USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title. Ecosystem-wide effects of roadway runoff on headwater streams in Maine

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Congressional district. 2nd Congressional District, Maine

Statement of critical regional or State water problems

The impending widening of the Maine Turnpike, recently approved by the voting public, has raised concerns about the effects of road construction, as well as general effects of roadways, on surface water quality throughout the state. It is acknowledged by the Maine Department of Environmental Protection (MDEP), however, that the present level of understanding is not sufficient to provide substantive guidance to public and private groups that may be required to monitor and maintain the quality of surface waters affected by roadway activities (e.g. Maine Department of Transportation, Maine Turnpike Authority).

Preliminary evidence based upon research funded by the MDEP indicates that changes in stream invertebrate communities (taxonomic richness, biomass) and ecological processes (detritus decomposition) do occur in some streams as they pass beneath the turnpike, and that at least in one case these changes are correlated with heavy metal contamination from non-point sources. Based on these preliminary results, it is clear that there is evidence indicating the potential for water quality problems because of chronic disturbances from the turnpike (e.g. heavy metals, sediments, other contaminants). Because existing data are not strong, however, the reality and the breadth of this potential remains to be determined in a rigorous but timely manner.

Statement of results or benefits

The results of this proposed research will benefit the public of Maine by providing data required to narrow the information gap concerning the effect of roadway runoff and non-

point heavy metal pollution on streams in southern Maine by quantifying longitudinal gradients of:

- physical habitat variables, water chemistry, and concentrations of heavy metals contained in the sediments of a minimum of three streams that flow beneath the Maine Turnpike in the general vicinity of Saco
- community structure (macroinvertebrates, fish), secondary production (macroinvertebrates), detritus decomposition, primary production, and ecosystem metabolism in these same three streams

These data will:

- document the potential ecosystem-wide effect of the Maine Turnpike on stream health · assess the performance of metrics that measure ecosystem process and function in addition to structure
- establish an information base required to document the effects of the turnpike construction that will begin within the next 3 to 5 years

The resulting information will be used by the MDEP as a basis for:

- determining the potential effects of roadways on stream ecosystems in northern New England
- providing a quantitative basis for establishing guidelines to public and private groups required to monitor and maintain the quality of surface waters affected by roadway activities (e.g. Maine Department of Transportation, Maine Turnpike Authority)
- development of protocols for the mitigation of such effects if deemed warranted.

It is important that this information be obtained in a timely fashion in order to have the pre-construction information required to document the environmental effects of the turnpike widening that will begin within the next 3 to 5 years.

Nature, scope, and objectives of the research

Introduction. The effects of roadways on the ecology of streams that pass beneath them are poorly understood, but are acknowledged to be a potentially important environmental issue throughout the United States (Cline et al 1982, Hoffman et al 1985, Tsihrintzis & Hamid 1997). The impending widening of the Maine Turnpike has raised concerns about the effects of road construction, as well as general effects of roadways, on surface water quality throughout the state. The Maine Department of Environmental Protection has made a recent initiative toward addressing these concerns by funding a comprehensive study of patterns of water quality, as indicated by invertebrate community structure, in a single stream, Goosefare Brook, that passes beneath the Maine Turnpike near the town of Saco. This study is in progress, but early data definitively show a significant decline in invertebrate richness, abundance and biomass as Goosefare Brook passes through a series of culverts beneath the turnpike (Figure 1).

This abrupt change in invertebrate community structure is maintained for several kilometers below the turnpike crossing. It is apparent that this decline in water quality is a response to an increase in the concentration of a number of heavy metals in association with the turnpike interchange at Saco (Figure 2). Although the turnpike may eventually be implicated, it is probable that the major source of contamination is industry located in the immediate vicinity (e.g. Saco Steel, Saco Defense), rather than the turnpike itself (Figure 2). The ongoing study of Goosefare Brook is so far successful in definitively documenting the presence and general location of a severe and ongoing water quality problem (the actual source of the heavy metal contamination is unknown at present). The potential effect of the turnpike on this particular stream system, however, remains unclear because of these confounding circumstances.

This proposal seeks to generalize the initial study of Goosefare Brook by pursuing two complimentary goals. The first is to initiate a long-term study of the effects of the turnpike on water quality of several headwater streams (rather than a single stream) in southern Maine. This will allow a more rigorous assessment of the effects of the turnpike on streams than is presently possible. The addition of more streams to the study will allow us to determine whether the decline in stream water quality in Goosefare Brook is a general phenomenon associated with the turnpike. The second goal, more exploratory in nature, is to initiate a ecosystem-wide approach to the bioassessment of the general effects of non-point pollution on streams in Maine. Such an approach is needed because non-point pollution of streams is often manifested by subtle changes in levels of nutrients and other pollutants (e.g. pesticides, suspended solids) (Shaheen 1975, Maltby et al 1995). The environmental response to such changes may be equally subtle, existing as effects on general ecosystem processes (e.g. production, decomposition), rather than large effects on community or ecosystem structure (Stout & Coburn 1989, Casper 1994).

Objectives. The first general objective of this proposal is to narrow the information gap concerning the effect of roadways on streams. This will be accomplished by conducting a rigorous investigation of changes in population, community, and ecosystem characteristics of a minimum of three streams that cross the Maine Turnpike in the general vicinity of Saco. This will involve the measurement of a suite of population to ecosystem variables that may be used to monitor stream health in a comprehensive way. The choice of streams associated with the Maine turnpike is reasonable because effects of paved roadways are surely to be greatest in this region, and should serve as a worst-case scenario for the state as a whole (cf. Davis & George 1987). These streams will be considered baseline demonstration sites for comprehensive long-term monitoring of ecosystem effects of roadways on streams in southern Maine. We stress here that it is particularly important that this information be obtained in a timely fashion in order to have the pre-construction information required to document the environmental effects of the turnpike widening that will begin within the next 3 to 5 years.

