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THE POTENTIAL EFFECTS OF CLEARING AND SNAGGING ON STREAM ECOSYSTEMS

...n and Wildlife Service

U.S. Department of the Interior

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>
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ABSTRACT

Clearing and snagging, the removal of obstructions from streams to increase the channel's capacity to convey water, is conducted to drain floodplains for agriculture, to protect citizens from floods, or to maintain navigable waterways.

This review examines the widely held contention that such stream alteration reduces fish populations and is otherwise detrimental to the use of stream ecosystems. It was prepared for use in assessing the ecological impact of clearing and snagging projects. Because of the lack of direct quantitative evidence about clearing and snagging effects, the mechanisms involved in producing the effects are discussed indirectly as potential effects.

Recent concepts of stream ecosystem function relate the functions of different groups of stream organisms to organic matter synthesis and degradation in various sizes and types of streams. This review emphasizes the roles obstructions (typically removed by clearing and snagging) exert on these stream ecosystem functions. Recent literature allows one to identify potential effects of clearing and snagging on stream function. Some effects are obvious when viewed in this process-oriented context while others are less clear. For example, an obvious potential effect of clearing and snagging would be to decrease the rate at which organic matter loads are degraded by the stream system. A less obvious potential effect would be the effects of clearing and snagging on the plankton in streams. The depression of fish populations by clearing and snagging potentially occurs in two ways: 1) through alteration of the nature and abundance of the organisms utilized by fishes as food, and 2) by direct effects on fish behavior (territoriality) and reproduction (spawning areas).

This review identifies some potential ecological impacts of clearing and snagging, but does not yield quantitative predictions of the impacts. Pertinent recent literature on stream ecosystem function is reviewed and has much application in impact assessment. Parameters which could be measured for quantitatively evaluating the ecological effects of specific clearing and snagging projects are described.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

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INTRODUCTION

This report reviews the complex expanding literature of functional stream ecology and assesses the impacts of clearing and snagging on streams. The literature dealing directly with the effects of clearing and snagging is scant and peripheral to other questions. Therefore, the review first provides a current perspective on stream ecosystem function so that questions of impact can be related to this material. Since this perspective includes geomorphic and hydraulic considerations, these basic concepts are included in the discussion. A discussion of potential effects is presented, based on this perspective. Some of the effects are obvious. Other potential effects are less obvious, and firm statements should be avoided or made with appropriate caution.

The intensity of clearing and snagging ranges from the selective removal of single fallen trees or large rocks to the replacement of removed timber with a revetment to restore stream bank stability. Operations of greater magnitude, i.e., dragline excavation to deepen and/or straighten channels may include snagging and clearing as preliminary events, but these are not considered in this discussion. Clearing and snagging as defined in this report refers to removal of obstructions from the stream channel and stream banks, including the removal of vegetation and accumulated bedload material to increase the stream's capacity to convey water. It may include the removal of sediment bars, drifts, logs, snags, boulders, piling, piers, headwalls, and debris. Removal of vegetation from the stream banks and floodplain is considered only when it has an immediate direct effect on the stream.

Clearing and snagging is done for essentially three reasons: 1) to drain floodplains for agricultural development; 2) to protect citizens from floods; and 3) to maintain navigable waterways. Clearing and snagging is done primarily to small (low order) streams when flood protection or wetland drainage is the objective and to large (high order) streams to maintain navigable channels.

It is widely held that clearing and snagging reduces both biotic production and diversity, presumably by reducing habitat diversity. Data from controlled experiments on streams to assess and quantify the mechanisms of reduction, if they exist, have not been published. The values of snags and log structures to fishes in streams appear in the fisheries management literature (Rounsefell and Everhart, 1953; Everhart, et al., 1975). This management literature, however, refers predominantly to trout streams; warmwater streams and rivers are not as well understood. So, while the intent here is to inquire into the potential effects of engineering modifications, the information also has the potential for use in enhancing the fishery or other aspects of stream ecosystems.

A CONCEPT OF STREAM FUNCTION: A GENERAL REVIEW

Over the past decade or so stream biologists have been developing principles which have led to new hypotheses about stream ecosystem functions. Hypothetical-deductive techniques are more possible now, in part, because of new techniques for handling and analyzing large amounts of data, but also because of an appreciation of the power of experimental approaches applied in situ.

The underlying principles of stream ecosystem function are geomorphic; the nature of bedrock and its resistance to erosion, regional geological history such as glaciation, uplift, faulting, serve as the ultimate independent variables controlling channel configuration as well as the chemical composition of water. That is, the broadest constraints to be placed on the range of potential stream ecosystem types are dominated by geological characters. The energy expended by running water on landscapes is dissipated in various ways from headwater streams to the mouths of larger rivers; i.e. slope, current, velocity, turbulence, discharge, and load capacity all change along this gradient so that the channel assumes the most efficient configuration for distributing the energy. The "order" system of stream classification includes some of these parameters (Leopold, Wolman and Miller, 1964; Horton, 1945; and Strahler, 1971).

To the geomorphologist a stream order is specifically defined as a measure of the position of a stream in a hierarchy of tributaries. The highest (geologically youngest) channels from their point of origin to the point of junction with another channel, are designated first order; two first order channels join to form second order channels; second order channels join to form third order channels and so on. Applied throughout a watershed this system numbers the trunk stream leaving the watershed with the highest order designation. The analysis of stream systems using this approach reveals that the sum of the lengths of low order channels exceeds the lengths of high order channels; about 75 percent of all stream lengths are first and second order. However, the high order channels have the highest discharges.

The most concise and recent statements of ecological function of stream systems in this geological context are Vannote (1977) and Cummins (1975), though elements of the view have been appearing for several decades (e.g. Moon 1939 and Allen 1951). Vannote and Cummins (ibid.) recognized that biotic components of these systems ought to be adapted to these geomorphic changes and that the functional components of streams might be expected to vary along the length of a stream in some systematic way. Kuehne (1962) applied this idea to the distribution of fishes in a Kentucky watershed. Harrel, Davis and Dorris (1967) and Harrel and Dorris (1968) compared diversity of fishes and invertebrates to stream order in Oklahoma. Some components, dominant in headwaters, disappear but are replaced by other components with different functions in downstream sections of the river system. Those components which persist in the entire system are generally less dominant in downstream reaches (high order streams) than in the headwaters (low order streams).

