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Woody debris collectors improve salmonid rearing habitat in a large inland river in southeastern British Columbia

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ABSTRACT

Large woody debris (LWD) collectors were tested in the lower St. Mary River, southeastern British Columbia, from 1991 to 1993 to assess the effects of in-channel debris placement on channel morphometry, fish utilization and structural durability. Previous studies found adult westslope cutthroat trout (Oncorhynchus clarki lewisi) distribution to be highly regulated by low flow condition: LWD deposited along channel margins often became dewatered by late summer leaving suitable depth and surface turbulence to provide the only form of in-stream cover. Debris collectors were installed in glide habitats at three different locations in the lower river to provide additional overhead and in-stream cover. A paired comparison was conducted to detect mean differences in fish abundance between control and treatment locations, before and after installation of the collectors. Post-treatment evaluations showed substantial lateral scouring around debris collector structures after two years, where debris remained intact, and thereby provided attractive sites for adult rearing. The mean number of cutthroat trout at the three treatment locations increased significantly following debris collector installation however, no significant difference in abundance was shown for mountain whitefish (Prosopium williamsoni). Five of the six collectors had a mean number of 8 cutthroat trout per structure (range 2-15). Use of treatment sites previously avoided by trout suggests that added structural complexity to channels at low flow stage can improve salmonid carrying capacity. Structures were found to be durable at peaking flows in excess of 200 $m^3.s^{-1}$ however continued monitoring is needed to assess longterm benefits.

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INTRODUCTION

The capacity of a stream to support salmonid populations is largely determined by the availability of food and space (Chapman 1966). The amount of fish habitat is defined by channel morphology whose form and pattern is modified by structural elements such as woody debris, boulders and bedrock (Sullivan et al. 1987). These structural elements of the stream ecosystem create variations in morphology (or hydraulics) that provide a variety of habitat units, such as pools, riffles and glides, characterized by variations in depth and velocity. The frequency of each habitat unit is dictated by stream gradient, channel confinement and degree of structural complexity (Vannote et al 1980) which produces both spatial variability and fish habitat heterogeneity within distinct stream reaches (Marston 1982; Sullivan et al. 1987). Salmonid species have evolved certain life history strategies to exploit a variety of habitat alternatives (Scott and Crossman 1973; Bisson et al, 1988). Given the dynamic nature of lotic environments however, annual variation in flow regime may alter the availability and quality of habitat units (Heede and Rinne 1990).

Large woody debris (LWD) has been shown to be a structural (Ward and Slaney 1979; Bryant 1983; Sedell et al, 1984; and Bisson 1987) and functional (Bilby and Likens 1980; Speaker et al 1984; Harmon 1986; Ward and Aumen 1986) component of the stream ecosystem which affects channel dynamics, sediment storage and organic matter storage. Its importance as effective cover for a variety of salmonids (*Oncorhynchus kisutch*, *O. mykiss*, *O. clarki clarki*, *O. c. lewisi*, *Salvelinus malma* and *S. confluentus*) has been demonstrated experimentally (Ward and Slaney 1981; Elliot 1986; House and Boehne 1986; Moore and Gregory 1988) or observed directly (Shepard et al 1982; Pratt 1984). A review of the same literature however, suggests its utility in modifying whole channel morphology (ie channel sinuosity, longitudinal profile) appears restricted to first and second order streams with a wetted cross-section generally less than 10 m. In the larger third and fourth order streams (> 10 m wetted width), it occurs more commonly along channel margins or in-channel bars or islands and has a greater influence on bank stability and bedload deposition. More importantly however, LWD is considered an important structural and cover component of small streams at all flow stages whereas in large streams its distribution may be limited to the floodplain and at low flow condition exhibit little value as cover.

The St. Mary River, located in southeastern British Columbia, is a fourth order stream characterized by long riffle-glide sequences. It consists mostly of a single thread which is longitudinally controlled by transverse gravel bars, with few deep (> 3m) pools, throughout its lower reaches. Under low summer flow, the amount of instream LWD is limited. As a consequence, the distribution of rearing sub-adult and adult westslope cutthroat trout is restricted to areas where suitable depth, surface turbulence or large boulder clusters provide in-stream cover. On average, less than 20 % of the wetted area of riffle-glide units was estimated as suitable habitat for resident cutthroat trout (Oliver 1994).

