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BALTICA Volume 19 Number 1 June 2006 : 38-46

Morphometric investigations of the main dune ridge on the Curonian Spit, Lithuania

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Paškauskas, S., 2006. Morphometric investigations of the main dune ridge on the Curonian Spit, Lithuania. *Baltica, Vol. 19 (1), 38–46.* Vilnius. ISSN 0067-3064.

Abstract The main dune ridge of the Curonian Spit (in Lithuanian – Kuršių Nerija) stretches in the Lithuanian part of the spit not continuously. It is composed of four sectors of different length, from 1.2 up to 31.4 km, which are oriented in N–NE direction and occupies the eastern part of the spit, extending along the Curonian Lagoon (in Lithuanian – Kuršių Marios). The total length of ridge is 44.3 km. It extends at an average distance of 0.94 km westwards from the Baltic Sea coast. The average absolute altitude of the ridge is 32.5 m and width is 661.6 m. The asymmetry coefficient is 1.32. The links between morphometric indices were evaluated by correlation coefficients, which range within 0.15–0.66 at probability $p<0.05$.

Keywords *Curonian Spit, dune ridge, morphometric analysis, Lithuania.*

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Manuscript submitted 23 May 2006; accepted 15 June 2006.

INTRODUCTION

The greatest dune massifs of the world are concentrated in arid and semi–arid domains (Lancaster 1995). Yet the geographical distribution of aeolian forms goes beyond the limit of arid zones. They occur on the ocean and seacoasts and in the coastal plains from equator as far as the Arctic latitudes (Lancaster 1995; Carter *et al.* 1990). Reworking the abundant accumulations of unconsolidated sand, the wind shapes a specific morphological relief characterized by a great variety of aeolian forms (Lancaster 1995; Pye & Tsoar 1990).

The aeolian forms of relief occur also on the Baltic Sea coasts. They are especially widespread in the south-eastern coast including the Curonian Spit, where lies the main dune ridge that is the longest in the Baltic Sea. The ridge extends almost along the whole spit. Its dunes are among the highest in Europe yielding only to the great Pyla Dune in the coast of the Bay of Biscay towering 115 m above the surface (Mader 1995). Carter and other researchers (Carter *et al.* 1990) point out that it is difficult to define the aeolian relief as it stands out for a chaotic character. This is especially true of coastal dunes highly varying in size and type. Morphometric investigations can be helpful in this respect. The height, length, width and other indices of aeolian forms expressed in quantitative characteristics are the most informative and objective ones. On their basis, the problems of migration, stability, classification, etc. of the aeolian forms can be solved (Evans 2003; Hesp & Hastings 1998; Sauermann *et al.* 2000). As regards the main dune ridge of the Curonian Spit, only its height and slope shift have been so far emphasized (Minkevičius 1982; Česnulevičius, Morkūnaitė 1997). A broader spectrum of morphometric characteristics is lacking.

The necessity to fill the gap of morphometric information about the impressive dune ridge of the Curonian Spit was the aim of the present studies. Morphometric characteristics of the Lithuanian part of the ridge, the regularities of dune transformation and the interrelations between the length, width and height of the dunes are the main topics of the present work.

METHODS

The topography studies of the Earth surface require data about the length, width and height of its forms. Without them comprehensive studies of relief geometry are impossible (Pike 2000). Performing measurements in the natural environment and deriving them from air photographs and cartographic material collect the mentioned data.

The morphometric data about the main dune ridge were taken from topographic maps (1:25 000) compiled in 1955; the readings of altitude and horizontal component have been spaced every 250 m across the ridge, perpendicular to the coast line. The exposure of the ridge to the marine and lagoon coast was evaluated by measuring the distance between the ridge bottom and the coast.

The topography of the ridge is defined based on the following geometrical parameters of forms: height of the dune crest (H), length of the declivous slope (L_W), length of steep slope (L_S), width of the ridge base (W), and width of the crest (W_C). The cartography data were used for calculation of the slope angle (λ = tanH/L), asymmetry of the form of vertical section (K_A = L_W/L_S) and coefficient of the planar form of ridge crests in the horizontal section ($K = d_1/d$, where d_1, d – maximum and minimum diameter). Furthermore, the vertical (amplitude of relative relief variations) and horizontal (distance between the relief elevations) structural components of the ridge were evaluated. Each morphometric character is expressed in statistical values: minimum, maximum, average value, standard deviation, and asymmetry coefficient. The links between morphometric characteristics are expressed in correlation coefficients. The significance of the latter was estimated by Pierson's criteria at a probability value $p<0.05$.

