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Project Summary

Macroinvertebrate Inventories of the White River, Colorado and Utah: Significance of Annual, Seasonal, and Spatial Variation in the Design of Biomonitoring Networks for Pollution Detection

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An aquatic macroinvertebrate monitoring program is proposed for early warning detection of toxic discharges to streams in oil shale development areas. Changes in stream biota are used to signal the need for increasing levels of chemical analyses to identify and quantify toxic pollutants. This study compiles invertebrate data taken during three seasons (spring, summer, and fall) and over five years (1976 to 1980) from riffles along the White River in Colorado and Utah. Spatial and temporal variations in the biota are described along with their implications for the development of a monitoring system that incorporates such comparative surveys. In addition, the data provide benthic biological information that is generally comparable to previous studies on the White River and that can be used to expand the biological monitoring data base before massive oil shale development ensues.

This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, NV, 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

Development of oil shale resources in the western United States will increase the potential for contamination of surface water resources with a host of inorganic and organic toxicants. It is not feasible to establish an "early warning" stream monitoring network for the timely detection and location of toxic substances strictly through chemical monitoring because the long list of inorganic and organic constituents identified as energy-related waste and effluent components makes extensive use of comprehensive chemical analyses prohibitively expensive. Therefore, in order to expand surveillance of potentially affected streams, this study incorporates both biological and chemical monitoring. Changes in stream biota are used to detect subtle impacts from low-levels of toxicants released to the stream. These changes signal the need for chemical analyses to identify and quantify the substance(s). This method of coupling biological early-warning surveys with follow-up chemical analyses permits efficient monitoring of entire stream systems for toxic discharges.

Comparative surveys of faun will most effectively detect the effects of pollution when natural variation of the biota is well documented. This assures that false alarms will be minimized and, at the same time, that the effects of toxicants will not be mistaken for naturally occurring biotic fluctuations. The full report on which this summary is based records and synopsizes five years of macroinvertebrate data from the White River of Utah and Colorado.

Study Area

The study area consists of a 200-km section of the White River in Utah and Colorado (Figure 1). Sampling site distributions provide good representation of riffle environments found along the river and ranging from clear, cold headwaters with stable substrates and rich invertebrate fauna to highly turbid downstream reaches with unstable debris-choked substrates. The White is representative of larger streams flowing out of the Rocky Mountains and across semi-arid lands of the western United States to the Colorado River.

The White River watershed is currently relatively undisturbed by human activities, but industrialization, in the form of oil shale mining and processing, has recently begun within the watershed and is expected to expand greatly over the next few years.

Methods

Survey Design and Sampling Sites

A total of 74 invertebrate sample sets from 27 White River collection sites and 11 different collection times were processed (Figure 1, Table 1). These collections represent from 3 to 15 replicate samples each, with the large majority consisting of five replicates. Collections were designed to depict three basic features of natural faunal variation: (1) temporal (annual, seasonal, and short-term) changes at specific collection sites; (2) spatial (longitudinal) changes along the White River on specific dates; and (3) annual changes in the degree of similarity between adjacent collection sites.

Annual variation in community composition was assessed using collections taken during September and early October for four consecutive years, from 1976 through 1979. Collections from spring, summer, and fall of both 1978 and 1979 documented seasonal changes within a given year. Invertebrate data were also compared over shorter time intervals (early versus late September 1976 and April versus May 1978) to examine within-season changes. September 1979 sample sets taken from 16 separate sites provided documentation of longitudinal changes in community structure. Changes in degree of similarity between adjacent sites were evaluated using data obtained at sites located just upstream and downstream from the confluences of Piceance and Yellow Creeks, two White River tributaries most likely to be affected by oil shale development (Figure 1).

Field Methods and Sample Processing

All invertebrate samples were obtained in riffle areas using the Standardized Traveling Kick Method. Formalin-preserved samples were thoroughly rinsed in the laboratory, and debris and organisms

