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THE RECENT INVESTIGATIONS AND PROVIDENCES ABOUT ACTIVE AEOLIAN FORMS IN CURONIAN SPIT (LITHUANIA)

Morkūnaitė R., Bautrėnas A., Česnulevičius A. **Współczesne badania i prognozy rozwoju aktywnych form eolicznych na Mierzei Kurońskiej (Litwa)**. Mierzeja Kurońska, powstała w środkowym i późnym holocenie, ma złożoną budowę geologiczną i jest badana pod różnymi względami. W niniejszym artykule przedstawiono dane dotyczące dynamiki ruchomych wydm na tle analizy reżimu wiatrowego w latach 2003–2014 (stacje meteorologiczne: Nida i Klaipėda). Obserwacje dynamiki wydm są stale prowadzone na głównym paśmie wydmowym – wydma Vingiakopė – za pomocą precyzyjnych przyrządów geodezyjnych (teodolit Zeiss Elta R55 i GPS Trimble). Wspomniana wydma znajduje się w granicach rezerwatu krajobrazowego, dzięki czemu przeobrażenia jej ukształtowania są spowodowane wyłącznie przez naturalne procesy eoliczne. W 11-letnim okresie obserwacji nie zmieniła się wysokość wydmy (51 m n.p.m.), zaobserwowano natomiast największe przemodelowanie na wschodnim, dystalnym stoku tej formy: podnóże stoku cofnęło się o 5–15 m w kierunku zachodnim. Bilans masy piaszczystej jest ujemny: akumulacja na zachodnim (proksymalnym) podnóżu stoku, na samym zachodnim stoku i na wierzchołku wydmy sięga 4 592 m³ na pasie o szerokości 1 metra, a deflacja na wschodnim stoku i w różnych częściach wierzchołka sięga 10 124 m³ na pasie o szerokości 1 metra. W obrębie wydm, na których ma miejsce ruch turystyczny (np. wydma Nagliai), zmiany rzeźby są coraz bardziej zauważalne. Autorzy artykułu proponują przenieść ruch turystyczny w okolice wydmy Nagliai.

Моркунайте Р., Баутренас А., Чеснулевичюс А. **Современные исследования и прогнозы развития активных эоловых форм рельефа Куршской косы (Литва)**. Куршская коса – геологическая структура среднего-позднего голоцена, изучаемая по разным аспектам. В данной статье представлены результаты наблюдений за димамикой подвижных дюн, измеряемых современными геодезическими инструментами (теодолит Zeiss Elta R55, Trimble GPS). Упомянутые наблюдения проводятся нами на дюне Вингякопе на Главном дюнном хребте с 2003 г. Анализ преобразований поверхности дюны проведен на фоне ветрового режима (метеостанции Нида и Клайпеда) за период 2003–2014 гг. Анализированы изменения на подветренном и наветренном склонах отмеченной дюны Вингякопе, в пределах которой запрещены туристические походы (находится в чертах дандшафтного заказника). Вингякопе под влиянием лишь естевтвенных дефляционных и аккумулятивных процессов не изменила свою высоту (51 м абс.), но потеряла 10 124 м³ песка на полосе шириной в 1 м (аккумуляция составила 4 592 м³ на такой-же полосе) и заметен отодвиг подветренного склона к западу, причину чего следует детально изучить. Упомянуто, что на других дюнах, которые подвержены туризму, величины динамики заметно отличаются. Предложено изменить местоположение туристических проходов на другие посещаемые дюны (в основном на дюны окрестностей Нагляй).

