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Disturbance and riparian tree establishment in the Sespe Wilderness, California, USA

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The riparian forests of southern California are subject to disturbance by both fire and flood. These agents are capable of causing pulses of mortality and recruitment, but it remains unclear how they interact to determine patterns of stand development. We use dendrochronology to identify establishment dates for stems of major riparian tree species in the Sespe Creek watershed, in order to examine their relationship to regional flooding and fire history. Our 11 study sites were burned by major fires in 1932 and 2002, with a smaller 1975 fire affecting only two sites; major floods were concentrated within the second half of the 1933–2009 streamflow record, with the largest floods occurring in 1969, 1978, and 1983. Three periods of stand development are evident: (1) the oldest alder (*Alnus*), cottonwood (*Populus*), and oak (*Quercus*) stems became established soon after the 1932 Matilija Fire, (2) minimal stem establishment between the 1940s and mid-1960s, and (3) continued, although irregular, recruitment of alder and cottonwood since the late 1960s. These patterns show episodes both of regeneration following a catastrophic site-clearing event (Matilija Fire) and of more localized stem replacement during the recent period of increased flood magnitude, with implications for changes in the composition of these forests.

Keywords: riparian vegetation; disturbance; fire; flood; regeneration; Sespe Wilderness; CA

Introduction

Among the principal foci in research on ecological disturbance is the role that disturbance plays in facilitating regeneration (Oliver, 1981; Paula et al., 2009; Pickett & White, 1985). In a variety of environments, more or less even-aged demographic cohorts mark pulses of establishment following major disturbances (Keeley, Fotheringham, & Baer-Keeley, 2005; Kneeshaw & Burton, 1997; Tinker, Romme, & Despain, 2003).

Riparian plant communities are particularly subject to disturbance, because of their near-inevitable exposure to floods (Bendix, 1998; Bendix & Hupp, 2000; Osterkamp & Hupp, 2010). Consequently, there are numerous empirical examples of regeneration in the aftermath of flooding (e.g. Corenblit, Steiger, & Tabacchi, 2010; Craig & Malanson, 1993; Malanson, 1993; Stromberg, Richter, Patten, & Wolden, 1993), although the relationship of floods with stand establishment may be mediated by climate (Baker, 1990). In dryland environments, flood disturbance is a particularly important process linking

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vegetation and landforms (Bendix & Stella, 2013; Parker & Bendix, 1996; Stella, Rodríguez-González, Dufour, & Bendix, 2012).

In recent years, there has also been an increasing recognition of the role of fire as a riparian disturbance agent (Brathwaite & Mallik, 2012; Pettit & Naiman, 2007a; Vaz et al., 2011), especially in the western United States (Bendix & Cowell, 2010a; Charron & Johnson, 2006; Dwire & Kauffman, 2003; Stromberg & Rychener, 2010).

The relative importance of the two disturbance agents seems to be quite spatially variable. Pettit and Naiman (2007a) suggested that fire is generally less frequent and less intense in riparian zones than in surrounding uplands, a logical contention given the moist conditions typical of riparian environs. Because of the lower fire intensity in a Sierra Nevada riparian setting, Kobziar and McBride (2006) concluded that the riparian zone can actually serve as a natural firebreak (a phenomenon often exploited by wildland firefighters; J. Bendix personal observation). Similarly, in other Sierran streams, Russell and McBride (2001) found that fire was rare and had minimal impact on riparian conifer forests. However, Pettit and Naiman (2007a) also suggested that steep, low-order streams within dry climate regions may experience fire regimes more similar to the upland matrix. Such is evidently the case in the low-order southern Californian streams where Bendix and Cowell (2010a) found high mortality rates in the riparian zones, with no diminution of impacts near the channel. Indeed, where climate is sufficiently dry, fire can also cause significant mortality even in larger, high-order streams (Stromberg & Rychener, 2010). In the front ranges of the Canadian Rockies, Charron and Johnson (2006) found that the relative roles of fire and flood were determined by geomorphic setting, with tree age being determined by flood history on point and lateral bars, and by fire where those oft-flooded depositional features are absent. Fire and floods are not independent of each other, as fire, through its effect on vegetation, alters hydraulic resistance, whereas floods, through the distribution of woody debris, affect the spatial arrangement of fuel load for fires (Bendix & Cowell, 2010b; Pettit & Naiman, 2007b).

