WOOD DEBRIS RECRUITMENT FROM DIFFERING RIPARIAN LANDFORMS IN A GULF COASTAL PLAIN STREAM: THE ROLE OF FLOODS

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REFERENCES: *Proceedings of the 2005 Georgia Water Resources Conference*, Held April 25-27, 2005, at the University of Georgia, Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. Wood recruitment dynamics in Coastal Plain streams are complex. Recruitment rates are dependent on stream valley morphology, forest composition, and flow diversity. Infrequent high flows are critical in the maintenance of the instream debris pool. Following extensive flooding in 1994, surveys of downed trees were made across replicated riparian landforms (floodplains, terraces, and sand ridges) in a Gulf Coastal Plain 5th order stream. Annually, the fate of these trees was determined and newly recruited trees were noted. Generally, tree recruitment was greatest in years with substantial floods (1994 and 1998). For each riparian landform type, tree mortality was correlated with the maximum daily flow during the period preceding annual debris surveys.

INTRODUCTION

Numerous studies (Gurnell and Sweet 1998) have documented the importance of large wood debris (LWD) in streams and rivers (e.g., habitat for fishes and invertebrates, bank stabilization, sediment retention, altering water flow, structuring instream and riparian habitat, and enhancing productivity). Throughout North America and most of the world, there has been a long history of wood removal from streams and rivers (Benke 2001). In addition, extensive riparian deforestation combined with flow regulation and channelization has reduced overbank flooding and limited potential sources of LWD recruitment.

Many streams and rivers of the southeastern Coastal Plain have a long history of human-caused degradation. Beginning in the early 1800's with snagging operations and continuing through the 1900's with river regulation and pollution, streams have been managed for human benefit with little thought to ecological consequences (Benke 2001). Interestingly, while human degradation of streams is prevalent, many remain free flowing in the southeast (Benke 1990). Also, in some areas the distribution of human populations has changed dramatically during the last 100 years. For example, since 1920 the population in many rural counties in southwestern Georgia has been declining. This has resulted in decreasing numbers of small farms and livestock, particularly along stream corridors (Craft and Casey 2000). As a result, riparian forests have recovered to some degree from extensive disturbance in the late 1800's and early 1900's (Craft and Casey 2000) and are approaching maturity. These rivers and their tributaries offer an opportunity to examine the recovery of stream/riparian interactions under minimally altered flow regimes.

The objectives of this study were (1) to compare debris recruitment in average flow years to those years with substantial flooding, and (2) to compare debris recruitment and characteristics across differing riparian landforms.

STUDY SITE

This study was conducted at the Ichauway Ecological Reserve, an 11,500 ha reserve located in southwestern Georgia, U.S.A. The reserve is bisected by twenty-three km of Ichawaynochaway Creek, a 5th-order black-water stream. Repeatable riparian landforms occur along the stream corridor and include sand ridges, terraces, and floodplains. Floodplains occur along reaches with broad stream valleys and are low in elevation relative to the base-flow channel. Sand ridges occur within narrower valley segments and, compared to floodplains, are high in elevation above the base-flow channel. Terraces are abandoned floodplains that occur in stream valleys of variable width and elevation.

The streamside forest (i.e. that growing laterally along the stream banks) is classified as mature or climax and supports a diverse forest with 47 woody species having a dbh ≥ 5 cm. Streamside forest composition is similar across riparian landforms (Palik et al. 1998).

METHODS

Study site characteristics

Wood debris recruitment was sampled in 6 reaches that were representative of the range of riparian landforms along the stream. Both sides of each reach were sampled, since riparian geomorphology was not always similar on opposite sides of the reach. Upper and lower reach boundaries were determined from field observations, as well as changes in soils and vegetation apparent on GIS data layers.

Coarse woody debris sampling

Coarse woody debris recruitment was sampled initially following a summer 1994 flood. Each study reach was resampled annually following large floods or more normal later winter/early spring high flow periods. On each sampling date only recently recruited trees were sampled. The lateral area for debris sampling was restricted to the active channel at approximately bank-full width. Each dead tree was labeled with a numbered aluminum tag and its position recorded using a global positioning system.

RESULTS

Hydrologic conditions

During 1994, stream discharge was greater than the 500 year recurrence interval (Table 1) due to unusual numbers of tropical storms. Maximum discharge during the spring of 1995 had a recurrence interval between 5 and 10 years (Table 1). In 1996 and 1997 hydrologic conditions were average with maximum discharge having recurrence intervals of less than 2 years. During the winter of 1997 and 1998 above average rainfall resulted from El Niño conditions, the warm phase of El Niño/Southern Oscillation (ENSO). An early spring storm caused extensive flooding and the second highest flows of record in many streams of the lower Flint River Basin (FRB). Stream discharge was slightly less than the 200 year recurrence interval (Table 1).

