The Effects of Woody Debris on Stream Restoration

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Introduction

The relationship between woody debris and stream ecology is not yet well understood (1). One long-term study site for the role of woody debris in stream restoration is Quartz Creek, a major tributary of the McKenzie River, in Oregon. Prior to the 1980s, large woody debris was absent from the stream due to land use practices. In 1988 the Forest Service replaced missing woody debris with installed jams with the goal of providing more tranquil (as opposed to turbulent) habitat, and for five years monitored changes in the creek geomorphology, wood and leaf retention, and fish populations (cutthroat and rainbow trout). Monitoring of the site for wood movement and stream geomorphology has been continuous since 1988. In 1996, two massive flood events lead to undertaking of further study of fish populations, however no census of fish populations had occurred since 1997.

Methods

Our project considers the effects of woody debris on the channel unit structure, geomorphology, leaf matter retentiveness, and the effects of these ecosystem characteristics on fish populations and wood retention over time. We continued with monitoring methods established in 1988. Channel width and depth measurement were taken manually along established transects in the river, beginning in late June and finishing in early July. Tagged wood mapping was undertaken in the same time frame, with teams of searchers locating tagged pieces of wood based on maps of wood placement from previous years. All new wood in the stream over 1 meter in length and 10 cm in minimum diameter were flagged for future tagging and addition to the study database. A multi-drop leaf release study conducted over three days the fourth week of July involved dropping batches of 4000 ginkgo leaves (a non-native species with highly visible leaves) into 6 established 50 meter stretches of the stream and recording the number of leaves to reach nets downstream. A fish census undertaken in the first three weeks of August involved teams of two snorkel observers moving upstream, 10 meters apart recording, how many fish of various length could be observed in each channel unit.

Results

We analyzed resultant data by, firstly, exploring the causal relationships between wood recruitment and stream geomorphology by analyzing the detailed historic data available for the site. Based on snorkel survey data collected this year, we determined that fish population numbers have not changed significantly since the installation of wood into the stream, and actually found populations have returned to levels below those of last monitoring in 1997 (see appendix). An important consideration in analyzing this data was taking into account the number of adult fish within a population compared with fry observed (see appendix). Timing of observation could greatly affect this data, and no record exists for when, during previous seasons, snorkel observations were completed. Scaling up to observe how geomorphology changes in the stream might be affecting where fish are found, both tranquil and turbulent habitat has increased in the study area since 1988 (see appendix). Fish observation reinforces the original supposition that fish in general prefer tranquil over turbulent habitat (see appendix).

Building on this analysis we developed Bayesian Belief Networks (BBNs) to determine conditional probabilities of fish abundance in the stream. Bayesian Belief Networks are used commonly in ecology to explain the relationships within complex ecosystems (2).

The BBNs were developed to describe the perspective of a single log. Thus the probability of a single log's survival was related to its probability of being in a certain state within the following variables: “Cabled,” “Zonation,” “Length,” “Duration,” “ChUn,” “Fish,” and “StreamFlow.” “Zonation,” and “Length,” are binary variables describing whether wood is cabled or not, in the stream directly or not, and less than nine meters or not, respectively. “ChUn,” “Fish,” and “StreamFlow” are also binary variables describing whether wood is in a tranquil channel unit or not, near a healthy fish population or not, and in the river during a year with below mean stream flow or not, respectively. “Cabled” is a ternary variable with states “yes,” “part,” or “no,” corresponding to whether was chained on shore and in stream, in one or the other, or in neither, respectively. “WoodDuration,” assigned “yes” to a piece of wood if, after the nth year of the study it had been present in the stream for less than n/2 of the years, and a “no” if present for greater than or equal to n/2 years. Also, since it took a while to complete the fish survey, the “Fish” node was not included until later.

