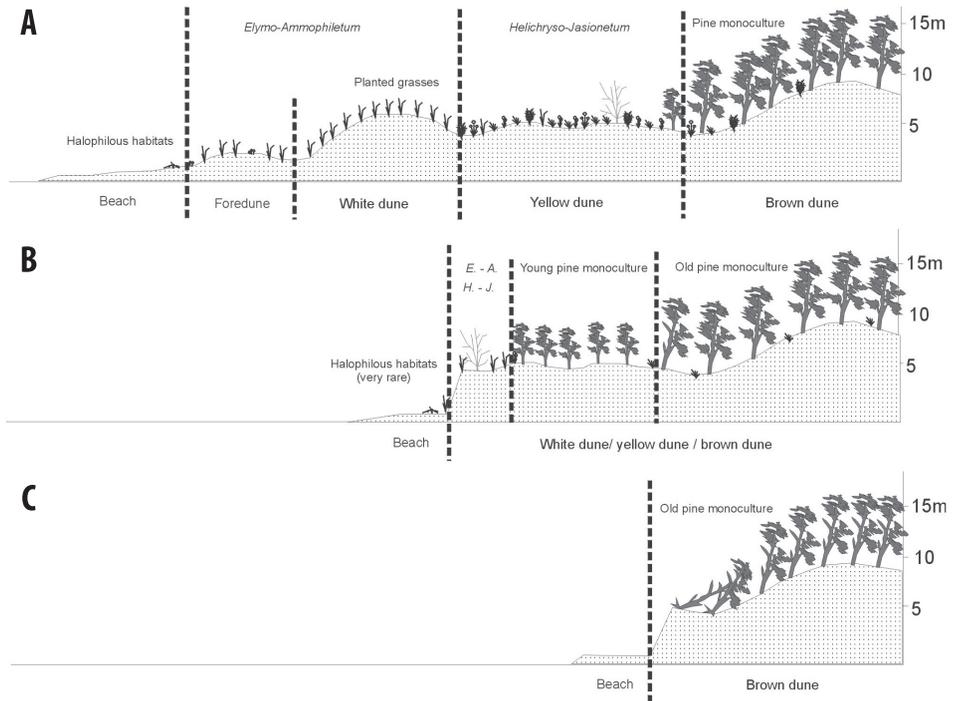


Fig. 1. The history of dune shore management on the Polish coast (simplified after Piotrowska, Gos 1995). A, after 2001 (only sandbar of Swina, Łebsko, Vistula outlet). B, after 1983 (general). C, after 1983 (locally), after 2001 (common).

endings of the river valleys and proglacial valleys. There are also some coastal field dunes, located in coastal areas due to land retreating (Łabuz 2005). The sandspits of the Polish coast and their dunes were formed over the last 5000 years during the relative stabilization of the coast, after the end of the maritime transgression from the Atlantic period (Tomczak 1995).

The sand texture in the foredunes of the Polish coast is between 0.16 and 0.25 mm. It is fine-grained sand, rarely with the addition of medium sand, accumulated during winds blowing at high speed. More than 90 % of the sands consist of light quartz grains (Łabuz 2005). In recent decades, the level of the Baltic Sea has been observed to increase steadily (Zeidler et al. 1995). The fluctuation of the sea level is associated with the oscillation of pressure systems and winds resulting in sea waves.

The amplitude of observed fluctuations in sea level reaches over 3.2 m in Świnoujście, 3.4 m in Kołobrzeg, and 2.6 m in Gdańsk. The greatest number of storm surges is observed in autumn and winter. Most of the storms on the Western coast (with force greater than 6 on the Beaufort scale) are produced by northerly winds (55 %), north-westerly winds (31 %) and north-easterly winds (14 %). The strongest storms, of force 10 to 12 on the Beaufort scale, occur during NE winds. Over the last ten years, strong storms on the Polish coast have been responsible for considerable destruction of coastal dunes and their plant habitats (Łabuz 2005).

The first stage of succession on the upper beach is determined by the halophytic species sea sandwort (*Honckenya peploides*), marram grass (*Ammophila arenaria*) and lyme grass (*Elymus arenarius*), forming a *Elymo-Ammophiletum honckenyetosum* community (Fig. 1; Kornaś 1959; Piotrowska, Celiński 1965). On foredunes (white dunes), psammophilous grasses from *Elymo-Ammophiletum typicum* are the most predominant. Reports indicate that sea holly can be found on foredunes (Piotrowska, Celiński 1965; Ćwikliński 1979; Piotrowska 2002).

Predunes as a poor habitat subject to the activity of strong winds and are affected by autumn and winter storms. Gradually, due to succession, the accumulation sections are invaded by species typical for the next succession stage on the partly fixed dunes characterized by a psammophilous sward from the community *Helichryso-Jasionetum* (Piotrowska, Celiński; Piotrowska, Gos 1995). This is a rich habitat, most frequently covering fixed dunes (yellow dunes) and is a preferred habitat of sea holly (Ćwikliński 1979; Łukasiewicz 1992).

In the area of the coastal towns, yellow dunes are subset to human activity and have been planted since the 19th century for protecting. The last stage of succession on the coastal dunes are the forest communities (*Empetro nigri-Pinetum*): various types of coastal pine forests (Wojterski 1993) in natural conditions covering brown dunes, with a developed podzol soil profile. On the low, marshy backs of the dunes, the forests are characteristic of humid areas with large biomass of plants and broadleaf trees.

