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Growth and disturbance in the spatial dynamics of an endangered seashore grass *Arctophila fulva* var. *pendulina*

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ARTICLE INFO

Article history:
Received 12 January 2006
Received in revised form
19 April 2007
Accepted 24 April 2007
Published on line 11 June 2007

Keywords:
Arctophila fulva var. *pendulina*
Disturbance
Endangered species
Isostatic land uplift
Patch dynamics
Primary succession

ABSTRACT

The shores of the Bothnian Bay in the northern Baltic Sea are characterised by relatively rapid isostatic land uplift (ca. 6.9 mm year^{-1}) continuously exposing virgin land for plants to colonise. Autogenic and allogenic changes in soil and plant communities will eventually make these exposed sites unsuitable for the early colonisers. The course of the primary succession in the waterfront is often delayed and shaped by frequent disturbances by ice scouring, water level movements and suffocation of extant vegetation by floating plant debris. Hence, we hypothesise that disturbances are the key processes underlying the local short-term dynamics of the plant populations of the seashore meadows. We monitored formation, growth, shrinkage and mortality of patches of a critically endangered early successional grass species *Arctophila fulva* var. *pendulina* for four consecutive years at the Liminka Bay in Finland. The data allow estimation of quality, magnitude and frequency of the wintertime disturbance and the growth during the summer. We formulated and parameterised a spatially explicit simulation model to predict the fate of the population in the area. Simulations with the fitted parameter estimates predicted that the area of *A. fulva* population will considerably decrease in the next 30 years. A parameter sensitivity analysis showed the probability of a new patch formation to be the most important factor for the population persistence, whereas changes in the dispersal distance, for example, are less important. The best way to enhance the persistence of the population is to promote the new patch formation. This could be done by transplanting rhizome fragments of the species to the suitable open areas in the shallow water where they are not immediately displaced by the later successional species.

1. Introduction

Conservation biology seeks the scientific basis for the reduction of the extinction probability of threatened populations, and to provide guidelines for the management of species and their environments (e.g. Wilcox and Elderd, 2003). Awareness of the consequences of disturbances on the plant population dynamics is important for the species management and conservation (Menges and Quintana-Acencio, 2003). Spatial and temporal environmental variation caused by the disturbances, such as fires and storms, is often among major factors behind short-term changes in demographic parameters of plant populations that decrease growth rate and increase the risk of local extinction (Menges, 2000). The disturbances may also affect positively plant populations and increase their growth by opening competition-free space (Canales et

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0304-3800/$ – see front matter
doi:10.1016/j.ecolmodel.2007.04.016

al., 1994; Cipollini et al., 1994). Therefore the predictions of regional population dynamics in habitats subject to disturbance require detailed descriptions of the disturbance regime and the patterns of colonisation and succession (Sousa, 1984).

Early successional plant species are able to maintain viable populations only in restricted growing conditions and they will gradually vanish when later successional species invade the area. The pioneer species have to be able to colonise new sites and, hence their persistence will depend on the availability of early successional habitats and on the activity of forces that create and maintain such habitats. The disturbances may, however, alter the competitive interactions between the early and the late successional species and delay the succession by releasing valuable resources such as space and light allowing expansion and dispersal. Many early successional species require disturbance to persist (Sousa, 1984; Bélanger and Bédard, 1994; Lesica and Cooper, 1999; Ramage and Schiel, 1999).

The shores of the Bothnian Bay in the northernmost Baltic Sea are characterised by a relatively rapid primary succession caused by the isostatic land uplift (the relative land uplift is 6.87 mm year^{-1}, Johansson et al., 2004) creating virgin land for the pioneer species to colonise. Subsequently the same deterministic process gradually elevates the habitat making its soil less waterlogged. This change in the physical properties of the soil, together with the autogenic succession by plants, eventually makes the habitat unsuitable for the early colonisers. However, frequent disturbances of the waterfront by ice scouring, water level movements and floating plant debris strongly influence the vegetation dynamics of the area by destroying extant vegetation cover and concomitantly creating open space for the species to colonise. Frequency, intensity, spatial location and the exact timing of the disturbances are largely unpredictable, although they usually are seasonally predictable: the ice scours vegetation during winter and spring, the suffocation by debris takes place usually in the spring and early summer, and autumns are typically characterised by stormy weather including flooding.

