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WATER QUALITY MONITORING PROTOCOLS - REPORT 3

MONITORING STREAM SUBSTRATE STABILITY, POOL VOLUMES, AND HABITAT DIVERSITY

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INTRODUCTION

On a regional scale in Idaho, there are basically two major stream types that are clearly differentiated on factors limiting fish abundance: Stream/riparian systems dominated by forest overstory, and those dominated by grass/shrub riparian vegetation. Forest canopy dominated streams occur primarily in mountain settings in Idaho and occur generally on gradients greater than 1.5 percent, while grass/shrub streams occur in intermontane valleys, mountain meadows, and plains and are graded generally less than 1.5 percent.

As indicated by Kozel and Hubert (1989b), Moore and Gregory (1989), and Klamt (1976), salmonid production in forested mountain streams is limited primarily by habitat structure. Such streams generally occur on gradients greater than 1.5 percent. Physical habitat diversity seems to be the key to fish production because in steeper gradient streams, resting areas and refugia are physically limited. Fish abundance is often related to overhead bank cover, the numbers and complexity of pools, backwater eddies, runs and glides, amount of large woody debris, and sediment accumulation (Kozel and Hubert 1989a; Moore and Gregory 1989). In some cases, canopy closure is limiting primary production and availability of drifting prey due to lack of light energy penetration in these forest streams (Wilzbach 1989). At the pre-emergent stage, sediment accumulations affect embryo survival, because the deposits coincide with low-energy sites used by spawning fish. At rearing stages, sediment accumulations also affect habitat quality in low-energy sites such as pools. Pool filling and de-stabilization as a result of sedimentation of the substrate can alter habitat structure and diversity important to fish (Lisle 1987). The subject of fine sediment effects on salmonids is summarized for the Northern Rocky Mountains in Idaho by Chapman and McLeod (1987).

Protocols for the effects of sediment on habitat are contained in: Water Quality Monitoring Protocols Report numbers 1, and 2 (IDHW, DEQ 1990/91) which address sediment impacts to salmonid incubation, and intercobble living space. In addition, an excellent method for monitoring habitat structure and diversity and fish abundance is according to the basin-wide technique developed by Hankin and Reeves (1988).

I. CHANNEL BED STABILITY AND POOL DIVERSITY

Change in channel bed elevation is a useful indicator of the overall channel adjustments created by increasing sediment load. Evidence for the loss of pool/riffle morphology from stream channel aggradation has been documented (Lisle, 1982). Thalweg profile surveys can be used to measure bed elevations and monitor changes in bed morhpology.

The ability to detect pool/riffle contrasts within the channel and the diminishments of habitat diversity over periods of increasing aggradation provides a means of measuring beneficial use impairment in streams used for rearing salmonids. The thalweg profile technique provides a sensitive measure of pool quality and pool/riffle composition within the stream channel.

A review of the literature by Chapman and McLeod (1987) covering effects of sediment on salmonids in the Northern Rockies Ecoregion indicates that in high-gradient streams, adult salmonids tend to lie in pools that are sand-silt depositional areas. A study by Hunt (1969) showed that increases in pool volume and average stream depth, and a reduction in substrate fines significantly benefited adult salmonids in Wisconsin.

Chapman and McLeod concluded that: "Loss of pool volume due to sediment deposition reduces suitability of a stream for adult salmonids."

The rod and level thalweg profile procedure:

Reach identification:

A reach of stream, preferably representative of a longer section of stream is chosen for the profile measurements. The stream reach length is equal to, at minimum, 20 times the full channel width.

