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The Zonation of Mosses and Lichens Along the Salmon River in Idaho

Abstract

Communities of mosses and lichens below high water mark on the Salmon River in Idaho are viewed as distinct associations. These zones may be as much as several meters in depth. Based on the species present and on fluctuating water levels, four zones are found. Results from paired transects indicate that stability of the substrate, force of the current, and distance above the low water level determine species dominance. Compared to the headwaters, the lower reaches of the river have more favorable conditions for growth of mosses and lichens and for development of zonation patterns.

The Salmon River is unique because it is the largest river in the western United States that does not have regulatory dams. Its headwaters are protected by Wilderness and Wild and Scenic River designations. The Salmon River originates in the granitic Idaho Batholith in central Idaho, and the lower section flows over basalt. The zonation described in this paper occurs on both granite and basalt along the course of the river.

Lichens and other forms of vegetation can be used for flood frequency analysis and for calculating river channel capacity (Gregory 1976). Lichens may also be useful in water quality studies (Hawksworth 1974). The zonation of plants along a river can be used for the prediction of discharge from channel geometry at ungauged sites (Gregory 1976). Furthermore, absence of lichens from suitable habitats may indicate river channel disturbance or modification.

Crytogam zonations along streams have been reported by Hale (1950), Glime (1970), Pentecost (1977), and Craw (1976). These zones were no broader than 10 cm per zone and less than 40 cm total (Craw 1976). In comparison, zonation along the Salmon River is higher and therefore more significant for use in management. Since the Salmon River fluctuates as much as several meters in depth, these broad zones may be useful indicators of flood frequency and flood levels (Fig. 1).

The purpose of this study is to describe the lichen and moss associations found along the Salmon River and to relate differences in species composition to hydraulic characteristics of the channel and to substrate stability. Also of interest is the way in which plant associations changed over the river's course.

Study Area

The study area included the Main and the Middle Fork of the Salmon River, Idaho, USA. The Middle Fork was studied from Dagger Falls (1767 m) downstream to its confluence with the North Fork of the Salmon. The main Salmon River was studied from its confluence with the Middle Fork to its mouth at the Snake River (335 m).

Spring snowmelt in the mountainous headwaters results in maximum flows, and

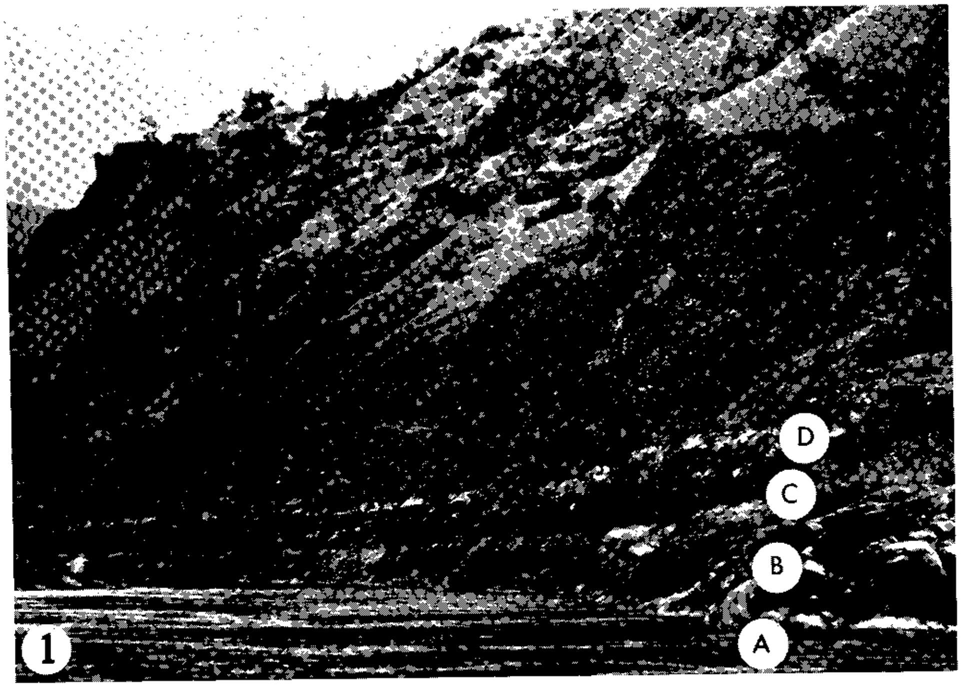

Figure 1. An overview of vegetation zones on the lower reaches of the Salmon River in Idaho: A. Low Water Zone; B. Normal Flood Zone; C. High Flood Zone; D. Extreme Flood Zone.

minimum flows occur in winter (December). Measurements for Whitebird, Idaho (lower main Salmon) are as follows: 64 year average discharge, 320 m^3/sec (11,290 cfs); maximum recorded discharge 3,680 m^3/sec (130,000 cfs) 17 June 1974; minimum recorded discharge, 44.7 m^3/sec (1,580 cfs) 11 December 1932 (U.S. Geological Survey 1976).

