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Importance of streamside forests to large rivers: The isolation of the Willamette River, Oregon, U. S. A., from its floodplain by snagging and streamside forest removal

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With 2 figures and 1 table in the text

Introduction

The river continuum concept (VANNOTE et al. 1980) stressed the point that the influence of the terrestrial system on a stream diminishes as the stream gets larger. The concept argued for greater autochthonous carbon inputs and lower tributary inputs of carbon to higher order streams (7—9th orders). The role of floodplains in the river continuum concept was limited to decomposition of particulate organic material during periods of low water and the subsequent return of organic materials by flood waters and surface runoff. This floodplain interaction existed naturally on all rivers, including lowland streams and very large rivers (9—12th orders).

The river continuum concept (VANNOTE et al. 1980) emphasizes some functions of streamside forest in inferring a downstream decrease in influence, but does not give attention to other functions related to overbank flow that increase in importance downstream as outlined by WELCOMME (1979). WELCOMME (1979) examined the great floodplain rivers of the tropics and argued for a tight coupling of the floodplain with the river system. His basic premise is that the productivity of floodplain fisheries was dependent on the extent and duration of flooding. WISSMAR et al. (1980) reported that inorganic and organic materials of terrestrial origin probably influenced the microbial activity of the mainstem Amazon River, its tributaries, and its varzea (floodplain) lakes.

The relationship of floodplain and mainstem in large rivers in North America and Europe no longer exists and is rapidly disappearing in Africa, South America, and Asia. The influence of the floodplains has been reduced by (1) the extent of local activities such as snagging the mainstem, diking, and improved drainage of floodplains for agriculture or urbanization; and (2) reduction of the extent of flooding because of upstream activities such as flood control dams. These alterations within the stream and on the floodplain have modified the relationship between mainstem and floodplain by changing the composition and structure of the floodplain vegetation and changing the sources and sinks for organic matter along large rivers. The combined effects isolate a river system from the influence its floodplain has on the structure and nutrient capital of the aquatic ecosystem.

The river continuum concept (VANNOTE et al. 1980; WELCOMME 1979) hardly mentions the role of downed trees in large rivers. The ecological role of wood in large rivers will never be completely understood because wood has been systematically removed along most rivers around the world for timber, firewood, or as obstructions to ship and barge navigation (SEDELL & LUCHESSA 1982).

SEDELL et al. (1982) document snags (downed trees) pulled from many rivers in virtually every region of the United States of America. Stream improvement for navigation was well financed by the United States government from 1870 to the present. Over 800,000 snags were pulled in a 50 year period along the lower 1600 km of the Mississippi River. The snags were primarily cottonwood and sycamore averaging 1.7 m in diameter at the base and 0.7 m at the top and had an average length of 35 m (SEDELL et al. 1982).

These snags created shoals, dammed sloughs, caused large side jams, and often completely jammed a lowland river. The historical records of streamside forests are the only evidence remaining of the importance of downed trees to channel geomorphology in pristine rivers.

This report describes the pristine and present streamside forest, channel geomorphology, and

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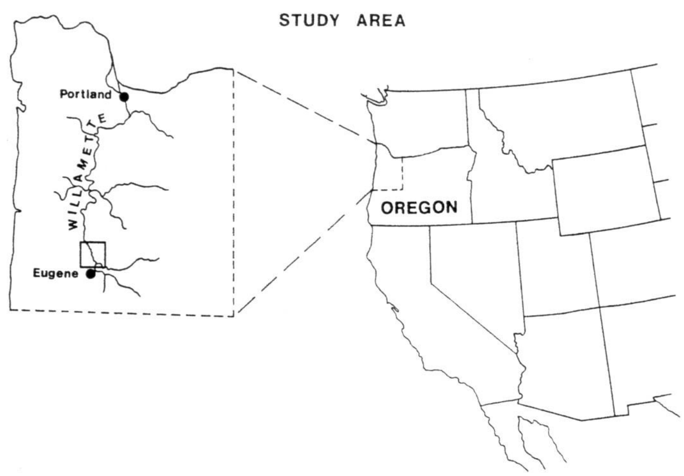

Fig. 1. Location of Willamette River, Oregon, U. S. A. and study reach.

role of downed trees in the Willamette River, Oregon, U. S. A. From this case history, a modification of the river continuum concept is presented.