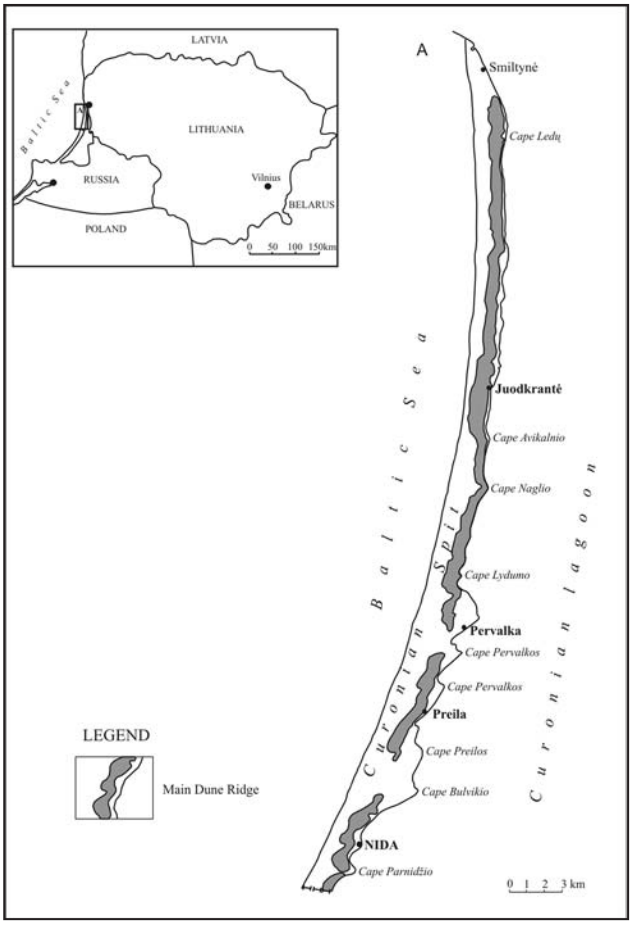

Fig. 1. Main dune ridge on the Curonian Spit.

LOCATION OF THE MAIN DUNE RIDGE

There are two dune ridges on the Curonian Spit. One of them is composed of the fore-dune extending along the sea shoreline at a distance of beach width. The second one, known as the main dune ridge, is considerably higher, of 70 km long, extending along the whole eastern Curonian Spit rim across the its Lithuanian and Russian parts. In the northern, Lithuanian, part the ridge extends of 44.3 km from south to north up to the Smiltynė settlement (Fig. 1).

The main dune ridge (further – D_k) is a morphologically heterogeneous aeolian landform. It is dissected by a few breaches. The length of continuous ridge sectors and the width of breaches differ considerably (Table 1).

The breaches almost coincide with the spit capes. V. Gudelis (1998) assumes that there is a direct link between these spit elements, and the formation of breaches affects the dynamics of the eastern coast of the spit. The dune ridge also is heterogeneous in terms of morphodynamics. Active aeolian processes go on in some of the dunes at the Juodkrantė–Preila sector and south of the Nida settlement. The total length of morphodynamic active dune ridge is 11.2 km. The remaining part of the ridge (74.7%) is protected from the aeolian modification by plant cover.

Investigations of the spit relief (Gudelis 1960; Gudelis 1989–1990) show that due to aeolian processes, the ridge used to be replenished by sand supplies from the sea-side and gradually moved eastwards. Due to different causes, this process was synchronous neither temporally nor spatially. Therefore, the (D_k) unevenly receded from the sea coast. Today some western segments of the ridge lie closer or farther from the sea. These segments are separated by the spit plain of different width varying from 0.10 up to 1.80 km. The average distance of the ridge from the sea coast reaches 0.94 km. Some ridge segments, what at present are rather close or rather far from the sea coast, account only 6% of the ridge length. The greater part of the ridge (over 2/3) extends at a distance of 0.5–1.2 km from the sea coast (usually – from 0.75 up to 1.0 km). The dispersion of data is close to the normal density law (Fig. 2). The distance variation along the spit is rhythmic. The variability curve is nearly a sinusoid.

Table 1. The length of continuous ridge sectors and the width of breaches.

Ridge sector		Ridge breach	
Location	Length, km	Location	Width, km
South of Nida	1.2		
Nida	4.9	Parnidis Cape	0.08
Preila–Pervalka	6.8	Bulvikis Cape	2.2
Pervalka–Smiltynė	31.4	Pervalka Cape	1.3

The ridge comes closest to the sea in the vicinities of Juodkrantė (0.1–0.4 km) and Nida (0.6–0.8 km) settlements. It is farthest from the sea coast in the northern part of the spit (up to 1.0–1.2 km). South of Juodkrantė the distance is 1.1–1.5 km, and in the vicinity of Pervalka it ranges within 1.3–1.6 km.

A similar pattern can be traced on the eastern side of the ridge. About 18% of the ridge comes nearby to the coast of the Curonian Lagoon and is separated from it only by a narrow, a few metres wide beach. This is typical for straight coast sectors. At the capes, the distance between the ridge and the lagoon increases to a few hundred metres, in some places even up to 1.5–2 km. The greater part of the ridge (68%) is separated from the lagoon by a narrow, up to 0.25 km wide strip of the land (Fig. 2). The average distance from the lagoon coast is 0.24 km, i.e. over three times smaller than the distance from the sea coast. Due to specific distribution pattern of the data it is more relevant to give other characteristics, describing the data centre median, which equals to 0.13 km.