An interesting feature of community structure is that the geologically youngest portions of river systems, the headwaters, house some of the evolutionarily most primitive insects derived from forms of terrestrial origin, while the geologically older sections are inhabited by fewer insects, representing the less primitive groups, and by invertebrates, such as molluscs, of marine origin (Ross 1963).

With the possible exception of fishes and molluscs, the faunas of streams and rivers of the United States are poorly known. Perhaps the most troublesome groups amoung the macroinvertebrates are the insects. Yet they are important to the assessment of clearing and snagging impacts on streams and their fisheries. In terms of functional importance in streams and rivers, the immature life history stages rather than adult insects are the objects of attention. Unfortunately, the adults are most often used by taxonomists for identification. Systematic and taxonomic classifications of stream organisms ultimately will be important to our understanding because they denote the species to be the basic evolutionary unit. On the other hand, Cummins (1974) has wisely pointed out, however, that it is not so clear that the species is the basic unit of ecological function. Not all species or life history stages are of equal importance in streams. For example, larvae of different ages feed on different things in different places, and pupae and adult insects may not even be a part of the aquatic system. Furthermore, systematic and taxonomic progress lags far behind present practical needs. Cummins (1975), Boling et al. (1975) and Merritt and Cummins (1978) have established the beginnings of a classification with functional criteria (Fig. 1). The functional view of streams considers that the organic resource base, while always photosynthetic, may enter the stream either from the drainage basin or from producers in the stream itself. Depending on the nature of the resource base, populations of herbivores and carnivores (organic matter processors) are variously abundant. If the inputs are in the form of leaves and other coarse (large) particles, those organisms which can feed directly on them (shredders) operate functionally to reduce the particle size for utilization by collectors and/or export downstream.

Collectors are typically adapted for filtering fine particles from the stream drift or gathering fine particles from the sediments. Scrapers (=grazers), on the other hand, are not adapted for utilization of coarse particles but depend on such organic sources as attached algae, bacteria, or fine particulate organic matter deposited on surfaces. Predator populations subsequently respond to the abundance of prey populations.

THE INTEGRATION OF STREAM CHANNEL STRUCTURE AND ECOLOGICAL FUNCTIONS

The response of biological function to geological definition only is probably not possible since other environmental features (e.g. temperature and light) are also significant. On the other hand, current velocity, substrate and material export seem to be related to stream order designations, and there is general agreement that low order streams (ca. 1-3) in most regions show common characteristics. Mid-order streams (ca. 4-6) show some common transitional characteristics, and high order streams (ca. 6-12) show another set of common features. Figure 2 (from Cummins, 1975) is a hypothetical representation of the sort of functional shifts expected to take place along the length of a river system.

The low order streams (1-3, cf. Fig. 2) in most ecoregions are covered by the canopy of the riparian forest. This cover has two functional effects. First, light intensity and temperature are reduced and second, the canopy provides the primary source of coarse particulate organic matter (CPOM) as leaves and twigs fall into the stream. The leaves do not move downstream very far, rather they aggregate to form "packs" of coarse material on the upstream sides of boulders, branches and other obstructions (i.e. snags). This material is the primary energy resource base for the headwater stream ecosystem (Fisher and Likens, 1972; Cummins et al., 1973; Iversen, 1973).

Upon falling into the stream, the leaves exhibit an initial rapid loss of weight, presumably the soluble and easily leached organic fractions. McDowell and Fisher (1976) found that nearly 17% of litter input was released to the water as dissolved organic matter (DOM) within three days of entry. Bacteria and fungi invade leaves of any given species rapidly, and further weight loss (decomposition) takes place at a rate which is dependent upon temperature (Petersen and Cummins, 1974). Hynes and Kaushik (1969) showed that the nitrogen and protein content of leaves in controlled laboratory experiments increased in the early stages of decomposition if a source of inorganic or organic nitrogen was added. Hynes (1970) suggested that other nutrients, such as phosphate, can be implicated in this effect. Presumably, the activities of the microflora increase available protein in the resource. Aquatic insect detritivores, both shredders and scrapers, are likely to utilize the "enhanced" resource, but the relative importance of the leaf itself and/or microflora as food has not been fully resolved. Shredders, however, cannot grow on sterile leaves, and different microbial species on leaves yield different growth rates by some detritivores (Baerlocher and Kendrick, 1973).

Ultimately the CPOM is respired, deposited in sediments, converted into growth of detritivores (invertebrates and/or microflora), or exported downstream. The particles exported downstream are generally much smaller, i.e. fine particulate organic matter (FPOM) (including invertebrate feces). The fate of FPOM is a subject of speculation, but the alternatives include: deposition and further decomposition (anaerobic), utilization by filter feeding organisms (collectors), or further aerobic degradation by microflora (Kaushik and Hynes, 1968 and 1971; Cummins et al. 1973; and Petersen and Cummins, 1974). Generally, more organic matter enters the stream and is respired than is produced in the stream, resulting in photosynthesis-community respiration ratios

(P/R) of less than one. Odum (1956) used unity as the distinction between autotrophic and heterotrophic systems. Low order streams are typically heterotrophic, but in some cases, depending on season or geographic region, they may be autotrophic.

When the stream has no canopy cover, as may be the case in the desert, steppe and in very high altitudes and latitudes, then CPOM from trees is reduced, and light penetration may support greater rates of photosynthetic production (P/R may exceed 1.0). Streams which have been channeled and cleared of riparian forest may also have P/R values greater than 1.0 (Gelroth and Marzolf, 1977).

The intermediate sized streams (orders 4-6) are less dependent upon direct terrestrial inputs and more dependent upon photosynthetic organic production *in situ* and upon the input of FPOM from upstream. The ratio of photosynthetic production to community respiration is often greater than one (P/R > 1) in contrast to the headwaters above and large rivers below in which respiration exceeds primary production (P/R < 1). These intermediate sized running waters can be characterized as: Producer-grazer-FPOM-bacteria-collector systems. Scrapers (= grazers) and collectors inhabit substrates provided by snags and debris in streams and filter and gather the suspended load from those sites.

Large rivers (orders 6-12, Fig. 2) tend to be turbid with heavy sediment loads -- the culmination of all the upstream processes. These systems undoubtedly possess well developed plankton communities, although respiration still exceeds photosynthetic production. These rivers could be characterized as FPOM-bacteria-collector systems.