In 1991, as a pilot study to address this limitation, debris collectors were tested experimentally at three locations in the lower river to assess changes in channel morphometry and fish use as well as to determine structure durability. This paper evaluates in-channel habitat manipulation with LWD collectors as a potential enhancement tool for inland resident trout streams.

METHODS

Study Area

The St. Mary River originates in the Purcell Mountains and flows east joining the Kootenay River in the Southern Rocky Mountain Trench near Fort Steele (Fig. 1). The upper and lower rivers are separated by St. Mary Lake. The lower river is 54 km in length and flows between the cities of Cranbrook and Kimberley.

The annual flow regime is typical of most interior B.C. streams with spring maxima occuring in June (mean 221 $m^3.s^{-1}$) and winter minima in February (mean 9 $m^3.s^{-1}$); mean annual discharge is approximately 52.7 $m^3.s^{-1}$ (Anon. 1988). Flow is largely controlled by the amount of annual snowpack although rain storms during spring and late summer often cause isolated peaks. During winter, some anchor ice occurs from December to February.

Mean monthly water temperature ranges from a low of 0.1 °C in January to a high of 16.4 °C in August. Mean summer temperature (June 15 to September 30) is 12 °C.

The river downstream of St. Mary Lake has long riffle and glide-run sequences dominated by boulder. The single channel over most of its length is bounded by river terraces. Bed materials include gravel, rubble, boulder and infrequent bedrock outcrops. The amount of in-stream LWD is low particularly during low summer flow. The upper one-half of the lower river lies within the Interior Douglas Fir biogeoclimatic zone while the lower one-half occupies the Ponderosa Pine (PPdh2) zone (Braumandl and Curran 1992). There are five major tributaries in the lower river: Hellroaring, Matthew, Mark, Perry and Joseph Creeks. With the exception of Joseph Creek, the tributaries are steep, cool and relatively unproductive. A complete description of biophysical and chemical characteristics of the mainstem river and its tributaries is available elsewhere (Oliver 1994).

The six species of sportfish naturally occurring in the lower river include mountain whitefish, cutthroat trout, bull trout, burbot (Lota lota), rainbow trout and eastern brook trout (S. fontinalis). Non-sport species include coarsescale sucker

(Catostomus catostomus), northern squawfish (Ptychocheilus oregonensis), longnose dace (Rhinichthys cataractae) and slimy sculpin (Cottus cognatus).

Debris collector location, design and installation

Woody debris collectors were installed at three locations in August 1991: the upper most site, in the vicinity of Wycliffe, B.C. and the lower two sites approx. 1.5 km upstream and downstream of the Highway 95 crossing (McPhee Bridge) between Kimberley and Cranbrook (Fig. 1). All three sites were typical of long, straight, glide habitats. Channel geometry was characterized by a skewed, U-shaped cross-section where the thalweg occurred near one streambank and depth gradually shallowed toward the opposite bank. Debris collectors were positioned within the shallow one-half of the channel cross-section (ie within 10 to 25 m of the streambank; wetted channel width from 40 to 56 m in total) where suitable depth and velocity prevailed, yet cover was absent. Suitability criteria for sub-adult and adult westslope cutthroat trout were used from a previous study (Oliver 1994) to determine in-channel placement. Two collectors were installed at each of the three sites and positioned approximately 60 m apart. An offset alignment was chosen to increase debris catching efficacy of the downstream structure.

Debris collectors were patterned after a structural design modified from Slaney et al (1991) by Hay and Company Consultants to improve aesthetics of the design (Fig. 2). The need to entrap surface debris during freshet was identified as a key requirement of its design. By trapping and holding woody debris within the area of the normal low water channel, the structure was intended to create local velocity shears and variations in depth that would provide attractive sites for adults, in habitat normally avoided by trout.

