94 TFW-WQ20-96-001

TYPE 4 & 5 WATERS WORKSHOP PROCEEDINGS

TIMBER FISH & WILDLIFE

October 16, 1996

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PRESENTATION SUMMARIES

Timber Fish & Wildlife
Cooperative Monitoring Evaluation and Research

Type 4 & 5 Waters Workshop

Discussing processes in-situ and downstream and how these waters are influenced by forest practices

Wednesday, October 16, 1996
NMFS Sandpoint Facility, Seattle

Conference Agenda:

8:00	Registration		
8:30	Welcome and introduction	*Jim Rochelle*	*Chair, CMER Committee*
WATER QUALITY			
8:45	Flow and Temperature	*Susan Bolton & Jenelle Black*	*University of Washington*
9:45	Sediments	*Matt O'Connor*	*O'Connor Environmental. Inc.*
10:15 - 10:45	**Break**		
10:45	Nutrients / Large Woody Debris	*Robert Bilby*	*Weyerhaeuser Co.*
11:15 - 12:15	**Water Quality Panel**		
12:15 -1:15	**Lunch** (on your own—food service available on site)		
HABITAT			
1:15	Wildlife and Amphibians	*Kathryn Kelsey*	*University of Washington*
2:15	Invertebrates	*Robert Plotnikoff*	*WA Department of Ecology*
2:45 - 3:00	**Break**		
3:00	Fish	*Jeff Cederholm*	*WA Department of Natural Resources*
3:30 - 4:30	**Habitat Panel**		
4:30 - 5:00	Summary & Wrap up	*Peter Bisson*	*US Forest Service*

Please share this with other interested people in your area, region, or division

CONFERENCE REGISTRATION

Advanced registration required. Space is limited. Registration deadline October 4, 1996
CONFERENCE FEE: $10

Please make checks payable to: *WFPA (Washington Forest Protection Association)*
Please mail to : *Type 4 & 5 Streams Workshop / WFPA*
711 S Capitol Way, Suite 608
Olympia, WA 98501

TFW TYPE 4 AND 5 WORKSHOP

STREAM FLOW AND TEMPERATURE

SUSAN BOLTON
AND
JENELLE BLACK

UNIVERSITY OF WASHINGTON
COLLEGE OF FOREST RESOURCES

OCTOBER 16, 1996

ABSTRACT

This document summarizes current knowledge about flow and temperature in small forested headwater streams (as defined by Washington State Forest Practices) and the effects of land management on them. The water flow and temperature processes occurring in these streams are described, and the functions they serve in the ecosystem are discussed. Literature on flows and temperatures in small streams and on how management impacts them is reviewed. Issues regarding stream processes and management impacts which are considered important but which have not been addressed are noted. The implications of this review in terms of policy-making are discussed.

Stream Sources and Temperatures

(Pilot Study)

Jenelle Black and Susan Bolton
University of Washington
College of Forest Resources

with funding from Olympic Natural Resources Center

Abstract:

This study addresses the lack of information about flows and temperatures in headwater stream sources and how they might affect downstream water conditions. Mid-summer stream source locations, types, discharges and temperatures are monitored and described. The low-flow, high-temperature conditions are sought. This information is collected and will be compared for pre- and post-harvest conditions and for harvested and paired unharvested streams. Some preliminary observations are presented.

TYPE 4 AND 5 WORKSHOP

Topic: **Sediment Production, Transport and Routing**

Presenter: **Matt O'Connor**

Key Messages:

- Type 4 and 5 waters often function as zones of accumulation and episodic scour in regions where there is significant, frequent, shallow rapid mass wasting. This takes place in both managed and unmanaged systems, but at sharply higher rates in managed systems.
- Large wood in the stream creates sediment storage that slows the net rate of delivery downstream.
- Sediment is also delivered to these channels by small-scale streamside mass wasting, soil creep, and bank or bed erosion.
- Boulders, cobbles, banks, roots and woody debris create complex flow patterns and provide significant flow resistance; these obstructions create eddies where stream energy is low during peak flows, and sediment can be temporarily stored.
- Wood appears to be a significant sediment-storage element in Type 4 streams.
- In the absence of significant large-scale mass wasting, the primary process of sediment production is creep of soil from hillslopes into channels. These processes include bank erosion, windthrow of rootwads, burrowing by rodents, and small-scale streamside mass wasting.
- Channel morphology (roughness, including woody debris) and local hydrology determine the rate at which sediment entering channels from hillslopes is routed downstream to fish-bearing water.
- Fluvial erosion and transport of mass wasting deposits from Type 4 & 5 channels is likely to be significant.
- In the absence of significant mass wasting, sediment production and delivery from Type 4 & 5 channels is likely the primary source of sediment for fish-bearing waters, excluding bank erosion processes in fish-bearing streams.

Implications:

- Gradual loss of wood dams results in a net increase in sediment yield corresponding to the gradual release of sediment from storage.
- Sediment entering type 4/5 streams lacking woody debris will be more rapidly delivered to fish-bearing streams.
- In the case of erodible beds and banks, it is possible that the long-term loss of wood could result in channel incision and oversteepening of hillslope toes, creating conditions for long-term increases in sediment production.

Information Gaps

- Rates of recruitment of wood, dam frequency, and processes of formation and failure of dams are not well-quantified.
- Data for Eastern Washington Type 4 & 5 streams is virtually non-existent.

Large Woody Debris in Type 4 and 5 Streams: Abundance, Distribution, Function and Relationship to Forest Management

Bob Bilby, Weyerhaeuser Company

Key messages: Woody debris

Characteristics of woody debris in small streams:

- more abundant than in larger streams
- average piece size is less than in larger channels
- is transported infrequently
- is typically not clumped in distribution
- vary regionally

Functions of woody debris in small streams:

- creation of habitat heterogeneity
- sediment retention
- organic matter storage
- nutrient storage and transformation
- thermal influence-causes subsurface flow-cools water

Sources of woody debris in small streams:

- primary source is from streamside forest stand
- input of stable debris occurs more rapidly, i.e. from younger forests, in small than large streams, but higher decay rates of small wood affects overall in-stream levels
- decay rates vary with tree species

Management implications:

- sediment is delivered downstream more rapidly in streams lacking woody debris
- loss of wood after source is removed occurs slowly;
- non-replacement will affect sediment movement rates.
- young forests can serve as a source of stable debris; but will not supply the large pieces that have greater influence on channel form and function than small pieces.
- considerations for maintenance of woody debris levels in small streams
- include source, size and rates of input and loss.

Information needs:

- better understanding of streamside vegetation dynamics,
- influence of varying debris levels on sediment export and rates of release and form of organic matter.
- improved understanding of contribution of wood from type 4/5 streams to fish-bearing waters.
- (principally by mass failure)

Wildlife Use of Riparian and Stream Habitat in Washington State

Kathyrn Kelsey, University of Washington

Key messages: Wildlife and amphibians:

Most of the information presented was from TFW studies - type 3 streams and is preliminary.

West-side forests - riparian and upland forests are similar; wildlife species composition and abundance don't differ dramatically.
West-side - changes in relative abundance occurred after harvest of adjacent uplands; 2 bird species no longer present, 11 "edge" species appeared. All species of mammals present in both riparian and upland forests.
West-side - bat activity higher in riparian than upland forests; higher activity in uplands after clearcutting.
East-side of Cascades - riparian and upland forests differ from each other more than on the west side; diversity and abundance of mammals are higher in riparian forests; bird diversity and abundance are greater in upland forests.
East-side - riparian bird communities changed following clearcut harvest of adjacent uplands.
East-side - numbers of amphibians and reptiles captured overall were low; amphibian captures were higher in riparian areas, reptiles captures were higher in upland areas, respectively.

Literature reports some amphibian (tailed frog, Dunn's, southern torrent) densities and biomass lower in managed than unmanaged forests. Pacific giant salamander densities not different in forested and buffered type 4 streams - western Washington.
Low sediment loads, coarse rock substrates, in-stream wood, unharvested condition associated with higher densities of stream-breeding amphibians.

Management implications:

Riparian and upland communities of bats, breeding birds, small mammals and terrestrial salamanders are similar - transition between riparian and upland habitats is not a barrier.
Some stream-breeding amphibians appear to be negatively affected by forest management practices which increase sediment loads and reduce levels of woody debris.
Measures to reduce sediment loads and protect habitat complexity and diversity in small streams would benefit stream-breeding amphibians.
No-entry buffer strips suggested as measures to maintain stream integrity - shading, bank stability, and as sources of woody debris - but significant problem with windthrow in areas studied.

Information needs:

Experimentation to examine alternative buffer configurations; other approaches to habitat protection. Site-specific flexibility is important in coming up with protective measures that benefit both landowners and natural resources.

Topic: Aquatic Invertebrates in Type 4 & 5 Streams

Presenter: R .W. Plotnikoff
Washington State Department of Ecology

Key Messages:

- Distinct and sometimes diverse invertebrate assemblages are found in small, headwater streams.
- A major source of nutrient introduced into headwater streams originates from the riparian canopy.
- The headwater shredder- and collector-gatherer functional feeding groups are key processors of organics used by the downstream biotic community.
- Physical features of the headwater stream channel, especially those on a microhabitat scale, appear to be influential to the invertebrate assemblage.
- Current research describes detectable biotic change following some forest practice activities in headwater streams. The understanding of mechanisms that instill biotic change, however, is incomplete.

Implications/Observations:

- Biological assemblages in disturbed channels become less diverse and do not immediately recover.
- Reduction of riparian canopy along some headwater streams has resulted in reduction of macroinvertebrate biomass and activity.
- Disruption of the invertebrate assemblage in Type 4 & 5 streams results in an effective loss of one food source for downstream communities. The potential for productive downstream communities is reduced from inefficient use of available food in the headwaters.
- Destabilization of streambanks that result in considerable erosion raises sediment concentrations in the stream. Significant downstream drift has been measured in the aquatic invertebrate assemblage following active sedimentation.
- Restructuring of the biotic assemblage occurs over longer time periods and is a function of: 1) severity of the initial disturbance, and 2) the return to pre-disturbance physical conditions. Long-term monitoring for effects of forest practice activity on stream biota can discern natural from anthropogenic changes. Key physical features that change drainage or channel hydrology and result in biotic adjustment requires more intensive investigation.

Topic - Use of a Case Study (The Response of a Cutthroat Trout Population to a Logging Road Caused Debris Torrent Event in Octopus-B Creek) to Demonstrate the Effects of Debris Torrents in Type 4 and 5 Waters on Fish-bearing Waters Downstream

Presenter - Jeff Cederholm, Washington Department of Natural Resources

Key Messages

- Type 4 and 5 waters are the source of many important physical and biological factors that support downstream salmonid populations, including 1) water, 2) nutrients, 3) wood, 4) gravel, and 5) aquatic insects.
- The scouring that results from headwater debris torrents can result in reductions or loss of fish production or populations in downstream habitats.
- The cutthroat population in a stream reach downstream of the torrent was nearly eliminated immediately post-slide, recovering to only 50% of the pre-torrent population over the 13 year study period.
- The torrent resulted in a 34% decrease in total water surface, and a 76% reduction of pools >.35 m., which contributed in large measure to the lack of fish population recovery.
- Certain resident salmonid populations are often at great risk to overall impacts of debris torrents; they may spend their entire life within a limited reach of stream.
- Fish population recovery in fish bearing waters subjected to debris torrents is likely to be dependent on habitat recovery, requiring the input of new large wood. Where the riparian forest has been impacted, it may take >50 years prior to input of woody debris to the channel.

Implications

Logging and roading operations in headwater areas of type 4 and 5 waters can result in significant long-term impacts to downstream fish-bearing waters. These impacts can reduce or eliminate fish production capability, and may place resident fish populations that spend their entire life within a limited reach of stream highly vulnerable to even a single event such as a debris torrent. When operating in or near headwater streams, it is imperative to avoid potential on-site effects as well as potential downstream effects.

Summary and Wrap Up

Peter Bisson
10/16/96

I. Classification

- Current classification system does not appear to be working very well.
  - ◊ Size criteria (<2 ft) may be in error on many maps.
  - ◊ Fish presence/absence appears to be in widespread error; no obvious reason.
  - ◊ Classification system does not reflect either changes on importance of ecological function.
- Ecological functions in headwater streams are important. The inputs, storage, sediments & organic matter processing functions appear to vary considerably regionally.

II. Management activities have altered these ecological functions

- Increased the rate of "large disturbances"
- Accelerated erosion - primarily road related
- Loss of large woody debris has significantly altered sediment and organic matter storage and processing
- Some aspects of functional groups of aquatic invertebrates shift.
- Physical habitat diversity (e.g., LWD piece size change width riparian stand structure) may be reduced
- Diversity of animals in stream and riparian zones appears to be down for most major groups, with possible exception of birds, which represent greater abundance of upland species.

III. Buffers and Large Woody Debris (LWD) on small streams can make a difference

- Temperature changes tend to be short-term and can be ameliorated by slash and release of understory vegetation.
- LWD is very important for controlling the morphological and sediment/organic matter storage.
- Some very large pieces seem to be important for creating sediment terraces.
- LWD forms habitat for certain types of animals; e.g. some aquatic insects, tailed frog larvae.
- Buffers provide certain types of organic matter inputs that are not generated by understory vegetation.
- It is not entirely clear what buffer configuration most effectively ameliorates anthropogenic changes.
- Single tree width buffers appear to be prone to rapid initial changes.
- It would be very helpful to establish pilot-scale headwater buffer experiments involving no buffer, thin buffer, wide buffer, and patch buffer treatments.

PRESENTATIONS

TFW TYPE 4 AND 5 WORKSHOP

STREAM FLOW AND TEMPERATURE

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This document summarizes current knowledge about flow and temperature in small forested headwater streams (as defined by Washington State Forest Practices) and the effects of land management on them. The water flow and temperature processes occurring in these streams are described, and the functions they serve in the ecosystem are discussed. Literature on flows and temperatures in small streams and on how management impacts them is reviewed. Issues regarding stream processes and management impacts which are considered important but which have not been addressed are noted. The implications of this review in terms of policy-making are discussed.

TOPICS TO BE ADDRESSED

- What is known - Literature Review
- Processes and Functions
- Problems, Information, Gaps, Management Impacts
- Resource Implications and Policy Recommendations
- East vs. West Side Issues

WHAT ARE TYPE 4 AND 5 STREAMS?

(from Washington Forest Practices Rules, 1995)

- Small Headwater Streams
- No Significant Fish Populations
- No Developed Water Supply
- < 5-10 Feet Wide at High Water
- Minimum Low Flow < 0.3 cfs (0.009m^3/s)
- No Required Riparian Buffer Strip
- Some Regulations on Skidding across Streams and Protecting Streams from Road Sediment Inputs
- Less protection from forest chemicals

LITERATURE REVIEW

Streamflow

- Freeze (1972) - Groundwater important to flow maintenance in headwaters
- Where does flow come from?
  - Seeps
  - Springs
  - Channel interception of groundwater (shallow or deep)?
- Topography a major factor in storm response
- Headwaters Tend To Be :
  - Small
  - Steep
  - Flashy
  - Coarse-grained
  - Episodic in sediment transport

Temperature

- TFW Reports (Sullivan et al., 1990 and Caldwell et al., 1991)
  - 8 streams in Western Washington
  - T ranged from 13.5 - 23.1 C
  - Q much less than 0.3 cfs (.009 m^3/s)
  - Factors affecting temperature
    - Shading levels
    - Groundwater temperature
    - Percent flow as ground water
    - Elevation
  - Conclusions
    - Higher than expected shade levels due to slash
    - Minimal influence on downstream temperature
    - Highly responsive to local conditions
    - No anticipated cumulative effects
  - Limitations of TFW Study
    - Few sites
    - Many different zones
    - Mediocre model performance

- Hostetler (1991)
  - Temperature recovery slow if high harvest levels

- Sinokrot and Stefan (1993,1994)
  - Conduction important in shallow streams for hourly but not avg. temperature
  - conduction can be same order of magnitude as ET and convection

- Constanz et al. (1994)
  - Temperature affects hydraulic conductivity and therefore flow

- Hatten and Conrad (1995)
  - Olympic Peninsula, 11 low-elevation streams
  - Percent late seral important temperature predictor
  - Shade and elevation less so
    - Supports Beschta and Taylor (1988)

PROBLEM AREAS

Science

- Where does water come from?
- Where does heat come from?
- Does harvest increase groundwater temperature? (Hewlett and Fortson 1982)
- Are RMZ's effective on Types 1-3? (Rashin & Graber 1992)
- Reliability of current models for small shallow streams?
- Cumulative effects?

Management

- Accuracy of stream typing
- Personnel not available to update mistypes
- Compliance

PROCESSES AND FUNCTIONS

- Type 4 and 5 streams can be 80-90% of river system in large basins

- Riparian functions affected by alteration to Type 4 and 5 channels

  - Hydrologic cycle components
  - Storm flow timing and volume
  - Overall water yield and water sources
  - Water quality due to flow path changes
  - Pollutant and sediment filters
  - Shade and temperature (aquatic and terrestrial)
  - Nutrient inputs
  - Habitat diversity and habitat corridors
  - Bank stabilization
  - LWD contributions to channel
  - Catastrophic event buffers

- Temperature

  - Dissolved oxygen
  - Biotic composition
  - Pathogen development
  - Metabolic processes
  - Growth of aquatic organisms
  - Hydraulic conductivity

RESOURCE IMPLICATIONS AND POLICY RECOMMENDATIONS

- Objectives of regulations must be clearly defined
- Possible objectives
  - harvest levels
  - slope stability
  - habitat - for what species - aquatic or terrestrial
  - temperature
  - other water quality parameters
  - flow regimes
- How interact with other activities
  - Habitat Conservation Plans (HCP)
  - Watershed Analysis

EAST SIDE VS. WEST SIDE

- Few east side data
- Canopy probably less dense
- Radiation levels higher

REFERENCES

Beschta, R.L. and R.L. Taylor, 1988. "Stream Temperature Increases and Land Use in a Forested Oregon Watershed." *Water Resources Bulletin*, 24(1):19-25, February, 1988.

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Stream Sources and Temperatures

(Pilot Study)

Jenelle Black and Susan Bolton
University of Washington
College of Forest Resources

with funding from Olympic Natural Resources Center

Abstract:

This study addresses the lack of information about flows and temperatures in headwater stream sources and how they might affect downstream water conditions. Mid-summer stream source locations, types, discharges and temperatures are monitored and described. The low-flow, high-temperature conditions are sought. This information is collected and will be compared for pre- and post-harvest conditions and for harvested and paired unharvested streams. Some preliminary observations are presented.