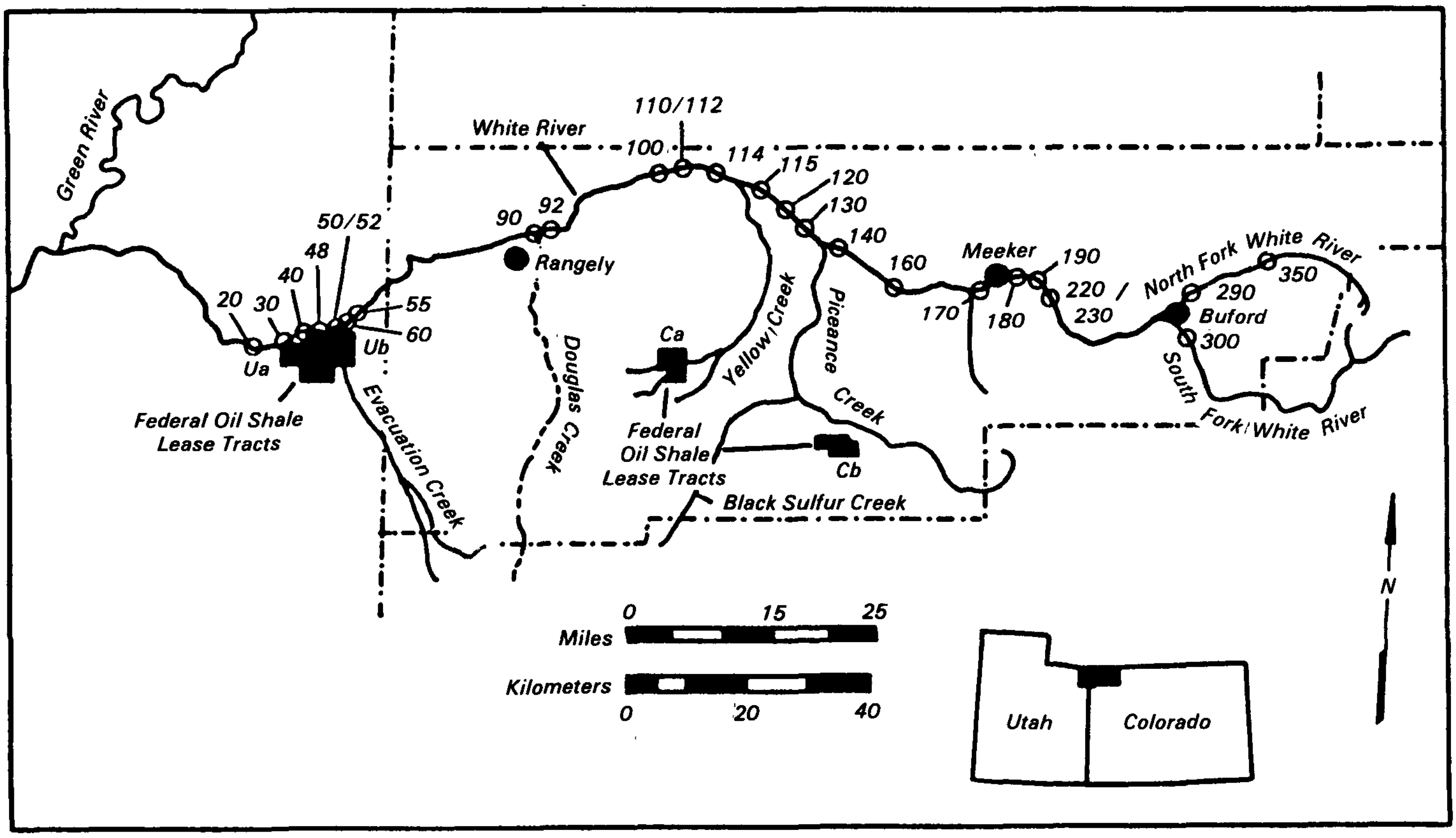

Figure 1. Approximate locations of biological sampling stations in the White River, Utah and Colorado, 1976 to 1980 (numbers indicate stream reaches, as shown in Table 1).

were then separated from gravel. Most groups of invertebrates were identified to the lowest taxonomic level possible from available literature.

Results

White River macrobenthic collection sites were grouped for presentation purposes by river section. Rangely, Colorado, separates the downstream and middle reaches, and Meeker, Colorado, separates the middle and upstream reaches (Figure 1 and Table 1). Typically, differences exist in terms of relative abundance rather than of presence or absence. Important sources of natural variation that should be considered for the design of biomonitoring surveys include annual variation, seasonal changes, short-term temporal variation, and faunal changes along the river.

Incorporation of Macroinvertebrate Data into an Integrated Monitoring Program

In the absence of man-induced disturbances or natural phenomena that substantially alter stream characteristics, changes in macroinvertebrate community composition in a downstream progression are normally gradual. Consequently, abrupt changes in the biota between adjacent upstream/downstream sites may be an indication that significant water quality changes have occurred, thereby signaling the need to incorporate additional elements into the monitoring program.

The degree of community change will determine the level of monitoring required to identify and quantify causative agents (Table 2). If differences between upstream and downstream communities fall within the range of natural variability, as established by baseline sampling, the communities are judged not to have been affected, and level 1 monitoring is continued. If level 1 monitoring reveals between-site differences that exceed natural variability, a water quality impact is suspected, and level 2 monitoring is initiated to identify causative agents. If level 1 monitoring reveals complete or nearly complete downstream alterations in the biota, level 3 monitoring is implemented.

Criteria for the degree of community change needed to trigger a monitoring decision are derived by close inspection of predevelopment baseline data, including variations in these data. Large community changes will alert the aquatic biologist to recent toxic discharges. In such cases, the biologist will easily be able to further pinpoint the location of recent toxic discharge(s) by collecting downstream from the reference site until changes are first noted.

