since 1961

Baltica
www.geo.lt/Baltica/baltica.htm

BALTICA Volume 18 Number 2 December 2005 : 49-55

Field investigation of dune ridge reinforcement in the Curonian Spit

Darius Jarmalavičius

Jarmalavičius, D., 2005. Field investigation of dune ridge reinforcement in the Curonian Spit. *Baltica, Vol. 18 (2), 49-55.* Vilnius. ISSN 0067-3064.

Abstract The article is based on the field data and is an attempt to find optimal measures for seashore dune ridge reconstruction. Two gullies in the Curonian Spit (Kuršių Nerija) near the Nida settlement were chosen for analysis of the efficiency of their neutralisation measures. In the autumn of 1998 one of the blow-outs was covered with a thick layer of pine branches. The other blow-out was equipped with three rows of shields of planks across it. Both discussed ways of liquidation of blow-outs in the dune ridge yielded positive results. The blow-outs were filled up by sand in a few years. Yet the filling rates in the blow-out covered with branches were twice as high as in the blow-out covered with board shields. Moreover, the first blow-out was filled consecutively from foot to top and its profile was level, i.e., without unnatural breaks. The filling rates in the blow-out with shields were lower, the filling was not consecutive and the forming profile obtained an unnaturally scarping profile.

Keywords *Sea coast, blow-out, aeolic process, Curonian Spit.*

Darius Jarmalavičius [jarmalavicius@geo.lt], Institute of Geology and Geography, Ševčenkos 13, Vilnius 03223, Lithuania.
Manuscript submitted 30 March 2005; accepted 28 November 2005.

INTRODUCTION

The intensifying flow of holidaymakers to the coastal zone is an outcome of the recently improving living conditions in Lithuania. Some seaside health resorts in warm summer days even get overcrowded. The signs of recovery of Lithuanian economy are welcome of course. Yet, on the other hand, there occur new challenges in the sphere of dune ridge protection. The network of deflation forms tangling the dune ridge is especially striking the eye. It is ever thickening and expanding with increasing recreational load. The blow-outs crossing the dune ridge system entail especially adverse consequences. Due to these blow-outs the dune ridge becomes more dissected and the blowing out of sediments from the dune ridge to its rear intensifies. The continuity of the dune ridge is disrupted and leading to its decay. Different measures are applied for liquidation of blow-outs: direct – mechanical covering of blow-outs and reconstruction of the dune ridge – and indirect ones – development of recreational infrastructure and education.

The problems of seashore dune ridge protection and reinforcement have existed since its formation in the Curonian Spit (Kuršių Nerija). Already in the beginning of 20th century German scientists not only studied the development patterns of the dune ridge but also carried out its reinforcement and regeneration works (Gerhardt 1990; Kurz 1904; Musset 1916; Wichdorf 1919). Later on these works were carried on by Lithuanian forest researchers (Daujotas 1940; Daujotas 1958). Yet the measures of dune ridge reinforcement were at that time chosen intuitively without taking into consideration a great number of factors. Little attention was also paid to liquidation of blow-outs in the dune ridge. With an increasing stock of knowledge and technical means the mentioned problem was solved in a more complex way. Its solution is of topical importance in the countries using their dune ridge resources. Special attention was devoted to blow-outs of the dune ridge. Many research works focused on issues of wind field transformation in blow-outs, bypassing obstacles of varying roughness by wind (Olson 1958; Pye & Tsoar 1990; Pluis 1992; Hesp & Hyde 1996; Fraser et al. 1998), occurrence and development of blow-outs (Jungerius et al. 1981; Jungerius 1984; Carter et al. 1990) and dune ridge conservation (Carter 1988; Pye 1990; Olšauskas 1991). Unfortunately, most of the mentioned works considered only certain aspects of the problem. On the other hand there can be no universal solution of the problem due to diversity of patterns in blow-out formation and development predetermined by different hydrometeorological factors as well as varying composition and morphometry of the dune ridge. Due to this the dune ridge investigations are regional in their nature.

The article is based on the field data and is an attempt to find optimal measures for dune ridge reconstruction.