Key words: Curonian Spit, aeolian processes (deflation and accumulation), dynamics of dune
Słowa kluczowe: Mierzeja Kurońska, procesy eoliczne (deflacja i akumulacja), dynamika wydm
Ключевые слова: Куршская коса, эоловые процессы (дефляция и аккумуляция), динамика дюн

Abstract

Curonian Spit, created in the mid and late Holocene, has a complex geological structure. In the article are presented data on the dynamics of coastal dunes and conducted the analysis of meteorological data station Klaipėda and Nida during the period 2003–2014. Observation of the dynamics of the dunes is constantly made on the Main Dune Ridge. For observing changes in the aeolian landscape was used the precision geodetic devices (theodolite Zeiss Elta R55 and Trimble GPS), making repeated levelling on dunes Vingiakopė. Dune Vingiakopė is situated in landscape reserve, which means that the change of the slopes was acting exclusively by aeolian processes. For the period of observation in the whole did not change the height of the dune (51 m above sea level). The biggest

changes took place on the eastern slope. The foot of the slope departed for 5–15 m to the west. The balance of sand is negative: accumulation on the western foot of the slope, on the western slope and the top of the dunes dates back to 4 592 m³ belt width of one meter, and deflation on the eastern slope and in different parts of the peak reaches 10 124 m³ belt width of one meter. The dunes, which is allowed to tourists (dune Nagliai), changes of aeolian slopes and peak are not similar. The authors suggest the cognitive changes of traffic in the vicinity of dunes Nagliai.

INTRODUCTION

The Curonian Spit landform exhibits the dynamic sedimentation processes at the land – sea interface that span the Holocene, barrier spit formation, coastal erosion and accumulation, aeolian processes and episodic paleosols formation. The Curonian spit is a young geological structure that appeared in the Middle – Late Holocene as a result of sediment transport by coastal currents and wind (KHARIN G. S., KHARIN S. G., 2006).

The principal contribution studying processes of the Curonian spit in our ages belong to Vytautas Gudelis and other geographers (MICHALIUKAITĖ, 1967; MINKEVIČIUS, 1982; GUDELIS, 1998, ŽILINSKAS, JARMALAVIČIUS, MINKEVIČIUS, 2001). Geologists recorded the age dating and measurements of inner structure of parabolic dunes (BITINAS, DAMUŠYTĖ, 2004). A contribution to the study of management aspects was made by the scientists of the Klapėda University (POVILANSKAS et al., 2009). The Main Dune Ridge was stationary studied by geodesic devices during last decades (MORKŪNAITĖ, 2000; MORKŪNAITĖ, ČESNULEVIČIUS, 2005; ČESNULEVIČIUS, MORKŪNAITĖ, 1998; MORKŪNAITĖ et al., 2016, BAUTRĖNAS, MORKŪNAITĖ, 2016). The measurements based on stationary and continuity principles.

In this paper are analyze data on dynamics of one of biggest dune in Curonian Spit (Lithuanian part) Vingiakopė and shortly show the diversity of erosion and deflation small relief forms in environment of Main Dune Ridge (fig. 1; photo 1). Under the conditions of changing the wind regime and the aeolian relief transformations it is necessary to use modern devices for measuring in stable cross-section and observations of winds according the meteorological stations. For measurement was used electronic Theodolite Zeiss Elta R55 in 2003–2004 and Trimble GPS equipment in 2014. Meteorological data were obtained from the archives of the Lithuanian Hydrometeorological Service. The data of meteorological stations in Nida and Klaipeda were during 2003–2014 and data of levelling in cross section on Vingiakopė were during 2003–2014. The compared data analysis was show the common view of dynamics tendencies in high dune Vingiakopė (about 51 m a.s.l.).

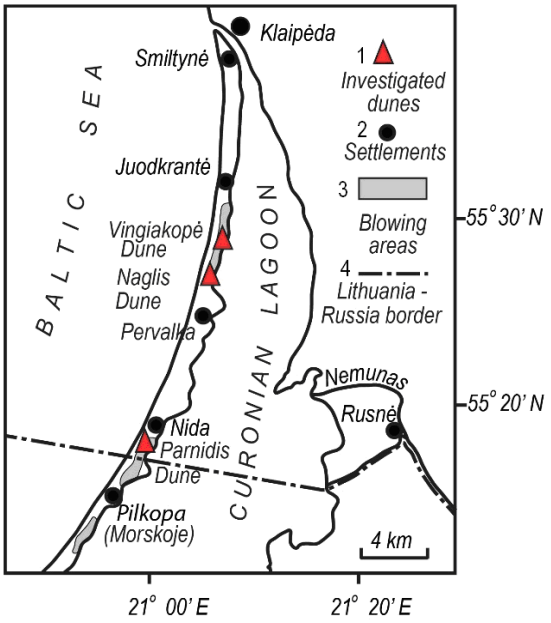

Fig. 1. The situation of investigated area
Rys. 1. Obszar badań:
1 – badane wydmy, 2 – punkty osadnicze, 3 – obszary rozwiewane, 4 – granica litewsko-rosyjska
Рис.1. Исследуемая территория:
1 – анализируемые дюны, 2 – поселения, 3 – развеваемые территории, 4 – государственная граница Литва – Россия

