Jennifer Hoffman
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HC 441: Columbia River Ecology
Clark Honors College

Large Woody Debris (LWD) and the Columbia River Basin

INTRODUCTION:

Large woody debris (LWD) is an important part of riverine ecosystems. As Neumann and Wildman note, “Large woody debris enhances aquatic habitat diversity in streams by creating hydraulic complexity, storing sediment and fine organic matter, and creating off-channel habitat” (Neumann and Wildman 240). However, human interference has led to a decrease in the amount of available LWD, and the resulting habitat degradation has now become apparent. A recovery operation movement is now in progress, necessitating more than ever the need to understand the purpose of LWD in the ecosystem, so that restoration attempts can be at their most successful.

LWD, “generally defined as pieces >10 cm in diameter and 1.5 m long” (Larsen et al. and Kaufmann 286), encompasses many types of wood that fall into waterways, including “full trees, trunks, branches, tree heads or root masses” (NSW DPI). They enter the river by a variety of ways including falling in after banks are undercut, washing in during floods (NSW DPI), and beavers cutting them down and using them. (Oregon Fish and Wildlife). While individual tree mortality will deliver a fairly consistent amount of LDW to a watershed (Bragg 1390), catastrophic or stochastic events, such as avalanche, flood, fire, wind, timber harvest, inset outbreak (Bragg 1383), “ can result in the episodic delivery of large woody debris and boulders to the stream channel”

(McIntosh et al. 1490). The result is "prolonged, long-term oscillations….the stream loads will likely experience almost continual aggradation and ablation" (Bragg 1390). Thus, while it may be nice to have a certain number of LWD that should be in a stream at one time, the natural process involves oscillation (Bragg 1384). Once it is in the waterway, LWD becomes jammed in the river or stream, where it served important functions in the ecosystem. Large trees are the best, because they will most likely topple over and keep their rootwad, rather than breaking off (Abbe and Montgomery 218). In this way, they are more likely to become waterlogged and remain in place, serving important functions to the ecosystem, which can be categorized as follows: hydrological, geomorphological and ecological processes (Abbe and Montgomery 201).

First, LDW affects the hydrology of the river or stream by changing the way that water flows; it acts as roughness elements or "individual objects that locally retard the flow" (Lisle 539). Depending upon the amount of LDW and where and how it is located in the river or stream, impacts "flow resistance, flow patterns and the water surface profile, but their gross effect, particularly in smaller rivers is to increase flow complexity and water retention" (Gurnell et al. 602). When the flow of the water is backed up by LWD, pools may form, which are an important habitat for many species of fish (McIntosh et al. 1478). This can become especially important if the water level drops during a draught, because there is still water for biota to live in (Lisle 547).

The flow of the river also affects how much LWD falls into the river, because it can direct the flow of the water to undercut a bank, which may result in more trees from the bank falling into the water. (Bragg 1391). Not only does the water effect tearing away sediments, but it also transfers mineral and organic sediment (Gurnell et al. 601).

This includes woody debris, leaf litter (Roni et al. 2), gravel, and sediment (Mossop 1955). By affecting the way that the water flows, it enhances the complexity of hydrological flow, which, in turn, helps to move sediments around so that they can eventually get trapped behind LWD. Thus, the sediments are retained in the environment, rather than getting washed downstream. By increasing flow complexity, LWD increases the chances of them getting trapped behind LWD (Lepori, Palm, and Malmqvist 236). According to Roni, "The delivery of organic matter…, water, and sediment are some of the major processes dictating channel morphology and the formation of habitat" (Roni et al. 2). Thus, hydrological functions are inseparable from the geomorphological functions performed by LWD.

This second function of LWD, its affect on geomorphology, is most importantly seen in the formation of "pools, bars and islands" (Abbe 218) and effects the "stream banks, the stream channel, and the stream substrate" (Kershner 1364). As Gurnell writes, "For example, Bisson et al. (1982, 1987) developed a classification of pools, riffles and glides found in woodland streams; and of the 10 pool types, six were associated with wood" (Gurnell et al. 602). Thus, it is clear that LWD serves an important function. It has also been found to increase channel stability (Gurnell et al. 603). Its importance as a stabilizing element becomes clear when it is removed. As Gurnell notes, "the role of wood accumulations as natural check dams is illustrated by the channel incision that can result when wood is removed" (Gurnell et al. 608).

