A Report on Acid Precipitation and Its Effects on Fish and Wildlife Resources in Minnesota and Wisconsin

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Introduction

Acid precipitation has been generally defined as atmospheric deposition in any form having a pH less than 5.6 - the expected pH of distilled water in equilibrium with normal atmospheric carbon dioxide. Approximately two-thirds of the North American continent are presently receiving precipitation which meets that definition . Within certain regions of North America, Europe and Scandanavia where precipitation acicity is particularly high and geologic buffering capacity low, adverse impacts to aquatic and terrestrial resources are occurring. Following a general discussion of the acid precipitation phenomenon on a national and international basis, its specific implications to Minnesota and Wisconsin will be discussed.

Overview

The process leading to formation of acid precipitation is initiated with the injection of high levels of nitrogen and sulfur oxides into the lower atmosphere by the tall (300-400 meter) smokestacks primarily associated with fossil fuel-powered utilities, industries and metal smelters. In North America, the sulfur/nitrogen oxide contribution to precipitation acidity is roughly 2 to 1, with half of the latter coming from automobile emissions. In the presence of normal atmospheric moisture, the above precursor compounds can be transformed into strong acids which may return to earth hundreds of miles distant in the form of rain, snow or fog. Sulfate particulates can also return to earth as dry deposition. Precipitation acidity tends to vary across North America in a roughly west-to-east manner, with the highest average acidities (lowest pH values) recorded to the east in New York, Pennsylvania, Ohio, southern Ontario and southern Quebec. Sulfur oxides predominate in precipitation over the east half of the United States, while oxides of nitrogen tend to be more strongly correlated with acidity in the west.

While precipitation acidity on an average annual basis tends to change relatively little over short distances, the acid buffering capacities of watersheds, subwatersheds and individual lakes can vary substantially. It is thus possible for surface waters vulnerable and invulnerable to precipitation acidity to exist in close proximity. Factors affecting the susceptibility of individual lakes include (1) acid buffering abilities of watershed bedrock formations and overlying soils, (2) watershed size in relation to size of the lake, (3) presence or absence of surface inlets or outlets, (4) watershed vegetation type, (5) percent of watershed consisting of bog (palustrine scrub-shrub) wetlands. An additional variable which must be considered is the fact that precipitation pH values for a given area vary seasonally and with individual precipitation events. Snow core pH values have been shown to be as much as 0.5 pH units lower (5 times as acidic) than the average annual value for a given site.

There is near unanimous agreement that acid precipitation is responsible for a variety of adverse effects on aquatic and terrestrial ecosystems, agricultural productivity and cultural features (buildings, bridges, etc.). Aquatic effects can differ among species as well as among age groups and populations of the same species. Such effects range from reduced fecundity, egg viability and other non-lethal physiological effects in fish and other aquatic organisms to the loss of nearly all native plant and animal life in strongly acidified waters. Documented and/or suspected terrestrial vegetation effects range from reduced seed germination and growth to the loss of individual plant species or groups of species in forests, grasslands and croplands. Sulfur dioxide is also an irritant to the breathing passages of most mammals, including humans.

A number of physiological responses by fish and other aquatic organisms in acidified environments have been found to be closely linked to associated trace metal toxicity. Trace metals - along with a variety of non-metallic ions, nutrient elements and synthetic organic compounds - are common components of stack emissions from combustion-related industrial and energy production facilities. In addition to being a minor component of atmospheric deposition, aluminum is a common element of the earth's crust. In areas of low buffering capacity, percolation of low pH water can leach aluminum from watershed soils and rock into receiving waters and enhance its availability and toxicity to aquatic plants and animals. Mercury, on the other hand, reaches aquatic systems predominantly through direct atmospheric fallout. Low pH waters tend to retain more mercury from precipitation, revolatize less back into the atmosphere and transform greater amounts to the more toxic monomethyl form. While mercury is directly toxic to aquatic organisms, it can also bioconcentrate in aquatic food chains to levels deemed harmful to human health.

The foregoing was intended to be only a superficial overview of the major elements of a very complex process. For a more detailed discussion, the reader is referred to the June, 1982 series of publications entitled "The Effects of Air Pollution and Acid Rain on Fish, Wildlife and Their Habitats" (FWS/OBS 80/40.3-40.11).

