American Journal of Environmental Science and Engineering
2017; 1(2): 34-39
http://www.sciencepublishinggroup.com/j/ajese
doi: 10.11648/j.ajese.20170102.11

The Response of *Galilea mucronata* (L.) Parl. to Simulated Flooding Experiments and Its Capacity as Dune Stabilizer

Stoyan Vergiev

Department of Natural History, Varna Regional Museum of History, Varna, Bulgaria

Email address:
stvergiev@gmail.com

To cite this article:
Stoyan Vergiev. The Response of *Galilea mucronata* (L.) Parl. to Simulated Flooding Experiments and Its Capacity as Dune Stabilizer. *American Journal of Environmental Science and Engineering*. Vol. 1, No. 2, 2017, pp. 34-39. doi: 10.11648/j.ajese.20170102.11

Received: March 10, 2017; **Accepted**: March 24, 2017; **Published**: April 10, 2017

Abstract: Sustainable development of coastal systems and low-laying inland areas require replacement of artificial coastal stabilization and protection structures with "soft" transplanting techniques of native, salt-tolerant plant species. They can effectively minimize erosion and reduce storm damages with minimal negative impacts to natural ecosystems. Ecosystem services require searching for well adapted plants with extensive root systems and studying their ability for erosion and flooding control. Although, the Bulgarian Black Sea Coast is relatively protected from sea floods due to the small amplitude tides, extreme storms may cause flooding, erosion and destruction of communities of dominant sand stabilizers *Leymus racemosus* (Lam.) Tzvelev subsp. *sabulosus* (M. Bieb.), *Ammophila arenaria* (L.) Link and *Carex ligerica* J. Gay. In such cases *Galilea mucronata* (L.) Parl. colonizes territories from these dune pioneers and become a major dune stabilizer. This study aims to establish the viability of this species and possible negative consequences during simulated flooding experiments and thereby to investigate its capacity as dune stabilizer. The experiments established that *G. mucronata* were very tolerant to immersion impact and salt stress. Whole plants stay viable longer than the flood with a maximum duration along the Bulgarian Black Sea Coast, and rhizomes were able to regenerate after 30 days in seawater. Statistical analysis of experimental data shows that the water itself as a defining factor increase rhizomes viability, biomass and roots to shoots allocation, whereas other factors, such as duration of immersion and temperatures of sea water have not significant effect. *G. mucronata* were much less tolerant to water immersion than other psammophytes, but demonstrate a high potential to be a key species for dune stabilization and could contribute to the protection of coastal sands during storms.

Keywords: Immersion Tolerance, Viability, *Galilea mucronata*, Dune Stabilization, Frosion and Flooding Control

1. Introduction

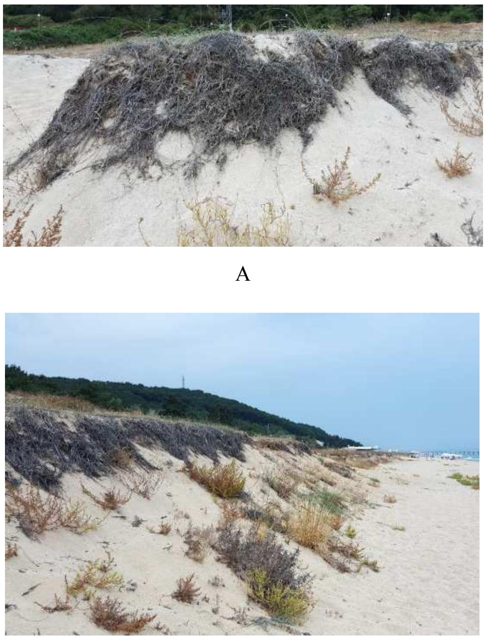
A cumulative effect of global climate changes, sea level rise and frequent storm surges as well as strengthened anthropogenic impact may cause sea water flooding [1–3] and erosion [4] to low lying coastal areas. As a result habitats for many rare and endangered species will be lost.