In the Mediterranean-climate subset of dry regions, fire has been clearly identified as an effective disturbance agent (Bendix & Cowell, 2010a; Davis, Keller, Parikh, & Florsheim, 1989; Vaz et al., 2011). Insights are still lacking, however, regarding the importance of these disturbances in initiating riparian stand establishment. It is not clear whether the demonstrable fire-induced mortality does result in colonization by new stems, nor, if it does, how important a factor this is relative to flood disturbance. This study represents an initial examination of the role of wildfire and floods in stand establishment of riparian gallery forest in two small southern California streams. Our specific questions are (1) what are the establishment dates for stems of major riparian tree species in the study watersheds? and (2) are the riparian tree establishment dates related to the history of fires and/or floods in the study area? The answers to these questions provide some insights into the relative importance of the two disturbance types in this setting.

Methods

Study area

Our study sites are located in the Sespe Creek watershed in California (Figure 1). The sites are within the Sespe Wilderness, in the Los Padres National Forest. The region has a Mediterranean-type climate, characterized by dry summers and wet winters (Figure 2). We studied riparian stands along two tributaries of Sespe Creek, Piedra Blanca Creek

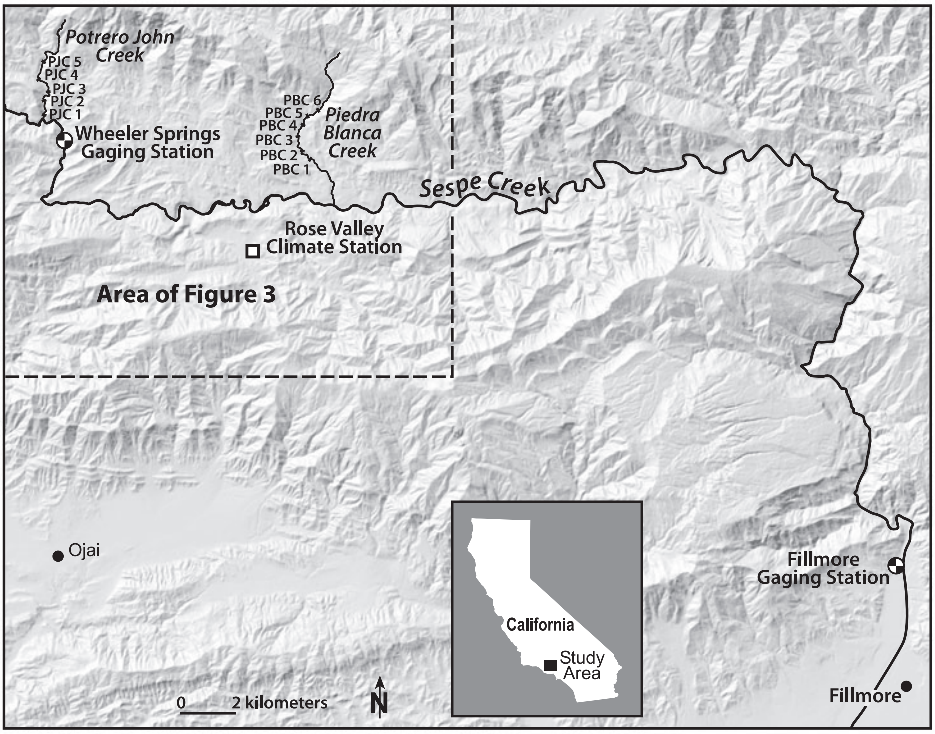

Figure 1. Map of study area, with sampling sites and weather station and stream gage locations.

(34°34′N, 119°10′W), and Potrero John Creek (34°36′N, 119°16′W). Site elevations range from 950 to 1400 m. The Sespe watershed lies within the Transverse Ranges, and the steep slopes and shallow soils of the surrounding uplands contribute to flashy hydrologic response to precipitation. Piedra Blanca and Potrero John Creeks occupy narrow valleys, with valley floors typically <150 m width. Hillslope vegetation is chaparral, primarily *Adenostoma fasciculatum* and *Arctostaphylos* spp.

Vegetation on the valley floor is dominated by *Alnus rhombifolia*, *Quercus agrifolia*, *Populus fremontii*, *Salix* spp. and *Quercus dumosa*. Among these taxa, *Q. agrifolia* is represented by few individuals, but they are so large that they contributed disproportionately to stand basal area; conversely, *Salix* and *Q. dumosa* are numerous, but typically quite small.

