AFS Policy Statement #7:
POLICIES ON TWO ISSUES OF ENVIRONMENTAL CONCERN

A. Issue Definition

"Acid Rain" is defined as precipitation that has a pH lower than 5.61 which is the pH expected in distilled water exposed to the atmosphere. The pH of precipitation undoubtedly is affected by a variety of natural sources of acidic and alkaline materials (e.g., volcanic gases, gases from decomposing organic matter, and soil dust). However, it has recently become apparent that rain and snow in certain regions of the earth are consistently more acidic than expected. The European Atmospheric Chemistry Network first recognized that the pH of precipitation was declining in Scandinavia during the late 1960's. Current data indicate that the mean annual pH in this region declined from 5.0 -5.5 in the late 1950's to *4.2 -4.4* in the mid- 1970's. In eastern North America, precipitation is now more acidic than in Scandinavia. The median pH for 1978 -79 ranged from *4.0* to *4.4* in northeastern U.S. and southeastern Canada.

Although there is disagreement over the source and nature of acidic precipitation, the most widely accepted view is that the increased acidity is a result of the presence of increased quantities of sulfuric and nitric acids. These acids are believed to result from oxidation of sulfur and nitrogen oxide gases. Sulfur oxides and nitrogen oxides are produced from combustion of fossil fuels, metal smelting, and various industrial processes. Although natural sources of these gases may be greater than anthropogenic sources on a global scale, anthropogenic sources are concentrated in the northern hemisphere and far outweigh natural sources in populated areas. Transportation of these gases to distant locations is facilitated by the trend toward increasing height of smokestacks, and increasing use of particle precipitators. Tall stacks increase dispersion of gases, and particle precipitators reduce the quantity of particles that absorb and neutralize gases. The end result is long-range transport of gases, which are transformed to strong acids and deposited with precipitation at distant locations.

In addition to strong acids, other pollutants are transported atmospherically and deposited in areas distant from any known source. Heavy metals, such as mercury and selenium, and complex organic compounds, such as polychlorinated biphenyls and polynuclear aromatic hydrocarbons, are emitted to the atmosphere by fossil fuel combustion and industrial processes and have been detected in acidic precipitation. It is believed that sources and transport mechanisms are similar for acids, metals, and organic compounds, and that these pollutants may interact with each other in the environment.

There is growing evidence that acidic precipitation is adversely affecting water quality in certain regions of the world and, as a result, sensitive aquatic species are declining or disappearing in these regions. In lakes and streams in affected areas, pH levels are reduced and concentrations of metals and complex organic compounds are increased. Aquatic organisms such as algae, macrophytes, invertebrates, fish, and amphibians have been reduced as a result of these changes. If acidic precipitation remains at present levels of control, these effects will probably spread over larger geographic areas.

B. Impacts on Aquatic Environments

The impact of acidic precipitation on an aquatic ecosystem is determined by the geochemistry, geomorphology, and hydrodynamics of the system. These factors determine the buffering capacity-the ability to neutralize acids and resist change in pH of soil and water. Declines in pH of surface waters have been recorded in areas that receive acidic precipitation and that are also low in buffering capacity. Concentrations of heavy metals and organic compounds have also increased, as have concentrations of certain metals, such as aluminum, which are dissolved from the environment by the strong acids. These chemical changes have had adverse impacts on sensitive aquatic organisms. Such changes have been recorded in Scandinavia, Nova Scotia, Ontario, and New

York. Decreases as great as 2 pH units and rates of change of 0.12 units/year have been observed. Lake and stream pH levels have decreased to values as low as 4.0, and sometimes even lower. When buffering capacity of the watershed is exhausted, lakes and streams generally reflect the pH of the precipitation.

Acidic lakes have been shown to contain higher concentrations of metals than do similar non-acidic lakes. Metals not only occur in precipitation, but also are leached from watershed soils or lake or stream sediments by the acids in precipitation. For example, aluminum is not found in precipitation but is leached from the watershed by acidic precipitation and occurs at abnormally high concentrations in acidic lakes.

Severe depressions in lake and stream pH and increases in metal content have been associated with spring snowmelt. Contaminants are stored in the snowpack until released by melting. The release rate of contaminants is not directly proportional to the amount of melting, but is greater during the early stages of melting-apparently as the result of an ion separation of freeze-thaw process. During early stages of snowmelt, pH levels as low as 3.8 and aluminum concentrations as high as 1 mg/ 1 have been measured in streams in New York.

