

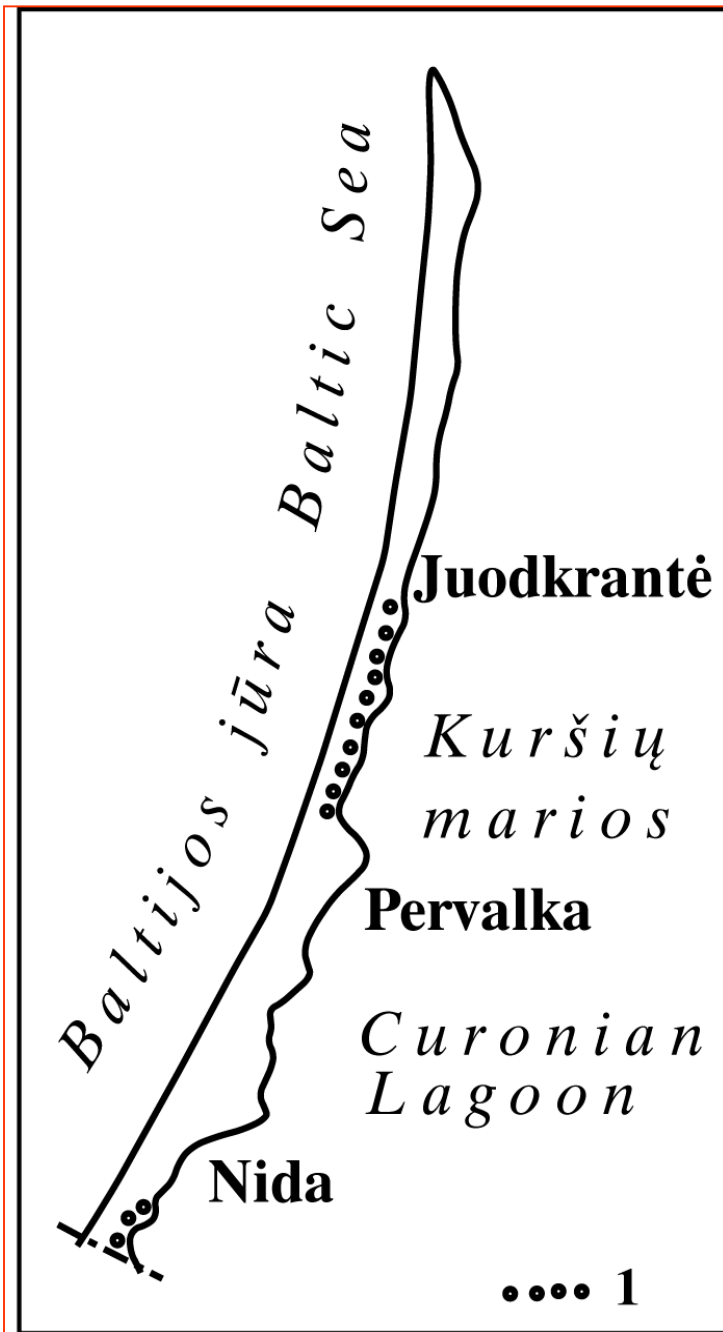
***THE PROGNOSIS OF CURONIAN SPIT DUNES
EVOLUTION AND THEIR PROTECT STRATEGIES
BECAUSE OF CLIMATE CHANGE***



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Introduction

The principal contribution studying processes of the Curonian spit belong to V. Gudelis and other geographers (Gudelis 1955, 1957; Gudelis & Stauskaitė 1959; Gudelis & Michaliukaitė 1962). The detail analysis and morphodynamic evaluation of the foredunes was made by V. Minkevičius (Minkevičius, Žilinskas & Jarmalavičius 1996), differentiation of eolian sand on the shore was studied by D. Jarmalavičius and G. Žilinskas (Jarmalavičius & Žilinskas 1996), deflation sites in the foredunes were mapped by V. Minkevičius, S. Paškauskas and Žilinskas, the velocity alteration of wind was assessed by D. Jarmalavičius (Jarmalavičius 1997). The areal subdivision work of the Curonian spit is also important (Gudelis & Karužaitė 1993; Kavaliauskas & Kriauciūnienė 1986). The inner structure of parabolic dunes, its age dating and measurements of parabolic dunes was been recorded by geologists (Bitinas & Damušytė 1998), the vegetation dynamics of foredunes has interested by botanists (Olšauskas 1995). The scientists of the Klaipėda University made a contribution to the alteration study of shore banks (Povilanskas 1998). However, the Main ridge was insufficiently stationary studied during last decades.



**Segments of blown dunes
in Main Ridge of Curonian
Spit (Lithuanian part): 1 –
blown dunes.**



**Northern part of
Main Ridge of
Curonian Spit**



Southern part of Main Ridge of Curonian Spit

The factors determined dunes dynamics and evolution

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graph TD; A["The factors determined dunes dynamics and evolution"] --> B["Carry of sand"]; A --> C["Displaced of sand"]; A --> D["Regime of winds"];
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Carry of sand

Regime of winds

Displaced of sand

The movement of sand in end of XIX century was stabilized

1. After the middle of the XIX century, when artificial dune ridge was formed on the seashore, stopping the sand supply to the Main Dune Ridge, the movement of sand was stabilized.