METHODS

Two blow-outs of seashore dune ridge in the Curonian Spit not far from the Nida settlement (Fig. 1) were chosen for analysis of the efficiency of their neutralisation measures. These blow-outs are representative enough for Lithuanian sea coast due to similar hydrodynamic and lithodynamic conditions. The narrow (about 1.5–2.0 m in width) blow-outs of average depth (up to 1.5 m) used to cross the dune ridge and served as a comfortable approach to the sea. Observation of blow-out dynamics since 1995 showed that the form of their profiles – especially in the deepest spot – has remained almost unchanged. The most appreciable transformations were recorded at the dune ridge foot – where phytoaccumulative hillocks have developed – and in the rear – where great amounts of sand have been blown across the blow-outs. The blow-outs acted as a transitory zone which after reaching a profile of optimal equilibrium remained almost unchanged.

In the autumn of 1998 one of the blow-outs was covered with a thick layer of pine branches which were mounting 40 cm above the surface (Fig. 4a). The other blow-out was equipped with three rows of shields of planks across it (1.5×0.8 m) in 2000 (Fig. 5a).

Regular (since 1995) levelling of cross sections had been carried out and wind velocity transformations measured before the experiment. When the blow-outs were supplied with protective covers wind velocity was again measured, wind field changes determined and regular levelling of the cross sections continued till 2004. Wind velocity was measured at heights 0.2, 0.5, 1.0, 1.5, and 2.0 m (Table 1).

Shear velocity (V_*, m/s) – a variable in proportion with the vertical wind velocity gradient in the logarithmic scale and surface roughness (z_o, m) the height at which mean wind velocity decreases to zero – were calculated on the basis of collected data.

Annual cross sections of blow-outs were also drawn and were used as a basis for calculation of the changes of sand layers and sand amount per one linear meter of the beach (Q m^3/m) (Table 2).