Objective: Investigate stream sources during low-flow, peak-temperature conditions.

- source type
- source water temperature
- spatial features of streams and topography
- stream flow and temperature
- effects of harvesting on sources

Approach:

- clearcuts with immature regeneration compared to similar mature forest units
- old, mature forest units compared before and after harvesting.

Method:

- map and describe first appearance of water down the channel
- measure flow rate, temperature, channel characteristics, and shading; describe channel and topography
- compare this information among stations, among different study sites, and between before and after

Sites

- all streams studied originate on unit and flow into Type 3 or greater streams
- most units have logging road around the top of the unit.
- two types of sites:

  paired mature & immature regen

  mature before & after harvest

<u>paired immature and mature drainages in the Hoh Valley</u>

- 30-acre sub-basins, 1600' to 2800' elev.
- steep streams (70%)
- hemlock, fir and cedar
- extremely unstable slopes with thin rocky soils
- dendritic stream pattern
- harvested units cut in the late 1980's

<u>mature forested sites slated for harvest in the next year</u>

- moderately-sloped mature forests to be harvested by the summer, 1997
- 10 to 50 acre units, **500' to 700'** elev.
- hemlock, fir, cedar, and alder
- slopes from **10%** to **40%**
- moderately deep soils
- streams tend to be unbranched and flow into larger stream at bottom of unit

Preliminary Observations

- most forested sources begin in wetland area
    - most of these wetlands in heel of earth slump or failure
- harvested sites drier, thinner-soiled, less marshy area; spring source areas small (springs)
- springs observed in sides of incised channels
    - may appear due to channel interception of subsurface flow
    - subsurface flow localizations may have caused channel formation
- flows dispersed and difficult to measure;
    - Q in headwaters from 0.001 to 0.1 cfs [0.02 - 3 l/s]
    - confident my method gives good idea of Q
    - within sampling std. dev. = 5% to 10% vs. between sampling differences of >20%
- stream water often goes subsurface
    - debris piles in stream
    - stream flattens and flow seeps into ground
- spring temperatures very cool, remain constant
- wetland source temperatures tend to follow Tair
- temperatures generally increased downstream
- streams protected by slash remained cooler than streams under forest shade
- amphibians seen in forested sites, none in clearcuts

Future Work

- more pre-harvest sites
- post-harvest of this year's sites
- early deployment of recording instruments
- more dataloggers
- check measured temperatures versus model predictions

Acknowledgments

- Olympic Natural Resources Center
- Washington State Dept. of Natural Resources
- Rayonier - Northwest Forest Resources
- Hoh Nation

SEDIMENT PRODUCTION, TRANSPORT AND ROUTING

Matt O'Connor, O'Connor Environmental, Inc.

Type 4 & 5 Waters Workshop
October 16, 1996, National Marine Fisheries Service Sandpoint Facility, Seattle, Washington
Timber Fish & Wildlife, Cooperative Monitoring Evaluation and Research

CURRENT STATE OF KNOWLEDGE: AN OVERVIEW

Definition

Type 4 channels are waters not classified as Type 1, 2 or 3 having width > 2 ft (0.6 m) between ordinary high water marks (OWHM). Type 5 channels, defined as "...streams with or without well-defined channels, areas of perennial or intermittent seepage, ponds, natural sinks, and drainageways having short periods of spring or storm runoff." (WAC 222-16-030(5)).

Extent

Type 4 & 5 streams comprise a watershed's headwaters and account for about two-thirds or more of the length of the stream channel network. They range in slope from around 4% to over 50%, and encompass a wide range of channel morphology. Type 4 streams often have characteristics of Type 3 channels, lacking only a salmonid population. In other cases, Type 4 streams may be steep bedrock cascades that extend upslope to within about 100 m of ridgetops. In western Washington, Type 5 streams are often so small as to have no obvious topographic expression, and are therefore frequently difficult to accurately map. In eastern Washington, Type 5 streams are mapped in obvious convergent topography, but field investigation may reveal that no channel is present.

Geomorphology

For these type of headwater streams, there is a hierarchy of process and function that is controlled by hillslope geomorphology. In regions where there is significant, frequent shallow rapid mass wasting on steep slopes in or near the head of channel networks that sometimes transform into debris flows, Type 4 and 5 waters function as zones of accumulation and episodic scour. Any given stream reach in such areas have some finite probability of being severely disturbed by debris flow deposition and/or scour at a frequency ranging from several decades to several centuries or more. Mass wasting and soil creep are the main sources of sediment entering these channels.
The scale of material (sediment and wood) transport of these events is much larger than that of streamflow-driven transport. Over the long-term, debris flow probably accounts for about 70% of sediment transport and fluvial processes accounts for the remaining 30% (O'Connor 1994).

Runoff in these areas tends to be driven by long-duration rainstorms, with high peak flows. There are typically 2 to 4 bedload-transporting flow events per year. Sediment transport capacity is greater than sediment supply, so the routing of sediment downstream is a functions of sediment supply rather than capacity (i.e. supply-limited). Large wood in the stream creates sediment storage that slows the net rate of delivery downstream..

channels by small-scale streamside mass wasting, soil creep, and bank or bed erosion. Runoff in these areas may be driven by rain and/or snow-melt. Near the Cascade crest, stream flow is flashy and influenced by rain-on-snow. In this region, the routing of sediment is likely to be supply-limited. Farther east, spring snow melt is the dominant source of runoff, and peak flows from year to year vary less than in the warmer, wetter regions of the Cascades. In these areas, there is a higher likelihood that sediment routing is controlled by transport capacity (annual streamflow). In addition, sediment delivery to the channel network is expected to be significantly less because of a generally lower rate of mass wasting.

Sediment Transport Capacity

Type 4 & 5 channels are capable of transporting surprisingly large quantities and sizes of sediment, comparable to that of alluvial mainstem streams. Field investigations in the northwest Olympics showed that sediment finer than about 1-2 mm is quickly routed downstream as suspended load. Sediment coarser than 1-2 mm and finer than about 128 mm is transported as bedload. Sediment in the bedload fraction is equally-mobile; tracer studies showed that there was no systematic difference in transport distance as a function of particle size (tracer size range was 20 - 120 mm). Coarser material (boulders) is mobile, but is not likely to be routed out of the Type 4 & 5 channel network by fluvial processes (O'Connor 1994).

Suspended load is typically 3 to 4 times greater than bedload. Observed and model sediment yields from these types of channels are on the order of 10 to 100 t/km^2/yr. Sediment yield from these headwater channels is usually roughly equivalent to the average watershed erosion rate. The model for fluvial sediment transport in the northwest Olympics predicted sediment transport capacity for bedload to be about 3 to 50 times greater than sediment supply. This result suggests that fluvial transport of sediment delivered to channels by mass wasting is rapid in this region, and may be limited only by the depth of deposition and the concentration of particles coarser than about 128 mm. It is likely that this conclusion can be extrapolated to upland areas throughout western Washington.

PROCESSES & FUNCTIONS: ROLE IN A FORESTED LANDSCAPE AND IN RELATION TO DOWNSTREAM FISH-BEARING WATERS

Channel Hydraulics, Roughness, and Sediment Storage

Type 4 & 5 channels are headwaters, collecting subsurface flow from hillslopes and allowing for rapid open-channel conveyance of water and sediment. Steep slopes and confined channels typically concentrate the energy of the flowing water on the channel bed; flows generally do not spread onto floodplains in this portion of the network. The capacity to transport sediment is proportional to the product of flow depth and bed slope. The high depth-slope product (dominated by slope in Type 4 & 5 channels) is compensated by the high degree of roughness in these channels. Boulders, cobbles, banks, roots and woody debris create complex flow patterns and provide significant flow resistance.

Despite high roughness, the very steep slope generates high bed shear stresses during peak flows, creating a tendency to erode sediment from the channel bed. Flow obstructions create eddies where sediment can effectively hide from the flow, and be temporarily stored. Dams formed by woody debris are semi-permanent sediment storage reservoirs, hiding sediment from erosive flow while the debris dam remains in place.

Role of Woody Debris in Sediment Storage

Wood appears to be a significant sediment-storage element in Type 4 streams. This tends to be true because of the high transport capacity and the role of wood in "hiding" sediment from the flow. A typical debris dams in the western Olympics is sufficient to store about 2 years of sediment produced by creep processes along 1 km (0.6 mi) of channel (O'Connor 1994). Wood dams stored about half of observed sediment storage in Type 4 channels in the South Fork Skokomish watershed (unpublished data).

In smaller Type 5 streams, stream channels may become spatially discontinuous, or may have insufficient flow to transport any but the finest sediment size classes. In these settings the role of wood may diminish. However, if wood has accumulated in channels over the long-term, it may serve to provide structure for a matrix of potentially-erodible sediment. This may be an element of the process by which colluvium creeping from hillslopes fills hollows that may be episodically evacuated by mass wasting processes.

Linkage Between Hillslopes and the Channel Network

The high proportion of total stream channel network in Type 4& 5 waters is evidence that these headwaters constitute the primary linkages in a watershed between hillslopes and streams. Sediment eroded from most watersheds is generated primarily in headwaters and routed downstream. In the absence of significant large-scale mass wasting, the primary process of sediment production is creep of soil from hillslopes into channels. Creep processes include bank erosion, windthrow of rootwads, burrowing by rodents, and small-scale streamside mass wasting. The transfer of hillslope material to the channel by these processes occurs at low intensity over large areas and over long periods of time. Once delivered to a channel, fluvial processes become the primary means of routing in the absence of debris flow.

Sediment Routing and Significance to Fish-bearing Streams

Channel morphology (roughness, including woody debris) and local hydrology (annual precipitation, runoff regime, and watershed area) determine the rate at which sediment entering channels from hillslopes are routed downstream to fish-bearing water. A model for sediment routing in the northwest Olympics for Type 4 channels with varying numbers of woody debris dams computed residence times of bedload sediment in a 1 km^2 model watershed. With abundant wood dams, median residence time (average transit time through the Type 4 channel network) ranged from about 70 to 150 years. With a more typical frequency of wood dams, residence time ranged from about 40 to 80 years.

The importance of sediment production in and delivery of sediment from Type 4 & 5 waters to fish-bearing waters depends on watershed hydrology and geomorphology. In areas where large-scale mass wasting by debris flow is common, sediment delivery by fluvial processes may be of secondary importance to fish-bearing streams. On the other hand, fluvial erosion and transport of mass wasting deposits in Type 4 & 5 channels is likely to be significant. In the absence of significant mass wasting, sediment production (inputs via hillslope soil creep processes) and delivery from Type 4 & 5 channels are likely the primary source of sediment for fish-bearing waters, excluding bank erosion processes in fish-bearing streams.

POTENTIAL MANAGEMENT EFFECTS

Potential Effect of Wood Loss on Delivery of Sediment to Fish-bearing Streams

The most obvious question for forest management is whether wood is significant in these streams in its role of modulating sediment transport to fish bearing waters. The sediment routing model for streams in the northwest Olympics with abundant wood dams and excess sediment transport capacity predicted that simulated residence time would decrease to a range of about 20 to 70 years from a range of about 70 to 150 years. The mechanism for this decrease in residence time is the gradual loss of wood dams as the recruitment rate of wood diminishes following harvest.

The gradual loss of wood dams, modeled to occur over a 60 year period, results in a net increase in sediment yield corresponding to the gradual release of sediment from storage. The magnitude of the increase ranged from about 40 to 130%. If this magnitude of change in fact occurs, it is reasonable to expect potentially-significant cumulative effects in fish-bearing streams. This degree of increase may not be significant compared to sediment delivery from management-related landslides. In areas where mass wasting is less important, the potential effect of loss of wood-related sediment storage on downstream fish-bearing waters is greater.

It is possible that sediment storage in these streams, once filled, has no net effect on sediment yield. In other words, if wood related storage exists in an approximate steady state and available storage capacity is filled, then there is no effect on sediment routing. Output (yield) must be equal to input when there is no change in storage. In this case, if wood recruitment processes are permanently changed by forest management (clearcutting riparian stands), then there may be a "one-time" pulse of sediment delivered downstream over a period of decades as wood decays and is not replaced.

However, if wood accumulation (or sediment accumulation independent of wood effects) can continue as long as wood is recruited to the channel, with no upper limit of density, then it is possible that storage capacity could increase continuously until, for example, a debris flow scours the channel. This scenario implies that recruitment of wood from the riparian stand would increase the quantity of sediment produced by creep processes stored in Type 4 & 5 channels, and reduce fluvial transport to downstream reaches, at least temporarily. These two conceptual models of sediment routing and the influence of wood have very different implications for managing aquatic ecosystems, and it is not clear whether one, both, or neither are correct.

Rain-on-Snow Runoff Enhancement

Small watersheds drained by Type 4 & 5 channels have frequently been harvested, leaving the entire catchments vulnerable to enhancement of runoff by rain-on-snow processes. In regions where sediment routing is supply limited, the increase in runoff merely adds to an existing excess of transport capacity, suggesting that there should be little change in sediment yield. However, if runoff enhancement interacts with streambanks and hillslopes to deliver more sediment to channels, or if the channel beds are erodible, then the increased runoff could potentially lead to increased sediment yield. In the case of erodible beds and banks, it is possible that the long-term loss of wood could result in channel incision and oversteepening of hillslope toes, creating conditions for long-term increases in sediment production.

Accumulation of Wood For Delivery to Fish-bearing Streams by Debris Flow

Another important function of Type 4 & 5 channels may be accumulation of wood (and sediment) for eventual delivery to fish-bearing streams by debris flow. Where debris flows are an important process, debris flow is a major mechanism delivering wood to fish-bearing channels.

INFORMATION GAPS

Wood Recruitment and Wood Dam Dynamics

Rates of recruitment of wood, dam frequency, and processes of formation and failure dams are not well-quantified. These data are critical to simulation models for sediment routing. There is also little sediment transport or streamflow data for these types of streams. The spatial and temporal variation of wood dams has been quantified in few areas.

Type 4 & 5 Processes in Eastern Washington

Data of these types for Type 4 & 5 streams in the eastern Washington is virtually non-existent. Sediment productions rates tend to be lower because there tends to be less mass wasting. As suggested above, this implies that sediment storage by wood is more likely to be significant in sediment routing to fish-bearing waters. Peak flow hydrology tends to be driven by spring snowmelt, and streams are less flashy, suggesting lower sediment transport capacity in Type 4 & 5 streams. Management implications with respect to sediment routing in this region have yet to be systematically addressed.

Large Woody Debris in Type 4 and 5 Streams:
Abundance, Distribution, Function and Relationship to Forest Management

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Type 4 and 5 Waters Workshop
October 16, 1996
NMFS Sandpoint Facility, Seattle, WA

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Large Woody Debris in Type 4 and 5 Streams