I developed a web of causal relationships based on expert guidance from Randy Wildman, Desiree Tullos, and Stan Gregory, as well as my colleagues Tracy Jacobs and Ben Blonder, and my own fieldwork experience. I decided to use Netica to create my networks, due to its use in several papers, (3). I began by developing three networks with varying levels of complexity, incorporated five case files of three hundred randomly selected cases each (using MATLAB). I then used the “Learn Using Gradient” tool to measure the networks’ reaction to cases. The simplest of the three networks responded similarly, so I decided to use the model in Figure 1 because of its simplicity and its intuitive causal structure.

Once I developed the network and incorporated case files I could begin to ask questions. The first question was what sorts of management decisions can be made to maximize the probability that a piece of wood remains in the stream. We consider each of the environment nodes to be decision nodes and, after training our model on five case files of 300 case nodes each, I use the MPE function of Netica to determine which decisions should be made.

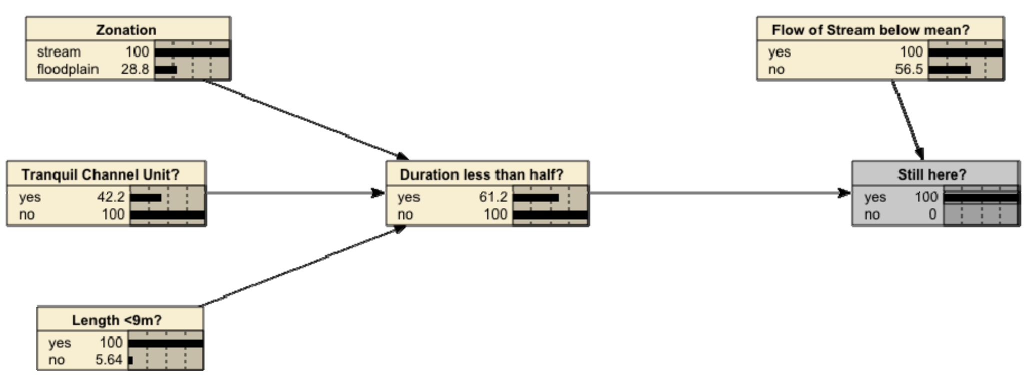

Figure 1: Delta Network with MPE applied to “Persistence?”

The model showed that the log was most likely: of length <9m, zoned in the stream, in a non-tranquil channel unit, not cabled, and existed in a year with below average stream flow. It also seems that the probability of a log remaining in the stream is independent of how long it has been in the stream previously. This may be a problem with the definition of “Duration.”

Even though the recent paradigm in river management has shifted away from introducing cabled logs into streams, we still use large logs that span the river. Thus, I queried the Bayesian network as to the most probable explanation for a log being both over 9m long and persistent from one year to the next. The table below shows that a log over nine meters long that persists behaves similarly to the whole set of persistent logs, yet it also demonstrates the inverse relationship between log length and percent duration. In every case except for Case 3, we see that a “yes” for Length <9m? implies a “no” for Duration less than half? and vice versa. Due to the counter-intuitiveness of the result, I theorize that there is a lower bound on log length below which length will determine a duration of less than half. Thus, a better model might use a ternary node to describe length.

Wood is most likely retained when:					
Test	Length <9m	Duration<1/2	Zonation=stream	ChUn=tranquil	Stream flow < mean
1	yes	no	yes	no	yes
2	yes	yes	yes	no	yes
3	yes	no	yes	no	yes
4	yes	no	yes	no	yes
5	yes	yes	yes	no	yes

Table 1: Most probable explanation for retained wood, over five cases

Wood is most likely retained AND of length >9m when:				
Test	Duration<1/2	Zonation=stream	ChUn=tranquil	Stream flow < mean
1	yes	yes	no	yes
2	tie	yes	no	yes
3	no	yes	no	yes
4	yes	yes	no	yes
5	no	yes	no	yes

Table 2: Most probable explanation for retained and long wood, over five cases.

To test the effects of cabling on properties of wood, it did not suffice to construct random case files and hope that they included a few pieces of cabled wood. Since only one hundred pieces of wood were either partially or fully cabled out of four thousand, it was necessary to construct cases of only cabled wood, only partial wood, and only non-cabled wood and compare the results.

