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Some Scale Considerations for Watercourse Restoration and Rehabilitation

Robert R. Ziemer[1]

SUMMARY: Appropriate temporal and spatial scales vary between rehabilitation objectives. A scale appropriate within a physical or biological context might not be appropriate within a political or social context. For example, corporations and stockholders consider quarterly profits and losses to be an important measure of corporate health. Politicians often focus on election cycles as their measure of a program's success. Those who ignore the quarterly balance sheet or the next election may find themselves out of a job. Company- and government-sponsored rehabilitation programs, therefore, are often expected to produce interpretable results within months to a few years. For many issues, unusual events are more important than average conditions. For example, the morphology of mountainous channels and much of their diversity in aquatic habitat are shaped by infrequent large storms that may occur only once every 25 years or more. Rehabilitation programs that focus on the consequences of small "normal" storms will likely be inadequate because the critical geomorphic events that produce the physical and biological concerns are missing. Rehabilitation programs often stop at some political, social, organizational, or disciplinary boundary, although such boundaries make no sense within the physical or biological context of the issue. Relevant spatial scales also vary by issue. The appropriate area to rehabilitate the quality of a small community's water supply is defined by the boundary of the watershed supplying that water. In contrast, the area to restore salmon runs would include both freshwater and ocean habitats, encompass several large river basins, and extend far offshore.

THE MAIN POINTS OF THIS PAPER

* Successful restoration depends on clearly identifying the issue of concern and then mapping the important components and links that affect that issue.
* The relevant scales of time and area depend on the specific issue being addressed.
* Temporal and spatial scales appropriate within a physical or biological context might not be appropriate within a political or social context.
* Each restoration activity should be evaluated across a hierarchy of scales that range from a broad region to an individual site.

1. INTRODUCTION

Degradation of ecological resources by human activities is continuing and cumulative (Naiman et al. 1995; Williams et al. 1997). Concern about diminishing resources has resulted in numerous restoration programs. Many of these restoration programs begin with recognition of a broad-scale ecosystem issue or problem, but the focus is narrowed quickly because of jurisdictional politics, user interest, funding, or time. Too often, this narrowed view leads to projects that are well designed and well intentioned, but are irrelevant and ineffective in attaining program objectives. In some cases, expensive projects are located where they will have little effect. In other cases, the completed project is simply destroyed by the next moderate storm (Frissell and Nawa 1992). In still other cases, projects designed to benefit one component of the ecosystem severely damages other components (Franklin et al. 1988; Rosgen 1994). A common thread that runs through failed projects is that the plans consider only the particular site or problem and ignore the greater context of the landscape, time, or ecology.

2. MAPPING THE PROBLEM

Successful restoration requires that the issue of concern be clearly stated. Once the issue is clear, it is important to map the important components and links that might affect that issue. For example, a generalized diagram of some possible important interactions between land use and "Disappearing Salmon" can be constructed (Figure 1). Land-use activities such as agriculture, logging, grazing, and urbanization potentially affect only part of the salmon's life cycle (Ziemer and Reid 1997). An index that moves directly from land use to disappearing salmon without considering the influence of ocean conditions, fishing (sport, commercial, subsistence), predation (marine, fresh water, terrestrial), migration blockage (dams, road culverts, channel aggradation), and additional factors, will probably be inadequate. Figure 1 itself is an abbreviated description of the numerous components that might be important to the problem of disappearing salmon. A variety of other influences could be added to the diagram and each box could be expanded to more completely display multiple interactions. For example, the "higher peak flows" box can be expanded to become Figure 2.

The object of this issue mapping exercise is not to develop elegant textbook diagrams that describe everything that is known about peak flows or salmon. Nor are these

[1] USDA Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, California 95521, USA

