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Project Summary

Habitat Preservation for Midwest Stream Fishes: Principles and Guidelines

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Natural and man-induced events (e.g., changes in land-use and channel modifications) exert major effects on biotic components of streams and rivers. Historically, man's efforts to reverse water resource degradation have emphasized physical and chemical attributes of water (water quality) while ignoring other factors that determine the quality of a water resource system. One of the most neglected components of water resource quality in stream ecosystems is physical habitat. Indeed, concern for in-stream/near-stream physical habitat is as critical to restoring a fishery as is water quality. Among the primary man-induced stresses on fish communities (sedimentation, nutrient enrichment, navigation, impoundments and levees, toxic substances, consumption of water, altered hydrological regimes, introduction of exotics), most have major impacts on physical habitat conditions. The trend toward declining fish resources in running water ecosystems will continue until effective programs to improve physical habitat are instituted.

The degradation of running water resources is at least partly due to a lack of understanding of the physical and biological dynamics of stream and river ecosystems and to the lack of a comprehensive, integrated approach to watershed management. In the final report such an approach is outlined, physical and biological dynamics are reviewed, and a set of habitat preservation guidelines for maintaining ecological integrity are presented, with emphasis on warmwater fish communities. Also, present programs dealing with water resource problems in agricultural areas are analyzed and institutional approaches suggested for halting and reversing stream and river degradation.

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

The surface waters of the United States absorbed effluents as well as other impacts of a developing society for several centuries before signs of degradation (e.g., grossly polluted water and associated losses of aquatic resources, particularly fish) could no longer be ignored. By the mid-twentieth century, early legislative efforts were initiated and water quality planning addressed the objective of halting and reversing this trend.

Formerly, however, water quality planners often lacked the interdisciplinary perspective to consider the full array of ecosystem functions and needs. Their primary target was restoration of the chemical quality of water; desirable biological quality, it was assumed, would follow. In most cases, streams were viewed only as conduits for the transport of water. The fundamental biological nature of aquatic systems and their complex interrelationships with terrestrial watersheds frequently went unrecognized. As a result, habitat quality continued to become degraded, and improvement from effluent control was minimized.

A multivariate complex of factors determines the integrity of a water resource system (Figure 1). The attributes of a running water ecosystem are ultimately determined by characteristics of the terrestrial environment. The physical structure of stream channels and their flow reflect climate as well as topography, parent material, and land-use in the basin. These factors interact to produce surface and groundwater dynamics. The riparian environment plays a major role in mitigating these influences at the land-water interface. Within the stream itself, five major sets of variables interact to affect biotic integrity: water quality, flow regime, physical habitat, energy source, and biotic interactions (Figure 2).

Historically, water resource planners have considered only water quality and, to a lesser extent, flow regime when analyzing streams and rivers. But protection of physical habitat is a prerequisite for maintenance of biotic integrity, one that requires knowledge of biological dynamics as well as the hydrological conditions that produce specific physical habitat characteristics. Both biological and hydrological background are recommended in the final report. Biologists should no more ignore the hydrological underpinnings of the stream ecosystem than should engineers and hydrologists ignore the ecosystem's biological foundations.

This project summary briefly reviews the history and background of the problem and the hydrological and biological foundation of physical habitat in running water ecosystems. Guidelines and recommendations for preservation of physical habitat characteristics of warm-water streams and rivers in the Midwest are provided in the report, which also includes a comprehensive review of ecological literature dealing with relationships between physical parameters and stream fish communities.

History and Background

Water Resource Quality

The passage of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) stimulated many efforts to improve water quality through establishment and enforcement of criteria and standards for specific contaminants. The use of these criteria has been attacked on numerous grounds. For example, they did not account for naturally occurring geographic variation of contaminants (e.g., copper, zinc), or consider the synergistic and antagonistic effects of numerous contaminants; nor did they consider sublethal effects (e.g., reproduction, growth, behavior) of most contaminants. In addition, monitoring water quality parameters, such as nutrients, pesticides, dissolved oxygen, temperature, and heavy metals may miss short-term events and long-term patterns critical to assessment of biotic impacts. Thus, the primary dependence on a chemical-contaminants approach is limited in attaining biotic integrity in running water ecosystems.

An additional disadvantage of a chemical-contaminants-defined water quality approach is the fact that several key determinants of biotic integrity are not evaluated. Chemical monitoring misses many of the man-induced perturbations which may impair use. For example, chemical sampling does not detect flow alterations or physical habitat degradation.

