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Editorial

Process geomorphology and ecosystems: Disturbance regimes and interactions

Geomorphic processes are important agents of ecosystem disturbance, and ecosystem functions moderate the magnitude and frequency of geomorphic events. Developing an improved understanding of the interactions between geomorphic and ecological processes represents a key challenge for both disciplines, as is exemplified by the large number of special issues published on the topic in the last few years (Viles and Naylor, 2002; Thoms et al., 2007; Hession et al., 2010; Rice et al., 2010; Darby, 2011; Wheaton et al., 2011; Butler and Sawyer, 2012; Rice et al., 2012).

This special issue contains eleven papers, mostly delivered at a session organized by the guest editors at the European Geosciences Union (EGU) General Assembly in Vienna (Austria) in April 2011. The main goals of the session were to bring together researchers interested in (i) quantifying plant and animal impacts on geomorphic disturbance regimes as well as of geomorphic disturbances on aquatic and terrestrial ecosystems; (ii) elucidating the interactions and feedbacks between process geomorphology and ecosystems at any scale; and in (iii) investigating how ecosystems might be used to infer past geomorphic disturbance histories.

In the first paper of this special issue, Coombes et al. focus on the impacts and bioprotective role of seaweed in the intertidal zone. The authors examined the influence of seaweed canopies (*Fucus* spp.) on near-surface microclimate and on conditions for mechanical rock decay and under-canopy ecology on artificial coastal structures built of limestone and concrete in South West England. The authors demonstrate that the range and maxima of daily summertime temperatures were significantly lower (56% and 25%, respectively) in areas colonized by seaweed compared to experimentally cleared areas. Using seaweed as an example, they develop a conceptual model of the relationship between biological cover and microclimate in the intertidal zone. They conclude that in urban coastal environments, where disturbance tends to occur more frequently, facilitating the establishment and recovery of canopy-forming species on rocks and engineered structures may enhance the durability of construction materials as well as support conservation, planning, and policy targets for biodiversity enhancement.

In contrast to these largely hidden zoogeomorphic effects of the intertidal zone, two papers in the special issue focus on the impact of mass-wasting processes on the establishment and vitality of forests. Deligne et al. address the repaving of landscapes by effusive volcanic eruptions and the associated challenges for ecological recovery presented by dense, sterile, inhospitable lava deposits. The study made use of two sites with recent volcanism in the central Oregon Cascades and used a combination of LiDAR analyses, field observations, and soil characterization to demonstrate that the presence of external sediment or soil sources, in particular flood-borne deposits or syn- or post-eruptive tephra, facilitates plant establishment, growth, and survival. They conclude that the nature of external sediment sources or soils strongly affects the recovery and distribution of forests on young lava flows.

The second mass-wasting paper, by Corona et al., addresses interactions between trees and rockfall on forested talus slopes. While the presence and density of vegetation have a profound influence on rockfall activity, rockfalls also exert control on the presence, vitality, species composition, and age distribution of forest stands. The authors use the interactions between biotic (tree growth) and abiotic (rockfall) processes in a mountain forest to gather reliable input data for a 3D model of rockfall on a slope in the Swiss Alps. They demonstrate that differences between simulated and observed numbers of tree impacts can be minimized through a careful definition of active source areas and a weighted distribution of block sizes as observed in the field. The authors conclude that a combination of field-based dendrogeomorphology and modeling approaches can significantly improve hazard mapping because it allows a more reliable spatial characterization of rockfall frequencies, a more realistic representation of past rockfall dynamics and an improved understanding on where and how rockfalls disturb trees and forest stands.

In an interesting departure from previous work on the biogeomorphic impact of salmon, Albers and Petticrew investigated the role of Pacific salmon (*Oncorhynchus* sp.) on the disturbance and redeposition of fine sediment during spawning and the associated distribution and storage of marine derived nutrients (MDN) from salmon death and decay. Using experimental enclosures in the Horsefly River spawning channel in north-central British Columbia, the authors quantified the magnitude of organic and inorganic sediment export and retention from an active-spawning area and determined the contribution of fine sediment MDN storage using a suspended sediment mass balance model, marine isotope enrichment and a time series of gravel bed sediment infiltration. They clearly illustrate that strong linear relationships exist between sediment infiltration and marine-derived nutrient enrichment and that localized patterns of sediment deposition are regulated by salmon activity, which in turn act to control MDN storage within, and release from, the gravel bed.

The majority of the contributions in this special issue address the mutual impacts and interdependencies of river dynamics on riparian vegetation with modeling, aerial photography and tree-ring reconstructions. Based on a series of flume experiments, Crouzy et al. discuss how the balance between uprooting by flood events and reinforcement by plant roots determines the ability for vegetation to colonize the riverbed. The authors highlight the role of varying local stream power on these processes and illustrate the influence of vegetation root length, number of roots and stem height for the survival of vegetation in the

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riverbed after a flood. In a model-based assessment of stream processes, woody debris and riparian ecosystems, Davidson and Eaton consider the consequences of anthropogenic decoupling of streams from riparian ecosystems and thence wood recruitment processes. The authors used a physical model to examine the impact of different wood load on channel morphology and hydraulics. The addition of large wood significantly decreased the reach-averaged velocity in all experiments, and was associated with decreased sediment transport and increased sediment storage in the reach. Increases in bed and water surface slope were shown to compensate for the loss of energy available to transport sediment, and to enable the system to reach a new steady state within 6 to 9 years. The retention of fine sediment was shown to increase the availability of spawning substrate, while increased water stage improved floodplain connectivity. The authors illustrate that the changes in habitat complexity were generally related to the wood load added to the reach, but that they also depended on the orientation and arrangement of the pieces.