The azimuth of the D_k extending along the eastern part of the spit is comparable to that of the spit itself because a comparatively narrow strip of the land, up to 3.8 km in width, limits the possibility of meandering. The uneven distance from the sea implies the varying direction of the long axis of the ridge. Dissection of the ridge into uniformly oriented sections in terms of azimuth shows that the long axis of the ridge resembles a broken line rather than even semicircle of the shoreline. It should be noted that the azimuth of Lithuanian part of the Curonian Spit, measured along the sea shoreline, varies from 352–357° in the northern part to 25–29° in the vicinities of Nida. The resulting direction is almost 12°. The azimuth of dune ridge (according to the steep eastern slope) varies within a wider range from 308° to 48°. The range of direction shifts from NW to NE is 100°. In the northern part of the spit, till the Nagliai Cape the ridge axis line is zigzag-like, i.e. the NW and NE rhumbs alternate. Southwards from the Nagliai Cape, the ridge orientation is uniformly NE. These variations are closely linked with striking of the spit. The NW and NE oriented ridge segments are unevenly distributed but the NE direction is being the dominant (65%). The average azimuth of NE oriented segments is 24° and of NW is 342°. The resulting general azimuth of the ridge is 6° differing from the spit azimuth almost twice. The ridge azimuth changes every 1.8 km on the average.

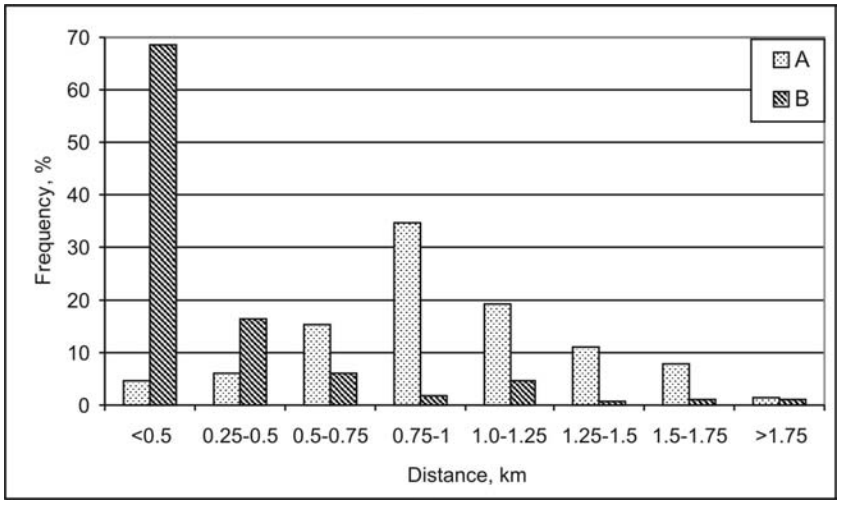

Fig. 2. Distribution histogram: the distance between the ridge and the seacoast (A), and between the ridge and the lagoon coast (B).

MORPHOMETRIC PARAMETERS

Delineation of the dune ridge

Identification of the ridge is an easy task because it is situated on a plain surface up to 10 m above the sea level (a.s.l.). The western border of the ridge begins at a height of 5–10 m by a gradual elevation of relief. Between Smiltynė and Juodkrantė its altitude varies within 7.5–10 m, and the average height is 8.8 m. In the sector Juodkrantė—Pervalka the foot of the dune ridge goes down to 5 m. In the Juodkrantė—Preila sectors the base rise till 10 m, and from Nida towards the area of blown dunes it is again lowering. The average altitude of the western foot of the ridge is 7.3 m. The eastern boundary of the ridge is usually marked by an abrupt change of relief inclination. The altitude of the eastern foot somewhere reaches 7.5–10 m and varies along the ridge following almost the same pattern as that of the western foot with the

only difference that it is lower by 1/3. Somewhere the ridge is separated from the lagoon by a wider strip of the land. The dominant foot altitude is 5 m. The eastern foot of ridge closest to the lagoon goes down to 2.5 m and lower. The average height of the eastern foot is 4.9 m, i.e. by 2.4 m lower than the western one.

The main body of the ridge begins at an average altitude of 6.1 m above the sea level. Its width varies from 70–400 m up to 700–1180 m. The narrowest segments of the ridge occur at the deflation gullies, rudiments of breaches, and in places where ridge lowering or ridge azimuth changes considerably. The widest portions of the ridge up to 700–1180 m (the average width is 920 m) occur at Juodkrantė where two generation of dunes join (Paul 1944; Minkevičius 1982). The sector of old parabolic dunes on the lagoon side is 4.1 km long and 350–800 m wide (the average width is about 500 m). It is in some places wider than the adjoining ridge of the younger generation. A slightly narrower (760 m) ridge with an adjoining fragment of parabolic dunes is situated at Nida. In this area, the old dunes compose a small 1.6 km long and 250–300 m wide sector.

The width of the blown dunes ranges within 470–810 m. The narrowest section of the ridge is situated between the Avikalnis Cape and the Nagliai Cape, where its width does not exceed 470 m. At the Lydumas Cape the ridge widens up to 800 m on the average. South of the Parnidis Dune its width reaches 680 m. The distribution pattern of width is rather small (variation coefficient is 0.27). The length of very narrow (<0.4 km) and very wide (>1 km) sectors is rather evenly distributed. The dominant width is 600–800 m. Its distribution is comparable to Gauss curve (Fig. 3). The average width of the main dune ridge is up to 660 m.