Site description

The Willamette River originates in the Calapooya Mountains of southwestern Oregon and flows in a northerly direction through the Willamette Valley to the Columbia River, a distance of some 474 km (Fig. 1). It is bounded by the Coast Range on the west and the Cascade Mountains on the east and drains an area of 29,138 km^2. A 9th order channel, it is the 10th largest river in the continental United States in terms of total discharge. The southern two-thirds of the river is characterized by a meandering, braided channel that has, historically, shifted position on a yearly basis. The valley floor is composed of easily eroded fluvial deposits. The northern one-third of the river channel, incised in basalt bedrock, has shown relatively little shifting (Hoerauf 1970; Towle 1974).

The reach of stream examined in this paper extends from the confluence of the McKenzie River to Harrisburg, a distance of 25 km (Township 15 and 16 S., Range 4 W., Willamette Meridian, Linn County). The channel at Harrisburg is 108 m wide. Average water-discharge at Harrisburg is 347.5 $m^3 \cdot s^{-1}$ with a maximum recorded discharge of 5,950 $m^3 \cdot s^{-1}$ and a minimum of 56.4 $m^3 \cdot s^{-1}$. The average gradient along this section is 0.9 $m \cdot km^{-1}$.

The climate of the Willamette Valley is generally described as humid temperate with an average annual precipitation of 127 cm and an average temperature range of 4.4—19 °C.

The Willamette Valley is one of the older settled regions of the American West. The first agricultural settlement in the Valley in 1830 occurred at the same time that the humid prairies of the Midwest were coming under the plow.

The detailed facts on river channels and the distribution of riparian forest in the valley at the time of settlement were compiled from records of the Federal Land Survey Office when the Willamette Valley was subdivided during the 1850's. These land survey records are located in their original form at the United States Department of Interior — Bureau of Land Management in Portland, Oregon. Although some parts of the valley were homesteaded and fields planted to crops several years before the surveys began, the major portion of the valley was surveyed before or concurrently with settlement. Snag removal from the Willamette River channel by the United States Army Corps of Engineers did not begin until 1868. Yearly snagging records were kept by the U. S. Army Corps of Engineers, Portland District, Portland, OR. These historical records were reviewed to reconstruct the changes in the channel morphology, riparian forest, and structural role of downed trees on a 25 km reach of the upper Willamette River, Oregon, U. S. A.

Results and discussion

The Willamette River valley was first discovered by European man, by the LEWIS and CLARK expedition in 1805. It was described by fur traders in the 1820's (ROSS 1849; FRANCHERE 1854) and by naturalists and homeseekers in the mid-1800's (DOUGLAS 1914; WILKES 1845; PALMER 1847). These early explorers described the vegetation as extensive prairies maintained by annual fires set by Indians. These fires created a prairie-open woodland vegetation complex (HABECK 1961; JOHANNESSEN et al. 1970; TOWLE 1974). The trees were present either in the riparian zones or swales in the valley and in woodlands on the steeper slopes. The vegetation must have seemed dense as the early explorers referred to the swales as thickets. When they entered the river floodplain, they recorded that it was difficult to traverse and commented on the thick underbrush and large cottonwoods (NASH 1878).

The pre-settlement stream had banks 1.5 to 2.6 m above the low water line with a floodplain 1.6 to 3.2 km wide. A dense woodland covered most of the floodplain. The species composition of the streamside forest was described by HABECK (1961) and JOHANNESSEN et al. (1970). Douglas fir (*Pseudotsuga menziesii*), Oregon white ash (*Fraxinus oregana*), cottonwood (*Populus trichocarpa*), willow (*Salix* spp.), alder (*Alnus rubra*), and bigleaf maple (*Acer macrophyllum*) were the dominant species recorded by the survey of 1854, as they are today. Along the Willamette River, the average extent of the riparian woodland was 1.5 to 3.5 km on either side of the river. At the confluence of the major tributaries, the riparian forest reached widths up to 10.5 km (TOWLE 1974). The floodplain was dissected by various sized sloughs and "during floods was covered with swiftly-running water to a depth of 1.5 to 3 m. Each year new channels were opened, old ones closed; new chutes cut, old ones obstructed by masses of drifts; sloughs became the main bed while the latter assumed the characteristics of the former; extensive rafts are piled up by one freshet only to be displaced by a succeeding one; the formation of islands and bars is in constant progress where the velocity of the current receives a sudden check only to disappear at the very next high water" (Reports of the Secretary of War 1875). The only constant in this dynamic process was the riparian forest and the accumulation and input of downed trees to the big river.