Dune vegetation is formed under the combination of specific site conditions such as exposure to sun, wind, salt spray, sand blasting and the specificity of the substrate [5, 6]. Some of the species form an extensive system of horizontal and vertical rhizomes that reduced wind speeds across the surface, trapping and holding a great amount of sand [7]. Thus, they support sand stabilization and increase the dune's ability to buffer inland areas from erosion and flooding.

Unlike artificial coastal stabilization structures used in coastal protection, the transplanting techniques of native, salt-tolerant plant species can effectively minimize erosion and reduce storm damages with minimal negative impacts to natural ecosystems [8]. Ecosystem services require searching for well adapted plants with extensive root systems and studying their ability for erosion and flooding control.

The experience of the recorded extreme meteorological events over the Bulgarian Black Sea Coast [9] shows the high potential of the root system of native psammophytes to accumulate sands and prevent from washout [10, 11]. Although, the Bulgarian Black Sea Coast is relatively protected from sea floods due to the small amplitude tides [10], some extreme meteorological events, such as unusual storms may cause flooding and erosion of dunes. Storm waves carry away sandy sediments and cause destruction of communities of dominant sand stabilizers *Leymus racemosus* (Lam.) Tzvelev subsp. *sabulosus* (M. Bieb.), *Ammophila arenaria* (L.)

Link [11] and *Carex ligerica* J. Gay [12]. In such cases *Galilea mucronata* (L.) Parl. become a major dune stabilizer and colonizes territories from the dune pioneers (Figure 1).



A

B

Figure 1. *Galilea mucronata communities along the beach between Kamchia River and Fandakliiska River: a) three months after storm; b) one year after storm.*

Data about the impact of flooding to *G. mucronata* are insufficient unlike those about *L. racemosus* subsp. *sabulosus* [11], *A. arenaria* [11, 13, 14] and *C. ligerica* [12], which show high viability of psammophytes to the stress of flooding in short-term intervals.

The aim of this study is to establish the viability of *G. mucronata* and possible negative consequences during simulated flooding experiments and thereby to investigate its capacity as dune stabilizer.

2. Materials and Methods

2.1. Description of the Study Area

The beach between Kamchia River and Fandakliiska River (Figure 2) is the longest continuous sandy strip over the Bulgarian Black Sea Coast (about 12 km). The coast is low and cumulative and is formed on the border of Low Kamchia structural depression [15]. According to Velev [16], the climate is moderate continental and milder strongly influenced by the sea with annual rainfall of 498 mm with maximum in July and minimum in February and September. The average air temperature in January is 1.2°C, and in July it is 23°C. The Black Sea is the largest anoxic water body with 18‰ average water salinity and average temperature of 13°C (average minimum of 4° C and average maximum 23°C) [17].

