BIOGEOMORPHOLOGY

Species signatures in landscapes

Plants influence geomorphology. Research on salt marshes suggests that feedbacks between geomorphic processes and life-history traits of plants produce species-specific signatures in the organization of biogeomorphic landscapes.

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Organisms contribute to the modulation of the shape, structure and texture of landscapes, from microscopic to regional scales[1]. Among the variety of species capable of modifying geomorphology over ecological to geological timescales — including humans — plants have been identified as a frequent protagonist. Plants are particularly influential within ecosystems at aquatic–terrestrial interfaces, such as that of riverine and coastal systems[2,3]. These ecosystems are subject to disturbances such as floods, tides and storms, and thus to stressful habitat conditions. Scale-dependant abiotic–biotic feedbacks often occur in such ecosystems, resulting in self-organized fluvial and coastal landscapes that originate from local interactions between geomorphic processes and plants[1]. Writing in *Nature Geoscience*, Schwarz and colleagues[4] demonstrate that the organization of salt marsh landscapes is a result of feedbacks between plants and sedimentation and erosion that depend on life-history traits, such as the mode of reproduction, of the plant species involved.

The pattern of landscape organization is initially formed according to the distribution of key habitat conditions for plant recruitment that determine where and what kind of plants can grow at the local scale. This in turn affects where sediment is more readily trapped and where it is more readily eroded, establishing a pattern that is then reinforced and maintained via local positive feedbacks involving, for example, sediment trapping, as well as plant growth. At a larger scale, diversion of wind and water flows by plants can increase erosion and obstruct plant recruitment.

Although it is well established that plant morphology affects sediment trapping[5], only recently has it been suggested that biologically controlled geomorphic changes may depend on the specific biological traits of a particular dominant plant species or group of species[1]. Different spatial patterns of sediment deposition and erosion were observed in a flume experiment involving various morphological and biomechanical traits of the salt marsh species *Spartina anglica* C.E. Hubb, *Puccinellia maritima* (Huds.) Parl. and *Salicornia procumbens* Sm. (ref. [6]).

Fig. 1 | The patchy colonization of the plant species *S. anglica* leads to the formation of an entrenched channel in-between patches of vegetation in a salt marsh creek of the Seine River estuary, France. Schwarz et al.[4] analyse a different salt marsh in the Netherlands and find that whether the dominant plant species is a slow or fast colonizer influences the resulting organization of channel networks at the landscape scale. Image courtesy of F. Azémar, EcoLab.

Schwarz and colleagues[4] take the next step and demonstrate in situ and at the landscape scale that the biogeomorphic landscape patterns and dynamics of salt marshes can indeed be species specific. In the studied salt marsh in the Netherlands, two dominant herbaceous pioneer plant species colonize intertidal surfaces that are exposed to water and sediment fluxes: *Salicornia europaea* L. is a fast-colonizing annual plant and *S. anglica* is a slow-colonizing perennial plant. *S. anglica* is characterized by a strong root system and a high capacity of lateral expansion by way of rhizome growth — a strategy that enhances the establishment of patchy vegetation patterns, which promotes scale-dependant feedbacks.

The researchers find that when intertidal surfaces are colonized by *S. anglica*, erosion is concentrated between laterally expanding and aggregating tussocks, and vegetated levees cause the formation of entrenched channels (Fig. 1). Such a vegetation colonization pattern controls the tidal drainage network geometry via the competing effects of landform construction and vegetation growth on a local scale, and landform destruction by erosion and plant recruitment obstruction on a larger spatial scale[7].

Schwarz and colleagues demonstrate that life-history traits play a crucial role in shaping landscapes because they control the modality and rate of colonization of the vegetation. The patchy clonal establishment of *S. anglica* induces the formation of new and deeper channels in-between the vegetated patches, thus generating a self-organized biogeomorphic landscape. In contrast, the homogeneous seedling establishment of the fast-colonizer *S. europaea* stabilizes the existing lower channels instead of generating new ones, and thus reinforces the existing biogeomorphic landscape. The life-history traits that control the potential for landscape self-organization thus also affect the long-term resilience and adaptability of such biogeomorphic ecosystems to climatic change.

The findings add to our growing understanding of the role that plants play in the evolution of landscapes at the interface between water and land. Initially considered as only a source of roughness that affects hydrodynamic or aerodynamic forces, it is becoming increasingly evident that the role of plants should be viewed in an integrative eco-evolutionary framework: biogeomorphic landscape patterns and dynamics result from ecological and evolutionary feedbacks between geomorphology and engineer plant species over both ecological and evolutionary timescales[1–3,8]. This concept, in which life — whether individuals, populations or communities of organisms — and geomorphology influence each other over a range of temporal scales, implies that biologically modified landforms are potentially adaptive functional components of the ecosystem. The functionality is a result of natural selection and evolution, which shape organism traits, including life-history strategy. Thus, some landscapes engineered by biology may reflect the functionality of the organisms that live there.

Schwarz and colleagues have provided significant empirical evidence in support of the hypothesis that key geomorphic parameters should relate on a functional basis to key traits of the engineer plant, in particular its life-history strategy. Species-specific, biologically controlled geomorphic changes can affect the average chances of survival, growth and reproduction of the engineer plant species[3,8]. For example, geomorphic modifications driven by *S. anglica* in salt marshes in the United Kingdom act to maintain the ecological requirements of this engineer species[9]. *S. anglica* promotes sediment trapping that in turn increases species survival and growth by reducing inundation stress and enhancing nutrient availability and soil drainage.

The findings of Schwarz and colleagues that the configuration of a salt marsh landscape can be shaped and maintained by the life-history traits of its engineer plants, combined with evidence that such biogeomorphic feedbacks also promote the survival, growth and reproduction of the plant species, suggest that there is still much to be learned about the signatures of organisms in landscapes and the influence of biogeomorphic feedbacks on organism ecology and evolution. Instead of considering the physical and biological properties of landscapes separately, an integrated framework — or 'evolutionary geomorphology'[10] — may be the way forward. ❐

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