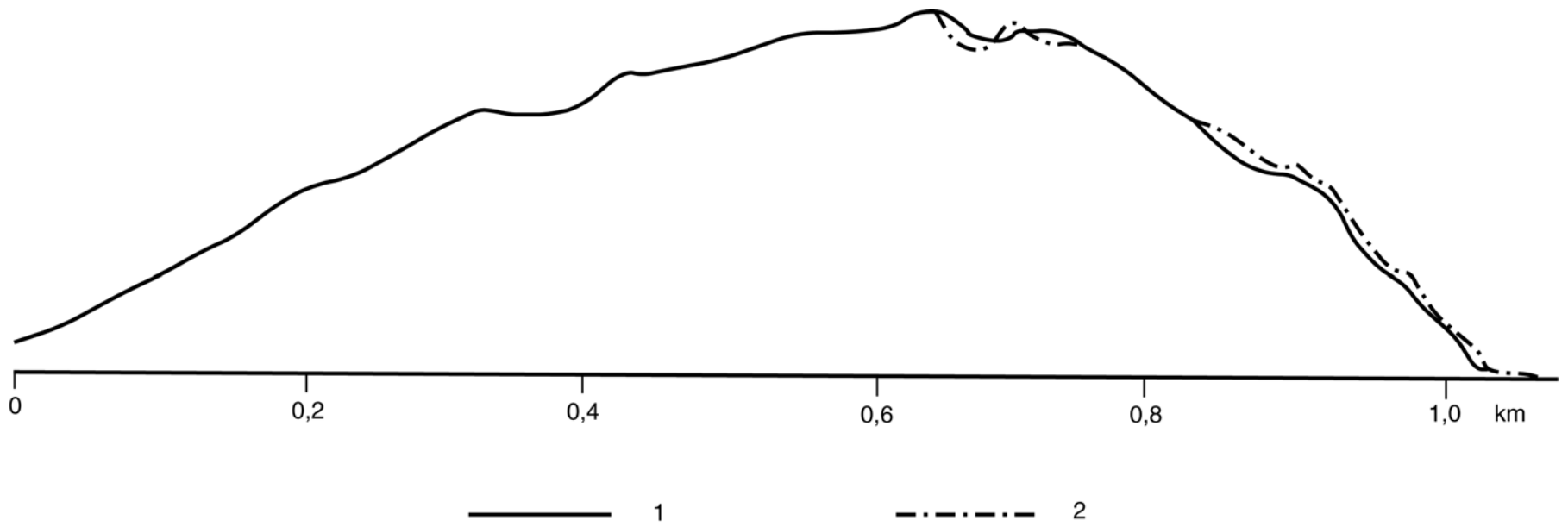
2. The wind displaced sand, which accumulated until the XIX century. This sand displacement did not transform the structure and shape of Main Ridge of Curonian Spit.

3. In the beginning of the XX century vegetation occupied lower part of foredunes and pervaded in the Main Ridge.

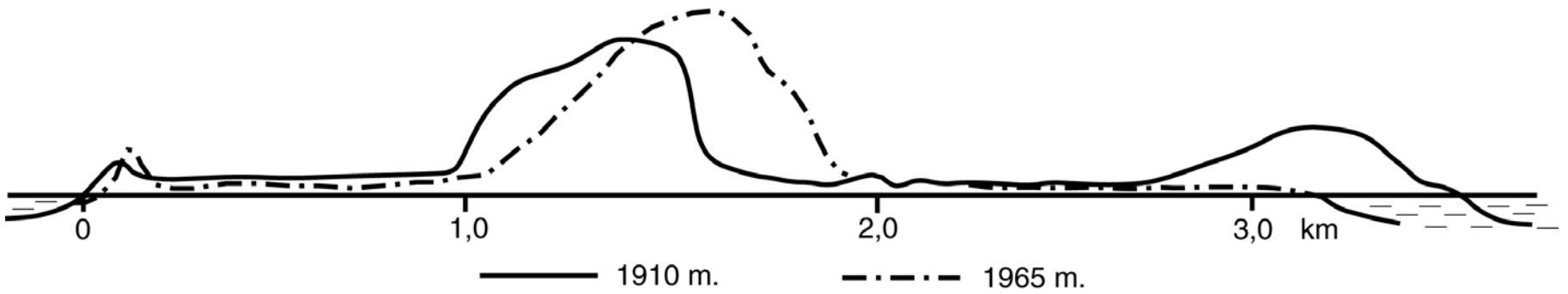
4. In the second part of the XX century large part of the Main Ridge was forested. Today there are only 2 segments in Lithuanian territory, where eolodynamic processes take place: Juodkrantė – Pervalka (north) and Nida – Rasytė (south).

Velocity of dunes movement during XIX – XX centuries

Area	Changes in 1837 – 1861		Changes in 1910 – 1965	
	m	m / y	m	m / y
Smiltynė	272,2	11,3	0,0	0,0
Bear Hollow	173,4	7,3	0,0	0,0
Juodkrantė	129,5	5,4	0,0	0,0
Old Nagliai	272,8	11,4	124,0	2,9
Pervalka	122,9	8,2	0,0	0,0
Bulvikis Cape	197,6	8,2	0,0	0,0
Urbas Hill	60,5	2,5	68,6	1,6
Grobštas Cape	320,5	13,4	102,9	2,3



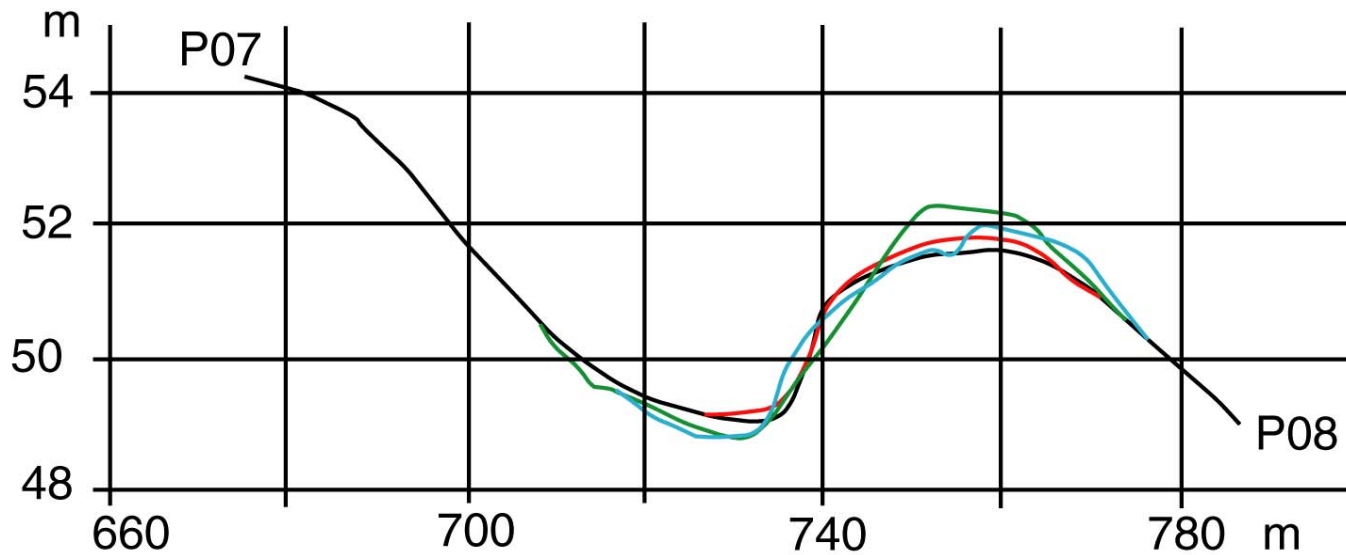
Main Ridge shape changes in Parnidis Dune area.



Main Ridge shape changes in Grobštas Cape.