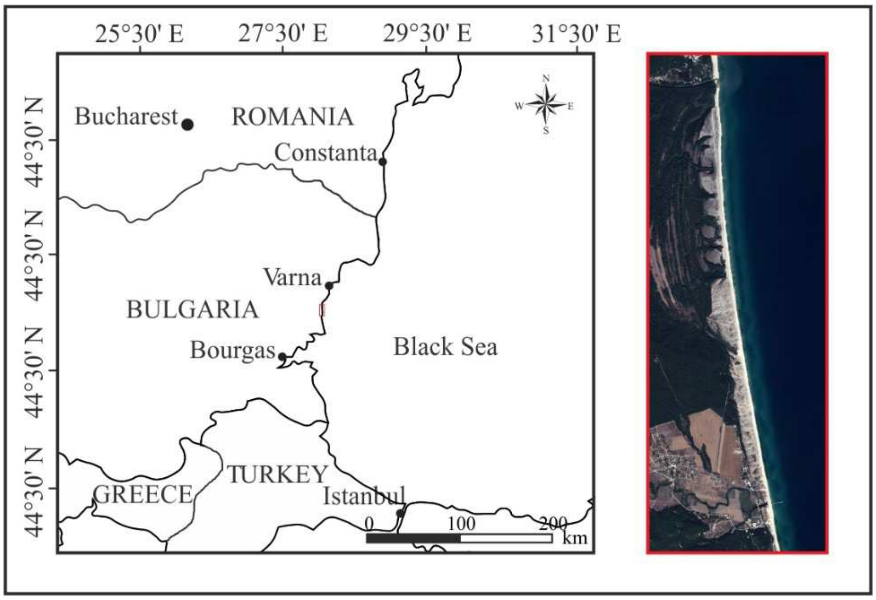


Figure 2. *Location of the investigated area.*

2.2. Study Species

Galilea mucronata (L.) Parl. (syn. *Cyperus capitatus* Vand.) is a perennial plant from family Cyperaceae with creeping rhizomes, up to 50 cm high, triangular or nearly rounded stem and basal revolute leaves [18]. The species is included in the Red Data Book of Bulgaria as endangered [19]. In the investigated area, *G. mucronata* forms monodominant communities with high abundance and poor floristic composition.

2.3. Simulated Flooding Experiments

Rhizomes and whole plants of *G. mucronata* were collected at the sandy beach (42°59′00.83″N, 27°53′31.79″E) in April 2015 for the first experiment and in January 2015 for the second experiment. The simulated flooding experiments were conducted in the Botany Laboratory of the Varna Museum of Natural History. All plant materials were immersed in glass tanks (40 l), filled with sea water at a depth of 2–4 cm below the water surface with constant maintained temperatures (4±1°C, 13±1°C and 23±1°C). The water was changed several times per day.

In the first experiment, ten whole plants were immersed for 20 days. Visible morphological changes of different parts of the specimens (leaves, stems, roots) are recorded and assessed in 12 parameters [11].

In the second experiment, twenty rhizomes per treatment were removed every fifth day and were planted in washed and sterilized sand in plastic pots in the glasshouse with controlled air temperature [13]. Control rhizomes were planted directly. Rhizomes were watered with fresh water daily and allow growing for one month before harvesting [11]. All plants were cleaned and oven-drying at 60°C for 24 hours.

2.4. Statistical Analyses

Mean bud viability was measured as the percentage of rhizome nodes, that produced vegetative shoots and roots [13]. Maximum rhizome bud viability is defined as the bud viability of the rhizome replicate with the highest bud viability for each treatment [13]. Mean bud viability as well as mean dry weight biomass per plant replicate and R:S ratio (root mass/shoot mass) were analyzed with two-factor analyses of variance (ANOVA). Where necessary, data were transformed in order to obtain homogeneous variances.

3. Results and Discussion

The most important factor in assessments of negative consequences of flooding to natural plant communities is the exposure time to sea water. Flooding simulated experiments based on the direct submergence of psammophytic species are more appropriate than the experiments of studying substrate salinity and salt spray due to their regular exposure in sea water [11] and specific mechanisms of neutralizing sea water salt. Therefore, in the present study direct methods were conducted in order to establish the changes and adaptations of *G. mucronata* to the stress of flooding in certain short-term intervals and the period of which whole plants, submerged in sea water still maintain viable buds capable of producing new plants, without taking into consideration the direct mechanical effect of storm waves.

No mortality of the specimens occurred during the course of the first experiment. Beginning of the decomposition of leaves of the submerged plants started from the 6^{th} day (Table 1). On the 7^{th} day, a growth of stems and root sprouts was observed. There were no visible decompositions of newly grown stems, roots and rhizomes till the end of the experiment (20^{th} day). All investigated parameters were unrelated to water temperature.