The topography of the study area varies from steep hills to a narrow canyon with vertical walls. The river channel is usually controlled by bedrock and thus is narrow and rarely meanders.

The surrounding vegetation varies from mesic forests in the upper reaches and on north-facing slopes to xeric grasslands in the lower reaches and on south-facing slopes. The forest habitat types are in the *Pseudotsuga menziesii* (Douglas fir) and *Pinus ponderosa* (Ponderosa pine) series (Steele *et al.* 1981). Shrub steppe communities occur on steep open slopes and rocky areas; these include *Artemisia, Purshia,* and *Cercocarpus. Amelanchier, Rhus, Alnus,* and *Populus* are the riparian shrubs and trees in the side draws and drainages. The grasslands have the potential to support *Agropyron spicatum* (Bluebunch wheatgrass) and *Festuca* (fescue) habitat type series (Tisdale 1979).

Methods

Sampling consisted of ten paired transects at intervals of approximately 70 km along the course of the river. Paired transects allowed comparison of species responses to

Figure 2. Effect of current force in the normal flood zone on the Salmon River in Idaho: A. The upstream side of the rocks which receive the stronger current are covered by *Dermatocarpon reticulatum*; B. The protected eddy side of the rocks are covered by *Scouleria aquatica.*

hydraulic conditions unaltered by elevation or by other changing environmental conditions along the river's length. At each site, individual transects were selected to include variation in stream hydraulic conditions. For example, a transect pair might have one transect in a direct current and a second transect at the same rapid on a similar rock type but in an eddy current. River rocks that were altered by man, with a known disturbance date, were noted but were not used for transect sites.

Sampling was done in a low water period, allowing easy access to seasonally flooded areas. Line transects ran perpendicular to the shoreline from water level through the high flood level, as marked by the occurrence of strictly terrestrial vegetation. For each decimeter point along the transect line, species presence was recorded. The intervals between points were narrow enough to detect such small-scale topographic changes as the top or side of a small boulder.

At each decimeter point on the transects, the following data were recorded: 1) location in the current, 2) rock type, 3) degree of siltation, 4) percent slope, and 5) species. Species that occurred in fewer than four transects are not reported here, nor are occasional vascular plants occurring beneath sample points. Instead, the nearest non-vascular species were recorded if they were present within 1 dm^2. Percent cover was calculated by species presence at sampled dm points over the total dm points in a transect.

Species of *Verrucaria* were not separated in the sampling. *Barbula rubiginosa* and

Grimmia montana are often difficult to destinguish in the field without sporophytes, and flood waters physically batter the leaf awns, so they were counted together in the transect data.

Nomenclature of lichens and mosses follows lists of Hale and Culberson (1970) and Crum *et al.* (1973). Nomenclature of vascular plants follows that of Hitchcock and Cronquist (1973). Voucher specimens for the cryptogams are at MONTU.

Photographs were taken at various sites along the river. Since these may be useful for comparison in further studies of the area, 18 of the photographs are on file at the Idaho Historical Society Library, Boise, Idaho.

Results and Discussion

The results from transect pairs placed in contrasting current forces indicate the importance of current to community composition (Fig. 2 and Table 1). As current force

TABLE 1. The average percent frequency (with 95% confidence interval) of species in the normal flood zone from 10 paired transects contrasting stream hydraulic conditions.

	Transects in Strong Current	Transects in Weak Current
Scouleria aquatica	9.7% ± 7.3	89.6% ± 9.5
Dermatocarpon reticulatum	28.7% ± 10.4	9.4% ± 9.6
Verrucaria spp.	40.0% ± 10.1	0.0% ± 0.0
Bare rock (no species present)	21.5% ± 14.2	1.2% ± 0.9

decreases, species dominance shifts from *Verrucaria* spp. to *Dermatocarpon reticulatum* and finally to *Scouleria aquatica.*

Several distinct zones of vegetation corresponding to recurrent flood patterns were found along the Salmon River: low water zone, normal flood zone, high flood zone, and extreme high flood zone. The characteristic species in each zone are as follows (Fig. 4):

1. Low water zone—*Verrucaria* spp. and algae.
2. Normal flood zone—*Dermatocarpon reticulatum* or *Scouleria aquatica.*
3. High flood zone—*Barbula rubiginosa* and *Grimmia montana.*
4. Extreme high flood zone—barren of vegetation or occupied by terrestrial vegetation.

