



United States  
Department of  
Agriculture

**Forest Service**

Pacific Northwest  
Research Station

General Technical  
Report

PNW-GTR-596

January 2004



# Proceedings: Views From the Ridge—Considerations for Planning at the Landscape Scale



# Scale Considerations for Linking Hillslopes to Aquatic Habitats

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The title of this conference, “Views From the Ridge,” suggests a particular scalar view of issues. From the ridge, one obtains a somewhat broad but restricted view of the landscape. Certainly, “Views From Space” would provide a larger spatial overview in which landscape pattern becomes a dominant theme. For an aquatic or riparian theme, “Views From the Valley” would suggest looking upward to the hillslope and ridges, in contrast to looking down from the ridge. Issues concerning appropriate scale have been prevalent in most of the recent landscape assessments, including the Northwest Forest Plan (FEMAT 1993), the PACFISH (1994) strategy, and, most recently, the Forest Service *Roads Analysis* (USDA Forest Service 1999) procedure. In all of these efforts, three struggles were common: (1) issue identification and integration of information across multiple disciplines, (2) appropriate spatial scales, and (3) appropriate temporal scales.

## Issue Identification and Integration of Information Across Multiple Disciplines

Several decades ago, some of us thought that it would be a good idea to get a bunch of fishery researchers and watershed researchers together for a joint meeting. The joint meeting lasted about 4 hours until someone voiced the opinion that we had nothing in common to speak about and the meeting broke up into two different rooms: one room for the biologists and another for the physical scientists. Since that time, interdisciplinary work has improved. At least now we occasionally can identify common issues. But still, people continue to struggle with understanding the crosscutting complexity within a common issue. For example, foresters tend to identify forestry issues as centered around trees; hydrologists see forestry issues as related to water quality or quantity; biologists see the same forestry issues as revolving around birds, salamanders, or fish. Seldom

are we successful in dealing with the full complexity of the issue across disciplines. Traditional ways of looking at problems are either from the top down, or from the bottom up.

### Top Down

The top-down approach (fig. 1) starts with some land use activity, such as logging, grazing, or urbanization. The next step is to identify the onsite changes produced by that activity; that is, how does that land use activity modify the site—soil, vegetation, terrain, slope, and so forth. Then, how are these onsite changes translated into altered watershed products? Primary products of altered watersheds are water, sediment, organics, chemicals, and heat. And finally, how are these products transported away from the site of disturbance to cause some offsite impact? For example, suppose there are logging and associated roads in a particular watershed. These activities compact the soil, modify the vegetation, and alter the topography by making the slope steeper at road cuts and fills. These physical changes can modify runoff timing and volume, wood input to streams, surface erosion, and landslides. The result can produce changes in peak flow, base flow, water temperature, channel condition, and sediment. Society is more concerned about the consequences of these changes offsite: increased flooding, increased sedimentation, fewer salmon, and so forth. By looking at the full set of potential influences of a land-disturbing activity, a broader range of potential concerns can be identified than if we simply focused on our favorite impact.

### Bottom Up

Another equally useful approach (fig. 2), which is a common engineering exercise, is to identify some offsite impact and trace the way back up to find the activity that caused that offsite impact. For example, if a bridge was washed out, there could be many potential reasons including increased peak flow, channel erosion, water diversion, battering by debris, and so forth. Identification of the correct process and successive linkages is important in order to be successful in preventing future failures or to identify the guilty party.

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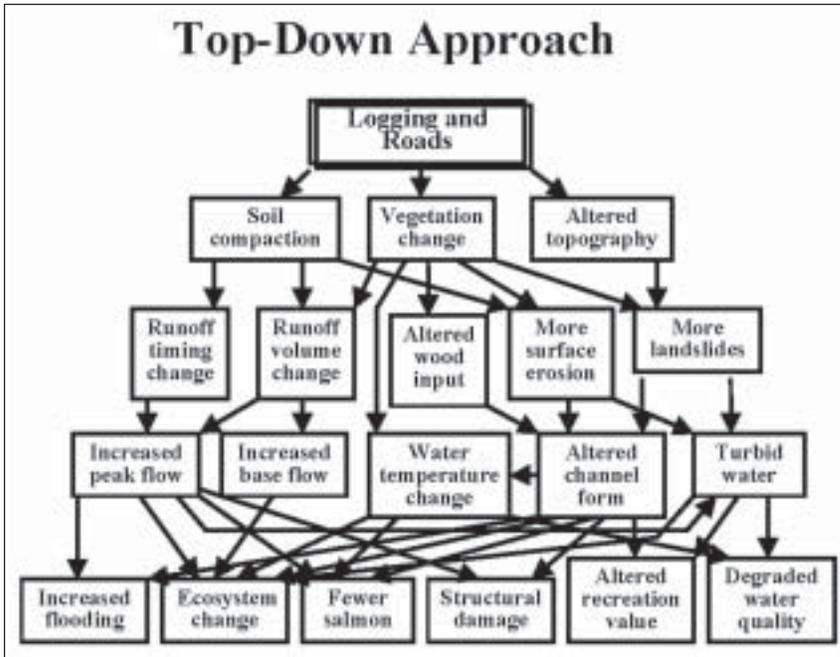


Figure 1—The top-down approach starts with a land-disturbing activity, then describes the onsite changes, the subsequent effects of these changes, and finally the consequences (from Ziemer and Reid 1997).