These obstructions also retain mineral and organic sediments, which keeps nutrients in the area (Gurnell et al. 602) "by creating low-energy depositional environments" (Lisle 547). It is important that these sediments are trapped, because “small, forested streams are typically heterotrophic ecosystems in that secondary production depends on inputs of leaf litter and other allochthonous coarse particulate organic matter (CPOM) from the riparian vegetation rather than primary production within the stream” (Lepori, Palm, and Malmqvist 229). However, unless LWD traps them, the flow of the water would soon wash them downstream. One way the LWD keeps nutrients in fish bearing streams is by trapping the carcasses of anadromous salmmonids. As Minakawa and Gara note, “carcasses of anadromous fish increase N or P concentrations in freshwater systems” (Minakawa and Gara 163). In Minakawa and Gara’s study on the retention of fish carcasses, they found that by the end of the spawning season, LWD had trapped 51.4% and 47.9% of the carcasses they tagged each year (Minakawa and Gara 166). Without being trapped by LWD, these nutrients would soon have been carried downstream

Finally, the importance of these processes becomes apparent, when we consider their effect on biota. The variety of habitats that are provided by the effect of LWD on “depth, cover and flow” (Neumann and Wildman 240) is important to fish and other organisms for several reasons. Firstly, it offers different types of habitats for their different life stages. Also, it provides cover and by varying stream velocity and depth” (Lisle 538) it may help protect biota from being dried up during a draught, feeling the full effects of pollution (Gurnell et al. 603), being hit with the high-velocity water during winter.” (Lisle 538), or being prey to larger fishes (Lisle 538). It provides “a substrate or a food source and as a retention device for fine particulate organic matter” to shredders (Siler 1635) by effecting the “the storage, breakdown and regulated release of organic matter within wood accumulations” (Gurnell et al. 603). In turn, it provides “forage and refuge for fish" (DeLong, Thorp, and Haag 413). It is important to keep this diversity, because fish are adapted to this diverse environment (Shields et al. 251). For example, it assists in maintaining species diversity. By providing a diverse environment, LWD gives all the biota a suitable environment.

HISTORY:

Human activities have harmed riverine ecosystems in a lot of different ways, only one of which is loss of LDW. As McIntosh et al. note, "Human activities modify aquatic habitats by altering one or more of the following ecosystem attributes: channel structure, hydrology, sediment, water quality, riparian forests, and exogenous material" (McIntosh et al. 1479). These are the result of the following activities: road building, logging (Karret al. 1029), dam building, application of herbicides (Oregon Fish and Wildlife), livestock grazing, agriculture, urbanization, and mining (Kershner et al. 1363-4). As McIntosh et al. note, the result is "simplification of stream channels and loss of habitat complexity (McIntosh et al. 1479). This has been the result of a century of management strategies that focused on extracting resources from the environment, with little or no concern for its environmental impacts (Karr et al. 1029). These practices have had devastating results on "instream habitat, water quality, hydrology, riparian vegetation, and aquatic biota (Kershner et al. 1364). One factor that has had an effect on all of these processes is the loss of LWD.

One way that we have lost large woody debris is by the drastically reduced populations (Oregon Fish and Wildlife) of beaver (*Castor canadensis*), which had helped to recruit LWD into streams and rivers and to secure it in the streams by building dams (Shields et al. 251). Another way that LWD has been reduced in the Pacific Northwest is by people removing it for one of three reasons: they think it is in the way, they want to use it, or they think it is in the way of fish migrations. Originally, LWD was removed from rivers and streams increasing accessibility for logging, navigation (Neumann and Wildman 241), land drainage (Lepori, Palm, and Malmqvist 229), and flood mitigation (NSW DPI). People also believed that they were stabilizing the river channel, by removing LWD that would scour the riverbed, although LWD has actually been found to stabilize banks (NSW DPI). Finally, LWD has been removed because of urbanization, since people think that LWD in the streambed is not aesthetically pleasing.

