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Short research contribution

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INVASION OF *DESCURAINIA SOPHIA* (L.) (CRUCIFERAE) IN ALPINE MEADOW IS ENHANCED BY GROUND DISTURBANCE MADE BY *MYOSPALAX FONTANIERII* (MILNE-EDWARDS)

ABSTRACT: Because of cold weather and extremely harsh environment, there is few exotic species in Qinghai-Tibetan Plateau. Plateau zokor (*Myospalax fontanierii*), dominant borrowing small mammal, plays a role as 'ecosystem engineer' in alpine meadow ecosystem. We measured and compared the dispersion area, branches, height and number of branches of flixweed tansymustard (*Descurainia sophia*) on the area disturbed by zokor mounds and in the undisturbed alpine meadow. Flixweed tansymustard is cool-season annual or biennial typical farmland weed in China, and is not found in alpine meadow before. The results indicated that zokor mounds significantly increased the dispersion area, number of individuals in each dispersion area, height and number of branches of flixweed tansymustard on the area disturbed by zokor mounds compared to those in undisturbed alpine meadow. These results suggest that ecosystem engineering by native species of rodent could promote the invasions of alien plant species in alpine meadow ecosystem, leading to higher abundances of invaders.

KEY WORDS: *Descurainia sophia* alpine meadow ecosystem, biological invaders, *Myospalax fontanierii*, Qinghai-Tibetan Plateau

Biological invasions create the significant disturbances affecting ecosystems worldwide (Vitousek *et al.* 1997, Mack *et al.* 2000). Different mechanisms have been proposed to explain why exotic plants successfully invade natural communities, including the release of natural enemies of exotics (Keane and Crawley 2002), allelopathic effects of exotics on native plants (Hierro and Callaway 2003, Callaway and Ridenour 2004) and resource opportunities for exotics upon arrival in new ecosystems (Shea and Chesson 2002). Ecosystem engineers are organisms that directly or indirectly modulate the availability of resources to other species, by causing physical state changes in biotic or abiotic materials (Jones *et al.* 1994). Physical changes in the habitat made by so called 'ecosystem engineers' may also enhance successfully the biological invasions (Crooks 2002, Cuddington and Hastings 2004, Anderson *et al.* 2006). But few study focus on the role of native ecosystem engineers during biological invasions. Only a recent research in extreme environmental conditions discovered the new mechanism facilitating the impact that native ecosystem engineer species may have on the distribution and performance of exotic plants (Badano *et al.* 2007).

Qinghai-Tibetan Plateau is called the third pole of the world for its cold weather and extremely harsh environment (Tibetan

Plateau Scientific Expedition Team CAS 1984). The average altitude (more than 4000 m a.s.l.) of the plateau is the highest of the earth. The productivity of alpine ecosystem here is low, and also the stability of the ecosystem (Zhang and Cao 1999). This region has supported livestock alongside a diverse assemblage of wild herbivores for millennia, and pastoralism continues to be the mainstay of the local economy and chief land-use (Mishra *et al.* 2004). However, the traditional pastoral management has changed drastically over the last few decades, as traditional practices (like rotational grazing, seasonal movements) have broken down (Leneman and Reid 2001). Therefore, the over-grazing is ubiquitous in this plateau (Zhao *et al.* 2000), the degradation of the grassland is serious (Shang and Long 2005), and the possibility of biological invasion to the alpine meadow ecosystem is increasing in this way.

Plateau zokor (*Myospalax fontanierii*) is the dominant below-ground rodent in Qinghai-Tibetan Plateau (Zong *et al.* 1991). The species is small (females: *ca* 220 g, males: *ca* 270 g), but it has strong digging ability, and its main hole can reach 2 m belowground (Zhou and Dou 1990). A zokor can deposit 1024 kg soil to the surface each year (Wang and Fan 1987), and the mounds (height up to12.8 cm in average) of one zokor can cover an area of 22.53 m^2 (Wang *et al.* 1993). Plateau zokor greatly influences on the succession of vegetation and primary production of alpine meadow (Zhang and Liu 2002, Zhang *et al.* 2004). It can increase the decomposition of organic matters in the mound, and the amount of available nutrient is much higher in the disturbed area than in undisturbed alpine meadow soil (Wang *et al.* 1993). Zokor's mound increases the environment heterogeneity of alpine meadow, offers survival habitat for more species (such as *Ajania tenuifolia* (Jacq.) Tzvel., *Polygonum sibioicum* Maxim, *Glaux maritima* Linn. and others) (Wang *et al.* 1993), and also increases the chances for biotic invasions. Therefore, plateau zokor is the native 'ecosystem engineer' in alpine meadow ecosystem (Zhang *et al.* 2003).