GEOLOGICAL AND GEOMORPHOLOGICAL PECULIARITIES OF STUDIED AREAS"

Modern geophysical and geochronological equipment as ground-penetrating radar [GPR] surveys, LIDAR data and radiocarbon [^{14}C] dating enabled detailed investigations of palaeosols were carried out in the Dead (Grey) Dunes massif located between Juodkrantė and Pervalka settlements on the Lithuanian half of the Curonian Spit. Several soil-forming generations (phases) have been distinguished (DOBROTIN et al., 2013): 5800–4500, 3900–3100, 2600–2400, and from 1900 BP until the present. According to BITINAS et al. (2001), the layers in the cross-profile near Vingiakopė are as follows: below the mobile dunes of the first and the second generation (thickness or height reaches >60 m) and the coarse-grained marine sand (5–10 m thickness) is lying, the latter is underlain by the Baltic Lake glaciolacustrine medium grained sand and marl (10 m thickness), while deeper than 30 m there is the subformation of Medininkai Glacier. Baltic Lake sapropel occurs only near the Curonian Lagoon. It is understandable that Vingiakopė is a high dune (about 51–53 m a.s.l.), because it is lying on 40 m deep Pre-Quaternary sediments (fig. 2).

A

B

Photo 1. Aeolian forms changing in Main Dune Ridge between Juodkrantė and Pervalka settlements:
A – the moon landscape after the rain in a deflationary hollow with turf insertion and clear-cut sand texture (phot. by R. Morkūnaitė), B – sand ridge with beach-grass (*Ammophila arenaria*) in the deflationary hollow (accumullation meso-form) (phot. by R. Morkūnaitė)

Fot. 1. Formy eoliczne centralnego pasa wydmowego pomiędzy osiedlami Juodkrantė i Pervalka:
A – „księżycowy" krajobraz niecki deflacyjnej po deszczu z widocznymi fragmentami darni i strukturą piasku (fot. R. Morkūnaitė), B – piaszczysty wał akumulacyjny porośnięty piaskownicą zwyczajną (*Ammophila arenaria*) w niecce deflacyjnej (mezoforma akumulacyjna) (fot. R. Morkūnaitė)

Фот. 1. Эоловые формы рельефа на приморских дюнах Куршской косы между поселениями Юодкранте и Пярвалка:
А – „лунный" ландшафт после дождя в дефляционной котловине с наблюдаемой текстурой отложений и дерном на северном склоне (фот.: P. Моркунайте), В – песчаный аккумулятивный вал частично обросший *Ammophila arenaria* в дефляционной котловине (аккумулятивная мезоформа) (фот.: P. Моркунайте)