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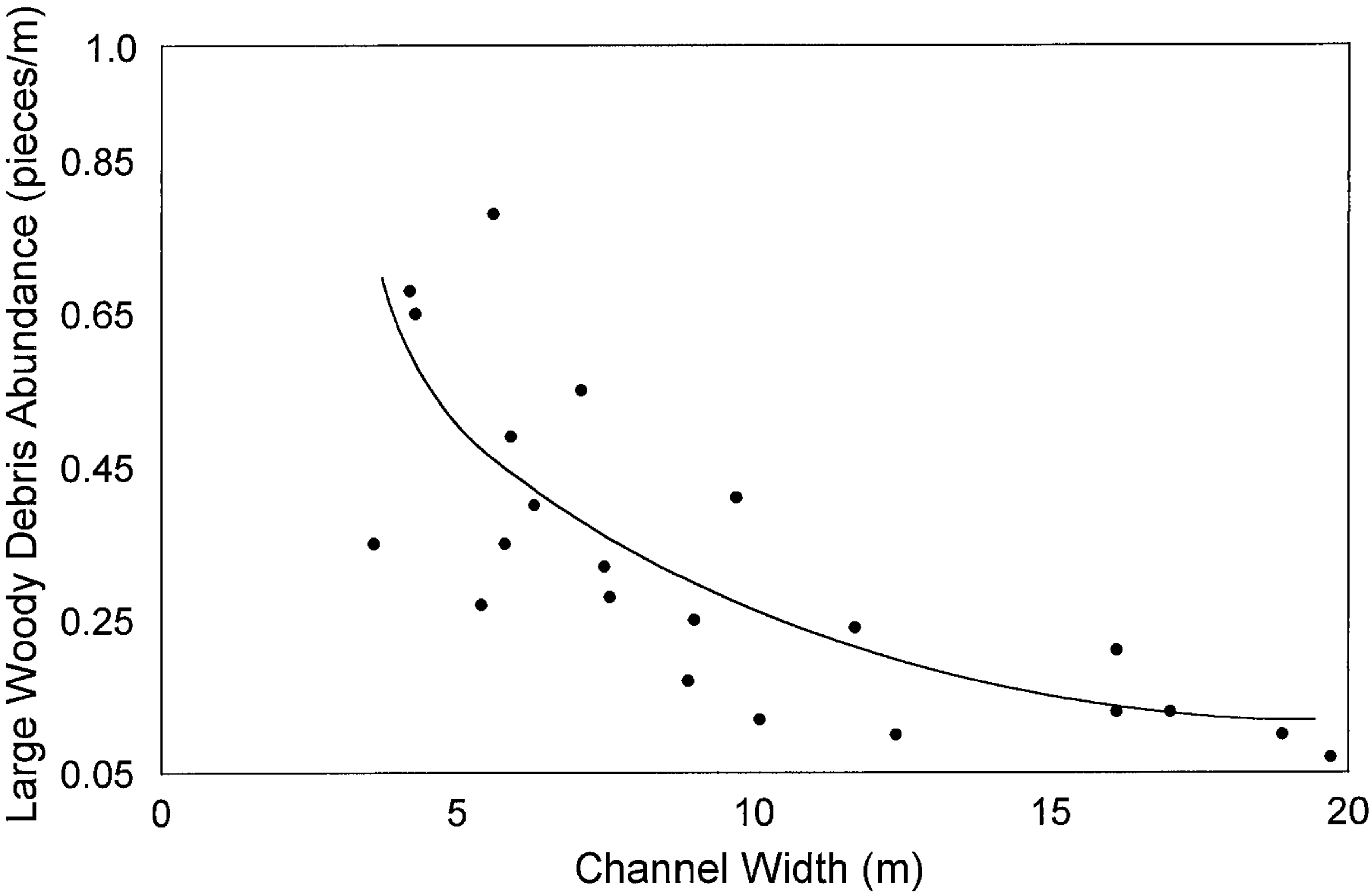
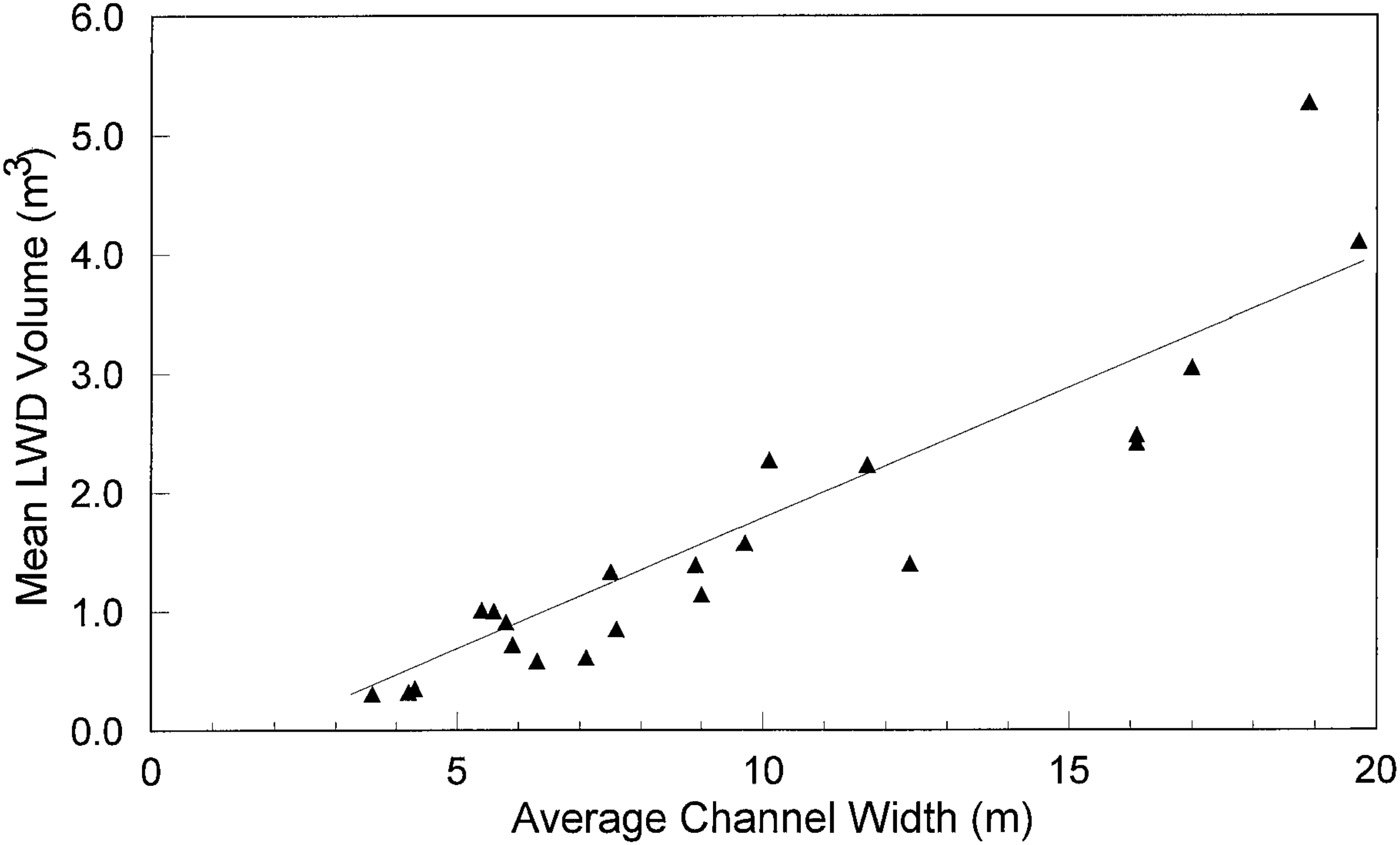
Abundance, Distribution, Function and Relationship to Forest Management

Abundance and Distribution of LWD in T4 and T5 Streams

- More abundant than in larger systems
- Average piece size is smaller than in larger channels
- Amount of LWD varies regionally
- LWD transport is infrequent: Distribution typically not clumped

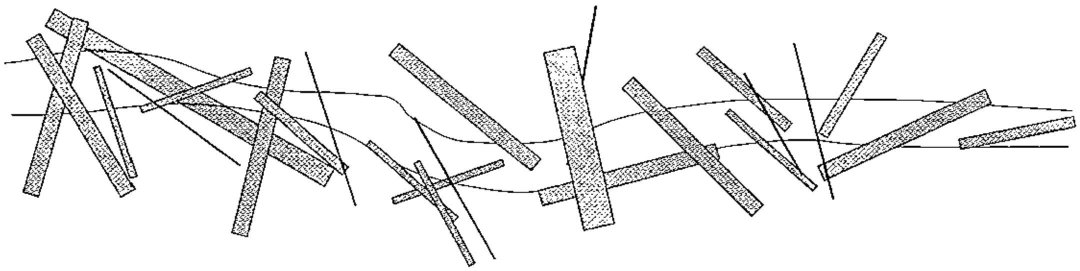


Large Woody Debris Abundance (pieces/m)
1.0
0.85
0.65
0.45
0.25
0.05
0
5
10
15
20
Channel Width (m)

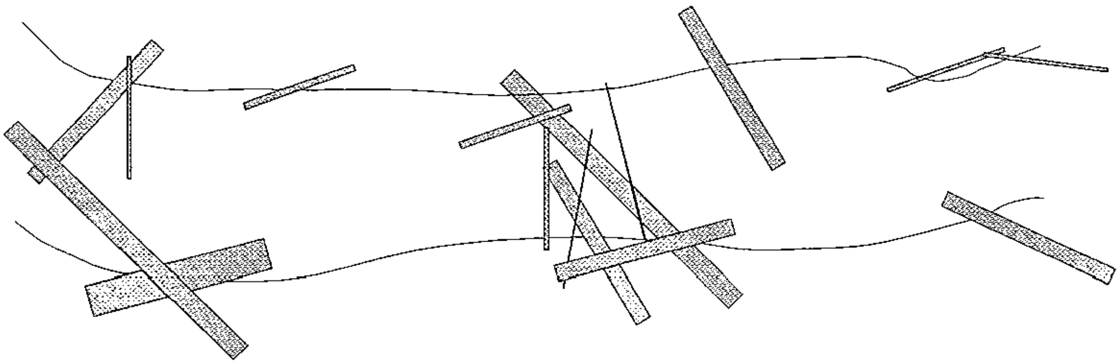


6.0
5.0
4.0
3.0
2.0
1.0
0.0
Mean LWD Volume (m3)
0
5
10
15
20
Average Channel Width (m)

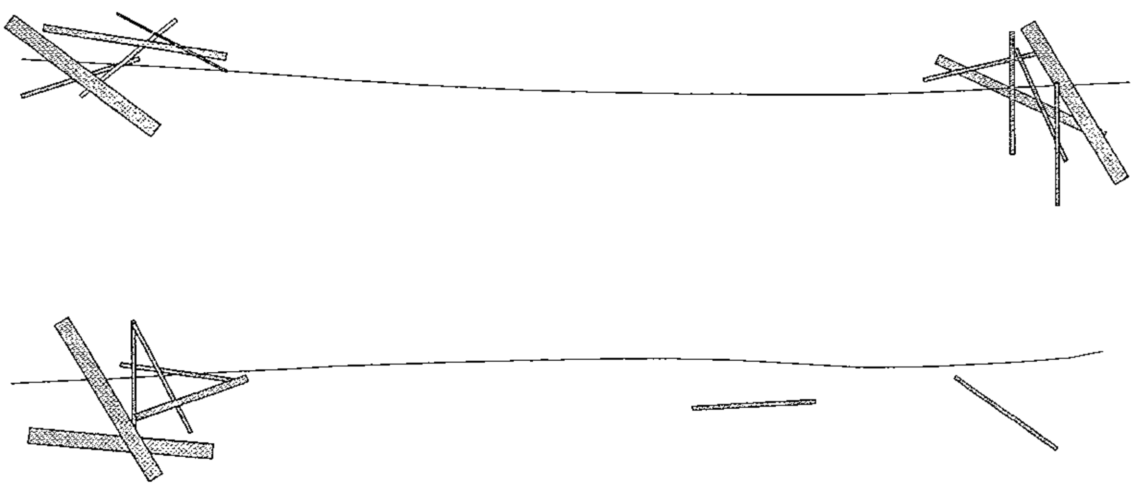
First-Order Channel



Third-Order Channel



Sixth-Order Channel

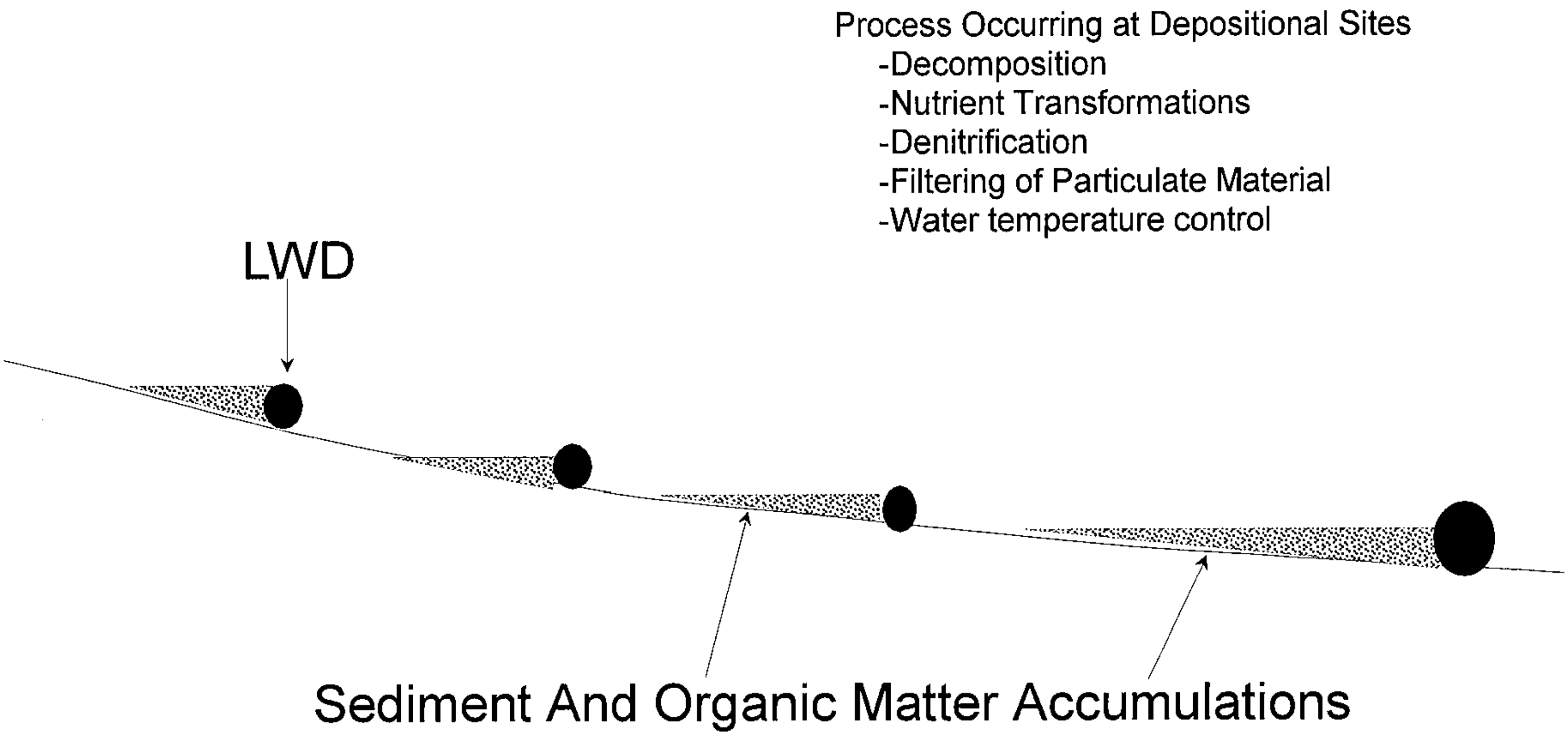


LWD Abundance in Streams with Channel Widths less than 5m in the Pacific Northwest

Location	Dominant Tree Species	Number of Reaches Measured	Mean Basin Area (ha)	Mean Channel Width (m)	Mean LWD Volume (m^3/ha)
Idaho	Pine	2	3600	4.4	22
Idaho	Engelman Spruce	2	965	3.0	69
Prince of Wales Island, AK	Sitka Spruce, Western Hemlock	4	---	3.5	166
Western Washington	Douglas Fir, Western Redcedar	3	110	4.0	462
Klamath Mts., CA	Douglas Fir	8	95	3.1	369
Western Cascade Mts., OR	Douglas Fir	15	87	3.2	796
Sierra Nevada Mts., CA	Giant Sequoia	2	175	4.8	775
Northern California Coast	Coastal Redwood	6	225	4.0	1765

Functions of LWD in T4 and T5 Streams

- Habitat heterogeneity
  - Waterfalls
  - Low-gradient sites
- Sediment Retention
  - Formation of depositional areas
  - Energy dissipation
- Organic Matter Storage
  - Retention of non-woody organic matter
  - Alteration in form of exported organic matter
- Nutrient storage and transformation
  - Influence on dissolved material
  - Storage of nutrients associated with particulate material
- Thermal Influence

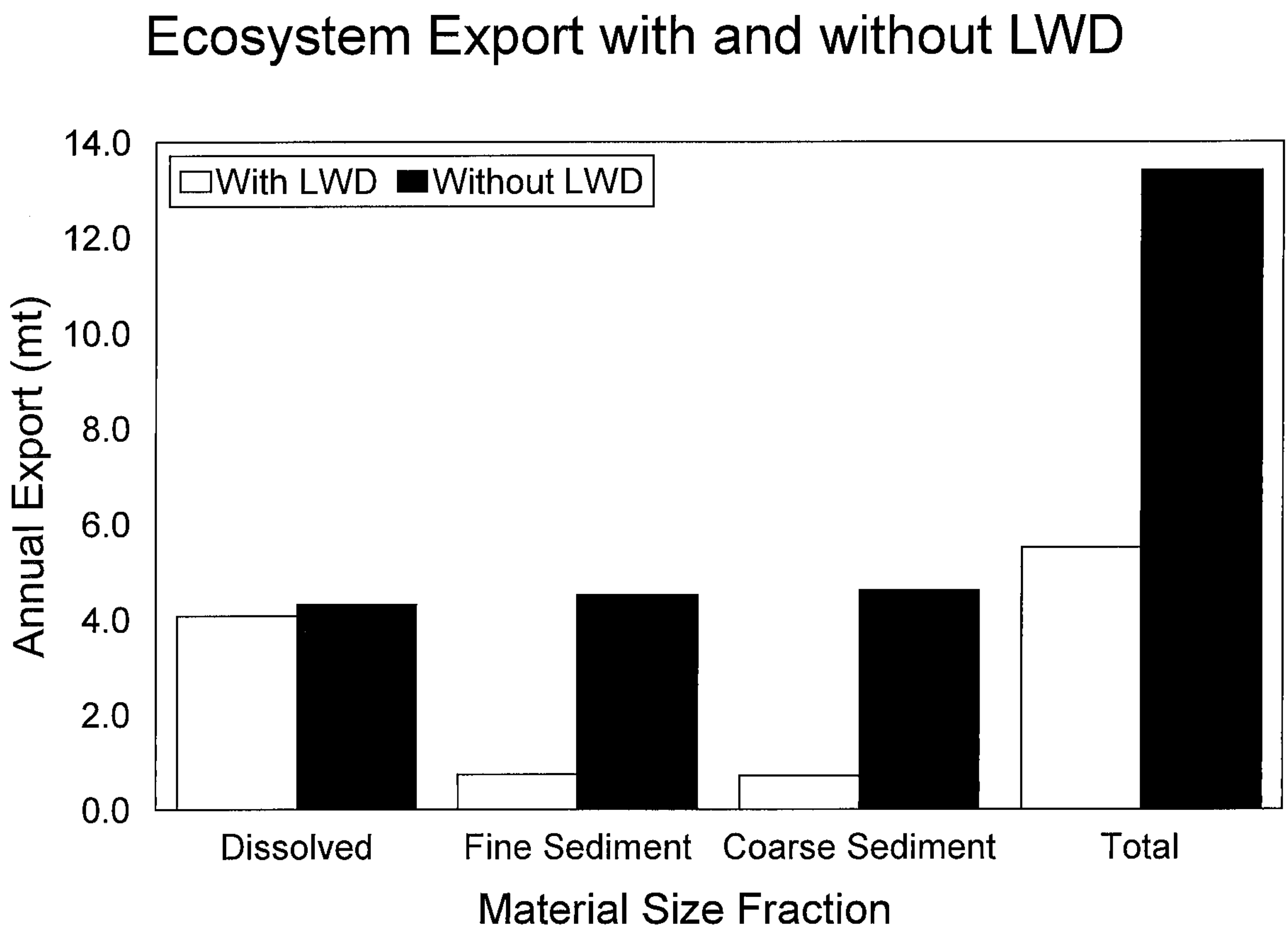

Process Occurring at Depositional Sites
-Decomposition
-Nutrient Transformations
-Denitrification
-Filtering of Particulate Material
-Water temperature control
LWD
Sediment And Organic Matter Accumulations

LWD Waterfalls in Small Streams

Watershed	Channel Width	% Elevation Drop due to LWD Falls
Skookumchuck R.	4.3	31.1
	4.2	19.9
North R.	3.6	8.4
Deschutes R.	5.4	17.2
	5.6	26.7
	5.8	13.2
Tilton R.	5.9	16.7
Average		19.0

Stand Age and Channel Width

Stand Condition	Basin Area (ha)	Channel Width (m)	Width per 100 ha (m)
Old-Growth	169	5.6	3.3
Clear-Cut	234	4.6	2
Second-Growth	230	3.2	1.4


