HABITAT NETWORKS FOR DISPERSAL-LIMITED PLANT SPECIES HAVE TO BE CONNECTED AT SMALL SCALE

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Abstract:
Xeric sand calcareous grasslands (habitat type 6120 of Natura 2000) are characteristic landscape elements in Brandenburg. However, they occur increasingly in rather small and isolated patches with increased risk of local plant extinctions. In regional meta-population dynamics extinctions could be balanced by colonisations. We studied the meta-population dynamics of *Armeria elongata*, a characteristic, but declining, species of the 6120 habitat type. Observed local extinctions were outnumbered by colonisations. However, the small size of many populations suggests further extinctions. Experimentally verified potential habitats were not colonised by the species, indicating dispersal limitation. Other characteristics of *A. elongata* such as self-incompatibility and insect-pollination are likely to render it vulnerable to habitat fragmentation. When we compared such characteristics among the 32 characteristic species of this habitat type *A. elongata* appeared not peculiar. We conclude that habitats in networks for plant species conservation should be connected at relatively small scale, which appears not to be the case for the existing Natura 2000 network, at least in Brandenburg.

Keywords: *Armeria elongata*, connectivity measures, dispersal limitation, fragmentation, land use change, meta-population dynamics, Natura 2000 habitat type 6120, * Xeric sand calcareous grasslands

Introduction

Fragmented plant populations are small and isolated and therefore face high extinction risks due to demographic, environmental or genetic stochasticity (Lienert 2004). Loss of genetic variation due to low gene flow, genetic drift or inbreeding, followed by reduced fitness, may be most severe in formerly common, insect pollinated, self-incompatible plant species (Leimu et al. 2006) Colonisations could balance local extinctions as part of meta-population dynamics, if species manage to disperse to suitable sites. However, studies on regional plant dynamics are rare (Ouborg & Eriksson 2004).
We studied aspects of the meta-population dynamics of the common, but declining, insect-pollinated self-incompatible *Armeria maritima* ssp. *elongata* (Plumbaginaceae), a characteristic species of xeric sand calcareous grasslands (Natura 2000 habitat type 6120) typical for the German state of Brandenburg. However, even there it has decreased in numbers and size due to more intensive or abandoned land use. To address whether other species are as likely to be affected by fragmentation as *A. elongata* we compared its characteristics with the ones of other characteristic plants of this habitat type

Materials and methods

In 2004 and 2006 we recorded all extant populations of *A. elongata* in three study regions of 30 km^2 each in Brandenburg in northern Germany. For a colonisation experiment, we sowed seeds from 8 randomly chosen source populations per region to 8 potentially suitable sites within 500 m from the source populations. We sowed further seeds also to their home sites. After 16 months we recorded seedling establishment.
For the comparison of *A. elongata* with co-occurring species we used 31 plant species typical for 6120 habitats (Ssymank 1998, Beutler & Beutler 2002) occurring in Brandenburg. We obtained trait information assumed relevant for species vulnerability to habitat fragmentation from literature and data bases (Table 1). As relevant traits we

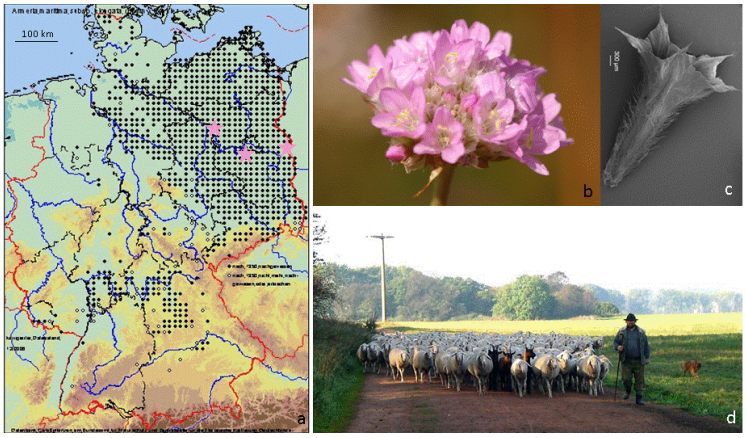

Figure 1. *Armeria elongata* as representative of xeric sand grasslands: a) Its distribution in Germany, open symbols: extinctions after 1950 (BfN 2006); asterisks: location of the three study regions. b) Insect-attracting inflorescence (M. Petru). c) Fruit, shaped for adherence to fur (H. Baumbach). d) Rotating sheep-pasturing in one of the study regions (B. Seifert)

considered rarity (Leimu et al. 2006), degree of threat (Frankham 1995), habitat specialisation (Fischer & Stöcklin 1997), life span (Fischer & Stöcklin 1997), mating system (Honnay & Jacquemyn 2007), pollination vector (Aquilar et al. 2006) and long distance dispersability by wind and sheep (Poschlod et al. 1998, Tackenberg 2001). For each trait we ordered species values from less sensitive to more sensitive to habitat fragmentation and assessed the rank of *A. elongata*.
For the reported FFH (EU-directive on flora, fauna, habitats) -sites that represent the xeric sand calcareous grasslands we analysed their size and connectivity data.