The most important cause of degradation of coastal habitats has been planting of dune grasses (*Ammophila arenaria*), willow shrubs (*Salix arenaria*) as fashion fences, and pine trees (*Pinus sylvestris*). Today, most of the pine forests covering coastal dunes have been planted (Piotrowska, Stasiak 1984; Wojterski 1993). Moreover, dune communities are vanishing due to the development of tourist infrastructure.

Coastal towns occupy more and more land for construction purposes. On the Western coast, tourist centers have coalesced in a 30-km long town (from the 361st to the 291st km of the coast, according to the Polish scale). Buildings are not only at the back of the coastal dunes but also more and more on the ridge of the foredune or the beach (Łabuz 2003b).

Recent habitats of sea holly of the Polish coastal dunes

In the past, sea holly was present on the whole dune coast area of the present Polish coast. It was often observed on white dunes (Ćwikliński 1979; Wojterski 1993) and protected only in the Woliński National Park on the West coast (established in 1960) and in the Słowiński National Park on the East coast (established in 1966). Sea holly is a symbol of the Polish dune coast. It is present in the community of pioneer grasses *Elymo-Ammophiletum* and psammophilous sward *Helichryso-Jasionetum*. In the sward community on yellow dunes, sea holly develops better due to the stable substratum and smaller influence of winds and drifting sand. Its seeds grow slowly and, when blown towards the forest, suffer from mortality due to the difficult habitat conditions (Łukasiewicz 1992).

Fig. 2. The characteristics and locations of dunes of the Polish coast (Łabuz 2005) with sea holly (*Eryngium maritimum*) habitats (2002 - 2006). I, dune localisation (a - land dunes, b - foredunes). II, height of dune coast (c) and the width of coastal dune areas (d). III, localisation of sea holly: e - profile localisation; f - abundant sea holly (over five specimens per 200 m); g - site of sea holly (below five specimens per 200 m); h - individuals; i - coastline scale, every 50 km; j - coast nourishing of white and yellow dune (between 2002 and 2006).

Sea holly has adapted to disadvantageous conditions on coastal dunes by developed underground and hard parts, and waxy above ground parts. The woody root of mature specimens may even be 5-m long (Łukasiewicz 1992). The very appearance of the overground parts in their color, stiff and thorny leaves, flowers, makes the holly different from other plants. This appearance may be the reason why tourists remove the plant, collecting it as a beautiful seaside souvenir (Ćwikliński 1979). Another reason for its scarcity is the drifting of the seeds by winds blowing from the sea towards the forest, where this plant does not grow (Łukasiewicz 1992). Moreover, the exposure of its brittle roots (Łukasiewicz 1992) to wind may result in mechanical damage and in effect, lead to the death of individual specimens. In addition, intensive accumulation of sand may be disadvantageous for development.

Studies carried out in the 1960s and in 1970s indicated the highest densities on the middle and East coast of Poland (Piotrowska, Celiński 1965; Ćwikliński 1979; Piotrowska, Stasiak 1984). Investigations of sea holly populations on the Polish coast by Ćwikliński (1979) showed that this plant was most dense on the Middle coast. The highest density was observed on a 50-km-long section of the coast between Mielno and Ustka, with about 720 specimens per kilometer (Ćwikliński 1979). Another sea holly-rich section of the coast was the Vistula Spit, between Kały Rybackie and the border with Russia. On the Western coast, the species was most numerous on Dziwnów Spit, on both banks of the Dziwna river outlet to the sea (391 km) and on the Wolin Island near Wiselka (about 404 km).

On the Hel Peninsula, holly was most numerous near the town of Chałupy (7 km Hel). Interestingly, the species was particularly rare on a very long section of the East coast, from Hel to Rowy (also in the Słowiński National Park). For example, only 12 specimens of sea holly were observed along a 40-km section in the Park. Ćwikliński (1979) cites other authors when considered that holly had not been present in the area from 1920 to 1957, probably due to destruction by locals and tourists.

In the 1980s, Piotrowska and Stasiak (1984) observed that the species was endangered due to forestation of the dunes. Numbers decreased also by planting grasses and tree overgrowth. On the Vistula Spit, sea holly was present only in a few areas: Piaski (1 to 2, 8 km), Krynica Morska (12 to 13 km), Przebrno (21 km), Stegna (39 to 40 km), Sobieszewo (53 km). Another recorded area was the Łeba Spit in the Słowiński National Park, with rare habitats in high psammophilous grass communities on white dunes and psammophilous swards on yellow dunes near Łebsko Lake (193 km), Dołgie Lake (207 km) and the town of Rowy (215 and 217 km; Piotrowska et al. 1997).

During studies conducted in 1986 and 1994/1996 on the Middle coast dominated by narrow spits, sea holly was observed in the vicinity of Wicko Lake (262 km), Dąbki town (280 to 281 km), Łazy (287 to 288 km) and in the area of the channel outlet from Jamno lake (292 km; Piotrowska 2002). These area previously supported the large populations of sea holly (Ćwikliński 1979). According to other reports conducted in middle coast cliffs, sea holly was present in the area of Gąski (Piotrowska, Chojnacki 1972).