Table 1. *Results from simulated flooding experiment. Visible morphological changes of different parts of the specimens (leaves, stems, roots) assessed in 12 parameters.*

Parameter	**Days in seawater**		
	4°C	**13°C**	**23°C**
Beginning of the decomposition of leaves	6	6	6
Beginning of the decomposition of stems	15	15	15
Beginning of the decomposition of roots	20	20	20
Complete decomposition of leaves	20	20	20
Complete decomposition of stems	n/a	n/a	n/a
Complete decomposition of roots	n/a	n/a	n/a
Growth of the stems	7	7	7
Growth of the root sprouts	7	7	7
Beginning of the decomposition of newly grown stems	n/a	n/a	n/a
Beginning of the decomposition of newly grown roots	n/a	n/a	n/a
Complete decomposition of newly grown stems	n/a	n/a	n/a
Complete decomposition of newly grown roots	n/a	n/a	n/a

As a result of this test, Critical Decomposition Time (CDT) for *G. mucronata* was obtained. CDT is defined as the time point at which each plant shows signs of irreversible decomposition of vegetative organs [20] and indicates that the plants will not survive and their communities will not be able to recover. This parameter is used for vulnerability assessments of flooding impacts to coastal plant communities [21]. CDT for *G. mucronata* is 6 days, which is longer than the flooding with a maximum duration for the Bulgarian Black Sea Coast [11, 20]. This value of the CDT is similar to other psammophytes [20].

Results from the second experiment show that *G. mucronata* rhizomes remain viable immersed in sea water for 30 days, which is the maximum duration of the simulated flooding experiment. This is in agreement with studies of other psammophytes (e. g. *A. arenaria*) which evaluate their rhizomes viability from 13 to 70 days in sea water [11, 13, 14].

Despite different temperatures, all treatments show identical trends (Figure 3). Mean bud viability gradually increases to the maximum of 61.5% (treatments with 4°C) on the 20^{th} day of sea water submergence, followed by slightly decrease at the end of the immersion (Figure 3). All the treatments have higher values than the mean viability of the untreated control (58.5%) and appears to be enhanced slightly by sea water ($P = 0.033$). The same trend was observed for other psammophytes mean bud viability [11]. The values are similar to the mean viability of *C. ligerica* [12], and lower than psammophytes from family Poaceae [11].