The debris trap is formed by logs floated at the river surface and anchored to piers. The collector consists of two logs (fir or larch) approximately 5 m in length with a minimum diameter of 300 mm. Two 50 mm holes, inset approximately 0.3 m from each end and fitted with 38 mm ID steel pipe, serve as points of attachment. Each log is anchored by a single 4 m steel pier (constructed from railway rail; dimensions approx. 150 mm base, 180 mm height, 80 mm top) driven into the streambed leaving approximately 0.3 m of its length above grade; the piers are positioned in line approximately 7 m apart and perpendicular to the direction of flow. Each log is connected to a pier with a 4 m length of 10 mm dia steel chain and both logs then joined together at their downstream end forming a "V"; the attachment is again completed with steel chain of the same size. A third pier (optional) is placed midway between the open ends of the logs and driven into the streambed to a similar vertical position. The apex of the collector is then connected to the middle pier for added strength and stability under load. All connections are completed with 13 mm dia shackles or bolts. More recent modifications include a "chain basket" towards the apex of the structure to ensure debris catchment (refer to Fig. 2).

Preparation of the steel piers required cutting 12 m railway rails into three equal sections. Each section was pointed at one end to facilitate installation into the streambed and a 50 mm by 150 mm hole cut at the opposite end to facilitate handling. All modifications were completed with an oxy-acetaline torch. Similarly, all logs were cut to size, drilled and fitted with steel sleeves prior to transport to each experimental site. Onsite, a large track hoe excavator complete with a vibratory compactor installed the steel piers. The base of the compactor was fitted with a 160 mm length of 160 mm channel iron; the length of the channel iron having been welded to the base of the compactor. The lateral sides of the channel iron were drilled with a 30 mm dia hole. The piers were then attached to the compactor by placing the channel iron over the blunt end of the rail (lying in its upright position), lining up all three holes and pinning (25 mm pin dia) the rail at 90 degrees to the base of the compactor. Each pier was lifted vertically, walked into place, positioned with the rail base facing upstream and vibrated into the streambed. Each log was then floated into place, held parallel to the flow and anchored to the appropriate pier. The downstream ends of each log were chained together completing the "V" and a third chain added from its apex to the middle pier. To ensure active scouring of each structure during the following spring freshet (1992), each collector was "seeded" with a mixture of small and large woody debris occurring naturally along adjacent dry gravel bars or channel margins.

Channel description and fish enumeration

Prior to debris collector installation, whole-stream, cross-sectional profiles were completed in August 1991 using 5 transects to describe each site. Transects were located 5 m above the upstream piers, through the center of the "V", and midway between the two collector positions. Depth and mean velocity measurements were recorded at 5 m intervals along each transect as well as 1 m from each streambank. Profiles were again completed in August 1993 to reflect any large-scale change in channel morphometry. A 13 by 18 m, a 13 by 21 m and a 13 by 15 m grid was completed over one collector at each of Sites 1 through 3, respectively, to describe site-specific changes in depth after two years of scour. The grid consisted of five to seven 13 m transects spaced 3 m apart. Depth measurements were completed at 1 m intervals across the debris collector beginning 3 m upstream of the in-line (upstream) piers. The grid, completed in 1993 only, provided streambed area profiles ranging from 195 to 273 m^2 beneath the three structures.

During August 1991, snorkel counts were employed to estimate pre-treatment salmonid abundance using the method of Slaney and Martin (1987); 5 counting lanes over 15 m of channel width (where structures were to be deployed) and over a longitudinal distance of 100 m. Control sites either immediately upstream or downstream of experimental sites were similarly enumerated in glide habitats to account for temporal variation in numbers and compare differences in species use between reference and manipulated areas. Snorkel evaluations following two years of in-channel placement were conducted in August 1993. However, five counting lanes (2 shore, 2 near-shore and 1 mid-channel) were used over the entire channel width. The mid-channel lane enumeration was expanded to account for the two unobserved lanes (or 6 m of channel) between the mid-channel and near-shore counting lanes. Underwater visual distance during both census years was measured at 3 m and all counts were replicated twice.

Experimental design and analysis

A paired comparison was used to detect the effect of habitat manipulation on fish abundance by testing the mean difference in number between control and treatment sites (ie treatment - control) before and after installation of debris collectors. In this study, treatment sites were specifically chosen on the basis of access for heavy equipment and control sites similar in habitat type were selected immediately adjacent to the treatment sites. The three treatment locations, considered as independent replicates, were tested for before and after mean differences using a one-tailed t-test.

RESULTS

Collector durability and debris recruitment

Following the spring freshet of 1992, each collector was assessed for durability, additional recruitment of river-transported debris and depth of scour. Of the six collectors, only one structure (lower collector, Site 3) successfully maintained or accumulated a debris load. It was apparent from observations made during peak flows that five of the structures were completely submerged and the installed debris swept away. Only during receding flow conditions did the collectors re-surface and function as designed. As a consequence, only three of the six structures (upper collectors at Sites 1 and 2, lower collector Site 3) had accumulated sufficient debris to cause further scouring.

