Co-evolving Physical and Biological Organization in a Restoration Reach of Wildcat Creek, California, USA

Organisation physique et biologique en évolution constante dans une aire de restauration de Wildcat Creek, Californie, Etats-Unis

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RÉSUMÉ

La gestion durable des rivières nécessite souvent des approches innovantes et intégrées qui favorisent des conceptions fonctionnant en synergie avec la nature, plutôt que de s'appuyer sur une ingénierie traditionnelle lourde. La restauration de Wildcat Creek à Berkeley, en Californie, aux Etats-Unis, s'est appuyée sur une approche naturelle soutenue par la compréhension scientifique. Le cadre de conception reconnaît la formation d'un profil en escalier comme un processus auto-organisateur qui produit une morphologie rythmique sous-jacente. Après avoir placé les particules des marches aux endroits prévus dans le lit du cours d'eau selon la théorie hydraulique, l'approche d'auto-organisation a permis aux processus fluviaux d'affiner les roches en séquences ajustées. Une zone d'examen « expérimentale » de 30 mètres a également permis d'examiner la coévolution des caractéristiques géomorphologiques et écologiques. Les roches éparpillées à l'extrémité amont d'un lit plat construit permettaient aux flux naturels de les disposer sous forme de paliers. Des relevés de terrain, des scanners LiDAR et des échantillonnages de macroinvertébrés benthiques ont suivi la formation du chenal restauré, y compris les communautés biologiques et l'habitat. L'échantillonnage biologique dans une zone de référence a également permis la comparaison avec la portée restaurée. Les résultats ont montré un canal de mares en paliers avec des habitats dans les marches et les bassins. Les communautés biologiques se sont également formées, bien qu'elles n'aient pas encore approché les valeurs de référence. La compréhension de la manière dont les caractéristiques biophysiques s'organisent ensemble après la restauration et créent un paysage équilibré peut faciliter le développement de conceptions intégrées et innovantes.

ABSTRACT

Sustainable management of rivers often requires innovative and integrated approaches that emphasize designs that work with nature, rather than traditional hard engineering. The restoration of Wildcat Creek in Berkeley, California, USA utilized a natural approach grounded in scientific theory. The design framework recognized step-pool formation as a self-organizing process that produces an underlying rhythmic morphology. After placing step particles at expected locations in the stream channel according to hydraulic theory, the self-organizing approach allowed fluvial processes to refine the rocks into adjusted sequences. A 30-meter "experimental" reach also allowed examination of the co-evolution of geomorphological and ecological characteristics. Rocks strewn at the upstream end of a constructed plane bed allowed natural flows to sort them into step-pool sequences. Ground surveys, LiDAR scanning, and sampling of benthic macroinvertebrates tracked the formation of the restored channel, including biological communities and habitat. Biological sampling in a reference reach also enabled comparison with the restored reach. Results showed an emergent step-pool channel with step and pool habitats. Biological communities also formed, though they did not yet approach reference values. Understanding how bio-physical characteristics co-organize toward an equilibrium landscape after restoration may facilitate development of integrated and innovative designs.

KEYWORDS

Bio-physical co-evolution, Human impacts, Integrated monitoring, Natural design, Restoration

1 RESTORATION OF WILDCAT CREEK, CALIFORNIA, USA

Heavy flows during winter of 2005-2006 eroded approximately 250 meters of Wildcat Creek that flowed through Tilden Park Golf Course in the densely populated city of Berkeley, California, USA. The East Bay Regional Parks District (District) engaged the Urban Creeks Council (UCC) to provide an initial assessment of the damage. The UCC developed a conceptual design to restore the creek under the guidance of the District and the Federal Emergency Management Agency. Serving as environmental engineering consultants, the Restoration Design Group (RDG) designed an ecologically-based restoration of the eroding channel. The design included a step-pool channel based on a state-of-the-art, self-organizing approach, placing step particles at locations predicted by hydraulic theory. Whereas traditional methods (e.g., Chin et al. 2009) typically wired artificial step-pool structures in place, the self-organizing approach allowed fluvial processes to refine these sequences into hydraulically-adjusted positions over time (Chin and Phillips 2007). The installation only anchored a few “keystones” step particles in place to ensure stability of the restoration reach.