History

Though various aspects of atmospheric chemistry have been the object of scientific interest for over 300 years, the concept of long range atmospheric transport and deposition of acids and other pollutants was developed and first studied during the 1950's in Scandanavia and northwestern Europe. At that time, precipitation over a broad area was found to be strongly acidic and damage to aquatic resources was already apparent. Since that time, southern Sweden and Norway, portions of Belgium, the Netherlands, Germany, France and the British Isles have experienced an average annual precipitation pH of 4.0 to 4.5 - roughly 20 to 40 times the acidity of "normal" pH 5.6 precipitation. Concurrently, the fish populations of some 2500 lakes in Sweden have definitely been damaged by acidification (the loss of a water body's residual bicarbonate buffering capacity) and another 6,000 lakes appear to be adversely affected (Muniz, 1984). A similar situation has developed in southern Norway where brown trout populations have become extinct in 1500 lakes covering 13,000 square kilometers (5,000 square miles), with an additional 20,000 square kilometers of water (lakes) becoming acidified. In Scotland and northwestern Europe, impacts attributed to acid precipitation range from loss of riverine and lake fisheries to loss of many thousands of acres of coniferous forest.

Acid precipitation research and monitoring in North America has been more recent and less well coordinated than that of Europe and Scandanavia. Declining fish populations in remote lakes and streams in southern Ontario and Nova Scotia prompted a number of investigations in the early 1970's. By 1976, the extinction of fish populations in the Adirondack Mountains of New York had been documented (Schofield 1976). Evidence suggests that emissions from a heavy concentration of coal-fired power plants constructed in the Ohio River Valley during the 1950's and 60's may be responsible for much of the acidity of precipitation falling across the northeastern United States and eastern Canada. The "acid loading rate" (i.e., precipitation acidity X volume on an annual basis) for much of that region exceeds that for areas of Scandanavia which have already experienced widespread acidification and loss of aquatic systems. Recent estimates put the number of Ontario lakes which have lost all fish populations at 140. More than 2,000 additional lakes have pH values less than 5.0, which places them in imminent danger at present loading rates. Ontario considers an additional 27,000 of its lakes susceptible to acidification or associated metal toxicity in the future (Harvey and Lee 1981). Nova Scotia has lost Atlantic salmon fisheries in at least nine rivers with pH values below 4.7. An additional 22 rivers have salmon populations whose extinction is imminent to likely over the next 15-20 years at present rates of acid loading (ibid). Similarly, a study of the fate of 40 Adirondack lakes sampled in the early 1930's and again in 1975 showed a pH decrease and a loss of brook trout populations in 26 lakes (Schofield 1977). Acidification-related losses of fisheries have also been reported for streams in New Jersey (Johnson 1979) and northern

Florida lakes (Crisman, et al 1980). In several instances, aluminum toxicity was thought to be operative prior to the attainment of normally lethal pH levels.

Status in the Upper Midwest

A trend of declining precipitation pH occurs from west-to-east across the Upper Midwest region, with average annual values ranging from approximately 5.2 in western Minnesota to 4.2 in eastern Michigan. Since average annual precipitation volumes tend to increase in a west-to-east manner, Michigan is subject to the highest acid loading rates and Minnesota the lowest. Because Michigan is being addressed in a report by the RCA biologist in East Lansing, it will not be considered further here.

It is clear from the above that both Minnesota and Wisconsin are receiving predominantly acidic precipitation. Ongoing monitoring programs in those states have shown that precipitation pH values vary seasonally and with individual events, but appear to be holding steady or declining only slightly on a volume-weighted average annual basis. In areas of either state which are underlain by limestone formations or which possess calcareous soils (with one possible exception to be discussed), acid precipitation appears to be of little consequence to aquatic or terrestrial ecosystems. However, much of northeastern Minnesota and northern Wisconsin contain soils low in calcium carbonate ($CaCO_3$) buffering capacity due in large part to their origins and glacial histories.

Minnesota

Much of the Superior National Forest and Boundary Waters Canoe Area in northeastern Minnesota lies on exposed or thinly covered granite, gabbro, slate and greenstone formations which are inherently low in bicarbonates. Consequently, runoff is swift and buffered very little prior to reaching surface waters. An extensive region of Minnesota to the south and west of the Boundary Waters Canoe Area is comprised of deep deposits of glacial material in the form of outwash plains, drumlins, ground moraines and terminal moraines. Within that region - stretching to within 50 miles of the Twin Cities and north to Koochiching and Itasca Counties - numerous individual lakes with low alkalinities have been found at higher elevations on sandy moraines. Isolated from regional groundwater tables and having small, steep watersheds on porous soils, the water chemistries of those lakes are heavily influenced by direct rainfall combined with runoff whose contact with watershed soils is minimal.