According to cartography data, the relative relief of the ridge ranges from 10 m up to 67 m a.s.l. In the lowest places, its relative height does not exceed 5 m. The relative height of blown dunes differs up to three times. The differences are distinctive of blown and forested dunes. The lowest blown dunes are concentrated in the Avikalnis—Nagliai sector, where their average altitude is 26 m. The ridge becomes gradually higher moving to the south, reaching the average height of 35 m a.s.l. in the sector between the Naglis Cape and Libis Bay. It is even higher in the environs of the Nagliai Bay. Similar average height of 43 m a.s.l. occurs also south of the Nida sector of blown dunes. The average altitude of blown dunes is 37 m.

The forested ridge sector between Smiltynė and Juodkrantė also is gradually elevating: from 25.8 m in Smiltynė to 35.3–36.4 m a.s.l. at Juodkrantė. The average altitude of this sector is 31 m, but in the Pervalka—Preila sector increases up to 33 m a.s.l. The differences of altitude in this sector also increase from 22.5 m up to 44.6 m. The altitude of stable dunes in the environs of Nida settlement decreases to 24 m. The average altitude of the whole ridge is 32 m a.s.l., i.e. half of the relative height of the highest dune. The relative relief of the ridge is 26 m above the spit plain surface. The altitude of the greater part of the ridge (>80%) belongs to the interval of 20–50 m a.s.l. The altitude of the remaining part (37.1%) is within an interval of 30–40 m a.s.l. The altitude data are distributed following the normal distribution pattern (Fig. 4).

The ridge crest profile is flat or slightly convex. Only the crests of blown dunes are a bit more pointed. The crest width ranges in different sectors from 73 to 132 m. The crest width of forested dunes reaches up to 94–160 m; the average width is 118 m. The width of the crest in the greater part of the ridge (70%) is up to 150 m.

The length of the crests and azimuth were measured along the long axis. The width of the crest was measured along the short axis. Due to extremely large length of one of the dune crests this value was not included into statistical calculations. The sector of the dune ridge at Alksnynė reminds a mound. The 170–180 m wide flat crest extends for 1100 m. The sector is the only of this kind in the ridge.

The length of more than 50% of crests ranges within 70–170 m and the width within 40–80 m. The average crest length is 130 m and the average width is 62 m. The form of the planar surface of the crests varies from almost circular (K=1.11–1.5) to very elongated strip–like (K=4–6.80). The average value K=2.08 shows that the planar form of the crests resembles an elongated ellipse. The almost circular crests account for 16%. They are concentrated in the northern part of the ridge. The ellipse–shaped crests (K=1.5–2.5) are dominant (58%).

The orientation of crests along the ridge is varying. No direction can be pointed out as dominate. According to calculations, 30% of crests are oriented NNE–ESE

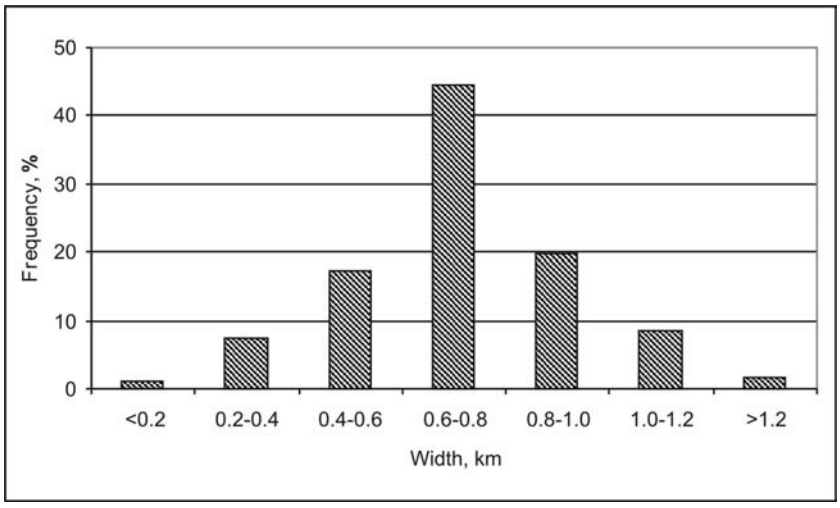

Fig. 3. Distribution histogram of the ridge width.

(67.5–112.5°). The crests extending in meridional and sub-meridional direction account for 25%. The high variation of crest exposition (variation coefficient 0.64) implies that the ridge surface is affected by winds of different directions. It cannot be denied that the exposition of dune crests also depends on the directions and velocities of winds at the air–ground interface. This is confirmed by field and aerodynamic modelling data (Frank & Kocurek 1996; Momiji *et al.* 2000; Walker 1999).