For vascular plants associated with seasonal flooding along the Salmon River see Appendix A.

Irregular and recurrent disturbances are a part of many climax communities; for example, fires are a part of some climax Ponderosa pine communities (Steele *et al.* 1981). The moss and lichen zones are apparently adapted to and maintained by different flood frequencies and durations. These communities do not appear to be successional states leading to other vegetation types, nor do they accumulate soil. Two old photographs from the early 1900s (60-52.869 and 60-175.19 in the Idaho Historical Society Library) show the presence of these vegetational zones, proving their prolonged existence.

Zones on smooth vertical walls were distinct at a resolution of 1 dm. However, zones on broken topography did not have distinct divisions. These irregularities can be explained by physical configuration and are comparable to the vegetational zones

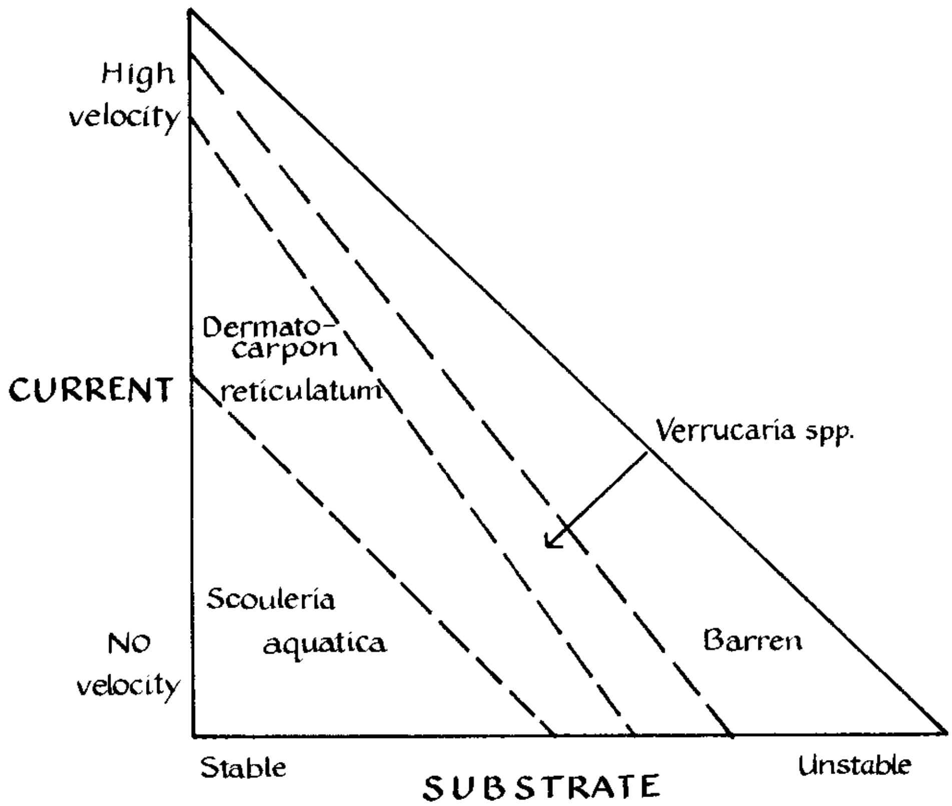

Figure 3. Hypothetical model for the effect of current velocity and substrate stability in controlling species composition in the normal flood zone.

found on a mountainside with broken topography. Sampling at decimeter intervals recorded irregularities that caused some noise in the zonation patterns; a larger sampling interval might avoid this. Nevertheless, what appears as noise in the results may be explained at a finer level of analysis as substrate stability, orientation of microsites to the current, and sheltering by other rocks.

Low Water Zone

The low water zone containing *Verrucaria* spp., crustose lichens, was poorly sampled in transects because much of the zone was submerged. *Verrucaria* is adapted to and occurs on submerged rocks in many regions of the world (Swinscow 1968).

Normal Flood Zone

The normal flow zone contained *Dermatocarpon reticulatum*, an umbilicate lichen, and *Scouleria aquatica*, a moss. Species dominance is apparently determined by substrate stability, current force, and height above the water level.