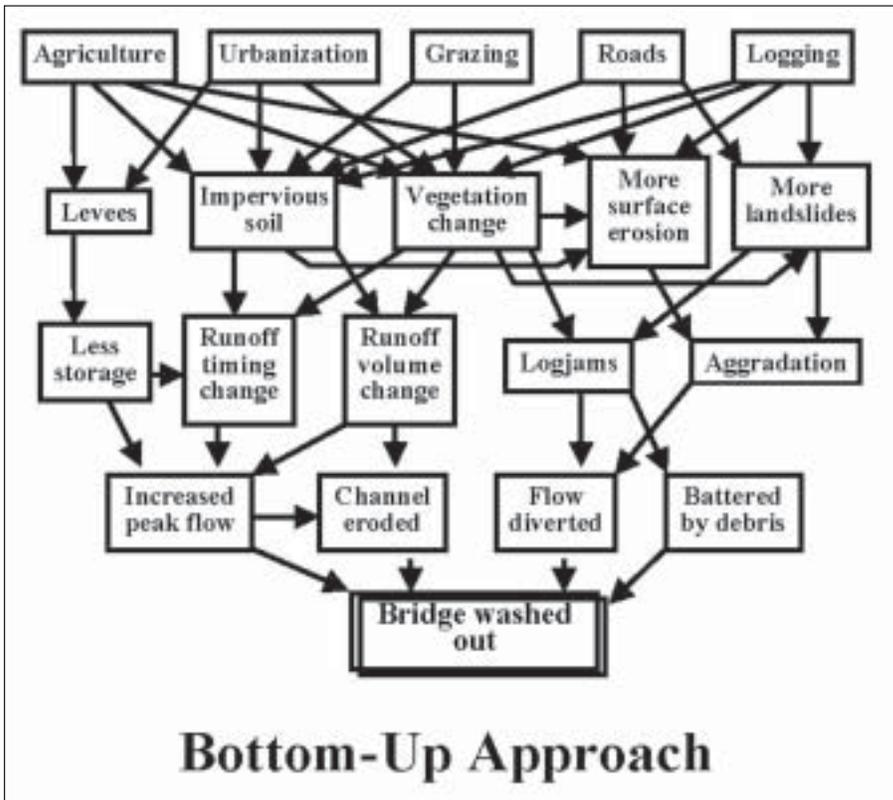


Figure 2—The bottom-up approach starts with an identified consequence (bridge washed out), then describes the important conditions and linkages that could have produced the problem, then the processes that caused the conditions, and finally links to the land-disturbing activities (from Ziemer and Reid 1997).

To be most successful, we should analyze the issues simultaneously from the top down and bottom up by linking the land use activity to potential offsite impacts, and also by linking identified offsite impacts to potential land use activities (fig. 3).

### Putting It Together

As an example, let us take “disappearing salmon” as an issue for consideration (fig. 4). If we were to simply focus on the number of salmon at a particular point as the appropriate metric of success, we may develop some programs of salmon restoration that are rather silly when the problem is considered within its broader context. For example, we might try to restore habitat above a dam or a culvert where the fish are unable to reach. Or, perhaps the reason the fish numbers are low is because they were caught downstream. By producing diagrams similar to figure 4, we can begin to visualize and understand the complexity and interactions within the issue of concern. The process of developing the diagram is more important than the final diagram itself. In building the diagram, individuals with different backgrounds and focus can identify where their knowledge contributes to the solution of a single issue. In figure 4, there are three major components potentially affecting salmon: land use, human predation,

and ocean conditions. The land use and terrestrial conditions include the traditional issues and linkages: logging, grazing, agriculture, urbanization, dams, and so forth, with their associated effects. The human predation component addresses sport, commercial, and subsistence fishing. The ocean conditions influence a major portion of the salmon’s life cycle.

The traditional view of the problem (fig. 5) is to ignore all of this complexity and other influences and focus on the parts that we particularly care about. We select a land use of interest and evaluate the linkages and pathways between that land use (logging) and the target concern (disappearing salmon). Commonly, we further narrow the scope to a specific component, for example, to woody debris. We want to demonstrate that a change in woody debris has some effect on disappearing salmon. So this becomes our top-down approach. We only think about how woody debris is affecting the salmon and we ignore all of the other influences.