Since people have been concerned with extracting resources, rather than preserving them, they have not been engaging in sustainable practices. One of the main ways that people have directly hurt the habitat is through the removal of timber (Kershner et al. 1364). As McIntosh et al. note, “Intensive timber harvest and road construction continued until the late 1980s, when concerns for endangered species and old-growth forests slowed harvest” (McIntosh et al. 1491). However, Karr et al. observe, “Land managers’ focus on commodity extraction—sharpened by recent changes in forest policy, regulations, and laws that encourage salvage logging after fires—perpetuates this trend and its harmful impacts” (Karr et al. 1029). Postfire salvage logging has been shown to “have a multiplier effect, because fire-affected ecosystems are sensitive to further disturbances” (Karr et al. 1029). If loggers remove wood that is in the riparian zone, there is less LWD to be moved into the channel; its absence will negatively affect the natural processes of the habitat (Lisle 538). Clear-cut areas have been shown to have lower accumulations of LWD, “because post-logging cleanup depletes accumulations of debris” (Lisle 547). The types of trees that grow back after logging are also not as beneficial for providing LWD, as forests go from being “conifer-dominated to hardwood-dominated forests” (Roni et al. 8); hardwood has been shown to not be a good long-term source of LWD (Roni et al. 8). Finally, by removing the largest trees, loggers removed the trees that were “most likely to topple and retain their rootwads instead of snapping above the ground” (Abbe and Montgomery 218). In other words, the LWD that remains is not as useful to the riverine habitat.

Finally, in more recent years, people have been removing LWD from rivers and streams in the mistaken belief that they are improving the habitat for migratory fish species (McIntosh et al. 1491) (Abbe and Montgomery 218). It is ironic that one of the reasons that LWD was removed was an attempt to recover good habitats.

CONDITIONS:

The result of these land use practices can now be seen in the present river and stream conditions. As McIntosh et al. note, “Research based on paired watersheds and pre- and post-treatment comparisons have shown that human activities simplify stream habitats. The results were similar; whether the dominant land use was grazing, mining, agriculture, flood control, urbanization, or multiple use” (McIntosh et al. 1489-90).

While the effects of poor resource-use practices have affected all aspects of the rivers and streams, the effects of the absence of LWD are still discernible.

The removal of LWD has had an effect on organic and mineral sediments; they are being washed downstream, because they are not being blocked by LWD. As the Oregon Department of Fish and Wildlife notes, “Slow meandering streams, flowing over expanses of gravel and into heavily sedimented wetlands have been converted to fast, deeply channeled flows, which have often cut down to bedrock” (Oregon Fish and Wildlife). The result is that there is a depletion of gravel at the bottom, which is essential for salmon spawning. Organic sediments are also being washed downstream in the form of course particulate organic matter (CPOM), which reduces the food source for detrivores (Lepori, Palm, and Malmqvist 234). The decrease in the number of detrivores results in lower numbers of food sources for species in higher trophic levels.

Hydrological flow is also responsible for washing out sediment and toppling trees and other LWD into the river or stream. However, after logging, there is a reduced amount of LWD (Neumann and Wildman 241), because it has all been logged out. After logging, “hardwoods and tall shrubs may dominate riparian zones and suppress conifer growth for decades” (Roni et al. 8). Thus, the replacement LWD is not of the same type. Finally, many logging practices do not leave any LWD behind, and there may not be a new source of LWD until new trees have grown. However, the LWD that is in the stream at the time “decomposes and is transported downstream” (Lisle 548). The result is a large-scale depletion of available LWD, which may last for decades.

The geomorphological aspects of the habitat have also been severely affected.

While studying the quantity and quality of pools in the Columbia River basin currently compared to historical records from the 1930s, McIntosh et al. found “a strong relationship between the management emphasis and land use history of the study watersheds and the direction of the change. The quantity and quality of pools increased or remained unchanged in natural streams, but decreased in commodity streams. The variability and range in pool frequencies remained unchanged in natural streams, but decreased among commodity streams over the study period” (McIntosh et al. 1489). Similarly, channel stability has been decreased. As Faustini notes, “LWD removal has led to moderate to substantial erosion and a coarsening of the bed surface, presumably due to a decrease in channel roughness and a consequent increase in boundary shear stress available to transport sediment” (Faustini 189). Thus, the limited availability of LWD has already decreased the diversity of habitat in streams.