Studies covering the West coast of Poland in the 1960s (Piotrowska, Celiński 1965) and 1970s (Ćwikliński 1979) show that sea holly was most numerous in the *Elymo-Ammophiletum* community in the area of the Woliński National Park, near Grodno, Wiselka villages (402 to 404 km) and on the Dziwnów Spit near Międzywodzie (393 to 395 km) and Dziwnów (391 to 393 km). In most cases, it occurred on a low foredunes at the bottom of the moraine cliff, or was present on the high dune ridge on the spit.

Ćwikliński (1979) reported that sea holly was endangered due to dune afforestation.

Even then, 41 % of the observed habitats on the dunes were planned to be forested. Another 10 % of habitats were in newly sown forest and were likely to disappear. To protect them, he proposed the creation of reserves: 5th km of coast on the Vistula Spit (540 specimens), the 244th km on Wicko Lake Sandbar (3800 specimens), the 265th km on Kopań Lake Spit (4200 specimens), the 293rd km on Jamno Lake Sandbar (2222 specimens) and the 391st km on Dziwnów Sandbar (357 specimens).

Present sea holly habitats of the Polish coastal dunes

The proposed reserves have not been established to this day. The only sites of dune vegetation protection are in the Słowiński National Park and some locations in the Woliński National Park. Additionally, a strict bird reserve at the Vistula estuary near Mikoszewo has been created. Some hope for dune vegetation and sea holly protection in particular has been given by the Nature 2000 network. On the Polish coast, the network includes the Vistula Spit, Hel Spit, the Słowiński National Park, and the Woliński National Park, a section of the West coast near Kołobrzeg, and a section of the East coast near Białogóra. Unfortunately, except for the Vistula Spit, sea holly does not occur in the mentioned areas (Fig. 2).

Decade-long studies on the dynamics and the morphodynamics of plant habitats indicate a drastic depletion of white and yellow dunes (Łabuz 2005; see Fig. 1). The white dunes on the Vistula Spit have disappeared due to abrasion; moreover, pine planting is still being used for dune consolidation (Łabuz, unpublished data). The Hel Peninsula is under strong adverse human impact due to protection of the coast and the development of tourist infrastructure. Most of the dunes and beaches on the peninsula, except the tip, have been

Table 1. The present distribution of sea holly (*Eryngium maritimum*) on the Vistula Spit

Kilometre scale of the coast	Location	Habitat description
2 to 3 km	State border	Some individuals on the undisturbed dune ridge and on its south slope
4 km	Piaski	Few individuals at the south slope of the abraded foredune, along pine forest border
9 to 10 km	Piaski, west	Few individuals on the abraded dune top, close to the pine plantation on the south slope; also between low pine trees
11 to 13 km	Close to Krynica Morska town	Many specimens on the top and south slope of the dune. In some places dying within young pine plantation (trees now 1 m high). Only few individuals in pine forest (trees 4 - 5 m high)
22 to 23 km	Przebrno	10 specimens on the first ridge not covered by pine
23.4 to 25 km	Skowronki	8 specimens on the uncovered by pine first ridge. 5 withered between pine trees
46 to 47 km	Vistula outlet	Some behind first dune hidden between willow shrubs. Protected against pine forest by a wider dune belt