In the section of the Willamette River between the confluence of the McKenzie River and Harrisburg, multiple channels existed, all of which were filled with snags and fallen trees "too numerous to count" (Reports of the Secretary of War 1875). These snags often drifted together forming large rafts at river bends that cut off channels and diverted flow. Many of the gravel bars and shoals were directly attributable to the accumulation of wood and the encroachment of willow thickets. The Willamette River in this area was described as "cut up into so many useless sloughs, and at each liable to undergo very marked and frequent changes, it would be impossible to confine its waters in one main and permanent bed" (Reports of the Secretary of War 1875). In 1875, there were two main channels near Harrisburg which were between 30—60 m wide. Above Harrisburg, 4 or 5 main channels were not uncommon.

Snagging impacts on channel characteristics

By 1872, the channels and sloughs of the Upper Willamette were being closed off and the water confined to one channel (Fig. 2). These channels were closed off using nearby snags from the channel and cottonwoods growing along the river. Wing dams were con-

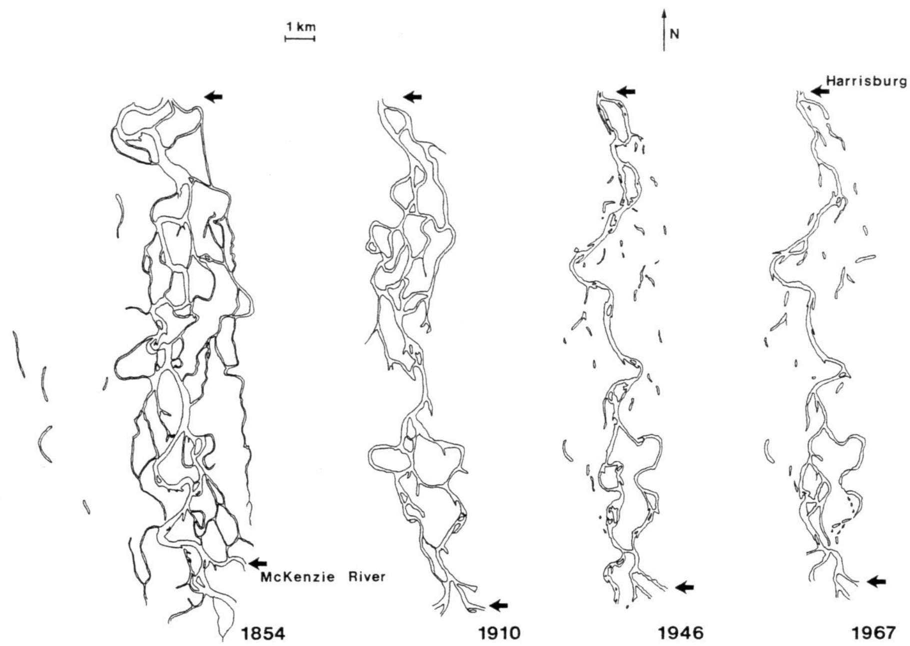

Fig. 2. The Willamette River from the McKenzie River confluence to Harrisburg, showing reduction of multiple channels and loss of shoreline 1854—1967.

Table 1. Summary of snags pulled and streamside trees cut along 282 km of the Willamette River, Oregon, U. S. A., for purposes of navigation. Five year totals from 1870 to 1950 are reported. The river between Albany and Eugene, a distance of 114 km, accounts for 90 % of the snags pulled from the Willamette.

Year	No. of snags	No. of streamside trees
1870– 75	1566	17
1876– 80	4620	542
1881– 85	3900	3 910
1886– 90	2556	545+
1891– 95	3735	1 211+
1896–1900	7070	4 520
1901– 05	2246	918
1906– 10	2701	1 744
1911– 15	3055	6 810
1916– 20*	7 498	
1921– 25	250	
1926– 30	891	
1931– 35	2 130	
1936– 40	4 221	
1941– 45	1 960+	
1946– 50	836+	

* Snags and streamside trees not listed separately after 1919.

structed with firs and willows and other smaller trees cut from the banks. From 1870 to 1950, over 65,000 snags and streamside trees were pulled and cut up (Table 1), an average of 550 snags per kilometer. The average size of these snags ranged between 30—60 m in length and 0.5—2 m in diameter. The cottonwoods were the largest and were often 50 m long and 2 m in diameter. The 550 snags · km^{-1} figure, obtained by dividing the total snags and trees cut by kilometers of river snagged, results in a potential of one downed tree every 1.6 m of stream. The numbers are impressive when compared to a present day average of one downed tree every 300 to 400 m.

