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Influence of pH on aluminum toxicity in pumpkinseed sunfish (Lepomis gibbosus rafinesque).

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INFLUENCE OF $_{p}H$ ON ALUMINUM TOXICITY IN PUMPKINSEED SUNFISH (*LEPOMIS GIBBOSUS* RAFINESQUE)

by

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Abstract:

Increased aluminum levels have recently been correlated with fish mortality in acidified lakes. The toxic response to Al in freshwater is variable and depends on pH moderated chemical speciation of the Al. At around pH 5.0, maximum fish mortality results from polymeric aluminum hydroxides. At lower pH levels, mortality is still observed and the effect is likely due to monomeric Al. Populations of forage fish sepcies are less sensitive to Al and their abundance has increased in acidified lakes. The pumpkinseed sunfish (Lepomis gibbosus Rafinesque), a common forage species in U.S. lakes, is considered fairly insensitive to low pH, however Al toxicity data for this species are presently lacking. Pumpkinseed post-larvae were exposed to Al and low pH water in a flow-through system with nominal Al additions of 50, 100, 500, and 1000 μg/L at a pH range of 4.1-5.5. At pH≈4.5, 50% mortality occurred within a nominal range of 500-1000 μg Al/L, while at pH≈5.0, 50% mortality occurred within the range of 100-500 μg Al/L. At the higher end of the pH range, mucus accumulation on the fish gills suggested mortality resulted from respiratory failure. At the lower end of the pH range, no gill damage was observed and mortality may have resulted from osmoregulatory distress. At intermediate pH levels, mortality of post-larvae was likely caused by a combination of both factors. Compared to other fish, pumpkinseed sunfish appear to be more

tolerant of low pH and elevated Al concentrations. As a result, the relative abundance of pumpkinseed sunfish may increase in North American lakes that are subjected to increasing acidity.

Introduction:

The concentration of toxic trace metals are increasing in some surface waters subjected to polluted atmospheric deposition. Some metals are introduced by atmospheric fallout, while others such as aluminum are mobilized from the soil and rocks by acidic deposition (Wright and Gjessing, 1976; Schindler, et al., 1980). Lake drainage basins with poorly buffered parent material are particularly susceptible to Al mobilization. Aluminum concentrations in unacidified waters are usually below 100 μg/L, while in lakes with low pH, Al can exceed 1400 μg/L (Schofield, 1976). Acidified lakes in Norway, Sweden, and the United States have Al concentrations five to ten times greater than neutral lakes in the same regions (Dickson, 1975; Schofield, 1976; Wright and Henriksen, 1978). Field studies in these regions indicate that among all chemical variables tested, changing Al concentration was the primary factor limiting fish survival (Schofield and Trojnar, 1980).

Aluminum in freshwater is usually present as organically bound forms and dissolved or colloidal inorganic forms. The organic Al fraction is generally predominant in freshwater, but it may not cause toxic effects in fish (Driscoll, et al., 1980). Baker (1981) reported no toxic response by brook trout and white sucker fry to organic Al forms. The inorganic Al fraction may cause toxic effects in fish, however the toxicity of inorganic Al to aquatic biota varies with the pH dependent chemical speciation (Driscoll, et al., 1980). The inorganic forms are dissolved monomeric Al (free Al ion) which is most abundant at about pH 4.0, dissolved polymeric Al (aluminum hydroxides) which are most abundant at about pH 5.0, and aluminum fluoride complexes where the concentration depends upon availability of fluoride ligands (Hem and Roberson, 1967; Baker, 1982). Although the current literature suggests that inorganic Al species account for observed fish mortality, no studies have quantified the specific dose response relationship of monomeric and polymeric Al species separately. The major reason for this lack of information results from the dramatic change in Al speciation over a narrow and difficult to control pH range (4.0-5.5). Therefore, total Al measurements will give an overestimation of the Al available for toxic activity (Driscoll, 1980).