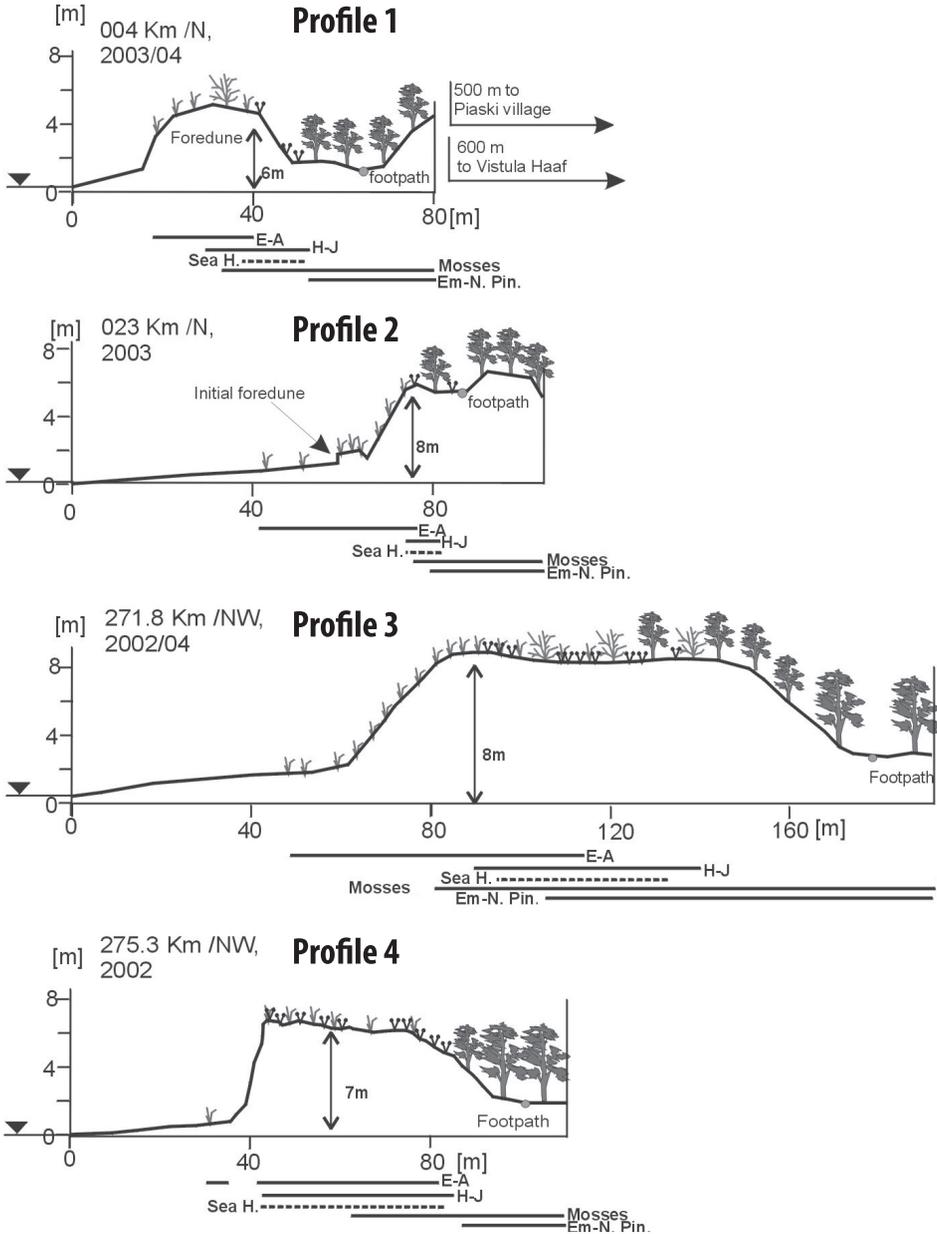


Fig. 3. Sea holly (*Eryngium maritimum*) distribution along coastal dunes in Poland between 2002 and 2006 (see Fig. 2 for location of profiles). Symbols for plant communities: E-A – *Elymo-Ammophiletum* habitats, H-J – *Helichryso-Jasionetum* habitats, Em-N. Pin. – *Empetro-Nigri pinetum*, Sea h. – sea holly habitats. Profile 1, foredune covered by grasses, pine monoculture at the back, sea holly specimens on the dune and on south dune slope, small tourist impact. Profile 2, seasonal low foredune with pine monoculture on the higher, narrow psammophilous habitats. Profile 3, very wide and high foredune with accumulation tendencies, wide natural dune habitats with numerous sea holly individuals. Profile 4, wide clipped foredune, wide habitats of grasses and other dune plants, large number of sea holly specimens. (continued)