These changes have had adverse effects on biota living in the streams and rivers. The loss of pool habitats has “reduce[d] the capacity of stream ecosystems to recover from disturbance, either natural or anthropogenic, and to support self-sustaining fish communities” (McIntosh et al. 1491). Thus, the loss of LWD has a multiplier effect, since loss of pools makes the ecosystem even more vulnerable to other disturbances. Changes in habitat quality and quantity is a major component in the severe depletion of anadromous fish numbers in the Columbia River basin” (Kershner et al. 1363). For example, the loss of habitat has “decreased the availability of suitable spawning sites for some species (Bond 612). The loss of pools and gravel are interrelated. As Abbe and Montgomery note, “Pool spacing, for example, is strongly correlated with LWD loading in small to moderately sized grave-bed channels” (Abbe and Montgomery 201).

RECOMMENDATIONS:

There has been an increasing amount of interest focused on watershed restoration, because of the decline in salmon runs. As Roni et al. note, " Millions of dollars are spent annually in individual river basins in an effort to enhance or restore habitat for salmonids and other fish species" (Roni et al. 1). Many people believe that fish numbers can be increased if their habitat is improved (Kershner et al. 1363). One aspect of fish habitat that has been receiving increasing amounts of research in the past 20 years is the importance of LWD to the habitat (Larsen et al. 286). Thus, there is now a movement to try to correct some of the problems. As Larsen et al. note, "Wood is placed directly into stream channels, the removal of large wood is prevented, and riparian corridors are protected to promote the regrowth of natural riparian vegetation that regenerates natural supplies of wood to channels" (Larsen et al. 286). However, there is confused understanding about what constitutes "indicators of success" (Lepori, Palm, and Malmqvist 229) in the recovery process.

First, we need to determine to what standards we are trying to "recover" the habitat. Since in the Pacific Northwest "human impacts are relatively recent," "it has been possible to reconstruct the character of pristine woodland river systems" (Gurnell et al. 602). As McIntosh et al. quote, "An understanding of historical ecology is essential, as White and Walker have states, 'to learn how to link historical information and current conditions, determining the rules by which the past becomes the present and the present will lead to a range of possible future states'" (McIntosh et al. 1479). By doing historical comparisons to today's conditions, we are becoming increasingly aware of the extent of the degradation. As Rheinhardt notes, "In order to restore altered headwater ecosystems, one needs information on their structure and functioning under natural conditions. Such information could also be used to evaluate the success of restoration, provided that success is based on conditions in unaltered ecosystems" (Rheinhardt et al. 242). By determining what our goals for recovery are, we can more closely ally our recovery practices with meeting those goals.

Second, we need to determine how we are going to measure recovery patterns. This information can be used by citizens to start restoration projects. As Roni et al. note, "Local citizen groups often lack adequate guidance on which types of restoration or enhancement to conduct first or which techniques are most successful" (Roni et al. 1). This information can also be used to determine what regulations need to be put into place and how to define them. As Bauer and Ralph note, "CWA regulations, however, generally do not adequately address the physical instream habitat characteristics and life history requirements…for fish and other aquatic biota" (Bauer and Ralph 14). By developing a quantitative system, people will be able to monitor the recovery process, which will likely take a long time. As Larsen et al. write, "Given that habitat degradation has probably been occurring gradually for decades and longer, and the recovery activities will not restore habitat within a short time frame at regional scales, a monitoring plan that tracks habitat features at regional spatial scales over decades is of primary importance" (Larsen et al. 284). One example of a possible model is designed by Hyatt et al., and uses the size of riparian zone trees compared to stream or river channel size to determine which areas need recovery assistance most desperately (Hyatt et al. 175).

While knowing what the habitats used to be like and knowing which ones need to be restored the most is all well and good, we still need to do something. First, we need to curb activities that are having bad effects. “A critical caveat may be that these watersheds are similar only if they are allowed to recover and function naturally. This means regulating activates (e.g., new roads, timber harvest, livestock grazing) in these watersheds so as not to impede or forestall recovery processes” (McIntosh et al. 1491). One way that we can do this is by not extracting resources as much as we can. For example, DeLong, Craig, Fall, and Sutherland propose a way to harvest timber that more resembles natural catastrophic events, such as forest fire, by leaving stands of trees. They state, “An underlying assumption of this management paradigm is that forest-dependent biota are adapted to the ecosystem characteristics and landscape patterns created by natural disturbance regimes. We expect that species and ecosystem functions should be more (323) resilient to the ecological changes associated with forest management activities if the pattern and structure created by these activities resemble those of natural disturbance events” (DeLong, S. et al. 323). “We demonstrate that a harvest pattern based on wildfire patch size is superior to the three-pass dispersed-block model in reducing roads, stream crossings, and snag depletion and that increasing stand-level retention results in more roads and fewer snags” (DeLong, S. et al. 330). Similarly, wood should not be cut in clear-cuts, because the “large debris left after clear-cutting constitutes the available supply of wood-created channel structure for several decades” (Lisle 549)

It is not merely enough to stop removing snags, because we have engaged in practices that will have depleted the availability in snags in some areas for a long time.