Reaches are intended to represent single geomorphic stream types as classified according to Rosgen, 1987. Single geomorphic stream types represented by the study reach may be further subdivided as influenced by any of the following:

- channelization
- riparian vegetation removal
- diversion and flow control
- any development activity affecting the morphology of the channel

(Field data form is shown in Appendix I)

Profile survey:

A rod and level survey is conducted on the longitudinal profile of the stream bed. The survey steps are as follows:

1 Locate the leveling instrument in fixed position (as with a tripod) at any position in the stream (often near mid-channel)

2 Select a location at random between 0 and 20 feet downstream of the instrument.

3 At the selected location, read the elevation of the channel bed at the deepest point in the channel cross section (or on the thalweg)

4 At this same location, read the bankfull elevation of the channel on the bank which provides the best bankfull level recognition

5 Also at this location, measure the width of the channel at the bankful eleveation

6 To select the next sampling location, use breaks in bed topography along the thalweg to measure the profile proceeding upstream, therefore: locate, progressively upstream, stations at pool tail-outs, pool bottoms, and pool entrances. Measure the distance to each measurement point from the begining station.

6 At each measurement station, repeat steps 3 to 5

7 Continue the survey of transects until it is no longer possible to site the surveying rod from the instrument station.

8 At the last possible siting of the survey rod, hold the rod in position on the thalweg. Move the instrument to a new location upstream of the survey rod. Re-read the elevation on the rod in its held position. This facilitates adjusting all profile elevations to a common datum.

9 Measure at all pool tail-outs, pool bottoms and entrances and other major topographic breaks along the channel thalweg within a reach equal to or greater than 20 times the bankful width.

The rapid thalweg profile procedure:

The rapid method follows exactly the steps listed above, only a rod and level are not used. All that is needed is a surveying rod and measuring tape to measure channel depths and widths. All water depths are read directly at the thalweg location in the channel. Bankful water width is measured directly at bankful indicators as in the rod and level approach. Bankful water depth is estimated. Readings are made at all pool tail-outs, pool bottoms, and pool entrences. Record all data on the Rapid Thalweg Profile Data form (Appendix I).

Measuring pool/riffle quality:

Thalweg profiles allow the measurement of several key variables. Reach gradient, total length of pools and riffles, the residual thalweg depth, and total thalweg depth.

Reach gradient is simply the total elevation change along the thalweg of the reach divided by the total length of the reach. It is expressed in percent slope. Reach gradient is used to varify that channels used in comparison (reference reaches) have similar energy gradients.

The total length of pools is calculated by summing over individual pools measured in the survey. Pools are defined by segments in the profile where elevation differences between stations are negative in the upstream direction.

The total length of riffles is calculated by summing over individual riffles measured in the survey. Riffles are defined by segments in the profile where elevation differences between stations are positive in the upstream direction.

The residual thalweg pool depth is the maximum pool depth when streamflow equals 0.

Total depth is the average channel depth at bankfull streamflow.

The residual pool index:

An excellent index of pool quality is the residual pool depth index. It is calculated by dividing the average depth of thalweg pools by the total depth as defined above. The index is a sensitive measure of pool quality within the channel. As pools fill and bed morphology looses diversity, this index approaches zero. These are typically aggradational channels. Streams with highly variable bed morphology (more frequent, deep pools and numerous riffles in between) are represented by index values around 10. These are typically degradational channels.

II. OVERALL HABITAT DIVERSITY

Habitat diversity appears to be an important factor limiting production of salmonids in Forested mountain streams. Moore and Gregory(1988) found greater abundance of rainbow trout in stream reaches having ample habitat structure and complex channel morhology in Cascade mountain streams. With increasing stream gradient, vital pool habitat types become increasingly limited in total volume. Populations of fish may be limited by the total quantity of this habitat requisite (Fraley and Shepard 1989). Gorman and Karr (1978) related stream habitat complexity to fish species diversity. They found that as habitat complexity increases, fish diversity and abundance also increases. They found that habitat diversity generally increased with increasing stream order. Low order streams tend to be those with steeper gradients, and shallower depths. They tend to favor smaller, younger fish. Larger streams with steep gradients also favor smaller, younger fish when pool quantity is limiting.