Muniz and Leivestad (1980a) and Leivestad (1982) conducted Al toxicity tests at varying pH levels with brown trout, and concluded that maximum Al toxicity results at around pH 5.0. They suggested that toxicity was likely due to polymeric Al species which predominate at pH≈5.0. However, Baker (1981) showed that mortality of brook trout and white sucker fry occurred at lower pH levels (ie. pH≈4.5) and suggested that the toxic response may be related to monomeric Al at pH≈4.5, while the mode of toxicity shifts to polymeric Al forms at higher pH levels.

The hydrogen ion concentration within the pH range of 4.1-5.5 causes no apparent physiological stress to brown trout (Muniz and Leivestad, 1980a), brook trout (Cronan and Schofield, 1979; Schofield and Trojnar, 1980), or white sucker (Baker, 1981). However Baker (1982) suggests that stress on brook trout and white sucker fry from elevated $\{H^+\}$ and dissolved inorganic Al may be additive.

Aluminum toxicity occurs in all age classes of fish, but young fish are more seriously affected (Beamish and Harvey, 1972; Beamish, et al., 1975; Wright and Snekvik, 1978; Peterson, et al., 1982). Mortality of young fish is the main cause of recruitment failure in acidified lakes in southern Norway (Leivestad, et al., 1976). However, at low pH (4.2-4.8), Al was beneficial to survival of brook trout and white sucker eggs (Baker, 1981). The eggs had greater survival after exposure to Al concentrations that were toxic to the larval forms of these species (Baker, 1981; Baker, 1982; Baker and Schofield, 1982). The post-larval age class is the most sensitive to aluminum toxicity and the impact of aluminum decreases with increasing age. The post-larvae may be more sensitive to increased aluminum levels than adults due to their greater body and gill surface area per unit weight, but little work has been conducted in this area (Schofield, 1976).

Aluminum toxicity has altered populations of sensitive fish species in many Scandinavian and North American lakes, while populations of less sensitive forage fish species such as yellow perch (Perca flavescens) have increased (Keller, et al., 1980; Harvey, 1982). This population shift may be due to a combination of lower aluminum sensitivity in perch and diminished predation (Rahel and Magnuson, 1980). Another forage fish species, the pumpkinseed sunfish (Lepomis gibbosus Rafinesque), is fairly insensitive to decreased pH and commonly occurs in acidified lakes (Harvey, 1980; Harvey and Lee, 1982; Hendrey, pers. comm.). It is common in many lakes in the U.S. and serves as a major food source for piscavores including bass, walleye, and northern pike. The common occurrence of pumpkinseed sunfish in acidified lakes suggests relative insensitivity to aluminum. Predicting increasing pumpkinseed sunfish abundance in acidified and aluminum enriched lakes depends on acquisition of Al toxicity data for this species.

The objective of our investigation was to evaluate the sensitivity of juvenile pumpkinseed sunfish to elevated concentrations of Al under environmentally realistic pH conditions. Since young fish are generally the most sensitive to Al, the effects of Al on post-larval pumpkinseed sunfish were studied in laboratory toxicity tests. Since sunfish are reported to be quite tolerant of low pH, the tests were designed to evaluate toxicity of Al in a pH range of 4.1-5.5. This pH regime corresponds to an Al speciation shift from monomeric to polymeric forms and is consistent with seasonal variations of pH in many acidified lakes (Driscoll, et al., 1980).

Methods:

Field collections of post-larval sunfish were made at Deep Lake, Monroe County, Pennsylvania (75° 23' 49" W, 41° 03'08" N). Deep Lake (3.1 ha) occupies a remote drainage basin (15 ha) in the Pocono Mountains. The Deep Lake fish community consists of a large population of pumpkinseed sunfish (*Lepomis gibbosus* Rafinesque), some bluegill sunfish (*Lepomis macrochirus* Rafinesque), and a few golden shiner (*Notemigonus crysoleucas* Mitchell). Recreational activity at this lake is minimal due to its isolation and restricted public access. The watershed lacks residential homes and public highways. Inputs to the lake are direct precipitation, runoff, and underground seepage springs; no permanent streams enter the lake. The lake area to drainage basin area ratio is 0.21. Lakewater and rainwater pH were monitored with a Model 640 Accumet field meter in a separate study by the coauthor. The lakewater pH ranged from 4.37-5.00 (n=18), while bulk precipitation pH ranged from 3.80-5.16 (n=14), from March-October 1983. There was no measurable alkalinity and total Al concentrations of 86±11 μg/L were measured during July-September,1982.