Fish populations generally show a transition from coldwater invertivores, to warmwater invertivores and piscivores, to planktivores (Fig. 2)

Figure 1. Diagrammatic representation of the structure and function in the headwater sections of stream ecosystems. The photosynthetic fixation of carbon into organic compounds upon which the stream depends takes place primarily out of the stream proper on the landscape of the watershed. In such headwater systems algae and vascular hydrophytes contribute minimally to the organic flux of the system. The organisms shown are merely possible representatives of the functional groups that have been identified. (Modified from Cummins 1973, and Cummins 1974).

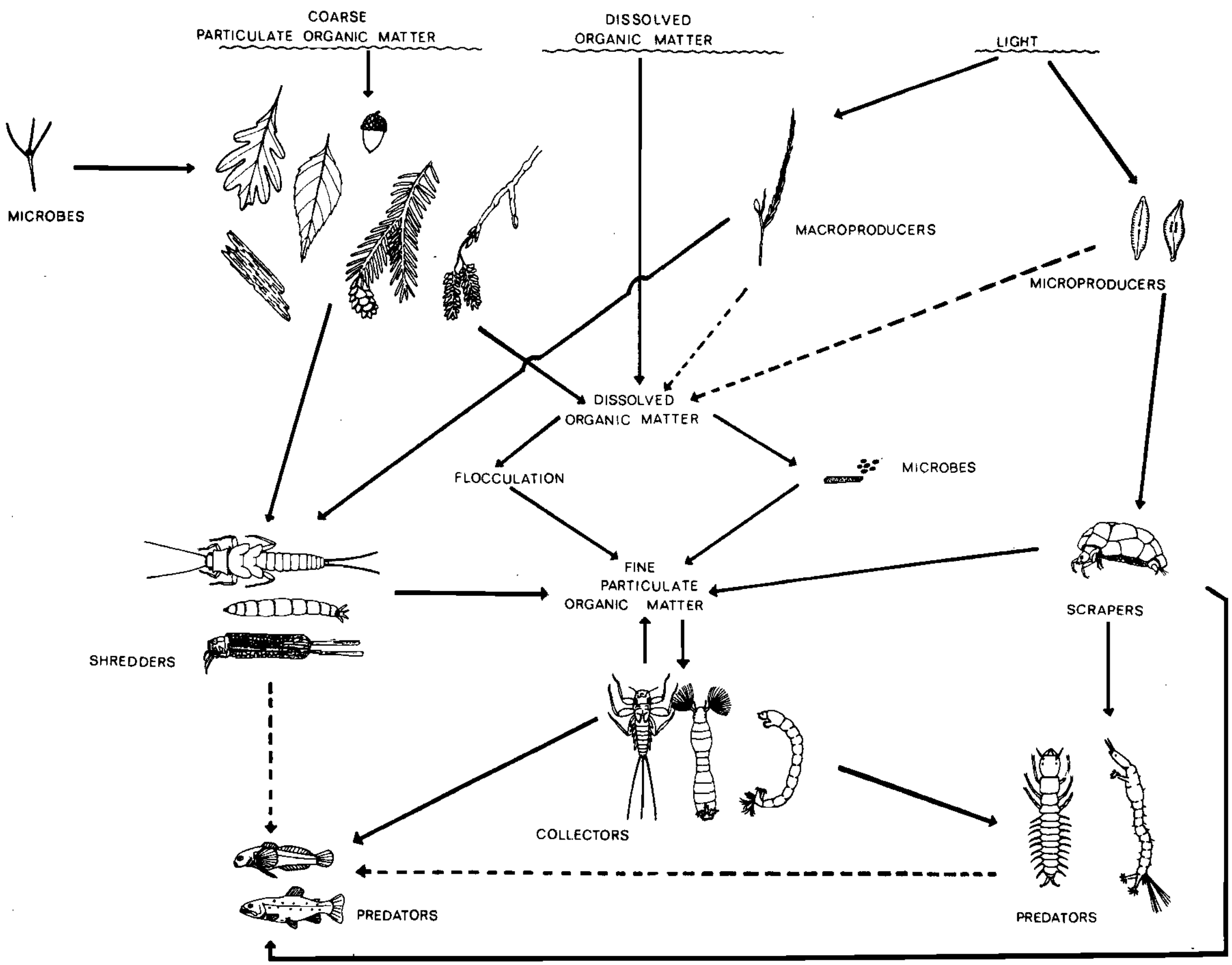
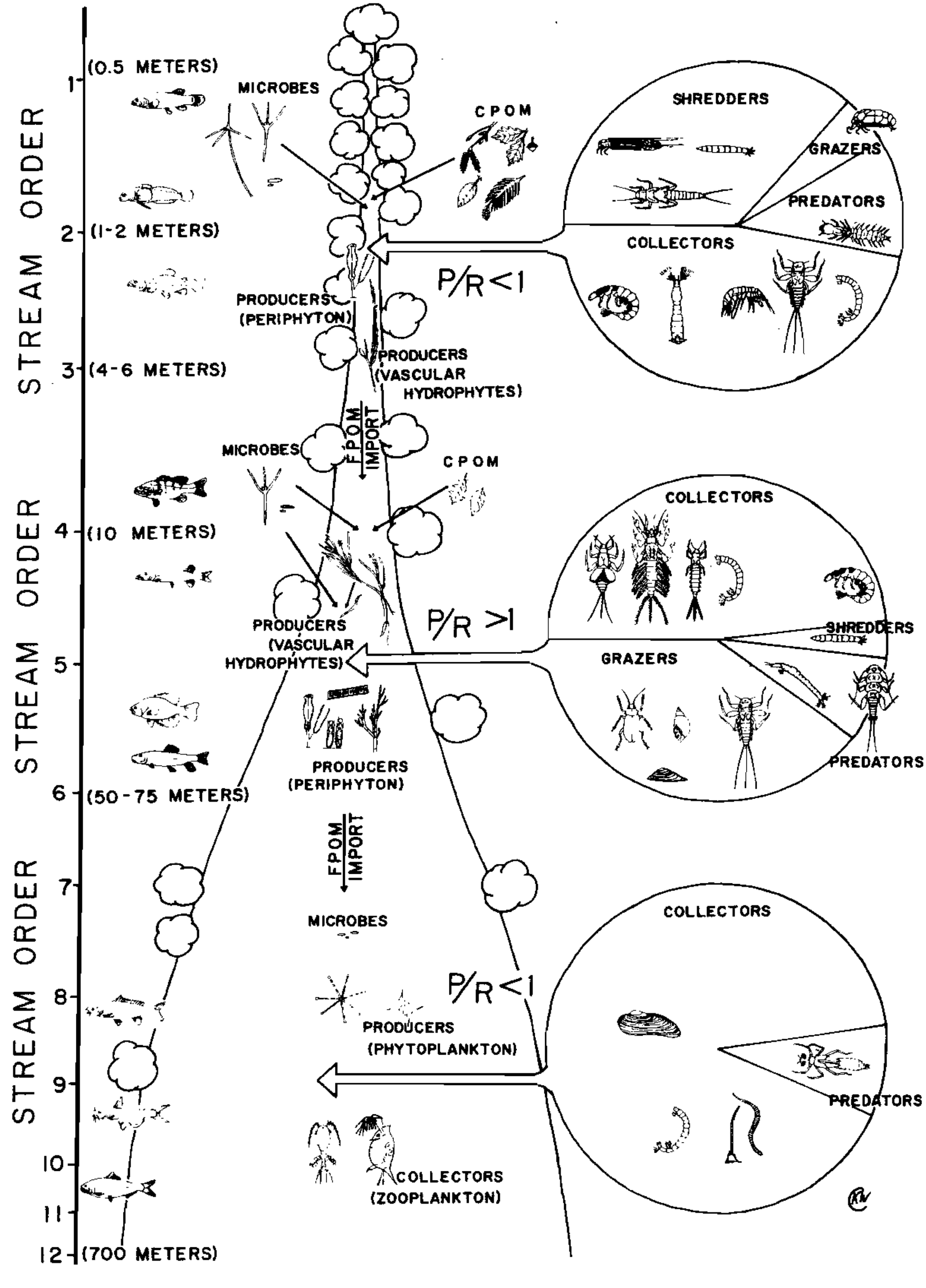