With passage of the Clean Water Act of 1977 (PL 95-217) a more comprehensive societal objective became clear when pollution was defined as "the man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water." Despite this refinement, regulatory agencies have been slow to replace the classical approach (uniform standards focusing on contaminant levels) with a more comprehensive approach. The holistic perspective of ecosystems (and the values derived from them) as integrated systems of land-water-biota-human needs to be recognized.

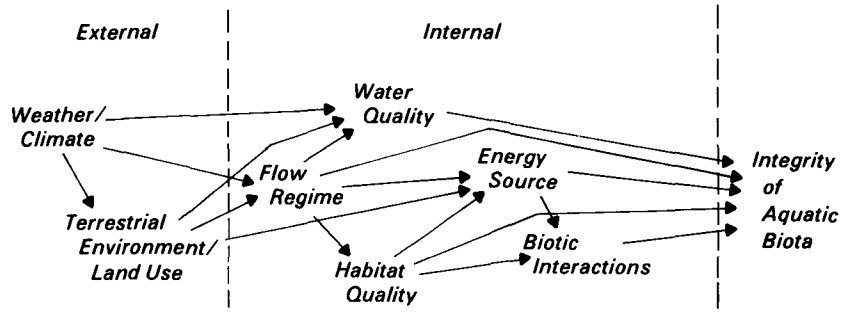

Figure 1. *Conceptual model showing the primary variables (and their interactions) external and internal to the stream that govern the integrity of an aquatic biota.*

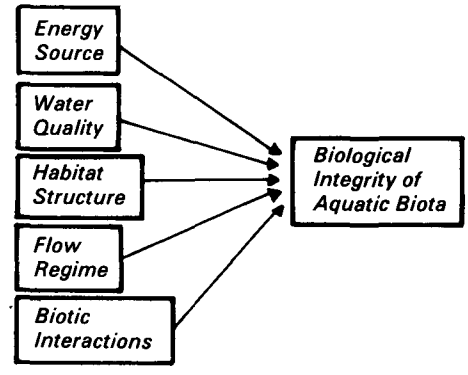

Figure 2. *Primary variables that affect the structural and functional integrity of an aquatic biota.*

Man's Influence on Stream Habitat

Human population increases, and technological advances during the last 100 years, have helped speed the degradation of water resources in the midwestern United States. Agriculture, urbanization, industrial development, navigation, hydroelectric development, and recreation have also made significant impacts on the physical attributes of lotic environments.

Impacts of modifications such as dredging and dam construction are obvious, while others are more indirect. Urbanization, for example, alters watershed hydrology which affects stream habitat conditions by disrupting flow dynamics and channel equilibrium. The driving forces of changing technologies, increasing population, and variable economic pressures, especially in the agricultural sector, disrupt stream ecosystems.

The cumulative impacts of human activities on midwestern stream fishes since the historical era of settlement have created a fauna of reduced harvestable productivity (sport and commercial) and have decreased species richness. Overall, the trophic structure of fish communities has been markedly altered. Species that have increased in abundance are typically those which are more tolerant of habitat degradation and having more generalized food habits. Because of extensive migration of fish among river reaches, the range and magnitude of local impacts on

fish communities is vastly extended. The magnitude of the degradation *of fish resources* can be seen in the Maumee and Illinois River watersheds where 44% and 67%, respectively, of the fish *species* known from those watersheds have declined in abundance or disappeared since 1850, mostly as a result of human activities.

The factors with greatest impact on fish communities seem to be:

Agriculture - changing land use and resultant drainage, erosion, sedimentation, and nutrient enrichment.
Navigation - maintenance of navigation locks and channels, especially in large rivers.
Impoundments and levees.
Toxics - from urban, industrial, and agricultural sources.
Consumption of water.
Introduction of exotics.

Most of these (except toxics and exotics) have major impacts on physical habitat conditions although habitat has received relatively little attention. In areas with agricultural, industrial, and/or urban perturbations that impact physical habitat, the biotic integrity of the aquatic ecosystem is degraded and there is little chance for recovery without efforts to restore degraded physical habitat. The degree of recovery possible depends on the degree of disruption, both local and regional, and the approach used to reverse the dominant trend of the past century. Without prompt treatment of physical habitat degradation, fish resources in many rivers will continue to decline.