Effects of cabling on wood	Test	Zonation = stream	Length < 9m?	ChUn = Tranquil	Cabled?	Duration less than half?	Streamflow below mean?	Persistence
cabled	1	no	no	no	yes	yes	yes	no
	2	no	no	no	yes	yes	yes	no
	3	no	no	no	yes	yes	yes	no
part	1	no	no	no	part	yes	yes	no
	2	no	yes	no	part	yes	yes	no
	3	no	no	no	part	no	yes	no
non	1	no	yes	no	non	no	yes	no
	2	no	yes	no	non	no	yes	no
	3	no	yes	no	non	no	yes	no

Table 3: Most probable explanation for cabling state of wood

Table 3 demonstrates the differences between cabled wood, partially cabled wood, and non-cabled wood, most notably that "Duration" is short with high probability when cabled, short with medium probability when partially cabled, and long with high probability when not cabled. This supports the observation that cabling wood into a stream does more harm than good.

Lastly, we considered the quality of fish populations nearby to woody debris. The BBN demonstrates that a healthy fish population seems to prefer stream zonation (which makes sense), wood of length less than nine meters, non-tranquil channel units, wood that has lasted less than half the time, wood that will persist to the next year, and years with stream flow above the mean. The implication that a healthy fish population prefers non-tranquil channel units is troubling, but may be an artifact of a small amount of tranquil channel units in comparison to all of the turbulent channel units.

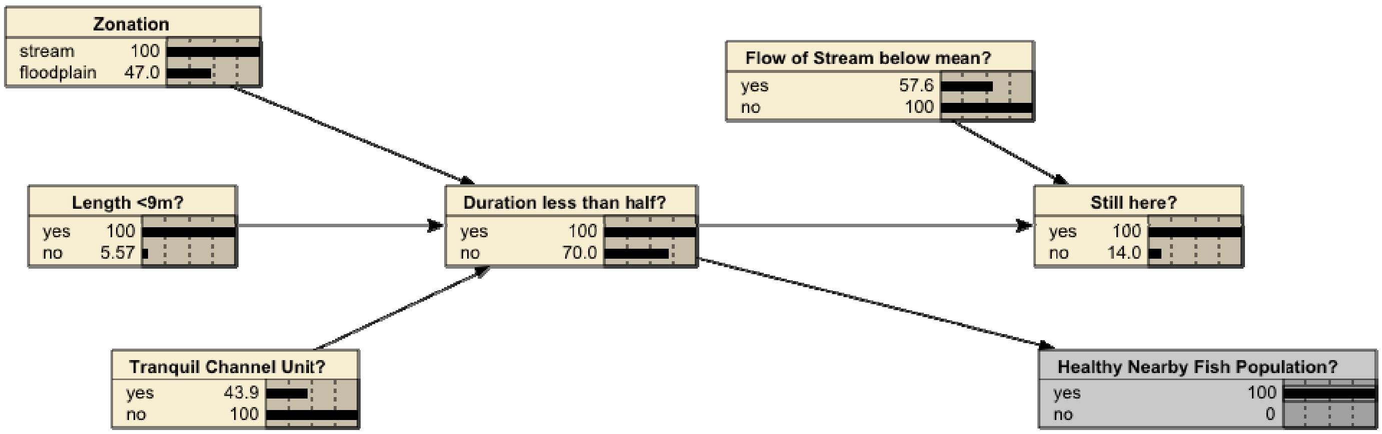

Figure 2: Most probable explanation of a healthy nearby fish population

Discussion

While we present conclusions based on the historical data and the data we collected this year, many problems with study design made it difficult to trust the viability of these conclusions. Firstly, overall conceptualization of the study stretch was limited by outdated maps and lack of proper on-site delineation. Understanding positioning of channel units would be greatly enhanced by regular placement of clearly visible metal poles, staked into river bed every 20 meters, marked with signs indicating the reach meter. This would make more precise recording of wood placement much simpler, as well as allowing for better overall navigation of the site. Overall conceptualization of geomorphology could have been simplified, as was discussed in a meeting with Stan Gregory, by limiting the channel units to two delineations (tranquil vs. turbulent) rather than the current six units in use. Further, implementation of study components in roughly the same time frame each year would greatly enhance supportability of data. For most of the historical data there is no record of when components of the study were undertaken, and with so much variability in flow levels from early spring to late summer, most every component of study at Quartz Creek would logically be affected by timing, especially width and depth measurement.

