Riparian forest dynamics on a large, regulated river (California, USA): impacts and implications for management

Dynamique de la ripisylve sur un grand fleuve régulé: conséquences et implications pour la gestion

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RÉSUMÉ

Sur les grands fleuves régulés, les ripisylves sont fréquemment affectées par des modifications du régime d'écoulement. Les impacts de ces modifications à large échelle comprennent souvent la réduction de la régénération des arbres, et le changement de la structure en âge des forêts et de la composition des communautés pionnières. Nous avons mené un vaste inventaire de la ripisylve du fleuve Sacramento (Californie, Etats-Unis), un cours d'eau méditerranéen qui a été régulé depuis 70 ans, afin d'étudier la réponse de la ripisylve à la gestion de la rivière. Au sein d'une chronoséquence de 4 á 107 ans, les peuplements de 40 à 60 ans sont les plus largement représentés dans la plaine et présentent les plus fortes valeurs en termes de surface terrière, de diversité des espèces et d'habitats fauniques fonctionnels. La surface terrière des arbres approche un maxima de 50 ans dans les habitats dominés par les peupliers, mais beaucoup plus tôt (32 ans) dans les habitats de saules, où la productivité est plus faible et plus constante dans le temps. Il y a un décalage temporel des espèces dominant la ripisylve avec dans un premier temps *Salix* et *Populus* puis *Juglans* et *Acer*. Après environ 90 ans, les peuplements qui colonisent les anciens bancs se dégradent, avec une surface terrière inférieure, moins de grands arbres, et plus de chandelles. Par conséquent, la gestion du chenal et de la plaine inondable devrait chercher à maximiser la présence de ces bois d'âge moyen à long terme en permettant la migration du fleuve et des événements de recoupements de méandres avec une fréquence suffisante pour maintenir une structure forestière multi-âge.

ABSTRACT

On large regulated rivers, riparian forests are frequently affected by modifications to the flow regime. Widespread impacts frequently include lower rates of seedling establishment and shifts in the forest age structure and composition away from pioneer communities. We conducted an extensive survey of riparian forest stands along the Sacramento River (California, USA), a large, mediterranean-climate river that has been regulated for 70 years, in order to document the species composition, size structure, and likely future dynamics of the riparian forest in response to river management. Across a chronosequence of 4–107 years (N=242 plots), stands 40-60 yrs old were the most extensive in terms of floodplain area, and represented the highest values of biomass, species diversity, and functional wildlife habitat. Plot basal area and mean tree diameter approached their maxima by 50 years in cottonwood-dominated stands, and by 32 years in the mixed willow stands, where biomass was much lower and constant over time. Dominant trees shifted from *Salix* to *Populus* to *Juglans* and *Acer* species over the chronosequence. After approximately 90 years, point bar stands begin to degrade, with lower basal area, fewer large trees, and more snags. Therefore, river and floodplain management should seek to maximize the middle-aged stands over the long term by allowing river migration and punctuated cutoff events with sufficient frequency to maintain a multi-aged forest structure.

KEYWORDS

Chronosequence, climate change, *Populus*, riparian forest dynamics, river management, *Salix*.

1 INTRODUCTION

1.1 Background

On large regulated rivers, riparian forests are frequently affected by modifications to the flow regime. Pioneer communities dominated by poplar and willow are dependent on the natural flow regime for regeneration and have declined along many regulated rivers in the southwestern U.S. and southern Europe. Widespread impacts of flow regulation frequently include lower rates of seedling establishment, increased susceptibility of adults to drought, and shifts in the forest age structure and composition away from young pioneer communities. The middle Sacramento River, (California, USA) is a prime example of a large, Mediterranean-climate river system that has been subject to flow regulation from big dams for the last 70 years. Pioneer forest establishment occurs in several contexts: (1) on shifting point bars along the active channel, where geomorphic activity is frequent and forest stands of varied ages develop in response to successive meander and deposition events (Fig. 1); and (2) within abandoned channels, after episodic channel cutoff events (Stella et al. 2011). However, the degree to which the forest structure and composition respond to decreased rates of river meandering as a result of flow regulation is unknown, and management strategies that promote a sustainable riparian community have typically only been tested at small scales.