The fish used in this study were pumpkinseed young of the year (1.5-3.0 cm standard length) that were collected by scuba divers using hand-held nylon seines. They were transported to the laboratory in insulated coolers, and held in aquaria for 48 hours prior to experimentation. The 2-3 month old fry were maintained on an *ad libitum* diet of live zooplankton collected from Deep Lake with an 85 μm plankton net. The diet was augmented with thawed *Artemia* that were extensively rinsed in Deep Lake water prior to feeding. The treatment dishes were cleaned one hour after feeding to remove uneaten *Artemia*.

Two Al toxicity tests were conducted during the summer of 1982. Each toxicity test consisted of three treatments: pH, Al, and Deep Lake water. In the two tests, an effort was made to manipulate the pH of the Al treatment levels within the range 4.1-5.5 to purposefully vary the proportion of monomeric to total Al. Six treatment levels were used. The first level consisted of ambient lake water with no pH modification. The second treatment level consisted of ambient lake water with the pH modified by additions of sodium hydroxide or hydrochloric acid. The remaining four treatment levels were pH modified lake water containing increasing nominal additions of total Al at concentrations of 50, 100, 500, and 1000 μg/L. The pH of these four dose levels was also modified as above. The dose regime was broad since the experiments were designed for the purpose of range-finding. Ten sunfish were placed in each culture dish by stratified random assignment, with three replicate culture dishes per treatment level. The arrangement provided 30 fish at each treatment level. A total of 180 sunfish were evaluated during each test.

The treatment containers were cylindrical 500 ml Pyrex culture dishes. All containers used in the experiments were washed with soap and water, rinsed with distilled water, placed in an acid bath overnight, and rinsed with deionized water prior to use. The treatments were siphoned into each culture dish from treatment bottles to maintain a continuous flow. The technique is similiar to that described by Smith and Hargreaves (1983). The treatment bottles were 20 L polyethylene carboys fitted with 1.0 mm OD teflon tubing to siphon the treatment solutions into each culture dish. Each dish was covered with nylon screening to prevent fish from jumping out of the dish. The flow rate for each treatment container was measured gravimetrically and was constant (±10%) due to the fractional change in the total pressure. The time for 90% replacement was 39 hours as calculated from the equation $C=C_0e^{-kt}$, where k (flushing constant) was .059/hr. The treatment solutions siphoned through the tubing into the bottom of pyrex treatment dishes. Overflow from the dishes went into the Living Stream system (Frigid Units Inc.) which acted as a controlled temperature water bath (23 ± 1^oC). Each culture dish was supplied with an inert nonmetal airstone to maintain dissolved oxygen. Daily measurements with a YSI Dissolved Oxygen electrode showed oxygen concentration ranged from 4.1-6.6 mg/L. All dishes were illuminated at 100 ft cd by cool white fluorescent lamps on a 16 hour light/8 hour dark cycle.

Daily pH measurements were made with an Orion Model 399A pH meter. Highly accurate pH adjustment was not possible with our apparatus and the experimental set-up allowed some daily pH and Al fluctuations. However, the treatment bottles were restocked daily and Al that had precipitated or changed species was replaced by new inputs of aluminum-dosed water. Table 1 shows that a broad dose regime for monomeric Al was effectively produced while maintaining pH within the range 4.1-5.5.

Death of fish in the treatment dishes was observed at 2, 6, 12, 24, 36, 48, 64, 72, and 96 hours after initiation. Dead individuals were removed at each observation period and preserved in a formalin solution. Criteria for death were the absence of respiratory movement and lack of response to external stimulation.

The Al concentration in samples collected from the culture dishes was measured. The technique of Barnes (1976) was used to analyze for monomeric and total Al at least once per experiment. Aluminum was extracted in methylisobutlyketone (MIBK), and refrigerated in polyethylene vials prior to analysis on a Perkin Elmer Model 373 Atomic Absorption Spectrophotometer using a nitrous oxide flame. Aluminum was measured in relation to standards prepared from dilutions of a 1 g/L Al reference solution (Fisher Scientific) that was extracted in the same manner as the samples.