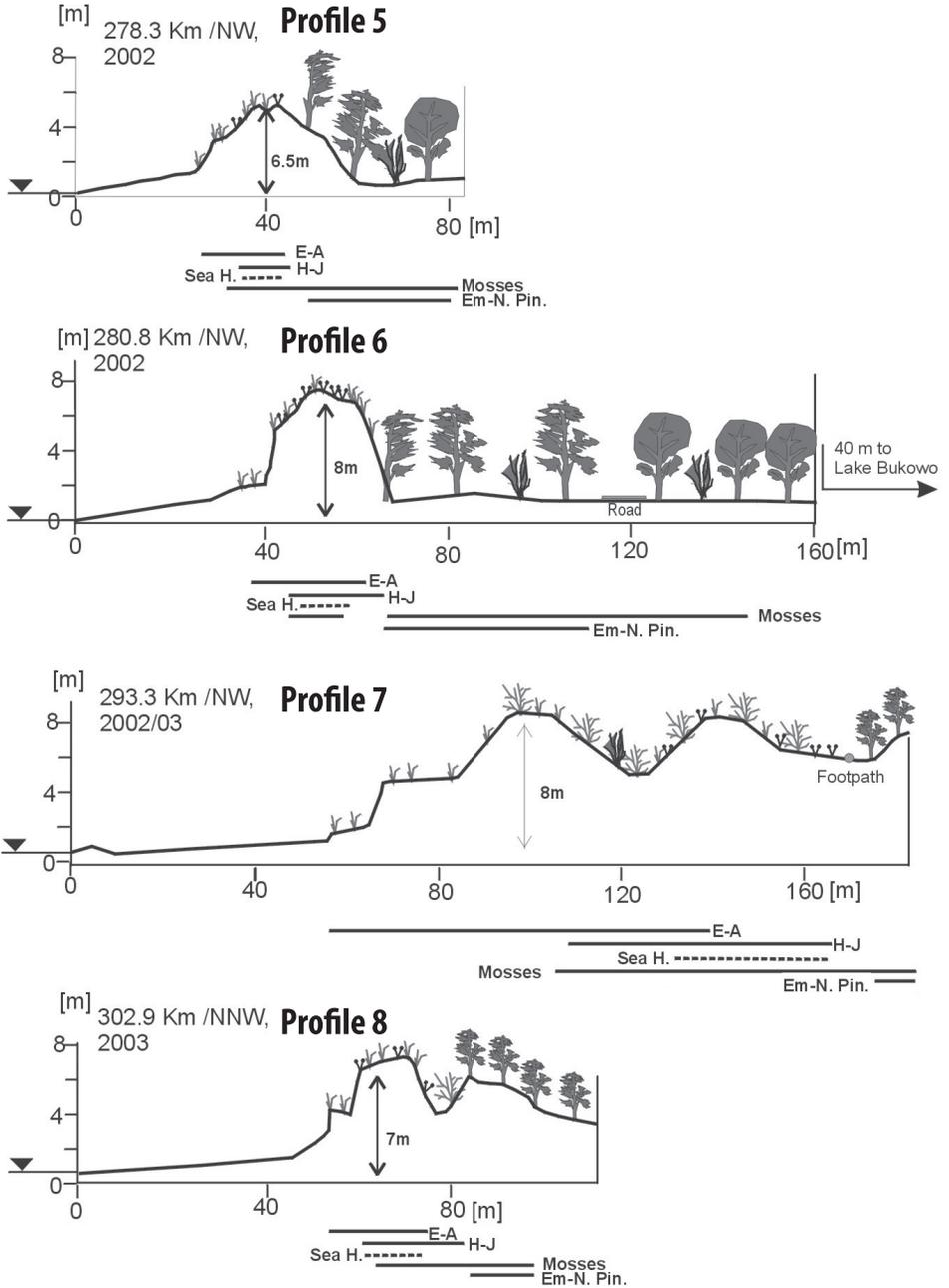


Fig. 3. (continued) Profile 5, narrow dune covered by dune grasses, at the back and low area covered by forest, narrow sea holly habitats. Profile 6, very narrow part of sandbar, narrow single dune covered by dune grasses, a few sea holly individuals, dune retreat in the south is burying forest. Profile 7, cliffed first dune with dune grasses, on the second ridge psammophilous greensward, vanishing dune habitats caused by tourist activities, sea holly close to the forest. Profile 8, abraded foredune with narrow psammophilous habitats, pine monoculture at the back, a few individuals of sea holly, also on abraded dune top.

reconstructed artificially. On the section between Hel Peninsula and Łeba Spit, the first dune from the sea is covered with pine forest (Piotrowska 2002).

Foredunes and a belt of dunes covered with psammophilous grasses can only be found in the area of the Słowiński National Park. On the middle coast, where sea holly used to be most numerous, the spit is retreating at a rate of 1 to 2 m a year (Łabuz 2005). In some places, the dune does not exist any more (the Kopań Lake Spit) or has been artificially reconstructed (the Bukowo Lake Spit). Only on the spit of Wicko Lake is the dune vegetation developing, in the area of the military training ground. In Jamno Lake Spit, tourist infrastructure is growing despite the retreat of the coast, resulting in an almost complete loss of non-forested dunes between 1998 to 2002 (Łabuz 2003a).

Spits on the West coast, apart from the Świna Gate Sandbar, tend to retreat at a rate of 2 to 4 m a year (locally even up to 6 m; Łabuz 2005). Between Kołobrzeg and Mrzeżyno, the shore has retreated and the first ridge is covered by pine forest. The foredune is developing only on some short sections of the coast. On the Dziwna River Spit, abrasion tendencies are predominant where dunes with pioneer grass habitats occur only on the Eastern shore of the river's estuary and near Międzywodzie. Sand accumulation tendencies and vegetation succession are found only on the Świna Gate Sandbar (Łabuz 2005; Łabuz, Grunewald 2007).

East coast

Studies carried out in 2003 and 2004 indicate that on the Vistula Spit sea holly was present only on the ridge of the yellow dune (second or third, looking from the beach) not covered by forest (Fig. 2, Fig. 3, profiles 1, 2; Fig. 4, profile 1A). Sometimes, only one specimen was found on a very long section of the coast, sometimes one per 50 m. Its presence was observed only in few sites of the spit in the psammophilous sward community (Table 1).

Another place where sea holly was abundant is a short part of the coast between Rewa Mew Peninsula and the Gdynia cliff (Mechelinki village). Along 2.5 km of the low dune coast (up to 1.5 m high) a large number of sea holly plants were found, mostly on a meadow (up to 20 m wide) between the sea and surrounding swamps. Some of them were present on a narrow beach (20 m wide). This part of the coast is not under significant touristic impact (data from 2007).

Sea holly was not found on the remaining sections of the coast, apart from two specimens on the Hel Peninsula (35th km of Hel Spit classification) and near Reda (Gulf of Gdańsk).

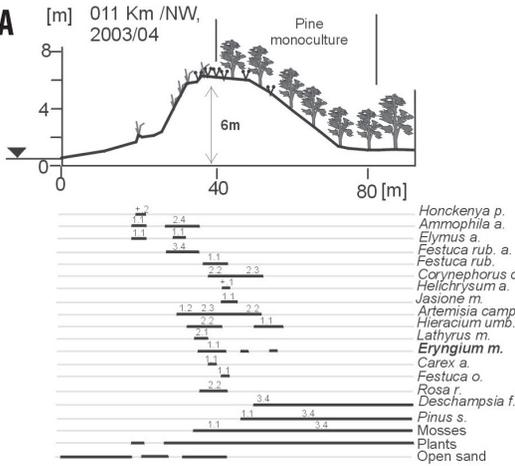
Middle coast

On a section of the coast in Słowiński National Park, sea holly was found only in the western part of the park near the town of Rowy.