Slope length and angle

The situation of the ridge and its meridional orientation show that it was formed by dominant western winds. They also predetermined the differences of slope length and angle. The slope length (western and eastern) range within similar intervals: from a few tens up to 600–660 m. Their average length and distribution value differ (Table 2). The western slope is by about 70 m (on the average) longer than the eastern slope. Their length ratio is 1.3. The little difference in length allows assuming that not only the western but also the eastern winds play an important role in ridge morphology. After elimination of extreme values, the length variation amplitude of the western slope reduces to 150–450 m. The distribution pattern of the data is comparable to Gauss curve (Fig. 5). The dominant length of the western slope (400 m) is characteristic of almost half of the ridge (41%). Similar distribution pattern of length data (slightly lower values) is also representative for the eastern slope. The modal length of the slope (200–300 m) accounts for 36%. The difference between it and the adjoining length intervals is not big. The distribution patterns of both slopes are comparable but the length values of the eastern slope are slightly lower. The eastern slope is also characterized by greater asymmetry of data (Fig. 5).

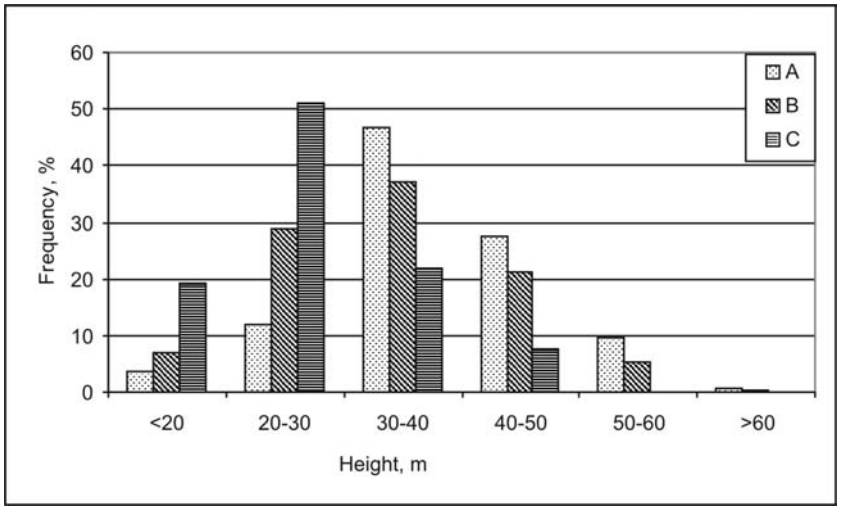

Fig. 4. Distribution histogram of ridge altitudes: A – crests, B – declensions, C – stationary measuring points (spaced 250 m).

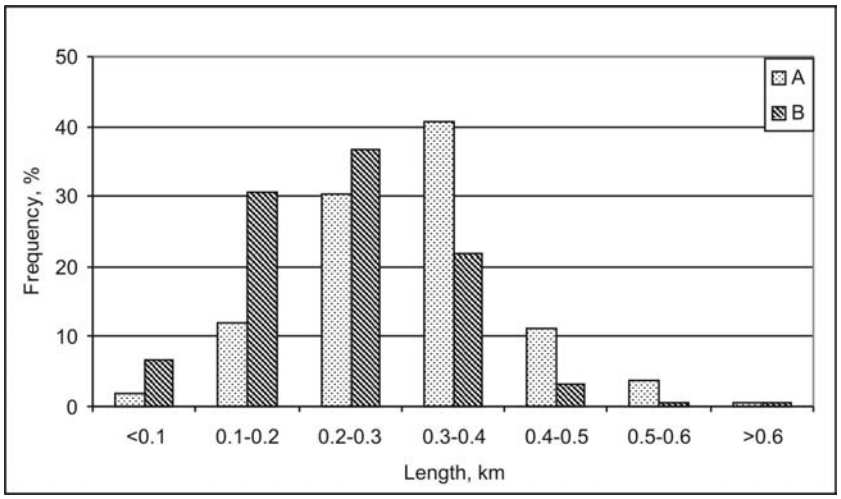

Fig. 5. Distribution histogram of ridge slope length: A – western slope, B – eastern slope.

The length of the western slope of blown dunes varies from 240 m at the Avikalnis and Nagliai capes up to 390–400 m in the environs of Lydumas Cape and south of Nida. The average length of the windward slope of blown dunes is 340 m. The length of the eastern slope varies following a similar pattern – from 138 to 275 m; the average depth is 210 m. The ratio of the length of eastern and western slopes is 1.62.

The length of the western slope of reinforced dunes ranges within 125–340 m and the eastern from 75 m up to 315 m. In the Juodkrantė—Smiltynė sector, the planted slopes are longer (western 295 m, and eastern 265 m) than the blown dune slopes south of Pervalka, where the length of the slopes is 254 m and 196 m, respectively. The average length of the planted western slope is 274 m and eastern 230 m. The ratio of the slope length is 1.19. Due to aeolian processes, the western slope is lengthening as the upper part of dunes is reducing. The western slope of blown dunes is by 20% longer and eastern by 9% shorter than the slopes of planted dunes.

The windward slopes of the aeolian relief are longer and have smaller angle than the leeward slopes. In blown dunes the angle of windward slopes may reach 30–34° (Lancaster 1995). Similar slope angle is possible in the blown sectors of the main dune ridge.

Table 2. Statistics of analysed parameters* of the main dune ridge of Curonian Spit.

