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Interpretation of a Lichen Lower Limit on Streambanks

Abstract

The vertical zonation of vegetation on a streambank provides a record of the hydrologic conditions existing at that location. Using data from nine USGS stream gauge stations, this study assessed the correspondence between the lower distribution limit of the lichen Xanthoria elegans *and three stream discharge parameters: 1) peak flood discharge, 2) number of days submerged, and 3) date of exposure on receding of annual flooding. The lower limit did not correspond with mean peak flood discharge or number of days submerged. At stations where the lower limit occurred greater than 40 cm above mean low water, the* Xanthoria *lower limit corresponded best with the stream level occurring in late-June and may document a minimum growing season necessary for the establishment of* Xanthoria. *Ice may prevent the establishment of* Xanthoria *lower than 40 cm above mean low water. The lower limit of lichen growth has been used to interpret the legal boundary of high water along streambanks. The lower limit of* Xanthoria *in this study did not correspond with mean peak discharge or mean period of submergence and so, would be a poor indicator of high water level.*

Key words: growing season, peak flood, submergence, zonation, *Xanthoria elegans*

Introduction

It may sometimes be necessary to estimate the discharge characteristics of ungauged streams (Leopold and Skbitzke 1967). For example, ownership boundaries may be defined by stage height, such as mean low water and ordinary high water. Flood stage height may also influence the design of bridges, roads, and trails.

Channel cross-section morphology has been used as evidence of bankfull stage height on ungauged streams (Riley 1972, Knighton 1984). The lower limit of mosses, lichens, herbs, and forbs has also been cited as evidence of flood stage (Leopold and Skbitzke 1967, Idaho Supreme Court 1978-1979).

Lichens on rocks along streambanks often grow in vertical zones (Hale 1967, Rosentreter 1984, 1992). The occurrence of *Dermatocarpon reticulatum* Magn. corresponded with mean high water, while *Verrucaria* spp. occurred below low water (Rosentreter 1992). The lower limit of the lichen *Parmelia conspersa* (Ehrh. ex Ach.) Ach. corresponded with a flood recurrence interval ranging from 1.14 - 1.37 years (Gregory 1976). The vertical zonation of lichen communities implies that different lichen species record different discharge parameter .

Along some stream segments in northwest Wyoming and southwest Montana, *Xanthoria elegans* (Link) Th. Fr. forms a conspicuous orange band on bedrock and large boulders close to stream level. Within local reaches, the *Xanthoria* zone is truncated at a uniform elevation above low water level, thus suggesting a correspondence with some stream stage height.

The purpose of this study was to determine how stream discharge controls the lower limit of *Xanthoria*. I tested for correspondence between the

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Xanthoria lower limit and three parameters: 1) mean peak discharge, 2) number of days submerged, and 3) date of exposure on receding of the annual flood.

Methods

I made observations at nine U.S. Geological Survey stream gauge stations in northwest Wyoming and southwest Montana (Table 1). At each station, I used a level to determine the height of the *Xanthoria* lower limit relative to the station's staff gauge (hereafter referred to as the "*Xanthoria* staff gauge height"). The *Xanthoria* staff gauge height was used to locate the lower limit with respect to minimum and maximum stream discharge levels.

Using the minimum daily discharge for each year of record (U.S. Department of the Interior 1963 - 1993), I calculated the mean minimum discharge for each station. From respective rating curves, I determined the elevation of the *Xanthoria* lower limit above mean low water.

Using the peak daily discharge for each year of record, I calculated a mean peak annual discharge for each station (D_{peak}). From respective rating curves, I determined the discharge that corresponded with the *Xanthoria* staff gauge height measured at each station (D_{Xanth}). Where the *Xanthoria* lower limit corresponded with mean peak annual discharge, $D_{peak} - D_{Xanth}$ would equal zero. For each station, I tested for that condition by t-test ($P < 0.05$).

From inspection of annual discharge records (U.S. Department of the Interior 1963 - 1993), I determined the number of days each year that flow exceeded the discharge indicated by the respective station's *Xanthoria* staff gauge height. Log transformation of the data failed to make the variances homogeneous. By Kruskal-Wallis ANOVA I tested the hypothesis that *Xanthoria* was submerged an equal number of days at all stations.

I similarly determined the mean Julian day at which discharge fell below that indicated by the *Xanthoria* staff gauge height at a given station. By ANOVA I tested the hypothesis that *Xanthoria* was exposed on the same day at each station. A post hoc comparison between gauge stations was made by Tukey honest significant difference for unequal sample size.

