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Project Summary

Natural Variation in Abundance of Salmonid Populations in Streams and Its Implications for Design of Impact Studies

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This project was an extensive literature review relating to stock size and production of salmonid populations in streams. The objective was to bring together data on the magnitude of natural variation in population size and to relate this variability to environmental conditions wherever possible. Recommendations are presented for the use of this information in designing studies to estimate the impact of nonpoint source (NPS) pollution. A partially annotated bibliography of 260 references is included in the Project Report.

A number of long-term studies, some up to 15-20 years, have provided useful data on temporal variation in population abundance. Other studies have examined spatial variation. Data from the best examples of both kinds of variation are presented. Temporal and spatial variation may be as high as several orders of magnitude in the extreme and, even at the least, are sufficient to mask significant pertubations caused by NPS pollutants. Environmental variables most closely associated with spatial variation are those relating to the quality of salmonid habitat, particularly physical characteristics such as cover in its many forms. Streamflow and food abundance have been associated with both temporal and spatial variation. In general, physical characteristics of habitat appear to be the most promising as descriptors of variability.

Considerable emphasis should be placed upon systems of rating habitat quality in attempts to minimize the effects of natural variation when evaluating the impact of NPS pollutants. First priority should be placed on the assessment of physical features. Thus far, this approach has been used mainly to explain spatial variation, but also has promise in explaining temporal variation. The other major emphasis should be in further development of systems of stream and watershed classification. The most useful of these systems devised to date take a perspective from geomorphology and focus on the potential of a stream system for biological production. As a means of more clearly separating natural variation from damage caused by NPS pollutants, more emphasis should be placed upon the study of basic processes in stream ecosystems and more extensive use should be made of paired comparisons in the design of impact studies.

This Project Summary was developed by EPA's Environmental Research Laboratory, Corvallis, OR,

to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Assessment of impacts on streams caused by nonpoint source pollutants is now receiving increasing attention. Salmonids are the principal fish species of economic importance affected by pollution in the western United States. Assessment of damage to these fish populations cannot be undertaken without some understanding of the natural variation in abundance within and between populations. Strategies of analysis must be devised that will separate natural variations from those effects due to man-made disturbances. The purpose of this review is to bring together literature and unpublished data on the natural variation in abundance of salmonid populations in streams and to attempt to relate this variation to physical, chemical and biological variables.

There are two kinds of variability to be considered, spatial and temporal. Spatial variation can be studied at several levels of resolution, ranging from microhabitat preferences to that variability occurring within and between streams. Temporal variation can occur on a diel, seasonal, or annual scale.

This report concentrates on studies of salmonid species during that part of their lives spent in the stream environment. These species include the coho salmon *(Oncorhynchus kisutch)*, chinook salmon *(O. tshawytscha)*, pink salmon *(O. gorbuscha)*, chum salmon *(O. keta)*, brown trout *(Salmo trutta)*, rainbow trout *(S. gairdneri)*, steelhead trout *(S. gairdneri gairdneri)*, cutthroat trout *(S. clarki)*, Atlantic salmon *(S. salar)*, brook trout *(Salvelinus fontinalis)*, and Dolly Varden *(S. malma)*. This review was begun with the emphasis on studies carried out on the West Coast of North America. However, it was found that most of the quantitative data on variability in resident salmonid populations came from other areas. Therefore, much of that information has been included in this report.

Much less information is available on population levels of the other fish species associated with salmonids. Though not included in this report, the importance of this element of the aquatic system should be emphasized and steps taken to fill this gap in our knowledge of fish communities.

Conclusions and Recommendations

The standing stock biomass of salmonid fishes in streams shows great natural variation, both in time and space. Reported levels of biomass vary from zero, or just above, to over 60 g/m^2. This variation is sufficient to mask large-scale perturbations caused by NPS pollutants such as those resulting from logging and agricultural practices. Among the most important causes of variation are differences in the physical characteristics of streams, including streamflow and habitat quality, particularly cover. Biological factors, such as food abundance and predation, may sometimes influence abundance. However, their mode of action is less clear and the case for their involvement more equivocal than that of the physical elements of the habitat.