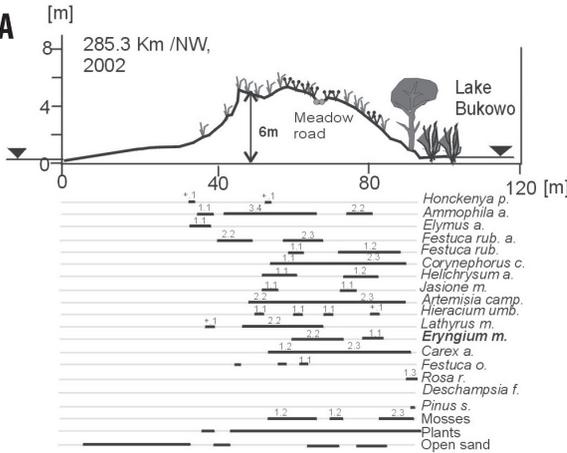
The greatest number of sea holly specimens was found from 2002 to 2006 on the section between Ustka and Mielno. Presently sea holly is very frequent on the coastal dunes of

Fig. 4. Example of localisation of sea holly individuals in respect to distribution of other plants (Braun-Blanquet method used after Pawłowski 1977). Profile 1A – East coast, Vistula Spit. Narrow accumulative dune coast with sea holly individuals decreasing due to pine forest growth. Profile 2A – Middle coast, Lake Bukowo Spit. Very narrow part of sandbar. Lake begins just at the back of the dune. Whole dune covered by dune grasses. Wide sea holly habitats. Profile 3A – West coast, Świna Gate Spit. Wide accumulative dune coast with sea holly individuals increasing in number every year.

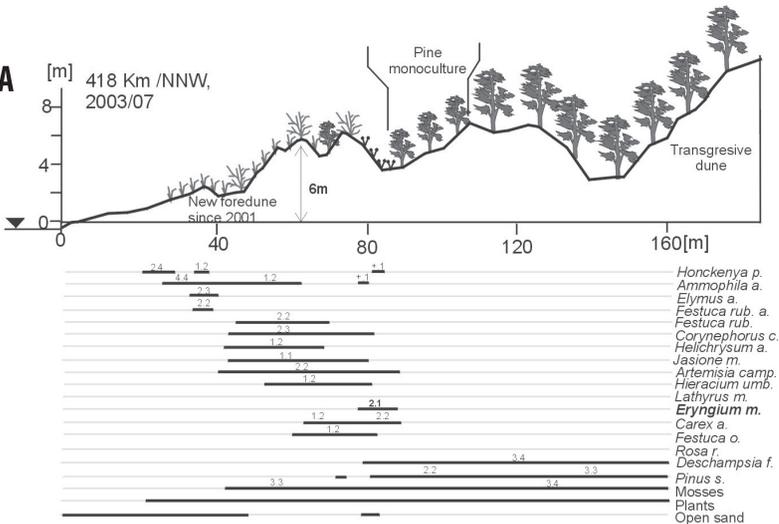
Profile 1A



Profile 2A



Profile 3A



Wicko Lake Spit (military area) and west of Darłówek until Dąbki (military areas). On the latter section, sea holly densely populates the wide coastal and non-forested dune (Fig. 3, profiles 3 and 4). A few dozen sea holly specimens were observed there, on a high non-forested dune by the border of the psammophilous grasses and sward (271 to 275 km). Also, further west on the particularly protected dunes of the narrow spit of Bukowo Lake from Dąbki to Łazy, sea holly was often observed on narrow dune dykes destroyed by the sea (Fig. 3, profiles 5, 6; Fig. 4, profile 2A), where dunes are covered by mostly psammophilous sward. Further, the section between Łazy and Unieście (on the Jamno Lake Spit) used to be under military administration, which limited tourist activities. On this section, sea holly was present in the community of *Helichryso-Jasionetum* on the non-forested dune (Fig. 3, profile 7). Sea holly was present even on the upper beach, where between 1997 and 2001 a new foredune was developing (293 to 294.5 km; Łabuz 2003a). After the storms of 2001 and 2003, the habitats became extinct. Only on the crown of the non-forested dune has sea holly been present until today (about one specimen per 50 m of the shore). Due to the retreat of the spit's shore, the dunes are being stabilized by planting dune grasses and pines, which results in the narrowing of sea holly habitats (Fig. 5, profile 1B). Moreover, the channel connecting Jamno Lake with the sea and the area further west is heavily exposed to tourists in summer months.