A habitat diversity index has been developed to assess the relative composition of various critical habitat units. Total habitat area of each unit is estimated along the entire stream reach using a technique developed by Hankin and Reeves (1988). Visual estimates of habitat areas are made for all habitat units in the stream. Visual estimates are calibrated to accurate measures of the habitat units made at some number of even intervals of habitat units along the length of the stream. Thus sample-based estimates are made so that all habitat units can be quantified without making detailed, time-consuming measurements of all units.

Habitat diversity - steps

1. The observer proceeds along the length of the stream channel and delineates macro habitat unit types on a map. The map can be made from color photo enlargements of aerial photography. A mylar overlay facilitates sketching the channel and recognizable features useful to identifying locations in the field.

2. Visually estimate the water widths of the following habitat types:

    a. Riffle: A portion of the stream where water flows swiftly over completely or partially submerged obstructions to produce surface agitation.

    b. Run/glide: A portion of the stream with moderate to swift velocity and without surface agitation (i.e. displays laminar or near laminar flow patterns).

    c. Pool: A portion of the stream with reduced current velocity (i.e. average velocity is generally less than 1 foot per second), and often (but not always) with water deeper than surrounding areas. Pools usually have flat water surfaces with no surface agitation.

    d. Shallows and side channel: A portion of the stream where side channels leave or enter the main channel, and shallow (border) areas used by young fish.

3. At every kth (where k is equal to any value from 5 to 10) habitat unit in the stream reach, after estimating the width visually, measure the width of that unit accurately.

4. Record the total length of the habitat unit from the map of the channel, and multiply the length of each unit by its corresponding width to determine habitat area. Total the visual estimates made in step 3 for each habitat type. This value (total area) is called "T".

5. Total all measured estimates made in step 2 for each habitat type. This value (total measured area) is called "Q".

6. Calculate the ratio: $M = Q/T$ for each habitat type.

7. Use the ratio in step 5 to calibrate visual estimates made for each of the habitat types. Sum the total visual estimate for each habitat type. Multiply the sum by the value of M. Record the result as calibrated total habitat area for that habitat type.

The diversity index is determined simply by calculating the variance on the mean of areas for all habitat types. Thus if;

a = total area of riffles, b = total area of glides, c = total area of pools, and d= total area of side channels, the mean is: $m = (a + b + c + d)/4$

and the variance (S^2) on the mean is:

$$S^2 = (|a-m| + |b-m| + |c-m| + |d-m|)/4$$

As the calculated variance increases, diversity decreases. Thus the diversity index is calculated as the difference from the mean divided by the mean or:

$$D = (m - S^2)/m \times 100$$

In this manner, diversity becomes a function of the even distribution of representative habitats and is expressed in percent of the mean. A more sophisticated diversity index can also be derived from the inverse variance on additional habitat types incorporating the combinations of various pool type identifiers.

REFERENCES

Chapman, D. W. and K. P. McLeod. 1987. Development of Criteria for Fine Sediment in the Northern Rockies Ecoregion. Final Report, Work Assignment 2-73, EPA Contract No. 68-01-6986.

Fraley, J. J. and B. B. Shepard. 1989. Life history, ecology and population status of migratory bull trout (Salvelinus confluentus) in the Flathead Lake and river system, Montana. Northwest Science, Vol. 63, No. 4. pp 133-143.

Gorman, O. T. and J. R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59(3). pp 507-515.

Hankin, D.G., and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. Journal Fish. Aquat. Sci. 45:834-844.

Hunt, R. L. 1969. Effects of habitat alteration on production, standing crops and yield of brook trout in Lawrence Creek, Wisconsin.

IDHW, Division of Environmental Quality. 1990. Water Quality Monitoring Protocols - Report No. 1. Protocols for Assessment of Dissolved Oxygen Fine Sediment and Salmonid Embryo Survival in an Artificial Redd. 25pp.

IDHW, Division of Environmental Quality. In press. Water Quality Monitoring Protocols - Report No. 2. Estimating intergravel salmonid living space using the cobble embeddedness sampling procedure. 20pp.

