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Woody Debris and Steelhead[1]

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Abstract.--In recent years, anglers have expressed dissatisfaction with the Lake Superior steelhead fishery. Before fishing can be improved, factors limiting survival must be determined and mitigated. A previous correlative analysis suggested that woody debris functioning as overhead cover may be a primary limiting factor for age-1 parr, thus the hypothesis was tested in north shore streams. Temporary woody debris cover structures were placed in nine north shore streams and survival of five successive year classes was monitored. Survival to age-1+ was generally poor (0-16%). Most age-1+ fish were found under the cover structures in the treatment reaches. The added cover did not improve survival appreciably or consistently. Thus I failed to reject the null hypothesis of no treatment effect. If the lack of overhead cover from woody debris ever limits survival, it does so infrequently and is not predictable given present understanding. The abundance of literature supporting the importance of woody debris suggests that it should not be dismissed as a limiting factor in north shore streams. It's primary function, however, is not clear.

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Introduction

Since the inception of sea lamprey *Petromyzon marinus* control and the resultant recovery of lake trout *Salvelinus namaycush,* the abundance of spawning steelhead *Oncorhynchus mykis* has declined in tributaries along the north shore of Lake Superior. Recent increases in steelhead spawner abundance in some streams in Lake and Cook counties as a result of a no-kill regulation are encouraging; however, the Section of Fisheries Management is seeking to increase spawner abundance in all streams so that the strain can be harvested.

To increase fish abundance, a fisheries manager must mitigate one or more limiting factors (Krueger and Decker 1993). Adult and smolt traps have been completed in the French and Knife rivers to evaluate lake and stream survival, and provide insight into potential limiting factors. Trap data indicate that hatchery-reared smolts have made a significant contribution to the catch of adults in recent years (MNDNR file data), suggesting that smolt yield may be limiting spawner abundance.

Three methods are available to increase the smolt yield, each having different risks and costs. Increasing fry stocking rates is relatively inexpensive and has a low genetic risk, but fry availability is limited. The stocking of hatchery-reared smolts is preferred by many steelhead anglers. However, there are limits to how many smolts can be cultured, costs are high, and geneticists warn that supplementation with hatchery-reared fish can be genetically hazardous to wild stocks due to domestication selection (Reisenbichler and Rubin 1999; Epifanio and Philipp 2001; McLean et al. 2003). As a result, stocking of hatchery-reared fish should only be considered when the stock can't recover on its own (Kapuscinski and Jacobson 1987). A third alternative, habitat improvement in the rearing streams, might increase the survival of parr, thus increasing smolt yield, and would have no adverse genetic consequences. Unfortunately, effective habitat improvement techniques for juvenile steelhead have not been developed and tested in Minnesota tributaries to Lake Superior.

Work done in the Pacific Northwest suggests that steelhead parr densities are positively correlated with the quantity of woody debris, particularly, large woody debris. Woody debris probably serves many functions and several of these functions have been identified. Elliot (1986), House and Boehne (1986), and Shirvell (1990) found that woody debris increases parr survival by providing lateral cover, protecting them from high water velocities during floods. Other investigators have determined that woody debris provides needed hiding cover (Pearlstone 1976; Murphy et al. 1986; Shirvell 1990; White 1991), winter cover (Sollazzi et al. 2000; Roni and Quinn 2001; Mitro and Zale 2002), or visual isolation (Chapman 1962; Bjornn 1971; Richard 1979). Woody debris often facilitates pool formation by impounding water or by facilitating substrate scour. Pools created in this way may provide critical habitat (Lisle 1986; Flebbe and Dolloff 1991; Roni and Quinn 2001). Submerged wood provides microhabitats for invertebrates (Benke et al. 1984; O'Connor 1991; Richards and Host 1994). Decaying wood provides some of the nutrients needed for primary production (Cummins 1974; Bilby and Likens 1980; Bilby 1981). Definitive evidence of the limiting effect of woody debris in north shore streams is lacking.

North shore streams are dissimilar to Pacific coast streams in many ways, making local investigations necessary. Streams in northeast Minnesota have different geomorphology, flows, species assemblages and temperatures, thus the streams and fish may not respond to woody debris in the same way. Recently completed research in Minnesota showed that survival of age 1+ steelhead was positively correlated with the amount of stream surface area containing woody debris (Close and Anderson 1997). Positive correlation suggests the possibility that the lack of debris cover limits survival but does not prove it (Thomson et al. 1996). Results of the Close and Anderson study (1997) and my observations suggest that adding woody debris as overhead cover may increase survival of age-1 parr, potentially resulting in more spawning adults.

Data from the French River smolt trap suggest that changing the age structure of emigrating juveniles could also increase the number of adult spawners. In 2003, 88% of the juvenile steelhead emigrating from the French River were age-0 or age-1 (Hendrickson 2003). Growth patterns in scale samples from returning adults show low contributions of age-0 and age-1 emigrants to the spawning stock (MNDNR file data). Thus, for management purposes, age-0 and age-1 emigrants can be considered mortalities. All age-0 and most age-1 emigrants have not yet smolted (Negus 2003), and may leave the stream because some habitat feature is lacking. Woody debris may be that feature.