Because the purpose of the biomonitoring approach outlined is to detect sources of complex mixtures of toxic pollutants, it is important that information on faunal changes be maximized. Thus, the data are analyzed at the species level rather than to reduce data into generalized indices, such as diversity measures or through use of clustering techniques. The additional effort required to carefully identify and compare more common species and groups from adjacent stream sites is minimal in relation to the total

Table 1. *Seasons and Years of Macroinvertebrate Collections Processed from White River Sampling Sites*

	Year and Season of Collections											
Collection Site[1]	*Fall*[2] *1976*		*Fall 1977*	*Spr.*[3] *1978*		*Sum. 1978*	*Fall 1978*	*Spr. 1979*	*Sum. 1979*	*Fall 1979*	*Spr. 1980*
Downstream Reaches												
20	X											
30	X	X	X									
40	X											
48		X										
50	X											
52		X										
55											X	
60	X	X	X				X				X	
Middle Reaches												
90			X	X		X	X				X	
92											X	
100											X	
110											X	
112						X						
114					X	X	X			X	X	X
115					X	X	X			X	X	X
120											X	
130		X	X	X	X	X	X	X		X	X	X
140		X	X	X	X	X	X	X		X	X	X
160											X	
170	X										X	
Upstream Reaches												
180			X								X	
190	X											
220	X											
230			X	X	X	X	X				X	
290			X				X				X	
300			X									
350							X					

[1]See Figure 1 for location of collection sites.
[2]First column represents early September 1976 and second column represents late September 1976.
[3]First column represents April 1978 and second column represents May 1978.

Table 2. *Suggestions for Using Community Change to Establish Monitoring Requirements*

Level	*Degree of Community Change*	*Degree of Monitoring*
1	*Within natural variation*	*Continue macroinvertebrate community monitoring schedule*
2	*Exceeds natural variation*	*Conduct water column monitoring for conventional parameters (e.g., conductivity, dissolved oxygen, temperature, pH). Conduct sediment and/or tissue analyses for suspected pollutants (e.g., priority pollutant scan).*
3	*Complete or nearly complete changes*	*Conduct level 2 plus water column analyses for suspected pollutants and bioassays with toxicant source (e.g., effluent, stream water, leachate, etc.).*

expenditure needed for the proper monitoring of streams. As the aquatic biologist becomes familiar with stream conditions and the biology and ecology of resident invertebrates, he will also become more efficient and accurate at making appropriate comparisons.

Information on the sensitivities of many aquatic invertebrates, including many species of immature insects, to various toxic metals and certain organic compounds (e.g., chlorinated hydrocarbons) is available in the literature. Disappearance or reduction in density of known sensitive species from a particular site would provide an immediate clue that toxic chemicals may be entering the system. Chemical analysis of sediments and stationary invertebrates may reveal the presence of complex mixtures of organic compounds that are below detectable levels in the water or which are caused by intermittent discharges and would consequently be missed by water-column sampling.

Although considerable information is available on the organic and elemental components of energy-related wastes and effluents, information on the toxicity to fresh water aquatic invertebrates of complex mixtures of organic compounds associated with these wastes is limited. Information on the toxicity of complex mixtures of wastes and effluents to resident stream organisms could be obtained from toxicity tests conducted in the field and laboratory. Information derived in this manner would aid considerably in relating changes in community composition to toxic wastes for purposes of interpreting biomonitoring data.

Conclusions

- Although annual (year-to-year) variations in White River biota can be substantial, these changes are generally consistent between adjacent collection sites with similar habitats. Thus, between-site faunal comparisons offer good reliability for detecting impacts originating in a stream reach bracketed by adjacent upstream-downstream sties. With this consideration, incorporating the biomonitoring survey method into a western stream monitoring program, as illustrated, is feasible.
- Short-term variability found in White River biota dictates that when several sites are sampled, they must be sampled as close to the same date as possible.
- Criteria for site selection must include the degree of longitudinal (site-to-site) variability of stream biota being surveyed and locations of areas of highest potential for toxic introductions. Stream biota in the middle reaches of the White River (between Rangely and Meeker, Colorado) change only gradually. Consequently, collection sites need only be established in the vicinity of potential pollutant sources (e.g., disposal piles, tributaries, subsurface seeps).
- Sampling frequency will depend on the importance placed on early detection of water quality deterioration. However, seasonal progression of stream invertebrate communities dictates a minimum of one sampling each spring, summer, and fall. Rates of recolonization of affected substrates by drift from unaffected areas upstream may, however, dictate more frequent sampling (e.g., monthly or every two months).
- Measurement of conventional water quality parameters and chemical analyses of selected invertebrates and sediments may aid identification and assessment of toxicants discharged intermittently or which are below detectable levels in water-column analysis. These measurements also assist identification of non-toxic factors that may cause community shifts (e.g., low dissolved oxygen or temperature shifts).
- The stream biota survey approach is suggested for detecting and assessing water quality changes in western lands as they open to development. Continued experience with its use in such a context will result in technique refinement, thereby increasing efficiency of the approach.
- If field surveys indicate that toxic pollutants have substantially altered macroinvertebrate communities, supplemental field and laboratory toxicity tests are suggested to assess the sensitivities of common White River species exposed to suspected pollutants. This information facilitates correct interpretation of survey results for detection and assessment of pollutant effects.

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The complete report, entitled "Macroinvertebrate Inventories of the White River, Colorado and Utah: Significance of Annual, Seasonal, and Spatial Variation in the Design of Biomonitoring Networks for Pollution Detection," (Order No. PB 84-198 936; Cost: $16.00, subject to change) will be available only from:

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