	L_S	L_L	L_W	L_E	H	W_C	S_W	S_E	W	K_A
Min	100	5	40	30	10	30	1.3	2.5	190	0.33
Mean	935.6	235.2	304.4	235.1	32.5	118.0	5.2	7.5	661.6	1.32
Max	1800	1490	630	660	65	365	10	22.4	1120	5.56
Median	890	127	310	230	30	110	5.2	6.3	680	1.34
S_{dev}	360.1	294.4	99.8	103.2	9,3	62.9	1.7	4.0	165.0	0.84
Skew	0.31	2.20	0.23	0.94	0.30	1.12	0.11	1.46	-0.19	1.77

* L_s – distance between the sea shoreline and the ridge (m); L_L – distance between the lagoon shoreline and the ridge (m); L_W, L_E – length of the western and eastern slopes (m); H – absolute altitude of the ridge (m, a.s.l.); W_C – width of the ridge crest (m); S_W, S_E – gradient of the western and eastern slopes (degrees), W – ridge width (m); K_A – asymmetry coefficient of the ridge.

The average slope angle of the ridge ranges from 3–6° on the windward side up to 5–12° on the leeward side. The varying density of contour line shows that the slope angle varies along the slope. In the lower part of the western slope of planted dunes the angle is 2–5°, in the middle part it increases up to 5–8°, and in some Preila and Nida dunes it reaches10–11°. Toward the crest the slope angle reduces to 3–6°. The eastern side of the ridge is steeper and the angle along the slope is even. Often the slope angle between the bottom and the middle part does not change ranging within 5–15° and may reach 18–25° in some dunes. The upper part of the eastern slope is easy (4–6°). The slope angle in different parts of the ridge varies: in the Smiltynė—Juodkrantė sector the dune slopes are gently dipping (western – 4.6°, eastern – 5.8°), whereas in Nida and Preila they are a bit steeper (4.8° and 7.5° respectively).

The angle of the lower part of the windward slope bottom varies from 3–4° (in the Juodkrantė—Pervalka sector) to 6° (the slope of Sklandytojų Dune). In the middle of the slope, the angle increases to 5–8° and in the upper part it reduces to 4–7°. The angle of the windward slope and its variations along the slope are comparable to the slopes of barchans (Hesp & Hastings 1998). The eastern slope is considerably steeper. Its angle in the sector of blown dunes ranges from 6–14° to 18–27°. The average angle of windward slope of blown dunes is 5° and leeward slope 10°.

Asymmetry of the ridge

The average value of asymmetry coefficient of the ridge (K_A) is 1.32. This value shows that its form is not an isosceles triangle. This coefficient varies from 0.93 to 3.18 in different ridge sectors, and its symmetric also differs with respect to the western and eastern slopes. This means that asymmetry is not characteristic of the whole ridge. There are sectors with cross sections of isosceles triangle or regular trapezium. There are few ideally symmetrical ($K_A = 1$) ridge sectors (they account only for 2.4%), and the sectors where (K_A) variations are small (0.9–1.1); they account together for about 10% of the ridge length.

The eastern asymmetry ($K_A < 1$) (when the western slope is shorter than the eastern one) accounts for 12 km of the ridge (28%). The eastern asymmetry and symmetric profile are distinctive for the northern part of the ridge (Smiltynė—Juodkrantė sector). Solitary cases of eastern asymmetry and symmetric profile occur in the Preila and Nida dunes. The dunes of this profile are forested. Contemporary the asymmetry of blown dunes (K_A) ranges within 1.6–1.8.

Vertical and horizontal sections of the relief surface

The width and height of the crest vary along the ridge and the surface assumes a wavy conformation. The vertical elements of the relief can be established counting the minimum and maximum altitudes of the surface. The highest spit dunes are towering 50 m and more above the sea level. The highest one is the Senosios Smuklės dune with altitude 67.2 m a.s.l.

The altitude of the crests of the main dune ridge varies from 15 m to 67.2 m. The dominant altitude (47%) of crests is 30–40 m, and the average maximum of absolute height is 36.1 m (Fig. 4). The minimum altitude of the ridge coinciding with the declensions between the crests ranges within 10–45 m. More than half of the declensions occur at a height of 20–30 m. This interval includes the average altitude (Fig. 4). The average absolute altitude of declensions is 25.8 m. It also represents the average altitude of the ridge as a continuous aeolian body. The difference between the crest altitude and declensions is 10.3 m. This is the maximum value of vertical dissection of the ridge surface.

The spaces between the crests vary from 50 to 1200 m. The dominant (70%) distance is about 100–500 m. The crests extremely far away from each other occur rarely. The data pattern reveals of bimodal distribution. The mode of 100–200 m stands out. It accounts for 25% of all measured distances. The mode of 300–400 m accounts for 24%. This distribution pattern is related with the differences of crest diameter. The smaller crests are spaced more densely than the dome-like larger crests. The distance between

Table 3. Correlation coefficients of analysed parameters* of the main dune ridge of Curonian Spit.