In order to better monitor wood in streams specifically, many changes to study design would have helped this project gather more comprehensive data. Implementing a tagging system whereby each piece of wood could have two unique tags (numbered 100A and 100B, for example) would allow for better tracking positions of pieces when wood breaks apart. In order to properly do the level of analysis undertaken in this study, measuring every piece of wood each year would make it possible to avoid biasing size change comparisons by limiting analysis to movers only. Further, improving spatial resolution of position data so small-distance moves can be noted would make movement data far more reliable and useful. At this point twenty years into the study, having a protocol for determining if wood is missing due to decomposition into soil seems a good step. Tagging live trees on the bank to determine where the input to the stream is coming from could also provide intriguing data for expanding wood debris study to a timeframe previous to placement in the stream.

Problems with lack of consistency in previous year's snorkeling methods and lack of availability for backing up snorkel data with electro-shocking this year were the major limiting factors affecting fish data. Though the methods laid out in the original proposal to the forest service for establishing fish populations involved a double snorkel count of the entire research stretch each year, only half the stretch could be surveyed in 1992, and only one pass was done in 1993, 1996 and 1997. Also, because we did no shocking this year we did not try to compare our results to shocked data, but if we had been able to shock we would have had limited data for comparison as no shocking was done in 1988 or1989, and on average only about half the stretch was shocked in years shocking was done.

Conclusions

We conclude that fish populations have not changed dramatically since 1988 and have recently fallen to below levels recorded in 1996 and 1997. Our data also supports fish preference for tranquil channel units over turbulent channel units.

The BBNs developed for this study demonstrate that wood retention relies on a number of factors and while we provide many suggestions for the processes behind this, there are definitely many more, and the implications of our results are sometimes counter-inuitive and worrisome.

Wood persistence relies on low stream flow, stream zonation, placement in a turbulent channel unit, length less than nine meters, and is independent of percent duration. Wood is most probably persistent and under nine meters in length during a year of low stream flow, zoned in stream, placed in a turbulent channel, and is also independent of percent duration. Curiously, wood length seems to have an inverse relationship to percent duration – longer wood spends less time in the stream and vice versa. Cabling of wood affects only percent duration, in that cabled and partially cabled wood is more likely to spend less time in the stream than its non-cabled neighbors. A healthy fish population is most probably located near wood that is: strictly located in the stream, less than nine meters in length, in a turbulent channel unit, of a percent duration less than half, persistent, and in the river during a year of below mean stream flow.