Ecosystem Export with and without LWD
With LWD
Without LWD
Annual Export (mt)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Dissolved
Fine Sediment
Coarse Sediment
Total
Material Size Fraction

Sediment Transport and LWD

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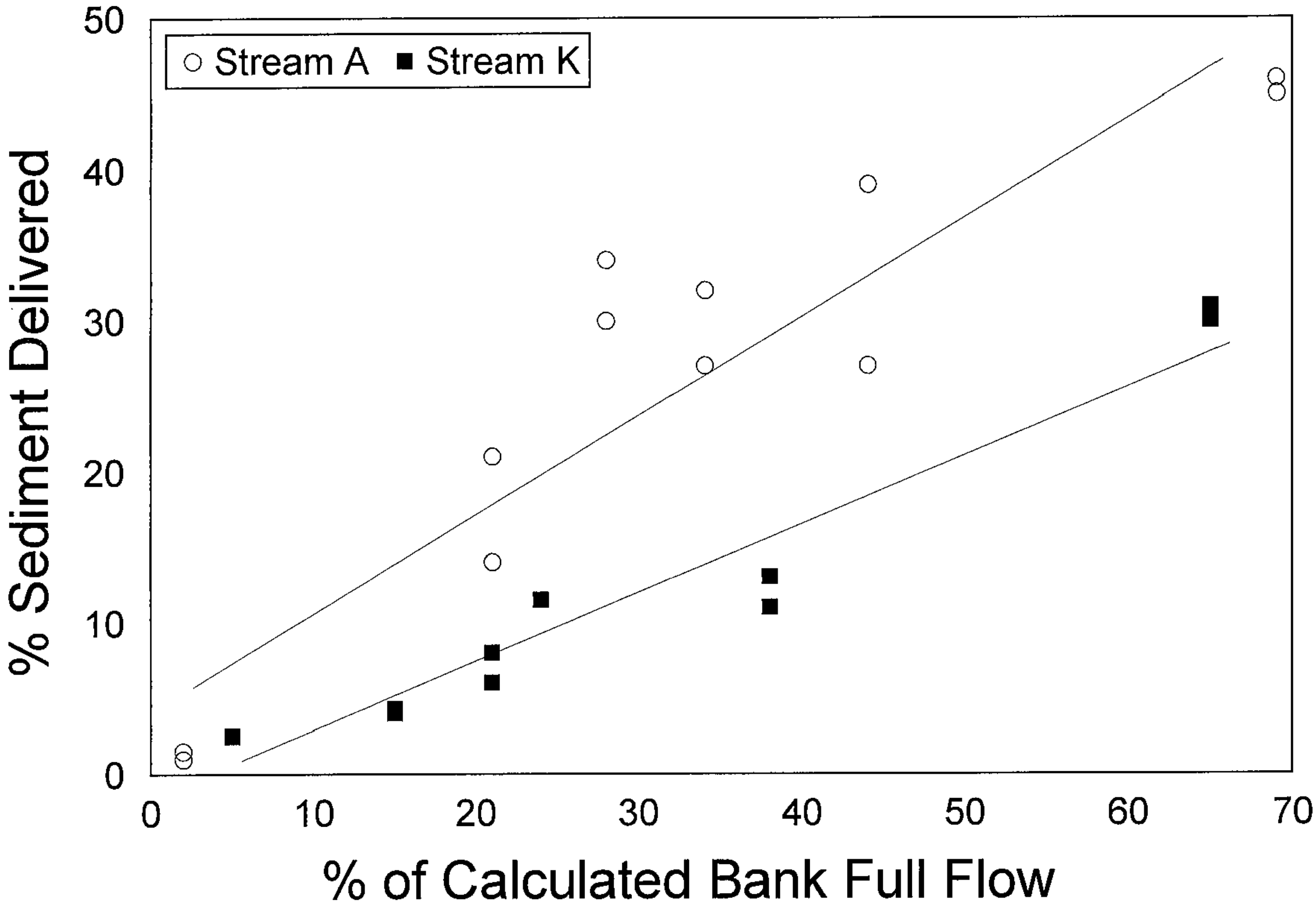
Characteristics of Study Reaches

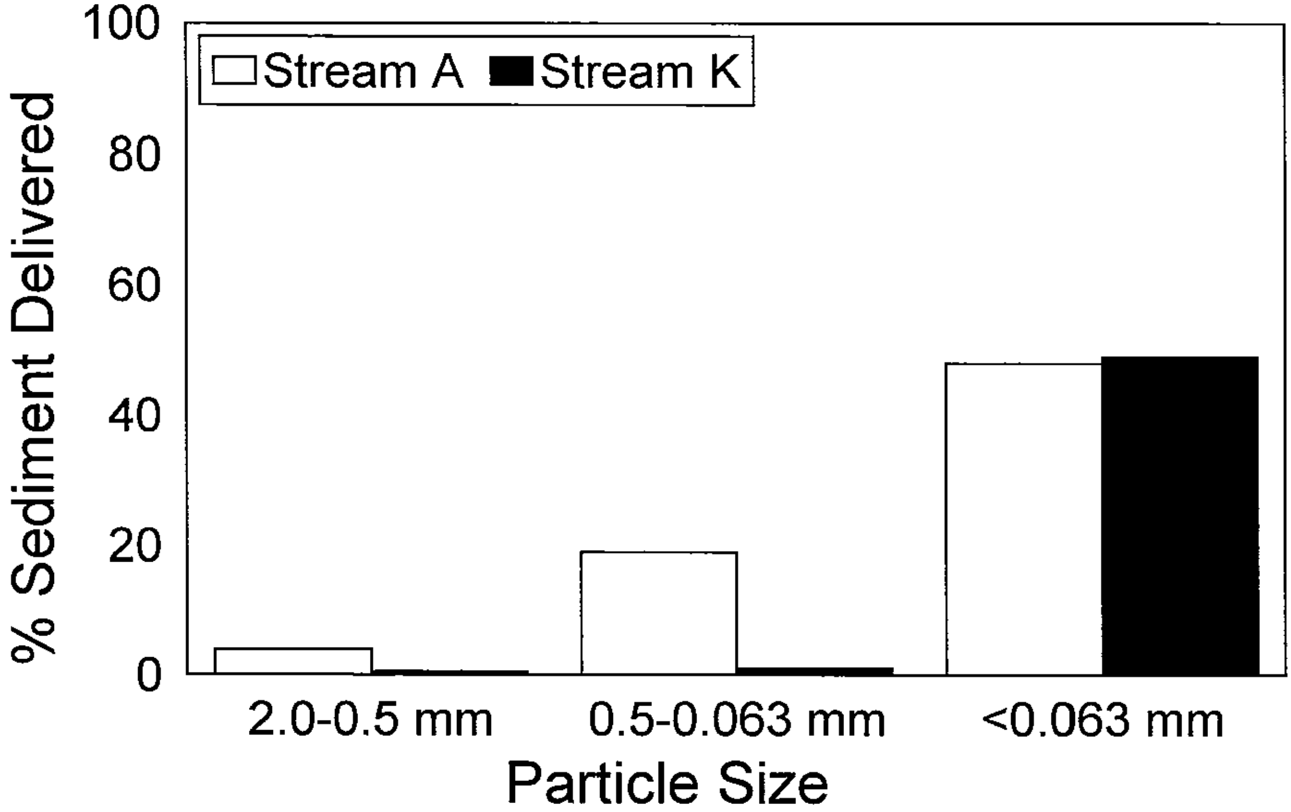
	Stream A	Stream K
Drainage Area (ha)	29	22
Gradient (%)	31	22
Channel Width (m)	1.9	3.0
LWD Coverage (%)	29	72
Bank Full Flow (l/s)	98	80



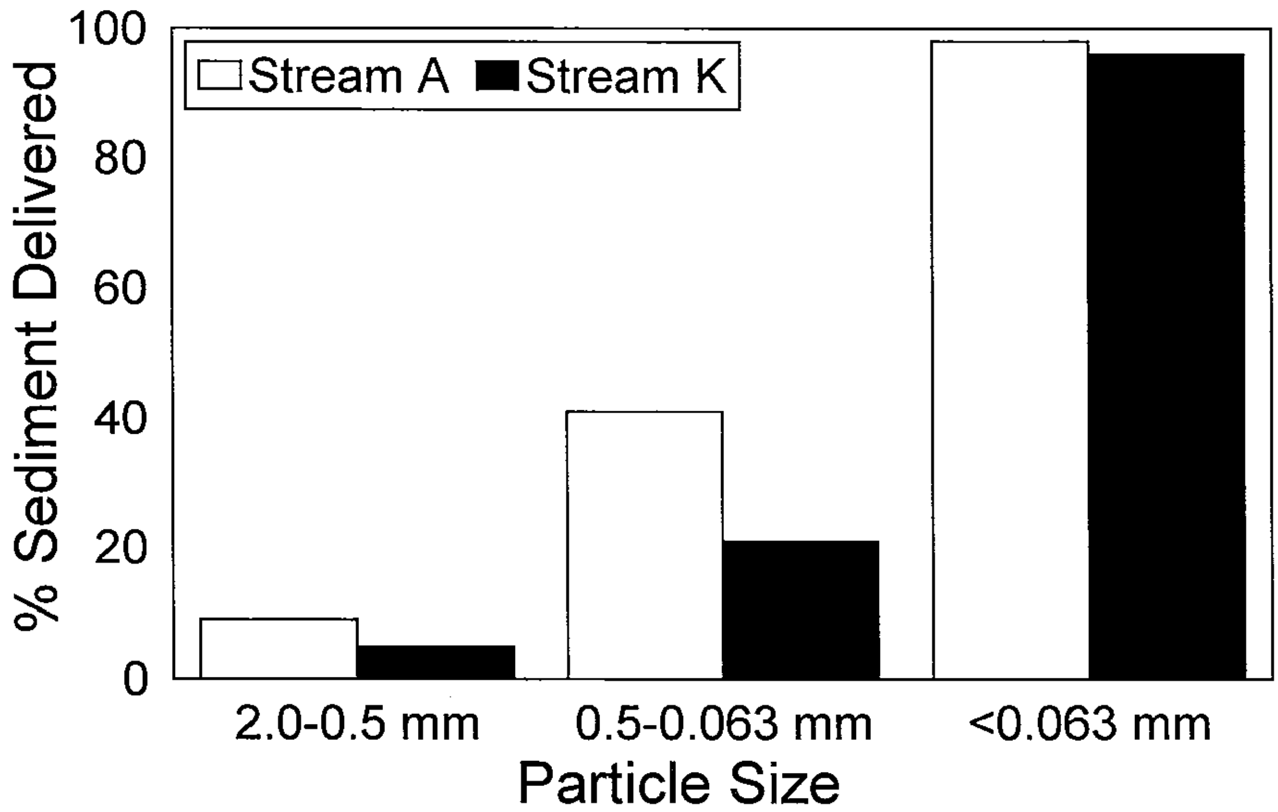
Stream A
Stream K
% Sedimented Delivered
% of Calculated Bank Full Flow
0
10
20
30
40
50
60
70