The second general objective is to assess the performance of metrics that measure ecosystem process and function in addition to structure as general indicators of stream health. The presence of the strong water quality gradient in Goosefare Brook should provide sufficient contrast to demonstrate a decline in ecosystem function to levels where

an acceptable standard of stream health is compromised. Although not considered an active component of the present proposal, it is our intention that the bioindicators associated with the strong water-quality gradient observed in Goosefare Brook will ultimately be used as the basis for a case study for providing a recommendation for a total maximum daily load (TMDL) for heavy-metal contamination of headwater streams in Maine. Initiating dialog about TMDLs is important because regulatory policy concerning non-point pollution should be based upon clear protocols for quantifying minimum acceptable effects on ecosystem structure. We plan to target Goosefare Brook because of the strong gradient of heavy metal contamination

The specific objectives of this study are to determine and evaluate differences in the following physical and biological variables in replicated reaches above and below the turnpike in each of the three study streams. The variable are categorized into physical and biological attributes. Biological attributes are further subdivided in those that more closely reflect ecosystem structure, and those that reflect ecosystem function.

Physical and chemical attributes of study reaches

- water and sediment chemistry in 3 study reaches above and 3 below the Maine turnpike for 3 streams draining independent watersheds
- suspended sediments (inorganic)
- reach channel form
- catchment land-use

Ecosystem structure

- community structure (abundance, biomass) for fish and invertebrates in each study reach
- maximum size and growth rates of macroinvertebrates (biomass, selected taxa)
- spatial and temporal patterns of primary producers (chlorophyll a, biomass)
- spatial and temporal patterns of benthic organic matter accumulation and storage

Ecosystem function

- annual macroinvertebrate production
- transported organic material
- rate of leaf detritus processing
- ecosystem primary production and community respiration

Predictions. The lack of precise information about the effects of roadways on streams in New England requires that our predictions be relatively general (note that these are "predictions" rather than "hypotheses"). It is our intention, however, that the testing of even general a priori predictions will provide an important element of structure to this essentially exploratory study. The following predictions will be tested, and are based upon ongoing work at Goosefare Brook (Figures 1, 2, 3).

- Changes in community structure, as measured by invertebrate richness, abundance, biomass, and representation among functional groups will be correlated with heavy metal levels and/or other chronic disturbances associated with the turnpike (see Figures 1 and 2). In general, richness, abundance and biomass will decline below the turnpike. It is important to note that declines will not be observed for all taxa, however. The proportion of midges of the subfamily Orthocladiinae, some genera of which are known for having high tolerance to metals, will probably increase, for example. Determining such contrasting patterns will be a major objective of this study.
- Secondary production of selected invertebrates will differ in reaches above and below the turnpike as a function of heavy metal levels and/or other chronic disturbances associated with the turnpike. We assume that production will decline as a function of a decline in growth rate, biomass, and maximum size below the turnpike (cf. Figure 1) because of the effects of pollution-induced stress. As indicated in the first prediction, however, some taxa may be little affected or may show increases below the turnpike.
- Rates of microbial leaf-litter processing will be impaired in reaches affected by heavy metals below the turnpike (Figure 3). Rates of leaf-litter consumption by invertebrates will be reduced in reaches affected by heavy metal levels and/or other chronic disturbances associated with the turnpike because of a general reduction in the richness and production of litter-feeding taxa (e.g. Goosefare Brook, unpublished data).q
- There will be an increase in periphyton standing crop and production below the turnpike because of a reduction in the production and resource demand of periphyton-feeding taxa in reaches affected by heavy metal levels and/or other chronic disturbances associated with the turnpike (e.g. Goosefare Brook, unpublished data).

Study Sites. Although the primary focus of the study will be Goosefare Brook, at least two other streams will be added to the study (a minimum of three streams). Six 100-m study reaches will be established along each stream (three replicate reaches upstream of the turnpike, three downstream), in addition to those already established in Goosefare Brook. Study reaches will be established within 3 km of the turnpike to reduce longitudinal affects on stream community structure (e.g. Vannote et al. 1981), and will be matched as closely as possible with regard to channel form and riparian characteristics. Although a sample of more than three streams may be desirable from a strict statistical standpoint, it is our opinion that a more comprehensive study of fewer streams will provide a more rigorous basis for assessing what may be relatively subtle affects of non-point sources of pollution. If potential turnpike effects can be identified, assessment metrics can then be selected on basis of results from the comprehensive study and the hypothesis that similar affects should be observed within a larger sample of streams can then be efficiently tested.

It is important to realize that the change in water quality that occurs in Goosefare Brook below the turnpike may not be related to turnpike effects. The two additional streams have been selected on basis of proximity and comparability to Goosefare Brook, as

determined by a detailed study of leaf processing and leaf pack community structure conducted in autumn 1997, and should provide an excellent contrast to Goosefare Brook that will allow detection of true turnpike effects. The Webhannet River is located approximately 30km south of Goosefare Brook along the turnpike, and is the only similar stream in the vicinity, in that it drains a heath area, and shares similar seasonal patterns of acidity (autumnal decline of two full pH units). It differs in that the catchment has little current human activity in the vicinity of the turnpike apart from the roadway itself. Cascade Brook has pH that is generally circumneutral, and represents a more typical southern Maine stream. The catchment of Cascade Brook is located immediately to the north of the catchment of Goosefare Brook.