The organic component of precipitation is poorly understood. Complex organic compounds of anthropogenic origin have been detected in lakes remote from any direct source.

Compounds such as polychlorinated biphenyls and polynuclear aromatic hydrocarbons, and pesticides such as toxaphene are known to be transported atmospherically and are detected in remote lakes, but the mechanisms of transport and deposition are not known.

The quantity and distribution of aquatic habitat vulnerable to acidification is not well known. Generally, areas underlaid by insoluble bedrock, such as granite or gneiss, have overlying soils and surface waters that are low in buffering capacity. Extensive areas of Scandinavia and North America contain such terrain. However, there is a great deal of variation from lake to take within potentially vulnerable areas, and regions containing large numbers of acidified lakes also contain many lakes that are apparently unaffected or much less affected. Other factors, such as lake hydrology, watershed order, or soil depth, may also be important in controlling the vulnerability of a particular water body to acidification.

C. Effects on Fish, Shellfish and Related Organisms

Changes in the chemistry of surface waters resulting from both direct and indirect effects of acidic precipitation affect the biota inhabiting these waters. Effects on fish have been widely reported, probably because fish are highly sensitive to acids and related contaminants and are the most visible component of aquatic ecosystems. The observed effects include mortality, reproductive failure, reduced growth, and skeletal deformities. The earliest recorded impacts of acidic precipitation were declines in populations of Atlantic salmon (Salmo salar) in a few southern Norway rivers, which were correlated with declines in river pH. Today, nine rivers in southern Norway are virtually devoid of salmon, whereas no such declines have been observed in 79 rivers in northern Norway that are not being acidified. A survey of more than 2,000 lakes in southern Norway revealed that about one-third had lost their fish populations (primarily brown trout, Salmo trutta) since previous surveys in the 1940's. The presence and status of fish populations were clearly related to lake pH: good fish populations were seldom found in lakes with pH < 5. It is estimated that acidic precipitation has affected fish populations in 20% of the habitat in southern Norway. In the LaCloche Mountain and Sudbury regions of Ontario, fish population declines have been recorded in more than 60 lakes. The number of species of fish present in these lakes was positively correlated with pH, and the sequence in which species disappeared was similar in all lakes. In the Adirondack Mountains of New York, at least 177 lakes totaling approximately 9,000 acres have been acidified and have lost their fish populations. Declines in salmon runs reported in rivers in southwestern Nova Scotia have been coincident with reduced pH in these rivers.

Acute mortalities of adult fish have been observed, usually following a sudden spring thaw or heavy rain. The cause of death may be either a decline in blood pH or loss of body sodium in response to increased external hydrogen ion concentration, or acute toxicity of metals such as aluminum or copper. The primary response of fish to acidic precipitation, however, appears to be reproductive failure. Several mechanisms have been reported, including failure to produce and deposit viable eggs, failure of hatching, and mortality of embryos and alevins. In general, early life history stages of fish are more susceptible than adults to low pH and other pollutants. The severe conditions associated with spring melt coincide with the occurrence of sensitive life stages for some species, especially salmonids.

Sublethal effects, such as reduced growth and skeletal deformities, have also been observed in fish inhabiting acidified lakes. Reduced growth was not correlated with food abundance and may have been an expression of sublethal stress from pH or metals. Skeletal deformities are believed to be related to a reduction in body calcium levels in response to low pH. Fish from acidified lakes may also contain elevated levels of mercury, which may render them unfit for human consumption.

All other biotic components of aquatic ecosystems may also be affected by acidic precipitation. Microbial decomposition of organic matter is depressed at low pH, and methanogenic bacteria are replaced by sulfate reducers. Phytoplankton species composition shifts: species of Chlorophyta and Chrysophyta decrease and species of Pyrrophyta increase. The abundance of Sphagnum mats increases as lake pH declines and other species of macrophytes are displaced. In Ontario, lakes with pH > 5 had 9- 16 species of zooplankton of which 3 or 4 were dominant, whereas lakes with pH < 5 contained I - 7 species of which only 1 or 2 were dominant. The number of species of benthic invertebrates, especially gastropods and mayflies, generally declines as lake pH declines. In Norway, the presence of 10 species of benthic invertebrates was significantly related to lake pH, and the number of species of mayflies and stoneflies declined from 8 - 12 at pH > 6.5 to I - 2 at pH 4.0 - 4.5. Snails are not found in Norwegian lakes with pH < 5.2 and are reduced in abundance at pH 5.2 - 6.6. Although pH appears to be the primary variable in determining these results, metals may also be important. For example, copper averaged 2 μg/1 in Ontario lakes not receiving acidic precipitation and ranged from 0.19 to 1.12 μg/1 in four Ontario lakes receiving acidic precipitation. Copper concentrations as low as 4.6 μg/1 are toxic to several invertebrate species in long-term (6 - 9-week) bioassays.