The Minnesota Pollution Control Agency has developed the following index to measure lake sensitivity to acidification:

Alkalinity		Lake Status
0 mg/l	as $CaCO^3$	acidified
1-5 mg/l	" "	extremely sensitive
6-10 mg/l	" "	moderately sensitive
11-20 mg/l	" "	potentially sensitive
20 mg/l	" "	non-sensitive

Applying that index to a 1981-82 survey of Lakes in Crow Wing, Itasca and Carlton Counties and the BWCA, the following results were obtained (MPCA 1983):

Area/County	No. Lakes Sampled	Percent in Each Category		
		<5 mg/l	6-20 mg/l	>20mg/l
Crow Wing County	52	2.0	11.5	86.5
Itasca County	158	6.0	16.0	78.0
Carlton County	18	22.0	39.0	39.0
BWCA	219	20.0	67.0	13.0

On the basis of the above and other data, there are no Minnesota lakes which are known to have become acidified as yet. The same can be said for its rivers and streams (Payer, pers. comm.). However, an indefinite continuation of present acid loading rates over sensitive areas of the state would likely lead to acidification of many of those lakes classified as sensitive today. In a related matter, while aluminum concentrations in Minnesota's lakes do not appear to have increased as a result of the acidification process, several recent studies have found significant mercury levels in fish taken from sensitive northeastern Minnesota lakes (Glazer and Bohlander, 1978, Heiskary and Helwig, 1983), including several individual fish of different species and from different lakes which exceed the 1.0 ppm Food and Drug Administration commercial guideline for human consumption.

There has been no apparent reduction in growth of trees or other vegetation in Minnesota.

Wisconsin

The geology of northern Wisconsin is characterized by deep glacial till and outwash deposits similar in many respects to the acid sensitive areas of Minnesota outside the BWCA. However, several important factors tend to make the situation in Wisconsin more critical from a time perspective. First, the acid loading rate -

again, a function of precipitation amount X acidity - is considerably higher over much of Wisconsin. Secondly, the lakes in northern Wisconsin tend to be smaller, with even smaller watersheds, thus presenting less opportunity for buffering of precipitation runoff. As a consequence, an estimated 30% (2,000) of the lakes in the northern one-third of Wisconsin have alkalinities of 10 mg/l or less (WDNR 1983). Of those, approximately 80 lakes have alkalinities approaching zero. Using airborne sulfate deposition as a measure of acid loading, continuation of the present 11-16 kilograms/hectare/year (kg/ha/yr) deposition rate for that area makes acidification of the latter group of lakes a likely event. An increase in the loading rate to 20kg/ha/yr would place the former group in jeopardy. While no lakes in Wisconsin are yet known to have become culturally acidified, several appear to be showing the early warning signs of concurrent drops in alkalinity and pH. As with Minnesota, fish in several northern Wisconsin lakes have been found with tissue mercury levels exceding the FDA "safe" limit of 1.0 ppm.

Fish and Wildlife Service Field Stations

A review of existing water quality data for refuges and fish hatcheries in Minnesota and Wisconsin was made in order to determine their relative near-term susceptibilities to acid precipitation.

Both Iron River and Genoa fish hatcheries appear to be buffered adequately to withstand present acid loading rates.

Rice Lake NWR, with pH appearing to range from 5.6-6.3 and alkalinities of 40-100 mg/l (Heffernan, pers. comm.) is not in imminent danger of acidifying, but its water quality parameters from an invertebrate and wild rice production standpoint (pH, alkalinity, sulfates) are worthy of close monitoring.

The Refuge Manager at Necedah NWR was unable to locate any recent water quality data, but his description of the refuge suggests a naturally acidic system which could be limiting to invertebrate food production at the present time. Also, Necedah may be subjected to a fairly high acid loading rate. I believe the situation there warrants a closer examination in the near future.

The impounded waters on all other refuges appear to be adequately buffered to withstand present acid loading levels. For reasons to be explained in the following section, I am somewhat concerned about ephemeral and temporary palustrine persistent emergent wetlands in the two states - on and off Service lands.