By 1946, the channel was set in its present configuration (Fig. 2) and while meanders continue to be cut off occasionally, the river is largely contained by revetments. The 25 km between Harrisburg and the McKenzie River confluence had over 250 km of shoreline in 1854, 120 km in 1910, 82 km in 1946, and 64 km in 1967. In 1983 there is even less shoreline. This represents a four-fold decrease in surface water volume in this section of the Willamette River, as well as a four-fold reduction in organic inputs; both leaf litter and wood.

Agricultural impacts on the riparian forest

Agriculture was the other major agent of change in the amount of wood in the channel of the Willamette River. There are no specific data on the cutting of the floodplain forest. The earliest settlers of the region had settled above the highest floodplain levee or away from the river, at least partially to avoid the annual floods (Bowen 1972). The best farmland, however, was on the active floodplain and the highest floodplain levees were soon cleared and settled. The earliest urban centers were located along the river and the floodplain forest must have provided a good deal of the timber and firewood used in these settlements. The many steamboats plying the river used between 10—30 cords of wood per day and were an important agent in the riparian forest cutting. Large-scale exploitation began shortly before 1900, when the softwood trees were cut and towed "in great rafts to the paper mill in Oregon City every year" (Nash 1904 p. 64).

The reach of the Willamette was closely associated with the expansion of irrigation. Irrigated land amounted to 405 ha in 1911, 1,250 ha in 1930, 13,405 ha in 1945, and 109,350 ha in 1979 (Highsmith 1956; Oregon State Water Resources Board, pers. comm.). By 1970, the gallery forest had been reduced to a narrow, discontinuous ribbon of woodland immediately adjacent to the Willamette and its major tributaries and small, isolated forest remnants scattered across the floodplain.

The loss of shoreline, fewer and smaller snags and reduced width of the riparian forest was an incredible loss to the Willamette River. Channel structural features, particulate organic inputs from litter fall, and retention capacity for filtering particulates from flood flows and entraining partially decomposed allochthonous organic materials were greatly reduced.

Implications to the river continuum concept

The Willamette River did not have an extensive floodplain like many rivers in Africa and Asia described by Welcomme (1979). This 9th-order river was provided with large quantities of organic material from its local floodplain, as well as by organic matter from the upper watershed. The organic material inputs took several forms — local litterfall, downed trees, and efficient combing of various sized particulate organic materials from flood flows, and efficient storage and retention of particulates in sloughs and snag-obstructed channels. The amount of carbon stored in the floodplain and channels of this large river was higher prior to the settlement by Europeans than it is today. The pristine river was well buffered with organic carbon which accumulated faster than it could be decomposed or transported downstream. The small secondary and tertiary channels functioned like 3rd- or 4th-order streams because a large proportion of the carbon inputs were derived from local riparian vegetation. The functional feeding groups of invertebrates and the fish communities were like those of lower order streams. While there was plenty of algal production, historically, there was probably less than we see today due to shading and fewer human-related nutrient inputs. More terrestrial carbon was stored. The water table was higher, creating thousands of hectares of marshy areas and more anaerobic areas along the river. The channels presented a very complex mix of standing water and running water of different velocities.

The major channel changes occurred before the flood control projects began. Eleven major dams have been built since 1946, after the river was essentially confined to a single channel. The agricultural and navigational demands resulted in the major channel changes and loss of downed-tree inputs before the hydrologic regime was regulated. The early use of rivers as the primary transportation routes and agriculture on the floodplain drastically altered the other major rivers of the continental U. S. A. before federal government flood-control efforts began in the 1930's.

Conclusions

The pristine riparian forest extended 1.5—3 km on either side of the river. The pristine river was a series of multiple channels, sloughs, and backwater areas. Historically, the floodplain and valley had extensive marshes. Numerous downed trees helped to create and maintain shoals, multiple channels, oxbow lakes, and complex aquatic habitats at the outside bends in the river. After 80 years of snag removal and riparian forest destruction, there now exists one main channel, few downed trees, relatively simple and homogeneous habitat for aquatic vertebrates, and over a four-fold decrease in river shoreline.

The few floodplain areas with extensive riparian forests along our major rivers must be treated as the last reserves of species and habitats approximating the condition of pristine rivers. These relics of the past will hold the key to relating inferences from the historical record to quantitative differences between what we now perceive as the normal condition and how the river interacted with the terrestrial ecosystem and its massive quantities of wood inputs in the past.

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