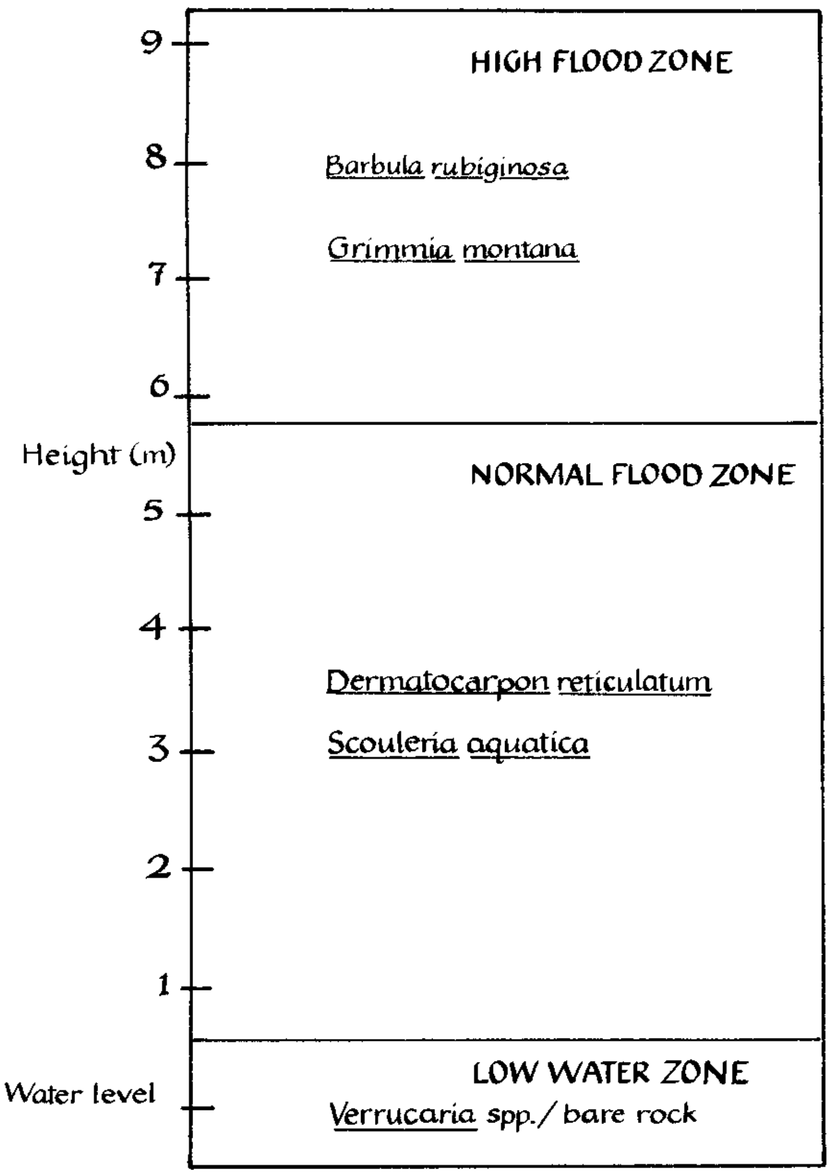

Figure 4. Species composition within zones and actual heights (= 1 dm) of each zone taken from the average of two eddy transects at Telcher Creek on the lower reaches of the Salmon River in Idaho.

Sites with increasingly stable substrate had a higher proportion of *S. aquatica,* less of *D. reticulatum,* and least of *Verrucaria* spp. (Fig. 3). Unstable substrates were often in the same location as strong current; in such cases the factors controlling the vegetation were not clearly distinguishable. An unstable substrate may be a soft, easily eroded rock type (Swinscow 1968) or a hard rock type that moves as part of the bed load. River banks must contain stable rock material to support a moss or lichen flora ("a rolling stone gathers no moss"). Bed load formulae (Hebertson 1969, Einstein 1950) are based on the principle that the capacity of the stream to transport sediment along its bed varies directly with the difference between the shear stress acting on the bed particles and the critical shear stress required for initiation of particle motion. The bed load is related to the amount of water, the stream's profile, and the hydraulic gradient; therefore, the greater the bed load capacity, the larger the rock which can be transported (U.S. Bureau of Reclamation 1973).

Colonization by aquatic lichens is slow (Swinscow 1968). For example, large boulders (1 m^3), which were moved in 1930 for road construction, show no moss or lichen flora colonization now, although a rich flora is adjacent to the boulders.