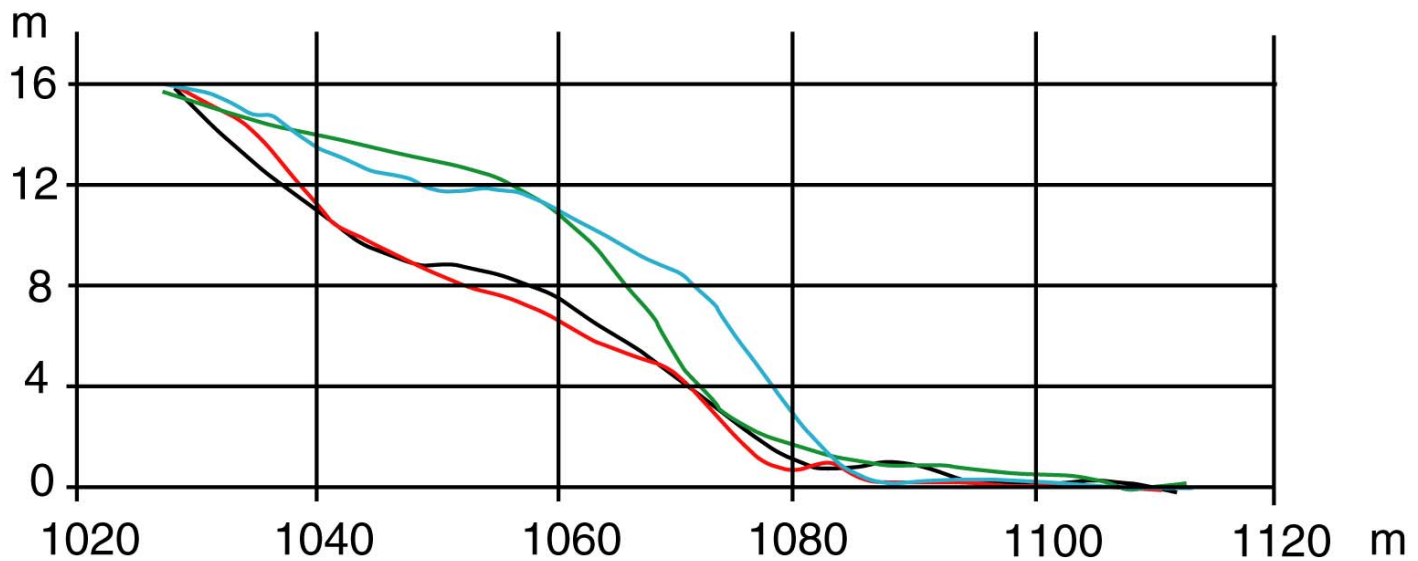
Transformation of dunes shapes

Area	Localization	Maximal changes, m
Parnidis Dune	Top	0.8
	Eastern slope	2,0
	Foot	4.0
New Nagliai	Top	0.5
	Eastern slope	1.5
	Foot	2.4
Vinkis Dune	Top	1.5
	Eastern slope	3.0
	Foot	4.0
Lybis Cape	Top	2.0
	Eastern slope	0.4
	Foot	0.6
Naglis Cape	Top	0.4
	Eastern slope	1.2
	Foot	0.2