In November 1998, a period of below normal rainfall began. For the next 24 months stream flows were generally below long-term averages and the lowest flows on record occurred during the summer of 2000. From 1999 to 2003, the recurrence interval for maximum average daily discharge was < 2 years.

Debris recruitment

Total tree mortality varied substantially across years. Generally, mortality was greatest in years with substantial floods (1994 and 1998) and debris recruitment during 1994 was significantly greater than other years (Figure 1, ANOVA $p<0.001$). Tree mortality also varied across riparian landform. Sand ridges and low terraces generally had greatest mortality during 1994, the year with greatest flooding. However, significant differences were only detectable for low terraces (ANOVA $p=0.001$). The pattern of debris recruitment for floodplains was somewhat different with greatest mortality occurring during 1998 ($p=0.025$), the year with wetter than average conditions during winter and early spring.

For each riparian landform type, tree mortality was correlated with the maximum daily flow during the period preceding annual debris surveys. This relationship was particularly strong for sand ridges ($r^2=0.942$) and low terraces ($r^2=0.915$), but was significant for floodplains ($r^2=0.413$) (Figure 2). Slopes of regression lines were significantly different for the different riparian landforms (ANCOVA $p<0.0001$). Greatest rates of debris recruitment per maximum daily flow were observed for sand ridges followed by low terraces. Flood plains had the lowest rates of debris recruitment. Tree mortality was also related to the maximum monthly flow for the period preceding debris surveys although the strength of the relationship tended to be weaker than for maximum daily flow ($r^2=0.86$, 0.80, 0.40 for sand ridges, low terraces, and flood plains, respectively, regressions not shown).

Table 1. Magnitudes and dates of maximum daily flows on Ichawaynochaway Creek in southwestern Georgia. Data are from USGS gage 02353500.

Recruitment Year	Maximum Discharge (m^3s^{-1})	Date of Maximum Discharge	Recurrence Interval (y)
1994	850	07Jul94	>500
1995	247	13Feb95	5-10
1996	73	06Feb96	<2
1997	102	25Feb97	<2
1998	532	10Mar98	100-200
1999	62	26Jan99	<2
2000	71	04Jul99	<2
2001	76	23Mar01	<2
2002	39	14Mar02	<2
2003	111	10Mar03	<2

DISCUSSION

Our study indicates that large floods, i.e. those with much greater than bankfull discharge, are the primary source of wood debris inputs to coastal plain streams. Riparian landforms also varied in their contribution to debris recruitment. Generally, landforms within more constrained stream valleys (sand ridges) contributed more debris than less constrained areas (floodplains).

While large floods are infrequent, and thus unpredictable events, their occurrence can be linked to long term variations in climate. Two primary factors, the ENSO and tropical storm frequency, control the seasonal timing and annual variation in rainfall in the Southeastern U.S. Warmer than

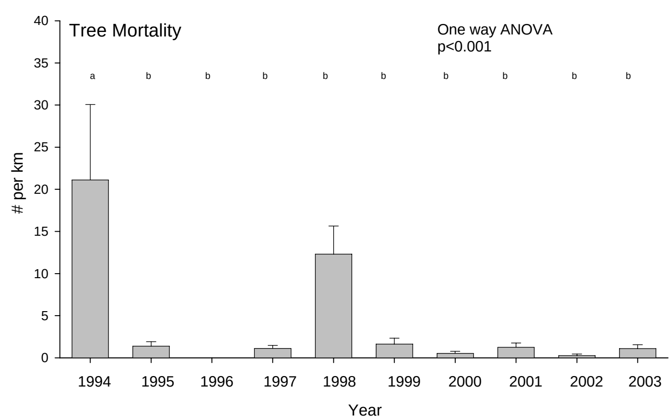

Figure 1. Tree mortality in Ichawaynochaway Creek.