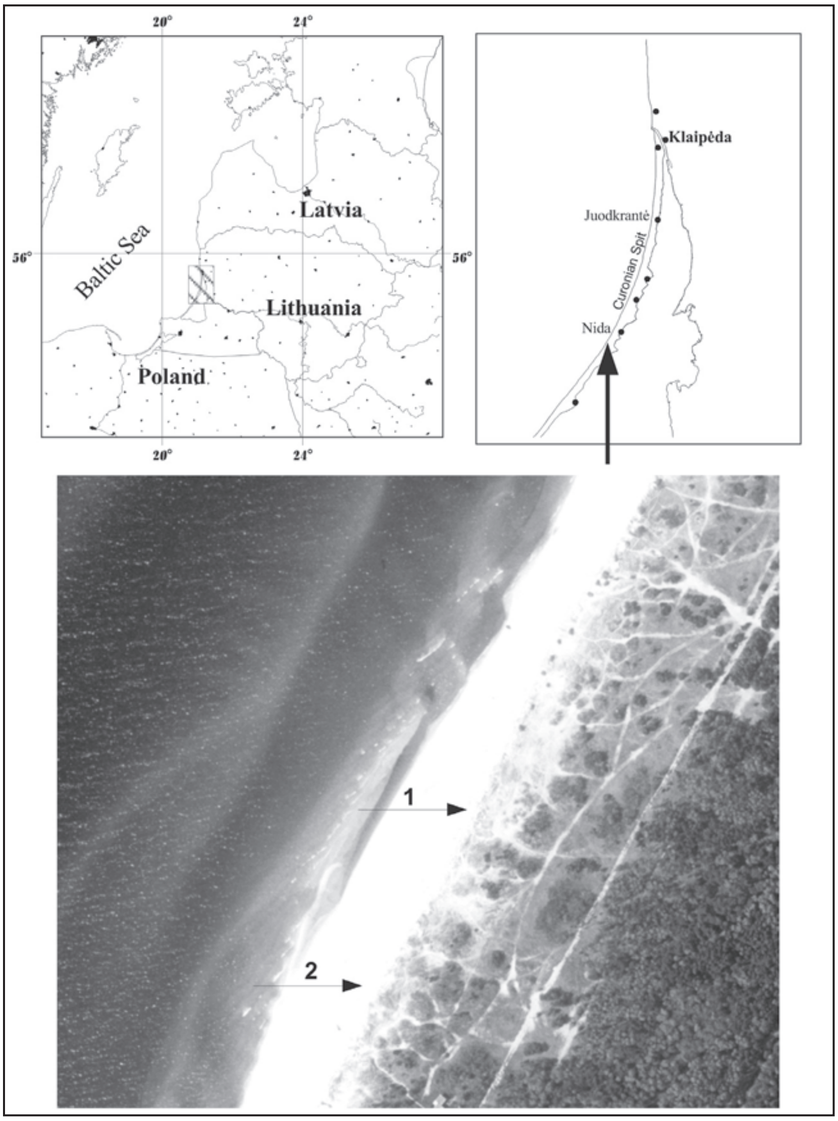

Fig. 1. Location of study area. 1 and 2 – location of blow-outs. Aerial photograph made in 1993 is courtesy of the State Institute of Aerophotogeodesy, Kaunas, Lithuania.

DYNAMICS OF WIND VELOCITY IN THE BLOW-OUTS

It was determined that the vertical changes of wind velocity in the naturally developing blow-outs did not ultimately correspond with the logarithmic distribution (Fig. 2). Some time ago it was determined (Hesp & Hyde 1996; Fraser et al. 1998; Žilinskas et al. 2001) that though the gradient of wind velocity remains the same as in the beach middle, its inversion occurs in the middle of the blow-outs under the

Table 1. Wind speed (v, m/s) in blowouts before and after installation of protective measures.

Distance from ground, m	**Blowout covered with branches V, m/s**		**Blowout covered with shields of planks V, m/s**	
	before	**after**	**before**	**after**
0.2	5.0	2.0	7.3	2.5
0.5	7.4	4.8	7.4	1.8
1.0	7.2	8.4	8.8	6.7
1.5	7.9	9.3	9.2	9.9
2.0	8.9	10.2	9.8	10.7

Table 2. Amount of sand (Q, m^3/m) accumulation in blowouts with different protective measures.

Date	**Blowout covered with branches, m^3/m**	**Blowout cowered with shields of planks, m^3/m**
1998-1999	4.5	–
1999-2000	7.5	–
2000-2001	3.0	4.3
2001-2002	3.8	1.3
2002-2003	0.7	2.5
2003-2004	0.3	6.9

„corridor“ conditions. The highest values of wind velocity were obtained at the heights of 0.5, 1.0 and 1.5 m. Wind velocity decreased at a height of 2.0 m. Thus, the wind velocity profile undergoes great transformations in naturally developing blow-outs. It should be emphasized that due to a higher wind velocity in the subaerial layer of the blow-out (if compared with the beach) the sand grains transported from the beach are unable to settle down. The blow-out serves as a transit zone for sand moving to the rear of the dune ridge. Therefore, under dominant onshore winds the blow-out cannot be filled with sand. This can happen only under the conditions of longitudinal beach winds. Therefore more attention was put in onshore winds characterisation. More details about wind climate in Lithuanian sea coast are described in previous work (Žilinskas et al. 2001).

Wind velocity in the blow-out after the covering underwent considerable transformations (Fig. 2). It distinctly reduced in the subaerial layer and slightly increased at the height of 2 m. The wind velocity reduction at the height of 0.2 m in the blow-out covered with branches was by 2.5 (z_o increased from 0.0003 to 0.10 m) and by 3 times in the blow-out with shields of planks (z_o increased from 0.0002 to 0.11 m). It should be pointed out that the shear velocity (V_*) also increased: from 0.25 to 1.40 m/s in the first case and from 0.36 to 1.43 m/s in the second case. The increase of the V_* values (by 4.0–4.6 times) implies better conditions for sand transport, yet due to pronounced decrease of wind velocity deflation was replaced by accumulation in the zone of most intensive sand transport (0–20 cm).

