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FORESTRY PRACTICES AND STREAM ECOSYSTEMS:

The Effects of Nonpoint Source Pollution from Silvicultural and Timber Harvesting Activities [1]

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Streams and the forests surrounding them are closely related and changes in the forest alter streams and affect aquatic plants and animals. Forests are commonly altered by human operations that result in rapid and dramatic changes in streams and other waters. Forestry practices, including both *silviculture* activities (involving the growing of trees) and timber harvesting operations, must be properly implemented to help minimize effects on streams and aquatic habitats. If mismanaged, silvicultural and timber harvesting activities produce *nonpoint source pollution* and disrupt stream ecosystems. Forestry activities cause an increase in a number of factors which have harmful effects on aquatic communities including:

- Sediments
- Stream temperature
- Streamflow
- Nutrients and Organic Matter
- Chemicals

When forestry operations increase these factors to a point where aquatic habitats and populations are affected, they are considered pollution. This commonly happens when operations are administered without the use of *Best Management Practices* (BMPs). BMPs are a set of techniques and guidelines which, when incorporated into forestry operations, can minimize nonpoint source pollution of our water resources.

Aquatic ecosystems and habitats are influenced by and dependent upon the environment surrounding them. In a forested ecosystem, a stream reflects the structure and composition of the surrounding forest. The forest cools the stream by giving it shade, provides it with varying amounts of organic matter and nutrients, and helps filter the water before it reaches the stream. Therefore, if the forest undergoes a dramatic change, the stream ecosystem, including the plants and animals, will also be changed. Understanding stream ecosystems and how they are influenced by nonpoint source pollution from forestry activities provides the basis for recognizing the importance of BMPs and the need to correctly apply them.

AQUATIC ORGANISMS AND THEIR HABITATS

The diversity of plants and animals living in streams is directly related to the habitats present. *Aquatic habitat* and *microhabitats* are the terms used to describe the homes for plants and animals in a stream, and these habitats are just as important as clean water. The types, sizes, and diversity of surfaces on which plants and animals can attach or grow on the bottom or sides of the stream are important components of the aquatic habitat. Many aquatic organisms, including fish, invertebrates (animals without backbones, such as crayfish, insect larvae and adults, mussels, clams, leeches, and worms) and plants, live on, around, and under rocks and other places along the stream bottom. Many species need very specific types of habitats. Some live on top of rocks or in the spaces between rocks, while some prefer submerged roots or vegetation. Some prefer the fast-moving current of riffle areas, while others choose the calmer water of pools. A stream which contains many sizes and shapes of rocks, logs, and other bottom structure provides a wide variety of habitats for aquatic plants and animals, and may increase the diversity of species present.

AQUATIC FLORA AND FAUNA

The list of aquatic organisms that live in streams is truly amazing. The ones that we see, such as large fish, only represent a small number of the species present. The majority of aquatic organisms are very small and hide themselves under and around cover on the bottom of the stream. Many of these species are sensitive to changes in their habitat. Learning about the different types of organisms and their requirements helps us understand how nonpoint source pollution causes their demise. While there are numerous organisms which live in streams, most of them can be grouped into one of four categories: aquatic plants, algae, macroinvertebrates, and fish.

FLORA: Plants and Algae

Plants, or *flora*, are an integral part of the *aquatic ecosystem* because they take energy from the sun and make their own food. Some common types of stream flora are aquatic plants, macroscopic algae, and *periphyton*.

Periphyton consists of microscopic plants and animals that form a slimy covering over rocks, logs, and other surfaces to which plants and animals can attach. Although we do not normally think of this slimy covering as an important part of the ecosystem, it provides one of the food sources for many aquatic insects and small fish. It is important that the proper habitat for these plants be present in order for the insects and fish to survive. Other types of plants that provide food and shelter for aquatic organisms are the trees, shrubs, and other *riparian* (area adjacent to stream) vegetation. The leaves they shed into the stream are broken down by bacteria and fungi and are consumed by many macroinvertebrates.