It is common to find that an agency only considers those components for which they are directly responsible and ignores the potential effects of other land uses. For example, a forestry agency becomes only concerned with the effects of forest land management on salmon, while the influence

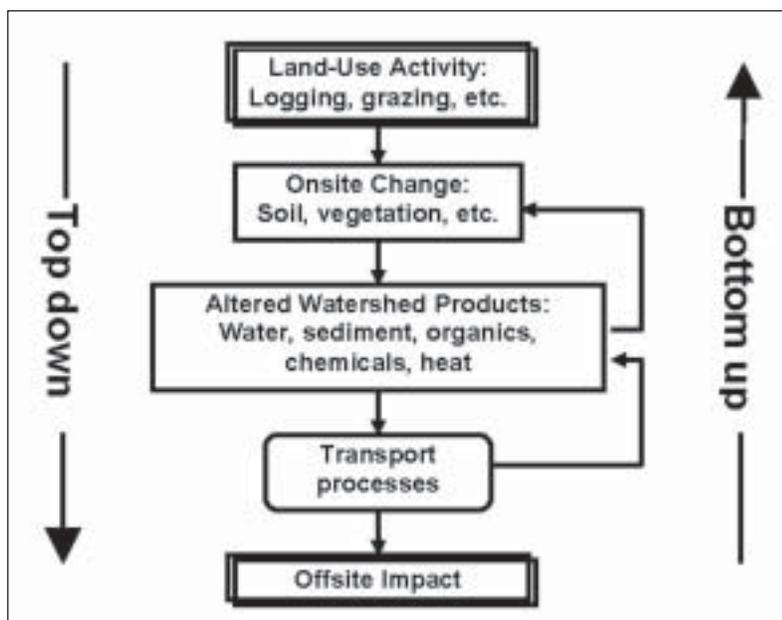


Figure 3—The top-down and bottom-up approaches can be merged into a single-analysis approach by linking the land use activity to potential offsite impacts, and also by linking identified offsite impacts to potential land-use activities.

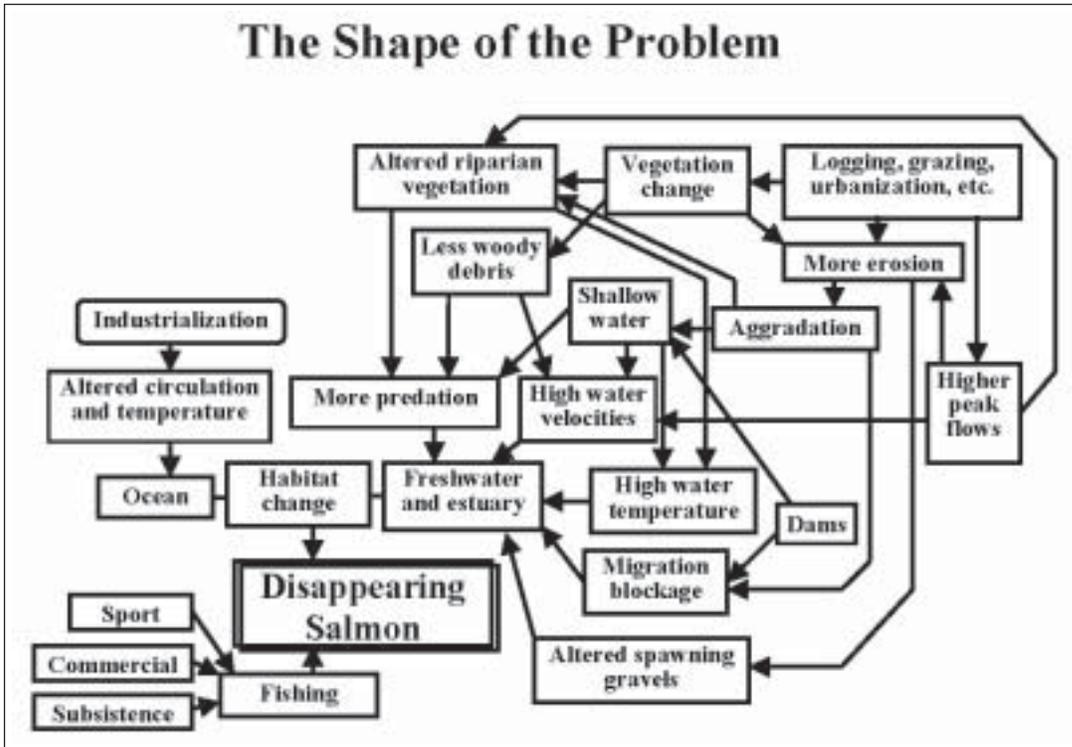


Figure 4—A generalized diagram of some possible important interactions affecting “disappearing salmon” (from Ziemer and Reid 1997).