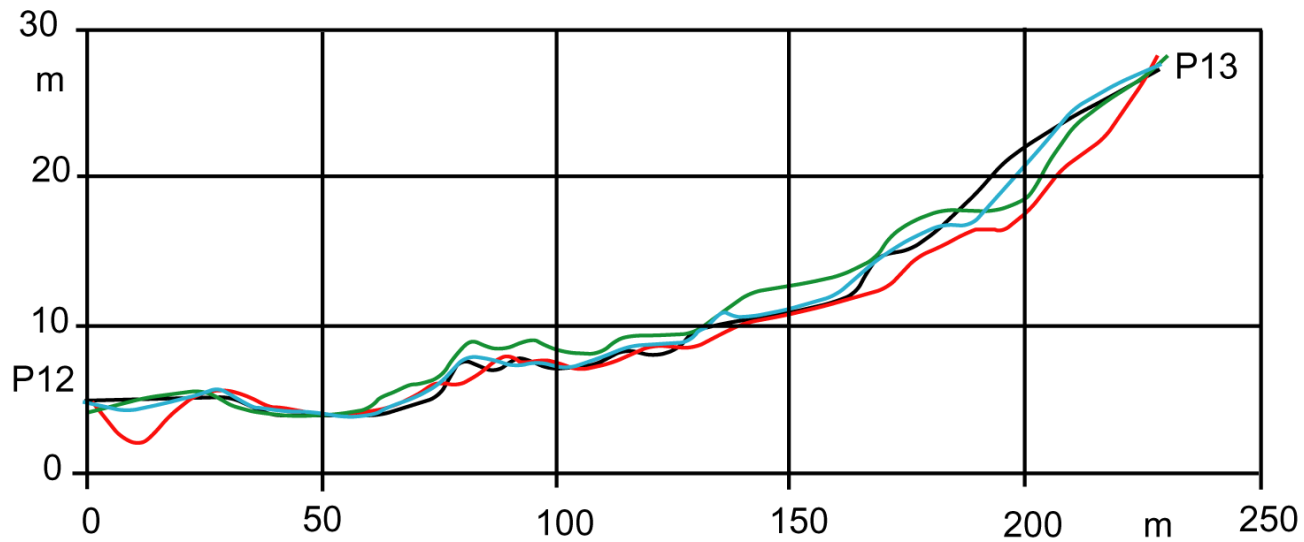
— 2003.06 — 2003.10 — 2004.06 — 2004.10

Shape changes of top part of Parnidis Dune



— 2003.06 — 2003.10 — 2004.06 — 2004.10

Shape changes of foot part of Parnidis Dune

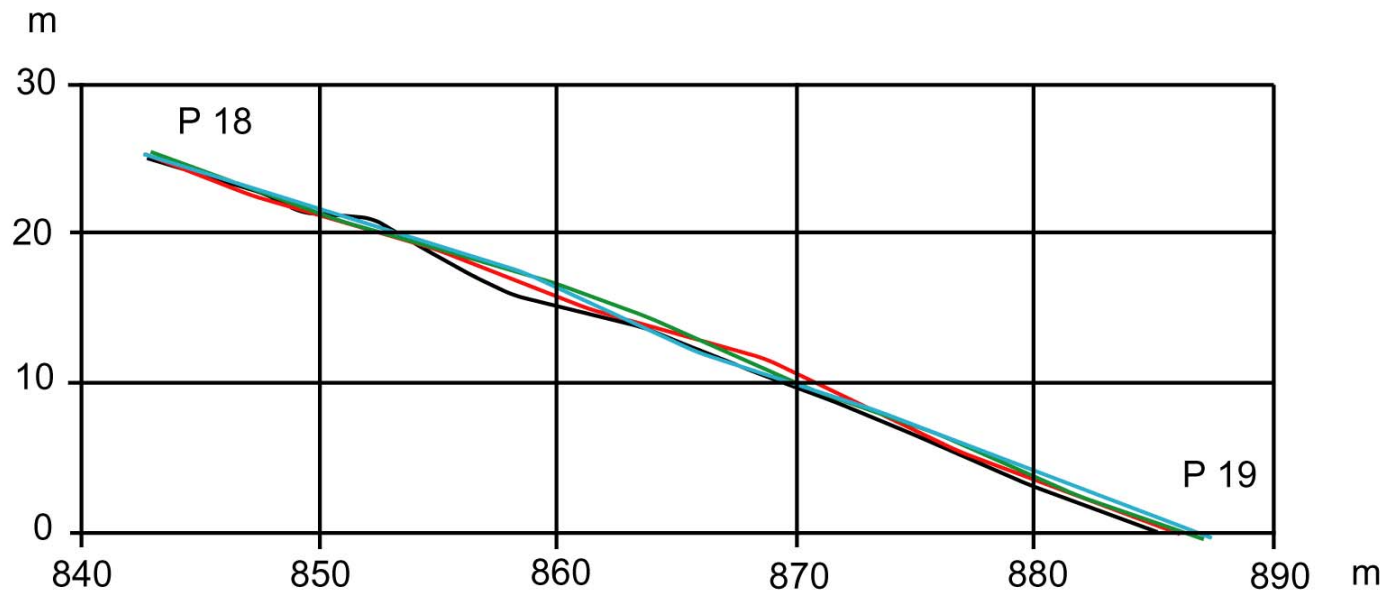


2003.06
 2003.10
 2004.06
 2004.10

Shape changes of top part of New Nagliai



Blown hollow in New Nagliai massive

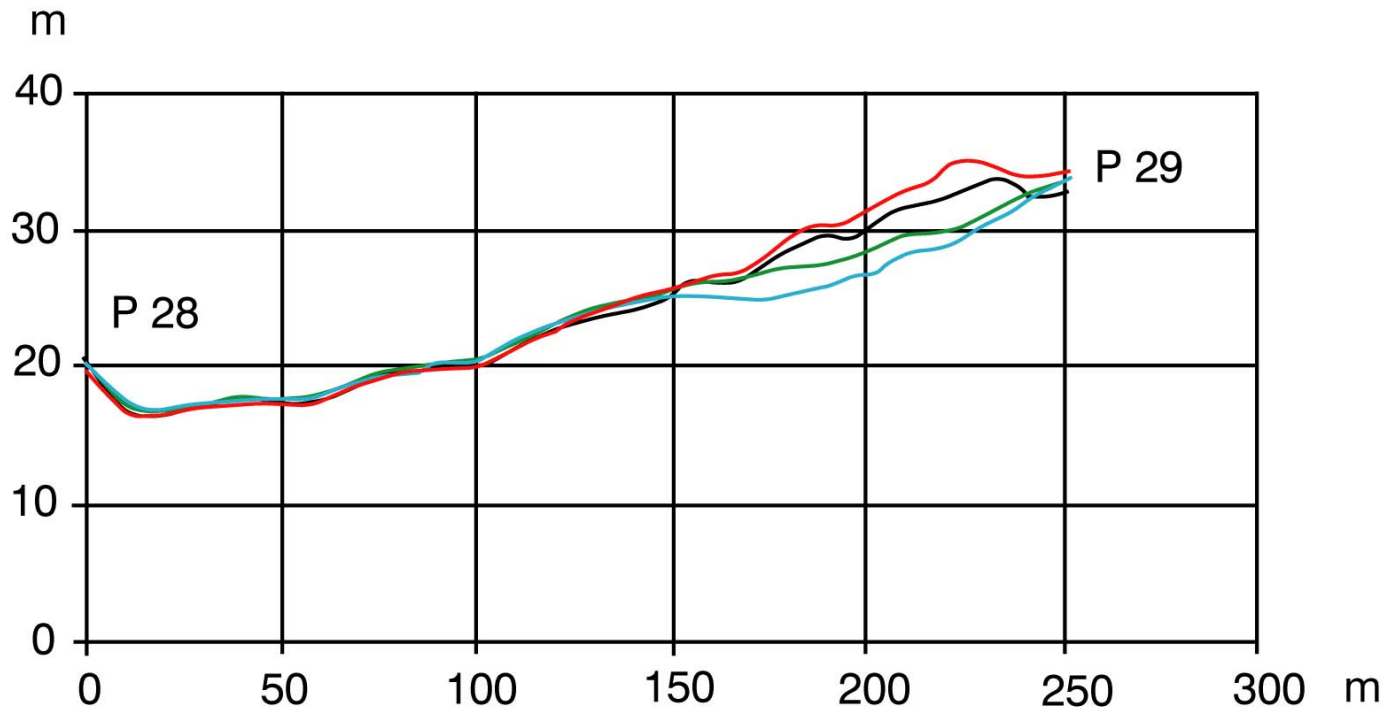


2003.06
 2003.10
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Shape changes of foot part of New Nagliai