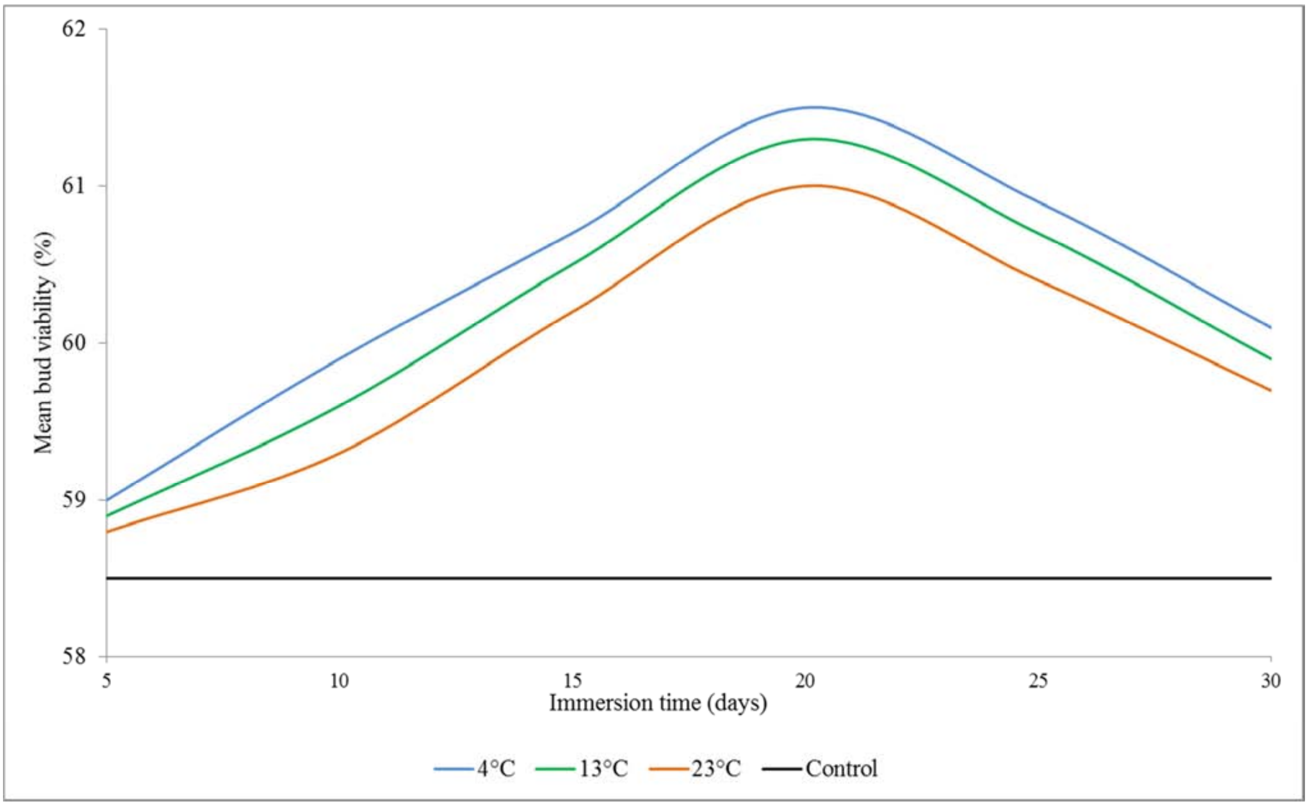


Figure 3. *Mean bud viability following sea water immersion.*

All treatments had a maximum rhizome bud viability of 100%. Each immersion period, even on the 30th day of immersion, 80% of rhizomes still had at least one viable bud and 5% of rhizomes had maximum bud viability (Table 2).

Table 2. *Rhizomes with maximum bud viability and rhizomes with more than 1 viable buds following sea water immersion.*

Submergence duration (days)	Rhizomes with max. bud viability%			Rhizomes with >1 viable buds%		
	4°C	13°C	23°C	4°C	13°C	23°C
0 (control)		5.0			80.0	
5	5.0	5.0	5.0	80.0	75.0	75.0
10	10.0	10.0	10.0	85.0	80.0	80.0
15	10.0	10.0	10.0	90.0	90.0	85.0
20	20.0	20.0	15.0	95.0	90.0	90.0
25	10.0	10.0	5.0	90.0	85.0	80.0
30	5.0	5.0	5.0	85.0	80.0	80.0

Storm events on the Black Sea Coast occur during winter and early spring when average surface sea water temperature is about 4°C [17]. In order to study the relation between temperature and viability of *G. mucronata*, two other treatments with temperatures of 13°C (average surface sea water temperature) and 23°C (average summer surface sea water temperature) were included in the simulated experiments.

Different temperatures are influenced rhizome viability in similar levels (P = 0.086), and average differences between coolest and warmest temperatures are only 0.45%. Replicates in all treatments demonstrate higher viability than the untreated replicates (P = 0.041). This is contrary to the results of study of *A. arenaria* rhizomes [14], which retained viability for longer in cooler water. So it can be concluded that the water itself as defining factor impact viability more so than the temperature of water.

While crucial for rhizomes viability is the cumulative effect on the durability of flooding and sea water temperature, defining factor in ability of psammophytes to fix loose sandy substrates and contribute for dune stabilization is the size of their root systems. In order to measure how immersion affected the root system, the mean dry weight biomass per replicate was taken as well as R:S ratio (root mass/shoot mass).

Dry weight biomass was increased by immersion in sea water till 20th days of the experiment (Figure 4) and remain unchanged till the end of the experiment. The water temperature had no significant effect (P = 0.081) on the biomass of the treated groups. Replicates in all treatments demonstrate higher biomass than the control replicates (Figure 4).