Fire history

We obtained fire history and fire perimeter information from the digital database maintained by the California Department of Forestry and Fire Protection's Fire and Resource Assessment Program. The database incorporates fire data from Federal, State, and local agencies for fires >10 acres (4.05 ha), dating to 1878 (CAL FIRE, 2010). Because severe fire conditions are presumably necessary to burn the relatively moist riparian zone, fires too small for inclusion in the database are unlikely to have been significant disturbance agents at our sites.

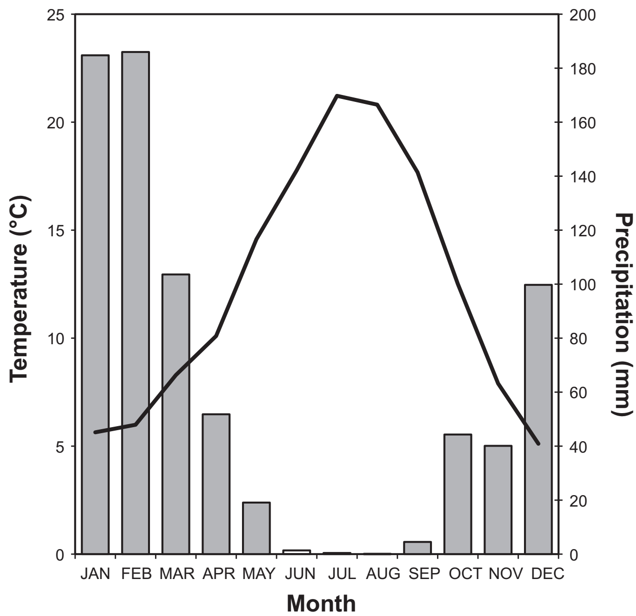

Figure 2. Monthly averages of temperature (line) and precipitation (bars) from the climate station at Rose Valley. Data are means for the period spanned by the station record: November 1993 through January 2012, obtained from the Western Regional Climate Center.

Flood data

Our primary flood data are annual peak flood magnitudes, as recorded at the Sespe Creek near Wheeler Springs gage. That gage is located on Sespe Creek, between its confluences with the two study creeks (Figure 1). Although the discharges on Piedra Blanca and Potrero John Creeks are certainly smaller than on Sespe Creek, the Sespe record constitutes a good indicator of relative flood magnitudes from year to year. This is especially the case because large floods in this region typically result from extensive frontal precipitation, so that the entire watershed is likely to experience synchronous flood events (Raphael, Feddema, Orme, & Orme, 1994).

The Sespe Creek near Wheeler Springs gage record spans the period from 1949 through 2009, with a gap from 1998 to 2002. To fill that gap and to extend the record further back in time, we developed discharge estimates based on the record from the Sespe Creek near Fillmore gage (Figure 1). We regressed the Wheeler Springs record on the Fillmore record, using data from 44 years in which the peak flows at the two gages were within 24 h of each other, indicating that they were responses to the same rainfall events. We used this regression equation ($R^2 = 0.86$, $p < 0.001$) to estimate discharge for the missing years from the Wheeler Springs record and to extend it to 1933, the first year of the Fillmore record. The explained variance of the regression, and the fact that the two gages are, in fact, on the same stream, suggests that the estimates should be sufficiently accurate to identify the years during which major floods occurred in the watershed. Because our interest is in identifying the years in which high discharges occurred, rather than in the exact discharges at the gage on Sespe Creek, we standardized the flood data by calculating *z*-scores for each year's peak discharge.

Tree ages

We extracted 42 total stems from trees on the valley floor in 2003, at the 11 sites shown in Figure 1. The cores include 29 from *A. rhombifolia*, seven from *P. fremontii*, and six from *Q. agrifolia*, numbers that approximate the relative abundance of these species at our sites (Bendix & Cowell, 2010a). Diameter at breast height (DBH) of the cored trees ranged from 5.0 to 77.8 cm. Cores were extracted at 45 cm above ground. The cores were mounted and sanded following standard procedures (Speer, 2010), and rings were counted under a binocular microscope to determine the date of establishment. We did not adjust for the time for stems to reach the 45 cm coring height. Field observations suggest that sprouts or seedlings of *Alnus* or *Populus* may reach that height in less than a year; we have not seen immature *Q. agrifolia* in the study area to calibrate that species' growth rate. All three species are capable of either sexual or vegetative regeneration under at least some circumstances (Steinberg, 2002; Taylor, 2000; Uchytil, 1989), so the stem ages may represent the growth of either seedlings or sprouts. To allow for possible errors in the age determinations, we grouped stems in five-year age cohorts, rather than assigning them to specific years.