Results:

The survival of sunfish among all treatment levels was compared within each experiment at each of the observation periods. The t-statistic was used to test the null hypothesis that mean percent survival among all possible pairs of treatment levels were equal. In Exp. I, the analysis showed that fish survival in the 1000 µg Al/L and 500 µg Al/L treatments was significantly lower ($p<0.05$) than in the 100 and 50 µg Al/L, and in the ambient and modified pH treatments at all observation periods (Fig. 1A). Fish in the 100 and 50 µg Al/L treatments had significantly decreased survival after 48 hours ($p<0.1$) compared to fish in the two lowest Al treatments. However, the 100 and 50 µg Al/L treatments were not statistically different at any time. There was 100% survival of pumpkinseed in all replicates of the ambient and modified pH treatments.

In Exp. II, fish in the 1000 µg Al/L treatment had significantly lower survival at all times ($p<0.01$) compared to survival at the remaining five dose levels (Fig. 1B). Fish in the 500 µg Al/L treatment showed lower survival than those in the modified pH lake water after twelve hours ($p<0.05$). However, the 500 µg Al/L treatment was only marginally more toxic to pumpkinseed than the other three treatment levels (100,50 µg Al/L. and ambient lake water) after twelve hours ($p<0.2$). At sixty-four hours, survival in the modified pH lake water was greater than in all other treatment levels ($p<0.05$). Fish survival in the 100, 50 μg Al/L, and ambient lake water treatments was not significantly different at any time during the experiment. There was 90% survival of fish in the modified pH lake water treatment by the end of the experiment.

The t-statistic was also used to compare survival between the two experiments for each treatment level. There was no significant difference ($p <0.05$) in survival between the two experiments for all treatment levels except the 500 μg Al/L treatment. In Exp. I, survival at the end of the experiment was significantly lower ($p<0.01$) than at 500 μg Al/L in Exp. II. An LT_{50} or time to 50% mortality was reached in 6 hours during Exp. I, while an LT_{50} of 39 hours occurred during Exp. II.

The general results of the toxicity test suggest that nominal concentrations of total Al of 500-1000 μg/L in the pH range 4.1-5.5 were highly toxic to the pumpkinseed sunfish tested. There also appears to be sensitivity at total Al concentrations of 50-100 μg/L, within the pH range of 4.8-5.2 after 24 hours (Fig. 1). These conclusions are based on the assumption that the nominal concentrations were achieved. Although all forms of Al in the treatment solutions were not measured, total Al was estimated from the measured monomeric Al concentration. If the proportion of monomeric Al in our treatments was approximately 10% of the total Al, as suggested by Baker (1982) for freshwater systems, then the dose concentrations can be estimated by multiplying the monomeric Al values in Table 1 by ten. The results of this inspection suggest the nominal dose was generally consistent with the established addition levels. However, the monomeric Al concentration in the 500 μg/L treatment of Exp. I (Table I) was not consistent with the nominal addition level, and we suspect an error was made in the extraction process of the analysis. Since the toxicity response trends for the two experiments are similiar, we feel that the dose regimes were probably achieved.

Discussion:

The results from this experiment suggest that information on pH and the concentration of monomeric Al may be useful in predicting the toxicity of Al to pumpkinseed sunfish. The percent survival of post-larval pumpkinseed sunfish was strongly influenced by the monomeric {Al} in the pH range 4.1-5.5. At pH levels <5.0, 50% mortality occurred at nominal Al levels of 500-1000 μg/L, while at pH levels ≈ 5.0, 50% mortality occurred within the nominal Al range of 100-500 μg/L.

The toxicity of Al to fish occurs through two modes of action that are dependent on pH moderated chemical speciation of the dissolved Al. At a pH range of about 4.0-4.5, monomeric Al predominates and causes osmoregulatory distress in sensitive fish species (Driscoll, et al., 1980; Baker, 1981). Muniz and Leivestad (1980b) report reductions in blood sodium and chloride levels of brown trout exposed to toxic levels of Al at pH 4.3. At a pH of approximately 5.0, polymeric aluminum hydroxides predominate and cause respiratory distress in sensitive fish species (Baker, 1982).