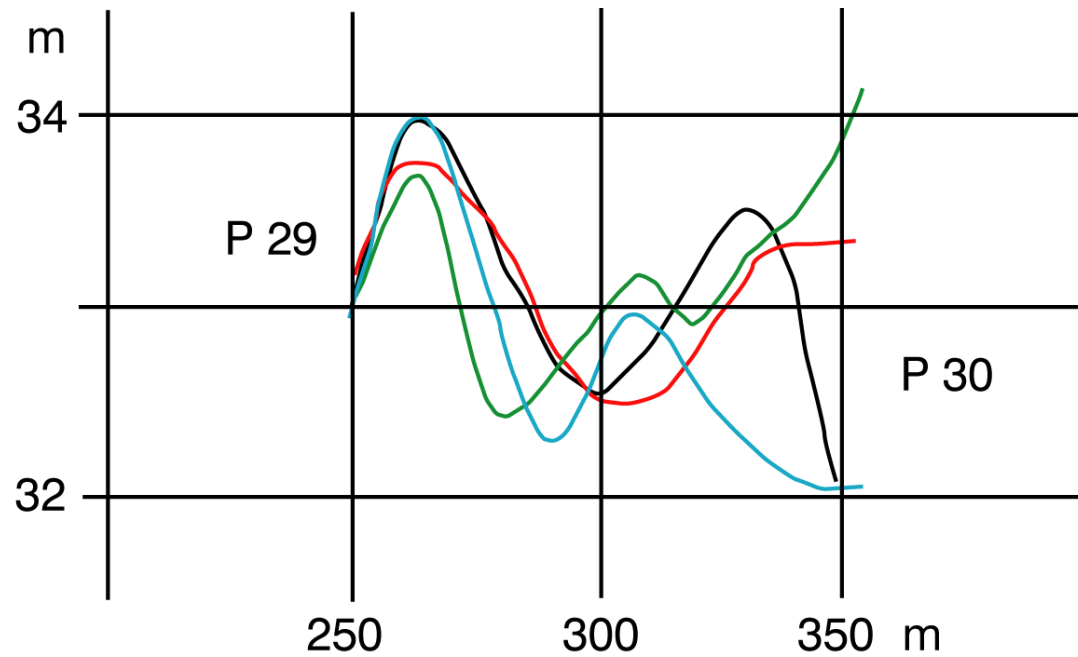


Sand accumulation in western part of New Nagliai massive



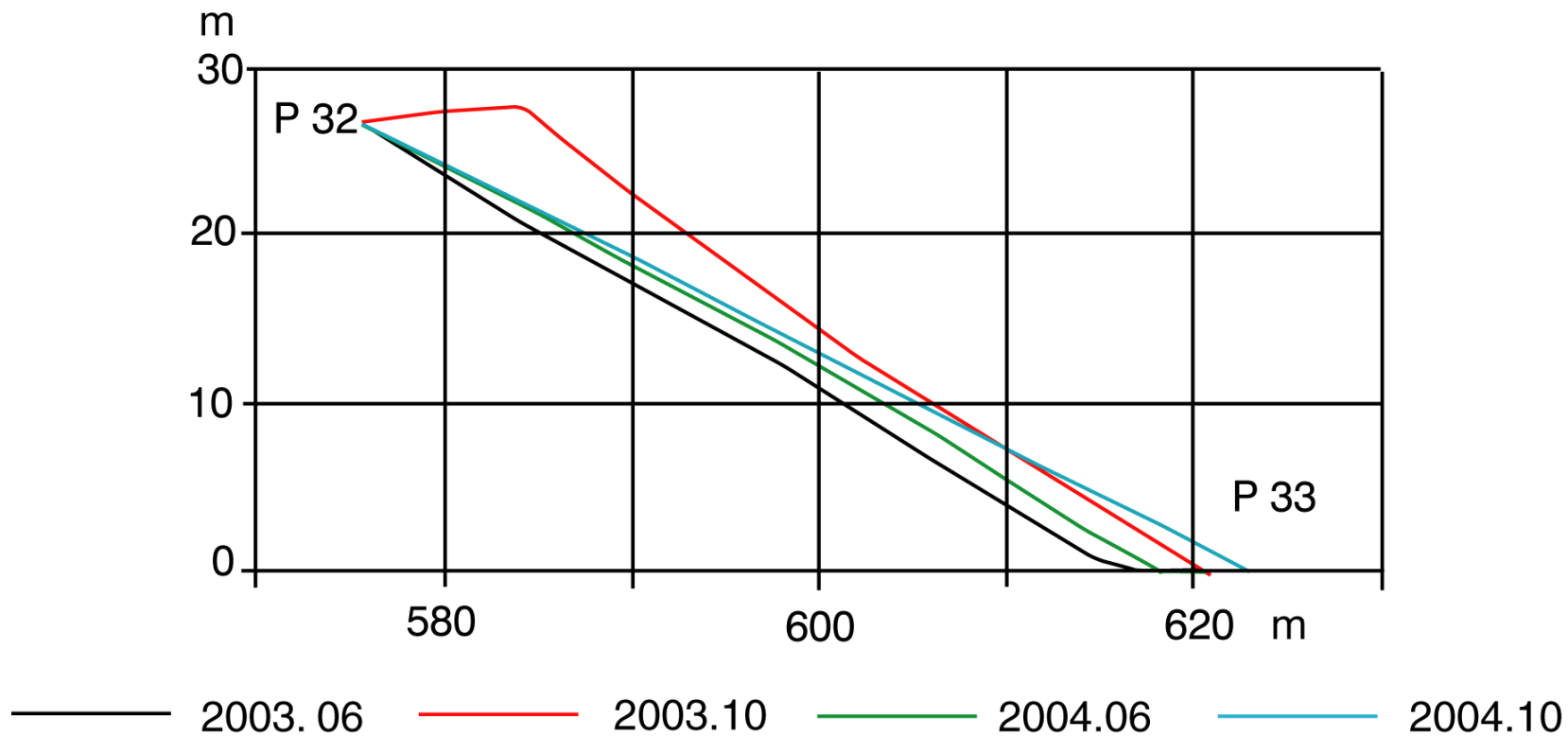
— 2003.06 — 2003.10 — 2004.06 — 2004.10

Shape changes of top part of Vinkis Dune



2003.06
 2003.10
 2004.06
 2004.10

Shape changes of plateau part of Vinkis Dune



Shape changes of foot part of Vinkis Dune



Burried soils in Maine Ridge

The changes of deflation depressions morphology and morphometric indices

- 1998-1999 fieldwork data was based for an earlier work (Morkūnaitė 2000) of the clear relief forms in the mobile dunes at the Juodkrantė – Pervalka strip.
- Depressions, their size and morphologic types have been described.
- The distributional peculiarities along the Main Dune Ridge were given.
- There was also reported formed microrelief and characteristics of erosion and deflation processes.
- Depressions have been grouped according to morphologic types: oval, corridors, wastes, composite, steep slopes and furrows in the blown-out remnants area. There were mapped more than 50 those structures.
- Deflation depressions are mostly displaced in the western part of the Main Dune Ridge and situated northwards from the Lydumas cape.

The changes of dunes shape

- Composite depressions and wastes, open to the lagoon, are mostly distributed from the Lydumas Cape toward Vinkis Dune.
- The formations, which were most changeable in the length and width of banks and width of gates, were started to measure.
- The changes of eolian forms in 2001 are larger as compared to 1999, and also in 2003 as compared to the data of 2002.
- The lengthening of the western banks about 4-7 m per year might have been also caused by the eastern direction winds, because the investigated depressions are open toward the lagoon.
- The eastern winds have blown out sand from the eastern depression part to the western one, thus shortening the eastern banks. The blown out sand was accumulated along the closed western slopes.