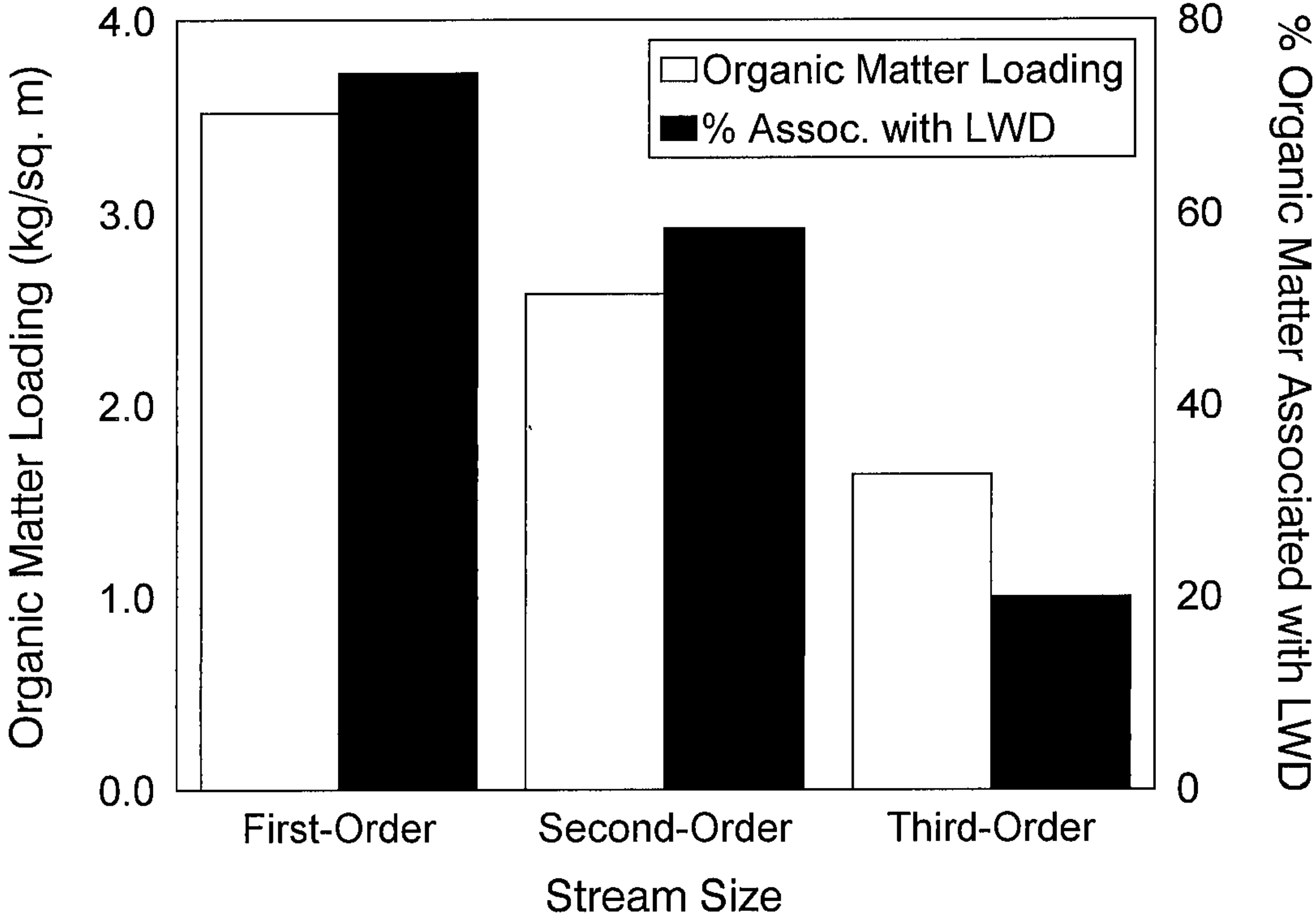
4b

10% Bank Full Flow

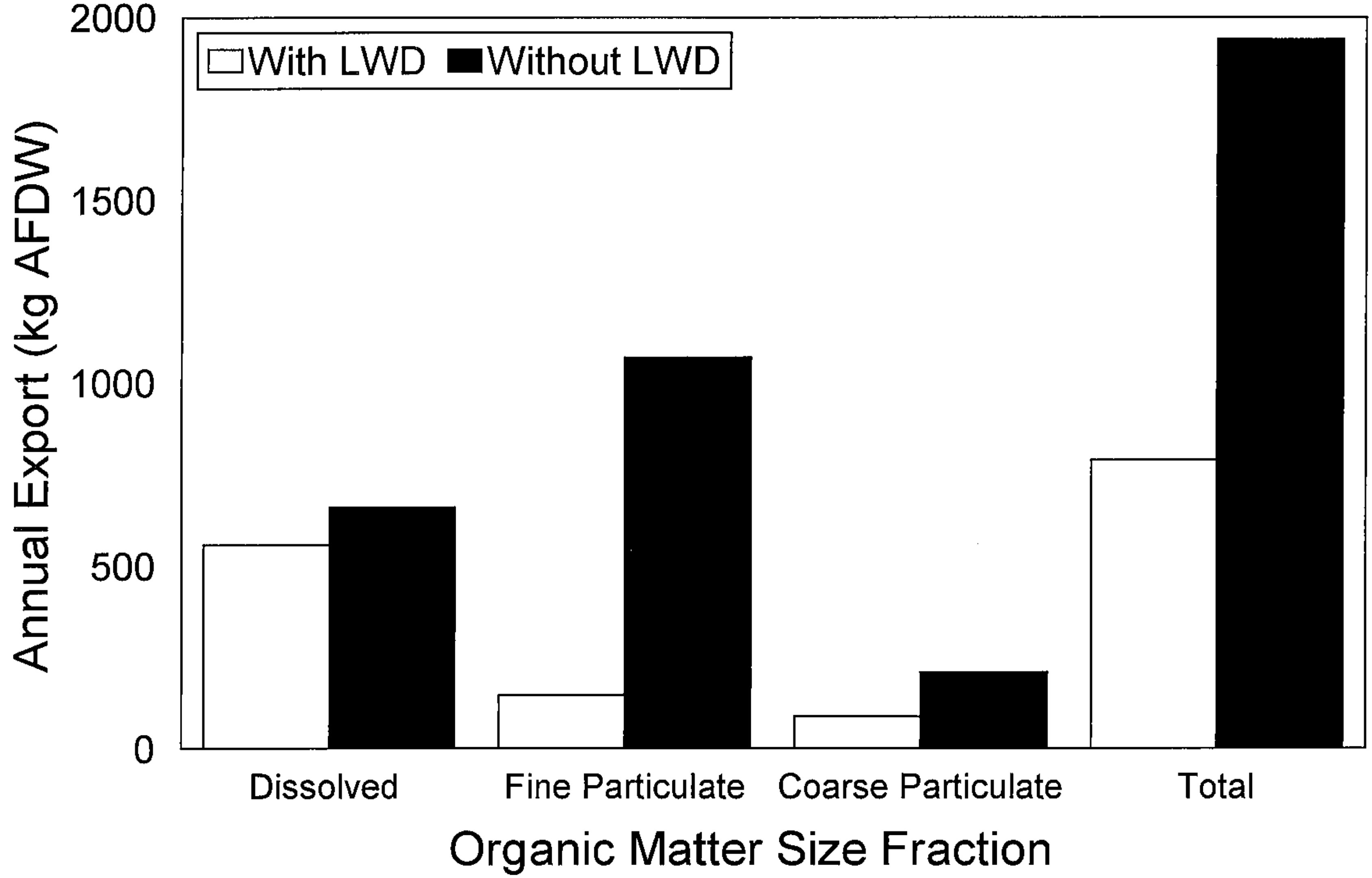


50% Bank Full Flow

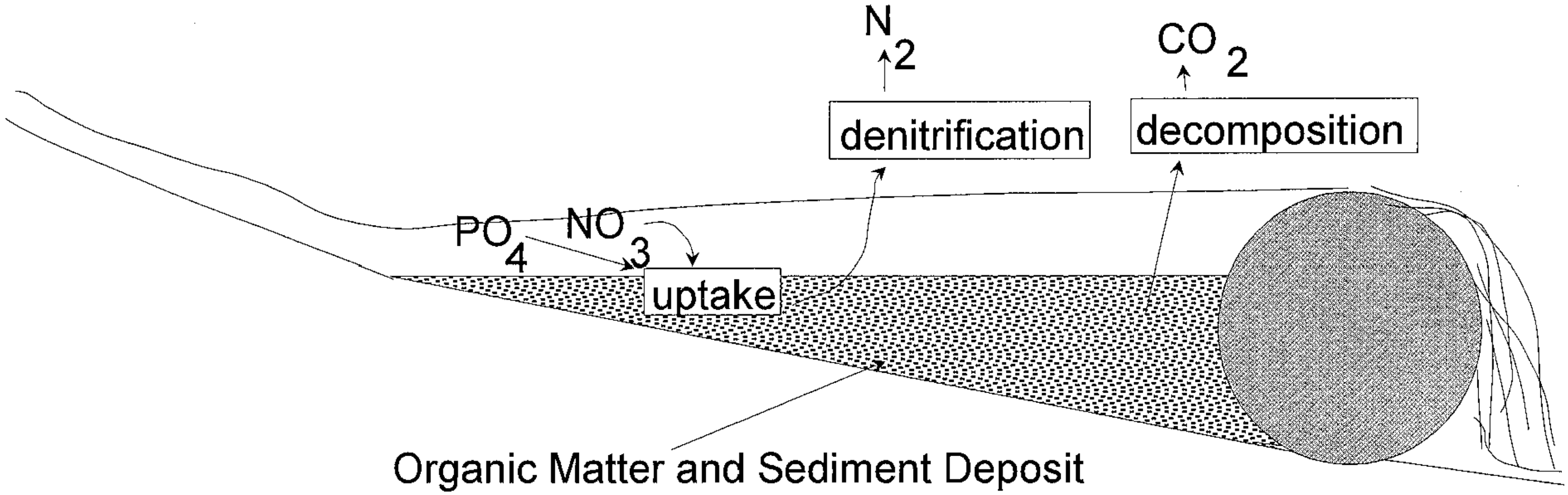



Organic Matter Loading
% Assoc. with LWD
Organic Matter Loading (kg/sq. m)
% Organic Matter Associated with LWD
4.0
3.0
2.0
1.0
0.0
80
60
40
20
0
First-Order
Second-Order
Third-Order
Stream Size

Influence of LWD on Organic Matter Movement

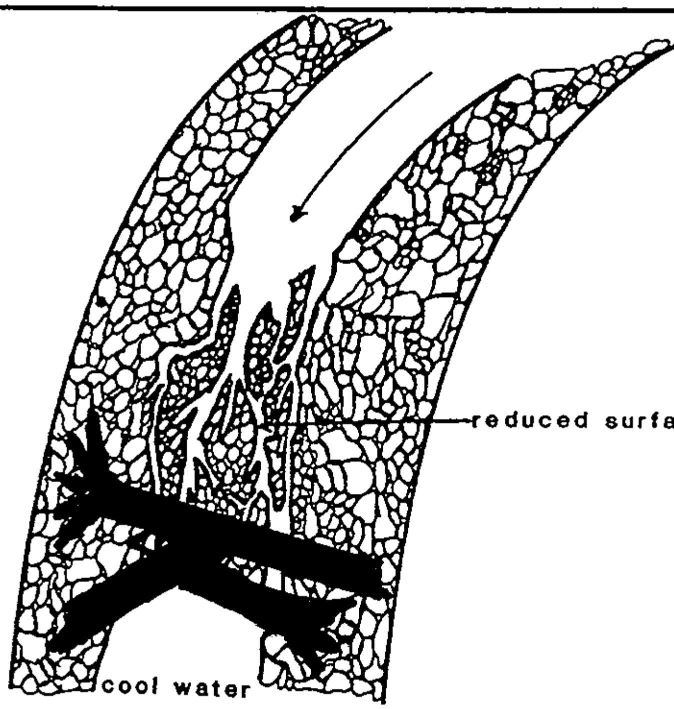


LWD Influence on Nutrient Transformations

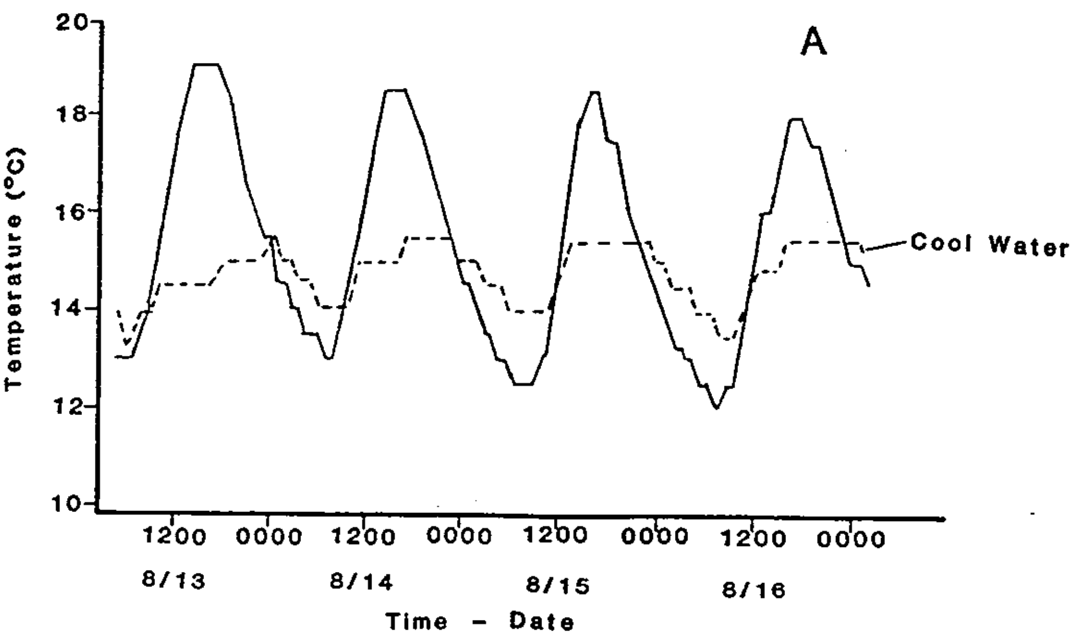


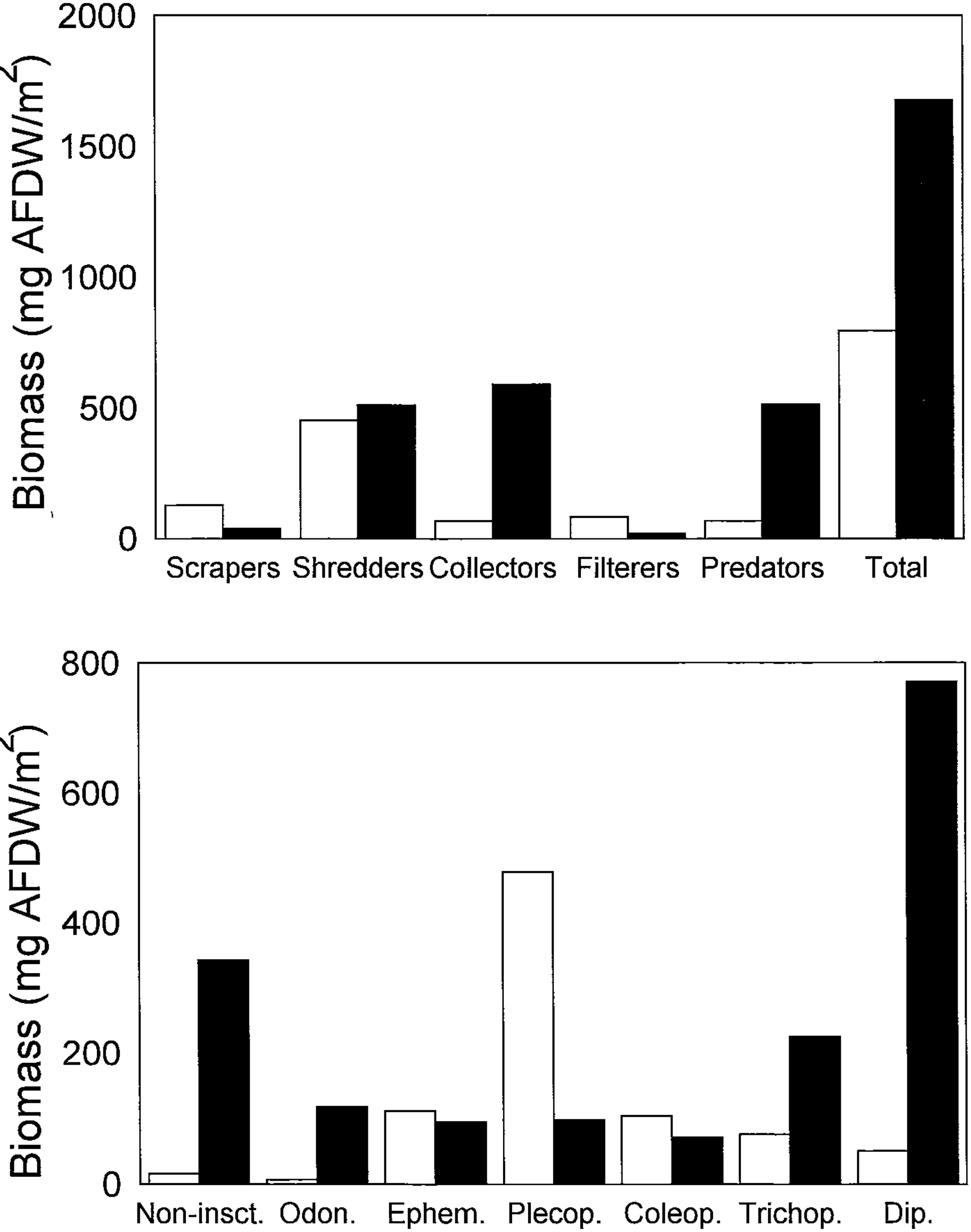
The estimated export of various elements from a watershed drained by a second-order stream in the White Mountains of New Hampshire before and after LWD was removed from a 175-m stream reach Relationships between export and discharge were developed before and after removal of LWD. Values presented represent estimates derived by applying the relationships to daily discharges during a single year (Bilby 1981).

Element	Annual Export with LWD (kg/y)	Annual Export without LWD (kg/y)	% Increase without LWD
Si	710	2350	231
Al	84.7	554	554
Fe	32.5	213	555
Ca	275	331	20
Na	152	225	48
K	63.3	212	235
Mg	66.5	110	65
Mn	1.1	7.0	536
P	1.1	5.3	382
S	389	392	0.8
C	791	1940	145
N	57.5	72.7	26
Total Export	5510	13440	144

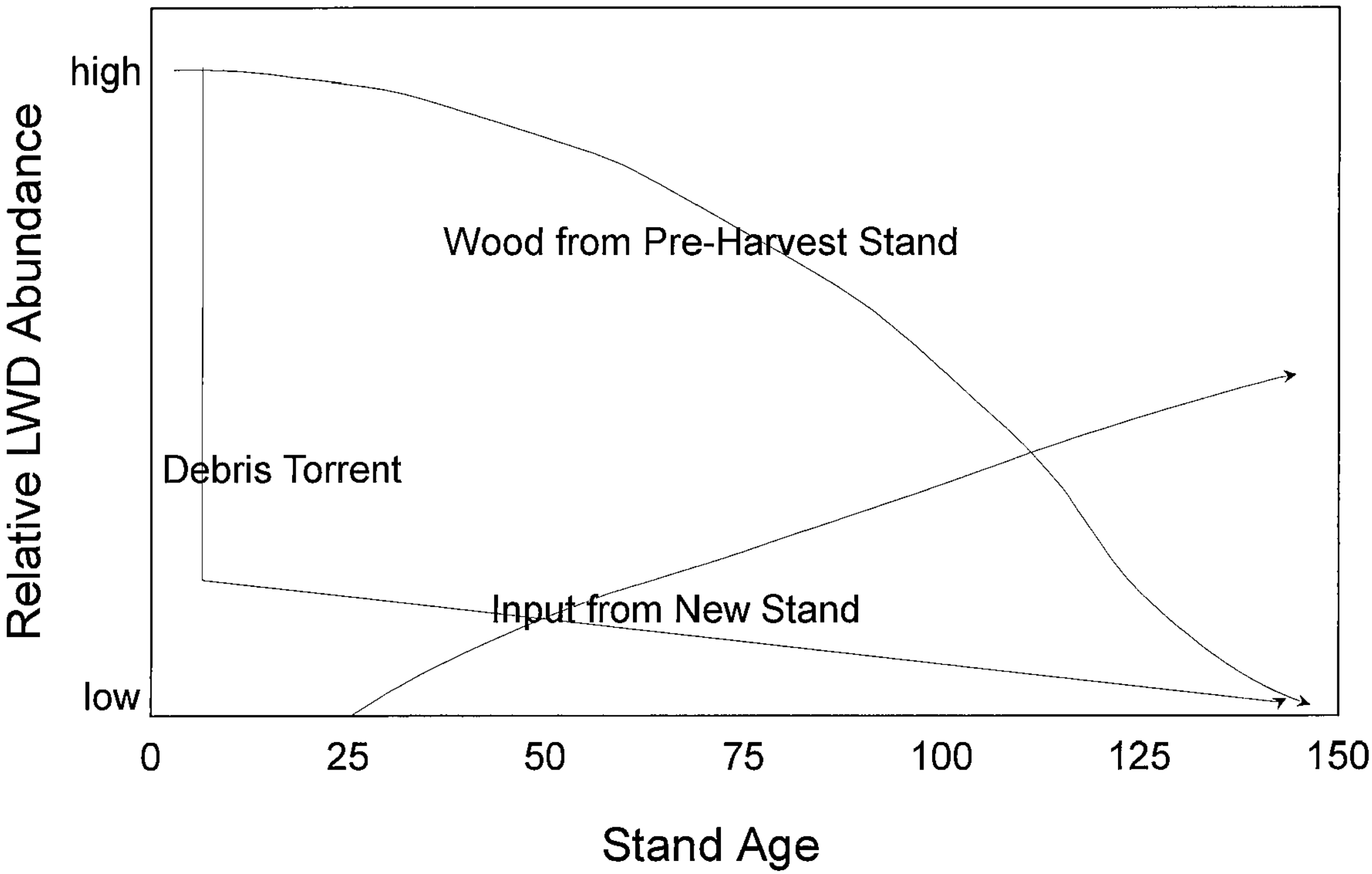


Flow Through the Bed




2000
1500
1000
500
0
Biomass (mg AFDW/m2)
Scrapers
Shredders
Collectors
Filterers
Predators
Total
800
600
400
200
0
Biomass (mg AFDW/m2)
Non-insct.
Odon.
Ephem.
Plecop.
Coleop.
Trichop.
Dip.

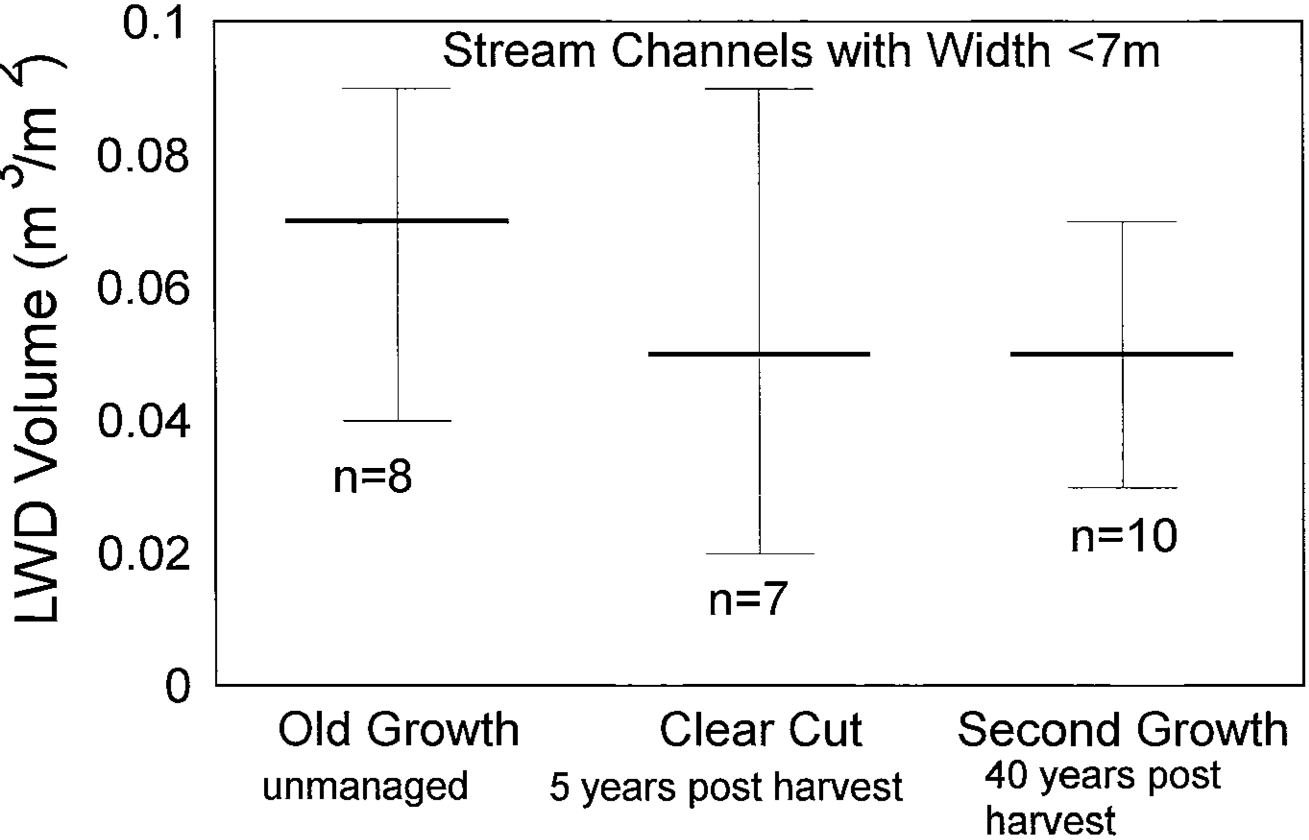
LWD Input and Elimination from T4 and T5 Streams