The gills are the primary target organ for Al toxicity (Schofield and Trojnar, 1980; Muniz and Leivestad, 1980b; Leivestad, 1982). Aluminum appears to bind on gill surfaces at pH levels approximately 5.0, and the most severe results occur when Al is oversaturated (Schofield and Trojnar, 1980; Baker and Schofield, 1982). Additionally, respiratory distress occurs due to decreased surface area available for oxygen exchange. Fish exposed to elevated Al show increased gill ventilation and opercular activity (Rosseland, 1980). Frequency of coughing, which provides a useful short-term indicator of respiratory distress, also increases with increasing Al levels (Ogilvie and Stechey, 1983). Overall, more energy is expended for respiration and ion exchange, leading to decreased energy available for other functions (McWilliams, et al., 1980).

Excised gill tissue from our pumpkinseed sunfish showed mucus accumulation in the interlamellar spaces of the gill. Severity of mucus accumulation and additional gill damage occurred in fish exposed to Al doses greater than 100 µg/L at higher pH levels (>5.0). At the lower end of the pH range in our experiments (<4.5), mortality of pumpkinseed sunfish occurred at the 500 and 1000 µg Al/L doses, but no mucus accumulation occurred on the gill lamellae. This suggests that at the lower pH range sunfish mortality may have resulted from monomeric Al induced osmoregulatory distress, while at the higher pH levels mortality may have resulted from respiratory failure. At intermediate pH levels, mortality of pumpkinseed sunfish was likely caused by a combination of both factors.

The results of Al toxicity tests with brown trout (Salmo trutta Linnaeus), brook trout (Salvelinus fontinalis Mitchell), and white sucker (Catostomus commersoni Lacepede) by other researchers are summarized in Table 2. The similiarity of testing regimes suggests data obtained for these species can be compared with the data obtained from our experiments. At low pH levels (<5.0), mortality occurred in all fish species with no evidence of gill damage. The brook trout and pumpkinseed sunfish fry were the most tolerant at Al exposure levels up to 1000 mg/L. At pH levels >5.0, gill mucus accumulation was documented in all fish species. At this pH range, pumpkinseed sunfish appear to be slightly more tolerant than brook trout fry to elevated Al concentrations at levels greater than 300 µg/L. At all pH levels, the white sucker and brown trout fry were intolerant of total Al concentrations greater than 400 µg/L. If the data are directly comparable, then it may suggest that the pumpkinseed sunfish tested during our experiments are not as sensitive to elevated Al concentrations as brown trout, brook trout, or white suckers.

The pumpkinseed sunfish used in our study may be physiologically adapted to the low pH and higher Al conditions of Deep Lake. If this is the case, sunfish from an unadapted population may experience toxic effects at lower Al levels due to the additive effects of low pH and elevated Al (Baker, 1982). The concentration and speciation of Al in a lake may have seasonal influences on fish survival. If pH excursions result in an Al speciation shift, the survival of the resident sunfish population may be in jeopardy even if these fish were adapted to low pH and high monomeric Al levels. For example, if unusually high primary production or inappropriate lake liming efforts result in a pH shift to >5.0, the formation of polymeric aluminum hydroxides could cause extensive respiratory-induced population mortality. Mortality of fish populations due to the rapid precipitation of Al during summer conditions of increased pH have been described from laboratory and field studies (Dickson, 1978; Grahn, 1981; Baker, 1982; Baker and Schofield, 1982).

In conclusion, it appears that pumpkinseed sunfish may be more tolerant of low pH and higher Al concentrations than such species as brown trout, brook trout, and white sucker. As a result of acidification-induced losses of other fish species, the relative importance of pumpkinseed sunfish may increase in North American lakes with increasing acidity.