To be of any value, the addition of woody debris must increase the abundance of age 1+ parr, not merely attract fish that are already present (Grossman et al. 1997; Lindberg 1997). To be certain that a true increase in abundance has occurred, Bohnsack et al. (1997) suggested that the researcher must insure that 1) other mechanisms that could explain increases in fish density are eliminated, 2) temporal and spatial scales are sufficiently large, and 3) the amount of added or altered habitat is a significant portion of the available habitat. With these requirements in mind, our objective was to measure and compare the survival rates of steelhead parr to age-1+ in two similar reaches in each of several north shore streams. One reach would contain the woody debris treatment and the other (no wood added) would serve as a control or reference.

Methods

Approximately 2 km in each of nine candidate streams, representing the size range of north shore streams supporting steelhead populations, were surveyed and mapped during normal summer low-flow using the depth/flow habitat categories of Oswood and Barber (1982) and the substrate categories of Close and Anderson (1997). Maps were drawn to a scale of 1 inch : 5 m. Surface areas were measured on a digitizing pad. Reaches selected for stocking were as identical as possible with respect to the percentages of each habitat category and substrate type to control for those variables (criterion one of Bohnsack et al. 1997). Success or failure at meeting criteria two and three cannot be measured because the terms sufficient and significant are subjective and must be left to professional judgment. Considerations such as time constraints on survey time, debris structure construction, and population assessment effort yielded the study reaches described in Table 1. All study reaches were above natural barriers to steelhead migration, eliminating the possibility of natural reproduction. Reaches were selected for treatment if they contained more naturally occurring overhead cover than the other reach and/or the landowner was more willing to allow the cutting of trees in the riparian zone to provide the material for additional cover.

Raft-like overhead cover structures were constructed from trees cut in the riparian zone (Figure 1). Trees were pulled into place using a chainsaw-powered winch. Logs were bound together with 9.5 mm ($3/8^{th}$ inch) diameter galvanized cable and cable clamps. The structures were held in place by a cable anchored to a log placed in the riparian zone perpendicular to the direction of flow. These anchor logs were cabled to standing trees for additional stability. In a few cases, the structures were cabled to large boulders in the streambed. A structure was placed in every suitable site in each treatment reach in an attempt to meet criterion three of Bohnsack et al. (1997; see Table 1). A site was deemed suitable if the structures could be placed such that each end of the structure rested on the bottom with deeper, quiet water beneath where the fish could hide and rest. Very little naturally occurring overhead cover was present in the reference reaches, thus, in our judgment, the amount of cover added to each treatment reach was significant.

Table 1. Surface areas (m^2) of the study reaches measured during summer low flow, and the number of woody debris structures installed in each treatment reach.

Stream	Treatment	Number of Structures	Reference
French River	610	9	540
Sucker River	898	9	907
Stewart River	770	7	598
Silver Creek	502	7	722
Encampment River	658	7	533
West Branch, Split Rock	930	10	604
East Branch, Split Rock	814	7	786
Beaver River	1,168	10	1,296
Two Island River	765	7	697

Figure 1. Three overhead cover structures in the Two Island River.

Each reach was stocked with steelhead fry at a rate of 1 fry $\cdot m^{-2}$(surface areas were measured on the maps). Unfed fry were stocked shortly after swim-up, and were evenly distributed throughout the reach. Populations of age-0 and age-1 parr were estimated in August of each year using backpack electrofishing gear. Population and error estimates were calculated using the modified Chapman mark and recapture model (Ricker 1975) if at least one fish was recaptured. The Carle and Strub (1978) model was used if no recaptures were observed in the second run catch, and the catch was smaller than the first run catch. In the rare case where neither was true, the total catch was used as the estimate. Differences in survival rates were judged to be statistically significant if their 95% confidence intervals did not overlap.

Results

Overhead cover did not appear to be a major factor limiting the survival of age-1 parr. Survival to age-1+ was generally poor (0-16%; Table 2). Age-1+ parr apparently preferred the cover provided by the structures because most of the fish captured in the treatment reach were under them. However, the added cover did not appear to increase survival or retain more age-0 parr. Survival was significantly better in the treatment reach in the French River for the 1999 and 2003 year-classes. Additionally, survival was also significantly better in the East Branch Beaver River for the 2001 year-class, but the survival rate was very low in both reaches. Survival was significantly better in the reference reach for the 2002 year-class in the Two Island River.

