Sea water flood resilience of five plant species with conservation status over the Bulgarian Black Sea Coast

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Abstract

The Bulgarian Black Sea coastal zone is relatively protected from sea floods. Only extreme meteorological events such as unusual storms can cause flooding of coastal areas. Crucial for the application of rapid methods for vulnerability assessment of coastal plant communities from flooding caused by unusual storms over the Bulgarian Black Sea Coast is to obtain experimental data for sea water flood resilience. This study aims to determine the plant species survival in simulated flooding experiments in order to identify sea water flood resilience of five plant species with conservation status: *Centaurea arenaria* M. Bieb. ex Willd., *Crambe tataria* Sebeok, *Aurinia uechtritziana* (Bornm.) Cullen & Dudley, *Silene thymifolia* Sm., and *Stachys maritima* Gouan. As a result of a simulated flooding experiment, Critical Decomposition Time (CDT) was obtained. The five species were within the most vulnerable group (CDT < 48 h). The CDT was significantly shorter than floods with a maximum duration for the Bulgarian Black Sea Coast. Only the values of the parameter beginning of decomposition of the leaves were accelerated by higher water temperatures. Other parameters were unrelated to different water temperatures. The investigated species have low survival rates and low degree of sea water flood resilience and their communities will not be able to recover after flooding with maximum duration within one vegetation season.

Keywords: Vulnerability assessment; Plant communities; Conservation status; Floods; The Black Sea Coast

1. Introduction

The Bulgarian Black Sea coastal zone is relatively protected from sea floods due to the small amplitude tides and the lack of flowing large rivers [1, 2]. Only extreme meteorological events such as unusual storms can cause flooding of coastal areas [1, 3].

Coastal zones provide habitats for many rare and endangered species, which will be lost due to the combination of negative consequences of flooding and erosion as well as increased human impact [4, 5, 6]. The flora of the beaches has dramatically changed during the last decades. Several species were extinct and others have lost territories that are occupied [7].

Preceding inventorization and distribution investigation of vascular plants as well as flood mapping over the Bulgarian Black Sea Coast identifies five plant species with conservation status as threatened by flooding [8]. The present study is focused on *Centaurea arenaria* M. Bieb. ex Willd., *Crambe tataria* Sebeok, *Aurinia uechtritziana* (Bornm.) Cullen & Dudley, *Silene thymifolia* Sm., and *Stachys maritima* Gouan.

Although, the coastal plant communities are well adapted to salinity due to regular exposure to sea water, some of the species are vulnerable and sensitive to the impact of waves and storms [9]. The necessity to assess and quantify this

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negative effects and consequences on natural habitats requires the development of rapid models for vulnerability assessment.

Different flood scenarios and models have been developed in order to assess possible negative consequences to coastal areas from storms [1, 10]. It is of great significance to obtain experimental data on plant survival in order to apply the rapid method for vulnerability assessment of coastal plant communities from flooding caused by unusual storms over the Bulgarian Black Sea Coast [2]. Proposed by Vergiev et al. [2] model allows experimental results to be applied directly to the present situation and to predict the effects of future storm events to the dune vegetation.

This study aims to determine the plant species survival in simulated flooding experiments in order to identify sea water flood resilience of five plant species with conservation status over the Bulgarian Black Sea Coast.

2. Material and methods

Thirty whole plants from each investigated species were eradicated from ex-situ collection of the Technical University of Varna in April 2021 and were planted in washed and sterilized sand in 10 × 10 × 17 cm³ plastic pots. After a month of acclimatization in the Biological Laboratory of the Technical University of Varna, the plants with pots, separated in three equal groups, were completely submerged in three 100 l glass tanks full of sea water with maintained constant temperatures of 4±1, 13±1, and 23±1 °C, respectively, for 480 hours. The water was changed twice a day in order to avoid water decay processes [2, 3, 4].

Visible morphological changes of different parts of the plants (leaves, stems, roots) and the effect of flooding on the viability of the studied specimens were recorded and assessed in 12 parameters. The beginning of decomposition of leaves, stems, roots was identified when visible changes of decay were more than 15% of the whole vegetative organ surface. Complete decomposition was when the visible decomposition of an organ exceeded 50% of its surface [3].

3. Results and discussion

Preceding identified as threatened by inundation plant species with conservation status were shown on Table 1. Current conservation status was checked also.

| Latin name                  | Family          | BDA | RDB  |
|-----------------------------|-----------------|-----|------|
| Centaurea arenaria M. Bieb. ex Willd. | Asteraceae      | +   | -    |
| Crambe tataria Sebeok       | Brassicaceae    | +   | En   |
| Aurinia uechtritziana (Bornm.) Cullen & Dudley | Brassicaceae | +   | En   |
| Silene thymifolia Sm.       | Caryophyllaceae |     | En   |
| Stachys maritima Gouan      | Lamiaceae       | +   | En   |

BDA – Bulgarian Biological Diversity Act (2002) – Annex 3 [11]. RDB - Red Data Book of the Republic of Bulgaria [12], EN – Endangered.

The parameter Critical decomposition time (CDT) was proposed and was substantiated in several studies for the Bulgarian Black Sea Coast [2, 3, 6, 7, 9]. It presents the time expression of plant species survival by linking the duration of flooding and resilience of plant species. Although the CDT is subjectively defined on visible morphological changes and represents the smallest degree of irreversible decay of vegetative organs (more than 15% of the whole vegetative organ surface), it indicates that the plants will not survive after flooding with longer duration and their communities will not be able to recover [2].