Suggested Research/Field Investigations

Effects of Acid Precipitation on Region 3 Wetlands

The hydrologic characteristics of palustrine persistent emergent wetlands in the upper midwest region make some of them potentially vulnerable to total or partial acidification during spring snowmelt. Rather than deal with the subject at length here, I have appended a proposal developed in March 1984 to investigate the magnitude of the potential problem.

Effects of Mercury on Fish-eating Birds

The lakes of northern Minnesota and Wisconsin constitute breeding habitat for common loons, American and red-breasted mergansers, goldeneye ducks and American bitterns. In both states, elevated mercury levels have been found in fish taken from poorly buffered lakes. Through analysis of birds collected from lakes showing high mercury levels, one could determine whether mercury exposure may be affecting the reproductive processes of the above species. Since mercury taken up by birds appears to accumulate in their feathers, the analysis of such feathers (shed on a periodic basis) would appear to provide a means to associate a given time frame with observed mercury levels. (The Minnesota Pollution Control Agency has requested that any dead loons recovered in northern Minnesota this season be turned in for mercury analysis. This is a questionable approach in that the likelihood of dead loons being recovered from lakes known to contain high mercury levels in fish is remote at best).

An Instructional Manual on the Collection, Analysis and Interpretation of Acid Precipitation Data

Should Region 3 Field Stations desire to become involved in acid precipitation monitoring in the future, involved invididuals will need to receive training in the maintenance and use of some rather sophisticated instruments, apparatus and procedures for determining pH, alkalinity, conductivity, etc. (the "Hach" Kit is woefully inadequate for the precision required). Such information is presently available in a diverse array of journal articles, government publications, books, etc.). I believe a concise manual combining "state-of-the-art" methodology available from the above sources (with appropriate credits) would be a definite asset. While development of such a manual might be the responsibility of the Office of Biological Services, an initial user training session could be conducted by the appropriate RCA Specialist.

Literature Cited

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Wisconsin Department of Natural Resources. 1983. Wisconsin Interpretive Assessment Document on Acid Deposition.

Appendix

Individuals Involved in Acid Precipitation Research Activities in Minnesota and Wisconsin

U.S. Environmental Protection Agency	Research Interest
Dr. Gary E. Glass Senior Research Chemist Environmental Research Laboratory-Duluth 6201 Congdon Boulevard Duluth, MN 55804 218/727-6692	Precipitation and lake water chemistry
John Eaton same as above	Aquatic community responses
U.S. Forest Service	
Elon S. Verry U.S.D.A. - Forest Service 1831 Highway 169 East Grand Rapids, MN 55744 218/326-8571	Forest hydrology and extent of acidification of water bodies on National Forests
Dale S. Nichols same as above	same as above
U.S. Geological Survey	
Dennis A. Wentz U.S. Geological Survey 1815 University Avenue Madison, WI 608/262-2488	Hydrology of acid-susceptible lakes in Wisconsin
Mark Have U.S. Geological Survey 702 Post Office Building St. Paul, MN 55101 218/725-7841	Acid deposition monitoring

U.S. Fish and Wildlife Service

Dr. James G. Wiener CNFRL - Field Research Station P.O. Box 936 La Crosse, WI 54601	Water chemistry v. fishery effects

State of Minnesota

Ronald Lawrenz Minnesota Department of Natural Resources Centennial Office Building St. Paul, MN 55155 612/296-0785	Effects on aquatic organisms
Dave Thornton Acid Rain Coordinator Minnesota Pollution Control Agency 1935 West County Road B2 Roseville, MN 55113 612/296-7336	All aspects

State of Wisconsin

Thomas B. Sheffy Wisconsin Department of Natural Resources 101 South Webster Street Madison, WI 53707 608/267-7648	Coordinates Wisconsin's Acid Deposition Research Program

Academia

Dr. Robert B. Cook University of Minnesota Duluth, MN 55812 218/726-7565	Water chemistry
George Rapp, Jr. same as above	same as above
Dr. Steven Eisenreich Environmental Engineering Program 122 CME Building University of Minnesota Minneapolis, MN 55455 612/373-2507	Precipitation chemistry

Dr. Evil Gorham Department of Ecology-University of Minnesota Room 208 Zoology Building 318 Church Street S.E. Minneapolis, MN 55455 612/376-1743	All aspects
Dr. James Perry Department of Forest Resources University of Minnesota 110 Green Hall St. Paul, MN 55108 612/373-0846	Effects on vegetative decomposition
Dr. William Swenson Center for Lake Superior Environmental Studies University of Wisconsin Superior, WI 54880 714/394-8410	Effects on fisheries
Dr. Thomas F. Waters Department of Fisheries and Wildlife Room 120 Hodson Hall 1980 Folwell Avenue St. Paul, MN 55108 612/373-1706	Effects on stream ecology