Results and Discussion

The vertical distribution of *Xanthoria* at Shields River and Soda Butte Creek was different from that at other

Table 1. *Gauge stations. YNP is Yellowstone National Park. N describes the number of years for which there were data during the period 1963-1993. Station numbers correspond with USGS gauge station description (Department of the Interior 1963-1993).*

Station name and location	Station number	N	Mean peak discharge (cms)	Mean minimum discharge (cms)	Figure labels
Big Creek near Emigrant, MT	06191800	7	11.3 ± 1.5	0.5 ± 0.0	BC
Gallatin River near Gallatin Gateway, MT	06043500	26	143.0 + 8.1	7.2 ± 0.3	GL
Gardner River near Mammoth, YNP	06191000	19	33.8 ± 2.3	2.1 ± 0.1	GR
Gibbon River near West Yellowstone, MT	06037000	7	17.7 ± 2.9	1.9 ± 0.0	GB
Lamar River near Tower Falls Ranger Station, YNP	06188000	12	218.3 ± 9.7	2.1 ± 0.2	LA
Shields River near Livingston, MT	06195600	15	60.1 ± 8.1	1.6 ± 0.1	SH
Soda Butte Creek near Lamar Ranger Station, YNP	06187950	5	33.2 ± 2.3	0.4 ± 0.0	SB
Yellowstone River at Corwin Springs	06191500	31	479.5 ± 21.7	18.7 ± 0.8	YC
Yellowstone River near Livingston, MT	06192500	31	564.1 ± 27.6	26.5 ± 1.1	YL

locations. Similar to other locations, cover percent diminished from about 50% to near zero over a vertical distance of a few centimeters. At other locations, *Xanthoria* was absent below this point. But at Shields River and Soda Butte Creek, scattered thalli occurred downward an additional 0.7 and 0.6 m, respectively, suggesting that colonization has occurred in response to fluvial adjustment. If, at the time of this study, *Xanthoria* had not fully colonized down to the new lower limit, then the *Xanthoria* staff gauge heights measured at Shields River and Soda Butte Creek would be higher than the true (future) lower limit gauge heights.

The *Xanthoria* lower limit ranged from 0.40 to 1.89 m above mean low water (Fig. 1). The lower limit occurred at a greater elevation at stations with high magnitude of seasonal fluctuation in discharge (see Table 1 for discharge comparisons).

The difference between peak discharge and the discharge corresponding to the *Xanthoria* gauge height (i.e., $D_{peak} - D_{Xanth}$) ranged from -0.2 to 176 m^3s^{-1} (Fig. 2). At five of the stations I rejected the hypothesis that $D_{peak} - D_{Xanth} = 0.0$ ($P < 0.05$). The variability between stations suggests that the *Xanthoria* lower limit is not an accurate indicator of mean peak flood stage height.

The mean periods of submergence ranged from 1 to 38 days (Fig. 3). I rejected the hypothesis that *Xanthoria* was submerged an equal number of days at all stations ($H = 61.7$; $P < 0.0001$). The variability between stations suggests that period of submersion is not a significant factor determining the lower limit elevation above stream level.

The mean date of exposure on receding of flood water ranged from Julian day 142 (May 22) to Julian day

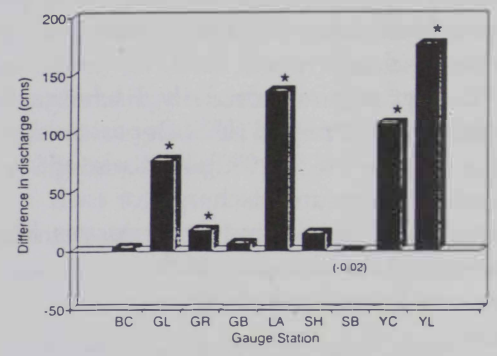

Figure 2. *The difference between mean peak discharge and the discharge indicated by the stage height at the Xanthoria lower limit. An asterisk denotes stations in which by t-test the difference did not equal 0.0 at P < 0.05.*

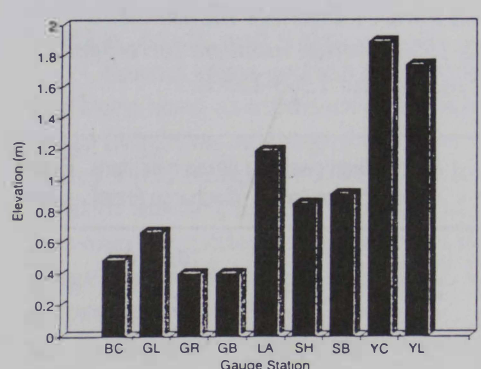

Figure 1. *Elevation of the Xanthoria lower limit above mean low water. Figure labels and sample sizes are described in Table 1.*