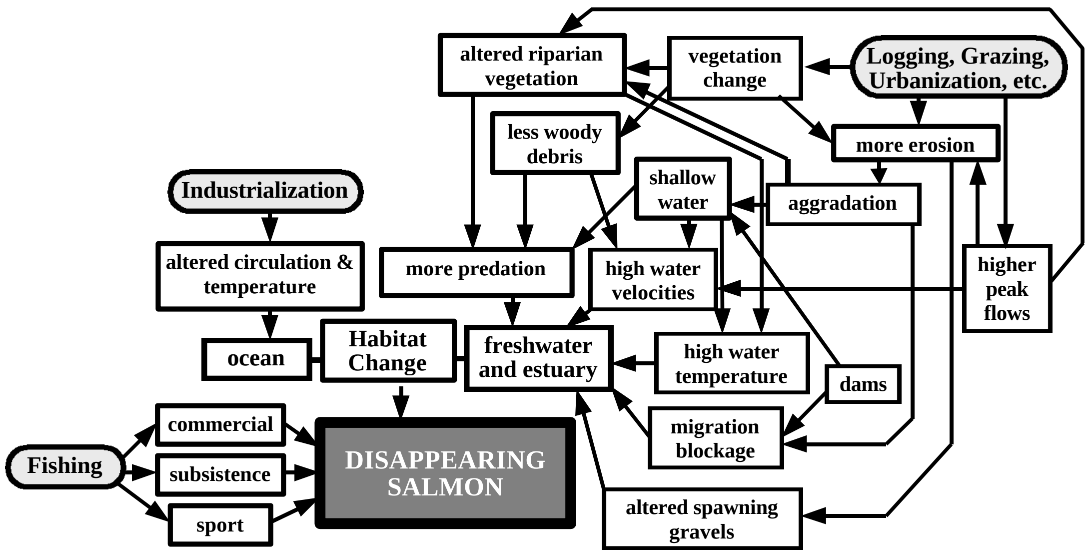

Figure 1. A generalized map of some possible important interactions affecting "Disappearing Salmon." (modified from Ziemer 1998)

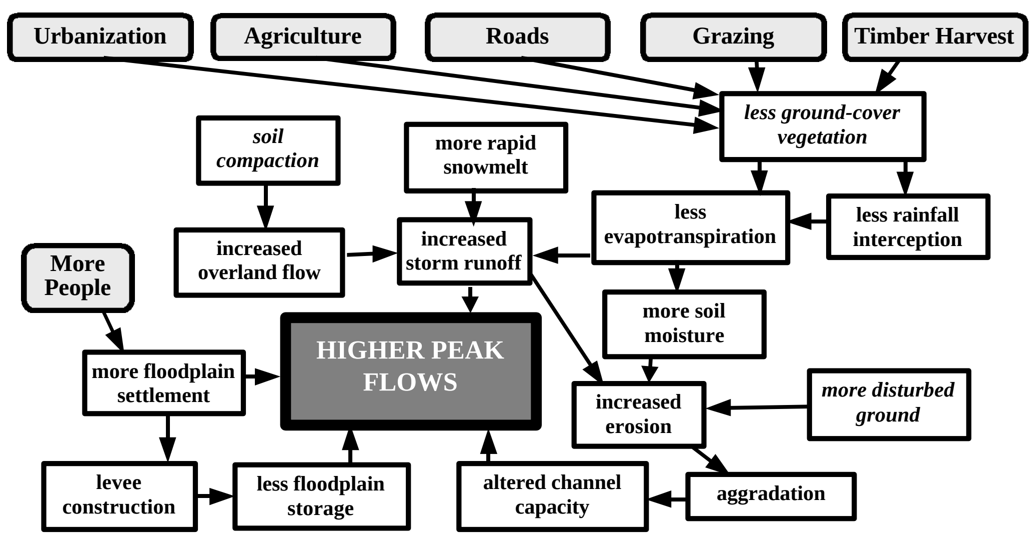

Figure 2. An expansion of the "Higher Peak Flows" box from the "Disappearing Salmon" example. Only one example, the linkage between land-disturbing activities (shaded rounded rectangles) on physical land condition (italics) (e.g., ground- cover vegetation), is shown. (modified from Ziemer 1998)

diagrams intended to be universally applicable. The process of taking the issue of concern and then developing a map that displays how that issue might be affected by local conditions is more important than the final map itself. A conscientious effort to understand the issue requires integrating information from representatives of many disciplines and interests. Such an exercise is a learning experience for everyone involved and new issues will emerge that will require further consideration. For example, Figure 1 does not consider the effect of hatcheries on fish genetics and disease, which upon further investigation may be a critical component of "disappearing salmon".

The information and understanding gained by this exercise will allow design of a restoration approach that has a greatly improved chance of modifying the proper components at the proper location at the proper time. A project designed to address a dwindling run of salmon, must not only understand the complex reasons why the run is dwindling, but how proposed local restoration projects might contribute to the solution. In some cases, the answer will be that the proposed local project will not be effective because of inadequate extent, conditions outside of the project area, or the wrong component is being addressed.