Discussion

These few and inconsistent results suggest differences in survival may have been effects of some unmeasured environmental variable that varied over time and among reaches. Identifying limiting factors can be a difficult task. The concept of limiting factors was first proposed by Liebig (1840, not seen, as cited by Fox 1995) as Liebig's Law of the Minimum, stating: biological processes are controlled by the resource in short supply. Difficulty in determining the resource in short supply comes from the fact that groups of factors act in hierarchical manner to regulate population density (Berryman et al. 1987), and the hierarchy may reorder in an unpredictable way. For example, if overhead cover limits survival during most years, and food was in unusually short supply immediately after stocking during the term of the study, then mortality may have occurred shortly after stocking and the lack of cover that would normally influence survival later, would have had a minimal effect. My goal was to identify limiting factors that occur frequently enough to be efficiently mitigated. Overhead cover from woody debris does not meet this requirement.

Summer flows were often quite low during the study, thus high water temperatures may have had a limiting effect. When flows are low, water temperatures are higher. Water temperature was not a significant variable in the Close and Anderson (1997) study, but flows were generally higher then. Low flows were most pronounced in the smallest streams where survival rates were frequently zero. Had flows been higher and water temperatures lower, any limiting effect of overhead cover may have been more detectable. Such temperature and flow fluctuations are normal for north shore streams. Therefore, an alternative interpretation of our results is that the limiting effect of overhead cover is simply lower in the hierarchy of limiting factors than I originally thought. Before trees provide overhead cover in the stream, they provide shading. Our experiments may have provided only a part of the services that aquatic communities need from riparian trees to thrive. Future experiments to define limiting factors should include measurements of water temperature.

Although overhead cover from woody debris does not appear to be a major limiting factor in north shore streams,

Table 2. Survival (%) of steelhead parr to age 1+ in the study reaches. Ninety-five percent confidence intervals were calculated when sample sizes permitted and are in parentheses. A dash indicates that construction was incomplete so the reach was not stocked with the year-class.

Stream	Year-class 1999	2000	2001	2002	2003
French River					
Treatment	11.0 (9.3-16.7)	2.1 (1.8-5.1)	1.0 (0.7-1.8)	7.0 (6.4-11.1)	5.9 (3.4-14.9)
Reference	2.8 (2.6-5.4)	1.3 (1.1-3.3)	1.1 (0.9-2.8)	4.6 (3.9-8.9)	0.6 (0.4-0.9)
Stewart River					
Treatment	7.1 (6.4-10.8)	14.8 (12.6-19.6)	3.1 (2.5-6.9)	0.3	0.4 (0.3-0.6)
Reference	7.7 (4.5-19.2)	16.0 (11.0-39.6)	3.8 (3.3-7.5)	0.2	0
Sucker River					
Treatment	-	0.2	*	*	0[a]
Reference	-	0.3	*	*	0[a]
Silver Creek					
Treatment	-	0	0	**	**
Reference	-	0	0	**	**
Encampment River					
Treatment	-	-	0	0	0
Reference	-	-	0	0	0
East Branch, Beaver River					
Treatment	-	0.9 (0.7-2.3)	0.4 (0.3-1.1)	0	0[a]
Reference	-	1.5 (0.8-3.6)	0.5 (0.3-0.8)	0	0[a]
West Branch, Split Rock River					
Treatment	1.8 (1.2-4.5)	2.9 (1.5-7.2)	1.1 (0.9-2.7)	1.0 (0.6-2.0)	0.3
Reference	1.8 (1.5-4.0)	2.3 (1.8-6.0)	0.3	0.5 (0.3-1.1)	3.3 (2.0-8.3)
East Branch, Split Rock River					
Treatment	-	0	0	0	0[a]
Reference	-	0	0.1	0	0.1
Two Island River					
Treatment	-	-	0.1	0.5(0.4-1.3)	1.0 (0.7-1.4)
Reference	-	-	0.9 (0.6-1.6)	3.3 (2.7-6.6)	1.1 (1.0-3.0)

* These reaches were not stocked due to a beaver infestation.
** Vandalism precluded the use of these reaches.
[a] These reaches were not electrofished due to the near zero survival of age-0 fish in 2003.

the importance of woody debris, particularly large woody debris, should not be dismissed. Our structures were constructed specifically to maximize overhead cover and probably did not adequately increase habitat complexity through pool formation, addition of lateral cover (protection from high flows), visual isolation, or invertebrate substrates. Nor was decay of the added wood sufficient to add additional nutrients to the stream. In a Wisconsin study, DuBois (2003) found a positive relationship between wood volume and salmonid biomass in several streams, but he did not speculate about its precise function. Knowing its function would help determine how to efficiently add wood to mitigate its limiting effect. In another study, DuBois (2001) attempted to mimic nature with addition of woody debris to enhance anadromous salmonid production, but his experiments yielded equivocal results. He reported, however, that several factors con founded his results and recommended further study. Despite the fact that the precise-functions of woody debris are not known for north shore streams, the abundance of literature supporting its importance (see the Introduction of this report) suggests that until methods to maximize the benefit of woody debris are identified, riparian forests should be protected so wood can recruit naturally.

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