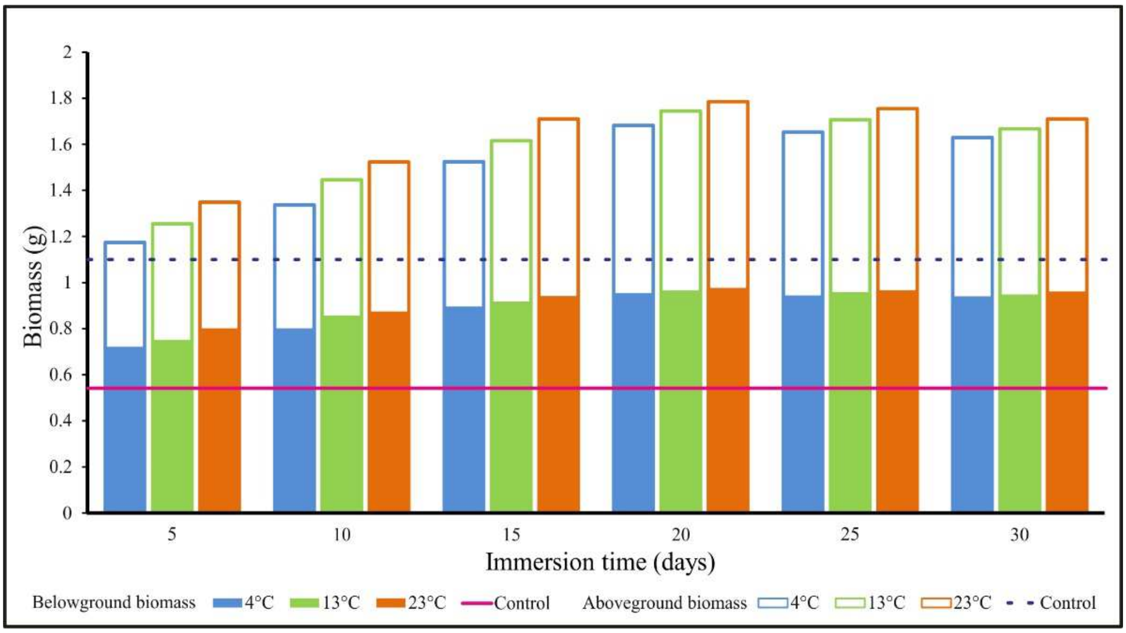


Figure 4. *Dry weight biomass following sea water immersion.*

R:S ratio measures plant allocation to above and belowground biomass [22]. This variable was not affected significantly by immersion duration (P = 0.072). Biomass allocation to roots in plants exposed to sea water was slightly increased. Increased water temperatures tended to decrease the R:S ratio, but the effect was insignificant (P = 0.059) (Figure 5). Replicates in all treatments demonstrate higher biomass than the control replicates.

