ANC and Biological Integrity

Because there is a continuum in the relationship between ANC concentrations and resulting biological effects, a characterization of the range of ANC values related to specific biological effects is needed. For this reason, five categories of ANC concentrations are suggested that correspond to specific biological health conditions/effects of aquatic communities, ranging from no impacts to complete loss of populations. These five classes are based on the relationships between ANC and ecological attributes, including species richness, diversity, community structure, and individual fitness of organisms. The paragraph below describes the biological impact potential for a range of ANC values and the scientific research that supports the grouping.

For freshwater systems, ANC concentrations are grouped into five major classes: Acute Concern (less than 0 μeq/L), Severe Concern (0–20 μeq/L), Elevated Concern (20–50 μeq/L), and Moderate Concern (50–100 μeq/L), and Low Concern (greater than 100 μeq/L), with each range representing a probability of ecological damage to the community (**Table 4.1-1**). Biota are generally not harmed when ANC values are above 100 μeq/L. For example, the number of fish species present in an aquatic ecosystem tend to peak at ANC values above 100 μeq/L (Bulger et al., 1999; Driscoll et al., 2001; Kretser et al., 1989; Sullivan et al., 2006). However, it should be noted that ANC values of >100 in the water bodies represented in this analyis are frequently associated with larger lakes or higher discharge stream segments. In such environments, with ANC concentrations at or above 100 μeq/L, the diversity of the aquatic community is more influenced by other environmental factors, such as habitat availability, nutrient loading, and introduced species rather than the acid-base balance of the surface water.

At ANC levels between 100 and 50 μeq/L,, it has been shown that for species sensitive to acidity, such as is the case for some fish and invertebrate species, their fitness and recruitment drops, which may result in a community diversity decline as a few highly acid-sensitive species are lost (**Figure 2.3-1**). However, minimal (no measurable) change in total community abundance or production generally occurs, resulting in good overall health of the community. While overall community impacts may be minor in this ANC range, certain key, focal, or endangered species such as Atlantic Salmon (*Salmo salar*)

may be adversely impacted (Perry 1990, Dill et al. 2002, NRC 2003). Waters with average ANC between 100 and 50 μeq/L are subject to episodic acidification substantially below 50 μeq/L (**Figure 4.1-2**) placing significant short-term stress on a variety of biota as described below. Such episodic acidification can lead to pH depressions capable of inducing severe stress or mortality in sensitive life stages of Atlantic salmon (Haines et al. 1990).

When ANC concentrations drop between 50 and 20 μeq/L, they are generally associated with negative effects on the fitness and recruitment of aquatic biota. For example, Kretser et al. 1989 showed a 50% reduction in the number of fish species occurred when ANC concentrations dropped below 50 μeq/L of lakes that were surveyed. Furthermore, Dennis and Bulger, 1995 shown that as ANC concentrations drop between 50 and 20 μeq/L, the overall fitness of most fish species are reduced, such as sensitive species of minnows and dace, (fathead minnow and blacknose dace) and recreation fish (lake trout and walleye). In addition to the changes in the fish community, some loss of common invertebrate species from zooplankton and benthic communities that include many species of snails, clams, mayflies and amphipods occur. These losses of sensitive species often result in distinct decreases in species richness and changes in species composition of the biota. However, the total community abundance or production remains high with little if any change. Waters with average ANC between 50 and 20 μeq/L are subject to episodic acidification below 20 μeq/L (**Figure 4.1-2**) placing significant short-term stress on a variety of biota as described below. Such episodic acidification can lead to pH depressions capable of inducing mortality in sensitive life stages of Atlantic salmon (Haines et al. 1990).

When ANC concentrations drop below 20 μeq/L, almost all biota exhibit some level of negative effects. Fish and plankton diversity decline sharply to levels where acid-tolerant species begin to outnumber all other species, thus significantly altering the structure of communities (Matuszek and Beggs, 1988; Driscoll et al., 2001). Loss of several important sport fish species is possible, including lake trout, walleye, rainbow trout as well as additional nongame species such as creek chub occur. In addition, several other invertebrate species, including all snails, most clams and many species of mayflies, stoneflies and other benthic invertebrates are lost or greatly reduced in

population size, which further depresses species composition and community richness. Also, below 20 μeq/L, surface waters are susceptible to episodic extreme acidification where a total loss of biota can occur when ANC concentration goes below an ANC of 0 μeq/L for a short period of time. Stoddard et al. (2003) showed that to protect biota from episodic extreme acidification in the springtime, base flow ANC concentrations had to have an ANC of at least 30-40 μeq/L (**Figure 4.1-2**).