D. Needed Actions

The "acid rain" phenomenon has only recently been recognized and there are many gaps in our knowledge of this subject. High priority should be placed on a coordinated research effort to determine with certainty the source of the strong acids responsible for the increasing acidity of precipitation in remote areas, the sources of metals and complex organic compounds, and the meteorological factors that determine the locations where these materials are deposited. The relative importance of acids, metals, and complex organic compounds in causing the observed effects needs to be determined. The factors that apparently increase or decrease the susceptibility of similar bodies of water to acidification are poorly understood, and the factors that govern the susceptibility of different organisms to changes in pH are unknown. The location and amount of vulnerable habitat is only generally known, and the dose/response relations between acidic precipitation inputs and surface water response is not known. Although research spending in North America has been woefully inadequate, these and other questions need answers before a rational future course of action can be determined.

Water quality data currently being collected are inadequate to assess the location of vulnerable habitat and to detect initial stages of degradation by acidic precipitation. Most water quality monitoring stations are located in high-order watersheds that are affected by human activities, such as agriculture and sewage disposal, which will mask acidification. Long-term water quality monitoring stations must be located in low-order watersheds remote from human habitation. Further, many field data are still collected by inappropriate techniques. The traditional fixed-endpoint alkalinity titration, for example, overestimates true alkalinity in waters of low ionic strength. Also, colorimetric pH indicators overestimate true pH by as much as 0.5 to 1.5 units in poorly buffered waters. Accurate pH meters and inflection- point alkalinity titrations must be adopted as standard procedures in areas where surface waters are poorly buffered.

A number of remedial and mitigative techniques are available to address the acid precipitation problem. However, we must understand the variables that control the response of aquatic ecosystems to the atmospheric input of acids, metals, and organic compounds in order to understand what to control and how much control is required. Reductions in emissions of pollutants to the atmosphere are an obvious solution, but since the source/receptor response is not known, the response to any given degree of reduction is unknown. Legislation limiting atmospheric emissions cannot be obtained without sound scientific evidence that links causes with effects, and documents the value of resources threatened if control is not obtained.

Several alternate solutions to the acid precipitation problem are available as interim solutions. Among these are the neutralization of acidic lakes and streams by addition of basic substances, and genetic selection of more acid-tolerant strains of fish raised in hatcheries. These techniques have value in preserving valuable fisheries or genetic stocks until permanent solutions to the problem are found, but they should not themselves be expected to provide permanent solutions.

The American Fisheries Society urges that the following actions be taken to address the problem of acidic precipitation:

1. A coordinated research effort be undertaken and adequately funded to identify the sources of strong acids, metals and organic compounds in precipitation, and the chemical composition of precipitation in all areas of North America;

2. A similar research effort be begun to determine the factors that govern the response of aquatic ecosystems to acidic precipitation;

3. Water quality monitoring stations be established in low order watersheds in geographically sensitive areas of North America to determine the amount and extent of habitat vulnerable to acidification and to acquire water quality data that can be used to assess changes occurring from inputs of acidic precipitation;

4. Water chemists and field biologists adopt appropriate methodology to obtain accurate water chemistry in areas of low buffering capacity;

5. Fish population surveys in lakes and streams located in potentially susceptible regions be increased in order to establish baseline conditions and to detect impacts of acidic precipitation in areas not now being studied;

6. Research be initiated to evaluate potential interim remedial and mitigative actions that may be used to protect endangered species, preserve gene pools, and supply recreational fishing in areas that are economically dependent upon it,

7. Results of all the above studies be continually reviewed and evaluated, so that scientifically valid actions can be taken to effect a permanent solution to the acid rain problem as soon as possible.