COARSE
PARTICULATE ORGANIC MATTER
DISSOLVED
ORGANIC MATTER
LIGHT
MICROBES
MACROPRODUCERS
MICROPRODUCERS
DISSOLVED
ORGANIC MATTER
FLOCCULATION
MICROBES
FINE
PARTICULATE
ORGANIC MATTER
SHREDDERS
SCRAPERS
COLLECTORS
PREDATORS
PREDATORS

Figure 2. Theoretical diagrammatic representation of certain changes in structure and function in running water ecosystems from headwater to the mouth (stream order shown at the left). The organisms pictured are merely possible representatives of the functional groups shown. The decreasing direct influence of the adjacent terrestrial component of the watershed and increasing importance of upstream import from the headwaters (orders 1-3) to the mouth is a basic feature of the system. Coupled with this is a decrease in shredders and an increased dominance of collectors. The mid-region of the river system is seen as the major region of primary production (growth of green plants) and associated grazer populations (orders 4-6). The lower reaches become more turbid with increased importance of plankton (orders 7-12). The fishes are dominated by invertivores in the headwaters, and piscivores in the larger sections with planktivores important in the highest order.



STREAM ORDER
STREAM ORDER
STREAM ORDER
1
2
3
4
5
6
7
8
9
10
11
12
(0.5 METERS)
(1-2 METERS)
(4-6 METERS)
(10 METERS)
(50-75 METERS)
(700 METERS)
MICROBES
CPOM
SHREDDERS
GRAZERS
PREDATORS
COLLECTORS
P/R<1
PRODUCERS
(PERIPHYTON)
PRODUCERS
(VASCULAR
HYDROPHYTES)
FPOM
IMPORT
MICROBES
CPOM
COLLECTORS
P/R >1
SHREDDERS
GRAZERS
PRODUCERS
(VASCULAR
HYDROPHYTES)
PREDATORS
PRODUCERS
(PERIPHYTON)
FPOM
IMPORT
MICROBES
COLLECTORS
P/R<1
PRODUCERS
(PHYTOPLANKTON)
PREDATORS
COLLECTORS
(ZOOPLANKTON)

GEOGRAPHICAL CONSIDERATIONS

The flow characteristics and chemical composition of streams are influenced further by climate (precipitation, evaporation, seasonality) and by vegetation which regulates such water related phenomena as: run-off, groundwater infiltration, and evapo-transpiration. Vegetation effects are more proximate to many biotic phenomena than the geological constraints and thus offer potential as controlling variables. Unraveling the complexities of these interactions is one of the objectives of regional plant ecology, (Kuchler, 1973). Full understanding of watershed phenomena is difficult, and generalities are rarely applicable to all regions where climate and soils yield different vegetational responses.

Bailey (1976) has produced a classification of vegetation ecoregions of the United States which incorporates the various influences of landforms, climate, soils and vegetation. Investigation of the role of logjams and debris in streams should consider this sort of regional variation because the vegetation is the raw material for the "jams", "snags" and "debris".

Stream organisms depend on pulses of organic matter entering streams from the watershed. The rate at which this material is utilized by stream organisms is dependent upon characteristics of the stream, but it also depends upon the nature of the source material. For example, leaves from different deciduous tree species are degraded at different rates under the same conditions. Debris from conifer forests differs from that from deciduous trees and that from grasslands and deserts, and though the effect has not been studied, stream organisms certainly can be expected to vary in other ways in their responses to stream processes.

This conceptual view of stream function, however, has geographical generality. The approach is applicable to headwater streams wherever there is a forest canopy over the stream. In the Pacific Northwest the existence of very large woody organic debris in streams has been shown to be related to the history of the timber stand through which the stream flows. Woody debris, in some cases the boles of large trees, lends stability to the stream channel and serves to retain finer particulate materials in the headwaters where further degradation and utilization occur. The amount of material in these northwestern streams seems greater than exists elsewhere, and differences in the functional significance may be a matter of increased scale. That is, the amount of material in these streams is orders of magnitude greater (Triska and Sedell, 1975; Sedell and Triska, 1977; and Anderson, Sedell, Roberts and Triska, 1977).