Acknowledgements

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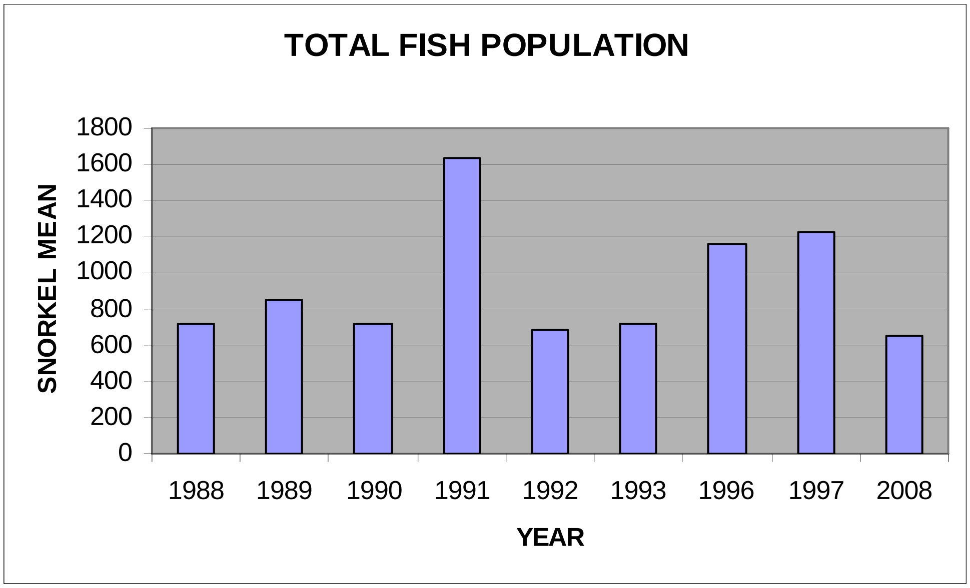
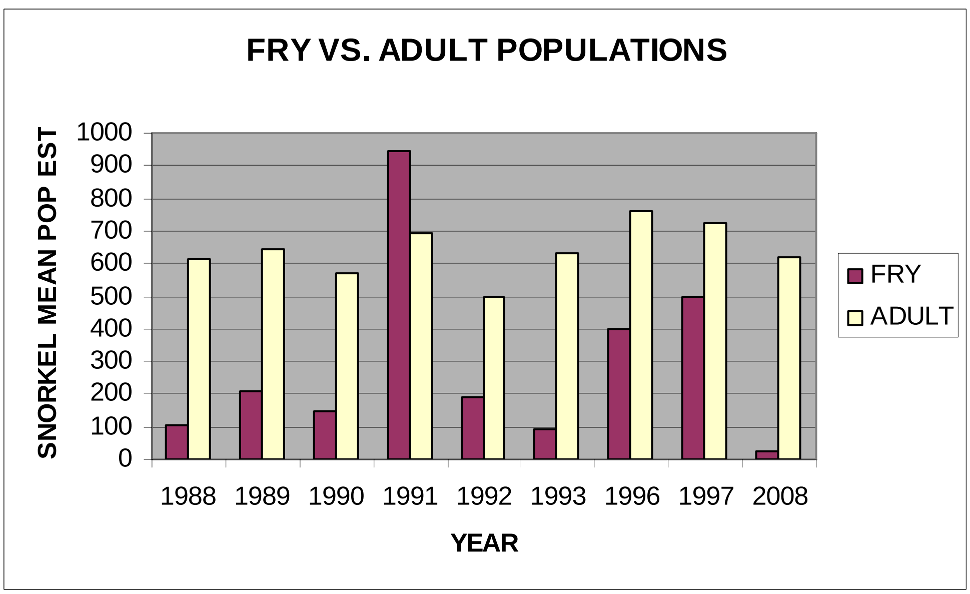
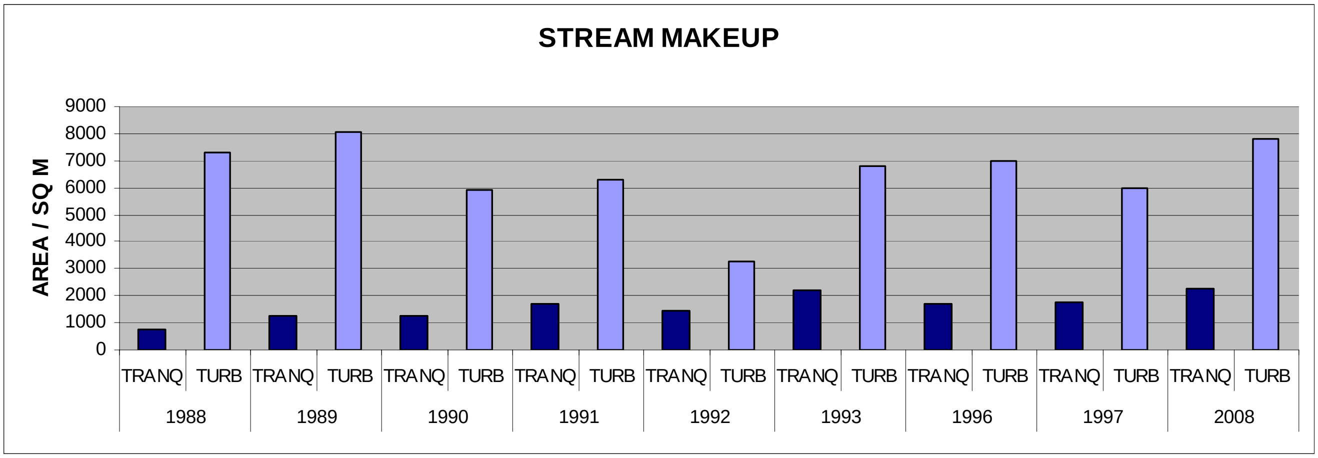
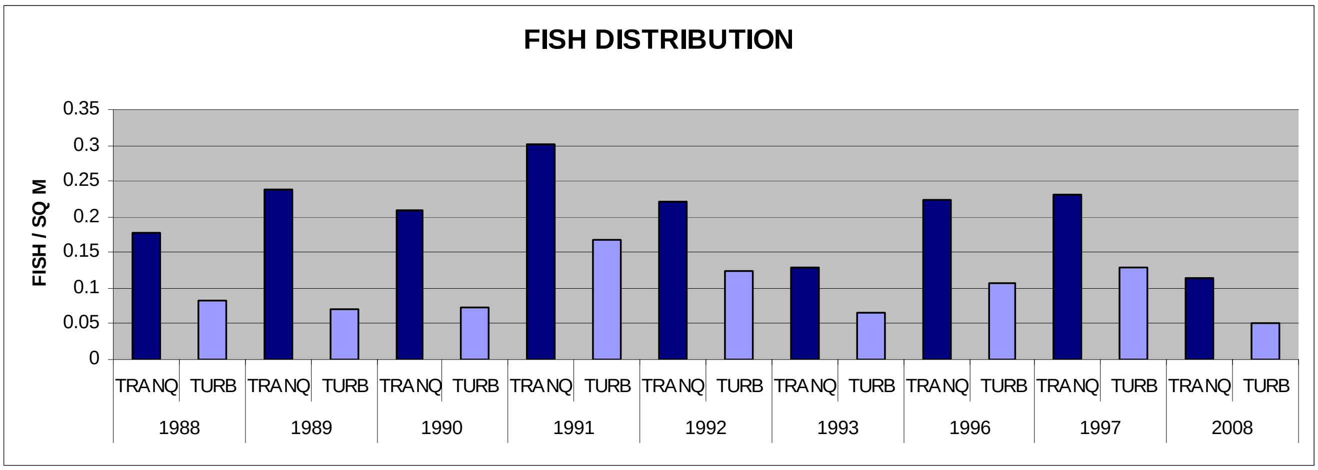
Appendix