FAUNA: Macroinvertebrates

Macroinvertebrates are visible (macro) insects, crustaceans, mollusks, worms, etc., which lack a backbone (invertebrate). The majority of these are found along the stream bottom, or "benthic" environment, and are commonly termed *benthic macroinvertebrates*. They are divided into several groups based on their feeding methods and the four most common methods are briefly described here. *Scrapers* scrape and consume the slimy layer of periphyton from rocks and debris in the stream and use it as their food source. *Shredders* process leaves and other organic matter that have fallen into the stream. In addition, they use the bacteria and fungi that colonize the organic matter as a food source. During their feeding, they shred the leaves and other matter into small particles, making it available for collectors. *Collectors* have specialized structures used to filter the water and capture particles of food. *Predators* feed on other macroinvertebrates in the stream. Each species in these groups of macroinvertebrates has adapted to a different habitat within the stream, and if that habitat is absent or destroyed, the species will not be present.

FAUNA: Fish

Fish are the largest and most noticeable form of aquatic fauna. While they can swim about and live in a variety of environments they are just as intricately connected to their habitats and water quality as macroinvertebrates. In some instances their habitat requirements may be more complex. Some fish require one type of habitat for feeding, another type for protection, and yet another habitat for reproduction. Fish species also have a wide range of food requirements. Some fish scrape algae and other organisms from bottom substrates, while others feed on macroinvertebrates or other fish. For a fish species to thrive appropriate habitats and water quality must be present. For example, there are several fish species which are limited to a relatively small number of streams and lakes. This is because many of our waters do not posses the habitats or water quality necessary for them to survive. While the food they require may be present, the water may be too warm or sediments and other pollutants keep them from successfully reproducing. While some more common fish species are very adaptable their numbers and where they occur are governed directly by habitats, water quality and abundance of food.

AQUATIC ORGANISMS: Indicators of Stream Health

Each stream has a distinct mix of habitats and water quality characteristics that differ with geology, topography, and type of forest. In undisturbed ecosystems, streams and aquatic habitats are in *dynamic equilibrium* with the surrounding land and forest and, depending on stream size, will support a diversity of aquatic organisms. Streams maintaining the highest diversity of aquatic life are often those having diverse

habitats and good water quality. Some benthic macroinvertebrate and fish species can tolerate polluted environments, but many others are intolerant of pollution and are adversely affected by nonpoint source pollution. There are also organisms which are moderately tolerant of pollutants and can live in degraded environments. Because aquatic organisms vary in their tolerance of nonpoint source pollution and other types of pollution, it is possible to monitor streams using biological communities as indicators of stream health. Aquatic biologists commonly sample aquatic communities to determine whether nonpoint source pollution has impacted the stream ecosystem.

FORESTRY POLLUTANTS
Types and effects of nonpoint source pollution

While each type of nonpoint source pollution has the potential to alter or destroy aquatic habitats, some are more prevalent than others. Two of the most widespread stream impacts resulting from improper timber harvesting and silvicultural activities are the delivery of *sediments* and *thermal* pollution (increase in temperature).

SEDIMENTS

Sediments consist of soil, sand, and other particles that have been washed with rain water into the stream or eroded from stream banks by the current. Timber harvesting and silvicultural operations, like intensive *site preparation*, can easily result in soil erosion and delivery of sediment to streams. Erosion occurs when the *duff layer* (the layer of leaves and humus) and the fine roots in forest soils are removed from an area, exposing bare mineral soil. Timber harvesting involves felling and the skidding or hauling of trees or logs from the forest. While the process of felling removes a portion or all of the forest canopy it generally does not extensively remove the duff layer or the upper layer of fine roots to an extent where large areas of bare soil are susceptible to erosion. However, the second step in harvesting operations, skidding and hauling trees or logs from the place where they were cut to a paved roadway represents the greatest threat of erosion and pollution. Disturbed ground does result from the construction of roads, *skid trails, log landings*, and stream crossings associated with timber harvests and some forest management activities. The density, placement, intensity of use, and the techniques used to build these structures are critically important factors which will affect the delivery of sediments to streams.

Studies of timber harvesting operations have shown that up to 90 percent of the sediments from these operations come from the skid trails, roads, and log landings. Other silvicultural activities, such as mechanical site preparation required to regenerate certain tree species, can also create large areas of disturbed ground. Mechanical site preparation is a practice designed to remove harvesting debris and unwanted vegetation from a site. These activities often remove the protective duff layer of the forest floor and expose bare soil, making it susceptible to erosion. Therefore, appropriate BMPs must be used to minimize the amount of sediment that reaches streams during forestry activities.