Working with the District and the permitting process, the research team created an “experimental” reach to capitalize on the rare opportunity to observe development of a step-pool channel sequences in a restoration reach. In this 30-meter (100-foot) segment, rocks of various sizes were placed in the upstream end of a plane bed channel constructed during restoration. The study then documented natural flow events that mobilized and sorted these rocks into step-pool sequences over several seasons, along with the formation of habitat and benthic macroinvertebrate communities. The study tested the hypothesis that physical and ecological characteristics co-evolve naturally toward a new equilibrium landscape following restoration. Completed in October 2012, data from the restoration channel reach allowed new insights toward development of integrated theories for next-generation restoration designs.

2 EVOLUTION OF THE RESTORATION REACH

2.1 Monitoring and analysis

Data collection and analysis during the first post-restoration storm season focused on two time steps. T0 (Oct-Nov 2012) was the initial state represented in the as-built, plane bed channel from which physical and biological characteristics develop. T1 were the months following the first winter rains in Dec 2012 that mobilized the rock pile at the start of the experiment reach. This time step documented the emerging step-pool morphology along with developing habitats and biological communities. Coupled with data collected before restoration (Aug 2012), these designated time steps served to evaluate the overall success of the channel restoration, in addition to addressing questions concerning the co-development of physical and biological organization in restored step-pool channels. Physical surveys included longitudinal profiles, cross sections, measurements of particle sizes, average reach velocity, and a plan sketch that mapped in detail the position and sizes of step clasts and habitats (i.e., step, pool, riffle/run). Additionally, samples of benthic macroinvertebrates characterized the development of biological communities and overall ecological conditions. These characteristics within the experimental reach are compared against reference values in a nearby upstream segment of Wildcat Creek, for which additional corresponding samples were obtained. Terrestrial LiDAR scanning further provided detailed data for tracking geomorphological processes (e.g., erosion and deposition) over time.

2.2 Preliminary results

Following the first winter rains that mobilized the rock clasts, initial step-pool development was evident in Dec 2012. During T1, at least six steps developed from groupings of coarse particles that spanned across the low-flow channel. These steps segmented the experimental restoration reach into emergent habitats, whereby scouring below steps formed small pools. In between step-pool units, the channel during T1 was largely still a plane bed comprising pebbles and finer materials, considered as riffles/runs. The longitudinal profiles also showed development of initial step-pool sequences from the plane bed.

Data from nine sampling sites corresponding to these emerging habitats documented the biological communities present at T1. These communities are characterized by their diversity and composition, community and composition structure, tolerance/intolerance measures, and feeding measures. At this initial stage of development of habitats, the biological communities are largely indistinguishable among habitats. When compared with characteristics of the reference reach, however, four metrics showed significant differences. The differences were in the % contribution of dominant taxon, family biotic index, % scraper abundance, and % gatherer-collector abundance.

The Shannon Diversity Index represented overall biological conditions within study reaches, as well as within habitats. During T1 in the experimental reach, the Shannon Diversity Index was 1.35 for steps, followed by riffles/runs (1.20) and pools (1.06), with higher values indicating better ecological quality. These values produced an average index of 1.21. Comparing the experimental reach with the reference reach shows higher values of the Shannon Diversity Index in the reference reach. The indices are 1.51, 1.41, and 1.31for steps, riffles/runs, and pools, respectively in the reference reach for T1. The same trend of a higher Shannon Diversity Index in steps, followed by riffles/runs and pools, is evident in the reference reach.

2.3 Continuing work

Results from T1 provide several tentative statements for evaluation during subsequent time steps (T2, T3). First, initial step-pool sequences formed readily with the first winter rains in 2012, following placement of the rock piles in the experimental reach of Wildcat Creek during restoration. The channel morphology at T1 was an emergent step-pool channel with at least six steps identified. Second, these steps allowed segmentation of the plane bed channel into initial habitats identified as step, pool, and riffle/run. Although biological communities were forming, these characteristics were largely not distinguishable among habitats at this stage of development. Third, the Shannon Diversity Index suggests that the biological conditions in the experimental reach were approaching towards, but were not yet similar, to those of the reference streams. Fourth, the results support the hypothesis of a co-organization of physical and biological characteristics following restoration toward a new equilibrium landscape. Finally, such results give promise for future restoration designs that favor natural approaches. Although McHarg (1992) initiated ideas for designing with nature for city planning and management, achieving sustainable rivers in highly impacted landscapes may require accelerating progress in this regard.

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