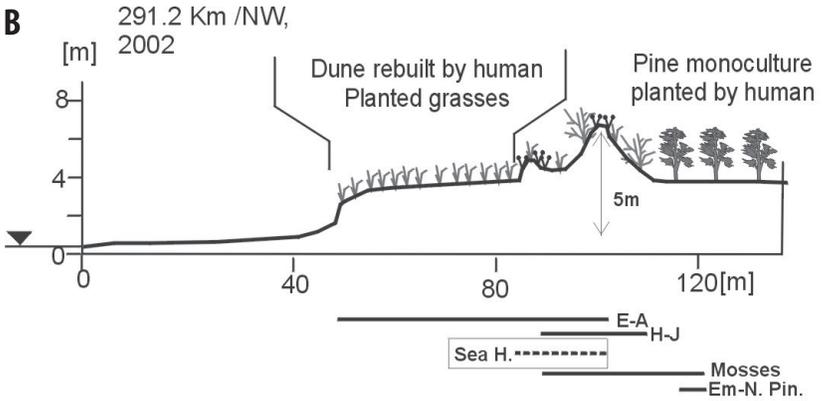
Similarly to many natural sites, the area lacks basic infrastructure, marked paths or boardwalks preventing walking on the dunes. In the area from the channel to the town of Mielno, a few sites of sea holly habitats on the ridge and the southern slope of the non-forested dunes (294.6, 296 and 297 km of the spit) were recorded between 1997 and 2001. This section is also intensely affected by the sea, which is indicated by abrasively cut dunes with steep slopes, devoid of plants. Between 1999 and 2003, all sea holly specimens in this area became extinct due to the retreat of the coast and the destruction of the dunes by tourists. The dune vegetation is aggressively destroyed by beach-goers and storms abrading the dunes (Łabuz 2003b).

An example of the effects of abrasion on sea holly habitats is the western bank of the channel connecting Jamno Lake with the Baltic Sea. Over the last four years the base and the ridge of the dune have retreated by 10 to 15 meters. Holly habitats on the slopes of the dyke were destroyed and the plant emerged on the low back of the dune in the surroundings of a low and sparse pine forest (profile 2B). Eight young specimens were observed (8th May 2007) close to the channel on an illegal parking place created on the degraded ground indicating the drift of seeds towards the land. Probably during the tourist season, all these specimens will be damaged by cars or trampled by tourists.

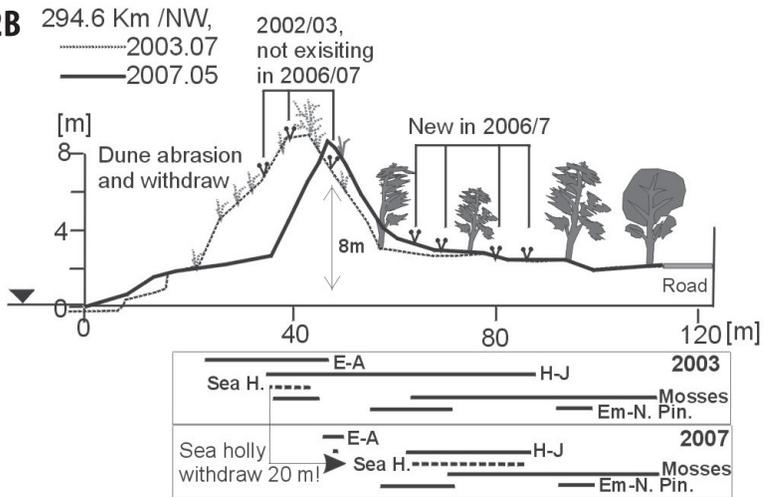
During studies in 2003 west of Mielno (to Sarbinowo), sea holly was observed on the non-forested dunes distant from the seaside resorts; a few specimens on the 303rd km (Fig. 3, profile 8). Further west, beyond Sarbinowo, no sea holly was found.

Fig. 5. Example of the vanishing sea holly specimens due to the main affecting factors. Profile 1B – dune stabilisation by planting. Vanishing sea holly caused by grass and pine plantations. Profile 2B – dune retreat. Between 2003 and 2007 dune moved back about 10 m, sea holly vanished completely in 2004. In 2007 sea holly reappeared on the low lying back side of the dune covered by degraded greensward. Profile 3B – dune improvement. Whole natural part of dune habitats were artificially covered by sand. Symbols of the plant communities: E-A – *Elymo-Ammophiletum* habitats; H-J – *Helichryso-Jasionetum* habitats, Em-N. Pin. – *Empetro nigri-Pinetum* habitats, Sea h. – sea holly habitats.

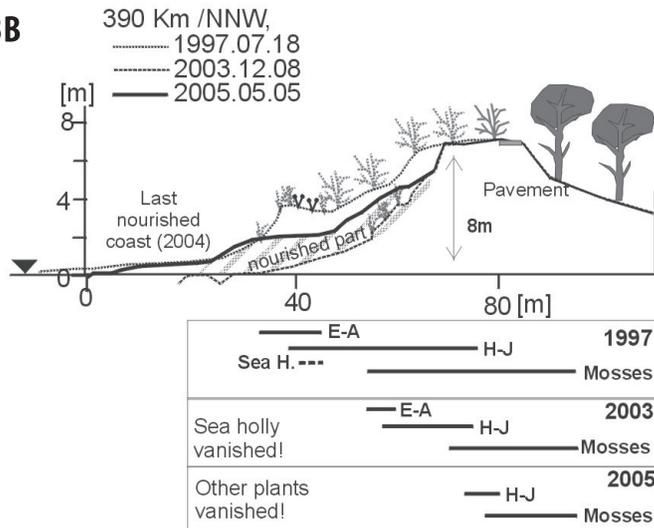
Profile 1B



Profile 2B



Profile 3B



West coast

On the West coast, sea holly specimens are even less frequent. The main habitat previously was on Dziwnów Spit between the towns of Dziwnów and Międzywodzie. Between 1997 and 2002 its presence on the dunes was limited to several sites. It was found in Dziwnów on the 389th to 391st km and in Międzywodzie on the 395th to 396th km. Since 2002 sea holly has not been observed in Dziwnów due to tourist pressure and action taken for protection of the coast from the sea. Strong storm surges from the winters of 2001 and 2003 resulted in the retreat of the dune dyke by 4 to 6 m and the destruction of plant cover and slope of the foredune. With this, whole habitats of natural dune vegetation were utterly destroyed (Fig. 5, profile 3B). The last two specimens of sea holly were found in 2005 on the 391st km, where the coast is growing and the dunes are developing due to accumulation of deposits by the breakwaters of the Dziwna River outlet. Between 1997 and 2004 individual specimens were found in the area of Międzywodzie and Wiselka (at present no data is available).