Under full debris load, the collectors showed little wear. However, in the absence of a direct load, the structures oscillated vertically in the current causing abrasion to both chain and logs. The design was improved by installing cross-chains below and above the "seeded" debris to ensure its entrapment under all flow conditions. Chain was added underneath each structure in 1992 to test its efficiency at debris capture without prior "seeding", followed by chain placement above "seeded" structures in 1993. Further strapping across the top of the collector was necessary where small diameter debris was prevalent. The lower structure at Site 3 in 1992 was initially supplied with larger sized material. Its inter-meshed nature and contact with the stream bottom resulted in minimal displacement of woody debris. Once in position, any debris extending above surface will continue to trap river-supplied material. As a consequence, incremental improvements in design and in accumulation of debris at five locations has resulted in a gradual change in stream profile and habitat complexity. The most dramatic change was observed at the lower site below McPhee Bridge (Site 3) over the two year period. Due to the enhanced stability under full debris load and peak flow, abrasion to any collector component was undetected.

Channel morphometry

The number of transects completed at each treatment location made it difficult to construct contour plots that provided sufficient resolution to distinguish differences in channel morphometry between years. Hence, depth and velocity characteristics following installation of debris collectors are only shown for the three structures (upper collector at Sites 1 and 2; lower collector at Site 3) that held woody debris. Whole-stream cross-sections immediately above (3 m) and below (1 m) each of the three operational structures are provided to illustrate differences in depth and velocity between 1991 and 1993 resulting from debris placement.

Depth profiles prior to installation of collectors at Site 1 (near Wycliffe) displayed a skewed cross-section with a thalweg of 1.6 m within 15 m of one bank gradually shallowing to its opposite bank and typical of laminar flow (Fig. 3a). Following placement of the structures, differences in bottom elevation were localized at the upper collector site where additional debris had accumulated during the freshet of 1993. A slight increase in depth and velocity was noted along the mid-channel side of the upper structure. Directly behind the collector, minimal velocities were observed. The low volume of debris of the upper collector at Site 2 (above McPhee Bridge) had a similar effect (Fig. 3b). Pre-treatment conditions were again similar in cross-section and flow (as Site 1) however, local scouring of the upper collector on its mid-channel side was not as extensive as that observed at Site 1. Notwithstanding, some scouring of bed materials shoreward was evident. Higher velocities along both sides of the collector prevailed and flow was less restricted immediately downstream. The most noteable change in depth and velocity profile was evident at Site 3 (below McPhee Bridge; Fig. 3c). Pre-treatment channel characteristics were typically U-shaped with a thalweg of 1.4 m closer to one stream bank and flow pattern was again laminar. Following debris placement, an increase in depth of scour along both margins of the lower collector was most prominent; gravel deposition immediately downstream of the collector created an instream bar that remained sub-surface. Similarly, the highest velocities occurred along each side of the collector and dropped sharply immediately downstream. This site offered the greatest habitat complexity (in terms of depth, velocity and instream cover) of all three locations.

A comparison of three-dimensional depth profiles underlying the three functional structures further emphasizes the degree of scour localization (Fig.4). At Site 1, only slight scouring at the downstream end of the upper collector occurred. At Site 2, a similar situation prevailed although some deposition of gravels was noticeable at the downstream end of the upper collector. At Site 3, scouring underneath and along both sides of the lower collector, to a depth of 1.5 m, was evident, where initial depths ranged from 0.5 to 0.8 m. Deposition of finer gravels at its downstream end is more clearly portrayed.

Fish use

Differences in the mean number of cutthroat trout per ha at the three treatment locations increased significantly over the period of census (1991 to 1993; Fig. 5; t-test; $p < 0.05$). Of the six collectors installed, only one structure was devoid of any fish species. Five of the six structures supported an average of 8 adult cutthroat (range 2 - 15) per structure during the 1993 census. Two of the five collectors had minimal or no debris within the structure, yet the physical presence of the two logs comprising the debris trap provided sufficient overhead cover to attract trout. Of the three functional structures complete with a larger volume of debris, the mean number of trout was 10 per structure (range 6 - 15). Underwater spot investigations at different stages of flow (late spring through late summer) indicated use by up to four species of fish including cutthroat, bull trout, mountain whitefish and coarsescale sucker. Cutthroat trout were observed feeding immediately downstream of the debris collector at Site 3 during the period of bank full discharge indicating use at extremely high flows as well as low summer flows. Differences in mean counts per ha between control sites for the two census years were most evident at Site 3; fewer numbers were observed in 1993.