One of the plant species which occurrence in alpine meadow connected with land disturbance by plateau zokor is flixweed tansymustard – *Descuriania sophia* (family Cruciferae). Flixweed tansymustard is a cool-season annual or biennial. It is the typical species for the genus, and is about 30–100 cm tall with basal and cauline leaves. Flixweed tansymustard is already a dominant farmland weed in wheat field almost in all the parts of northern China (Xia *et al.* 2000). We assume that the ecosystem engineering of plateau zokor that is the way of land disturbance made by this rodent species (mounds, holes and corridors) can facilitate the invasion of flixweed tansymustard in alpine meadow ecosystem in Qinghai-Tibetan Plateau.

The study was conducted near Haibei Alpine Meadow Ecosystem Station of Chinese Academy of Sciences (37°29′–37°45′N, 101°12′–101°23′E) in Menyuan County of Qinghai Province, at average altitude 3200 m. Annual mean temperature is -1.6°C (range from 27.5°C in July to -35°C in January), and annual mean precipitation average is close to 560 mm, 79% of which occurs between May and September, and annual mean wind speed is 1.7 m s^{-1} (Yang 1987, Li *et al.* 2004). The vegetation types belong to alpine meadow and alpine shrub. Dominant plants in alpine meadow are: *Stipa* sp., *Kobresia* sp., *Elymus nutans* Griseb., *Saussurea* sp., *Gentiana straminea* Maxim., *Pedicularis kansuensis* Maxim., *Leontopodium nanum* (Hook. f. *et* Thoms.) Hand.-Mazz., *Ajania tenuifolia* (Jacq.) Tzvel., *Potentilla* sp. The dominating wild herbivores are: plateau pika (*Ochotona curzoniae* Hodgson), plateau zokor, root vole (M*icrotus oeconomus* Pallas), Himalayan marmot (*Marmota himalayana* Hodgson). There are also little predators like polecat (*Mustela eversmanni* Lesson) and alpine weasel (*Mustela altaica* Pallas), birds of Passeriformes and raptors like upland buzzard (*Buteo hemilasius* Teminck *et* Schlegel).

People near around began to do the farming work in middle of the 1980s, so flixweed tansymustard entered alpine meadow quite recently. We selected a study site (size about 100 ha) not far away from peoples house in the alpine meadow in August 2005. With fence around it, the study site was not grazed in summer. Before the study was conducted, we asked the local people, and verified that the flixweed tansymustard was absent in the study site in 2003, and in 2004 only few plants occurred. Therefore we estimated the dispersion areas of flixweed tansymustard, and counted its number in each dispersion area. We selected 15 patches both in undisturbed meadow and on the zokor's mound randomly. Then the height of 10 randomly selected flixweed tansymustard plant in each patch was measured and the number of branches in each plant was counted.

The data on the size of dispersion area and the quantity of flixweed tansymustard in each area were not normal, therefore we used Mann-Whitney *U* test to analyse the difference between different habitats. The data of height and number of branches followed the normality, one-way ANOVA was used to analyse the results. All statistical analyses were conducted using SPSS 13.0 for Windows (SPSS Inc., Chicago, IL, USA).

The size of the dispersion area and the quantity of flixweed tansymustard in each area on the zokor's mounds were much higher than in the undisturbed alpine meadow (Fig. 1). And the differences between both habitats is highly significant (Mann-Whitney *U* test, $Z = 2.931$, $P < 0.01$ for dispersion area and Mann-Whitney *U* test, $Z = 4.311$, $P < 0.001$ for the amounts of flixweed tansymustard in each dispersion area). Also flixweed tansymustard in undisturbed alpine meadow is much smaller and with fewer branches than in disturbed, mound area (Fig. 2). The difference between both habitats is highly significant ($F = 44.654$, $P < 0.001$for height; $F = 65.162$, P <0.001 for number of branches). With more branches, the flixweed tansymustard has more legumes and seeds. With much higher height, the seeds can diffuse for a farther distance.