3. SCALE

The relevant time and area considerations for restoration depends on the specific issue being addressed. There is no one scale that is appropriate for all issues. Further, there is often no one scale that is appropriate for even a single issue. For example, a scale that is considered appropriate within a physical or biological context might not be considered appropriate within a political or social context. Failure to recognize these differing views can doom a restoration program. Historically, many restoration programs have been deficient because the time scale was too short and the spatial scale too small.

3.1 Political and Social Scales

3.11 Time. Corporations and stockholders consider quarterly profits and losses to be an important measure of corporate health. Politicians often focus on election cycles as their measure of a program's success. Corporate managers who ignore the quarterly balance sheet or politicians who ignore the next election may find themselves out of a job. Company- and government-sponsored restoration programs, therefore, are often expected to produce results within months to a few years. Unfortunately, ecological recovery may require decades, if not centuries.

People tend to have short memories. The more rapid the expected response to a restoration activity, the more likely that it will be considered in planning. The longer the period required to complete the activity or to observe a significant improvement, the less relevant restoration appears to daily life. Consequently, long-term restoration programs that require long-term recovery are often considered more a philosophical exercise than one of practical value. Long-term restoration programs may fall victim to flagging interest. Differences in time-perception create a tension between those seeking short-term solutions and those seeking to protect long-term value.

3.12 Space. As the size of an area increases, the perceived level of importance of the restoration activity to individuals changes. Interest is often highest if a program affects one's back yard. Personal interest tends to decrease, the farther the activity or the larger the area. A similar hierarchy exists within and between organizations and disciplines. It is not unusual to find that issues of concern and restoration programs stop at some political, social, organizational, or disciplinary boundary, although such boundaries make no sense within the physical or biological context of the issue. Non-traditional organizations and disciplines are often excluded under the assumption that they could not contribute to the solution of the problem or might even confuse the issue by introducing irrelevant concerns. Contrary to such conventional wisdom, serious consideration of these "irrelevant concerns" is precisely what is needed to avert failure of restoration projects designed with the tunnel vision provided by focussed "action" groups.

3.2 Physical and Biological Scales

3.21 Time. Relevant time scales vary by issue. A domestic water user might be concerned about changes in turbidity of drinking water during a single storm. A migratory species might depend on local habitat only several weeks out of a year. The appropriate analysis for this species would focus on whether past, present, and proposed restoration actions affect that specific habitat for those periods of occupation each year. Activities that affect the habitat only when the animal is absent would not be relevant. Changes in insect populations might be resolved at annual scales, while trends in salmon might need a sequence of several 4- to 6-year cycles. Long-lived and nonmigratory species may require an analysis that evaluates the effects of restoration activities over all seasons for several decades or perhaps centuries. Silvicultural concerns traditionally operate within 50- to 100-year time frames. Geomorphic processes that determine the physical condition of streams operate at time scales that range from decades to several centuries.

Many environmental evaluations of restoration programs are too brief to adequately reflect the patterns of response that are important to an issue. Data from such evaluations are almost always insufficient to identify even trends of change unless the impact is rapid and of large magnitude. Even in the case of a large, rapid response, abbreviated time scales for evaluation often make it impossible for the long-term significance of the restoration activity to be evaluated. In the case of sediment production and movement, a large infrequent storm may be required to produce significant erosion (Grant and Swanson 1995). Then, a number of large storms might be required to move the sediment from its point of origin to some location downstream. Both the erosion event and its subsequent routing result in a lag between the land management or restoration activity and its observed effect, particularly in large watersheds (Swanson and others 1992). As a classic example, Gilbert (1917) described the routing of sediment produced by placer mining in California during the 1850's. The fine-grained sediments were transported downstream within a few decades, but the coarse-grained sediments are still being routed to the lower Sacramento River, nearly 150 years after mining ceased.

For many issues, unusual events such as wildfire or floods are more important than average conditions. For example, the morphology of mountainous channels and much of their diversity in aquatic habitat are shaped by infrequent large storms. If a geographically isolated population of a nonmigratory resident species is removed by an unusual event, the species may not be able to reoccupy the site, even if prior and subsequent habitat conditions are perfect. Any short-term restoration program has a low probability of being tested by rare events that may occur only once every 25 years or more. Restoration programs that focus on the consequences of small "normal" storms will likely be inadequate because the design may not include the critical climatic or geomorphic events that produce the physical and biological concerns.