Investigations of wind regime

- One of the earlier records (Morkūnaitė, 2000) has mentioned function of breeze from the lagoon, but their parameters are not studied yet.
- The near-ground winds have been mapped, and there was cleared out, that the lithologic and morphologic maps are necessary to compose after each change of the wind regime.
- The wind blowing obliquely to the dune ridge changes its direction for about 30° in the windward slope and up to 50° in the leeward slope.
- The regularities of the interaction of wind and ground surface have to be determined, the study of which might help to forecast transformation of the eolian relief forms.
- According to these data, preliminary areas of deflation depressions might be marked, with a different surface relief and size of forms.
- The territory also might be subdivided into areas according to qualitative influence of deflation-accumulation processes preliminary assessed on the basis of insufficient observations.

Results of investigations: - In the highest part of the Main Dune Ridge – New Nagliai – the changes of **eolian hump** position reach about 13 m. The changes of **eolian hump height** were from 0.8 to 2.4 m. The same large changes of position and height of eolian hump was in **Vinkis Dune** segment. The eolian hump cap passed from 4 to 8 m, and height – from 0.8 to 1.6 m.

- The most geodynamic changes of eolian hump were in **gate** between **Nagliai and Vinkis Dune segments**. The position of hump passed 12 – 30 m in Curonian Lagoon direction and height changed from 0.6 to 2.1 m .

- The least changes of **dune shape** were in lower part of the Main Ridge – Nagliai Cape. The position of eolian hump cap passed from 3 to 5 m and height – from 0.3 to 0.6 m.

- The complex **evaluation of dunes shape and deflation depression** changes allows to distinguish different geodynamical segments of the Main Ridge. The first segment occupies the highest part of Main Ridge.

-The dunes **crest** reaches up to 53–57 m above the sea level. Very intensive deflation and accumulation processes are in this segment. In middle part of the Main Ridge there are areas of intensive and medium deflation – accumulation processes.

-- The **northern part of Main Ridge** is the area of weak deflation and accumulation processes.

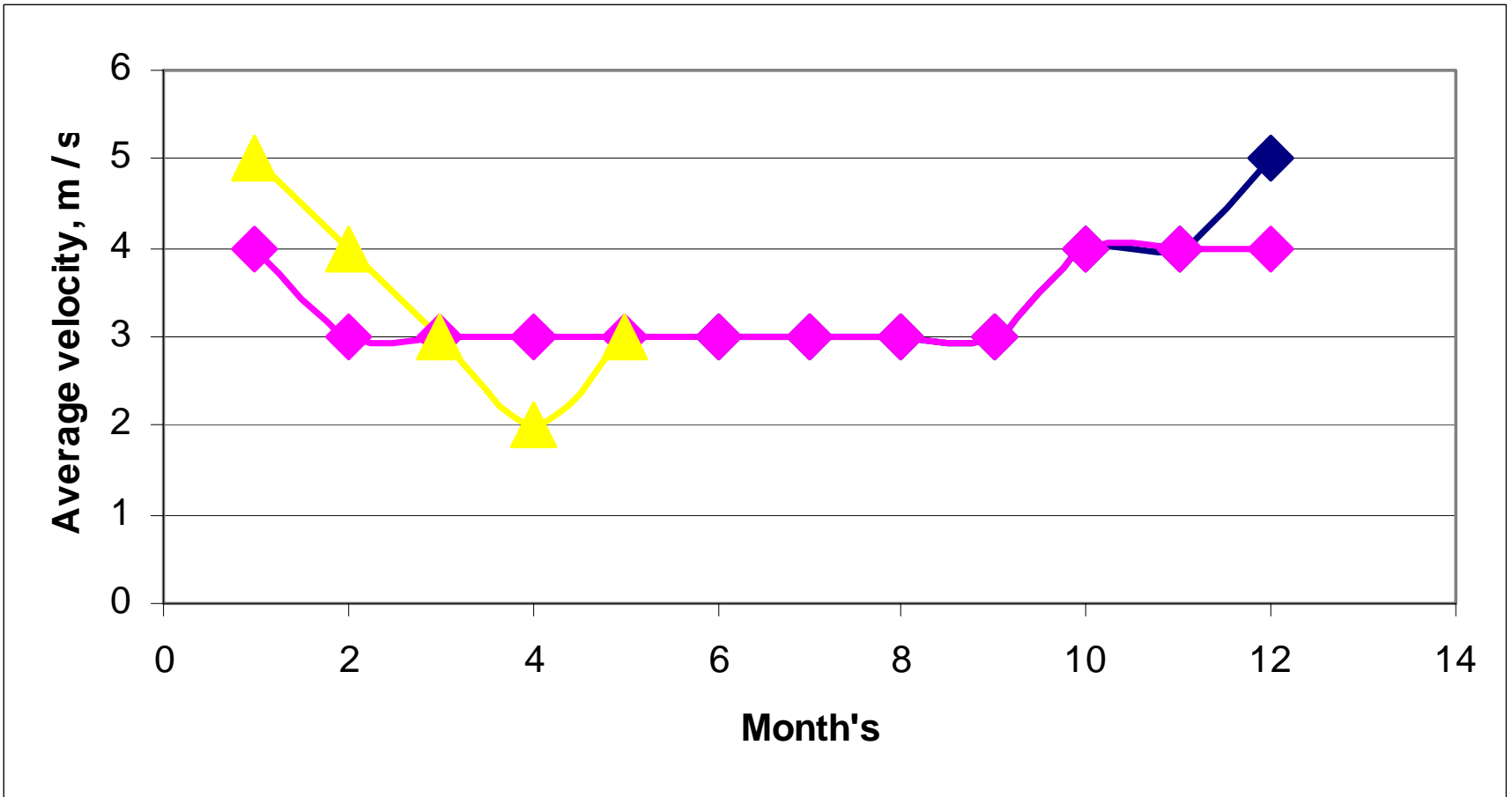
Regime of winds

According to the data of Klaipėda and Nida meteorological stations, the dry time span lasts from **May till October**. For example, the wind, the velocity of which was more than 15 m/s, occurred 3 times in May, 8 times in June, once in July, once in August, 3 times in September and 12 times in October.

In these months, the mean daily values of wind velocity (responsible for sand drying) also are higher.

The maximal wind velocity in waff reaches **17–19 m/s**, in net **25 m/s**. Comparison of available data (from Klaipėda and Nida meteorological stations) showed that in **2003–2005** the mean monthly values of wind velocity were slightly higher than in **1961–1990** implying that the period of **2003–2005** was more windy than usual.