Several courses of action are recommended that will help minimize the effects of this natural variation when attempts are made to evaluate impacts of a particular NPS pollutant. Habitat quality rating systems are being developed that show promise for explaining much of the spatial variation in salmonid populations in streams. These rating systems are based primarily on the assessment of physical features. They may also help to explain temporal variation caused by changes in streamflow, but other influences on temporal variation need further study. The other major approach that may aid impact assessment is the development of schemes of stream and watershed classification. One appears to be particularly promising in that it focuses upon the potential of a system for biological production, rather than a particular value of the moment and takes a biogeoclimatic perspective. Continuing emphasis on the study of basic physical and biological processes that lead to growth, mortality and production of stream salmonids is another promising approach to understanding natural variation in abundance. New approaches to the design of impact studies are suggested that may aid in more clearly separating natural variation from that caused by NPS pollutants and in monitoring the time required for biological systems to recover from perturbation.

Table 1 summarizes the advantages and disadvantages of four major approaches to watershed stream analysis. Studies may be grouped according to whether they bracketed (before-after) or followed (post) treatment. The other level of classification was based on whether detailed studies were made on one or very few streams (intensive) compared to less detailed study on many streams (extensive). This two level classification results in four categories, which are evaluated for efficiency and sensitivity of impact detection. This listing of advantages and disadvantages of each type reveals that no one design is optimum. The best approach appears to be a combination of post treatment analysis with carefully designed process studies carried out at one or more locations.

Table 1. *Summary of Advantages and Disadvantages of the Four Major Approaches to Watershed Stream Analysis*

A. Intensive Before-After (10-15 years; 5-7 years before and after treatment).

Advantages	*Disadvantages*
1) Possible to assess year-to-year variation and place size of impact in context of that variation.	*1) No replication; results must be viewed as a case study.*
2) Can assess short-term rate of recovery (ca. 5 years).	*2) Results not necessarily applicable elsewhere (areas of different soils, geology, fish species, etc.).*
3) No assumptions required about initial conditions.	*3) Results vulnerable to unusual climatic events (e.g. high or low rainfall season(s) immediately following treatment).*
4) Possible to monitor whole watershed impacts (provided substantial investment in facilities such as flow and sediment sampling wiers, fish traps).	*4) Final results and management recommendations require exceptionally long time to formulate - up to 15 years after initial planning stage.*
5) Long time frame provides format for extensive process studies.	*5) Difficult to maintain intensity of investigation and continuity of investigators over such a long period.*
	6) Must rely on outside agencies or firms to complete treatments as scheduled - considerable coordination required.

B. Extensive Before-After (2-4 years; 1 year before treatment, 1 year after).

Advantages	*Disadvantages*
1) Provides broader perspective across geographical area than (A).	*1) Lack of long-term perspective-- little opportunity to observe year-to-year variation.*
2) Larger number of streams examined lessens danger of extreme case.	*2) Able to assess only immediate results, which may not be representative of longer time sequence.*
3) Increased generality of results allows some extrapolation to other areas.	*3) Treatment vulnerable to unusual weather (if all treatments in same year).*
4) Relatively short time to achieve results (3-4 years from planning stage).	*4) Must rely on outside agency (see (A) above).*

C. Intensive Post-Treatment (One Watershed--Paired Sites) (4-5 years, following treatment).

Advantages	*Disadvantages*
1) Shorter time for results than (A).	*1) Provides no strict control--requires assumption that upstream control was identical to treated area prior to treatment.*
2) Moderate ability to assess year-to-year variation.	*2) "Control" most logically must be located upstream of treatment. Strong downstream trend in any feature would confound analysis.*
3) Provides opportunity for moderate level of effort on process studies.	*3) Provides no spatial perspective--results of limited application elsewhere.*
application elsewhere.	

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Table 1. (Continued)

D. Extensive Post-Treatment, 10-30 Watersheds (or more); all observations in 1-2 years (variable time after treatment).

Advantages	*Disadvantages*
1) Wide spatial perspective allows extrapolation to other areas.	*1) No data available on pre-treatment conditions--forces assumption that control and treatment were identical (on average).*
2) Long temporal perspective is possible--can assess recovery for as many years as past treatments have occurred.	*2) Control predominantly upstream.*
3) Provides ability to assess interaction of physical setting and treatment effects (e.g., effects of sediment input at different stream gradients).	*3) Total cost concentrated in very short period--requires extensive planning.*
4) Requires least time of all four designs to get results--as little as 2 years.	*4) Not as effective as (A) in assessing whole watershed effects.*
5) Probably most economical of all four approaches per unit of information.	*5) Methods used in early treatments may not be comparable to later ones.*

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The complete report, entitled "Natural Variation in Abundance of Salmonid Populations in Streams and Its Implications for Design of Impact Studies," (Order No. PB 81-163 214; Cost: $9.50, subject to change) will be available only from:

National Technical Information Service
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