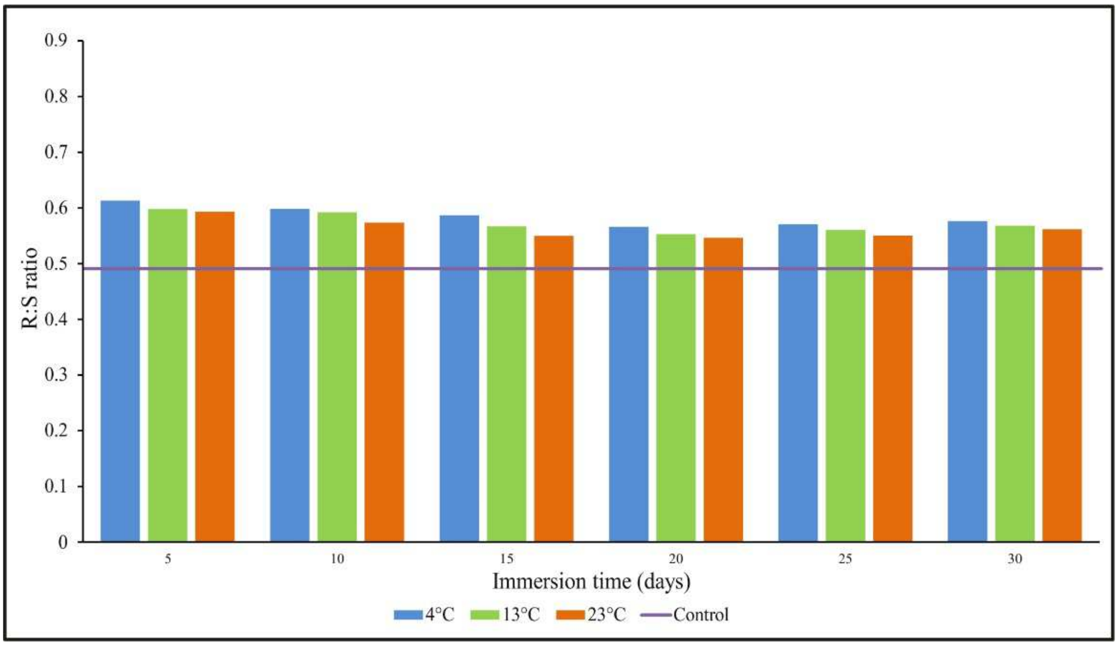


Figure 5. *R:S ratio following sea water immersion.*

4. Conclusion

G. mucronata shows high tolerance to sea water immersion and high viability during the simulated flooding experiments. Statistical analysis of experimental data shows that the immersion in water increase rhizomes viability, biomass and allocation to root biomass. Other factors, such as duration of immersion and temperatures of sea water have not significant effect. *G. mucronata* are much less tolerant to water immersion than other psammophytes *L. racemosus* subsp. *sabulosus*, *A. arenaria* and *C. ligerica*, but demonstrates high potential to be a key species for dune stabilization.

References

[1] R. J. Nicholls, and A. Cazenave, "Sea-level rise and its impact on coastal zones," Science, vol. 328, pp. 1517–1520, 2010.

[2] R. Weisse, D. Bellafiore, M. Menéndez, F. Méndez, R. J. Nicholls, G. Umgiesser, and P. Willems, “Changing extreme sea levels along European coasts,” Coastal Engineering, vol. 87, pp. 4–14, 2014.

[3] P. P. Wong, I. J. Losada, J. P. Gattuso, J. Hinkel, A. Khattabi, K. L. McInnes, Y. Saito, and A. Sallenger, “Coastal systems and low-lying areas,” in Climate Change 2014: Impacts, Adaptation, and Vulnerability, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., pp. 361–409, 2014.

[4] L. Airoldi, and M. W. Beck, “Loss, status and trends for coastal marine habitats of Europe,” In: R. N. Gibson, R. J. A. Atkinson and D. M. Gordon (Editors), Oceanography and marine biology: An annual review. CRC Press, Boca Raton, Florida, USA, pp. 345–405, 2007.

[5] A. Ogura, and H. Yura, “Effects of sandblasting and salt spray on inland plants transplanted to coastal sand dunes,” Ecological Research, vol. 23, pp. 107–112, 2007.

[6] J. Wilson, and T. Sykes, “Is zonation on coastal sand dunes determined primarily by sand burial or by salt spray? A test in New Zealand dunes,” Ecology Letters, vol. 2, pp. 233–236, 2001.

[7] M. A. Maun, “The Biology of Coastal Sand Dunes,” New York, Oxford University Press, pp. 265, 2009.

[8] J. R. Clark, “Coastal zone management handbook,” New York, CRC Press/Lewis Publishers, pp. 695, 1995.

[9] N. Andreeva, N. Valchev, E. Trifonova, P. Eftimova, D. Kirilova, and M. Georgieva, “Literary review of historical storm events in the western Black Sea,” Proc. of Union of Scientists – Varna, Marine Sciences, pp. 105–112, 2011.