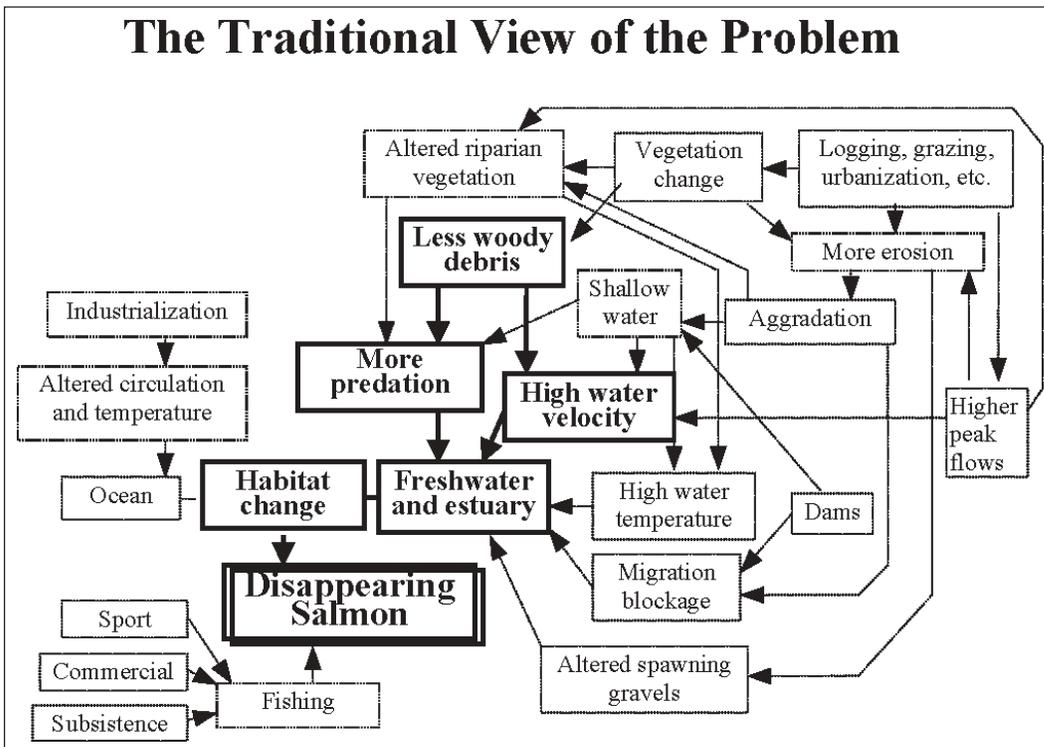


Figure 5—Example of a typical shortcut that ignores many of the important components in the generalized diagram to link a particular component to “disappearing salmon” (from Ziemer and Reid 1997).

of agriculture, urbanization, dams, fishing, and so forth are ignored because the forestry agency is only authorized to regulate logging or manage timberland. This focus is appropriate at a later time when the agency decides upon a program of action. Unfortunately, such a myopic view often misses the context of the agency's program within the larger issue and can lead to uneven regulation or to ineffective management actions.

The end point of problem simplification is to select some index that directly links the activity to the target issue without regard to other influences (fig. 6). For example, a group working to restore salmon runs in the South Fork Trinity River in northwestern California assumed that their favorite variable, changes in the volume of large pools in the mainstem river, was related to the number of returning salmon. The group decided to measure annual changes in the volume of these large pools and then to correlate these annual pool volume changes to logging and road building, which were assumed to produce decreased pool volume, and to the amount of future watershed rehabilitation, which was assumed to result in increased pool volume. In other words, pool volume was the index that was to tie changes in land use to fish. None of the other components or influences upon fish numbers were to be evaluated or considered. The problem was that the group had no information about what was happening to fish downstream and no independent indication that there was any relation between fish numbers and pool volume, let alone between land use and pool volume.

## **Spatial Scale**

Individuals who design projects, such as timber sales, roads, grazing permits, recreation facilities, and so forth, are quite accustomed to and comfortable in dealing with the project or subwatershed scale (fig. 7) that ranges from 10 to a few thousand acres. Project designers are less accustomed to evaluating the context of that project within larger scales. The appropriate size of that larger scale depends strongly on the issue being considered. If, for example, there is a concern about the effect of a project on the drinking water

supply for a small community, evaluating the subwatershed directly above the water supply intake is the appropriate geography and scale. Areas beyond that direct influence are not relevant to the problem. If, however, we are dealing with the effect of a project on anadromous fish, then we are dealing with a much different geographical and spatial arena. For each of the boxes and linkages in the disappearing salmon diagram (fig. 4), there are sets of scales that are appropriate to that box. For the fish population, the scales range from the individual stream reach to the Pacific Northwest, including the ocean. Salmon stocks from the Columbia River may compete in the ocean for food and resources with salmon from northwestern California. Anything that changes the competitive advantage of one stock is important to consider. Further, there may be migratory wandering of fish from one river system to another. A depleted stock from one river may result in success of stocks from another river because of reduced competition, or vice versa. It is important to recognize such external forces that are operating at the large scale outside of the immediate frame of reference. Similarly, within a given river system, it is not possible to evaluate the value of improving fish habitat quality at the small watershed scale without some understanding of how habitat along the migratory route influences the population. In the extreme example, improving salmon habitat above a migration barrier will have no effect, because the fish will never be able to use that habitat.