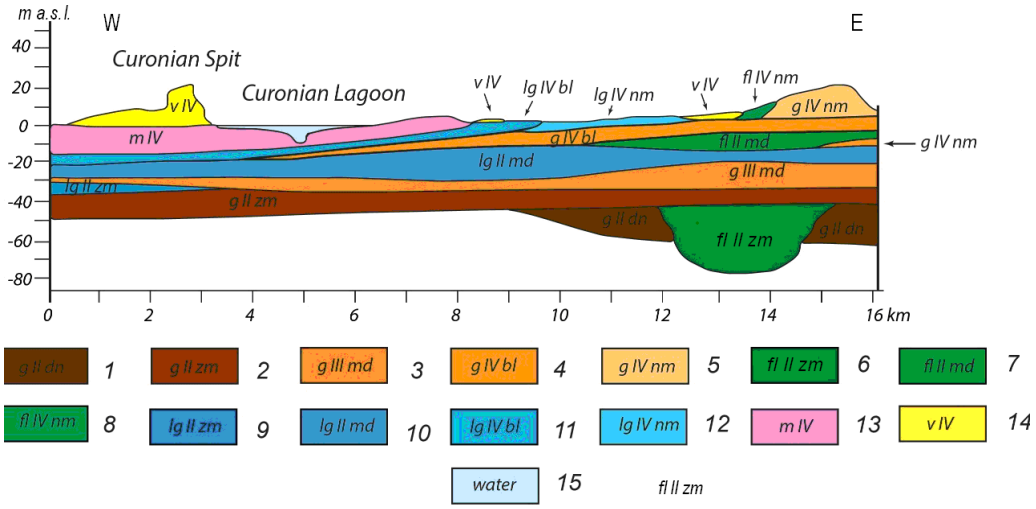

Fig. 2. The geological structure of north part of Curonian Spit (Vingiakope dune environment) (according KABAILIENĖ et al., 2009):
Glacial sediments: 1 – Dainava moraine, 2 – Žemaitija moraine, 3 – Medininkai moraine, 4 – Baltija moraine, 5 – Nemunas moraine; glaciofluvial sediments: 6 – Žemaitija, 7 – Medininkai, 8 – Nemunas; glaciolacustrine sediments: 9 – Žemaitija, 10 – Medininkai, 11 – Baltija, 12 – Nemunas; marine sediments: 13 – Holocene; 14 – Holocene aeolian sediments; 15 – water

Rys. 2. Budowa geologiczna północnej części Mierzei Kurońskiej w okolicach wydmy Vingiakopė (wg KABAILIENĖ i in., 2009):
utwory glacjalne morenowe: 1 – Dainava, 2 – Žemaitija, 3 – Medininkai, 4 – Baltija, 5 – Nemunas; osady glaciofluwialne: 6 – Žemaitija, 7 – Medininkai, 8 – Nemunas; osady glacilimniczne: 9 – Žemaitija, 10 – Medininkai, 11 – Baltija, 12 – Nemunas, 13 – osady morskie holocenu, 14 – osady eoliczne holocenu, 15 – woda

Рис. 2. Геологическая структура северной части Куршской косы в окрестностях дюны Вингякопе (по: KABAILIENĖ и др., 2009):
Гляциальные отложения (морены): 1 – Дайнава, 2 – Жямайтия, 3 – Медининкай, 4 – Бальтия, 5 – Нямунас; флювиогляциальные отложения: 6 – Жямайтия, 7 – Медининкай, 8 – Нямунас; гляциолимнические отложения: 9 – Жямайтия, 10 – Медининкай, 11 – Бальтия, 12 – Нямунас; 13 – морские отложения голоцена, 14 – эоловые отложения голоцена, 15 – вода

The evaluation of the Main Dune Ridge forms of aeolian relief and their extension was based on the geodetic and photographed methods from 1999–2003. Has been described all macro-rank (positive and negative), meso-rank (positive), micro-rank (positive and negative) and intermediate aeolian relief forms. The macro-rank positive forms are dune ridge (protective along sea-shore and main dune ridges); positive meso-rank forms are ridges, sand tongues, rollers, dome-shaped, humps, scrap and negative meso-ranks forms are depressions, potholes, ravines, gullies, tunnels (corridors); positive micro rank forms are ripples, corrosion remnants; micro-barchans; intermediate forms are steps, gates, slopes. The micro-rank relief forms like ripples (according to R BAGNOLD, 1941) it is subject to certain conditions crest. According V. MINKEVIČIUS (1968), the Curonian Spit dunes has large ripple, which is not very high. The average height is 10–15 cm and the distance between the crests varies between 22 or 13 cm. Large ripple formation occurs in conjunction with a damp or wet surface. Deflation-corrosion micro-forms and meso-forms are at least stable. They often found in the top of the ridge, or crest, where fracture takes place between the windward and leeward slopes. When deflation-corrasion micro-form achieve 1 m, it is already became a meso-form (MINKEVIČIUS, 1968) (phot. 2).