[10] E. Trifonova, N. Valchev, S. Keremedchiev, I. Kotsev, P. Eftimova, V. Todorova, T. Konsulova, V. Doncheva, M. Filipova-Marinova, S. Vergiev, J. Petkov, R. Nikolaev, W. de Vries, R. Silva, N. Andreeva, P. Galiatsatou, D. Kirilova, Y. Krestenitis, A. Polonsky, I. Androulidakis, K. Kombiadou, R. Weisse, E. Mendoza, G. Duran, T. Karambas, T. Koftis, P. Prinos, S. Kuznetsov, and Y. Saprykina, “Mitigating flood and erosion risk using sediment management for a tourist city: Varna, Bulgaria,” in Coastal risk management in a changing climate, B. Zanuttigh, R. Nicholls, J. Vanderlinden, H. Burcharth, and R. Thompson, Eds., Elsevier, pp. 358–383, 2014.

[11] S. Vergiev, M. Filipova-Marinova, E. Trifonova, I. Kotsev, and D. Pavlov, “The impact of sea water immersion on the viability of psammophilous species *Leymus racemosus* subsp. *sabulosus* and *Ammophila arenaria*,” Comptes Rendus de l’Academie Bulgare Des Sciences, vol. 66 (2), pp. 211-216, 2013.

[12] S. Vergiev, “The impact of sea water immersion on the viability of psammophilous species *Carex ligerica* J. Gay,” unpublished.

[13] R. Aptekar, and M. Rejmánek, “The effect of sea-water submergence on rhizome bud viability of the introduced *Ammophila arenaria* and the native *Leymus mollis* in California,” Journal of Coastal Conservation, vol. 6, pp. 107-111, 2000.

[14] T. M. Konlechner, and M. J. Hilton, “The potential for marine dispersal of *Ammophila arenaria* (marram grass) rhizome,” Journal of Coastal Research, vol. 56, pp. 434–437, 2009.

[15] V. Popov, and K. Mishev, “Geomorphology of the Bulgarian Black Sea Coast and Shelf,” Publishing House of the Bulgarian Academy of Sciences, Sofia, pp. 267, 1974 (in Bulgarian).

[16] S. Velev, “Climatic regions,” in Geography of Bulgaria, I. Kopralev, Ed., ForKom Publishers, Sofia, pp. 155–157, 2002. (in Bulgarian).

[17] A. Valkanov, H. Marinov, H. Danov, and P. Vladev, “The Black Sea,” Varna, Georgi Bakalov Publishing house, pp. 635, 1978.

[18] M. Markova, “*Galilea mucronata* (L.) Parl.,” In: Flora of the People’s Republic of Bulgaria (ed. D. Jordanov), Sofia, BAS Press, vol. 2, pp. 33, 1964, (in Bulgarian).

[19] D. Peev, and S. Tsoneva, “*Galilea mucronata* (L.) Parl.,” Peev, D. (Main ed.), Red Data Book of Republic of Bulgaria. Vol. 1. Plants and Fungi, IBER – BAS & MEW, Sofia, 2011.

[20] S. Hoggart, M. Hanley, D. Parker, D. Simmonds, D. Bilton, M. Filipova-Marinova, E. Franklin, I. Kotsev, E. Penning-Rowsell, S. Rundle, E. Trifonova, S. Vergiev, A. White, and R. Thompson, “The consequences of doing nothing: The effects of seawater flooding on coastal zones,” Coastal Engineering, vol. 87, pp. 169–182, 2014.

[21] S. Narayan, R. Nicholls, E. Trifonova, M. Filipova-Marinova, I. Kotsev, S. Vergiev, S. Hanson, and D. Clarke, “Coastal habitats within flood risk assessments: Role of the 2D SPR approach,” Coastal Engineering Proceedings, vol. 1 (33) Management 12, pp. 1-9, 2012.

[22] J. R. Obeso, “The costs of reproduction in plants,” New Phytol, vol. 155, pp. 321–34, 2002.