Existing Programs and Stream Habitat

Although stream habitat degradation results from a number of human activities, agriculture, because it makes up most of the watershed area, either directly or indirectly impacts the largest portion of midwestern streams. Several ongoing agricultural programs have been used to address water resource problems (e.g., SCS Conservation Farm Plans, Small Watershed PL 566 Plans, Rural Clean Water Program, etc.) but they have been largely ineffective in restoring stream habitat.

What is needed is an approach that embodies environmental protection along with agricultural production principles and will, in the long term, serve the interests of soil and water conservation as well as for protection of physical habitat in warm-water streams.

Development of Physical Characteristics of Stream Channels

The physical attributes of a natural stream channel result from a complex of physical processes mitigated by the biota of the entire watershed. Biologists and planners attempting to maintain or recreate desirable habitat must be aware of these dynamics or they may waste time and resources attempting to maintain a physical habitat incompatible with local hydrologic conditions.

The end result of these processes is the evolution of a "dynamic equilibrium" characterized by a stream channel morphology that efficiently distributes the energy flux required by the basin's water-sediment discharge regime. By disrupting stream equilibrium, land-use modifications and/or direct alterations of channels commonly result in marked changes in the structure and stability of stream habitats. These effects are further compounded by inter-relationships among stream habitat components and their interacting effects on biotic integrity.

Biological Foundations of Habitat Protection

Fish communities vary along the continuum from headwater streams to large rivers. Fish distributions along this stream-size gradient also vary with time and/or changing environmental conditions. Fish species in streams and rivers are associated to various degrees with distinct habitat types. These habitats form primarily as a result of natural fluvial processes and their characteristic physical and chemical attributes vary considerably with discharge. Like their general distribution patterns, the type of habitat in which a stream fish species is found may change with age, sex, reproductive state, geographic area, and/or fluctuating environmental conditions.

Pools, riffles, and raceways are the primary habitat divisions for fishes in small to medium-sized streams. In addition to these main channel habitats, large river environments have a diverse array of other habitat types (Figure 3) that are of critical importance to fishes. Side-channel and extra-channel habitats, for example, provide feeding, spawning, nursery, and overwintering areas for many fish species. Due to the dynamic nature of stream and river ecosystems, these main channel and extra-channel habitats are continually being created and destroyed by fluvial processes. However, under natural equilibrium conditions, a full mosaic of necessary habitats is maintained. All of these stream attributes must be protected to preserve high quality fish communities in warm-water streams. Improvement of fish communities and thus biotic integrity, in previously degraded areas requires programs that will restore missing habitat features that are essential to high quality fish communities.

Expected Benefits

A more integrative approach to the maintenance of physical habitat characteristics in warm-water streams can be expected to reverse the trend toward degradation of water resources through:

a. Improved water quality and quantity,
b. Improved fishery systems and other aspects of biotic integrity, including terrestrial wildlife associated with riparian environments,
c. More effective and efficient processing of natural and man-induced organic inputs to running waters,
d. Reduced sedimentation of channels and reservoirs from land and channel sources,
e. Decreased cost of channel construction and maintenance activities,
f. Increased recreational opportunities,
g. More cost-effective attainment of legislative mandates for water resource systems.

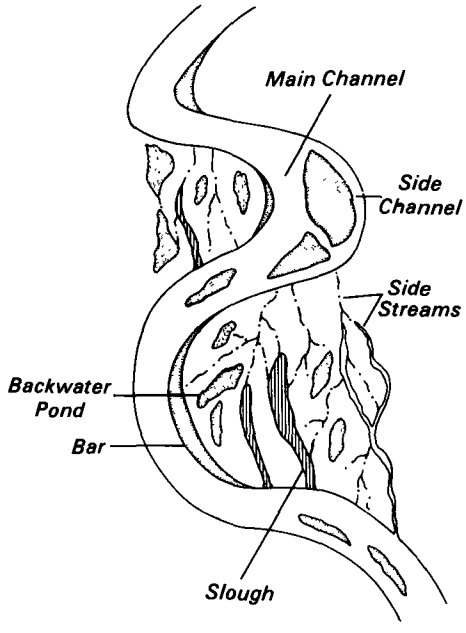

Figure 3. Diagrammatic representation of major habitats associated with large river environments.

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The complete report, entitled "Habitat Preservation for Midwest Stream Fishes: Principles and Guidelines," (Order No. PB 83-167 650; Cost: $14.50, subject to change) will be available only from:
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