Justification:

Since the mid-1970's, acid precipitation has been recognized as a threat to the health and survival of aquatic resources in parts of eastern North America and the Upper Midwest. Defined as atmospheric deposition in any form producing a pH below 5.6 (the expected pH of distilled water in equilibrium with normal atmospheric CO_2), acid deposition has been linked to aquatic impacts ranging from reduced fish egg viability and other non-lethal physiological effects to the loss of all animal life in some aquatic systems.

Over the past 10 years, the sources, extent and implications of acid precipitation to permanent aquatic systems in Minnesota, Wisconsin and Michigan have been studied intensively. Precipitation chemistry research completed to date tends to support the following: (1.) A trend of declining precipitation pH exists from west to east across the region, with volume-weighted average annual values ranging from approximately 5.2 in western Minnesota to 4.2 in eastern Michigan; (2.) Precipitation pH trends across the region appear to be holding steady or declining slightly; (3.) Snow core pH values may be as much as 0.5 units lower (five times more acidic) than average annual values for any given location (Thornton, personal communication); and (4.) the acidity and trace metals which accumulate over winter in snow and dry deposition are released over a relatively short period of time during snowmelt (Haapala, et al., 1975; Siegel, 1981). When the foregoing factors are considered in light of the substantial literature addressing the biological effects of depressed pH in aquatic systems, we can appreciate the magnitude of the problem facing aquatic and dependent terrestrial resources across the region.

Despite considerable research directed toward permanent aquatic systems, we are not aware of parallel efforts to address the question of potential acid precipitation effects on the chemical and biological integrity of ephemeral, temporary or seasonal wetland basins in this region or elsewhere. Those wetlands typically support an early spring irruption of aquatic life of extreme importance to the reproductive success of numerous waterfowl species. For reasons to be discussed, we believe there is a basis for concern that acid precipitation may be altering the water chemistries of some of these aquatic systems sufficiently to cause the loss or re-structuring of their animal communities.

By combining the results of various aspects of acid precipitation research with a general understanding of wetland hydrology, it is possible to envision the potential for significantly depressed pH and alkalinities in certain wetland types across the region. Ephemeral, temporary and seasonally flooded palustrine persistent emergent wetlands (formerly wetland Types 1, 2 and 3, respectively, in USDI Circular 39) often share the following characteristics: (1.) They consist of shallow depressions in the landscape and possess relatively small watersheds; (2.) They are typically perched with respect to the local groundwater table and thus are isolated from groundwater influences; (3.) They comprise discrete hydrologic units, i.e., they are neither fed by nor discharge to streams; (4.) Much of their previous year's vegetative growth remains standing throughout winter, trapping a disproportionate share of the total available watershed snow cover; and (5.) Though their soils may be saturated, they typically hold little or no surface water at the onset of spring snowmelt.

The above, somewhat generic characteristics of ephemeral to seasonally flooded wetlands tend to minimize opportunities for meltwater pH neutralization through contact with watershed soils, groundwater or surface waters stored over winter. Further, meltwater originating outside the wetland basin may receive little pH buffering if the terrain it passes over is frozen or saturated. Finally, soils in some areas of eastern Minnesota, Wisconsin and Michigan tend to be low in bicarbonates, thus possessing little buffering capability.

Ephemeral, temporary and seasonal wetlands have developed faunas capable of completing entire life cycles within narrow time constraints imposed by short (several week to several month) periods of surface water availability. It is during the brief spring period following snowmelt and before ice-out on semipermanent wetlands and lakes that these fauna constitute an available, abundant, high protein food source for returning waterfowl. Studies have shown aquatic organisms to comprise from 72 to 99 percent of the food of laying female dabbling ducks (Swanson, et al., 1979). Swanson and Meyer (1973) reported that such foods accounted for 92 percent of the diet of breeding Aythyinae (divers) in North Dakota wetlands. Two groups of aquatic organisms known to be particularly important to the diet of laying female waterfowl are snails and daphnids (Swanson, et al., 1979). Several studies have shown that the survival of either group is doubtful below pH levels of 5.5 to 6.0 (Davis and Ozburn, 1969; Parent and Cheetham, 1980; Okland, 1980; Gavre, 1980). Whether breeding waterfowl can readily shift their foraging activity from these and other intolerant organisms to more acid tolerant species is not known. Whether such a shift could occur without adverse reproductive effects on laying females also is in question. National species of special emphasis which could be affected include the mallard, black, pintail, canvasback, redhead and ringnecked ducks.