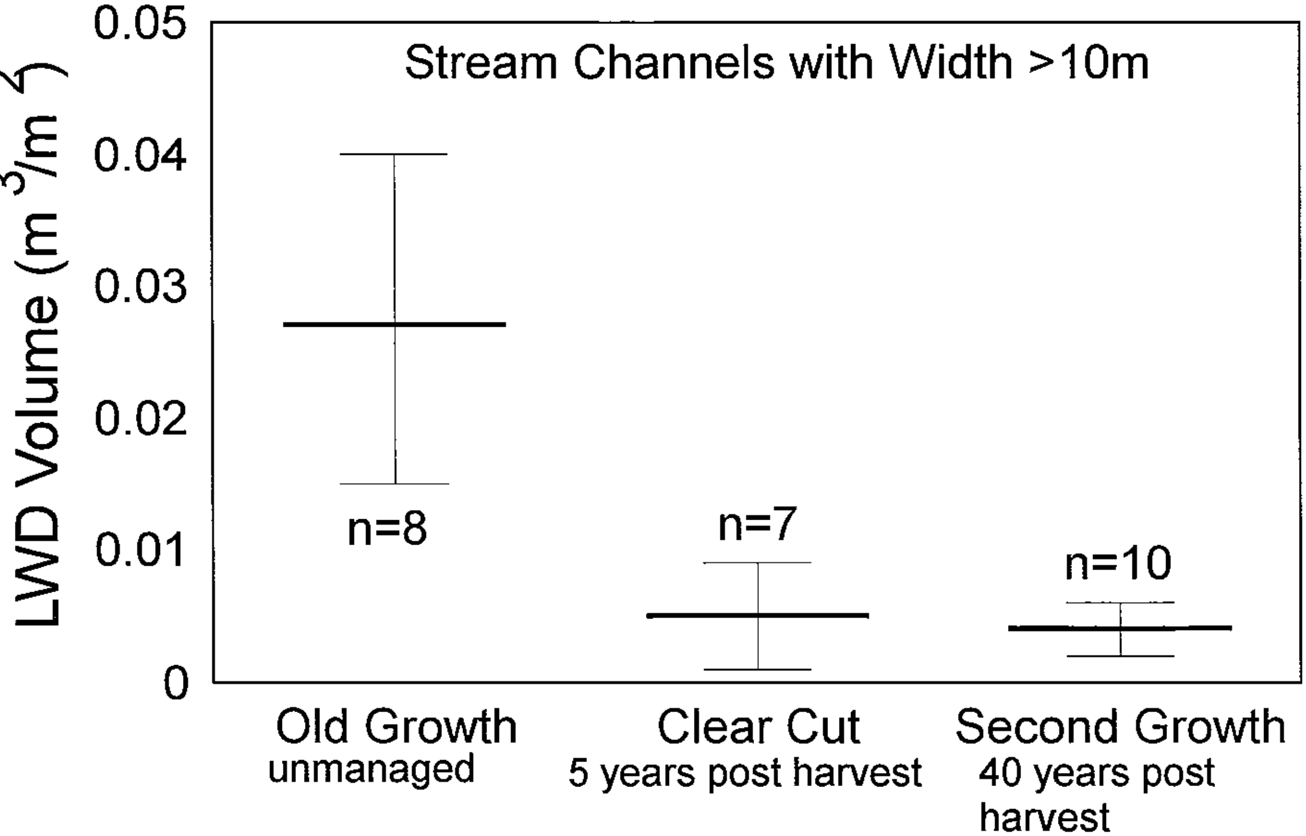


Input of LWD to a Small Stream from a Managed Stand

Dimension of Stable LWD	>6"
Age when Stable LWD Produced	25 years
Zone of Contribution	50'-70'
Stem Suppression during Rotation	23 per acre over 6" DBH
Potential LWD Production over 50-yr. Rotation	65 trees per 1000' of channel length

LWD Abundance at Three Stand Ages

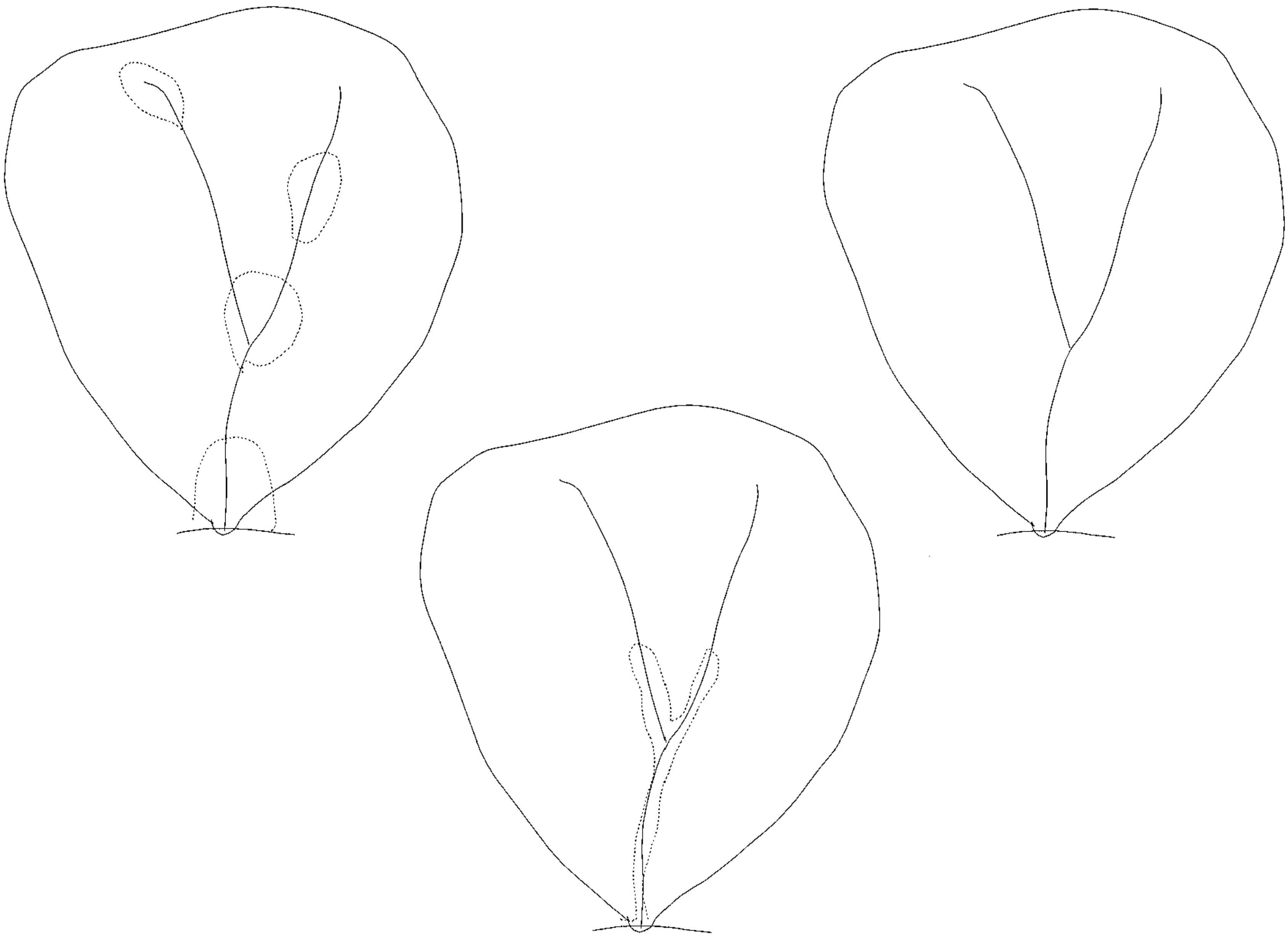




Influence of LWD Size on Function

- Channel Form
  - Larger pools
  - Greater diversity of pool types
  - Larger waterfalls
- Sediment Transport
  - Larger depositional areas
  - Larger waterfalls
- Organic Matter Storage
  - Larger CPOM Accumulations
  - Greater storage on depositional terraces

Management Options for T4 and T5 Streams



Wildlife Use of Riparian and Stream Habitat in Washington State

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The best documented riparian wildlife communities are those in semi-arid and arid climates of the western United States where extreme contrasts between upland and riparian vegetation communities exert a strong influence on wildlife communities. In semi-arid and arid regions, wildlife communities within riparian areas tend to be much more diverse than adjacent upland communities. Within Washington state, particularly on the westside of the Cascade Crest, riparian and upland forests are more similar and wildlife species composition and abundance do not differ dramatically. Preliminary results from the TFW Riparian Management Zone (RMZ) Project's research within managed forests support these conclusions. In fact, researchers in the northeastern part of the state found a greater abundance and diversity of spring bird communities in upland habitats than in riparian habitats. Presence of upland shrubs that had developed following earlier selective logging appeared to increase the diversity of upland avian species observed. When adjacent uplands were selectively cut in 1994 and 1995 leaving a regulation-width buffer strip (10-15m), two species, the Golden-crowned Kinglet and the Swainson's Thrush were significantly more abundant within riparian buffer strips. The researchers concluded that the standard RMZ prescription for small Type 3 streams may restrict these species to riparian habitat and reduce their numbers (M. O'Connell, personal communication, Eastern Washington University, Cheney, Washington). Small mammal communities in northeastern Washington forests showed a greater abundance and diversity in riparian habitats. Although data are not yet available, affects of timber harvest in upland areas may reduce small mammal abundance in both upland and riparian areas. Captures of amphibians and reptiles were too low to analyze quantitatively. However, amphibians were captured more frequently within riparian than upland forests. Reptiles showed a preference for upland areas with higher species richness and abundance than in riparian areas.

Preliminary results from the westside component of the RMZ Project revealed similar results (Stephen D. West, unpublished data, University of Washington, Seattle, Washington). Avian sampling found four species significantly more abundant in riparian areas: Winter Wren, Pacific-slope Flycatcher, American Robin, and Wilson's Warbler, although all four species were also found in upland areas. Following clearcutting of the adjacent uplands, the avian community changed dramatically. Hermit and Townsend's

Warblers disappeared from the sites, observations of Golden-crowned Kinglets decreased, and 11 species of forest edge-associated species appeared. Small mammals associated significantly with riparian areas were the montane shrew (Sorex monticulus), vagrant shrew (S. vagrans), long-tailed vole (Microtus longicaudus), and the jumping mouse (Zapus trinotatus). All species were captured in both riparian and upland forests. Analysis of data collected following timber harvest is currently underway. Bat activity was greater in riparian areas than in forested uplands, with 99% of the activity attributed to Myotis species, a group of widely distributed small bats. The 40-60 year old second-growth forests appear to be too dense for much bat activity, although stream corridors function as fly-ways. Following clearcutting, upland bat activity increased dramatically. Three species of terrestrial amphibians were captured significantly more frequently in upland than riparian forests: the Ensatina (Ensatina eschscholtzii), northwestern salamander (Ambystoma gracile), and tailed frog (Ascaphus truei). Of these three, only the tailed frog breeds in small streams and is generally not considered an upland species. During fall rains when trapping occurred, upland forests appear to provide important habitat for foraging as well as dispersal or migration. Pacific giant salamanders (Dicamptodon tenebrosus) and long-toed salamanders (Ambystoma macrodactylum) were captured significantly more often in riparian than upland forests. The Pacific giant salamander breeds in small, permanent streams and larvae develop in the streams. Surveys of stream-breeding amphibians in Type 4 and 5 streams have been conducted in unmanaged and managed forests in Washington and Oregon (e.g., Corn and Bury 1989, Bury et al. 1991, Kelsey 1995). Results from Oregon studies suggest that managed forest streams support significantly smaller densities and biomass of stream amphibians than unmanaged forest streams suggesting that timber harvest has a significant detrimental effect on tailed frogs, Pacific giant salamanders, southern torrent salamander (Rhyacotriton variegatus), and Dunn's salamander (Plethodon dunni) (Corn and Bury 1989). Studies of populations before and after clearcutting along Type 4 streams in managed forests of the western Washington Cascades revealed a significantly greater density of tailed frog tadpoles in control streams that remained forested than in streams with buffer strips (Kelsey 1995). Densities of Pacific giant salamander larvae were not significantly different in forested and buffered streams. Tailed frog adults were found in greater numbers and densities in very small, cold streams with steep gradients. Frequently, larvae were only found downstream of these upper reaches. Low sediment loads, coarse rock substrates, in-stream woody debris, and unharvested headwater forests have been associated with higher densities of stream-breeding amphibians (Hawkins et al. 1988, Corn and Bury 1989, Bury et al. 1991, Kelsey 1995). Forest management activities that alter these habitat features appear to negatively affect stream amphibian populations.

Although we impatiently await final results from the TFW-RMZ project, initial comparisons of riparian and upland forest communities of breeding birds, bats, terrestrial amphibians, and small mammals suggest there is a high degree of community similarity and that the transition from riparian to upland habitat is not a barrier to wildlife species. The case of stream-breeding amphibians is quite different. These species, as with salmonid fishes, appear to be negatively affected by forest management practices. Clearly, these species would benefit from measures designed to protect the ecological complexity and diversity of small streams. Observations at westside RMZ Project sites indicate that 8-10m no-entry buffer strips are vulnerable to wind throw, which diminishes the utility of the buffer strip in shading the stream, providing long-term sources of woody debris, and maintaining bank stability. There is a great need to experimentally examine other buffer configurations and alternatives. Discontinuous forest patches or buffer islands could be placed around stream areas of greater ecological significance. Selectively cutting along the edge of no-entry riparian buffer strips might reduce the amount of windthrow within buffer strips. Whirl pruning or topping trees might offer additional options for reducing windthrow. Some degree of site-specific flexibility in determining the best way to protect Type 4 and 5 streams from forest management practices will allow the maximum benefit for both landowners and natural resources.

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Corn, P.S., and R.B. Bury. 1989. Logging in western Oregon: responses of headwater habitats and stream amphibians. Forest Ecology and Management 29:39-57.

Hawkins, C.P., L.J. Gottschalk, S.S. Brown. 1988. Densities and habitat of tailed frog tadpoles in small streams near Mt. St. Helens following the 1980 eruption. Journal of the North American Benthological Society 7:246-252.

Bury, R.G., P.S. Corn, K.B. Aubry, F.F. Gilbert, L.L.C. Jones. 1991. Aquatic amphibian communities in Oregon and Washington. Pages 352-362 in L.F. Ruggiero, K.B. Aubry, A.B. Carey, M.H. Huff, technical coordinators. Wildlife and vegetation of unmanaged Douglas-fir forests. USDA, US Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-285, Portland, Oregon, USA.

Kelsey, K.A. 1995. Responses of headwater stream amphibians to forest practices in western Washington. Dissertation, University of Washington, Seattle, Washington, USA.

Abstract: Aquatic Invertebrates in Type 4 & 5 Streams

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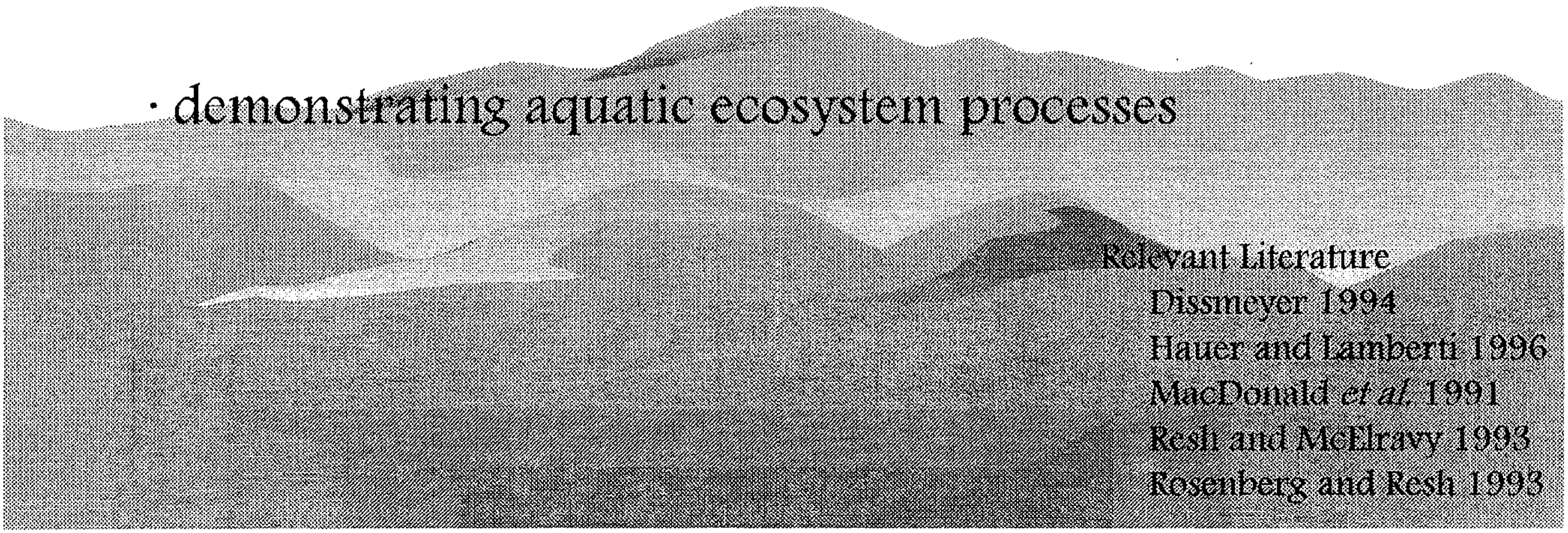
Washington State Department of Ecology

Distinct and sometimes diverse invertebrate assemblages are found in small, headwater streams. A major source of energy introduced into a drainage orginates from the riparian canopy of small streams. The shredder functional feeding group is key in processing this external energy and introducing it for maintenance of the immediate assemblage and cycling the food source to downstream biota. Reduction of riparian canopy along some headwater streams has resulted in reduction of shredder biomass. Destabilization of streambanks that result in considerable erosion raises suspended sediment concentrations in the stream. Significant downstream drift has been measured in the aquatic invertebrate assemblage following active sedimentation.