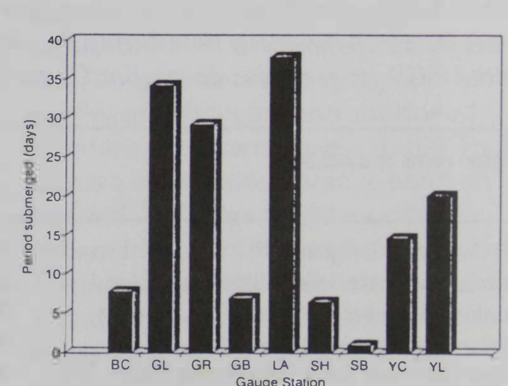

Figure 3. *The mean annual period of submergence of the Xanthoria lower limit differed between stations (P < 0.0001).*

181 (June 30; Fig. 4). I rejected the hypothesis that *Xanthoria* was exposed on the same day at all stations (N = 9, *P* < 0.001). At eight of the stations, the mean date of exposure did not significantly differ (*P* < 0.05). At these stations, exposure date ranged from Julian day 156 (June 5) to Julian day 181 (June 30).

Among that group of eight stations, Shields River and Soda Butte Creek had the earliest dates of exposure (Julian day 165 and 156, respectively). If the gauge height of the *Xanthoria* lower limit was overestimated at those stations (due to incomplete colonization), exposure of the future (true) lower limit would occur later than the dates presently indicated. At the remaining six stations, the mean dates of exposure were within six days of one another (Julian day 175 - 181).

The absence of lichens below a lower limit could be produced by: 1) the removal of established lichens by floods, or 2) the inability of lichens to colonize closer to stream level. Gregory (1979) reported that the lichen limit of *Parmelia* spp. represented discharge levels that were exceeded at least once per year and that some four to five annual inundations would result in lichen removal. Gregory appears to attribute

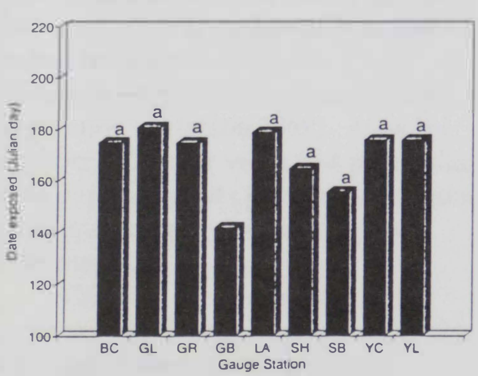

Figure 4. *Mean Julian day on which floods receded below* <u>*Xanthoria*</u> *lower limit. Stations with similar lowercase letters did not differ at P < 0.05.*

the development of the lower limit primarily to lichen removal.

My study suggests that lichen removal plays a minor role in the development of the *Xanthoria* lower limit. Among the 9 gauging stations, the mean period of lichen submergence at the lower limit varied from 1-38 days. If lichen removal was the dominant factor for lower limit development, one would expect less variability between sites.

My study suggests that the *Xanthoria* lower limit may form primarily due to an inability to colonize lower than a certain elevation above stream level. Of the three parameters investigated, mean date of exposure on receding flood was most consistent between stations. I speculate that *Xanthoria* may be limited by a minimum length of a warm-temperature growing season. Based on the similarity of dates from six stations and the potential for incomplete colonization at Shields River and Soda Butte Creek, late June may mark the beginning of a critical period for *Xanthoria* growing close to stream level.

With an exposure date of Julian day 142 and no evidence of colonization, Gibbon River is anomalous to other sites. To be consistent with an exposure date ranging from Julian day 175 - 181, *Xanthoria* at Gibbon River would have to grow closer to mean low water stage than the 40 cm that was measured. I speculate that colonization closer to mean low water may be limited by ice formation.

In combination with other evidence, the lower limit of lichen growth has been used to legally interpret the elevation of "ordinary high water" (Idaho Supreme Court 1978-1979). But my study indicates that the *Xanthoria* lower limit would be a poor high water indicator. Among the 9 study sites, there was considerable variation between the lichen lower limit and both mean peak discharge and mean period of submergence.

The *Xanthoria* lower limit provides a benchmark for documenting changes in stream discharge and channel morphology. Within local reaches, the uniformity of the lower limit elevation above stream level is evidence that the lower limit forms in response to some stream discharge characteristic. I speculate that length of growing season is the responsible factor. Colonization below the lower limit is easily detected and is evidence of a change in stream condition.

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