Current velocity controls the vegetational distribution in several ways. Increased current velocity is directly related to an increased ability to carry greater suspended loads. The type, size, speed, and amount of the suspended load in a river appears to determine distribution of mosses and lichens in its channel. For example, the Grand Canyon of the Colorado River carries large amounts of course sand and silt in its suspended load and has no moss or lichen flora (personal observation), whereas a river such as the Salmon, with a moderate suspended load, can support an aquatic moss and lichen flora.

The structure of the river channel creates differences in current force and, in consequence, differences in species dominance. Results from the transect pairs indicate that, as current increased, the vegetation became structuraly more compact and tougher in texture. Transects located in stronger currents consistenly contained *D. reticulatum,* which has a more compact growth habit and is apparently tough-textured, rather than the soft-textured *S. aquatica* (Fig. 2 and Table 1). Compact growth habits were less susceptible to destruction by hydraulic pressure. The textural difference may reflect selection by the abrasive forces. The less abrasive the forces occurring at a site, the softer the texture of the species than can occupy these sites. Therefore, the force of current, size, speed, and amount of sediment load within a river's cross-section determines the species composition at any given site.

High Flood Zone

The high flood zone contained two mosses, *Barbula rubiginosa* and *Grimmia montana.* This zone occurs along the river's course more consistently than any other zone. Height above mean water level was the only factor that appeared to relate to the high flood zone. Given a long period without a high flood, terrestrial vegetation probably could temporarily invade this zone.

Extreme High Flood Zone

The extreme high flood zone is an area that usually supports terrestrial vegetation. In 1974, an extremely high flood occurred which clearly marks this zone (Fig. 1). At present, this zone is predominantly barren of vegetation. The aquatic mosses and lichens in the other three flood zones are strongly attached to the rock substrate. Therefore, these species resisted the destructive hydraulic and abrasive forces of the extreme high flood, whereas terrestrial species were dislodged. The age of terrestrial species present in the extreme high flood zone could be used to date the occurrence of the last previous extreme high flood (Gregory 1976).

Patterns of presence and absence of vegetation suggest conditions required for the survival of aquatic moss and lichen communities. These requirements are a stable substrate, lack of strong abrasive forces, fluctuating water levels, and high dissolved carbon dioxide levels (Ruttner 1963, Gessner 1950).

The Salmon River is ideally suited for an aquatic moss and lichen flora zonation. Much of the stream channel is composed of solid stable bedrock or large stable boulders; the abrasive forces are moderate and decrease in areas not in the direct current; the Salmon is undammed and naturally exhibits a large recurrent seasonal fluctuation; and it is rapid throughout its length, which results in an abundant supply of dissolved carbon dioxide. Mosses are unable to photosynthesize using only bicarbonate ions as a carbon source (Ruttner 1963, Hynes 1970). Therefore, they are confined to water where there is an adequate supply of dissolved carbon dioxide. Rapids also protect streamside vegetation by restricting destructive winter ice floes to the midstream.

Comparison of Zonation between Headwaters and Lower Reaches

The headwaters had an average total height ($\pm$ 95 percent confidence interval) of streamside lichen and moss zones of 1.9 m ($\pm$ .3 m), compared to that of over 8.0 m ($\pm$ 1.1 m) for the lower reaches. Headwater transects had an average of only 80 percent ($\pm$ 32) cover compared to 99 percent ($\pm$ 2) cover in the lower reaches.

These differences may be explained as follows. First, the headwaters have a more open canyon topography with less stable rocks. The river gradient is steeper and thus the suspended load can be of a larger size and speed than in the lower reaches. Flooding of the headwaters is of short duration because of the small size and narrow elevational range of its drainage. By comparison, the lower reaches of the river drain a much larger area and a broader elevational range, resulting in more frequent floods of longer duration. The aquatic moss and lichen flora in the lower reaches is therefore consistentliy flooded for a longer period of time than those in the headwater reaches.

Since the climate is wetter in the upper reaches, there are more seepage areas that are not dependent on flooding for moisture. In comparison, the lack of moisture in the xeric climate of the lower reaches makes more of the flora dependent upon flooding. These differences may account in part for the greater development of zonation patterns in the lower reaches.