The appropriate scale or geography depends on the issue to be addressed. Some issues remain fixed in one location (trees, soil fertility), whereas others are mobile (animals, water, sediment). Products associated with aquatic issues (water, heat, chemicals, wood, sediment) tend to move downslope or downstream and are constrained within defined topographic boundaries. Fish move upstream and downstream, so for them, watershed boundaries are useful geographic limits. Terrestrial animals (deer, birds) are not constrained by watershed boundaries, and the watershed concept is not particularly useful. For these animals, movement range is a more useful scale than topographic boundaries.

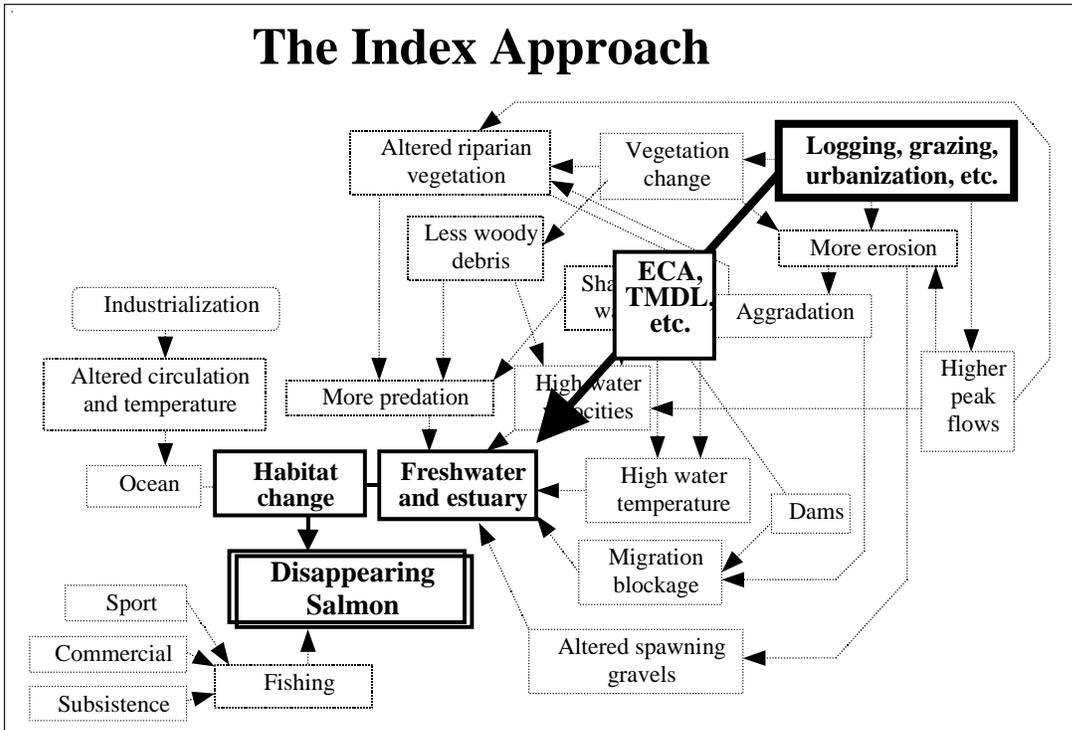


Figure 6—Occasionally, an index is used to link a land-disturbing activity to the target, ignoring all of the complexity and interactions that may also influence the target (from Ziemer and Reid 1997). (ECA = equivalent clear-cut area, TMDL = total maximum daily load.)

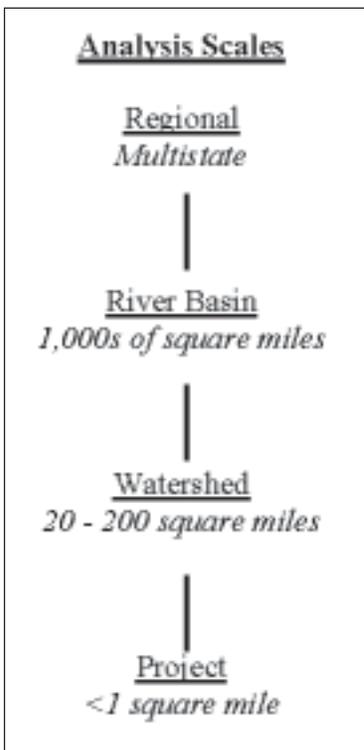


Figure 7—A hierarchy of spatial scales.

A survey of any geographic area will result in a high variance for most parameters. For example, consider a hypothetical survey of 30 streams to evaluate the risk of mortality of some species of fish (fig. 8). Some streams have good habitat and a low risk of mortality resulting from some action, whereas others will have a high risk. The level of “acceptable” risk has two components, biological and social. If the species is abundant, it may be biologically and socially acceptable to adopt a level of regulation that would overprotect some streams and underprotect others. As the species becomes rarer, a higher level of regulation may be appropriate, depending on the consequences of making a judgment error. The problem with regulations that produce or require a generic “designer stream” is that stream systems are dynamic and may require a wide range of evolving habitat conditions to be productive. The stream systems described by Reeves (this volume) require a substantial amount of perturbation and resulting productivity changes over time. Designing for the perceived “ideal” condition in all places all of the time may lead to a poor stream condition in the future. Further, a poor condition today may contain exactly the components needed for the best habitat in the future.