Results

Disturbance history

Fire history of the study area is shown in Figure 3. The entire area was burned in the Matilija Fire of 1932, one of the largest wildfires in California history. Since then, two of the sampling sites burned in a much smaller, unnamed 1975 fire. All of the sites burned in the 2002 Wolf Fire, but that was too recent for post-fire stems to reach our 5-cm DBH criterion for coring. The flood record (Figure 4) shows that peak flows were relatively low from 1933 through 1968, with the six largest floods in the record

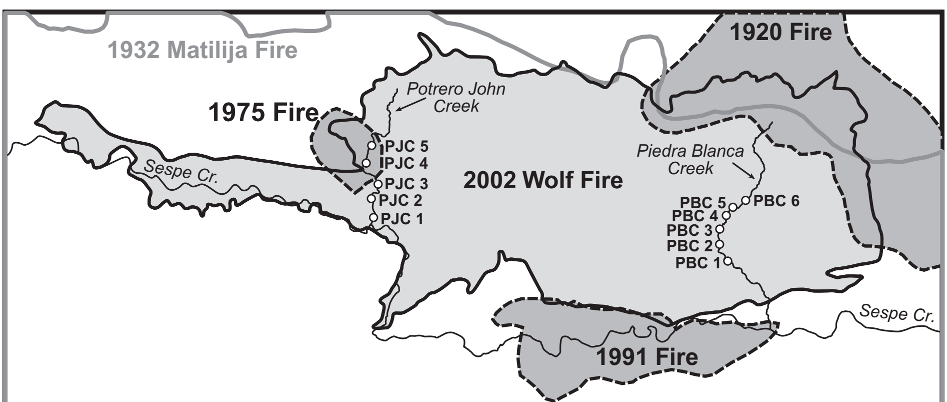

Figure 3. Perimeters of historical fires in the study area.

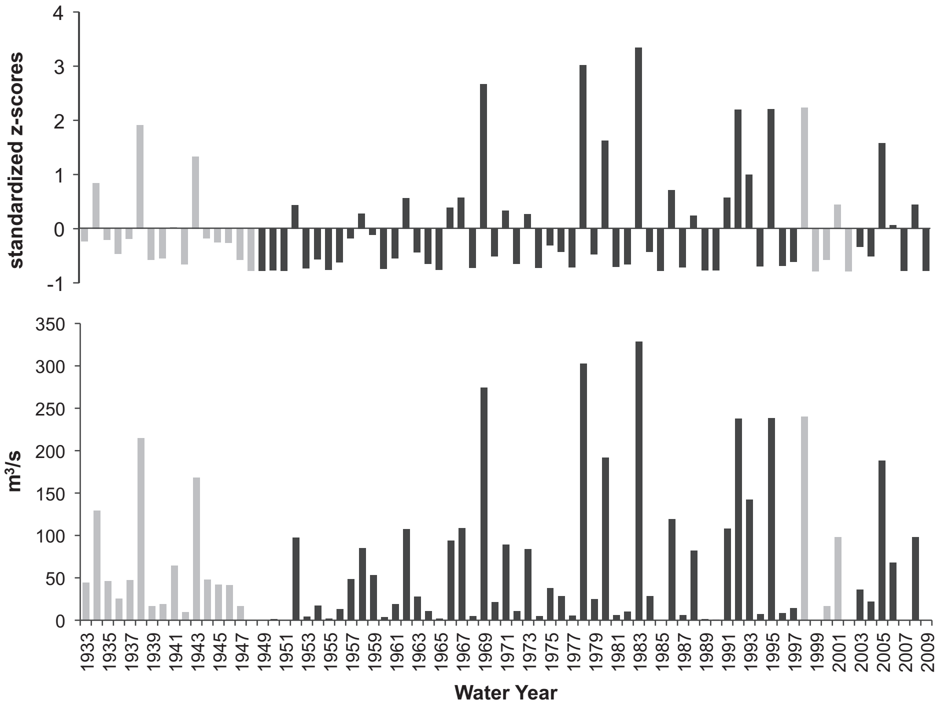

Figure 4. Annual peak discharge at the Sespe Creek near Wheeler Springs gage. Black bars represent data collected at the gage; gray bars denote estimates based on regression.

($z > 2.0$) occurring since 1968. The largest floods ($z > 2.5$) occurred in 1969, 1978, and 1983.