Henshaw et al. utilize multispectral Landsat satellite data to investigate the interactions between fluvial processes and riparian vegetation along the Tagliamento river (NE Italy) over the past 30 years, with the aim to evaluate the degree to which remotely sensed data can support the assessment of fluvial dynamics. The authors focus on spatio-temporal trends in vegetation cover and channel position at six sites and interpret observed changes using a series of hydromorphic data and survey-based biogeomorphic characteristics from the study sites. They nicely illustrate the limitations of Landsat TM data, which are mostly related to its relatively low spatial resolution, including geomorphic feature definition and active tract delineation, but also demonstrate that Landsat TM data can indeed reveal a wealth of information that could support further biogeomorphic investigations in other large rivers. The paper by Little et al. is also based on photo interpretation, but uses a 70-year aerial photo record and field data from the Carmanah River valley, Vancouver Island, British Columbia to study the diverse, shifting mosaic of forest patches in an alluvial forest and examine the hydrogeomorphic disturbance regime that structures it. Research was based on a landscape-scale analysis to quantify historical channel migrations and changes in the extent of specific forest types. The findings support a general conceptual model describing cycles of patch development and destruction in unconfined alluvial forests of the Pacific Coastal Ecoregion. They also demonstrate that Carmanah River has eroded nearly 30% of the alluvial forest in the course of the 20th century, and approximately 65% over the past 500 years. Interestingly, younger landforms were apparently disturbed more frequently than mature forest patches, suggesting that the likelihood of future disturbance decreases as biogeomorphic succession progresses. In addition, the authors conclude that larger floods, predicted to occur more frequently with climate change, might change the disturbance regime of floodplain forests and alter landscape composition.

Stella et al. consider how hydrogeomorphic changes affect key biological and physical processes that sustain riparian ecosystem health and constrain potential recovery. Working on the Drôme River, southern France, the authors study ecosystem response to channel incision due to gravel mining using tree-ring series from *Populus nigra*, a riparian tree vulnerable to changes in local hydrology. Cores collected at seven floodplain sites were used to investigate the severity and timing of local growth decline along the river. Regime shift analysis of the tree-ring series indicates that tree growth declined significantly at four sites since 1978, coinciding with documented channel incision. In addition, patterns of low growth and crown dieback are consistent with stress due to reduced water supply. However, the most impaired sites were not directly adjacent to local mining pits, and initiation of growth declines was most typically associated with drought years in these cases. In any case, the authors show quite clearly that riparian forests are vulnerable to hydrogeomorphic changes, but that the severity of impacts is likely to be conditioned by interactions between drivers at different scales, including regional climate variability, reach-based geomorphic alteration, and local lithological controls.

The contribution of Mikus et al. showcases results of long-term observations conducted in the gravel-bed river Czarny Dunajec, Polish Carpathians. The authors use morphological and botanical surveys to determine processes and patterns which govern the initiation and development of islands and their floristic complexity. Tree-ring records of riparian vegetation were used to date island inception and compared with the timing and magnitude of flood flows between 1970 and 2011. The authors show that in this high-energy braided river, islands originate through the deposition of large wood on gravel bars and the associated vegetative regeneration of living wood or the growth of seedlings in the shelter of wood accumulations. After 1997 the occurrence of low to moderate floods facilitated the formation and persistence of islands where species richness increased non-linearly with increasing age, area and shore length of islands. They also highlight that these islands substantially augment the overall floristic complexity of river corridor and that their re-establishment should be viewed as an important factor in the restoration of degraded mountain rivers.

The last paper in the special issue focuses on the relations between vegetation and sediment transport processes at Fishtrap Creek, British Columbia, where a fire burnt 62% of the basin's forest in 2003. Based on the analysis of local streamflow data and suspended sediment fluxes in comparison with nearby Jamieson Creek, which was not affected by the wildfire, Owens et al. observe that peak streamflows in Fishtrap Creek after the wildfire were not significantly higher than before the wildfire, but that total annual runoff had increased. After the wildfire, monthly total suspended sediment fluxes peaked in April in Fishtrap Creek and May in Jamieson Creek, which reflects a change in the timing of peak streamflow at the burnt site. Specific suspended sediment yields were low in the first year following fire and peaked in 2006, presumably reflecting a lack of winter precipitation and low intensities of summer rainfall events in the first year following the wildfire. Greater winter precipitation and associated snowmelt in subsequent years coincided with vegetation recovery. Interestingly, major changes in the wildfire-affected watershed included increased bank erosion and channel migration caused by a loss of root strength and cohesion, 3–5 years after the fire.

Together, these eleven papers yet again exemplify the wide range of interesting research questions sitting at the interface of ecology and geomorphology. Geomorphic processes affect ecologic systems, and flora and fauna can modulate the rate of occurrence and the impact of geomorphic disturbance events. In addition, ecosystems may record the geomorphic history of a region, and provide archives that are rarely exploited to date.

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