Average wind velocity of day reaches 4,7; 5,2 and 5,0 m/s in June decades and 4,5; 3,6 and 6,9 m/s in July decades.



Mean velocity of winds

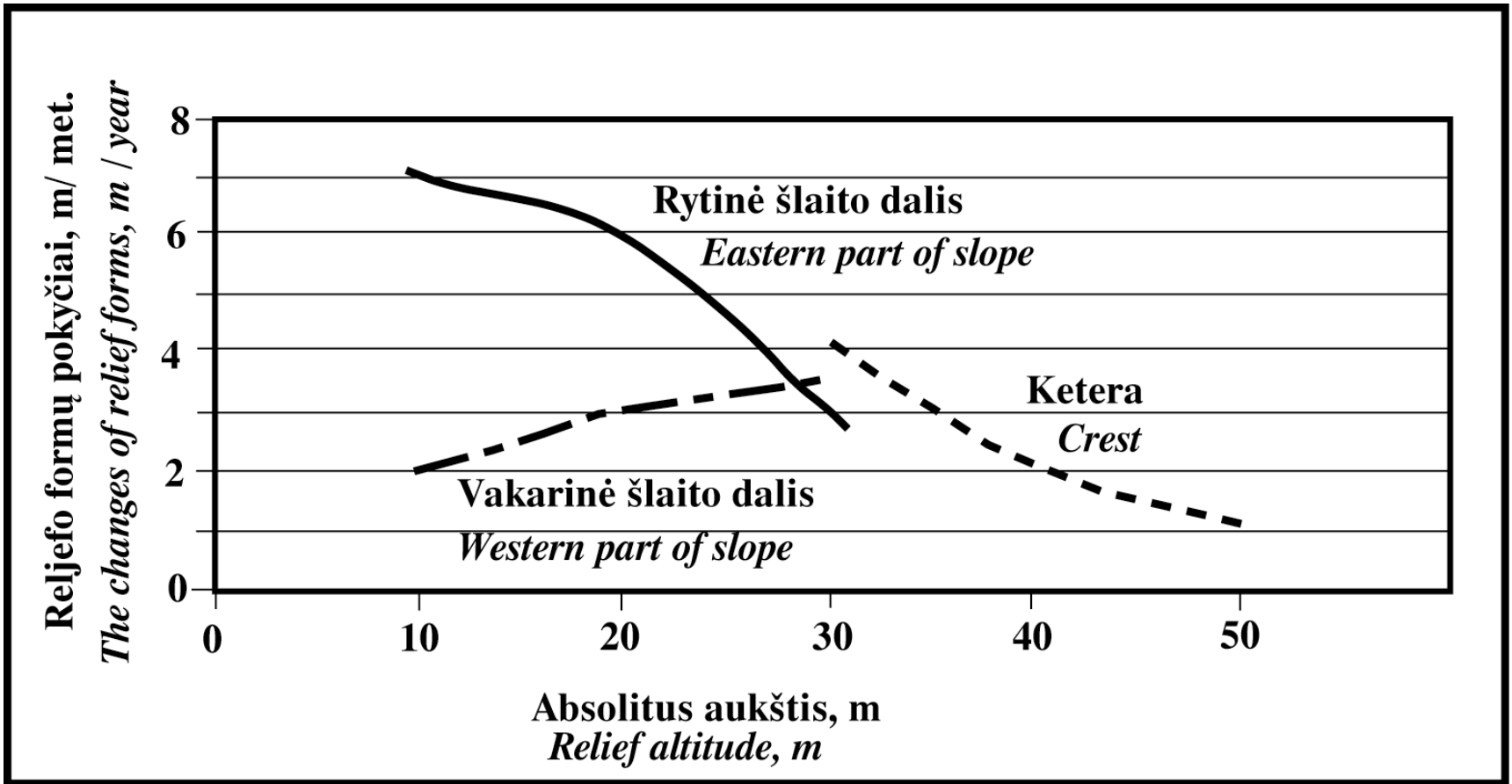
Year	Month	Mean velocity, m /s	Time, hours
2003	6	8	6
	7	8	3
	8	8	6
	9	10	6
	10	8	9
	11	9	3
	12	11	9
2004	1	10	9
	2	10	9
	3	6	9
	4	7	6
	5	8	15
	6	6	9
	7	9	15
	8	10	15
	9	6	12
	10	8	45
	11	11	12
	12	13	15
2005	1	9	60
	2	11	12
	3	6	15
	4	6	6
	5	9	6

**Time scale of
maximal mean
wind velocity**

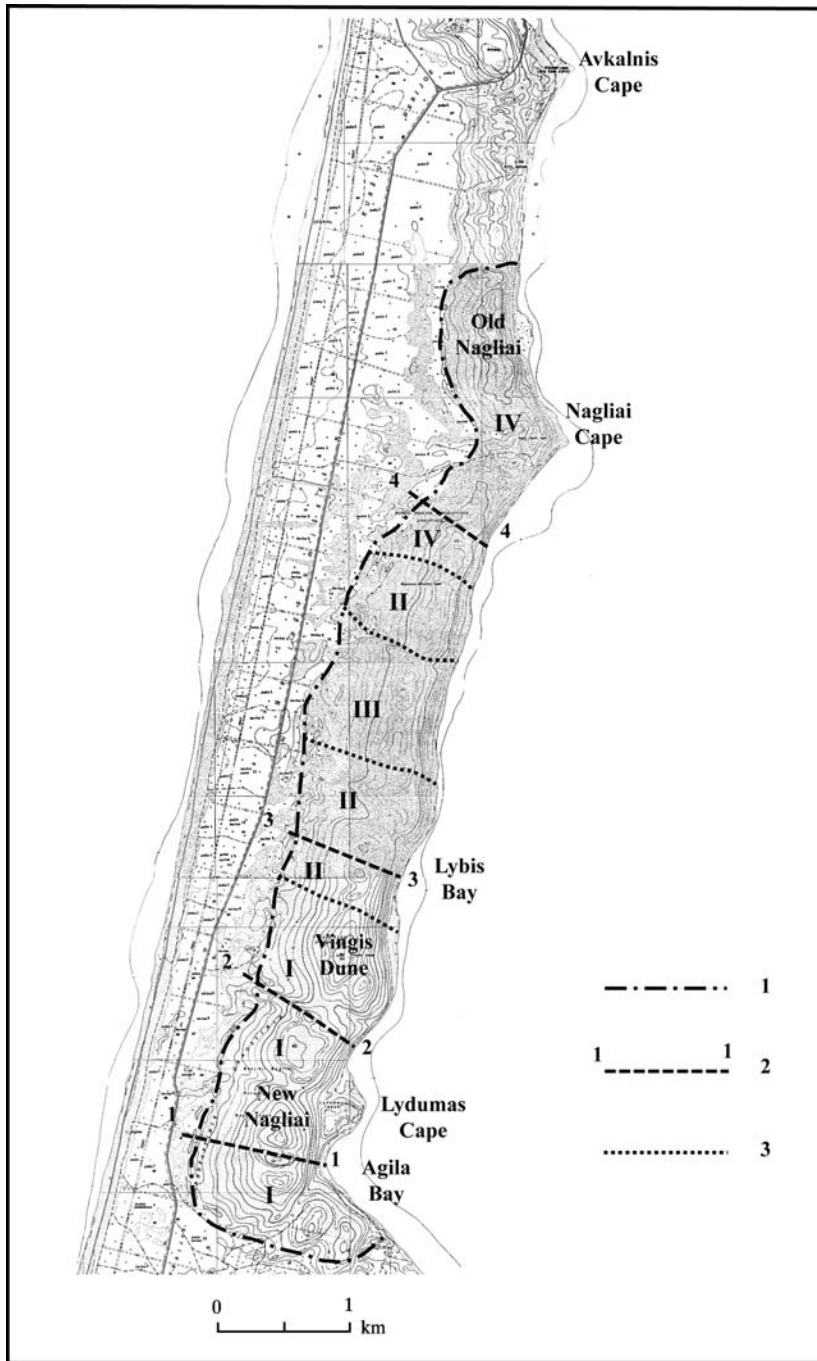
Similar situation was characteristic of the southern coast of the Baltic Sea.