Klamt, R.R. 1976. The effects of coarse granitic sediment on distribution and abundance of salmonids in the central Idaho batholith. M.S. thesis, University of Idaho, Moscow, ID.

Kozel, S.J. and W.A. Hubert. 1989a. Factors influencing the abundance of brook trout (Salvelinus fontinalis) in forested mountain streams. Journal Fresh. Ecology, 5(1):113-122.

Kozel, S.J. and W.A. Hubert. 1989b. Testing of habitat assessment models for small trout streams in the Medicine Bow National Forest, Wyoming. North American Journal of Fisheries Management 9:458-464.

Kozel, S.J., W.A. Hubert, and M.G. Parsons. 1989. Habitat features and trout abundance relative to gradient in some Wyoming streams. Northwest Science, 63(4):175-182.

Lanka, R.P., W.A. Hubert, and T.A. Wesche. 1987. Relations of geomorphology to stream habitat and trout standing stock in small Rocky Mountain streams. Transactions of the American Fisheries Society 116:21-28.

Lisle, T. E. 1982. Effects of aggradation and degradation on riffle-pool morphology in natural gravel channels, northwestern California. Water Resources Research 18: 1643-1651.

Lisle, T. E. 1987. Using "Residual depths" to monitor pool depths independently of discharge. USDA Forest Service. Pacific Southwest Forest and Range Experiment Station. Research Note PSW-394.

Marcus, M.D., M.K. Young, L.E. Noel, and B.A. Mullan. 1990. Salmonid-habitat relationships in the western United States. Gen. Tech. Rep, RM-188. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 84p.

Moore M.S. and S.V. Gregory. 1989. Geomorphic and riparian influences on the distribution and abundance of salmonids in a Cascade mountain stream. USDA Forest Service Gen. Tech. Rep. PSW-110.

Sullivan, K., T.E. Lisle, A.C. Dolloff, and others, 1987. Stream channels: The link between forests and fishes. In: E.O. Salo and T.W. Cundy, editors. Streamside management: Forestry and fishery interactions. University of Washington, Seattle, WA. pp 40-97.

Wilzbach, M.A. 1989. How tight is the linkage between trees and trout? USDA Forest Service Gen. Tech. Rep. PSW-110.

Wolman, M.G. 1954. A method of sampling coarse river-bed material: American Geophysical Union Transactions, 35: 951-956.

APPENDIX I

Field data forms

ROD AND LEVEL THALWEG PROFILE

STREAM NAME: ______________________ DATE: ______________

INVESTIGATORS: ______________________ ELEVATION OF DATUM: ______________

ROD READING OF DATUM: ______________ LOCATION DESCRIPTION: ______________

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Transect #	Distance from start (Ft)	Bankful Width (Ft)	Bankful rod reading (Ft)	Thalweg rod reading (Ft)	Backsite readings (Ft)	Pool Bottom ? (y/n)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

Comments: ____

RAPID THALWEG PROFILE

STREAM NAME: ______________________ DATE: ______________

INVESTIGATORS: ______________________

LOCATIONDESCRIPTION: ______________________

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Station #	Distance from start (Ft)	Bankful Width (Ft)	Bankful depth (Ft)	Thalweg water depth (Ft)	Notes	Pool Bottom ? (y/n)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

Comments: ______________________

HABITAT DIVERSITY INDEX

STREAM NAME: ______________________ DATE: ______________________

INVESTIGATORS: ______________________ STREAM REACH DESCRIPTION: ______________________

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HABITAT UNIT #:												
(V) visual or (M) measured:												
Length of unit (ft):												
Habitat type:												
Canopy density %:												
Dominant substrate type:												
Pool complexity index:												
Mean water depth (ft):												
Mean water width (ft):												
Mean bankful depth (ft):												
Mean bankful width (ft):												
Embeddedness estimate %:												
Dominant bank stability type:												
Percent undercut bank:												
Percent overhanging veg:												
TOTALS BY UNIT:												