	L_S	L_L	L_W	L_E	H	W_C	S_W	S_E	W	K_A
L_S	1,00	0,26	-0,46	-0,35	-0,40	-0,18	-0,09	0,05	-0,71	0,05
L_L		1,00	-0,18	-0,05	-0,08	-0,03	0,02	-0,15	-0,14	0,03
L_W			1,00	0,21	0,57	-0,10	-0,29	0,18	0,66	0,41
L_E				1,00	0,30	0,01	0,11	-0,60	0,58	-0,64
H					1,00	-0,01	0,51	0,38	0,51	0,01
W_C						1,00	0,04	-0,01	0,22	-0,09
S_W							1,00	0,11	-0,04	-0,35
S_E								1,00	-0,19	0,65
W									1,00	-0,06
K_A										1,00

* See Table 2 for definitions of variables.

the crests considerably varies in different sectors. In the Juodkrantė—Pervalka sector of blown dunes the crests are spaced at distances of 250–280 m. In the Smiltynė—Juodkrantė sector of forested dunes they are spaced 206–430 m on the average. South of Pervalka, they are distributed sparsely. The average distance between the crests is up to 490 m. The variations of the distance between crests are conspicuous what is proved by a high variation coefficient (0.61). The average distance between the ridge crests is 318 m. It reflects the horizontal dissection of the ridge.

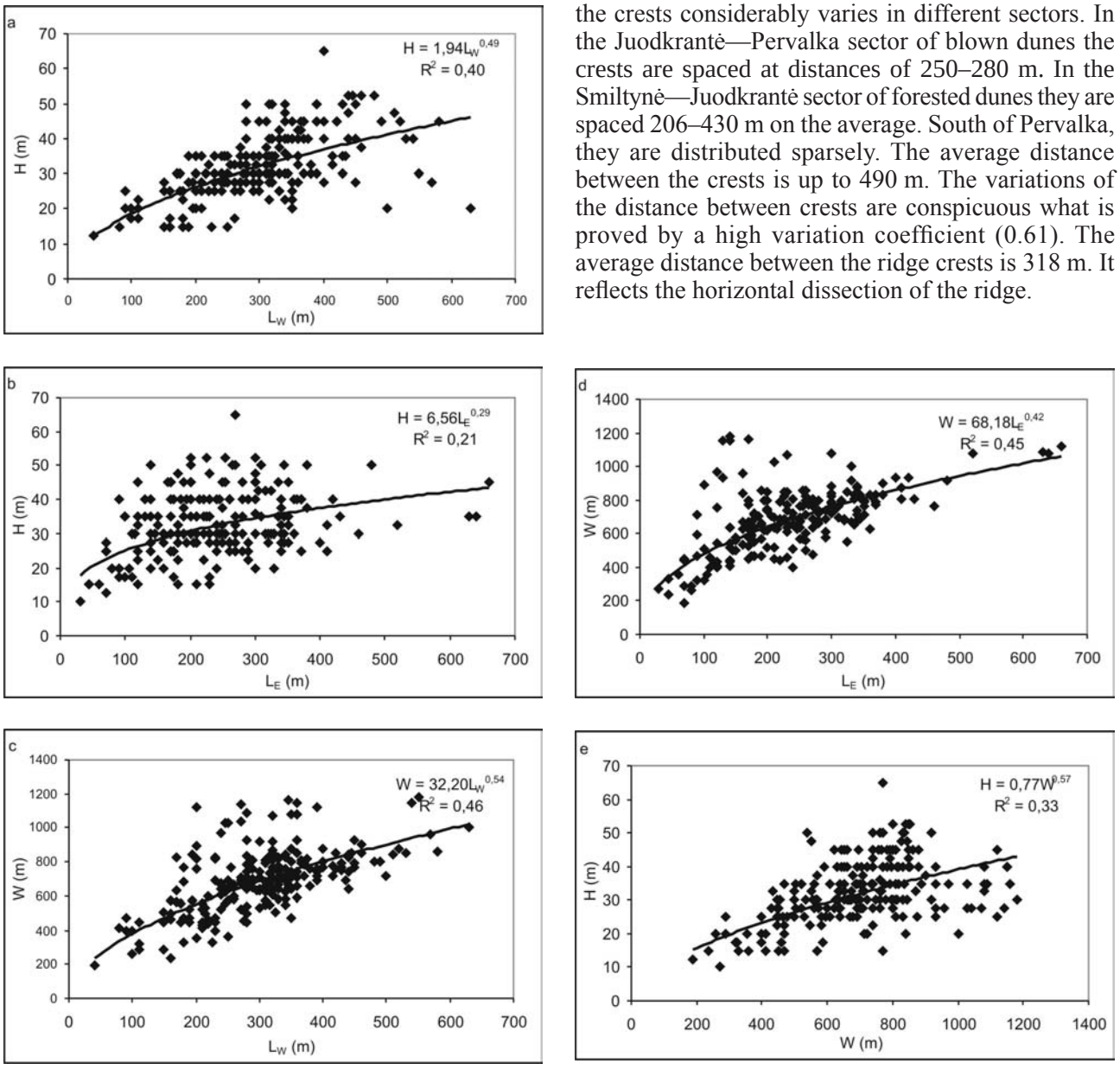

Fig. 6. Relations between the morphometric parameters of the dune ridge: a – altitude (H) and length of the western slope (L_W), b – altitude (H) and length of the eastern slope (L_E), c – width. (W) and length of the western slope (L_W), d – width (H) and eastern slope (L_E), e – altitude (H) and width (W).

