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Project Summary

Monitoring Approaches for Assessing Quality of High Altitude Lakes: Colorado Flat Tops Wilderness Area

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Three high altitude lakes were selected and sampled to develop monitoring approaches for assessing lake sensitivity to acid deposition. Sampling of Ned Wilson, Oyster and Upper Island lakes in the Flat Top Wilderness Area of Colorado was conducted in 1982 and 1983. These lakes are representative of the range of lakes sensitive to acid deposition in the area.

Data collected show the three study lakes are biologically and chemically similar. Available literature suggests biological communities of the study lakes are sensitive to acidification, with major impacts expected as pH drops below 5.5. Lack of specific acidity sensitivity data for most species of organisms inhabiting the study lakes precludes precise predictions of biological response to acidification. However, annual sampling for community changes and indicator species of phytoplankton, zooplankton, and macroinvertebrate populations is recommended. Data on fish population structure and maintenance mechanisms are needed before fish community information can be used for monitoring, but metal concentration data for fish tissue and sediments should be collected for residue levels. Nineteen physical and chemical water quality parameters, including eight metals, are recommended for annual scans.

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

This report summarizes results of a joint U.S. Environmental Protection Agency and U.S. Geological Survey sampling effort conducted during 1982 and 1983 on three lakes in the Flat Tops Wilderness Area of northwestern Colorado. Sampling was conducted to provide an assessment of the current biological and chemical conditions of these index lakes which is essential for assessing monitoring requirements and long term designs for these and similar lakes. Distributions, abundances and types of biota resident in these lakes determine the type of biological monitoring program most suitable for sampling frequencies, site selection and distribution, and identifying sensitive communities or community components. A basic understanding of the physical and chemical characteristics is necessary for parameter selection and determining sampling sites, distributions, and frequencies. Factors such as parameter responsiveness to acidification, ease of measurement, temporal, spatial, and vertical variability are important considerations in monitoring designs.

Located within the boundaries of the White River National Forest, the Flat Tops Wilderness Area of northwestern Colorado includes numerous lakes, many higher than 3300 m in elevation.

Background

Approximately 370 lakes within the Flat Tops Wilderness Area have been estimated to be very sensitive to acidification. All have alkalinities, either predicted or measured, less than or equal to 200 μeq/L $CaCO_3$; some have been recorded at 70 μeq/L $CaCO_3$. The high sensitivity of most lakes results principally from the small amounts of calcarious sediments in their watersheds. Basalt caprock underlies most lake beds and watersheds of the higher altitude lakes. Additionally, small watershed-to-lake surface area ratios reduce the water/soil contact time of runoff. Hence, the small amounts of $CaCO_3$ in sediments have little chance to dissolve in these runoff waters.

The severity of acid precipitation effects in the Flat Tops could increase due to expansion of the oil shale industry. Expansion of synfuels (including oil shale) production and coal-fired power plants on the Rocky Mountain western slope "Energy Belt" may increase hydrogen ion concentrations in wet and dry deposition and will undoubtedly, contribute increasing amounts of SO_2 and NO_x to the atmosphere.

Monitoring Requirements

Unique sampling problems are encountered in wilderness areas. Because the Flat Tops are accessible only by foot or horseback, severe restrictions are placed on the use of the cumbersome and/or fragile equipment used in more conventional studies. Additionally, sampling is normally restricted to summer (ice free) months due to a heavy snowpack most of the year. Because monitoring approaches and techniques tested in the lakes of the Flat Tops have helped identify techniques best suited for these conditions, refined monitoring strategies suitable for application in these types of areas can now be suggested.

Methods and Materials

Samples collected each year and methods used in their collection are summarized in Table 1.

Results and Discussion

Components of the Flat Tops lakes zooplankton, phytoplankton and fish communities are subject to alterations as the pH of water approaches 5.5, and certain macroinvertebrate species are known to be sensitive to waters with pH values of 6.0 to 6.5. Once these levels are reached disruptions will be expected in the biotic communities of the study lakes. Currently, summer daytime pH levels in all three study lakes are typically above 6.0.

Phytoplankton

Within-lake differences in phytoplankton assemblages were apparent in all lakes. However, between-station and depth related variability were largely attributable to rare species with dominant and co-dominant species relatively uniformly distributed throughout each lake. Discrete samples from the deep site on Upper Island Lake yielded slightly more diverse assemblages at 1 m than at 5 and 10 m. The majority of taxa collected at the various strata were present in the 1 m sample, suggesting that a near surface sample taken from a stratified lake will collect most of the more common phytoplankton species.

Annual and seasonal variability of the phytoplankton community were high in all lakes. Also, between-lake differences in the composition and abundance of phytoplankton communities were apparent in samples collected on approximately the same dates. Because of differences in the succession patterns of the phytoplankton assemblages in the various lakes, and because different assemblages were noted in individual lakes during mid August of two successive years, it seems unlikely that once-a-year sampling will provide adequate data to depict long term changes in phytoplankton assemblages in the various lakes. Differences in succession patterns need to be further investigated during the open water period. It is suggested that near-surface (e.g., 1-1.5 m) quantitative samples be collected and composited from 3 to 4 sites per lake at two week intervals, to examine succession patterns. In addition, replicate discrete quantitative samples should be taken at three depths (e.g., 1.5, 5 and 10 m) during a period of strong stratification and again during isothermal conditions to examine distribution throughout the water column.