## Temporal Scale

It is well known that “significant” hydrologic or meteorologic events occur rarely, and the temporal distribution of these events is not uniform. This presents a problem because most monitoring activities represent only a short snapshot of the temporal distribution of events. If the long-term distribution was uniform and well behaved, the snapshot may be an adequate representation of the expected population of future events. However, if the events are not uniformly distributed (fig. 9), then any short period of monitoring can produce flawed information. For example, assume habitat conditions are monitored on a stream continuously for 75 years, considered by most to be an exceedingly long record. If the monitoring period ran from year 1 to 75 (fig. 9), the conditions represented would be greatly different than if the period was from year 75 to 150. More realistically, most monitoring activities are

much shorter than 75 years, often 10 or fewer years. Any 10-year period in figure 9 could find conditions ranging from no severe storms to multiple storms. In other words, the temporal scale needed to adequately represent the significant geomorphic or ecologic drivers is often orders of magnitude longer than our monitoring database.

How does this relate to the level of regulation and risk of mortality? Suppose that the average of the streams depicted in figure 8 had a monitoring record of 30 years (fig. 10). The maximum risk of mortality, and perhaps the appropriate level of regulation, could differ substantially based on which period is monitored: for example, years 1 through 10, years 11 through 20, or the entire 30-year record.

What is the appropriate time scale to consider? The answer depends strongly upon the issue. Different folks or the same folks considering different issues look at the problem differently (table 1). For those in the corporate world of profits and losses, a quarter (of a year) is an important scale. Corporate well-being 150 years from now is often not an important consideration to the board of directors. Politicians like to see programs that they sponsor put into effect and have some result during their time in office. For politicians, the election cycle (2, 4, or 6 years) is an important time scale. The length of a human life is an important time scale for people, and sometimes planning includes several generations, that is, planning cycles ranging from 10 to perhaps 100 years. For most people, something that happened 20 years ago was a long time in the past. With some exceptions, such as planning for infrequent but catastrophic events such as earthquakes and floods, something that happens once every 20 years or so is beyond the immediate concern of most people. However, a 20-year time scale is extremely long for an insect species having several life cycles per year, or extremely short for a redwood or bristlecone pine having a life cycle of 1,000 years or longer. An individual storm becomes very important for the domestic water user who turns on the water tap and finds the water to be turbid. Geomorphic events that shape the stream channel may occur only once a decade, century, or millennium.

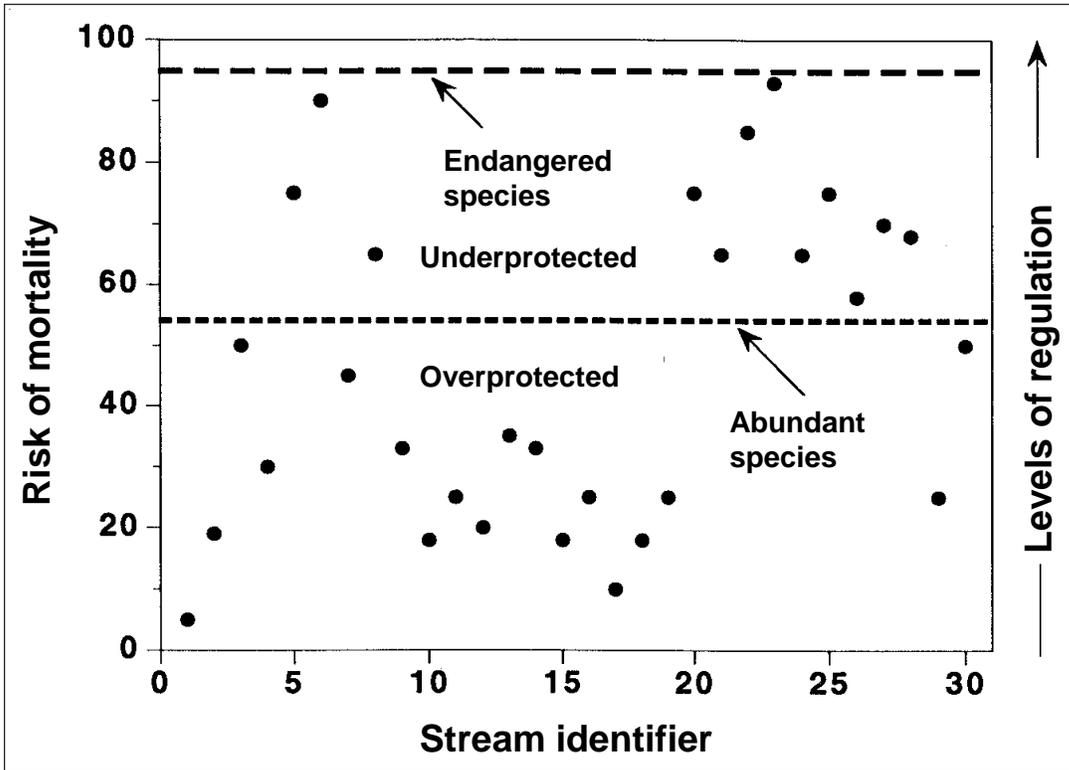


Figure 8—Hypothetical survey of streams for risk of fish mortality and the level of regulation needed to protect fish at two levels of abundance (from Ziemer 1994).