As Roni notes, "Many processes that create habitat operate on time scales of decades or longer (e.g., channel migration and the formation of off-channel habitats). Interrupting theses processes (e.g., by stabilizing banks or constructing roads or levees) can lead to loss of fish habitat over the long term" (Roni et al. 2). "As Beschta et al. concluded, the legacy of past practices already limits the function and integrity of existing watersheds. Today's managers must not only manage for current needs, but must also correct the mistakes of the past" (McIntosh et al. 1491). For example, the beaver population is severely depleted; so one source of LWD is severely reduced (Shields et al. 251). Therefore we will need to take on projects that replace LWD for a long time. " It may take centuries for trees to grow large enough to be recruited into streams" (McIntosh et al. 1490)

Replacing LWD is a good start. As Abbe and Montgomery note, "Recognition of the ecological importance of LWD as an in-channel element during the last few decades led many to advocate re-introducing LWD to channels and leaving riparian buffers to provide future LWD recruitment. Recognition and modeling of natural LWD structures provide a guide for the design of effective channel restoration schemes" (Abbe and Montgomery 218). Neumann and Wildman are in favor of their effectiveness, writing, "Habitat improvement for salmonids often consists of installation of log, tree branches and deflector structures that mimic the effects of naturally occurring large woody debris. (Neumann and Wildman 241). It seems to also be good for retaining mineral and organic sediment. Lepori found that "[coarse particulate organic material] (CPOM) retentiveness reflected most strongly the density of boulders and submerged woody debris at the study sites. Restored sites were on average twice as retentive as channelized sites and significantly more retentive than reference sites when discharge was controlled (Lepori, Palm, and Malmqvist 228). Thus, it appears that replacing LWD has a positive impact on the ecosystem.

However, Shields et al. note that the “progressive failure of the structures leaves the prospects for long-term ecological recovery in doubt” (Shields et al. 257). Also, Roni thinks, “Habitat modifications, such as placing log structures or protecting stream banks, often fail to create expected habitat conditions because they are constructed without consideration of the causes of habitat degradation” (Roni et al. 2). However, despite some objections to them, there are now companies that specialize in the manufacture of engineered LWD-type structures. One such company claims, “The object of this paper is to introduce an engineered logjam structure that is easy to transport and install by citizen volunteer and conservation crews” (ELWD 1). However, rather than replacing streams with manufactured structures that may “fail,” supplying areas with LWD for their own recruitment may be the best thing. By providing natural LWD where it naturally occurs, we can avoid the tendency to inundate all areas with LWD and damage ecosystems that do not require such large amounts of it (Roni et al. 2) or incurring economic costs that do not outweigh their ecological benefits (Karr et al. 1032).

Finally, we need to establish laws that protect riparian zones, so that LWD sources are not further depleted (Bragg 1383). If we do not, replacing LWD will be a never-ending process (Larsen et al. 286). While we are doing this, we need to carefully monitor LWD in the area. Since fish populations are already depleted, this may include removing large influxes of LWD that bar fish passage (Bragg 1390). While this is an unusual, although natural, problem, fish numbers are already so significantly depleted that such a natural disturbance would be detrimental (Lisle 549).

CONCLUSION:

LWD is a necessary component of riverine ecosystems with regards to hydrology, geomorphology, and ecology. By removing LWD and damaging the riparian vegetation that provides it, human impact has severely damaged the ecosystem. However, by researching the importance of LWD and implementing new practices that focus on recovery, it may be possible to restore these habitats. Recovery processes will take decades and must include the following: further research on the purpose of LWD, the formation of a way to empirically track improvement, replacement of removed LWD, improvement in riparian zones that provide LWD, and laws against practices that include the removal of LWD and damage to the riparian zone.

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