3.22 Space. Relevant spatial scales for restoration also vary by issue. For example, the appropriate area in which to restore the quality of a small community's water supply is defined by the boundary of the watershed supplying that water and the system by which the water is delivered to the consumer. In contrast, to evaluate the causes of "disappearing salmon" (Figure 1) would require considering those factors that influence the salmon's life cycle, including both freshwater and ocean habitats. For the "disappearing salmon" example, the affected area for some components (e.g., ocean conditions, predation, and fishing) might extend offshore from Alaska to southern California, while other components (e.g., altered spawning gravels, shallow water, and less woody debris) may be associated with a specific river basin or watershed, and still other components (e.g., dams or other migration blockages) are discrete point locations.

To be successful, restoration activities should be evaluated across a hierarchy of scales: regional, river basin, watershed, and site (Ziemer 1997). The regional scale is used to evaluate how resources can be targeted to best influence values or concerns throughout a large region. It is at this scale that an interconnected regional network of habitat protection might be established, based on region-wide habitat conditions or availability of refugia. Further, at the regional scale, river basins within the region can be ranked by importance, based on opportunities and ability to contribute to meeting specific restoration objectives. Within those river basins targeted for restoration work, individual watersheds within that river basin can be further ranked by importance to identify the most effective placement of resources to accomplish the restoration objectives. And finally, within those watersheds that were selected for activities, the individual sites can be identified and specific projects designed that will be most effective in accomplishing the objectives that had been identified at the watershed, river basin, and regional scales. With this hierarchy of scales, we can begin to ask such questions as: what are the issues that the restoration program is attempting to correct; how large a program is necessary to significantly improve the situation; which owners and agencies need to be involved; where are the priorities of places that require restoration; and what are the processes that must be corrected to accomplish the objectives.

Traditionally, restoration work has been tactical rather than strategic in nature. Commonly, programs concentrate on restoring specific small-scale, on-site problems using individual projects that affect areas smaller than a few hectares. There is increasing concern both about off-site problems affecting the restoration projects and about the impacts of the restoration projects on other on-site and off-site values. Historically, off-site issues have been considered only in the immediate vicinity of the restoration project, such as in individual pools or in individual stream reaches draining small upland watersheds. It is becoming more apparent that to be successful, restoration programs must evaluate the effectiveness of a proposed project within the context of not only watersheds, but the entire river basin. For some restoration issues, such as restoring salmon runs, even the entire river basin is too small for establishing context, and a regional perspective is necessary.

It is at the larger scales that the efficacy of proposed projects can be evaluated. For example, suppose there is a problem of excessive sediment in the stream. A budget is available to repair 20 culverts within a watershed to reduce the risk of failure and subsequent erosion of the stream crossing. But, an analysis of the entire watershed suggests that there are 2,000 culverts having comparable risk within the watershed. And further, there are 200,000 such culverts within the river basin. One must question the efficacy of repairing just 20 culverts. And then, one must ask whether the available resources could be better spent on an alternate program that might be more effective in reducing the amount of sediment delivered to the stream. For example, for the same cost of replacing a few culverts, one might reduce the total amount of sediment entering the stream by constructing "rolling dips" in the roadway or by "outsloping" the road surface. This simple grading technique would reduce the potential for water to be diverted down the road in case of culvert failure. In total, reducing the potential volume of erosion and delivery of sediment to the stream network caused by diverted water from 2,000 culverts might be much more effective than preventing the failure of only 20 of the 2,000 culverts at risk. In addition, an analysis at the watershed scale might reveal that while culverts are being upgraded in one part of the watershed on one ownership, roads are being constructed in other portions of the watershed by other owners using the old inadequate design (Ziemer 1997). In other words, such an analysis would suggest that this restoration program is not accomplishing the overall objective of reducing culvert vulnerability or sediment input on a watershed scale. A basin analysis might, in turn, reveal that restoration resources could be more effective in an entirely different watershed.

4. CONCLUSIONS

The success of any restoration program depends upon being able to identify a local concern, objectively analyze the information, and then design projects that are effective in addressing not only the local concern, but in producing a desired effect on concerns at progressively larger spatial and temporal scales and complexity. It is at these larger scales that the efficacy of proposed local restoration projects can be evaluated. Each local project should be studied to determine if the location, level of effort, and timing would produce a significant effect on identified large-scale concerns. Without consideration of the larger scale context, local projects too often are of the wrong design and wrong size, and placed in the wrong location at the wrong time. The success of a local project depends on how well that project contributes to a comprehensive restoration strategy.

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