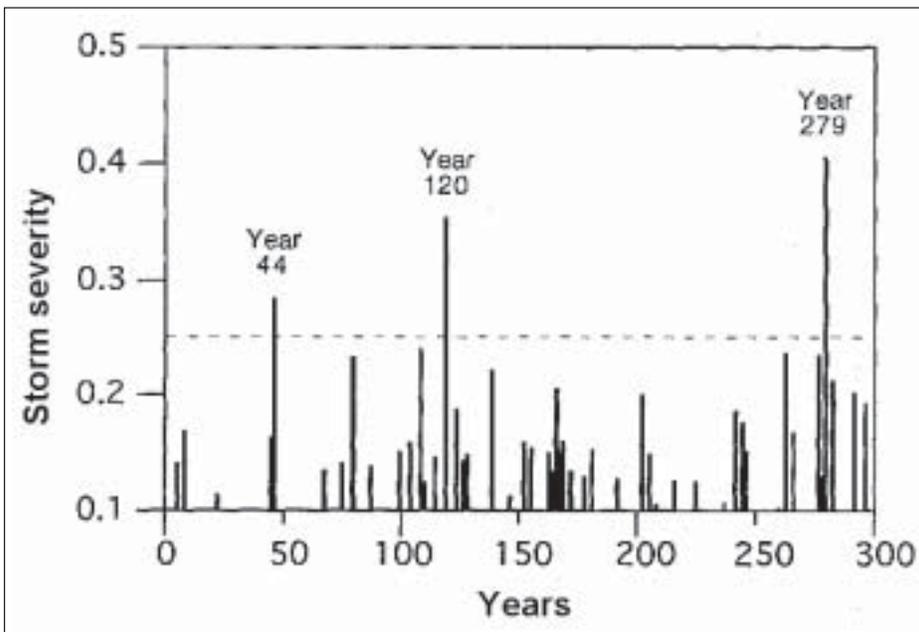


Figure 9—Distribution and magnitude of severe storms during a single 300-year simulation (from Ziemer 1991).

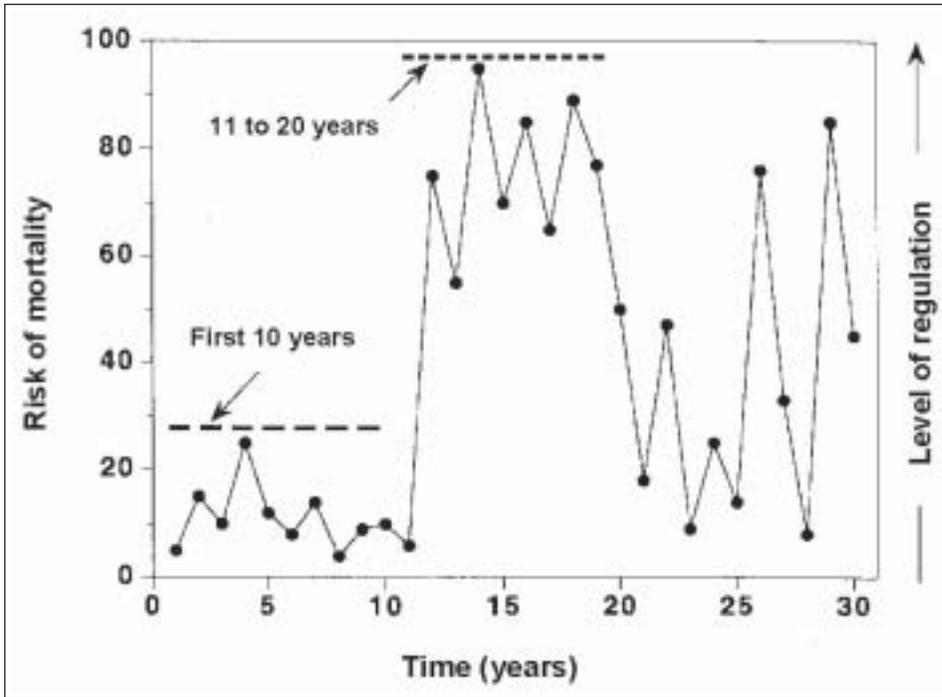


Figure 10—Hypothetical risk of fish mortality based on monitoring streams for different periods of time and the effect of cycles or unusual events on the perceived level of regulation needed to protect fish (from Ziemer 1994).