In addition to its general trusteeship responsibilities relative to waterfowl and other migratory birds, the Fish and Wildlife Service presently spends hundreds of thousands of Duck Stamp dollars annually in the acquisition and management of wetlands for waterfowl production. The foregoing discussion supports the hypothesis that acidification of wetlands important to the reproductive success of a variety of waterfowl and other water birds may be occurring within the states of Michigan, Wisconsin and Minnesota. The goal of the proposed study is to determine whether and to what geographic extent such acidification represents a present or potential future problem. Should the proposed study reveal a wetland acidification problem deemed significant, a detailed multi-disciplinary research and management effort should be undertaken to determine and quantify the impacts to waterfowl and other wetland feeders. From an operational standpoint, factors such as the relative suitability of individual tracts for purchase or easement as well as the need for mitigative measures on Service owned wetlands could assume great importance.

Objectives:

To determine the degree of acidification of selected ephemeral, temporary and seasonally flooded wetlands in Minnesota, Wisconsin and Michigan associated with spring snowmelt.

Procedures:

During the 1984 field season, a minimum of ten physically unaltered wetland basins representing each of three wetland types (ephemeral, temporary and seasonal) would be identified within six general areas across Minnesota, Wisconsin and Michigan (see attached map). The selected areas reflect east-west differences in precipitation acidity and amounts, differences in bedrock geology or soil types and, to some extent, differences in waterfowl breeding habitat preferences. Should visual observations prove inadequate to differentiate between perched and groundwater-influenced seasonal wetlands, surface water conductivity would be the determining factor. A limited number of wetlands found to be groundwater-influenced would be included in the survey for comparison purposes.

During the spring of 1985, surface water pH, alkalinity, conductivity and color would be measured from 1 to 2 weeks after disappearance of the winter snow cover at all selected sites. An attempt would be made to obtain a qualitative aquatic organism sample at each site by means of a throw-type plankton seine or sweep net. Those samples would be examined for the presence and relative abundance of various aquatic organism groups.

Measurements of SO_4 and NO_3 concentrations in surface waters are frequently used to establish the strength of the link between atmospheric deposition and surface water chemistry. However, because the present study is based on the premise that perched ephemeral, temporary and seasonally flooded wetlands hold little or no water immediately prior to the onset of spring snowmelt, SO_4 and NO_3 measurements are not proposed. Further, because this study is of a survey nature, covering a broad geographic area and requiring a large number of field collections and measurements over a short period of time, the collection and shipment of water samples for calcium ion and trace metals analysis was deemed infeasible. Should interpretation of data generated during 1985 suggest the need for information on any of the above or other parameters, such information could be obtained on a site-specific basis during subsequent surveys or through a more comprehensive research effort.

Locations:

St. Paul Field Office (Habitat Resources)
East Lansing Field Office (Habitat Resources)
Green Bay Field Office (Habitat Resources)

Work Schedule:

Wetlands to be included in the survey would be selected during the 1984 field season. Field work would be conducted during the spring of 1985 from 1 to 2 weeks after snowmelt in the selected locations. Data would be organized and a meeting called to discuss results by August 1, 1985.

Investigators:

Stanley L. Smith (RCA Specialist, St. Paul Field Office)
Terrence J. Miller (RCA Specialist, East Lansing Field Office)
Timothy J. Kubiak (RCA Specialist, Green Bay Field Office)
Up to three additional field assistants from SPFO, ELFO or GBFO