Wind velocity in the zone of most intensive sand transport or z_o – height at which wind velocity equals to zero – is the dominant factor in the capacity of sand transportation over obstacles of varying roughness. The surface roughness increases so much that sand transport in the subaerial layer becomes possible only by storm winds. Due to this almost all transported sand settles down in the front part of the blow-out covered with branches. Only when the branches closest to the sea are covered up with sand (reducing the surface roughness) accumulation may shift upslope. Wind velocity in the second blow-out (with planks) undergoes greater transformations. The shields cover the blow-out completely and stop the upslope accumulation. Yet,

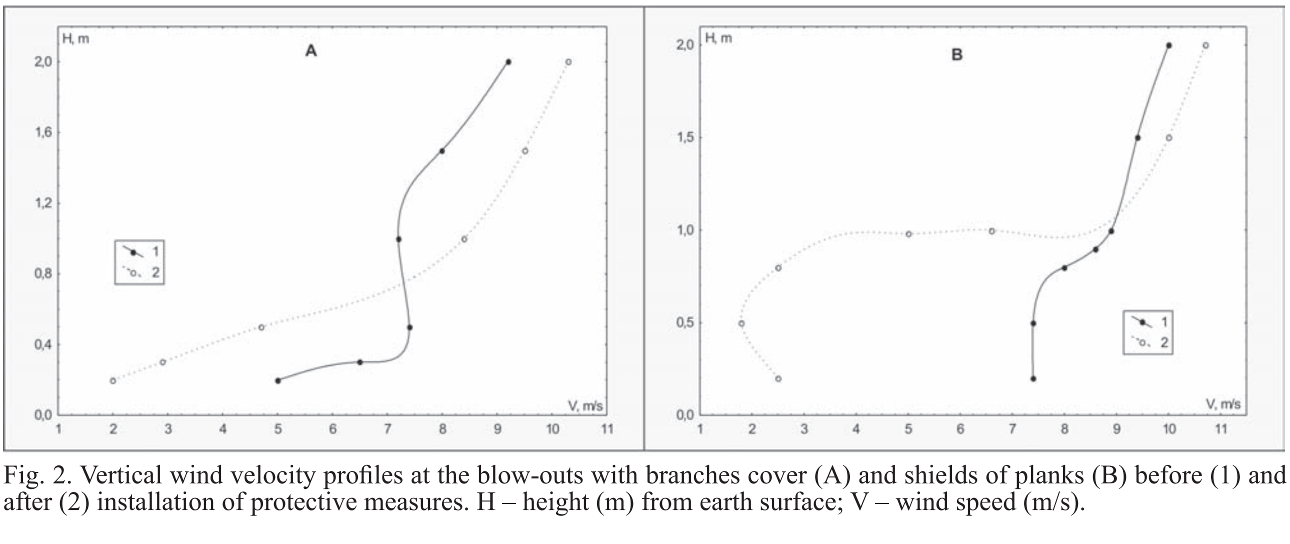

Fig. 2. Vertical wind velocity profiles at the blow-outs with branches cover (A) and shields of planks (B) before (1) and after (2) installation of protective measures. H – height (m) from earth surface; V – wind speed (m/s).

on the other hand, higher turbulence in the front part of the shields of planks may intensify deflation. Further accumulation of the sand in the blow-out is possible only after full or almost full covering up of the first (closest to the sea) shield. The shields of planks should be preferably semi-pervious. This would reduce the wind turbulence and support consistent sand accumulation up the slope.

TRANSFORMATION OF CROSS SECTIONS

It was observed that accumulation processes in the blow-out covered with branches (Fig. 3A) had set in immediately after covering the blow-out. Under dominant western winds a layer of sand 30 cm in thickness accumulated in the front part of the flooring (a sector of about 4 m in length) already in the first week. All