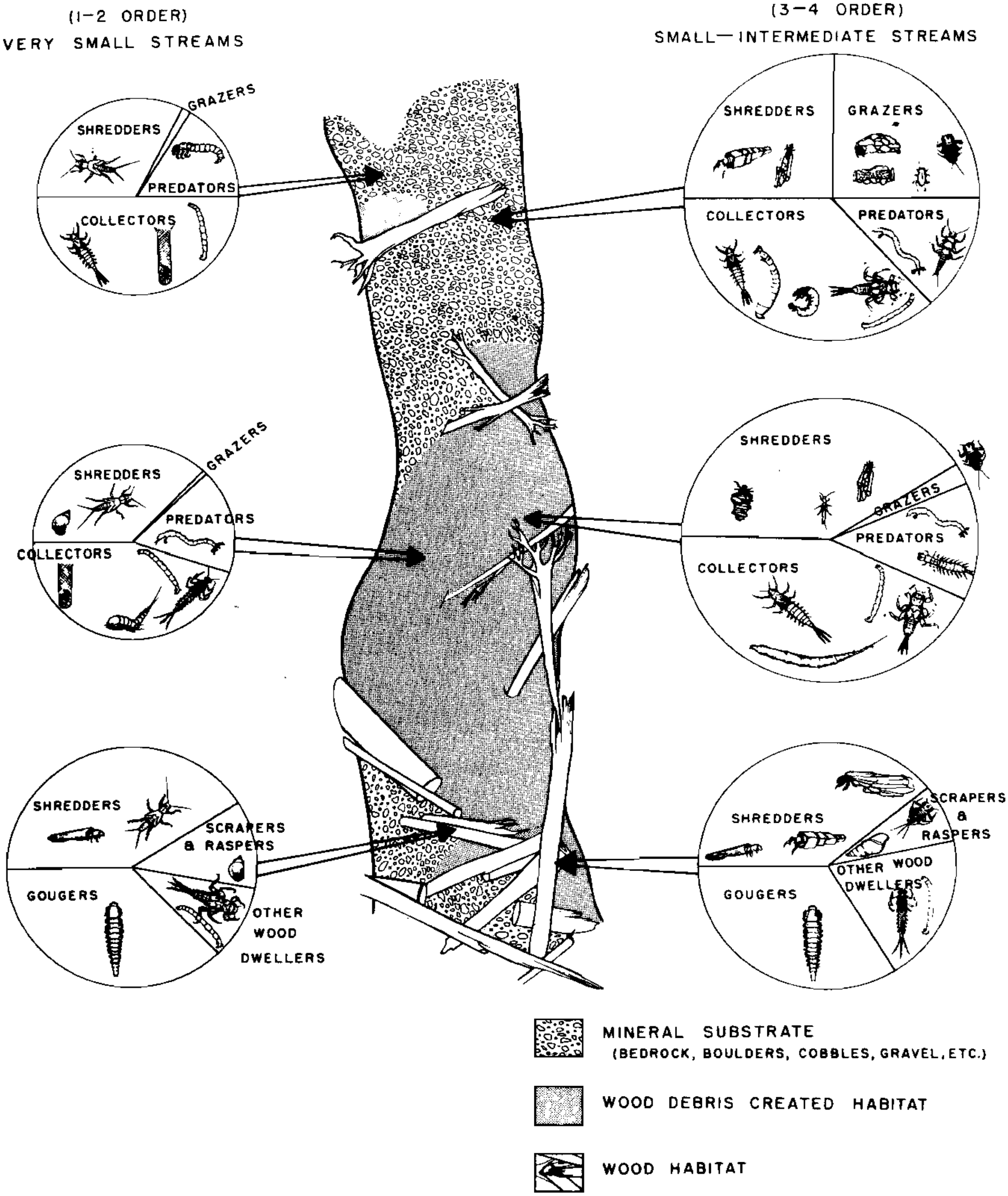
Gillespie (1977) suggests that, in the low gradient Satilla River of the coastal plain of Georgia, the availability of snags provides important substrate for macroinvertebrates. Therefore, the absence of this substrate would severely limit macroinvertebrate habitat. Ninety percent of the macroinvertebrate biomass was associated with the snags (ibid). The Satilla River is a mid-order stream so the observations should be carefully extrapolated to the headwater streams. Nevertheless, in low gradient streams, CPOM retention is less significant, and the availability of a substrate free from excessive siltation increases in significance for macroinvertebrate collectors. Sandy and muddy streams may exhibit similar substrate restrictions because of the instability of sand substrates. The substrates associated with debris dams and logjams is unique and may contribute to stream ecosystem function (Fig. 3).

Observations from streams with no canopy cover are too few to either extend or refute the generality of the concept. Nevertheless, the relative importance of structural and functional elements unquestionably is a response to differences in the organic resource base. An understanding of the nature of the organic matter resource is essential to understanding the function that any structural or biotic component performs in the operation of the ecosystem (Minshall, 1967; Nelson and Scott, 1962).

Questions and comments relative to the impact of clearing and snagging operations on streams and rivers will likely lead to useful measurements and consideration if they are communicated in this functional context.

Figure 3. Direct and indirect role of logjams and debris in influencing substrate types in streams. (From Sedell, personal communication).

FORESTED STREAM HABITATS



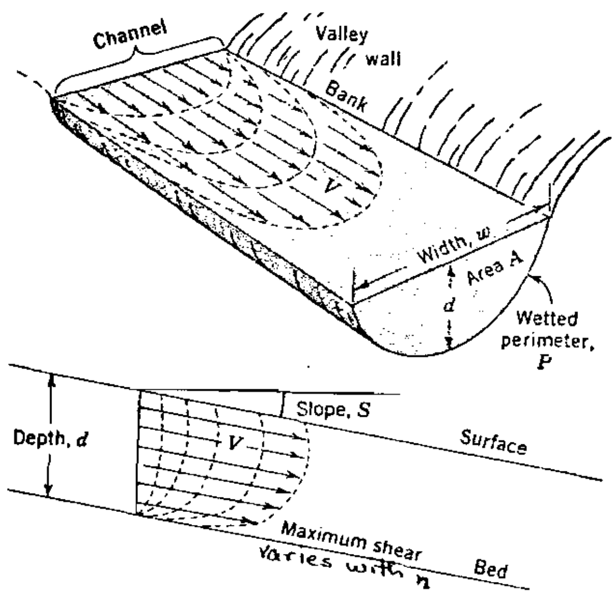
EFFECTS OF CLEARING AND SNAGGING

HYDRAULIC PROCESSES

Clearing and snagging is performed to improve the hydraulic characteristics of the stream channel. The basic equation of hydraulic engineering is the Manning equation:

$$v = 1.49 \frac{R^{2/3} s^{1/2}}{n} \quad \text{(for English units)}$$

$$v = \frac{R^{2/3} s^{1/2}}{n} \quad \text{(for metric units)}$$



where v is mean velocity, R is hydraulic radius (cross sectional area divided by wetted perimeter ... in wide shallow streams it is approximated by mean depth), s is slope and n is a roughness coefficient.