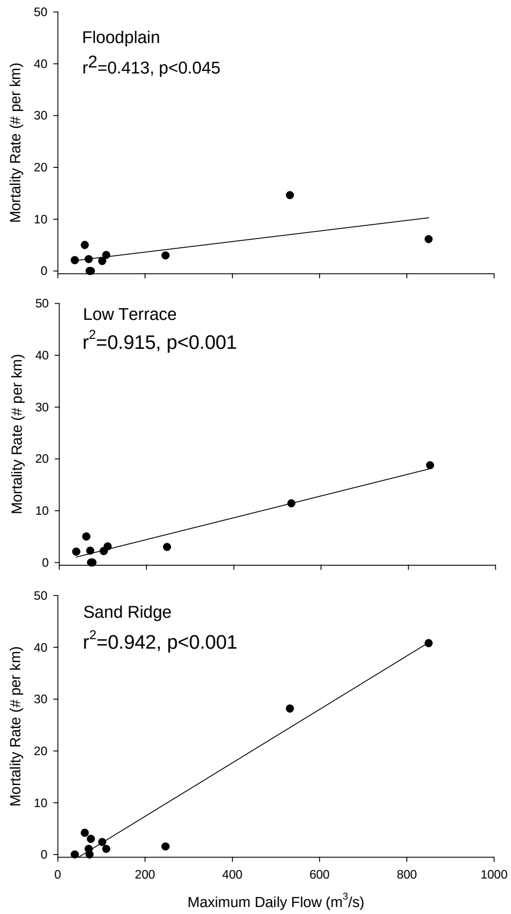

Figure 2. Tree mortality rate versus maximum daily flow.

average temperatures, termed El Niño, cause greater than average winter rainfall (Green et al. 1997). The early spring flood we observed in 1998 was a result of El Niño conditions. Since 1945, El Niño conditions have occurred during 11 years.

Tropical storm frequency also strongly influences patterns of rainfall and streamflow, particularly in the summer (Golladay et al. 2000). Tropical storm frequency is associated with cyclical variations in sea surface temperatures and patterns of precipitation in western Africa (Gray 1990). For example, the period from 1947 to 1969 was warmer and wetter than average, resulting in greater frequencies of hurricanes than the period from 1970 to 1987 (Gray 1990). Thus, while large floods are not predictable, their occurrence in the southeast is linked to cyclical climatic fluctuations and associated periods of greater than average rainfall. Cyclical variations in climate result in periodic pulses of wood debris entering streams and rivers. In addition to debris recruitment, large floods probably provide a number of additional ecological benefits to streams and riparian areas including stimulating recruitment of aquatic fauna, maintenance of habitat heterogeneity, and providing pulses of biologically important material that stimulate productivity (Michener and Haeuber 1998). This is consistent with the growing recognition that diverse natural hydrologic regimes are important in controlling the structure and function of stream ecosystems (Richter et al. 1997).

IMPLICATIONS FOR CONSERVATION

Larger floods that provided pulsed debris inputs are often lacking in regulated rivers (Gore and Shields 1995). Thus, it may be desirable to stimulate debris recruitment in order to provide ecological benefits. It may also be unrealistic or undesirable to wait for a large magnitude flood necessary for a significant pulse of debris. The relationship we observed between maximum average daily flow and debris input has important implications for river management and can provide some guidance in this area. For example, in our study, a discharge equal to 2 times greater than the long term average annual maximum flow would hypothetically result in the recruitment 42%, 45%, and 89% of the debris recruited during the 1994 flood for sand ridges, low terraces, and floodplains respectively. A flood pulse equal to the long term average annual maximum flow would recruit about half that amount. This relationship could be established for unregulated reference rivers and then tested in regulated rivers in the same region by the release of artificial flood pulses. The timing and duration of flood pulses could be varied under differing climatic regimes (i.e. wetter versus drier) to provide additional heterogeneity in the characteristics of debris inputs.

Our results are also consistent with the observation that some river systems are composed of a mosaic of functional units rather than a gradient of gradually changing conditions from small to larger streams (Frissell et al. 1986). This also has important consequences for river management and conservation. In our case, constrained reaches, the primary source of debris recruitment, represent about 12% of total stream length (Palik et al. 1998). Therefore, protection or restoration of constrained reaches would be a critical priority in the development of stream conservation and management plans in the coastal plain. Additionally, as trees have begun to break down and enter the mobile debris pool, we have observed that many unconstrained or floodplain reaches act as depositional areas for debris (Golladay, personal observation). These reaches represent an additional 6% of stream length (Palik et al. 1998). While debris recruitment is only one aspect of stream structure, our results indicate that this element of stream structure might be preserved by targeting a modest amount of stream length (approximately 18%). We acknowledge that complete and intact stream buffers (i.e. mature forests in the southeast) covering entire floodplains are a desirable goal. However, this goal is seldom attained in a developing watershed. If conservation priorities need to be established then the wood source and depositional areas would be strong candidates in efforts to preserve stream structure and function.

ACKNOWLEDGMENTS

We thank Sally Entrekin, Brian Clayton, Neil Pederson, Matt Lauck, B.J Harris, Maggie Kiser, J. Morgan Varner III, Slaton Wheeler, Kevin Watt and Susan White for assistance with field work. Frankie Hudson assisted with data entry. Jean Brock provided GPS/GIS technical support. Liz Cox assisted in locating key references. Financial support was provided by the Robert W. Woodruff Foundation, and the Joseph W. Jones Ecological Research Center.

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