Zooplankton

Zooplankton species richness in the three Flat Tops study lakes is low and changes in diversity will probably not be useful in future monitoring. However, permanent changes in community composition (acid sensitive and acid tolerant species) can be indicative of acidification. Sensitivity to acidification of the copepod species (*Diaptomus* spp.), having distributions restricted to high altitude lakes, are not known and their sensitivity should be determined for possible use in future monitoring.

Annual zooplankton differences within individual lakes, based upon August sampling during successive years, were minor. Differences that were noted were attributable principally to occurrences of rare species. Because with-in lake variability between sites was also low, it appears that replicate, depth-integrated samples collected at a single deep site during the period of strong stratification would be adequate to characterize the zooplankton communities of the study lakes for purposes of showing differences between lakes and over time.

Seasonal variability and succession patterns of zooplankton communities were not addressed in this study, consequently no conclusions or recommendations can be made regarding optimal sampling frequencies or seasons. Sampling at a single deep site at two-week intervals during the open water period would provide considerable information on succession patterns of zooplankton assemblages. Knowledge of these patterns would aid in the design of long-term monitoring programs with respect to required sampling frequencies and optimal sampling periods (e.g., stratified vs. non-stratified lake conditions).

Macroinvertebrates

Different macroinvertebrate communities occupied the littoral (shoreline) and profundal (deep) zones of the three Flat Tops lakes. Qualitative sampling in the littoral zone yielded more diverse assemblages than were found in quantitative grab samples from the profundal zone. To adequately characterize macroinvertebrate communities of individual lakes it is essential that both zones be sampled. Because the acidification sensitivity of individual taxa is not well known, it is important to examine entire assemblages occupying various habitats using changes in indices of community structure, (e.g., diversity, richness, density) when possible.

Annual differences in various study lake's macroinvertebrate communities indices were significant, hence frequent (yearly) sampling may be necessary to access annual variability. Because recruitment and emergence affect "seasonal" species population size, temporal variation during ice free periods should be determined at least once. Except for one shallow Ned Wilson Lake site, between-site macroinvertebrate community indices

Table 1. *Summary of Sample Sites, Dates, Numbers and Types Collected During 1982 and 1983 Flat Tops Lakes Surveys. Field Measureable Parameters, e.g., Temperature, pH, D.O., Conductivity, etc., are not Included in this Summary*

Lake	Sites	Sample	Type	Reps.	Total No.	Date[1]
Ned Wilson	1,2,3,4	Phytoplankton	D.I.G.[2]	2[3]	8	08/17/82
	"	Zooplankton	V.T.[4]	1	4	"
	"	Macroinvertebrates	Ekman	3	12	"
	shoreline	Fish-metal content		6	6	09/01/82
	"	Fish-stomach contents		1	1	08/17/82
	2	Phytoplankton	Grab[5]	1	1	07/21/82
	2	"	"	1	1	08/04/82
	2	"	"	1	1	09/10/82
	2	"	"	1	1	10/03/82
	shoreline	Macroinvertebrates	Qual[6]	5	5	08/17/82
	spring	"	"	1	1	08/18/82
Oyster	1,2	Phytoplankton	D.I.G.	2	4	08/18/82
	"	Zooplankton	V.T.	1	2	"
	"	Macroinvertebrates	Ekman	3	6	"
	shoreline	"	Qual	3	3	"
	2	Sediments-metal content		1	1	"
Upper Island	1,2,3,4	Phytoplankton	D.I.G.	2	8	08/20/82
	"	Zooplankton	V.T.	1	4	"
	4	Macroinvertebrates	Ekman	3	3	"
	shoreline	Macroinvertebrates	Qual	3	3	"
Ned Wilson	1,2,3,4	Phytoplankton	D.I.G.	1	4	07/25/83
	2	"	Grab	1	1	04/14/83
	2	"	"	1	1	06/28/83
	2	"	"	2	2	07/20/83
	2	"	"	2	2	07/29/83
	2	"	"	2	2	08/12/83
	2	"	"	2	2	08/17/83
	2	"	"	2	2	08/30/83
	2	"	"	2	2	09/10/83
	2	"	"	2	2	09/28/83
	1,2,3,4	Zooplankton	V.T.	3	12	08/25/83
	"	Macroinvertebrates	Ekman	3	12	"
	shoreline	"	Qual	4	4	"
	"	"	H.D.[7]	4	4	"
	"	"	B.K.[8]	4	4	"
	"	"	10-R.[9]	30[10]	30	"
	"	Fish-metal content		5	5	"
Oyster	1,2	Phytoplankton	D.I.G.	2	4	08/24/83
	"	Zooplankton	V.T.	3	6	"
	"	Macroinvertebrates	Ekman	3	6	"
	shoreline	"	Qual	3	3	"
Upper Island	1,2,3,4	Phytoplankton	D.I.G.	2	8	08/27/83
	4	"	Grab	2	2	08/10/83
	4	"	"	2	2	08/24/83
	4	"	Grab, 10 m[11]	2	2	08/27/83
	4	"	Grab, 5m	2	2	"
	4	"	Grab, 1m	2	2	"
	1,2,3,4	Zooplankton	V.T.	3	12	"
	4	Macroinvertebrates	Ekman	3	3	"
	4	"	Qual	3	3	"
	shoreline	"	10-R	30[10]	30	"
	shoreline	Fish-metal content		2	2	"
Ned Wilson	1,2,3,4	Alkalinity, Color	D.I.G.	1 per site		08/25/83