In practice, the relative roughness of a channel is determined by consideration of flow depth as well as bed particle size. As depth increases, bed particle size becomes less a factor. Thus, in deeper channels bed features are less of a determinant of resistance to flow.

In high order streams where clearing and snagging is practiced, the roughness coefficient will be reduced less than in a comparable operation in a small stream. Consequently, clearing and snagging will have little effect on the capacity of a high order stream to convey water. The removal of obstacles from large streams is likely, therefore, to be justified only on other grounds, such as navigation.

The estimation of roughness coefficients is a matter of professional judgment since the data for calculation (slope, depth and velocity for flows of different magnitude) are rarely available. This means, essentially, that the estimation of how a particular clearing and snagging operation will alter the roughness coefficient for a particular channel is a matter of judgment. There are no quantitative tests of the accuracy of predicted alterations in roughness coefficients. Leopold et al. (1964) discuss the features of stream channels which offer resistance to flow (dissipate the stream's energy) and conclude that three classes of resistance are involved: Skin resistance (most affected by the size and character of the material in the bed and bank), internal distortion resistance (includes bars, bends, individual boulders and bank protuberances) and spill resistance (energy dissipated by local waves and turbulence). The differentiation between these potential causes of flow resistance is difficult; quantitative study has been limited to laboratory experiments. The range in magnitude of the roughness coefficient, n in the Manning equation, appears to be from about 0.02 to 0.10. Barnes (1967) provides a set of color photographs of stream channels for which roughness coefficients have been determined. The purpose of these photographs is to provide a visual (empirical) guide to the estimation of this parameter. Morisawa (1968) provided a readable introduction to stream geomorphology and gives the following table of roughness estimates:

Values of Roughness Coefficient n for Natural Streams

Description of stream	normal n
On a plain:	
Clean straight channel, full stage, no riffs or deep pools	0.030
Same as above but with more stones and weeds	0.035
Clean winding channel, some pools and shoals	0.040
Sluggish reaches, weedy, deep pools	0.070
Mountain streams:	
No vegetation, steep banks, bottom of gravel, cobbles, and a few boulders	0.040
No vegetation, steep banks, bottom of cobbles, and large boulders	0.050
Floodplains:	
Pasture, no brush, short grass	0.030
Pasture, no brush, high grass	0.035
Brush, scattered to dense	0.050-0.10
Trees, dense to cleared, with stumps	0.150-0.04

Source: Data adapted from Chow (1959), pp. 112-113.

In summary, the hydraulic effects of removal relate to reducing the roughness coefficient and the wetted perimeter and increasing the cross sectional area. Altering these will influence current velocity which in turn will influence the patterns of erosion and deposition and the amounts and quality of suspended loads (Campbell et al., 1971). In the Pacific Northwest the removal of woody debris may reduce the stability of the channel (Swanson and Lienkaemper, 1977). Subsequent effects downstream are complicated by phenomena affecting the entire watershed. It would be difficult to observe the effects on a sixth- or seventh-order stream resulting from clearing and snagging one of its first- or second-order tributaries. Typically, the environmental impact assessment process, since it deals with single events, cannot effectively deal with hydraulic effects downstream. Questions of this sort, however, should be asked relative to other proposed or potential manipulations in the watershed.

BIOLOGICAL PROCESSES

There is scant literature dealing directly with the ecological effects of clearing and snagging, none of it in the refereed literature. Potential ecological effects of clearing and snagging are identified from the point of view of stream function. Published results are used here as a basis for reasonable, but untested, hypotheses or predictions. This is more an exercise in question development rather than an authoritative review. The coverage is not intended to be definitive or, for that matter, useful for all conceivable situations.

The likelihood for validity of the following potential effects is high enough that the burden of rejection will lie with those who seek to alter the stream by clearing and snagging. The potential effects should be stated as hypotheses to be tested in specific situations since they identify valid general concerns. If each clearing and snagging operation were considered as an experiment, appropriate questions asked and appropriate controls established, there would soon be a more reasonable basis for deciding about the detriment or benefit of such man-induced changes in streams.

Potential Effects on Primary Producers (Algae and Macrophytes)

Removing the Canopy. When the canopy over low order streams is reduced because of clearing the riparian forest along the stream, the light intensity reaching the stream will increase and so will the temperature of the stream (Ringler and Hall, 1975). Light typically is the limiting factor in photosynthetic production in these situations so increased insolation will also result in increased photosynthesis and a greater magnitude of diurnal oxygen fluctuations (Gelroth and Marzolf, 1977).

Hynes (1970), Kaushik and Hynes (1971), Petersen and Cummins (1974) and Fisher and Likens (1972) consider that the leaves falling from trees over and near a stream supply a highly significant fraction of the energy and material for the biological activities in low order streams. The shading effect from trees is probably secondary. The removal of shade may result in an increase of production in the stream itself, but the nature of the organic matter resulting from the photosynthesis of algae is very different in quality from that produced by trees. Organic matter produced from the two sources will require very different consumer components in the stream system. The fauna of headwater streams are adapted to the material from the trees, at least in those streams which have been investigated closely. The faunal changes which occur with a shift to autotrophic algal production have not been investigated.

Alteration of Plankton Production. Removal of logjams and debris dams which slow current velocities will diminish the likelihood that plankton algae populations will be able to maintain themselves in the increased current. Such production will no longer be possible, and the nature of the exported nutrient material will be changed, i.e. materials that would otherwise have been incorporated into algal production will be diverted elsewhere.

The relative importance of a planktonic component in streams is not well understood. Hynes (1970), Blum (1956) and others have given ample evidence that larger more sluggish rivers do have a plankton component. The factors which determine the proximity to the headwaters that plankton algae can occur are not well understood, and there are open questions about the source of the cells that become planktonic. Whatever the ultimate resolution of these questions, it will undoubtedly involve: 1) the existence of slow water refugia for planktonic existence, and 2) the erosion of benthic taxa which are adapted to continued existence as plankters (Swanson and Bachmann, 1976).