The greatest contrast of mean number per ha for mountain whitefish was observed between 1991 and 1993 at Site 1 (refer to Fig. 5). The response of whitefish was relatively unchanged at Site 3 although an apparent drop in use was evident at Site 2. Overall, there was no significant difference in mean number of whitefish between pre- and post-treatment periods (t-test; $p < 0.05$). The lower precision for replicate counts was also apparent for the 1993 estimate and resulted in a much wider confidence interval.

Differences in utilization by cutthroat trout by size category (1993 only) were most marked at Site 3 where an increase in sub-adult (200-290 mm) and adult (300-390 and 400+ mm) fish were observed (Fig.6). A slightly higher percentage of sub-adult and adult trout were also present at Site 1 however the size distribution was relatively unchanged at Site 2. The most noticeable difference in size distribution among whitefish was the added presence of fry at each of the three treatment locations (refer to Fig.6). This occurrence was most prominent at Site 1. The 100-190 mm size category displayed the greatest contrast in frequency between census periods at Site 3. With the exception of fry at the treatment location, Site 2 was little unchanged in size distribution for whitefish.

DISCUSSION

Stream positions occupied by salmonids have been shown to change in relation to body length where deeper and swifter habitats are selected as fish grow in size (Chapman and Bjornn 1969; Everest and Chapman 1972). The more profitable locations occur immediately adjacent to high velocity areas that provide a greater amount of invertebrate drift per unit time while simultaneously minimizing the energy costs of maintaining station (Fausch 1984). Where an appropriate ration of food has been provided experimentally, dispersal of cutthroat trout from micohabitats has been attributed to lack of suitable cover (Wilzbach 1985).

In the St. Mary River, in the absence of LWD or overhanging cover, adult westslope cutthroat trout position within riffle, glide or pool habitat units is restricted to areas of suitable depth (from 1.5 to 2 m) and overhead cover is largely provided by surface turbulence (Oliver 1994). As a consequence, trout distribution is often clumped and much of the available longitudinal profile and cross-sectional area of the habitat unit is vacant.

The placement of debris collectors within unutilized areas of glide habitat has demonstrated that previously vacant regions can become colonized by salmonids where existing velocities are sufficient to actively scour bed materials at high flow. The resultant change in channel morphology due to local velocity shears is considered beneficial by adding structural complexity to the stream and providing additional rearing sites to improve carrying capacity. While the information on channel modification is limited to essentially one of the six structures (Site 3), over a period of two freshet events, the preliminary data suggests that suitable habitat can be created by scouring segments of the streambed to a suitable depth along each side of the structure and depositing the finer sorted gravels immediately behind its downstream end. These changes in channel form may provide desirable features for cutthroat trout such as velocity refuges, visual isolation, and overhead cover whose importance has been experimentally demonstrated for juvenile steelhead trout (Fausch 1993).

A positive response by cutthroat trout was supported by a significant increase in the number of fish / ha following debris collector installation and a considerable increase in size at two of the three locations (Sites 1 and 3). Differences in relative abundance between Sites 1 and 3 may partially be explained by differences in angling regulations: whereas Site 1 and 2 have been designated "trout release", Site 3 is open to a 2 fish daily limit (> 30 cm) and thus lower estimates at both control and treatment locations at Site 3 may be due to angler harvest. The response by mountain whitefish was less clear in terms of numbers although a lower average velocity over the distance between each structure (eg. 0.43 $m.s^{-1}$ in 1991 vs 0.29 $m.s^{-1}$ in 1993; Site 3) following installation of the collectors appears to have favoured smaller size categories. The substantial drop in numbers of cutthroat and mountain whitefish between years at the Site 3 control location cannot be explained by angling alone. Differences in stage of flow between the two periods may explain some of this variation. There was a much higher mean monthly discharge (52.4 $m^3.s^{-1}$) in August 1991 compared to 1993 (32.1 $m^3.s^{-1}$; Water Survey of Canada, Wycliffe station 08NG012, file data, Cranbrook). This may have affected their distribution. Variation in discharge between census years was likely responsible for the high number of cutthroat trout enumerated at the Site 2 treatment location in 1991 prior to installation of the collector. The higher stage of flow caused adult trout to shift towards a mid-channel position away from the thalweg depth. This same area of channel was included in the 15 m wide pre-treatment underwater count and inflated the number of fish higher than would be expected at lower flows. A larger proportion of fish were again distributed along the deeper channel margin in 1993 (ie. adjacent to the thalweg and along the opposing streambank from the collector) and were enumerated as a result of the change in sampling method where the entire cross-section was surveyed.