**Table 1—Appropriate time scales**

Entity	Period	Years
Corporations	Quarterly profits and losses	0.25
Politicians	Election cycles	2, 4, or 6
Humans	Memory of significant events	1 to 20
Humans	Lifespan	50 to 100
Insects	Life cycle	0.2 to 1
Anadromous fish	Life cycle	2 to 4
Humans	Life cycle	50 to 100
Trees	Life cycle	100 to 1,500
Domestic water user	Individual storm	0.1 to 5
Channel adjustments	Large storm	1 to 1,000

Finally, how one views the world depends strongly on conceptual models about how things operate. For example, our belief about how the level of watershed disturbance is related to salmon habitat (fig. 11) has a strong influence on land management and restoration strategies. The initial assumption for both curves a and b is that the best habitat represents that area having the least watershed disturbance. In one model (fig. 11, curve a), a watershed can be increasingly disturbed with little effect on habitat quality until a threshold is reached, beyond which there is a precipitous decline in habitat quality. The management objective would be to allow disturbance activities to continue until just before the point is reached where habitat quality begins to drop rapidly. Conversely, curve a suggests that a severely degraded habitat can be restored with a small reduction in the amount of watershed disturbance.

The second model (fig. 11, curve b) suggests that a small amount of disturbance in watersheds having the best habitat can result in a rapid decline in habitat quality. Once the habitat quality is low, additional disturbance has little incremental effect on habitat quality. Conversely, curve b suggests that recovery of habitat quality in heavily disturbed watersheds will require a huge effort before any improvement will result. Many past land management plans followed assumptions of curve a. The Northwest Forest Plan (FEMAT 1993) aquatic conservation strategy follows the assumptions of curve b, that is, to identify and protect those watersheds that have the best remaining habitat (key watersheds), and to concentrate continued harvesting in those areas having the poorest habitat (matrix). It is important to determine which of these models best represents the relationship between watershed disturbance and habitat quality.

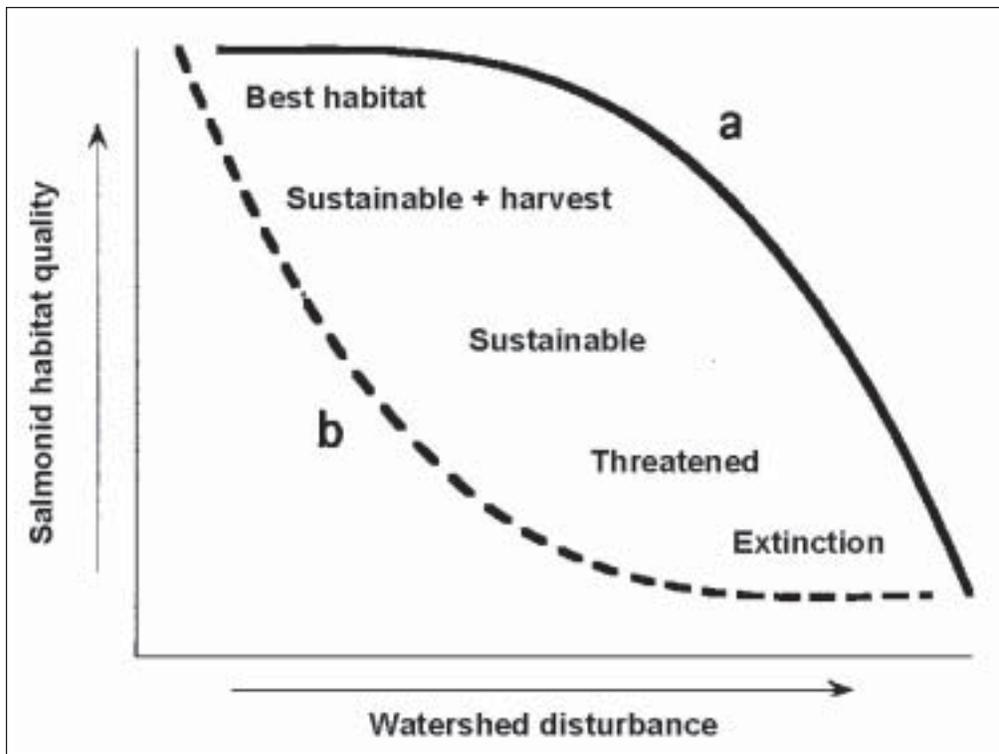


Figure 11—Two conceptual models of the relation between watershed disturbance and salmonid habitat: (a) habitat quality is not degraded until substantial watershed disturbance is reached; (b) habitat quality is degraded most quickly during initial stages of watershed disturbance (from Ziemer 1997).

## Conclusion

Management and policy strategies to sustain a resource depend on physical and biological hypotheses that often are untested. The success or failure of a particular strategy will depend strongly on how the resource actually responds once that strategy is applied. Understanding the response of the resource, in turn, will depend critically on viewing that resource from the appropriate scale in time and space.

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