Tree ages

Three periods are notable in the tree core record (Figure 5): 1935–1940, when most of the older stems were established; 1941–1965, with very little recruitment (just two stems of *Q. agrifolia*); and 1966–2000, when most of the *A. rhombifolia* and *P. fremontii* were established. For *A. rhombifolia*, only three of the 29 cored trees predated 1966, but there has been continuous, if irregular, recruitment since then. *P. fremontii* stems date to the late 1930s, the early 1970s, and the 1980s. Most of the *Q. agrifolia* stems were from the early 1940s, with none establishing since 1955. The latter finding is in keeping with the absence of small stems of *Q. agrifolia* at our study sites (Bendix & Cowell, 2010a).

Discussion

The 1932 Matilija Fire apparently cleared the slate in this area, as all but one of the trees we sampled (including long-lived *Q. agrifolia*) post-dated that event. The late 1930s establishment of most of the older trees of all three species can be seen as the product of colonization (either by germination or by sprouts from the root crowns of fire-killed stems) in the fire-cleared riparian zone. The importance of later disturbance events is more equivocal. The extensive recruitment in the 1970s could be interpreted

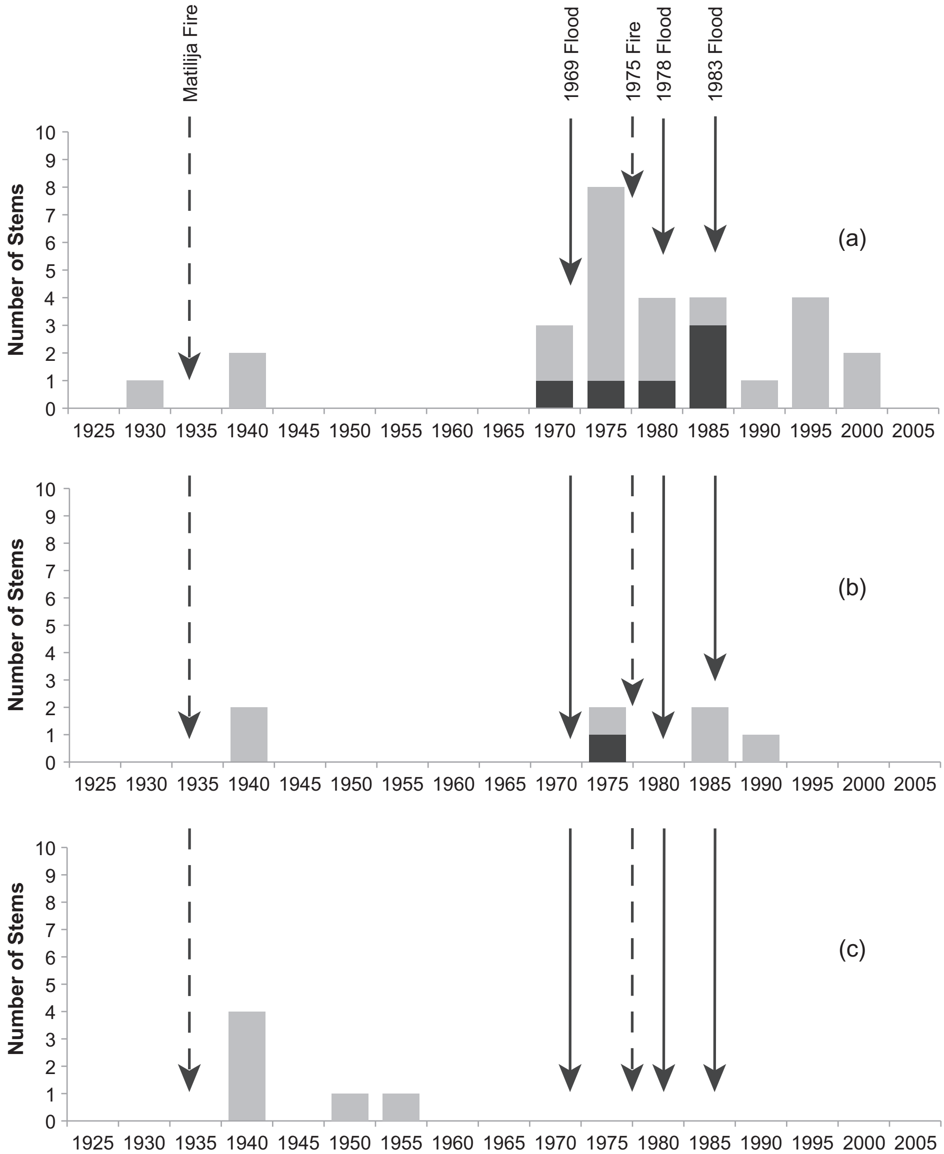

Figure 5. Tree establishment dates for *A. rhombifolia* (a), *P. fremontii* (b), and *Q. agrifolia* (c). Black indicates trees at sites that burned in the 1975 fire (PJC 4 and PJC 5), gray indicates trees at all other sites.

as a response to the 1969 flood. But that is an unsatisfactory explanation by itself, because fewer trees date to the period after the rather larger 1983 flood, and indeed *A. rhombifolia* recruitment continued through the relatively quiet (disturbance-wise) 1990s.