Table 1. *(Continued)*

Lake	*Sites*	*Sample*	*Type*	*Reps.*	*Total No.*	*Date*[1]
Oyster	*1.2*	*Total P, Nitrate*				
Upper Island	*1,2,3,4*	*Nitrite, Ammonia, TOC, DOC, Sulfate, Chloride, Fluoride, and Total Metals*	*D.I.G.*	*3 per site*		*08/24-27/83*

[1]Actual day may vary by ± one day.
[2]Depth Integrated Grab (Van Dorn) sample.
[3]Only one replicate phytoplankton sample per site processed in 1982.
[4]Vertical Tow-Standard Wisconsin Plankton Net; bottom to surface.
[5]Grab sample at surface.
[6]Qualitative Triangular Dip Net (570µm mesh).
[7]Hester-Dendy Plate sampler.
[8]Rectangular Basket with rocks.
[9]10-rock method.
[10]Three replicates analyzed.
[11]Discrete Depth sample.

were not significantly different in any lake during either year, hence replicate samples from one deep site should adequately assess the status of profundal invertebrate assemblages in these index lakes during future monitoring.

Salamanders

Salamanders in Oyster Lake may serve as useful monitors because they breed in pools subject to influx of snowmelt pollutants. Sensitivity of various *Ambystoma tigrinum* life stages to acidification are not known, and should be determined for use in future monitoring. Increased acidification of Oyster Lake could result in decreased population or loss of salamanders. *A. tigrinum* sensitivity to acidic conditions should be determined for possible use in future monitoring.

Limited sampling and visual observations revealed the presence of salmonids in two of the three study lakes. It is not known whether trout in these lakes are reproducing naturally or whether they are the result of repeated stocking. Because early life stages are more sensitive to acidification and associated effects (e.g., metal releases) than are adults, artificially maintained populations would not be good monitors of acidification induced changes. On the other hand, naturally reproducing populations would likely be affected by any reduction in ambient pH levels, or by additional releases or mobilization of metals because of the high vulnerability of egg and larvae stages. Determination of fish population structure and maintenance mechanisms is an initial essential step toward incorporation of fish surveys into a monitoring program.

Metal concentrations in whole homogenized brook trout were low in Ned Wilson Lake during both 1982 and 1983. Two specimens of cutthroat trout collected from Upper Island Lake during 1983 yielded levels of copper, nickel and zinc an order of magnitude higher than were found in Ned Wilson Lake brook trout. Concentrations in gills of fish from both lakes were much lower than in whole fish. Because these metals are biocumulative, it is recommended that analyses of whole fish (e.g. three specimens/lake) be conducted once annually to monitor tissue residue levels.

Metals in Sediments

Concentrations of metals within sediments of the study lakes are within expected ranges for unimpacted Western U.S. water bodies. Because changes in sediment metal chemistry may occur as a result of increased metal inputs or changes in water chemistry, annual collection and analysis of sediment samples for metal content should be an integral component of a long-term monitoring program.

Water Quality

Physical and chemical water quality data for the study lakes were similar to those reported for other lakes in this region of Colorado. Mean alkalinity values were less than 100 µeq/l in two of the lakes, but exceeded 200 µeq/l in one lake. The pH levels in the low alkalinity lakes were 6.3 to 6.8, whereas pH in the third lake exceeded 8.0. Conductivity levels were typically low (64-112) µmhos/cm) reflecting the low concentration of dissolved substances in the water. Concentrations of total metals were also low, with aluminum, iron, calcium and magnesium being the most abundant elements. Toxic metals were not measured in concentrations that pose any hazard to aquatic life.

Key water quality parameters recommended for monitoring include the nitrogen species (NO_2, NO_3, and NH_3), sulfates, pH, alkalinity, conductivity, total phosphorus, temperature, dissolved oxygen, total and dissolved organic carbon and dissolved inorganic carbon. Annual scans of total recoverable and dissolved aluminum, copper, lead, nickel, iron, silver, calcium and magnesium should also be included.

Conclusions

Lack of acid sensitivity data for most species of organisms inhabiting the study lakes preclude concise predictions of biological response to acidification. Testing for acid sensitivity of certain potentially indicator species, assemblages and whole lake ecosystems may help formulate accurate predictions of acid deposition effects on biota of high altitude lakes.

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The complete report, entitled "Monitoring Approaches for Assessing Quality of High Altitude Lakes: Colorado Flat Tops Wilderness Area," (Order No. PB 85-117 232; Cost: $19.00, subject to change) will be available only from:
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