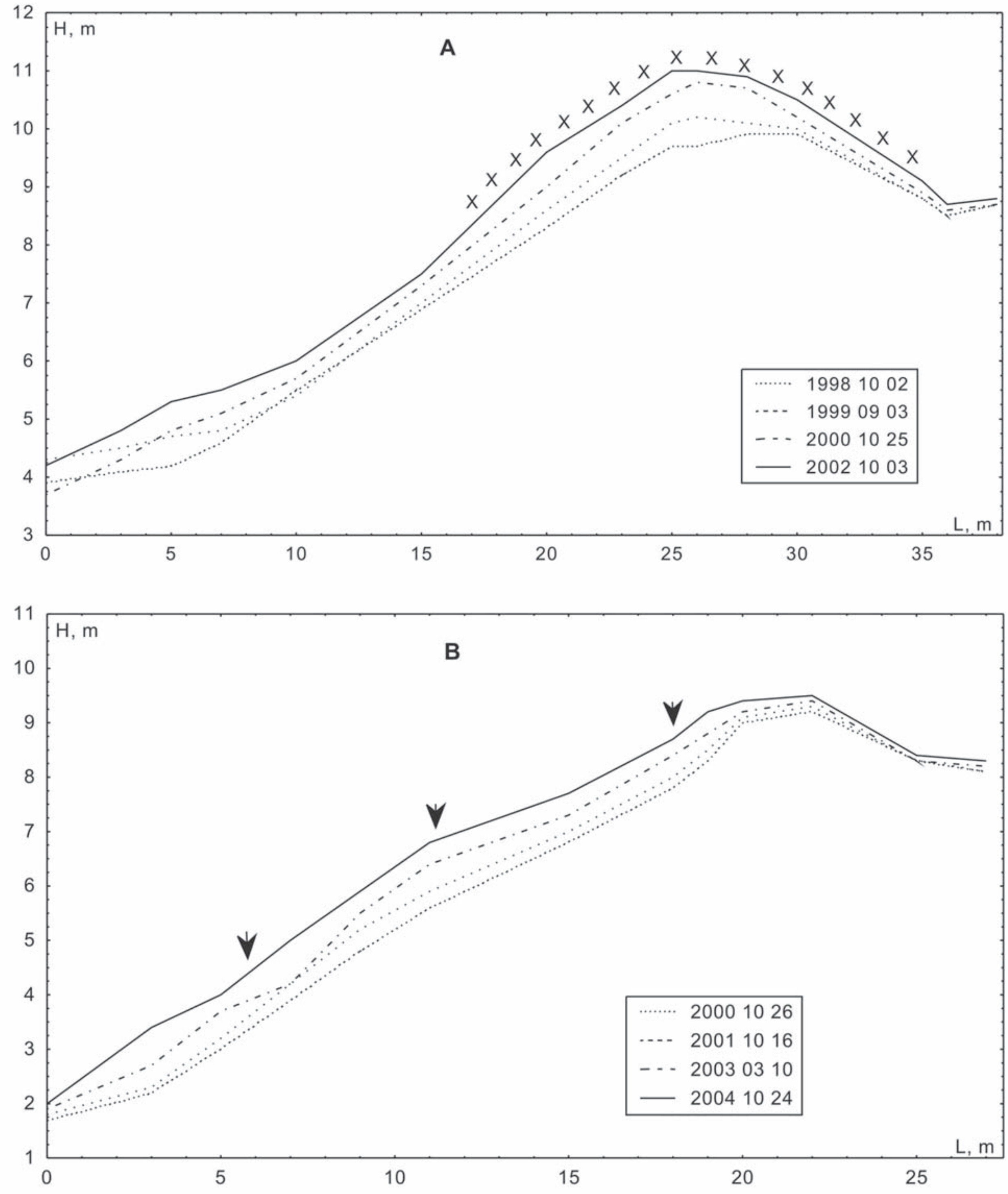

Fig. 3. Dynamics of cross section of blow-outs covered with branches (A) and equipped with shields of planks (B). XXX – branches cover site; arrows indicate shielded sites. H – height (m) from sea water level, L – distance (m) from dune ridge foot.