Regardless of their source, *suspended sediments* in the water directly impact macroinvertebrates and fish by interfering with their ability to filter food and/or oxygen from the water. Suspended sediments can also impact the stream by creating *turbidity* and *embeddedness.*

Turbidity

Turbidity is a measure of the cloudiness of water caused by suspended sediments. These particles limit the depth that sunlight can penetrate into the water, which decreases the amount of sunlight able to reach and be used by aquatic plants for photosynthesis. Not only are the plants impacted by this, the aquatic animals which depend on the plants for food and oxygen are also impacted. In streams which are directly exposed to sunlight turbidity can also increase stream temperature. The soil particles absorb energy from the sun which warms the surrounding water and can contribute to thermal pollution which is discussed below. Therefore, turbidity can have adverse effects on stream-dwelling organisms by decreasing plant growth and increase water temperature.

Embeddedness

Another problem associated with sediments in the stream is *embeddedness*. Embeddedness occurs when suspended sediments in the water settle to the bottom of the stream in a process called *sedimentation.* As these particles settle out of the water they embed, or cover, the rocks and crevices which serve as

habitat for many benthic plants, macroinvertebrates, and fish. While our streams naturally contain sediments and some embeddedness, improper operations can deliver large amounts of sediment to the stream resulting in harmful effects to the bottom. Embedded rocks do not provide habitat for macroinvertebrates, because the spaces around the rocks have been filled by sediments. Not only do sediments eliminate habitats for macroinvertebrates, but they also cover food sources and spawning sites for fish, and smother bottom-dwelling organisms such as macroinvertebrates.

THERMAL POLLUTION

Another type of nonpoint source pollution, called *thermal pollution*, occurs when water temperatures become too high for some organisms to live. Increases in stream temperature occur primarily from removal of the vegetation in the *riparian* area (area adjacent to the stream). Removal of the riparian vegetation exposes the stream to increased amounts of sunlight that increases the water temperature. Riparian vegetation affects stream temperature by shading the water, which protects organisms that have adapted to a cool environment. A second problem associated with thermal pollution is the reduction of dissolved oxygen levels. As water temperature increases, the amount of gas which can be held in the water decreases. Therefore thermal pollution results in a lowering of oxygen in a stream or other water body and reduces the number of organisms that require a plentiful supply of oxygen. Increased sunlight, especially when coupled with an abundant supply of nutrients often leads to overgrowths of algae. Overgrowths of algae, or algae blooms can lead to sharp decreases in dissolved oxygen, which changes the community structure of plants and animals in a stream. Because of this, often only tolerant species can be found living in oxygen limited waters.

Not only can removal of riparian vegetation cause thermal pollution, but it also eliminates a source of organic material in the stream ecosystem. Removing trees adjacent to a stream decreases the amount of leaves that fall into it and are available to be eaten by macroinvertebrates. Shredders feed on the leaves and shred them into smaller particles, which are then consumed by collectors. Therefore removing vegetation directly adjacent to the stream eliminates a valuable food source for many macroinvertebrates. Because of the potentially dramatic impacts of thermal pollution, maintenance of riparian vegetation is an important BMP which should be included in all timber harvesting and silvicultural operations.

ALTERED STREAMFLOW

Altering the flow of streams by increasing flow or redirecting current can cause nonpoint source pollution. Timber harvesting increases the amount of water flowing into a stream and is particularly important when a large portion of trees are cut from a forest. During the growing season, trees remove large amounts of water from the soil and send it back into the atmosphere through their leaves in a process called *transpiration.* Cutting trees reduces the amount of leaf area and reduces transpiration resulting in more soil water. Ultimately, this unused soil water flows into the stream resulting in increased stream flow. The increased flow can cause erosion of the stream bank *(bank cutting)* and an increase in suspended sediments. For most forests, regrowth is fairly rapid and normal flow is established within several years. However, bank cutting and the resulting slipping of the steam bank and the associated erosion can continue for long periods of time.

Increased flow can also cause *channel scouring* where macroinvertebrates and plants are stripped from the bottom of the stream, disrupting benthic habitats. This is enhanced high stream flows are coupled with increased sediments and debris.