Alteration of Substrate Type. The sediments deposited around obstructions which would be removed by clearing and snagging are often the substrate for specific kinds of benthic algae (Round, 1964). Clearing and snagging, then, results in the erosion and export downstream, not only of the substrate, but also of algal populations growing on it. Similarly, the substrate provided by woody debris itself is inhabitable by algae (Sladecekova, 1962; and Round, 1964). If the material is removed, the kinds of algae specific for these substrates will no longer be present.

Since all of these effects on algae occur at the base of the food resources for scrapers (= grazers) and collectors of fine particulate organic matter, higher trophic levels are therefore subject to potential influence. If the effect on higher trophic levels is not direct (which it is bound to be in some cases) then changes in competitive advantages, growth rates (food quality and temperature) and reproductive success are likely to have additional long range effects.

Alteration of Habitat for Rooted Macrophytes. In cases where the sediments deposited around obstructions to be removed by clearing and snagging serve as substrate for rooted macrophyte growth, the removal of the obstruction will result in the erosion of the substrate and the destruction of the macrophytes. Epiphytes, plankton and fishes which make up communities associated with macrophyte beds would disappear. The existence of macrophyte beds may be a general condition in mid-order streams, and their existence should always be considered (Westlake, 1975).

Potential Effects on Decomposition and Organic Matter Processing

One of the most significant functional roles of obstructions in streams (particularly low order streams) is the retention of particulate organic matter. When this coarse material is retained in the headwaters, fungal and bacterial populations can invade it and begin the degradation process immediately. If the material is not retained, it is obviously exported downstream. Typically, the leaves which fall into the stream are maintained near the point where they fall by just such obstructions as those which are removed by clearing and snagging operations. Headwater streams are usually more turbulent than higher order streams in the drainage basin, and reoxygenation by physical aeration is more effective at maintaining oxygen in equilibrium with the atmosphere. The headwater stream, therefore, is more able to withstand decomposition with depression of dissolved oxygen. If, on the other hand, the organic material is exported downstream and deposited in sedimentary areas which are not adequately reoxygenated, then those areas will become anaerobic and exert a higher oxygen demand on the stream. The likelihood of organic matter deposition in poorly aerated areas is very great since deposition and low exchange coefficients are both associated with low current velocity. It appears, therefore, that the CPOM retention feature is one of the critical roles of obstructions, serving to reduce organic loading of higher order reaches downstream.

Potential Effects on Macroinvertebrates

The role of macroinvertebrates in the processing of coarse particulate organic matter is closely geared to the retention of the material in low order streams and the invasion of the material by a microflora which is also used as food by the invertebrate detritivore. Ingestion of decomposing leaves will be accompanied by ingestion of the decomposers. Iversen (1973) discovered that the nitrogen content of beech leaves increased during the first month in a stream in association with microbial invasion of the leaves. A trichopteran shredder which fed upon the leaves did not begin to do so until the nitrogen content had increased. The macroinvertebrates which utilize the coarse particulate organic matter (CPOM) are known functionally as shredders. The crane fly larva, *Tipula*, some limnephilid caddis flies and some plecoptera are examples. One of the results of feeding activity by shredders is that large particles are broken into small particles (including shredder feces) which are exported downstream and utilized by other elements of the system. There is a higher ratio of shredders to scrapers in the headwater reaches; collectors, which use finer particles of organic matter in transport, are more abundant in higher order reaches.

Direct Effect of Snag Removal on CPOM Retention. The effects of clearing and snagging on macroinvertebrates which utilize coarse particulate organic matter are closely tied to the entire association (CPOM, microflora and macroinvertebrates) which disappears when the obstructions which retain them in the stream are removed. This is potentially the mechanism of substantial changes in the basic structure and functioning of stream ecosystems. Changes threaten ecosystem integrity.

Indirect Effects by Changes in Sediments. The fine sediments which will be eroded if obstructions are removed (Triska and Sedell, 1978) also serve as specific substrates for burrowing invertebrates, e.g. annelids, chironomids, burrowing mayflies, dragonflies, amphipods, crustacea, and pelecypod molluscs (Hynes, 1970; Anderson et al., 1977). Obviously, the erosion of the habitat will stimulate the emigration of these populations.

Detritivorous invertebrates utilize the organic matter and/or the microflora of fine sediments as a food resource (Chapman and Demory, 1963; Boling et al., 1974; and Anderson et al., 1977). The production of invertebrates in depositional areas can be substantial and in some cases greater than that of riffles (Idyll, 1943; and Nilson and Larimore, 1973). If utilized as food by bottom feeding fishes, then loss of these groups can represent a substantial resource base reduction for some species in the fishery (Klaassen and Marzolf, 1971; and Allen, 1942).

Direct Effect of Snag Removal on Macroinvertebrates. Collectors, such as net spinning caddisflies and siphlonurid mayflies, scrapers, e.g. heptageniid mayflies, and insect predators, e.g. stoneflies and hellgrammites are all common inhabitants of logjams and debris dams (Hynes, 1970; McLachlan, 1970). In larger streams and rivers where sand substrates are unstable, woody substrates are the only habitat available for these forms. It is axiomatic that the destruction of habitat causes the emigration or death of the organisms dependent on the habitat. Since these invertebrate forms are often the most important food forage items for fishes, any shift or reduction in their populations will alter this portion of the resource base and reduce the productivity of the existing fish populations to the extent that they are dependent upon invertebrates as a food resource (e.g. Hansen and Muncy, 1971). Other species are likely, therefore, to gain a competitive advantage in the altered situation. The fact that fishes tend to be opportunistic in their feeding habits may allow some latitude if alternative food sources are available, say, from terrestrial habitats.

Potential Effects on Fishes

The preceding paragraphs demonstrate that stream ecosystems cannot be fully considered without attention to the invertebrate fauna and food resources which support these fauna. Fishes, of course, respond to changes in the nature of their food resources, but the existence of vegetation and debris has effects on fishes other than those mediated through trophic structure.