branches till the dune ridge top had been covered up by June of 1999. In August of 2000 branches could be seen only in the rear of the dune ridge. The branches were covered up over the whole profile in two years. It must be pointed out that a year after gradual covering up of the branches with sand the upslope deflation processes again set in the front part of the blow-out. If the filled up blow-out was not repeatedly reinforced or overgrown with plants the reverse process would set in, i.e., blowing out of sand with remains of branches upslope. Yet in the studied sector the covering of branches by sand in autumn and winter was followed by a successful taking root of *Ammophila arenaria*. Due to this accumulation processes continued even after covering up of the branches. During the time frames 1998–1999 4.5 m^3/m and 1999–2000 –7.5 m^3/m of sand accumulated in the blow-out. It can be noted that the plant cover facilitated sand accumulation sand better than the branches. Yet favourable hydrometeorological conditions for sand transport also cannot be denied. Two years after the installation of the branch flooring in the blow-out the rates of accumulation reduced – the amount of accumulated sand in 2000–2001 was 3.0 m^3/m and in 2001–2002 – 3.8 m^3/m. After four years the blow-out disappeared (Fig. 4) and accumulation processes came to an end (2002–2004 – 1.0 m^3/m). Recently slightly more pronounced accumulation has been recorded only in the rear of the dune ridge and in the newly formed phytoaccumulative hillock. In the blow-out itself the rates of accumulation equalled with the rates of accumulation in the western slope of the nearby situated dune ridge. It must be pointed out that about 4–6 m^3 of sand used to be blown annually into the blow-out before covering it.

Accumulation also set in immediately after covering the other blow-out with board shields (Fig. 3B). Yet due to the specific construction of the cover sand was first of all accumulated only at the first (closest to the sea) shield. The 2d and the 3d shield of planks remained uncovered. Thus, the shields prevented the consistent filling of the blow-out with sand. Sand reached the 3d (upper) shield of planks only in a year and covered it up in 4 years. The inconsecutive filling was responsible for formation of delicate escarpments in the blow-out profile what is alien for the nearby dune ridge. The herbaceous cover (*Ammophila arenaria)* facilitated the processes of accumulation as in the first case. The amounts of sand accumulated by board shields were: 4.3 m^3/m in 2000–2001, 1.3 m^3/m in 2001–2002, 2.5 m^3/m in 2002–2003 and 6.9 m^3/m in 2003–2004, when the shields were fully covered up and the whole blow-out surface was overgrown by herbaceous plants. Thus, the grass cover almost by three times intensified the processes of accumulation. After covering up of the shields of planks and establishment of plant cover the scarping blow-out profile began to level down. The blow-out is today almost filled up by sand (Fig. 5) therefore it seems likely that the rates of accumulation will reduce until the blow-out reaches the dynamic state of the nearby dune ridge (as in the case of the first blow-out). In conclusion it is worth mentioning that that the investigated site contains a sufficient amount of sand for aeolodynamic processes and after the filling up of the blow-outs and development of the plant cover accumulation in this area continues.

GENERALISATION

Both discussed ways of liquidation of blow-outs in the dune ridge yielded positive results. The blow-outs were filled up by sand in a few years and obtained a

Fig. 4. Dynamics of blow-out covered with branches: (a) 1998 10 02; (b) 2000 08 21; (c) 2004 05 27.

grass cover (Figs. 4 and 5). Yet the filling rates in the blow-out covered with branches were twice as high as in the blow-out covered with board shields of planks (this was predetermined by the density and height of shield flooring). Moreover, the first gully was filled consecutively from foot to top and its profile was level, i.e., without unnatural breaks. The filling rates in the blow-out with shields were lower, the filling was not consecutive and the forming profile obtained an unnaturally scarping profile. The shields used for covering the blow-outs should be semi-pervious. This would reduce the turbulence and sustain consecutive