Logging debris, including tree tops and cutoff portions of branches and logs, left in the stream after improper harvesting and site preparation activities can alter or redirect the flow and cause bank cutting, resulting in increased turbidity, sedimentation and embeddedness. Proper disposal of logging and site preparation debris are important BMPs which should be adhered to in all harvesting and silviculture activities.

INCREASED NUTRIENTS and ORGANIC MATTER

Two other types of nonpoint source pollution related to silvicultural activities are overloading waters with nutrients and organic matter. Nutrients and organic matter are important components of stream ecosystems because they provide necessary chemicals for aquatic organisms. However, excessive amounts usually have harmful impacts on stream ecosystems and aquatic habitats.

Nutrients

Nutrients, including available forms of nitrogen, phosphorus, and potassium are found in organic matter, including leaves, bark, and woody debris which fall into the stream or are left on the ground after timber harvesting or silvicultural activities. The woody debris left in the stream will decay and release nutrients directly into the water. Minerals and nutrients can also reach streams through the leaching of the soil and decaying vegetation on the ground. Rain water, as it moves through the soil picks up available nutrients and eventually delivers them to the stream. Finally, increased nutrients can occur when fertilizers are used in harvesting or silvicultural operations. These operations must ensure that fertilizers are applied properly to eliminate or minimize the amount which is washed into streams.

Excessive amounts of nutrients can cause *eutrophication*, a process where algae rapidly increase in number. This reduces light penetration into the water, making less sunlight available to bottom-dwelling plants. However, eutrophication is rare in forested streams and more commonly occurs in lakes and impoundments.

Organic Matter

Leaves and other organic matter not only increase nutrients in the water, but also provide food for bacteria and some macroinvertebrates. Although some organic matter is also important to stream ecosystems, overloading streams with organic matter causes ecosystem problems. When large amounts of tree tops, especially those containing leaves are left in streams, bacteria take advantage of the abundant organic matter and their populations can increase dramatically. Bacteria use oxygen which decreases the amount of oxygen available for other organisms.

CHEMICALS

Chemicals used in timber harvesting or silvicultural operations include pesticides and fluids from vehicles and machinery. Pesticides include those chemicals which are used to control unwanted pests. The three most common types of forestry use pesticides include herbicides, which are used for controlling unwanted vegetation, and insecticides and fungicides used for controlling insects and fungi.

Forestry Chemicals

When applying pesticides, it is important to follow label directions. Some chemicals are labeled for aquatic use. However, chemicals used in silviculture operations should not be sprayed directly into streams or sprayed at times or in places that allow chemicals to enter streams through drift or runoff. Chemicals in the stream are nonpoint source pollution and can kill aquatic organisms.

Machinery Fluids

It is also important to keep machinery and vehicles far enough from streams and sinkholes so that fluids can not reach waters. Equipment should not be parked where leaking fluid can drip or wash into the water. Tanks and containers should be located so that leaks or accidental spills of fuels or fluids will not reach waters. All fluids should be drained into an appropriate container and not onto the ground where they can get into the soil and end up in the stream.

BEST MANAGEMENT PRACTICES: Techniques and guidelines for minimizing nonpoint source pollution

Because silvicultural activities and timber harvesting have the potential to create nonpoint source pollution, a set of techniques and guidelines called Best Management Practices (BMPs) has been developed by foresters, wildlife biologists, and water quality specialists to decrease or prevent nonpoint source pollution in streams and other waters. They include techniques which can be used to decrease nonpoint source pollution when building roads, harvesting timber, or engaging in intensive forest or plantation management (see Table 1). Each state and region of the country has specific BMP guidelines which should be used in all silvicultural activities. Research has shown that BMPs minimize the adverse effects that timber harvesting and other silvicultural operations can have on water quality and aquatic organisms by keeping the associated pollutants out of the stream. Reduction of nonpoint source pollution through the use of silvicultural BMPs results in healthier, more diverse aquatic habitats and stream ecosystems.

Table 1. This table summarizes, in broad terms, the relationship between nonpoint source pollutants, their sources, and BMP measures used to mitigate pollution in streams.