To address these knowledge gaps, we conducted an extensive inventory of riparian forest stands on point bars within the Sacramento River floodplain in order to document the species composition and size structure of the current riparian forest and to understand the temporal pattern of stand establishment and forest dynamics in response to river management. This work is conducted in coordination with agencies and NGO's that are concerned with maintaining these forest habitats for migratory songbirds and salmonid fish species, among other dependent taxa.

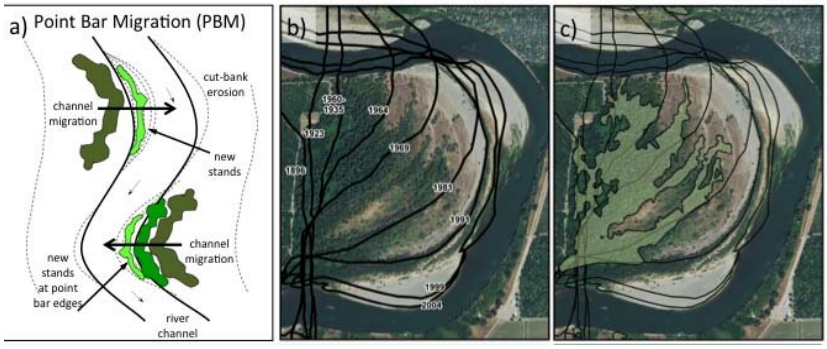

Figure 1. (a) Schematic of floodplain and pioneer forest development. Point bar migration on the Sacramento River (b), and subsequent establishment of pioneer forest (c, green polygons). Adapted from Stella et al. 2011.

1.2 Methods

The middle Sacramento River study reach extends 160 kilometers between Red Bluff and Colusa, in California's Central Valley, and is relatively unconfined with levees set back from the river and no major diversions. Upstream of the reach, Shasta Dam has regulated discharge and trapped sediment since 1942, resulting in decreased winter and spring flood peaks and elevated summer baseflow. Within the reach, we sampled 19 point bar sites on publically-owned land. We used a current vegetation map and repeat aerial photo series to delineate forest stands of known floodplain age (FPA), ranging from 4–107 years. We sampled three mapped vegetation types, cottonwood forest, mixed willow, and riparian scrub, and established 1–2 fixed-area (500 m^2) plots within each combination of vegetation type and FPA class present (N = 224 plots). Within each plot all woody stems >10 cm diameter were recorded as to species, diameter-at-breast height (dbh), canopy position, and vigor; all stems 2–10 cm diameter were recorded in understory subplots. A subset of *P. fremontii* trees was cored in each plot to assess establishment age, and the depth of fine sediment measured using a tile probe that penetrated the substrate until the coarse gravel/cobble surface of the former river channel bed.

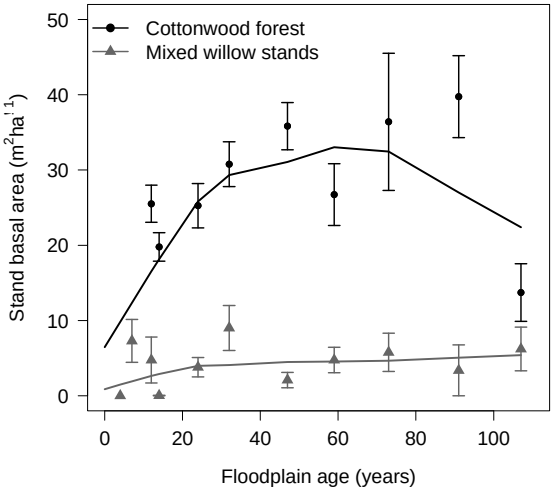

Figure 2. Variation in stand basal area with floodplain age. Lines are lowess splines calculated from the mean plot BA for each age class.