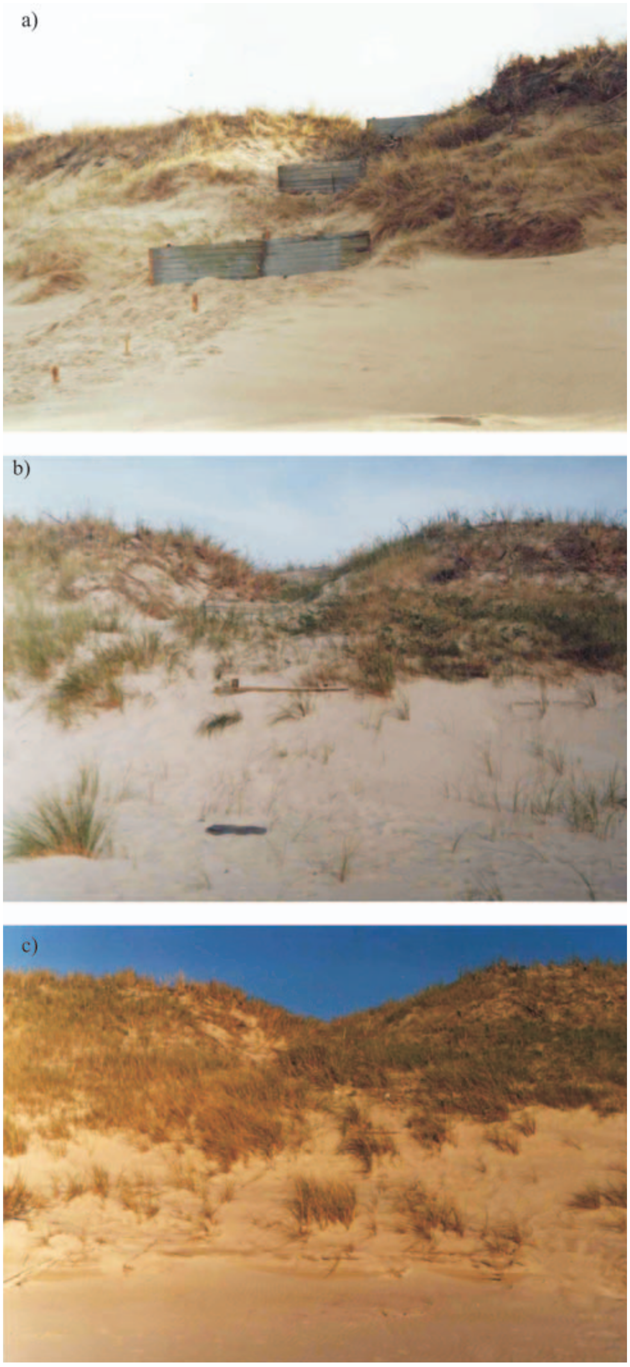

Fig. 5. Dynamics of blow-out equipped with shields of planks: (a) 2000 10 26; (b) 2002 08 09; (c) 2004 05 27.

sand accumulation up the slope. It should be recognized that covering of the dune ridge with branches is the simplest and best way to stop the deflation processes. Pine branches are best for this purpose. They are dense and not so easily pulled apart by holiday-makers. Yet covering with branches should be purposive, i.e., it is necessary to know *when, where* and *how densely* to cover.

Spring–beginning (before holiday time) of summer is the best time for covering. There are a few good reasons in favour of this time of the year: a sufficiently great amount of sand accumulates in the beach in warms season and is later successfully accumulated in the dune ridge. Consequently it is not so easy for sea waves to overcome the reinforced dune ridge in stormy season (autumn–winter). Moreover, it is not so easy for holiday-makers to walk on the branch flooring of the ridge slope what prevents from expansion of the unwanted deflation forms in the dune ridge.

The branch flooring should be mounted in the areas with the dune ridge and the near lying sufficiently wide (not less than 20 m in width) beach with good supplies of fine- and medium-grained sand supplies. When these conditions are absent (morainic cliff, narrow beaches covered by shingle and pebble) the branch floorings do not fulfil their function. The branch flooring should be mounted in all disturbed areas of the dune ridge.

Creation of branch flooring must be a regular measure. It should be repeated every 2–4 years (depending on hydrometeorological conditions) otherwise the processes of deflation may resume. Even after the ultimate filling of deflation forms they should be planted with herbaceous plants.

In conclusion it should be pointed out that after covering the investigated blow-outs holiday-makers chose some other comfortable places near the sea. After some time there appeared new blow-outs next to the old ones (Fig. 4c). This implies that the problem of neutralisation of blow-outs should be solved in combination with the planning the directions of the flows of holiday-makers (mounting of plank paths, stairs, etc.). Otherwise the attempts to neutralise the blow-outs will be futile.

CONCLUSIONS

Summarising the obtained results we can conclude that blow-out reinforcement should be based on the following principles:

The barrier flooring should be semi-pervious and should cover the whole surface of deflation form.

The height of the barrier flooring should not exceed 0.5 m above the surface (to ensure a consistent filling of the blow-out along the profile).