Possible sources of error in this study include the experimental design and sampling procedure. Despite the use of within river replication, the selection of treatment sites separated over a minimum distance of 3 km can be considered independent replicates for the purpose of this investigation. The choice of control sites immediately adjacent to treatment locations however, cannot be considered independent. Mean differences between control and treatment sites estimated at a single point in time (August) and at two different periods (1991 and 1993) may bias the results due to the lack of spatial separation and chance movement of trout between adjacent habitat units.

Differences in sampling methods where 5 observers were deployed at 3 m intervals from one streambank in 1991 to 5 observers deployed across the entire channel width in 1993 may account for some of the variation between years. However, expansion of middle lane counts for cutthroat would not be expected to bias the 1993 results upward due to the higher proportion of sub-adult and adult fish in shore and near-shore lanes observed in previous studies (Oliver 1990). The need for whole-channel distribution of trout was identified after 1991 to determine if resident stocks were merely shifting position to improved habitat without a net increase in production; a problem identified in a related study (Slaney et al 1991). Population trend surveys conducted from 1984 to 1989 at the same locations has provided a knowledge of fish distribution within the same habitat units (Oliver 1990). Whole-channel counts were completed in 1993 to compare relative differences in fish distribution from earlier surveys to that after collector installation. It was the concensus of the same divers used over several years of observation that Site 3 was the only treatment area having fewer fish in expected locations following collector placement. Relative differences in distribution between years could not be detected at the other two sites. These results seem reasonable if in fact numbers of fish are reaching capacity under catch and release regulation (Sites 1 and 2) causing all available habitat to be utilized whereas re-distribution of fish to improved sites may simply be a function of under-recruited habitat (Site 3; kill zone). A more rigorous test of this assumption using the modified BACI design described by Stewart-Oaten et al (1986) in conjunction with whole-stream and site-specific underwater enumeration techniques are recommended to resolve this issue in future treatment applications. This procedure will also address the problem of pseudoreplication and account for variation due to random population fluctuation. A much larger scale evaluation incorporating a much larger number of collectors is also recommended.

Similar habitat manipulations for a variety of stream orders in British Columbia have been reported for several salmonid species (rainbow, coastal cutthroat, chinook and coho) with similar success (Slaney et al. 1991, Shirvell 1990, Ward and Slaney 1993). For example, 50 % of the woody debris structures placed in the Nechako River in north-central British Columbia and intended to increase the amount of rearing habitat for juvenile chinook, were colonized by resident rainbow trout averaging 2 fish per structure. The St. Mary River is the second B.C. river system with peaking flows in excess of 200 $m^3.s^{-1}$ where debris collectors have been installed and evaluated. Installations have been durable where collectors have been "seeded" and/or equipped with additional chain above and below the logs. Capital and installation costs totalling $1100 per structure make this an attractive technique where heavy equipment access is permitted. This cost will more likely increase to $1500 where steel pipe is included in material costs; rails used in this study were donated.

This investigation has shown that areas within habitat units normally viewed as unsuitable can be manipulated to increase the spatial variability within stream channels and increase carrying capacity. However, these types of structures will require further evaluation over a much longer period to determine longterm durability and success relative to hydrologic condition (Frissell and Nawa 1992). The anchor systems, considered most crucial to the longterm performance of these structures, are least likely to fail. If there is a need for V-log replacement, materials required to complete the design can be re-installed at minimal cost. Manipulations of this nature can be considered a relatively quick means of restoring structural complexity to stream environments degraded by previous developments. An emphasis on evaluation under a variety of stream conditions is further recommended to determine their overall utility in inland rivers.

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