The number of flixweed tansymustard's seeds is very high (10 000–50 000 per plant), they are of tiny weight (thousand seed weight amounts 0.15 g) (Xia *et al.* 2000), and adapted to wind dispersion. The wind in Qinghai-Tibetan Plateau is heavy and strong (Tibetan Plateau Scientific Expedition Team CAS 1984), and this enhances the dispersion of flixweed tansymustard. The annual average temperature is low, and the precipitation occurs most in warm season (Yang 1987, Li *et al.* 2004), so the seeds can keep alive for a long time. Even if the seeds of flixweed tansymustard dispose to the areas not suitable for its growth, they may live for a long period

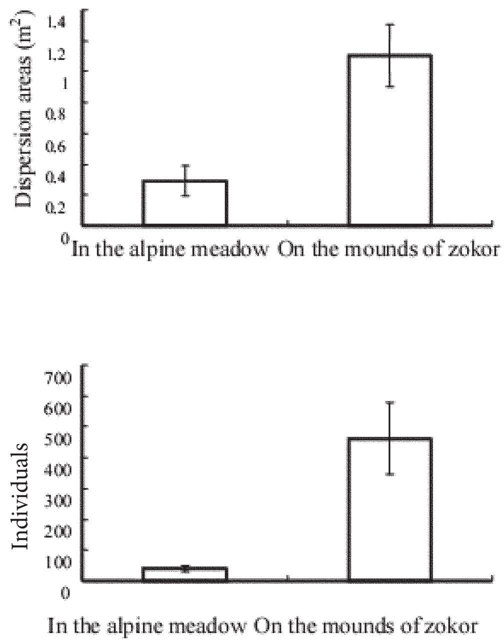

Fig. 1. The average dispersion area and number of *Descurainia sophia* individuals in each dispersion area in different habitats.

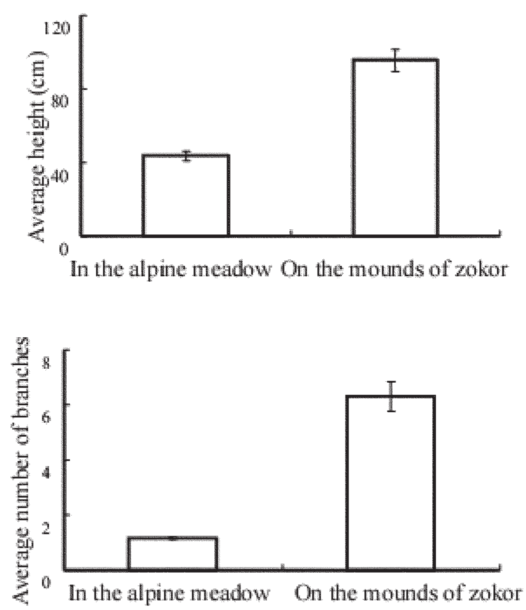

Fig. 2. The average height and number of branches of *Descurainia sophia* in different habitats.

even few years. The over-grazing and change of traditional pasturage fashion, lead to the degradation of meadow grassland, decrease the cover of meadow vegetation, make more bare ground, and change the character of the vegetation (Zhang 1999). All these enhance flixweed tansymustard to invade the alpine meadow.

Flixweed tansymustard is a typical farmland weed and the farmland is its most suitable habitat (Xia *et al.* 2000). The digging activity of plateau zokor (Wang and Fan 1987) makes small patches like farmland in alpine meadow. These small patches make harsh environment of alpine meadow much more suitable for flixweed tansymustard, and they grew much better on the mounds, having higher stems and much more seeds (Fig. 2).

Once the biotic invaders establish in the ecosystem, they can influence the structure, biodiversity and succession of vegetation of the ecosystem, even make ecosystem function lost and threaten its biosafety (Li and Xie 2000). Alpine meadow ecosystem is brittle (Zhang and Cao 1999) and the influence of biotic invasion may be much greater; it decreases local biodiversity evidently; disturbs the secondary succession and changes the community structure.

This study gives the evidence that the native ecosystem engineers can facilitate the establishment of the exotic species in alpine meadow ecosystem. Although there are not many biotic invaders in Qinghai-Tibetan Plateau, they will have more and more chances to invade alpine ecosystem with the increase of human activity and change of traditional practice (Mishra *et al.* 2004). Sustaining over-grazing (Zhao *et al.* 2000), breaking out of little mammals (Zhang *et al.* 1998) and other factors, prick up the instability of alpine meadow ecosystem, and make it more suitable for biotic invaders. The monitoring and study of biotic invaders of Qinghai-Tibetan Plateau, especially where small mammals density is high seem to be necessary in the process of restoration of degraded grassland.

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