Biological assemblages in disturbed channels do not immediately recover. Restructuring of the biotic assemblage occurs over longer time periods and is a function of: 1) severity of the initial disturbance, and 2) the return to pre-disturbance physical conditions. Physical features of the headwater stream channel, especially those on a microhabitat scale, appear to be influential to the invertebrate assemblage. Disruption of the invertebrate assemblage in Type 4 & 5 streams results in an effective loss of one food source for downstream communities. A drainage in which a large proportion of headwater streams are degraded would likely influence downstream biological assemblages.

Current Uses for Aquatic Invertebrate Information

- biological monitoring tool (stream quality expectations)
- upstream/downstream impact assessment
- demonstrating aquatic ecosystem processes



Relevant Literature

Dissmeyer 1994
Hauer and Lamberti 1996
MacDonald *et al.* 1991
Resh and McElravy 1993
Rosenberg and Resh 1993

Reliable Tools for Conducting Investigations

- taxonomic literature

  current publications:

  Merritt & Cummins 1996 (general)
  Stewart and Stark 1988 (stoneflies)
  Wiggins 1996 (caddisflies)

- species biological notes (behaviour, food preference)

- physicochemical relationships (living requirements)

  Relevant Literature
  Clark 1996
  Plotnikoff and White 1996
  Webb 1996

Physical/Biological Relationships

(focus of research & knowledge)

- substrate sizes/types
- temperature
- current velocity & flow pattern
- canopy condition

Relevant Literature
Hynes 1970
Minshall 1984
Newbury 1984
Ward 1992

Physical Influences on Macroinvertebrates

(specific disturbance or degradation)

- <u>sediment movement</u> substrate size/type
- <u>temperature increase</u> substrate type/canopy condition
- <u>current velocity/flow fluctuations</u> water source
- <u>loss of canopy</u> condition and type

Relevant Literature

Brittain and Eikeland 1988

Doeg and Milledge 1991

Analyzing Information

Populations (in part)

- abundance per unit area of stream bottom
- macroinvertebrate production (standing crop)

Communities (in part)

- species richness
- intolerant species richness (EPT Index)

Relevant Literature
Johnson *et al.* 1993
Plafkin *et al.* 1989

Interpreting Biological Information

· behaviour (mobility & feeding method)
(*e.g.*, clinger, grazer, sprawler)

· trophic relationship
(type and method of food consumption)

· tolerance to environmental factors

· life history (generation(s) per year)

Relevant Literature
Sweeney 1984
Williams and Feltmate 1992

Biogeography & Origins of the Modern Insecta

- primitive insects ⟶ cool, fast-running water

- dispersal of primitive insects via mountain ranges

- success of migration downstream
  - physiological tolerance
  - water conditions (*e.g.*, adequate dissolved oxygen)

Relevant Literature
Hynes 1988
Ross 1956
Wiggins 1996

Characteristics of the Headwater Stream

(hypothetical expectations)

- dense overhead canopy
- higher gradient
- larger substrate sizes
- disturbance type and frequency can be severe
  - flooding
  - ice formation
  - sediment transport

Relevant Literature
Vannote *et al.* 1980

Effects on Stream Condition

- light attenuation → canopy cover
- active sediment transport → gradient
- sorting of substrates → water energy
- potential for "living space" disturbance

Relevant Literature
Bjornn *et al.* 1977

Functions of Aquatic Invertebrates in Streams

- Shredders ➡ Coarse Particulate Organic Matter (>1 mm)
- Collectors ➡ FPOM (>0.05mm& < 1mm)

  UPOM (>0.0005mm & <0.05mm)

  filterers (water column feeders)

  gatherers (sediment & deposit feeders)

- Grazers (= scrapers) ➡ epilithic algae
- Predators ➡ live prey

Relevant Literature

Cummins 1973

Cummins and Klug 1979

Energy Transfer and the Role of Macroinvertebrates

- allochthonous food processing
  (food source from outside the stream)

- shredder biomass key for initial energy transfer

- collector biomass represents constant transfer rate

Relevant Literature
Angradi 1996
Cummins *et al.* 1989

Seasonal Changes in Headwater Communities

- summer & winter communities
  - summer ~ early spring to early fall
  - winter ~ late fall to late winter

- temporal replacement of community functions
  - (stability of energy transfer during each season)

- life histories (univoltine, multivoltine, semi annual)

Relevant Literature
Butler 1984

Critical Questions

- Stream threshold for masking biological degradation?
- Can "islands" of biological diversity exist?
- Disturbance of Type 4& 5 streams and the downstream influence?
- Interruption of food chain processes & the implications?

Stream Thresholds & Biological Degradation

- population/community indicator attributes
- key features that "mask" biological degradation
- combinations of physical characteristics
- adaptation by the macroinvertebrate community

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Tolerance of the Biological Community

Sediment Impacts

- reduction of living space
- substrate movement reduces habitable space
- increase in aquatic invertebrate drift

Canopy Cover

- biomass reduction of allochthonous food source
- promotion of new food source (same biomass input?)

Temperature

- exceed tolerance of some taxa
- usually resulting from canopy removal

Relevant Literature
Hill *et al.* 1995
Waters 1995

Further Biological Response to Degradation

Annual Hydrologic Pattern

- timing of flow increases/declines
- severity of physical changes during flow increases
- nutrient cycling dynamics are changed

Aquatic Invertebrate Response

- life cycle adjustment
- increases chance of exposure to high stress conditions
- nutrient processing inefficiency

Relevant Literature

Irons, III *et al.* 1994

Resh *et al.* 1988

Vuori and Joensuu 1996

Community Attributes & Degradation Response

- reduction of large shredder taxa (*e.g.*, *Pteronarcys* sp.)
- increase of scraper taxa (*e.g.*, *Epeorus* sp.)
- increase of filterer taxa (*e.g.*, *Hydropsyche* sp.)
- increase in dominant taxon (or top 3 dominant)
- decrease in intolerant taxa (EPT)
  (EPT~Ephemeroptera, Plecoptera & Trichoptera)

Relevant Literature
Fore, Karr and Wisseman 1996

"Islands of Biodiversity"

concern: nonrepresentative biological condition

- closely associated with channel segment type
- located where channel stability is apparent
- channel stability ~ reduced water energy
  (kinetic energy ➡ potential energy)

Type 4 & 5 Disturbance: Effect on the Drainage

- inefficient transfer of energy (units of biomass)

- functional replacement of food source unavailable

  algal biomass production depressed

  → nutrients are rate-limiting

- "leakage" of useable nutrient (loss of production)

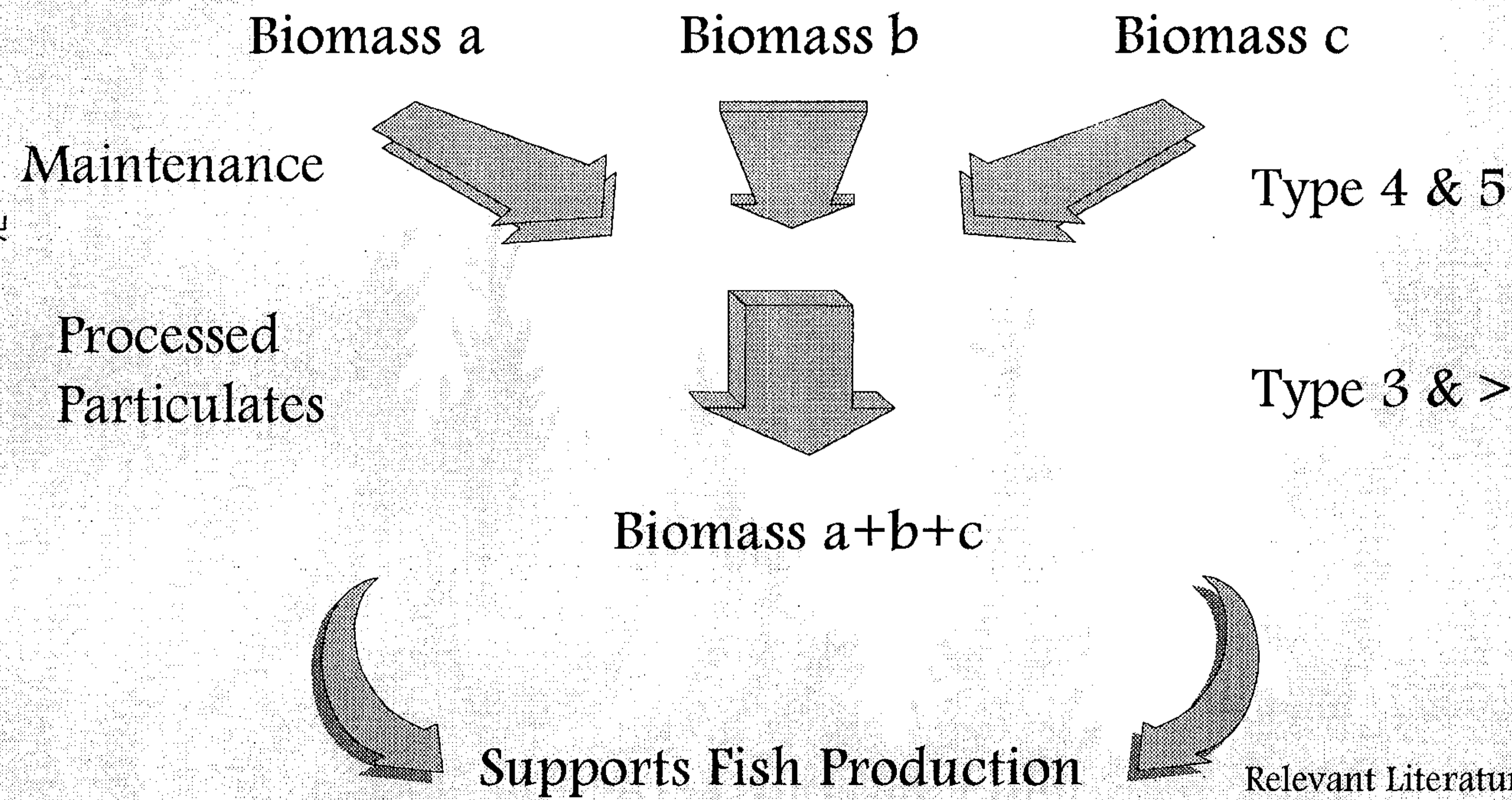
Relevant Literature

Newbold *et al.* 1981

Ricklefs 1979a

Stockner and Shortreed 1987

Energy Transfer: Charismatic Microfauna



Relevant Literature
Krebs 1985

Type 4 & 5 Stream Stability

- instability results in a "punctuated" transfer of energy

- stability maintains a "uniform" transfer of energy

consequence: oscillating energy transfer may limit downstream production.

- smaller streams are more easily disrupted (physically & biologically)

Relevant Literature
Ricklefs 1979b

Changes in Hydrology

Water Quantity

- reduction limits invertebrate habitat to the hyporheos
- reduction results in larger cyclical extremes (*i.e.*, temp.)

Sediment Organics

- reduction as a useable food source
- elimination resulting from continuous sedimentation

Relevant Literature
Culp 1987

Coastal vs. Interior Montane Conditions

Stream Sediment Condition

- <u>west side</u> generally coarse stream substrates
- <u>east side</u> sandy stream substrates (weathered granite)

Invertebrate Community Adaptation

- west side
  - a) sensitive to sedimentation
  - b) greater diversity of taxa
- east side
  - a) tolerance to some sedimentation
  - b) lower diversity of taxa

Relevant Literature
Kohler 1992

Conclusion

- physical changes (*e.g.*, sediment)
- interruption of nutrient/energy cycle
- <u>food loss for fish</u>

Relevant Literature

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THE RESPONSE OF A CUTTHROAT TROUT POPULATION TO A LOGGING ROAD CAUSED DEBRIS TORRENT EVENT IN OCTOPUS-B CREEK.

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INTRODUCTION

From headwaters to mouth, variables within a river present a continuous gradient of physical and biological conditions. Gradient elicits a series of responses within the constituent populations resulting in a continuum of biotic adjustments and consistent patterns of loading, transport, utilization, and storage of organic matter along the length of a river (Vannote et al. 1980). Headwater streams, referred to administratively as Type 4 and 5 Waters in the Washington Forest Practices Rules have few or no fish populations; however, they are the source of many important physical and biological factors that support downstream salmonid populations. These factors include: 1) water, 2) nutrients, 3) wood, 4) gravel, and 5) aquatic insects.

The precipitous mountain conditions on the west coast of North America are highly conducive to the formation of debris flows, and most of these events originate in Type 4 and 5 Waters. This is especially so under conditions of disturbance from man, such as in relation to clearcut logging areas and logging road crossings (Swanston and Swanson 1976; Tripp and Poulin 1986b). In many cases landslides that originate in steep headwater streams scour out downstream fish habitats before they dissipate in lower gradient areas. This can result in loss of fish populations that reside in headwater streams.

This serendipitous investigation began as a two year study of cutthroat populations in several headwater tributaries of the Clearwater River (Osborn 1980). This work provided a comparison of pre- and post-debris torrent information on cutthroat trout populations, as well as inchannel habitat conditions in a stream called Octopus-B Creek. Little is known about these interactions and how long it takes for fish and habitat recovery to occur.

METHODS

Octopus-B Creek is a third order headwater tributary of the Snahapish River, which is a fourth order tributary of the Clearwater River. This area is located on the hydrologically dynamic northwestern coast of Washington's Olympic Peninsula (Figure 1). The channel morphology of Octopus-B tributary is boulder-bedrock dominated, and the average stream gradient within the study area was 9.6%. The summer discharge is approximately 0.01 m3/s. In an eight day period from 13 to 20 December 1979, 79.5 cm of rainfall was recorded at a meteorological station located within four kilometers of Octopus-B Creek. A subsequent search of the area revealed that two debris torrents had traveled down the entire length of Octopus-B channel and came to rest in the main Octopus Creek. One torrent originated in a logging road fill after a plugged culvert caused it to become supersaturated, and the other on a steep slope that had been overloaded with sidecast material from road and landing construction.

The post-torrent investigation of Octopus-B Creek was limited to closely mirror the pre-torrent research that was carried out by Osborn (1980). This centered around making yearly censuses of the cutthroat trout population in a 152 meter reach during spring, summer, and fall. Both searun and resident cutthroat reside in Octopus-B Creek. Information was collected for the years 1978 to 1995 (excluding 1990-1992). Only the fall information on the populations and habitat conditions are reported here. The modified Peterson mark-recapture method (Chapman 1951) was used to make the cutthroat trout population estimates. Within the study reach, measurements of total water surface and pool water surface area, as well as the number of pools with a maximum depth in excess of 0.35 m, were made in most years.

RESULTS

The debris torrent was preceeded by two years of consistantly high numbers of cutthroat trout of three different age classes and total population within the study reach (349-359 age 0+; 67-97 age 1+; 12-15 age 2+; and a total population comprised of 441-458 fish) (Figure 2). These trout populations were supported by stable and abundant amounts of total water surface and pool surface area, and pool depth. However, in late 1979 the debris torrents changed both the fish populations and the habitat conditions. Soon after the storm subsided, an investigation of the study reach revealed that the cutthroat population was decimated. In fact we could only account for about 10 surviving trout. In the 3 years that followed the debris torrents cutthroat trout populations partially recovered, and then in the years that followed they stabilized and remained at about 50% of pre-torrent levels for the remaining 13 years of study. The post-torrent numbers in each age class have ranged as follows: 0-189 age 0+; 8-97 age 1+; 0-4 age 2+; and 31-220 total population over the course of the study (Figure 2).

The total water surface has dropped to a level that is approximately 66% of pre-torrent conditions, the total pool surface area has remained roughly unchanged from pre-torrent conditions, and the number of pools with a depth greater than 0.35 m has dropped as low as 24% of pre-torrent conditions. Both total water surface area and pool depth have shown signs of recovery in recent years (Figure 3), however, this recovery is only a short-term benefit during the fall, due to a build up of alder tree (Alnus rubra) leaves at the outlet of pools. In actuality, the year round pool depth has not recovered.

DISCUSSION

Assessing the effects of a major disturbance by reach analysis may be tenuous at best. Restricting one's investigation to just one salmonid species during a specific life history stage may also be viewed as quite suspect. However, the opportunities to study such a catastrophic event having current, onsite pre-disturbance information are also quite limited.

The December 1979 debris torrents were devastating to the stock of cutthroat trout within Octopus-B Creek. Long-term physical habitat changes in conjunction with ecosystem recovery may prevent the cutthroat trout population of Octopus-B Creek from rebounding to a level comparable to those measured during the two years immediately preceding the debris torrent. The declines of both total water surface area and pool depth probably contributed in large measure to the lack of full recovery of the fish populations.

The fish carrying capacity of a stream may be determined by the amount of summer lowflow habitat (Burns 1971). Total wetted area and maximum pool depth in October were two habitat parameters that we felt would be the least subjective to measure. The observed declines in both, we feel, would have been even more dramatic if not for the retention of water by leaf litter accumulations during the later years of the investigation. Both total water surface area and pool depth are directly related to discharge. Summer lowflow discharge may in fact increase after timber harvest (Harr et al. 1979), but will return to pre-harvest levels within 3 to 5 years as the root systems of a new forest develop. Thus the timing of our investigation relative to timber harvest related changes in the discharge of Octopus-B may partly explain the gradual loss of these habitat parameters during the years following the debris torrent.

Loss of wetted area in Octopus-B would be especially detrimental to the potential age 0+ trout carrying capacity. Moore and Gregory (1988b) found a strong positive correlation between the amount of lateral habitat area and the number of age-0 cutthroat trout. These authors were able to increase or decrease the age-0 densities by experimentally manipulating the amount of lateral habitat of a stream within an old-growth setting. They defined lateral habitat as low-velocity areas that occur at the margins of the streams. A narrowing of the wetted channel either by reduced discharge or channel degradation should adversely affect the amount of suitable lateral habitat.

In streams, depth may be the most significant factor limiting the amount of older age class trout (Dolloff 1983). Heggenes et al. (1991) found a significant regression between length of cutthroat trout and the depth and amount of cover of the habitat that they reside in. Fish were found to prefer deeper areas of the stream as they increased in size. The loss of pool depth would be most critical to boulder-bedrock dominated streams such as Octopus-B Creek, where other forms of cover such as undercut banks and large woody debris are in limited supply.