It is instructive to consider when recruitment (as inferred from surviving stems) did not occur, as well as when it did. There is no direct evidence as to the cause for the following 25-year hiatus in recruitment, but the burst of recruitment in the 1930s may be the key. The density of seedlings, saplings, and shrubs may have been too great to allow for further colonization. After a period of decades, self-thinning and/or intermittent flood mortality opened enough space to allow for intermittent, ongoing regeneration. Because the largest floods in the watershed all occurred after the interruption of recruitment, it is impossible to know whether earlier disturbance would have ended the interruption sooner, or if some decades were needed for the initial growth that followed the Matilija fire to thin. We emphasize floods in this post-Matilija context because the 1975 fire was evidently not severe enough (within the riparian zone, at least) to trigger significant establishment, as only one tree was established at sites burnt in that fire within the ensuing five years.

The interpretation outlined above leaves open the question of the gallery forest composition during the period between the Matilija Fire and the extensive regeneration of the 1970s–1990s. Although all of the species we studied are generally described as being disturbance adapted, Bendix and Cowell (2010a) reported that *A. rhombifolia* in the area generally failed to regenerate following the 2002 Wolf Fire. Similarly, Davis et al. (1989) found that *A. rhombifolia* had low rates of both resprouting and seed viability at burned riparian sites after the 1985 Wheeler Fire, immediately to the southwest of our present study area. Both studies concluded that *Alnus* was likely to be absent for timespans of years to decades following severe fire in riparian settings. Bendix and Cowell (2010a) identified *P. fremontii* as the species likely to increase its relative dominance the most in the aftermath of fire, and it seems likely that *Populus*, *Q. dumosa,* and *Salix* were all more important before *Alnus* began assuming a more dominant role in the 1970s. *Q. agrifolia* may have been more prominent as well, but given that species' generally limited rates of regeneration (Steinberg, 2002; Tyler, Kuhn, & Davis, 2006), it is unlikely to have rivaled the other riparian tree taxa in either density or frequency of occurrence.

The fact that our sample is derived from sites on small streams (<35 km^2 drainage area) and includes a limited number of stems per species suggests that these results cannot be extrapolated across all riparian settings. But this sample does provide empirical clues that are of value in an environment where demographic data for riparian trees are quite limited. Small low-order streams constitute a substantial part of the riparian habitat in any drainage system (Horton, 1945), and the vegetation type we sampled is common in the region (Bendix, 1994). Thus, these results constitute a valuable starting point for understanding stand establishment processes.

Conclusions

Our data suggest that disturbance may play two rather contrasting roles in affecting riparian tree establishment in this environment. The Matilija fire exemplifies the first role: stand-clearing disturbance that allowed for a significant pulse of recruitment. But the remainder of the record does not suggest an environment in which regeneration depends upon catastrophic disturbances followed by discrete episodes of recruitment. For the last three decades of the 20th century, there was plentiful regeneration, at least of *A. rhombifolia*, without stand-clearing disturbance (as evidenced by the plentiful surviving stems). Comparison of the flood record to the tree establishment record suggests that floods may have facilitated reproduction, but that they were not essential to it. Thus, regeneration occurs with or without stand-clearing disturbance, but when such disturbance does occur, it alters both the amount and the composition of recruitment. This reinforces earlier suggestions (Bendix & Cowell, 2010a) that wildfire in the riparian zone, while comparatively rare, is important because its impacts are quantitatively and qualitatively different from those of floods.

In this instance, the relatively subtle impact of floods may be partially due to the location of our study in small tributaries. Within this region, Bendix (1998) found that flood impacts on vegetation were significantly related to position in the watershed, so that the role of floods in our current study might have been much greater had it been undertaken further downstream. This consideration serves as a reminder that conclusions regarding riparian vegetation–environment relationships are always geographically contingent, ever dependent upon position within the watershed.

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