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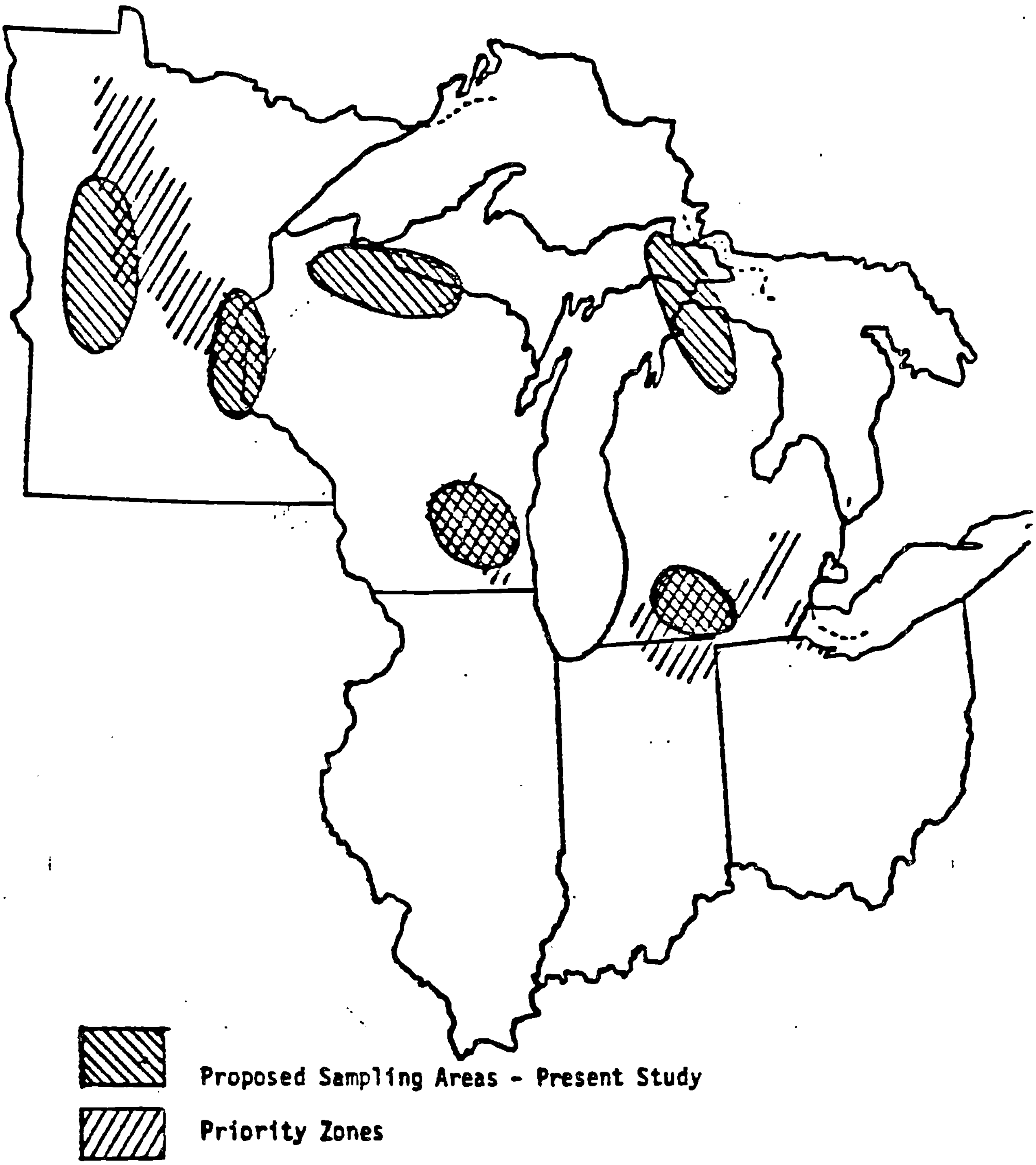
Estimated Costs

	FY84	FY85
Salaries:		
RCA Specialists (2)	$15,000.00	$34,950.00
Assistants (4)	(0.45 m.y.)	(1.06 m.y.)
Expenses:		
Per diem (S. Smith T. Miller, T. Kubiak and 3 others) 134 days x $60/day	3,600.00 (60 days)	4,440.00 (74 days)
Transportation: 15,000 miles x $0.30/mile = $4,500.00	2,250.00	2,250.00
Travel for training, etc.		1,490.00
Equipment:		
conductivity meters (3 at $1,300/each)	3,900.00	
pH meter, extra probes, etc. (5 at $600/each)		3,000.00
glassware, etc.		1,950.00
plankton seines, nets		400.00
Supplies:		
chemicals		360.00
film and developing		100.00
maps	60.00	
shipping (biological samples)		100.00
miscellaneous		300.00
Total	$24,810.00	$49,340.00
Grand Total		$74,150.00



Priority zones for wetland acquisition in Category 11.[1]

[1] Breeding Duck Habitat in the Great Lakes Region - Category 11. Department of the Interior, U. S. Fish and Wildlife Service, July 1979.