Intra-species differences in life histories between resident and searun cutthroat may have placed the resident population of Octopus-B Creek at greater risk to the overall impacts of the debris torrents. Resident cutthroat are known to have a more restricted life history strategy. They may spend their entire life within a limited reach of stream (Aho 1976; Miller 1957). Lowry (1965) reported having resident cutthroat making upstream spawning migrations of varying distances, but with many returning to the same pool that they resided in during the previous summer. Having all year-classes within a narrow window of time and space places the population highly vulnerable to even a single event such as a debris torrent.

Entire recovery of this cutthroat trout population will probably mirror the habitat recovery rate. Habitat recovery may take many more years, because the return of habitat characteristics that existed during the pre-torrent years may rely on the regrowth of the riparian forest. According to Grette (1985) it takes a second growth forest up to 50 or more years to reach a condition that will just begin inputing significant amounts of woody debris to channels.

This situation demonstrates how logging and roading operations in headwater areas of Type 4 and 5 Waters can have significant long-term impacts on downstream fish bearing waters. Therefore, when operating in these kinds of headwater streams it is imperative to consider not only the potential onsite effects, but also the potential downstream effects.

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Debris Torrents

Study Area

Figure 1. Location of Octopus-B Creek and Debris Torrents.

Figure 2. Octopus-B Creek Cutthroat Trout Populations From 1978 thru 1995.

Figure 3. Octopus-B Creek Habitat Conditions From 1978 thru 1995.

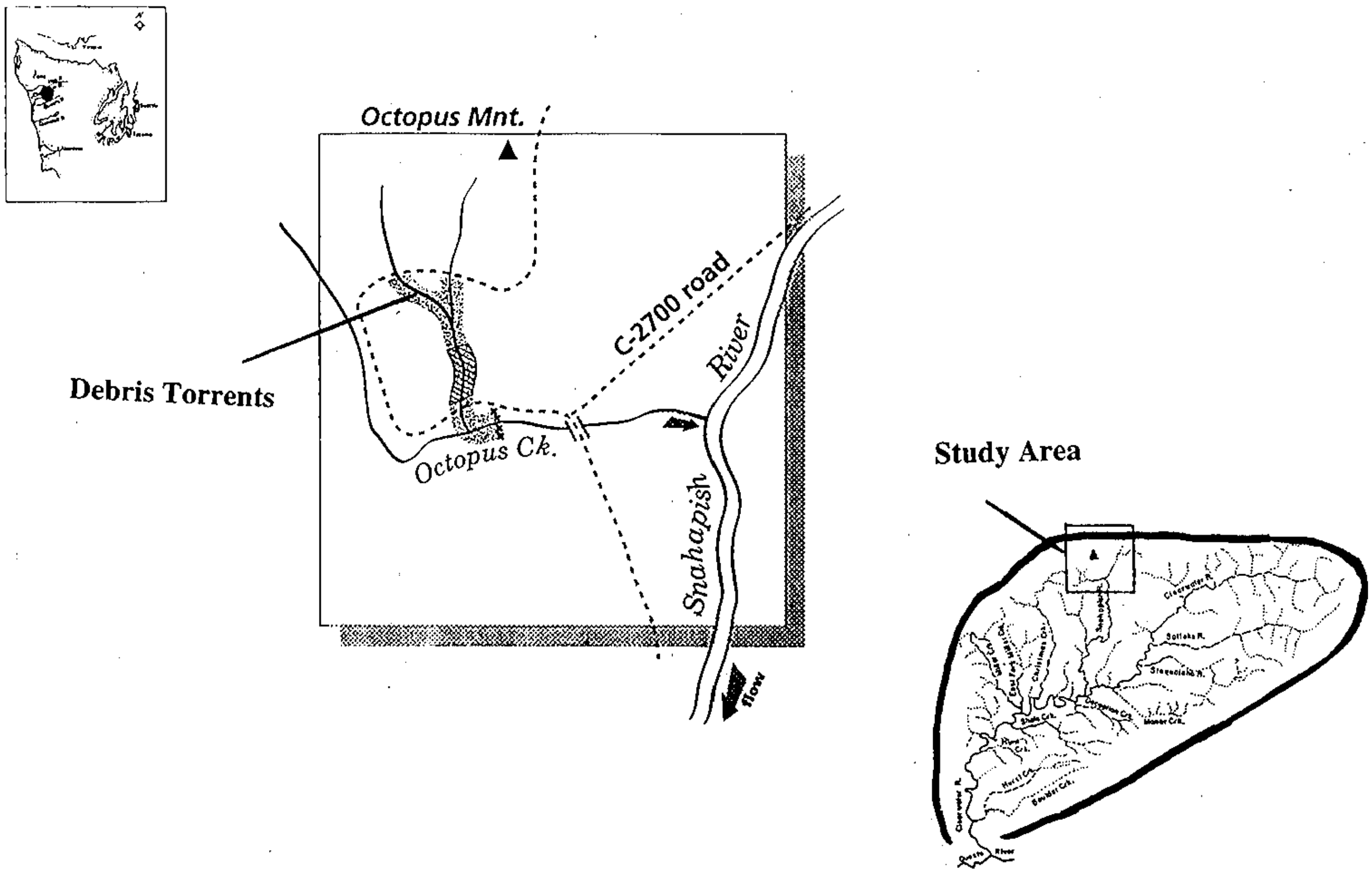

Figure 1. Location of Octopus-B Creek and Debris Torrents.

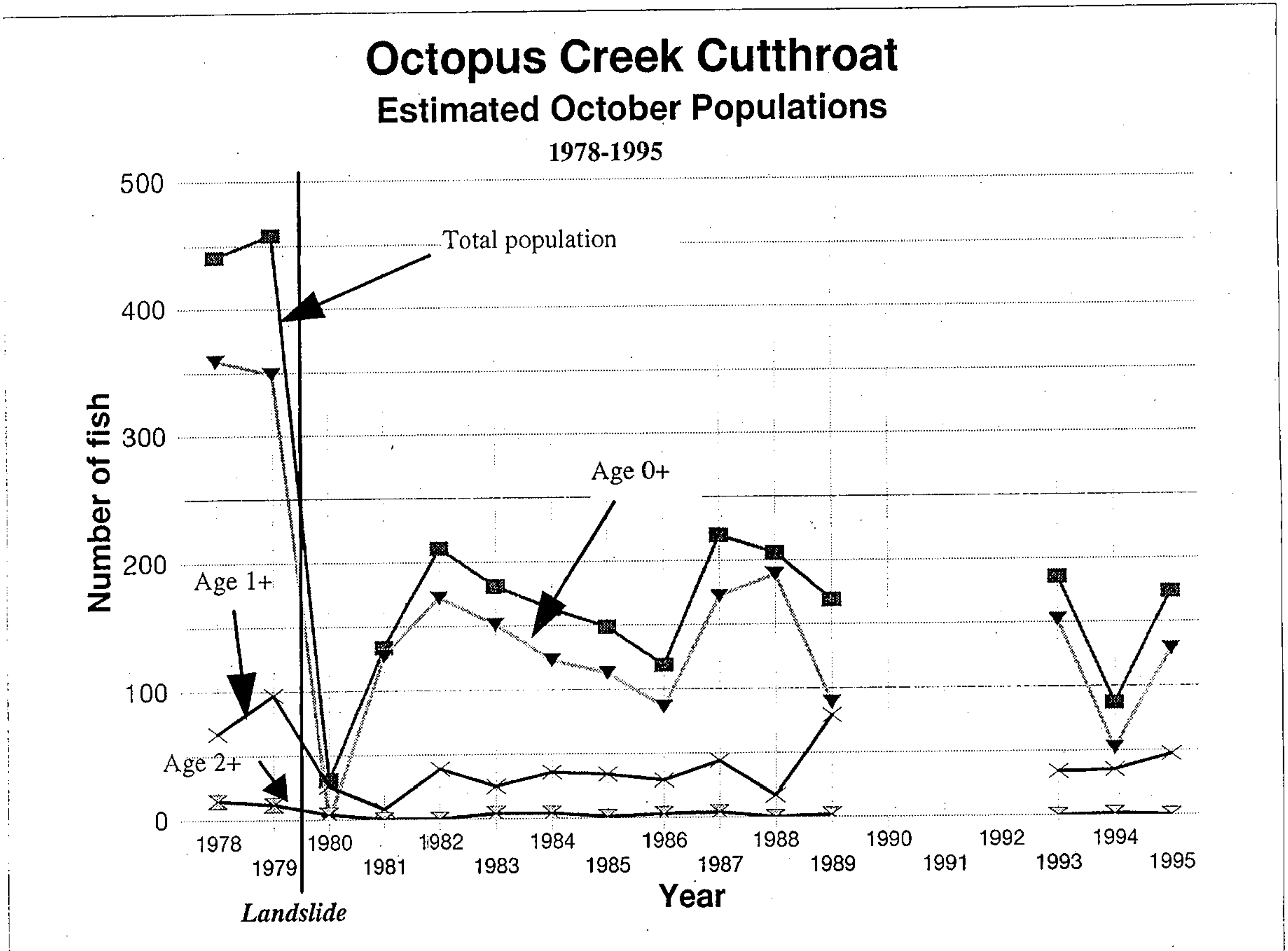

Figure 2. Octopus-B Creek Cutthroat Trout Populations From 1978 thru 1995.

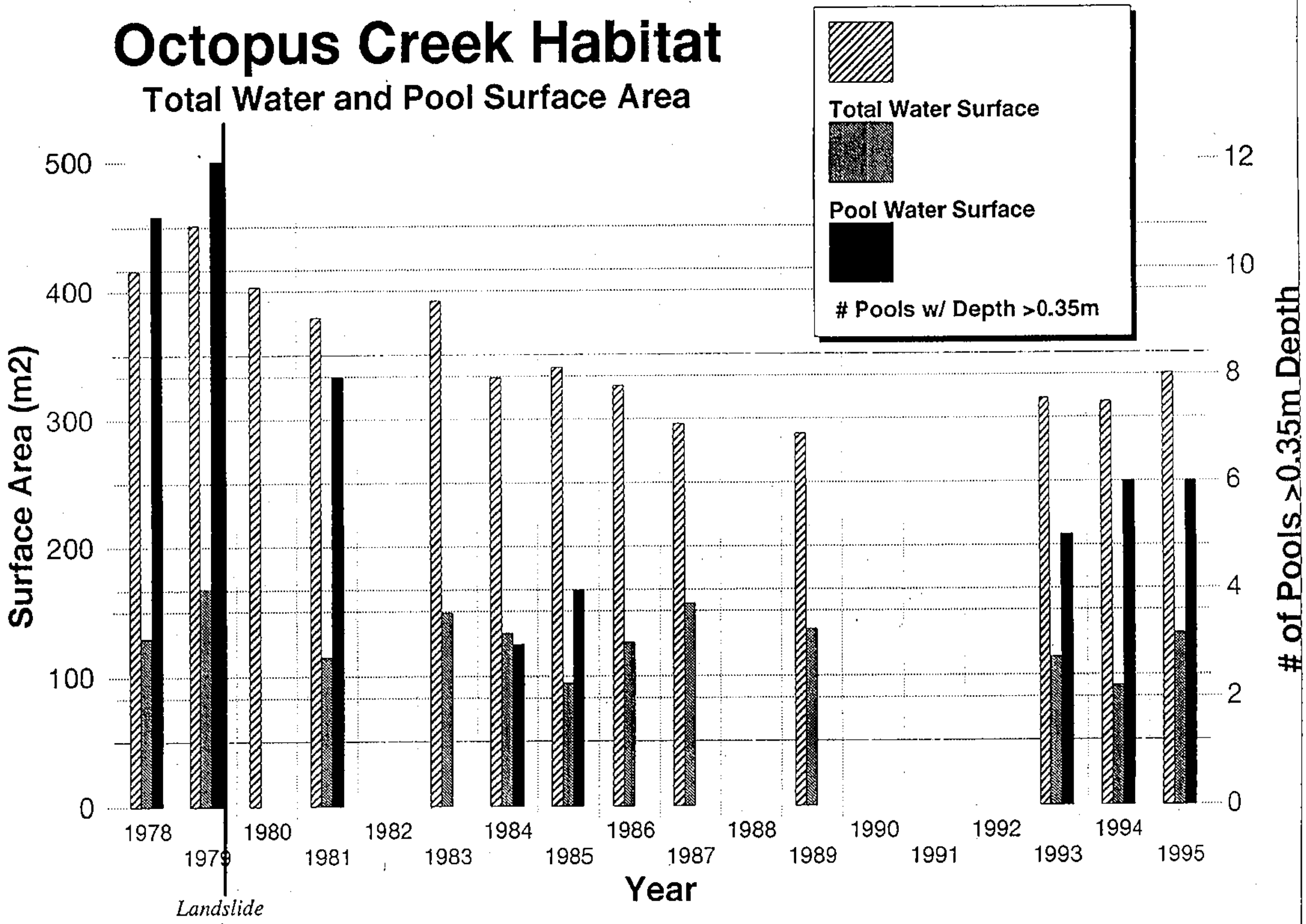

Figure 3. Octopus-B Creek Habitat Conditions From 1978 thru 1995.

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WORKSHOP EVALUATION SUMMARY

Evaluation Responses

Type 4 and 5 Streams Workshop
Sponsored by TFW CMER Committee
October 16, 1996- NMFS Sandpoint Facility

1. **Did the workshop adequately provide you information about type 4 and 5 streams?**

   Rating average (N=16): 3.4

- More info on non-salmonid fish.
- There is always a volume of info not able to be presented, but a good overview of components was presented.
- Lack of representation of eastside ecosystems. There is more than what was presented.
- This was a T3 stream paper presentation.

2. **Did the workshop provide adequate opportunity to exchange information?**

   Rating average (N=15): 3.4

- Good length of time allotted to Q & A.
- Information was presented - not exchanged.

3. **Was the length of the workshop (time) appropriate?**

   Rating average (N=15): 4.5

4. **Please rate the speakers.**

   Rating average (N=12): 3.9

- Bob Bilby was the **BEST.** Some very good; some very boring.
- Good speakers, although some presentation were too technical.
- Kathryn needed to break up 1 hour of slides, especially after lunch. Matt was a little lower because of content/disorganized.
- Afternoon speakers were 5s, morning speakers were 4s.
- Plotnikof: 4; Bilby: 5; Cederholm: 4; Bolton :4; Kelsey: 3; Others: 2.
- The speakers were very good.

5. **How was the content? Was it too technical or not technical enough?**

   Rating average (N=15): 3.6

- Some too technical, especially morning presentations.
- Presentation on sediments was good info but more info from less technical perspective would also have been interesting (practical applications or evaluations of sedimentation issues.)
- A little of both, but that was good.
- Some not specific enough for 4 and 5 streams.
- Highly variable.
- Just right, except section on invertebrates - all theory.

6. **How would you rate the overall quality of this workshop? What would you change?**

   Rating average (N=15): 3.7

- Provide prospectus to audience at time, or before workshop.
- Place some focus on management suggestions.
- Smaller, with more specific focus and opportunity for discussion.
- Length of workshop, including length of each presentation was very appropriate in my opinion. IF each presenter could provide a brief literature citation of pertinent material on subject matter, would be helpful. Some was provided.
- Some presentations not really pertinent to Type 4 & 5 streams.
- Need more eastside speakers.
- I did not learn anything that I didn't already know. This workshop like last week's TFW workshop on Wildlife, is about 2 years premature.
- Invite other current researchers to present preliminary results, and unpublished studies.
- Suggest that the speakers meet to discuss themes and connectivity between their talks. Several speakers prepared Jeff Cederholm for a grand finale related to fish use and food supply, but he did not take the bait!

7. What would you like to see in future CMER workshops?

- More practical applications or suggestions for practical applications for management.
- Focus on Habitat vulnerability for non-fish species.
- Identify key habitat elements.
- More on technical aspects of hydrology and geomorphology . An eastside data workshop.
- More management suggestions, more presentations pertinent to the subject.
- Buffer zone Quality and longevity.
- Redesigning small stream classification.
- Various strategies for riparian buffer management
- A workshop with solid management recommendations.
- Discuss wind throw models.
- Management of aggraded fish streams.
- "How to" workshops on successful experiments with RMZ widths vs. blowdown.
- I think the concept of the "river continuum" should be further examined. It seems to have significance to many of the management issues we are dealing with.
- "Management of Riparian Stands" i.e. conifer succession, silvicultural techniques, partial harvest strategies.
- Either change the word "workshop" to study presentations or put more effort into studys and research that deal with real management problems & possible solutions on T4 and T5 streams. (sic)

8. Would you be willing to work on a committee future workshop?

- 3-No's.
- Perhaps, depending on time. Mid-winter is slower period.
- No. Do not have the time.
- On the above subject, yes! ("Management of Riparian Stands" i.e. conifer succession, silvicultural techniques, partial harvest strategies)

9. Additional comments:

- Smaller, with more specific focus and opportunity for discussion.
- The most to the point informative talks came from Susan and Jeff Cedarhouse (sic).
- I wish the workshop had focused a little more directly on forest practices and less on elements on type 4 &5 streams. I was interested in how watershed practices directly affected the streams.
- More info on buffers- what works, what doesn't, what options do we have, what do we need, what do we want?
- I was glad to be spared the seemingly inevitable policy debate that always occurs...!
- In general, the info exchange was good. Several remarks were made by several authors (Jenelle Black and Rob Plotnikof) that were anecdotal (e.g., no amphibians are found in clearcuts) and not supported by data.
- I look forward to the completion of the TFW landscape project.
- Can we get copies of the technical papers? It was often too much to get down.
- Useful workshop and opportunity to talk to many folks.
- Good facilities.
- Some presentations were technical then they needed to be. Fish presentation was off subject, i.e., not about type 4 & 5s.
- Great job. Wonderful facility.
- This workshop really wasn't a "workshop" it was a presentation of s few studys that was done on T3 streams. It presented some information on T4 & T5 streams effects on T3 streams but otherwise was more of a presentation of studys done on T3 waters. (sic)
- The workshop successfully covered the known science on T4-T5. However, it did not get us much closer to how to craft watershed analysis riparian prescriptions for T4-T5 waters. This is a very difficult issue that is *currently* tying up at least three prescription teams.