Information from this study could be used in several ways. The *Barbula*-high flood zone could be used as an indicator of channel capacity and of high flood level at unguaged sites. At any given site and date, the water level could be compared to the vegetational zones, thereby evaluating the flood state. The frequency of high flood that determines the *Barbula*-high flood zone could, in a future study, be calculated by correlating the *Barbula* level to flood levels at a gauged site. Species composition at any given site could tell us about the stability of that substrate and the force of the current at that site.

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Literature Cited

Craw, R. C. 1976. Streamside bryophyte zonations. New Zealand Journal of Botany 14: 19-28.

Crum, H. A., W. C. Steere, and L. E. Anderson. 1973. A new list of mosses of North America north of Mexico. The Bryologist 76: 85-130.

Einstein, H. A. 1950. The Bedload Functions for Sediment Transportation in Open Channel Flows. USDA Soil Conservation Service Technical Bulletin No. 1026.

Gessner, F. 1950. Die okologische Bedeutung der Stromungscheindigkeit Fliessender Gewasser und ihre Messung auf Kleinstem Raum. Archivs für Hydrobiologie 43: 159-165.

Glime, J. M. 1970. Zonation of bryophytes in the headwaters of a New Hampshire stream. Rhodora 72: 276-279.

Gregory, K. L. 1976. Lichens and determination of river channel capacity. Earth Surface Process 1: 273-285.

Hale, M. E. 1950. The lichens of Aton forest, Connecticut. The Bryologist 53: 181-213.

———, and W. L. Culberson. 1970. A fourth checklist of the lichens of the continental United States and Canada. The Bryologist 73: 499-543.

Hawksworth, D. L. 1979. Lichens and indicators of environmental changes. Environmental Change 6: 380-386.

Hebertson, J. G. 1969. A critical review of conventional bed load formulae. Journal of Hydrology 8: 1-26.

Hitchcock, C. L., and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle.

Hynes, H. B. N. 1970. The Ecology of Running Waters. University of Toronto Press, Toronto, Canada.

Pentecost, A. 1977. A comparison of two mountain streams in Gwynedd. Lichenologist 9: 107-111.

Ruttner, F. 1963. Fundamentals of Limnology. University of Toronto Press, Toronto, Canada (English transl.).

Steele, R., R. D. Pfister, R. A. Ryker, and J. A. Kittams. 1981. Forest Habitat Types of Central Idaho. Intermountain Forest and Range Experiment Station Technical Report INT-114, Ogden, Utah.

Swinscow, T. D. V. 1968. Pyrenocarpus lichens: thirteen freshwater species of *Verrucaria* in the British Isles. Lichenologist 4: 34-54.

Tisdale, E. W. 1979. A Preliminary Classification of Snake River Canyon Grasslands in Idaho. Forest Wildlife and Range Experiment Station Notes No. 32, Moscow, Idaho.

United States Bureau of Reclamation. 1973. Design of Small Dams. A Water Resource Technical Publication, Second Edition.

United States Geological Survey. 1976. Water Resources Data for Idaho Water Year 1975. Water Data Report, ID-75, National Technical Information Service, Springfield, Virginia.

Appendix A

Vascular plants associated with seasonal flooding along the Salmon River.

Genus Species	Common Name	Common Site
Corydallis caseana	Corydalis	(headwaters only) silt
Dodecatheon jeffreyi	shooting star	(headwaters only) silt
Artemisia lindleyana	riverbank woodworm	rock or sandy areas
Aster hesperius	willow aster	rocky silted areas
Equisetum variegatum	variegated horsetail	water seeps (partial shade)
E. arvense	field horsetail	water seeps
E. hyemale	common horsetail	water seeps
Juncus spp.	rush	water seeps
Eleocharis spp.	spike-rush	standing water
Salix sp.	willow	variable
Carex nudata	torrent sedge	in silt
Elymus innovatus	riverbank wildrye	rocky silted areas
Mentha spp.	mint	variable
Rhus trilobata	poison ivy	disturbed and variable
Melilotus officinalis	yellow sweet clover	variable
Glycyrrhiza lepidota	licorice-root	(lower reaches) sand
Chrysopsis villosa	golden hairy aster	rounded river rocks
Tanacetum vulgaris	tansey	(lower reaches) deep silt
Conyza canadensis	horseweed	dry

Panicum scribnerianum	scribner witchgrass	water seeps
Bromus tectorum	cheatgrass	variable to dry sites
Chenopodium boytres	feather geranium	(lower reaches) sand
Apocynum androsaemifolium	dogbane	rocky, sand/silt areas
Celtis reticulata	hackberry	(lower reaches) variable
Zanthium strumarium	cocklebur	(lower reaches) sand

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