Blow-outs should be covered in spring–beginning of summer after the stormy season (autumn–winter).

The flooring is expedient only in beach sectors with sufficient supply of sand (the branch floorings are designed for accumulation of wind-transported sand and not for protection of the beach from sea waves).

The protective flooring must be built every 2–4 years depending on hydro meteorological situation.

After complete filling of blow-outs with sand the reconstructed blow-outs should be planted with herbaceous plants (such plants are the best medium for sand accumulation yet they are sensitive to recreational loads).

The flows of holiday-makers should be regulated by improving the beach infrastructure and through education (plank paths, stairs to the dune ridge, informative-educational stands, etc.).

Acknowledgements

The author wish to thank Dr. Gintautas Žilinskas and Mgr. Donatas Pupienis, who helped in collecting data and supported in field investigations. He is also thankful to Ada Jurkonytė for translation of this manuscript into English. The author thanks also reviewers Prof. Guntis Eberhards, Latvia, and Prof. Algimantas Česnulevičius, Lithuania, for critical reading of the manuscript and helpful comments.

References

Carter, R. W. G. 1988: Coastal environments. An introduction to the physical and cultural systems of coastline. London, San Diego, New York, Boston Sydney, Tokyo, Toronto, 616 p.

Carter, R. W. G., Hesp, P. A., Nordstrom, K. F. 1990: Erosional landforms in coastal dunes. In Nordstrom, K. F., Psuty, N., Carter, B. (Eds.) Coastal dunes. Form and Process. Chichester, New York, Brisbane, Toronto, Singapore. 387 p.

Daujotas, M. 1940: Our sea shore and it planting. *Mūsų girios 8-9*, 402-406. In Lithuanian.

Daujotas, M. 1958: Lithuanian sea shore sands planting. Vilnius. 178 p. In Lithuanian.

Fraser, G. S., Bennett, S. W., Olyphant, G. A., Bauch, N. J., Ferguson, V., Gellasch, C. A., Millard, C. L., Mueller, B., O'Malley, P. J., Way, J. N., Woodfield, M. C. 1998: Windflow circulation patterns in a coastal dune blowout, South coast of Lane Michigan. *Coastal research 14(2)*, 451-460.

Gerhardt, P. 1990: Handbook of dune process in Germany. Berlin. 627 p. In German.

Hesp, P. A., Hyde, R. 1996: Flow dynamics and geomorphology of a trough blowout. *Sedimentology 43*, 505-525.

Jungerius, P. D. 1984: A simulation model of blowout development. *Earth surface processes and landforms 9*, 509-512.

Jungerius, P. D., Verheggen, J. T., Wiggers, A. J. 1981: The development of blowouts in ‚de Blink' a coastal dune area near Noordwijkerhout, The Netherlands. *Earth surface processes and landforms 6*, 375-396.

Kurz, E. 1904: Structure of dunes in the Curonian Spit. Königsberg. 65 p. In German.

Musset, M 1916: Investigation of study results of the Curonian Spit dunes. Memel. 253 p. In German.

Olson, J. S. 1958: Lake Michigan dune development. 1. Wind-velocity profiles. *Journal of geology 66(3)*, 254-263.

Olšauskas, A. 1991: Influence of recreation on plant cover of the Lithuanian coastal dunes. *Ecology 3*, 50-61. In Lithuanian.

Pluis, J. L. A. 1992: Relationship between deflation and near surface wind velocity in a coastal dune blowout. *Earth surface processes and landforms 17*, 663-673.

Pye, K., Tsoar, H. 1990: Aeolian sand and sand dunes. London. 395 p.

Pye, K. 1990: Physical and human influences on coastal dune development between the Ribble and Mersey estuaries, northwest England. In Nordstrom, K. F., Psuty, N., Carter, B. (Eds.) Coastal dunes. Form and Process. Chichester, New York, Brisbane, Toronto, Singapore. 387 p.

Wichdorf, H. 1919: Geology of Curonian Spit. Berlin. 202 p. In German.

Žilinskas, G., Jarmalavičius, D., Minkevičius, V., 2001: Aeolic process on the sea coast. Vilnius, 283 p. In Lithuanian.