TOTAL FISH POPULATION
SNORKEL MEAN
0
200
400
600
800
1000
1200
1400
1600
1800
1988
1989
1990
1991
1992
1993
1996
1997
2008
YEAR


FRY VS. ADULT POPULATIONS
SNORKEL MEAN POP EST
0
100
200
300
400
500
600
700
800
900
1000
1988
1989
1990
1991
1992
1993
1996
1997
2008
YEAR
FRY
ADULT


STREAM MAKEUP
AREA / SQ M
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
TRANQ TURB TRANQ TURB TRANQ TURB TRANQ TURB TRANQ TURB TRANQ TURB TRANQ TURB TRANQ TURB TRANQ TURB
1988 1989 1990 1991 1992 1993 1996 1997 2008


FISH DISTRIBUTION
FISH / SQ M
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
TRANQ TURB TRANQ TURB TRANQ TURB TRANQ TURB TRANQ TURB TRANQ TURB TRANQ TURB TRANQ TURB TRANQ TURB
1988 1989 1990 1991 1992 1993 1996 1997 2008

Works Cited

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2. Jensen, F. V. (2001). *Bayesian Networks and Decision Graphs*. New York: Springer.

3. Marcot, B. G. (2001). Using Bayesian belief networks to evaluate fish and wildlife population viability under land management alternative from an environmental impact statement. *Forest Ecology and Management, 153*, 29-42.