Forestry and Anadromous Fish

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One of the most pressing . . . problem[s] involves the effect of timber harvest upon fish resources. . . . Rarely has so much discussion been generated around so few facts.

–D. W. Chapman, 1962

This statement is nearly as applicable today as it was when made more than twenty-five vears ago in the *Journal of Forestry*. The relationship between forest practices and anadromous fish production has continued to be debated during the intervening decades without a clear resolution. The issue is complicated because there are activities in addition to forest practices that affect anadromous fish production. The offshore fishery removes a large portion of those adults that would return to the streams to spawn. Instream fishing removes another portion of those spawners. Dams on the rivers reduce peak streamflows that influence channel morphology and sediment transport, as well as modify low-flow discharges in the summer. Much of the downstream river habitat is modified by major highways, agriculture, and urbanization. Estuarine habitat has been virtually eliminated from many rivers and severely modified for the remainder.

In the forested areas, past and present land use is variable. Many mountainous watersheds were severely modified by extensive placer mining and logging during the last century. In the late 1940s, the increased value of softwood species, such as pines and firs, started a new wave of cutting in the forests. Beginning in the mid-1950s large storms reactivated huge dormant streamside landslides. Not until the 1970s did forest practices legislation begin to address issues of riparian condition and habitat. The question facing researchers now is how to separate all of these influences, including the effect of past forest practices from present and future practices in relation to fish production. The important regulatory challenge is to be able to predict the influence of new activity given the present condition of the resource of concern.

In 1987, at the request of the California Advisory Committee on Salmon and Steelhead Trout, the Wildland Resources Center of the University of California convened a workshop at the U.C. Davis campus to define the needs and costs of a ten-year research, development, and education program related to salmon and steelhead trout. A cross section of commercial and sportfishermen, government resource managers, university scientists, and consultants compiled a list of one hundred and thirty-nine problems needing solution. From that list, eighteen problems were given highest priority for expanded funding and research. Two of those eighteen problems are directly related to the forestry and fishery interaction:

1. Determine how changes in inputs of sediment and associated changes in instream channels affect fish habitats under varying conditions.
2. Identify and assess the cumulative effects of timber harvest on erosion, hillslope stability, streamflow, and sediment in stream channels.

After decades of work, we still cannot predict biotic changes from measured changes in the physical environment of watersheds or stream channels. This limitation has, in some cases, resulted in the destruction of habitat in the name of protection. Until recently, forest practice regulations addressed water quality--not fish habitat. Our view of woody debris, for example, has changed dramatically over the past decade. Programs to protect water quality at times required extreme measures to clean up streams after logging. Occasionally these programs were translated into removing all woody debris from the stream--both natural and logging-induced. Often the result was accelerated erosion of channel beds and streambanks. Large woody debris is now recognized as an important component of healthy streams. It moderates the velocity of streamflow, influences the routing and storage of sediment, and increases the quality and diversity of fish habitat.

Most forest practices regulations, and most research on land use effects, have focused on short-term responses of local areas to single land uses. These responses are typically viewed as being isolated in time and space. Recently managers and researchers (and the courts) have become increasingly concerned with the "cumulative effects" of land management activities. The National Environmental Policy Act defines such effects in this way: " 'Cumulative impact' is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

Cumulative environmental changes may occur either at sites of land use disturbance or away from the disturbed sites. At the site of disturbance, multiple practices may combine or accumulate through time to affect a beneficial use. Away from the site, changes may accumulate through a sequence of impacts spread over many years or through the combined effects of multiple practices distributed throughout the river basin. Concern about cumulative effects introduces the concept that even though all activities are conducted in a manner which limits their individual effects to an acceptably low level, unacceptable harm may be experienced at some point in time or space when these activities function collectively.

Today we have no effective method for predicting the environmental response to a land use plan. To make matters worse, there is little agreement among disciplines, geographic regions, or interest groups over what actually constitutes cumulative effects or whether they even exist.

Determining the influence of land use on resident fish, let alone anadromous fish, is particularly problematic. First we need to understand how land use activities affect the removal over time of sediment, water, woody debris, nutrients, and heat from hillslopes and their delivery to streams. Then we need to know the transport rates of each of these products from the sites of land use to areas of concern. Moreover, we must determine how altered sediment, water, woody debris, nutrient, and heat transport affect resources of concern, such as diversity, composition, resilience, and structure of biological communities. Finally, since fish are near the top of the biological community structure, we need to understand the importance of these changes on not only the fish but also their ecological link to other parts of the community throughout their life cycle. It is much simpler to understand, for example, how a single land use activity over a short period affects erosion than to understand the biological consequences of the resulting sediment.

There are important issues related to scale-both spatial and temporal. In general, individual erosion events are limited to an area of square yards or, at most, acres. Individual land management activities, such as logging, usually occupy less than a hundred acres. The drainage area of the streams that contain most of the prime anadromous fish habitat exceeds a thousand acres, and usually more than ten thousand acres. In small areas, it is relatively simple to measure the relevant variables in order to evaluate cause and effect. As the area becomes larger, it becomes progressively more difficult to measure these variables at a scale that can give meaningful results. And as the spatial scale increases, so does the time required for a change to be observed. For example, the time required for sediment to be routed from a site of erosion within a one-acre watershed is much less than in a hundred-acre watershed or a ten-thousand-acre watershed. Therefore, the relevant response time between a land use activity and a significant effect should be expected to increase as the size of the area increases.