According to the data of [Kolobrzeg](#), [Putsk](#) and [Gdynia](#) meteorological stations, weaker and more stable western winds were dominant in the warm seasons (May–October) of 2003–2005.

Moreover, the warm season of 2003–2005 was more arid than the warm season of 1961–1990 both in the Lithuanian and southern coasts of the Baltic Sea. The August of 2005 was the only exception.



Interaction between absolute level of blown hollows and their shape transformation



The areas of different intensity of deflation and accumulation:

- places of cross-section,
- boundaries of geodynamical eolian areas

I – areas of very intensive deflation and accumulation processes, **II** – areas of intensive deflation and accumulation processes, **III** – areas of medium intensive deflation and accumulation processes, **IV** – areas of weak deflation and accumulation processes.

Conclusion:

-- In 150 years, the Main Dune Ridge of Curonian spit underwent a few dynamic stages of evolution:

- In the first stage (the first half of the 19th century), the dunes were moving eastward at an average rate of 8.5 m/y.

- In the second dynamic stage (the first and sixth decades of the 20th century), the average rate of dune migration was 2.3 m/y.

- In the third stage (the seventh decade of the 20th century—the beginning of the 21st century), the dune migration rates reached 0.9 m/y.

-- The lowering of migration rates is related to forestation of the spit. After forestation of the blown sand plain, the Main Dune Ridge lost its sand source from the sea.

-- Dune migration is now related only with the sand resources of the dune itself what leads to lowering of the ridge.

- **Recurring** winds are the main driving forces of deflation. According to the data of Klaipėda and Nida meteorological stations most windy weather occurred in June, August and October when maximal wind velocity in gusts reached 17–19 and even 25 m/s.

- **Deflation–accumulation processes** dominate in the western parts of slopes. They are responsible for stable alternation of positive and negative forms of relief. Slow migration of the upper edge of the slope eastwards (0.4–1.0 m/y) is the main trend of western slope dynamics.

- **Wind erosion processes** are dominant in the dune crest. In 2003–2005, the eroded layer reached 1 m in thickness. Accumulation processes were dominant at the bottom of the eastern slope.

-- When a critical sand mass accumulates at the edge of the eastern slope, **slumps develop**. Their base reaches the Curonian lagoon. Some sand is washed away during spring tides. Sand **accumulation rates** at the bottom of the eastern slope reach 7 m/y.

- The Main Dune Ridge has four areas of different accumulation–deflation processes. The first area (Garbès Cape – Vinkis Dune) is predominated by complex deflation basins. The greatest changes of accumulation swells occur in this area.
- During the period of investigation, the swells of the eastern slope shortened, whereas the swells of the western slope lengthened (for about 100–15 m). The length of accumulation swells in the second area ranges from 3 to 6 m. Benches on the western slopes of deflation basins are the typical feature of this area.
- The third area includes the sectors of the ridge moderately affected by deflation–accumulation processes. This area has few swells and the wash-outs in blown-out remnants areas transformed by 3–4 m on the average.
- The fourth area is represented by the Main Dune Ridge sector between the Nagliai Cape and Avikalnis Cape. It has fewest deflation basins. Swells in this area were most strongly transformed. Yet their transformations only can be measured up to 0.5 m.

BALTIC SEA

Neringa talasological state reserves

*Landscape regulative zone
of managed protection*

Landscape regulative zone

*Sand
complexes in strict reserves*

with extensive program of preservation

Nature heritage objects
zone of strict protection



The National Park has common objectives: protection of the natural and cultural complexes of the Curonian Spit as a whole. Any activity, that contradicts the aims and tasks of the National Parks, is prohibited.

- **The directions and equipments of managements of territory:**
- **1. The geomorphological reserves play important ROLE IN NATURE PROTECTION of Curonian National park; for example, the dunes of Nida, reserves of Hagen Ridge.**
- **2. It is proposed to create the new landscape object: the geomorphological monuments – the lake of Ozku ragas, new botanical object of nature heritage – Jonas mount forest hill, Griekyne hills forest habitation.**

- **The ways of natural ecosystem stability maintenance:**
- **to intensify the protective functions of forest ecosystem by increasing the biodiversity of their structure, planting and forming greater number of mixed woods,**
- **to stop the urbanization of natural territories of the National Park, not to plan and build residential, public, forestry and other technical complexes on the natural valuable territories,**
- **to leave minimum 5 m distance from expressive relief and hydrographic elements when designing and building new houses,**
- **To use mechanical means for protection of dunes from wind and visitors, e.g. fencing with wooden and metallic constructions, as well as planting,**
- **To establish new nature reserves (zones).**

The directions of recreation development during cognitive tourism:

- **To form conditions for visiting the National Park during the whole year**
- **To elaborate the network of bicycle and pedestrian paths**
- **To combine the recreational systems of Curonian Bay water and motor transport roads in Lithuania and in Kaliningrad district**



Thank you for attention!

From Winds, Sand ...
and “Protectors..”