In early publication, which based on 1998–1999 investigation (MORKŪNAITĖ, ČESNULEVIČIUS, 2005) deflation depressions (negative meso-form) grouped according to morphological types. There were mapped more than 50 those structures. Deflation depressions are mostly displaced in the western part of the Main Dune Ridge and are enough changeable.

A.

B.

C.

D.

Photo 2. Transformation of micro- and meso-forms by aeolian processes in Main Dunes Ridge: A – the small ripples in winter, 2015.01, B – the aeolian hump in winter, 2015.01, C – deflation remnant near Naglis Dune, 2014 m, D – corrasional processes in barchan dune near Sklandytojai Dune, 2016. 02 (all photos by R. Morkūnaitė)

Fot. 2. Transformacja mikro- i mezoform rzeźby eolicznej w głównym pasie wydmowym: A – małe ripplemarki zimą (styczeń 2015 roku), B – mały deflacyjny garb eoliczny zimą (styczeń 2015 roku), C – ostaniec deflacyjny w pobliżu wydmy Naglis (rok 2014), D – procesy korazji na grzbiecie barchanu w pobliżu wydmy Sklandytojai (rok 2016) (wszystkie fotografie: R. Morkūnaitė)

Фот. 2. Преобразование микро- и мезоформ эоловыми процессами на главном дюнном хребте Куршской косы: А – эоловая рябь зимой – январь 2015, В – небольшой эоловый дефляционный бугор зимой – январь 2015, С – дефляционный останец поблизости дюны Нагляй, 2014, D – корразионные процессы на бархане поблизости дюны Скландитояй – февраль 2016 (все фотографии: Р. Моркунайте)

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THE WIND SPEED REGIME AND WIND DIRECTION

According to *Climate Atlas of Lithuania* (2013) in Curonian Spit are on the average 60 days per year when winds in Klaipėda are stronger than 15 m/s and there are 40 such days in Nida. There are on the average 15 days per year in Klaipėda when wind is stronger than 20 m/s.

The wind cases are determined over the period from 2003 to 2014 according to the data of Klaipėda and Nida stations. Only the winds in March and October which speed ≥ 6 m/s were analyzed (fig. 3).

The prevailing wind directions were WSW (16.8 percents), W (14 percents), E (2.7 percents), S (3.7 percents). Such are of 13.7 percent of all winds cases. The number of days with higher than 15 m/s wind speed was 55. The last decade was "softer" than the period 19 93–2002 when there were 63 such days or the period 1981–1990 when there were 75 such days.