Table 4. Regression equations reflecting the ratio between the distance from the sea (L_S) and the dune ridge and morphometric parameters of the ridge: length of the western slope (L_W), length of the eastern slope (L_E), altitude (H), width (W).

Relation	Type of analysis	R^2	Description	Equation
L_W vs. L_S	Linear	0.15	Relatively weal	$L_W = 405.06-0.11x\ L_S$
	Logarithmic	0.05	Relatively very weak	$L_W = 581.48-40.98x\ln(L_S)$
	Power	0.06	Relatively very weak	$L_W = 945.84xL_S^{-0.18}$
L_E vs. L_S	Linear	0.13	Relatively weal	$L_E = 338.07-0.11x\ L_S$
	Logarithmic	0.06	Relatively very weak	$L_E = 627.90-57.74x\ln(L_S)$
	Power	0.08	Relatively very weak	$L_E = 1557.58xL_S^{-0.29}$
H vs. L_S	Linear	0.12	Relatively weal	$H = 41.08-0.01x\ L_S$
	Logarithmic	0.05	Relatively very weak	$H = 59.40-3.98x\ln(L_S)$
	Power	0.07	Relatively very weak	$H = 89.92xL_S^{-0.16}$
W vs. L_S	Linear	0.54	Relatively strong	$W = 1064.67-0.39x\ L_S$
	Logarithmic	0.44	Relatively medium	$W = 2329.43-242.29x\ln(L_S)$
	Power	0.38	Relatively medium	$W = 7584.72xL_S^{-0.36}$

Interrelation of the morphometric parameters

The data of morphometric parameters of the main dune ridge are summarized in Table 2. They show that the ridge is a large morphometrically heterogeneous aeolian landform. A correlation matrix was compiled for determining the interdependencies of morphometric parameters (Table 3). The obtained data show that only half of the interdependencies are significant. The minimal value of significant correlation coefficient (at $p<0.05$) is $|r|>0.14$. The length of the western slope is the dominant morphometric factor of the ridge. It is best correlated with the altitude, width and asymmetry coefficient of the ridge. According to correlation values the links can be estimated as weakly to averagely positive. The correlation with the length of the eastern slope is weaker (Table 3). The weak correlation is related to the size of the studied form and unevenness of its surface. For example, analogous correlation links of small solitary barchans are close to the unity, i.e. are very close and positive (Abbas 2002).

The dependence of the morphometric parameters of the ridge on the distance from the sea is simplex, i.e. negative. It is weak in majority of cases and stronger only with the width parameter. Moving away from the sea the ridge is lower and narrower along its whole length (with rare exceptions).

The analysis of correlating morphometric parameters: the linear, logarithmic and rate equations most excellent express the morphometric relations (Table 4). The altitude, width and slope length of the ridge are non-linearly interlinked. Their interdependence is better approximated by logarithmic and rate equations. Though the determination coefficient (R^2) of these equations is by 1.2–2.1 times higher than the linear regression, it is not high due to data dispersion (Fig. 6a-e). The relation between the morphometric parameters and distance from the sea is best represented by a linear equation (Table 4). This means that without sand transport from the sea beach the ridge recession from the sea took place in some sectors due to reworking of the western slope by wind, what affects most the width of the dune ridge.

CONCLUSIONS

The main dune ridge in the Lithuanian part of the Curonian Spit is not continuous or evenly distributed aeolian landform. The length of the continuous parts of the dune ridge (four parts are distinguished) varies from 1.2 km up to 31.4 km, and breaks between them are from 0.8 up to 2.2 km wide. The main dune ridge consists of the stable and mobile parts of meridional–sub-meridional direction. The distance from the sea coast and the main dune reaches up to 0.94 km.

The dune ridge morphometric parameters range within a wide amplitude, and variation coefficient varies from 0.27–0.60, which is predetermined by different sand supplies, unevenness of aeolian processes, plant cover and other factors. The statistical average of morphometric characteristics of the ridge is the following: asymmetry, wide slightly concave crest, width – 661 m, absolute altitude – 32.5 m a.s.l., relative altitude – 26.4 m, slope angles are of 5.2–7.5°, slope length – 235–304 m, the crest is dissected by declensions occurring every 318 m.

The ratios of morphometric parameters of the dune ridge are in weak correlation. The closest link exists between the morphometric parameters of the ridge and the length variations of the western slope. There is a negative linear dependence between the ridge morphometry and (it is significant only with some parameters) and ridge distance from the sea coast.

Acknowledgements

The author is very grateful to the reviewers Professor Vitalijs Zelčs, Latvia, and Dr. Gintautas Žilinskas, Lithuania, for the critical reading of the manuscript and helpful comments. He is also thankful to Ms. Ada Jurkonyte for translation of this manuscript into English and Ms. Julija Vaitkevičienė for preparation of illustrations.

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