During the recent decades some early successional species have diminished both in the number and the coverage of the populations in the shores of the Bothnian Bay. It has been proposed that the demise of these species is due to the cessation of traditional agriculture (e.g. pasturage) or gradual eutrophication of coastal water (Ryttäri and Kettunen, 1997; Hänninen and Leppäkoski, 2004). In addition, during the previous two decades the long-term mean of the sea level has been approximately five cm higher than predicted on the basis of the historical linear trend (Johansson et al., 2004), potentially indicating a long-term trend of rising sea level that is counteracting the land uplift. If this is the case, one can speculate that the reduction in competition-free space available for the early colonists can make these populations more susceptible for local extinction.

We studied the patch dynamics of a critically endangered early successional grass, *Arctophila fulva* var. *pendulina* at the largest extant population at the Liminka Bay in Finland. The previous study (1992–1999) on the population dynamics of the species indicated that the population is not in immediate danger of extinction (Rautiainen et al., 2004). The results suggested that disturbance of the shoreline is sufficient for maintaining a viable population. In this study we wanted to study closer the effect of local disturbances and competitive exclusion on the patch dynamics and the persistence of the species. We constructed and analysed a 4-year observation data with a spatially explicit patch-level model, which treats *A. fulva* patches as individual objects defined by area and location in space. The results will aid in planning suitable management for the species and its environment.

2. Materials and methods

2.1. Study species and area

The species aggregate *A. fulva* has a circumpolar distribution but the variety *pendulina* is endemic to the Bothnian Bay and its catchment. The number of populations of the variety *pendulina* has declined during the recent decades and the area of extant populations has diminished (Siira, 1994). Only eight clearly separate, small populations remain in Sweden and Finland, where the species is considered critically endangered (Ericson and Wallentinus, 1979; Rassi et al., 2001). The study population at the Liminka Bay (64°49′–65°25′N lat., 25°06′–25°25′ E long., Fig. 1) in the estuary of the Temmesjoki river in Finland is the largest of them, covering approximately 3000 m^2, while the others vary from less than a square metre to some tens of square metres in size.

A. fulva is a tall, perennial, clonal grass that usually grows as scattered monocultural patches in the shallow water on the shores of seas, rivers and sometimes lakes. It exhibits variable growth forms in heterogeneous environments. When growing in the running water it can form long flexible and floating shoots but usually it has an upright and firm growth form. The species flowers regularly in June–July, but no seedlings have been recorded in the study area (Rautiainen et al., 2004)

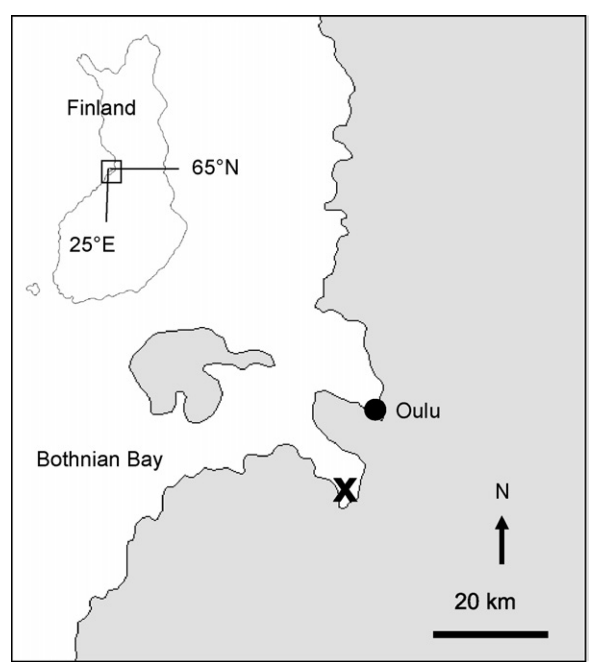

Fig. 1 – The location of the studied *A. fulva* population (denoted by X).