Nonpoint Source Pollutant	**Primary Source**	**Corrective BMP Measures**
Sediments: turbidity sedimentation embeddedness	Disturbed bare ground: - roads, trails, landings - intensive site preparation - mechanical tree planting	1) proper location and implementation relative to water bodies and sinkholes 2) revegetate and properly drain roads, trails, and landings 3) apply on the countour 4) minimize or, if possible, elimnate stream crossings.
Thermal	- removal of streamside vegatation	1) maintain streamside management corridors
Chemicals: herbicides pesticides	- runoff from site preparation activities - plantation stand management activities	1) proper application of pesticides, according to label 2) maintain streamside management corridors and sinkhole protection
Organic Matter and Nutrient Overloading: fertilizer logging slash	- runoff from retired, revegetated, fertilized roads - leaching and the breakdown of vegetation	1) maintain streamside management corridors and sinkhole protection 2) keep tops out of water bodies
Altered Streamflow: diverted flow increased flow	- large logging debris in streams	1) keep tops and logging slash out of streams

Glossary of Terms

aquatic ecosystem - All of the interacting living and non-living parts of an area found in or around water.

aquatic habitat - The living space of an organism within or around water.

bank cutting - The change in streambanks which occurs when increased stream flows result in increased erosion from streambanks.

benthic macroinvertebrates - Small but visible organisms which lack a backbone and live on or near stream beds.

Best Management Practices (BMPs)-Effective, practical structural or nonstructural methods that prevent or reduce the movement of sediment, nutrients, pesticides, and other pollutants from the land to surface or groundwater, or that otherwise protect water quality from potential adverse effects of silvicultural activities.

channel scouring - When sediments and other debris are pushed along stream bottoms, stripping rocks of periphyton and organic matter. This disturbance can disrupt and destroy aquatic habitat.

collectors - Macroinvertebrates which filter and gather fine organic matter from the water and stream bed.

duff layer - The layer of partially decomposed material on the forest floor beneath the layer of freshly fallen leaves, twigs and needles.

dynamic equilibrium- The state in which a change in one location or organism creates a corresponding change in another location or organism.

embeddedness - A state in which all of the rocks and crevices (which serve as habitat for fish and macroinvertebrates) are covered with sediment.

eutrophication - The presence of an excessive amount of nutrients such as nitrogen and phosphorus in water, this results in rapid growth of algae and depleted levels of dissolved oxygen

fauna - All of the animal life of a given area.

flora - All the plant species which make up the vegetation of a given area.

log landing - A place in or near a timber harvesting operation where logs are gathered for further processing or transport. The act of depositing a turn of logs into a landing or log deck..

microhabitats - A location within a habitat where an individual species is normally found.

nonpoint source pollution- Pollution that comes from a number of sources spread over a wide geographic area. A single source for the pollution is not readily identifiable. Generally, each source only contributes a small amount of contamination, but the sum impact may be substantial.

periphyton- Tiny plants and animals found on rocks and other surfaces of the stream bottom often forming a layer across these surfaces.

predators- Organisms which feed on other living organisms

riparian- Related to, living, or located near a perennial or intermittent body of water.

scrapers- Macroinvertebrates which scrape algae and other food sources from rocks and other structures found within streambed.

sedimentation- The process of sediments entering and settling to the bottom of a stream or other body of water.

sediment- Soil, sand and mineral particles that have been eroded from the land and deposited into a water body.

shredders- Macroinvertebrates which shred dead organic material such as leaves and twigs into smaller particles during feeding.

silviculture- The process of controlling the establishment, growth, composition, and health of forests and woodlands to meet needs and management objectives.

site preparation- Practices used to prepare a site for planting or regenerating trees. These practices are used to reduce or eliminate unwanted and/or competing vegetation that would threaten the survival or proper development of planted tree seedlings.

skid trails- A temporary, non structural pathway over forest soil used to drag felled trees or logs to the landing resulting in duff or ground disturbance.

suspended sediments - Sediments which are contained within the water column generally clay, silt and during high water flows sand particles.

thermal pollution- Nonpoint source pollution which results when water temperatures increase sufficiently to limit the ability of some organisms to survive.

transpiration- The process by which water vapor passes from the foliage or other parts of a living plant to the atmosphere

turbidity- Cloudiness in water normally caused by suspended sediments in the water column.

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[1] This publication is the text only version of the document to be printed as an FOR series publication.

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