Cover and Shelter. The evidence is strong that the availability of cover and shelter has distinct influences on fishes in streams. Boussu (1954) and Elser (1968) discuss the responses of trout populations to the introduction of artificial structures. In both of these cases the removal of natural cover was implicated in the reduction of trout populations. Butler and Hawthorne (1968) and McCrimmon and Kwain (1966) have made observations of individual trout responses to the existence of cover and to the levels of activity and use of cover at different light intensities. Saunders and Smith (1962) identified shelter as a consideration when altering streams to enhance trout production. Hickman (1975) has assessed the population responses of some warmwater species to the availability of cover in a Missouri stream. The total fish population at stations without snags was 25 percent lower than at stations with snags. When the analysis was restricted to catchable fish there were 51 percent fewer fish at stations without snags. Funk (1955) discussed the movements of warmwater fish in streams and related his observations, in part, to the position in the stream (headwaters vs. lower reaches) and to physical conditions in the stream. Congdon (1970) and Funk and Robinson (1974) further discussed the changes in fish populations in rivers which have been channelized.

Attraction to shelter seems to be more pronounced in larger streams and rivers where, according to Hynes (1970) fishes of many species congregate "near obstructions, in bays and along the banks, or anywhere else that offers some shelter." The flathead catfish, as it grows larger, is associated with water of increasing depth and larger shelter objects. Larger specimens are associated with fallen trees (Minckley and Deacon, 1959).

Territoriality and Orientation. The presence of fixed reference points in streams seems to aid fish in maintaining their position in the stream. Newell (1957) showed that trout are sedentary in streams and Larimore (1954), Scott (1949), Muncy (1958) and Hansen and Muncy (1971) have provided similar information for centrarchids and catfishes. Hynes (1970) comments that many species of fish, which are territorial in running water cease to be so when the flow is slowed or stopped.

Clearly, then, fish behavior in response to substrate features, territoriality, and response to shelter may be of overriding importance controlling the response of fish to clearing or snagging of stream channels. If fish behavioral response to such changes is simply to leave the area because they are no longer able to orient to the habitat (or for other reasons associated with territoriality), it is conceivable that all of the hypothetical food-related influences on fishes mentioned earlier in this report are immaterial to the existing fish fauna. Feeding considerations, then, would only apply to the fish fauna which develop in the stream after alteration. Mitigation structures such as deflectors or wing dams can be used to restore some of the habitat features which adversely influence fish behavior (Lund, 1976).

Spawning Areas. The spawning activity of a great many fish species is related to the character of the sediments. Clearing and snagging activities alter stream current velocities and consequently alter sediment particle distributions. For some fishes, e.g. catfishes, the cavities provided by logs are used directly as spawning sites. If spawning areas are obliterated, even if fishes remained in the stream, their reproductive capacities would be reduced.

SUMMARY AND CONCLUSIONS

Although there is a lack (in the literature) of quantitative ecological data on the direct effects of clearing and snagging in streams, it is possible to predict the potential effects from recent concepts of stream ecosystem function. These concepts relate ecological functions to geomorphic processes and consider the source and utilization of the organic resource base (from photosynthesis) in different sizes and types of streams. It is possible to develop geographical generality by utilizing general concepts of stream ecosystem function for prediction.

Hydraulic processes in streams are generally described by the Manning equation to develop the roughness coefficient (n). Clearing and snagging is practiced to reduce the value of n.

Potential effects of clearing and snagging on primary producers (algae and macrophytes) include: 1) removing the vegetative canopy thus admitting greater light intensity to photosynthetic organisms and raising water temperatures; 2) altering plankton production by increasing stream velocity; 3) altering substrate; and 4) altering rooted macrophyte habitat. Potential effects on decomposition and organic matter processing include reducing the capacity of the stream ecosystem to retain input material in the headwaters where degradation of CPOM is efficient. This also potentially increases the downstream organic load. Macroinvertebrates would be influenced by altering the source of food (leaves and related decomposition products), by changing sediments, and by removing habitats such as logs and debris. Fishes would be influenced by removing cover and shelter, by changing territorial and orientation behavior, and by removing spawning areas. All predictions can be supported by literature citations but judgment must be used in identifying effects of specific clearing and snagging projects. Table 1 summarizes biological consequences of various physical modifications.

TABLE 1. SUMMARY OF POTENTIAL EFFECTS OF CLEARING AND SNAGGING ON STREAM ECOSYSTEMS

PHYSICAL MODIFICATION	BIOLOGICAL CONSEQUENCES
Reduction of physical habitat diversity through decreasing hydraulic roughness of stream channels	Moves decomposition of organic matter (leaves, twigs) downstream Reduces benthos production Reduces spawning and nursery habitat Reduces fish cover and shelter Disrupts fish territoriality and orientation Reduces plankton production by reducing amount of quiet water
Removal of canopy	Increases light which increases stream temperature and encourages growth of benthic algae and macrophyte growth Decreases organic matter (leaves, branches) input from terrestrial vegetation
Changes of stream substrate	Changes production and kinds of benthic algae and macrophytes Changes distribution and species composition of benthic macroinvertebrates
Removal of snags, logs, and shoreline vegetation	Reduces habitat for nest- and case-building macroinvertebrates Reduces habitat for accumulation and decomposition of organic matter; results in less food for macroinvertebrates Reduces diversity and amount of fish food Reduces fish cover and spawning habitat Disrupts fish territoriality and orientation

RECOMMENDATIONS

Many of the effects of clearing and snagging are too obvious to warrant specific research, i.e. the time and money spent would be wasted on results so predictable that the research would be trivial. Some of the potential effects erected in this review are not so obvious, and information in these areas would clarify the point as well as add important information relative to basic stream research. If applied research can answer basic questions as it solves specific assessment problems, it should be encouraged. If, during the review of impact assessment, each clearing and snagging operation (or other manipulation for that matter) were viewed as an experimental manipulation, then the potential exists to make before and after estimates of stream processes which would tend to do several things: 1) begin to establish a set of process measurements which would identify geographical variation, 2) provide examples of direct (best) evidence about the effects, 3) foster greater interaction between applied and basic stream scientists.

Some measurements that might be considered are listed below. They are very general and any specific recommendation should be tailored to specific clearing and snagging events.

A. Estimation of the ratio of gross primary production to community respiration in the stream, above and below the reach being cleared and before and after the operation (Vollenweider, 1969).

B. Assessment of the suspended load characteristics including particle size distribution, FPOM, and chlorophyll above and below and before and after.

C. Assessment of the population densities of functional groups of macroinvertebrates.

D. Assessment of fish population density and species composition.

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