Similarly, the recovery time following disturbance should be expected to increase as drainage area increases. As the time between disturbance and expected effect increases, there is a greater chance that a natural event, such as a major storm, will occur within that interval and confuse any determination of cause and effect. In some cases, land management decisions can set the stage for substantial problems during serious storms. If conventional road engineering designs call for forest road culverts to withstand a fifty-year storm, for example, then during a hundred-year logging cycle all of the culverts would be expected to fail twice, on the average, and the associated road fill would be washed into the stream. This is not a natural consequence of a large storm; it is an economic and design decision.

Even when we eventually understand the relationship between land use practices and erosion and sediment production and routing, we will still be a long way from understanding the effect of that sediment on the biological community, including anadromous fish. The important point to keep in mind is that none of these relationships are simple. To evaluate the effect of logging on sediment production immediately below the area of activity is not enough when the area of interest is ten miles downstream. Furthermore, to understand the effect of that logging operation on the sediment regime ten miles downstream is not enough when the objective is to understand the effect of sediment on anadromous fish production.

It now becomes important to know the change in flux of that sediment throughout the life cycle of the fish and the effect of these changes upon growth, reproduction, and mortality. The effect may not be direct, but it may represent a change in food availability, feeding success, susceptibility to disease, or predation. Thus we must be concerned not only with the immediate effect of the sediment on the fish but also its effect on the ability of the fish to grow, compete, and eventually reproduce. If a change in sediment load, for instance, lessens the ability of a fish to survive and reproduce, that is perhaps as important an effect as killing the fish outright.

For several decades, the riparian zone has continued to be the focus of increasingly restrictive regulations-and for good reason. Thirty years ago the riparian zone was a place to locate roads, landing, and skid trails. Logs were routinely tractor-yarded to and down stream channels. Large volumes of soil and logging slash were left in the streams. Road construction debris was routinely side-cast, much of it in the stream. Studies of land management effects on fish usually focus on stream blockage by logging debris and lethal temperature increases resulting from removal of the tree canopy. More recent fish management programs have called attention to additional specific habitat requirements, such as spawning substrate, sedimentation, cover, pool volume, minimum instream flows, and the effect of land management practices on these requirements. Single-objective programs-for example, to increase the amount of suitable spawning substrate-often do so in the absence of the necessary collateral knowledge of sediment transport mechanics, channel morphology, and other aspects of fish habitat. Such programs are often a disappointment; they do not attain the objective of increased return of adult salmonids. The programs fail because they ignore major attributes of stream ecosystems that support the fisheries.

Clearly an ecosystem approach at an appropriate spatial and temporal scale will be required if progress is to be made on the question of forest practices and fish production. Regulating individual timber harvest units is not enough. Regulation must be made at the drainage basin scale, taking into account the effects of past and present practices. It is not sufficient to have streamside management regulations designed to maintain stream temperature. Regulations must also consider changes in streamside input of solar radiation, nutrients, food, litter, woody debris, and sediment over both the short and the long term.

As one example, management decisions in the riparian zone can substantially affect the supply of large woody debris without significantly affecting the other streamside inputs. If the management policy is to harvest continually only the large and decadent trees, leaving the vigorous intermediate and small-sized trees, little change would occur in any of these other streamside additions. The incidence of tree-fall, however, would be dramatically lowered. The quantity of large woody debris in the stream would gradually be reduced by stream export and decay, but new additions of large material would seldom be available. Eventually the stream would become devoid of large woody structures and the morphology of the channel would adjust, as would cover and other aspects of the aquatic habitat that are tied to the presence of large pieces of wood.

Besides transporting water, the stream transports sediment, nutrients, detritus, and organic matter from the surrounding forests and hillslopes. The riparian zone links hillslopes to streams and moderates the transport and delivery of these watershed products. The riparian ecosystem functions within the context of changing fluxes of these products, and anadromous fish use the streams draining the forested watersheds for only a portion of their life cycle. A recent symposium at the University of Washington assessed the state of the science on forestry/fish interactions. A reading of the 471-page proceedings clearly demonstrates that there has been progress in understanding pieces of the forestry and fish puzzle,

Tractor yarding equipment at a logging site. More stringent rules, coupled with stricter enforcement, are needed to reduce damage to streams from such operations, particularly in northern coastal California watersheds. (Herbert Joseph)

but much work remains before we can predict the effect of a proposed land treatment on fish production in any given drainage basin.

Since D. W. Chapman discussed the issues of forestry and fish resources a quarter-century ago, the populations of salmon and steelhead trout have continued to decline. Robert Z. Callaham, of the Wildlands Resources Center, U.C. Berkeley, and Bruce Vondracek, Department of Wildlife and Fisheries Biology, U.C. Davis, point out that "reversing the decline depends, in part, upon having new technology to improve management of these fisheries and that technology would he applied by a strong research, development, and extension (RD&E) program." The needs and costs of an RD&E program to improve the management of salmon and steelhead trout have been identified by others. Because of the importance of salmon and steelhead trout resources to the economy of the Pacific Northwest, these programs, recommended by commercial and sportfishermen, government resource managers, university scientists, and consultants, need financial and political support to move beyond the planning stage to implementation. The California Advisory Committee on Salmon and Steelhead Trout, in its 1988 report, emphasizes the urgency of the task: "California must aggressively confront the problems challenging salmon and steelhead survival. It is not too late to restore and protect this natural heritage. The time to act is now."

While complete reversal of anadromous fishery declines will depend on results of the research described above, promising interim actions are being taken. Tightening and better enforcement of the State Forest Practice Act is one such action. The high priority given to fisheries by the U.S. Forest Service, as outlined in its "Rise for the Future" program, is another such action. The Bureau of Land Management has announced that it intends to address fishery problems more vigorously. These actions, coupled with an ambitious research and development program, are certainly a glimmer of light at the end of what has been a very dark tunnel.