On the most westerly situated Świna Gate Spit (412 to 428 km of the coast), where plant succession is observed (Łabuz, Grunewald 2007) sea holly was present only on the third dune from the sea, which is non-forested and covered with a species-rich community of psammophilous sward (*Helichryso-Jasionetum*). It was found there between 2002 and 2007 on the 418th km of the coast (Fig. 4, profile 3A); 25 specimens were observed in an area of about 100 m². Another 14 specimens grew 100 m to the west. In 2004 willow bushes were cut there to obtain material for the fascine fences, which resulted in a threefold increase in specimens compared with 2005. However, the pine monoculture on the south side is threatening its development; five dead specimens were found on the tree line. Flowering specimens grew on the southern slope of the dune ridge. This area has no tourist pressure, the coast is growing and new dunes are developing. It is possible that at this site sea holly will develop without any serious threat.

Conclusions and perspectives

Studies on the distribution of sea holly on the Polish coast indicate that its habitats are vanishing (Ćwikliński 1979; Piotrowska, Stasiak 1984, Piotrowska 2002). The main threats are seaside tourism and coastal protection measures, along with the natural abrasion of the coast, which together destroy coastal dunes and their plant habitats.

In recent years, threats have intensified and the number of habitats has decreased dramatically (Piotrowska 2002). The abrasive character of the Polish coast results in the destruction and retreat of coastal dunes, the habitats for sea holly. This is confirmed by studies on the Middle coast (since 2001 to 2004) where numerous specimens of sea holly have disappeared from Kopań Lake Spit and partly from the spits of Vistula, Jamno, Bukowo and Dziwnów. Strong winds from the sea do not facilitate the development of new specimens. Seeds drift to the forests neighboring the non-forested dunes and sea holly grows only in rare cases in very sparse forests (Łukasiewicz 1992). Due to the development of seaside resorts along the coast and infrastructure on the ridges of the dunes, areas with a natural environment are becoming increasingly scarce.

Sea holly is no longer present on the dunes neighboring seaside resorts (Fig. 2). The exploitation of dunes by tourists has resulted in the destruction of dune vegetation. Individual specimens observed in 2002 do not exist at present. The plant may be found frequently in coastal areas situated further from the towns and on the dunes next to military areas (Wicko Lake Spit, Dąbki, and, until recently, Jamno Lake Spit). In these

areas, the plant is protected from tourists by a ban on approaching military areas, very often well-fenced and secured by the army. Planting grasses and bushes on the dunes and offorestation contribute to the decrease in biodiversity and the extinction of numerous species, i.e. sea holly. Planting pines quickly eliminates sea holly from its primary habitats. This has been shown by processes observed on the Vistula Spit and Jamno Lake Spit where dead specimens were found in the pine forest, and dying individuals observed in newly planted areas. Interestingly, sea holly is not present on dune sections with predominant rebuilding processes and the development of dunes, despite the fact that these sections are not affected by tourists.

In field studies, the longest sections of coast with sea holly habitat were observed on the Middle coast from Darłówek to Łazy. On the spits of the Jamno and Bukowo lakes sea holly covers dunes quite remote from seaside towns where the coast is virtually free from human activity. Sea holly is observed mainly on gray dunes covered by psammophilous communities with a predominance of *Carex arenaria* (Fig. 4). This is mainly a stable dune substratum where the supply of sand is not large, there are southern slopes or vast and flat dune ridges.

On the Polish coast sea holly is seriously endangered. At present, sea holly is not present in any great numbers in any of the existing Nature 2000 areas, apart from the Vistula Spit. To protect the species a reserve should be established; the most suitable location is the area of Jamno Lake Spit (290th to 294th km) or the section between Darłówek and Dąbki (271st to 275th km) where sea holly is most numerous.

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Kādreizējo un esošo jūrmalas zilpodzes (*Eryngium maritimum*) biotopu izvērtējums Polijas piekrastes kāpās

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Kopsavilkums

Pētījumi par jūrmalas zilpodzes (*Eryngium maritimum*) izplatību Baltijas jūras Polijas piekrastē, kas veikti no 1997. gada, izmantojot morfometriskas analīzes un populāciju apsekošanu, liecina, ka zilpodze ir kļuvusi par īpaši retu sugu. Jūrmalas zilpodze, daudzgadīgs piekrastes kāpu biotopu augs, Polijas teritorijā ir juridiski aizsargāts. Tomēr, zilpodzes augšanai piemēroto biotopu platības lēnām samazinās vētru un cilvēka darbības ietekmes rezultātā.