Most of the experimental methods used to study the response of investigated plants to sea water are focused to substrate salinity and salt spray from the waves. These standard methods are inapplicable to define the flood resilience are well adapted to substrate salinity due to their regular exposure to sea water [3, 4]. Numerous studies demonstrated that direct submergence in sea water flood simulations were more appropriate than the indirect experiments for studying substrate salinity and salt spray [3, 7, 9]. Therefore, in order to understand the effects of sea water inundation on these species, two experiments based on direct submergence were chosen.
One of the variables that can affect the survival ability of the investigated species is sea water temperature. Three sea water flood simulations with different temperatures were carried out in order to study the relation between temperature and CDT [3]. In winter and early spring, when the storm events at the Black Sea Coast occur, average surface sea water temperature is about 4ºC. Other two treatments with temperatures of 13ºC (average surface sea water temperature) and 23ºC (average summer surface sea water temperature) were included in the simulated experiment [3].

Table 2 shows the results from conducted flooding simulations as well as CDT.

**Table 2** Results from simulated flooding experiment. Data in bold present CDT

| Plant                  | T ⁰C | Parameters                  |          |          |          |          |          |          |          |
|------------------------|------|-----------------------------|----------|----------|----------|----------|----------|----------|----------|
|                        |      | Beginning of decomposition of | Complete decomposition of | Growth of |          |          |          |          |          |
|                        |      | leaves | stems | roots | leaves | stems | roots | stems | roots | stems | roots | stems | roots |          |
| Centaurea arenaria    | 4    | 48    | 180   | 204   | 108    | 360   | 384   | 190   | 120   | 300   | 320   | 400   | 408   |          |
|                        | 13   | 46    | 180   | 204   | 102    | 360   | 380   | 190   | 120   | 300   | 320   | 400   | 406   |          |
|                        | 23   | 46    | 180   | 204   | 102    | 360   | 380   | 190   | 120   | 300   | 320   | 400   | 406   |          |
| Crambe tataria        | 4    | 46    | 168   | 192   | 96     | 312   | 336   | n/a   | n/a   | n/a   | n/a   | n/a   | n/a   |          |
|                        | 13   | 42    | 168   | 192   | 96     | 312   | 336   | n/a   | n/a   | n/a   | n/a   | n/a   | n/a   |          |
|                        | 23   | 42    | 168   | 192   | 96     | 312   | 336   | n/a   | n/a   | n/a   | n/a   | n/a   | n/a   |          |
| Aurinia suechtritziana| 4    | 46    | 172   | 192   | 96     | 300   | 348   | n/a   | 148   | n/a   | 300   | n/a   | 372   |          |
|                        | 13   | 46    | 172   | 192   | 96     | 300   | 348   | n/a   | 148   | n/a   | 300   | n/a   | 372   |          |
|                        | 23   | 46    | 172   | 192   | 96     | 300   | 348   | n/a   | 148   | n/a   | 300   | n/a   | 372   |          |
| Silene thymifolia     | 4    | 44    | 168   | 192   | 84     | 384   | 312   | n/a   | 120   | n/a   | 384   | n/a   | 408   |          |
|                        | 13   | 42    | 168   | 192   | 84     | 384   | 312   | n/a   | 120   | n/a   | 384   | n/a   | 408   |          |
|                        | 23   | 42    | 168   | 192   | 84     | 384   | 312   | n/a   | 120   | n/a   | 384   | n/a   | 408   |          |
| Stachys maritima      | 4    | 42    | 160   | 180   | 84     | 192   | 240   | n/a   | n/a   | n/a   | n/a   | n/a   | n/a   |          |
|                        | 13   | 40    | 160   | 180   | 84     | 192   | 240   | n/a   | n/a   | n/a   | n/a   | n/a   | n/a   |          |
|                        | 23   | 40    | 160   | 180   | 80     | 192   | 240   | n/a   | n/a   | n/a   | n/a   | n/a   | n/a   |          |

The beginning of the decay of leaves was the first visible morphological changes. The time frame of this parameter for the investigated species is between 40 and 48 hours.

According to Vergiev et al. [2, 3] this value have to be accepted as CDT. In the practice of the rapid method for vulnerability assessment of coastal plant communities from flooding caused by unusual storms over the Bulgarian Black Sea Coast, the investigated species can be divided by CDT into 3 groups. The five species were within the most vulnerable group (CDT < 48 h). The CDT was significantly shorter than floods with a maximum duration for the Bulgarian Black Sea Coast [1, 2].

This value of the CDT is comparable with the results of *Crambe maritima* L., *Artemisia vulgaris* L., and *Eryngium maritimum* L. [2].

Only the value of the parameter beginning of decomposition of the leaves were accelerated by higher water temperatures, consistent with previous studies of vulnerable species [2] and contrary to experiments with psammophytes from the family *Poaceae* [3, 9] and the family *Cyperaceae* [7, 13]. Other parameters were unrelated to different water temperatures.
The investigated species have low survival rates and low degree of sea water flood resilience and their communities will not be able to recover after floods with maximum duration within one vegetation season.

4. Conclusion

The value of the CDT for Centaurea arenaria M. Bieb. ex Willd., Crambe tataria Sebeok, Aurinia uechtritziana (Bornm.) Cullen & Dudley, Silene thymifolia Sm., and Stachys maritima Gouan is between 40 and 46 hours. The five species were within the most vulnerable group (CDT < 48 h). The CDT was shorter than floods with a maximum duration for the Bulgarian Black Sea Coast. Only the values of the parameter beginning of decomposition of the leaves were accelerated by higher water. Other parameters were unrelated to different water temperatures. The investigated species have low survival rates and low degree of sea water flood resilience and their communities will not be able to recover after floods with maximum duration within one vegetation season.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare the absence of a conflict of interest.

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