Results and discussion

In 2006, there were 224 *A. elongata* populations with a mean size of 830 (± 2773.7 Std; median 88.5) flowering individuals. 53% of the populations had fewer than 100 flowering individuals, 85% fewer than 1,000. The 24 target populations had on average 8.4 (± 6.0 Std) neighbouring populations within 500 m distance. More isolated populations were smaller than less isolated ones ($R = 0.68$, $p < 0.001$).
Between 2004 and 2006 180 populations persisted, 32 were newly colonised, and 4 went extinct. Extinct populations had had less than 100 or even 10 flowering individuals. Colonisations occurred mainly along roadsides and in areas with rotating sheep-pasturing. These results indicate regional species dynamics and vector-assisted dispersal. Given the high proportion of small populations, increasing numbers of extinctions due to stochastic reasons appear likely.
In our sowing experiment seedlings established at all sites. Despite considerable variation this did not differ between occupied and potential sites (Fig. 2 left) clearly indicating that dispersal limitation impedes regional dynamics.
Variation among sowing sites explained most (42%) of the variation in establishment. Moreover, a significant source population x target site interaction suggests genetic differentiation in the response to different target environments. This corresponds well

with low gene flow among populations of the *Armeria maritima* complex, facilitating differentiation (Weidema et al. 1996). Our results suggest that gene flow and colonisation take place at rather small spatial scales in *A. elongata*.

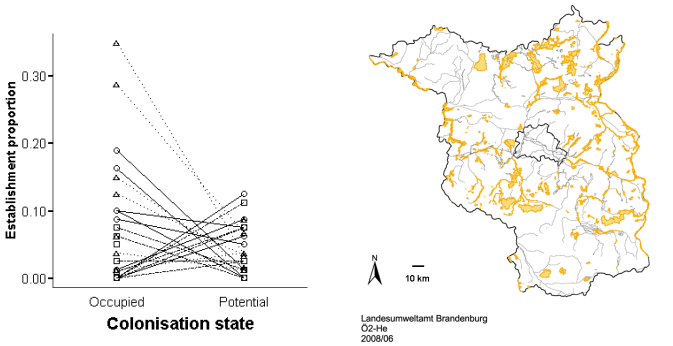

Figure 2. Left: Establishment of *A. elongata* seeds in potential vs. occupied sites. Each line-connected pair of symbols represent 2 x 80 seeds of a source population (n = 24). Different symbols denote the three different study regions. Right: Orange: FFH-sites in Brandenburg that contain the 6120 habitat type.

In Brandenburg, 173 scatty distributed sites of the Natura 2000 habitat type 6120 were reported (Fig. 2 right). Their total area of about 3500 ha comprises only 0.12 % of the state area (Beutler & Beutler 2002). The distances between neighbouring sites were between 0.3 and 95.7 km (mean 16.3), suggesting that gene flow and dispersal between sites are not guaranteed for species such as *Armeria elongata*.

Table 1. Fragmentation-relevant traits of *Armeria elongata* compared with 31 other xeric sand calcareous grassland plants. Parameter values were sorted from less sensitive to more sensitive to habitat fragmentation. Characters and rank of *A. elongata* are marked in bold. For some traits data were not available for all species. Data were obtained from [1] Fischer et al. 1996, [2] Tackenberg 2001, [3] Jäger & Werner 2005, [4] Bugla & Poschlod 2005, [5] Eichberg et al. 2007, [6] Ristow et al. 2006, [7] Klotz et al. 2002.

Trait	**Variable**	**less sensitive → more sensitive to fragmentation**	**Rank of *A. elongata***
Rarity	Abundance in Brandenburg at ordnance map scale [3]	> **90%** → 90-40% → 40-5% → < 5%	**5** : 12 : 10 : 5
Degree of threat	Red data book [6]	least concern → **vulnerable** to critically endangered	13 : **19**
Habitat specialisation	# Habitat types in Germany [7]	generalist (7 types) → **specialist** (1 type)	rank **18** of 23 **(2 types)**
Life span	Annuals vs. perennials (incl. biennials) [7]	**perennial** → annual	**30** : 2
Mating system	Self-incompatibility [7]	self-compatible → **self-incompatible**	15 : **8**
Pollination	Main pollen vector [7]	selfing → wind → **insects**	5 : 8 : **18**
Dispersability by wind	Mean diaspore weight [7]	light (0.53 mg) → **heavy** (7.05 mg)	rank **8** of 9 **(1.47 mg)**
	Mean falling velocity [2]	slow (0.20 m/s) → **fast** (2.30 m/s)	rank **11** of 15 **(1.70 m/s)**
Dispersability by sheep	Evidence for endo-and/ or **epizoochory** [1,4,5]	sensitive if sheep pasturing is abandoned	**16** of 19 species

A. elongata, although still common, shows many traits that render it vulnerable to habitat fragmentation. However, as these traits were not peculiar for *A. elongata* it appears likely that many co-occurring plants are similarly vulnerable (Table 1).

Conclusions

Habitats in networks for plant conservation (at least in xeric sand calcareous grasslands) should be connected at relatively small scale, which appears not to be the case for the existing Natura 2000 network in Brandenburg. Reported FFH-sites of the 6120 type should therefore be integrated in extended local conservation efforts rather than considered as sufficient for conservation. Conservation should take species-specific attributes into account to support regional dynamics. To do so, continuing or reintroducing traditional land use such as sheep-farming may be essential.

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