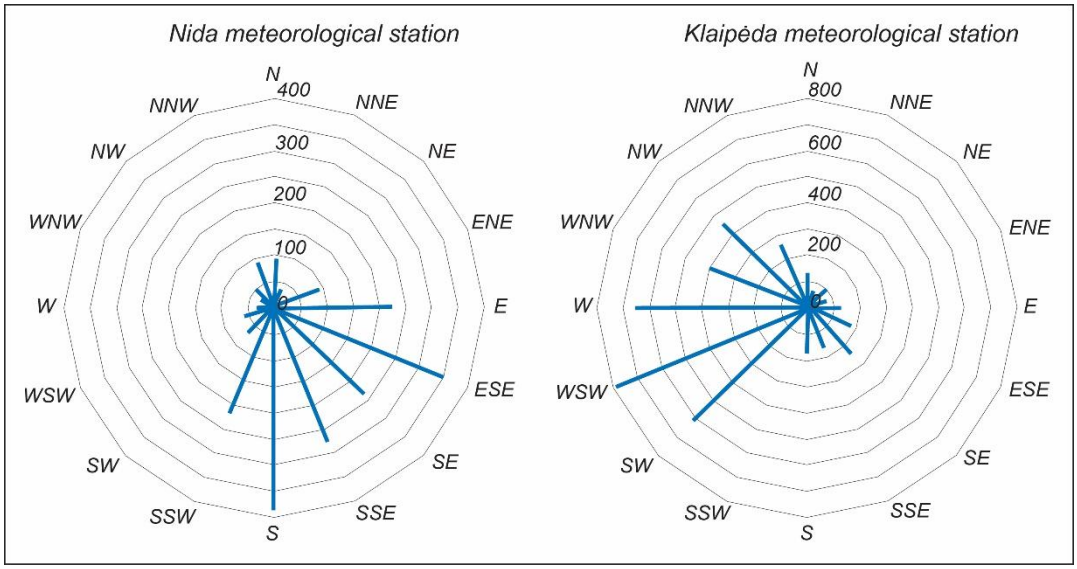

Fig. 3. The wind regime in Nida and Klaipėda meteorological stations in 2003–2014 (cases when wind speed was ≥ 6 m/s)

Rys. 3. Reżim wiatru na stacjach meteorologicznych Nida i Kłajpeda w latach 2003–2014 dla prędkości wiatrów ≥ 6 m/s

Рис. 3. Ветровой режим на метеостнциях Нида и Клайпеда в период 2003–2014 для скоростей ветра ≥ 6 м/с

THE DYNAMICS OF ONE OF THE BIGGEST DUNE

The repeated spring and autumn measurements were done in the selected Vingiakopė cross section (fig. 4). The first measurements started in June, 2003, the second measurements in May, 2014. We see that after 11 years the surface on the windward slope of the dune just before the peak (about 51.00 m a.s.l.) flattened, after the peak it stepped with accumulation focuses and in the leeward slope it lowered by 1 meter. At the foot of the Vingiakopė western slope we see the retreat by 0.5 meter from the lagoon. In June, 2003 and in October, 2003 the drift of the eastern slope towards the Curonian lagoon was seen in Vingiakopė cross section, but we do not see this after 11 years. The measurements in spring and autumn of 2003 show the concavity and convexity formation in the eastern

slope of after the summer season. This is not reflected in the multi-annual research results, as the slopes are influenced by the winter processes and lagoon ice-hazards, the eastern winds. This dune, unlike the Nagliai (57.33 m according to 2014 data) and Parnidis (53.52 m according to 2013 data) dunes (BAUTRĖNAS, MORKŪNAITĖ, 2016) is less exposed to tourists, so it reflects the changes of the surface more related to natural deflation and accumulation processes. Losses in Vingiakopė dune due to deflation reach -10 124 m^3, while the sand volume added by accumulation comprises +4 592 m^3.

It is obvious that the sizeable changes of dunes shape were in the Main Ridge during 2003–2014 years and need preservation. We suggest to changes network of pathways, to construct more the benchmarks in tourist places. The shape of dunes is less affected when the flows are distributed down a dense network of smaller pathways. It is important to prevent pathways running across dune tops and ridges.