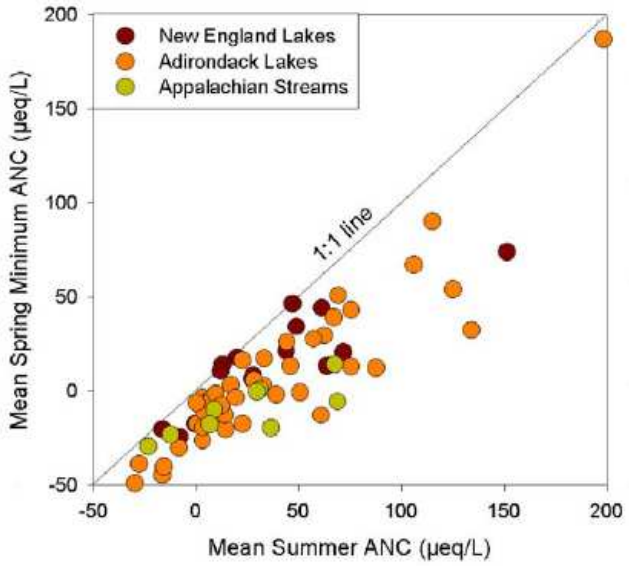

Figure 4.1-2 Relationship between summer and spring ANC values at LTM sites in New England, the Adirondacks and Northern Appalachian Plateau. Values are mean summer values for each site during the period 1990-2000 (horizontal axis) and mean spring minima for each site for the same time period. On average, spring ANC values are at least 30 μeq/L lower than summer values.

Complete loss of fish populations and extremely low diversity of planktonic communities occur when ANC concentrations stay below 0 μeq/L. Only acidophilic species are present, but their population numbers are sharply reduced. For example, under average ANC less than 0 μeq/L, lakes in the Adirondacks have been shown to be fishless (Sullivan et al., 2006). A summary of the five categories of ANC and expected ecological effects can be found in **Figure 4.1-3**, **Table 4.1-1**.

Table 4.1-1 Aquatic Status Categories

Category Label	**ANC Levels***	**Expected Ecological Effects**
Acute Concern	<0 micro equivalent per Liter (µeq/L)	Complete loss of fish populations is expected. Planktonic communities have extremely low diversity and are dominated by acidophilic forms. The numbers of individuals in plankton species that are present are greatly reduced.
Severe Concern	0 – 20 µeq/L	Highly sensitive to episodic acidification. During episodes of high acid deposition, brook trout populations may experience lethal effects. Diversity and distribution of zooplankton communities declines sharply.
Elevated Concern	20 – 50 µeq/L	Fish species richness is greatly reduced (more than half of expected species can be missing). On average, brook trout populations experience sub-lethal effects, including loss of health and reproduction (fitness). Diversity and distribution of zooplankton communities decline. Acid sensitive species or life stages subject to episodic mortality.
Moderate Concern	50 – 100 µeq/L	Fish species richness begins to decline (sensitive species are lost from lakes). Early life stages of Atlantic salmon may be impaired or subject to episodic mortality. Brook trout populations are sensitive and variable, with possible sub-lethal effects. Diversity and distribution of zooplankton communities begin to decline as species that are sensitive to acid deposition are affected.
Low Concern	>100 µeq/L	Fish species richness may be unaffected. Reproducing brook trout populations are expected where habitat is suitable. Zooplankton communities are unaffected and exhibit expected diversity and distribution.

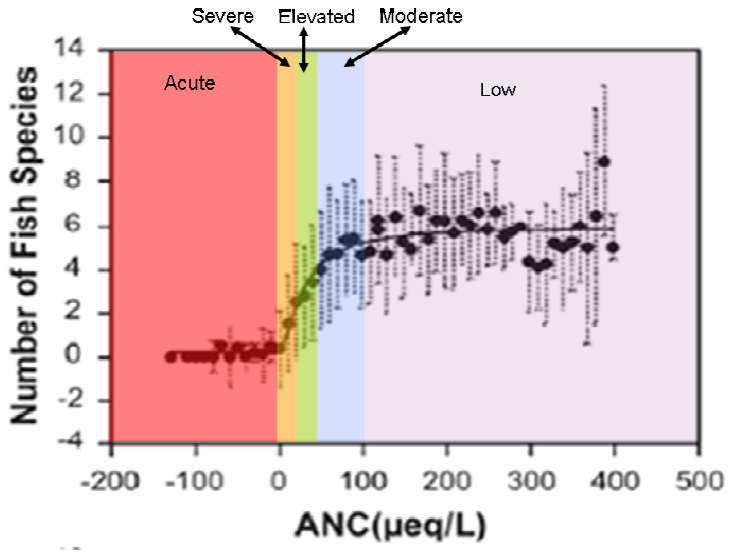

Figure 4.1-3 Number of fish species per lake or stream versus ANC level and aquatic status category (colored region) for lakes in the Adirondacks (Sullivan et al., 2006). The 5 aquatic status categories are described in Table 4.1-1.

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