2 RESULTS

2.1 Forest structure

Over all the plots sampled, the size distribution of common riparian tree species followed a negative exponential curve, similar to upland forests, with many small stems and few larger individuals. Stand stem density decreased exponentially with floodplain age within cottonwood forest stands, but within mixed willow stands the density (measured for individual stems at breast height) remained constant within all forest ages. Plot basal area and mean tree diameter reached their maxima by 50 years in cottonwood forest stands, but much earlier (32 years) in the mixed willow stands, where biomass was much lower and constant over time (Fig. 2). Cottonwood forest plots had greater woody species diversity than mixed willow, but both types reached their maximum diversity within the first 15 years. Stands 24–59 years old comprised the largest proportion of cottonwood forest area along the river currently. Most snags greater than 30-50 cm dbh were present in these middle-aged stands, and collectively they contained the greatest biomass, stem density, and woody species diversity of all the age classes, characteristics critical for wildlife habitat.

2.2 Species successional patterns

The density, size and basal area of the most common tree species peaked at different floodplain ages during the 107-year chronosequence, indicating a shifting dominance over time (Fig.3). Within the areas mapped as cottonwood forest, basal area for willow species decreased exponentially within the first three decades, whereas cottonwood basal area increased during that period and achieved 5–10 times the basal area of other species. Later successional species such as *Juglans californica* and *Acer negundo* increased in density and basal area from very low levels in early stands; *Juglans* was typically absent in young stands (<20 yrs).

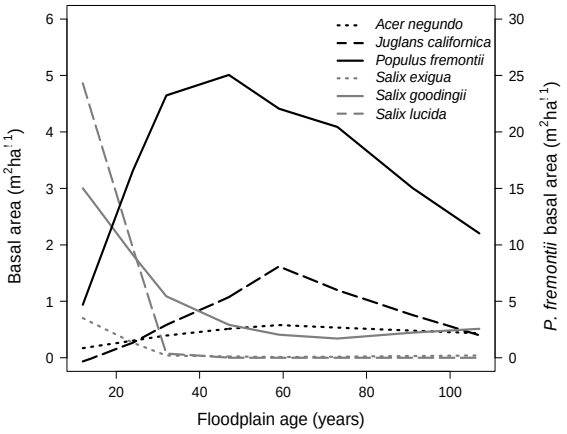

Figure 3. Basal area of common tree species across the chronosequence. Early successional species (all willows) are shown in grey, with species that reach maximum basal area later shown in black.

3 MANAGEMENT IMPLICATIONS

Our research indicates that of the point-bar associated forest patches, the middle-aged stands (i.e., 40–60 years old) are the most extensive in terms of floodplain area, and represent the highest values of biomass, tree size and woody species diversity along the forest successional continuum. After approximately 80 years, point bar stands begin to degrade, with lower basal area, fewer large trees, and fewer snags. Therefore, river and floodplain management should seek to maximize the middle-aged stands over the long term by allowing river migration (Piégay et al. 2005). Channel movement is also critical for maintaining an important alternate establishment pathway in abandoned channels (Stella et al. 2011).

The strong association of pioneer forest establishment with channel migration and abandonment has implications for corridor-wide populations of riparian trees as well as their associated ecosystem. Evidence from numerous field studies and population models (e.g.,Harper et al. 2011) indicate that opportunities for successful recruitment are the limiting demographic step for pioneer riparian trees. Therefore, it is important to maintain the ability of river channels to shift laterally via progressive meandering or punctuated cutoff events. Understanding the environmental conditions that foster a multi-aged forest structure in such a dynamic environment is important for predicting future trends under changing river management and climate that may further shift the hydrogeomorphic regime.

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