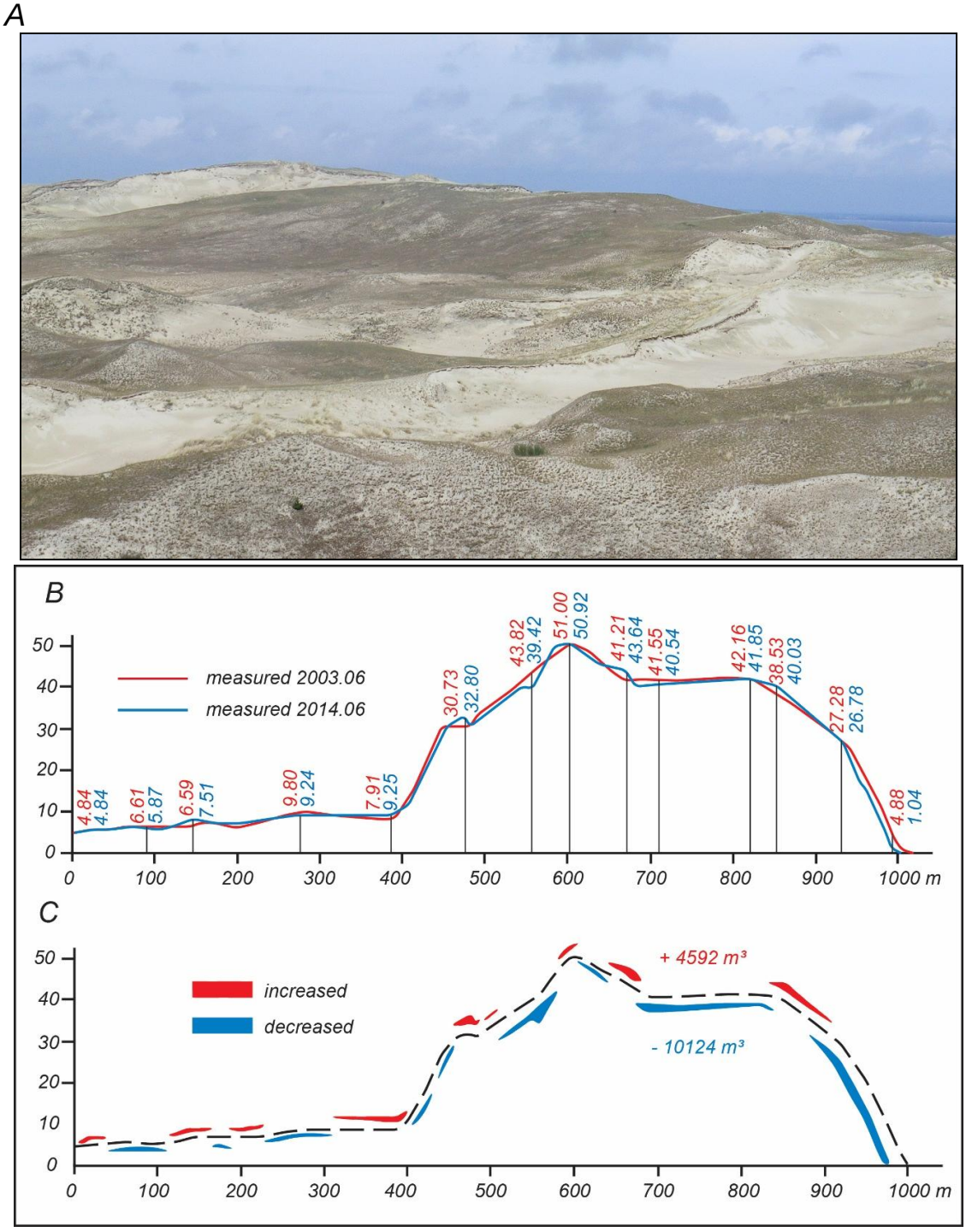

Fig. 4. A – Surroundings of Vingiakopė Dune (phot. by A. Bautrėnas), B – the cross-section in Vingiakopė Dune with the measuring of dynamics changes in 2003–2014, C – the cross-section in Vingiakopė Dune with the data of losses and accumulation of sand in 2003–2014.

Rys. 4. A – okolice wydmy Vingiakopė (fot. A. Bautrėnas), B – zmiana powierzchni wydmy Vingiakopė w latach 2003–2014 w profilu niwelacyjnym, C – bilans powierzchni piaszczystej w latach 2003–2014 w profilu niwelacyjnym

Рис. 4. A – дюна Вингякопе – общий вид (фот.: А.Баутренас), B – нивеляционный профиль через дюну Вингиякопе с измерением динамики за период 2003–2014, C – нивеляционный профиль через дюну Вингякопе – дефицит и аккумуляция песка за 2003–2014 гг.

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CONCLUSIONS

Like other analogical sands bars the Curonian Spit is an ephemeral structure formed in the Holocene due to the combination of many beneficial conditions. Changes of these conditions can destroy the existing ecological equilibrium.

According our investigations in 2003–2014 by precise devices we result that are intensely deflation and accumulation processes of different scale from meso- to micro-rank.

The levelling on Vingiakopė dune show that are the flattening of surface before peak and in western slope are the retreat by 0.5 meter from the lagoon. We think that the reasons of these dynamics case are insufficiently studied.

So it is need more detail microclimatic investigations of coastal dune landscape. Analysis of field investigation results in present understanding of dune processes and a range of ideas for new research possibilities are provided.

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