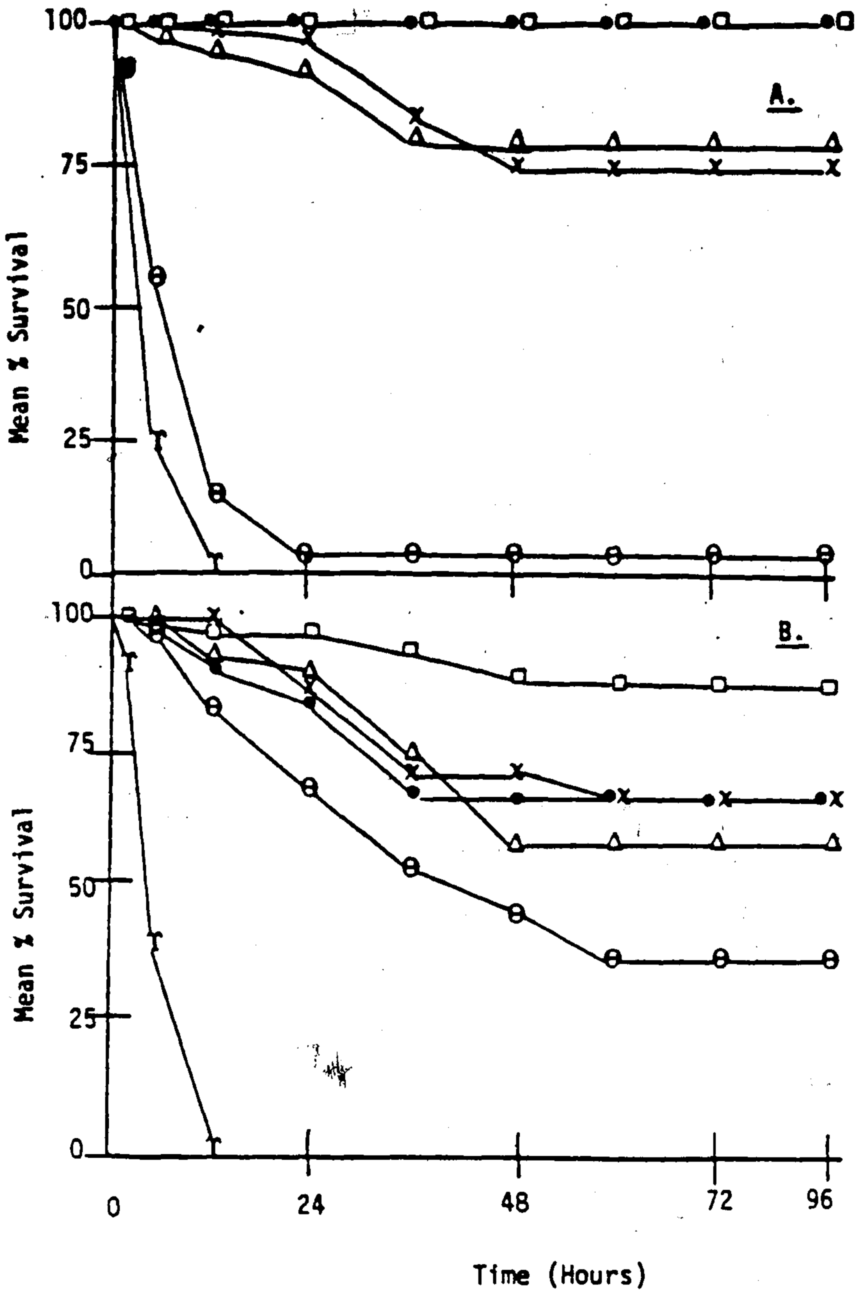

Fig. 1. Mean percentage survival (n=30) of pumpkinseed sunfish in Experiment I (A) and Experiment II (B) for the following treatments: ambient lake water (•), pH modified lake water (□), and total Al additions of 1000 μg/L (T), 500 μg/L (Θ), 100 μg/L (X), and 50 μg/L (Δ).

Table 1. Summarization of Nominal Al Additions, Measured Monomeric Al (mean ± one standard error) Estimated Total Al Levels, and pH (mean ± one standard error) for Experiments I and II.

Treatments	Total Addition (μg Al/L)	Measured Monomeric (μg Al/L)	Estimated Total (μg Al/L)	pH
Experiment I				
Ambient Lake Water	--------	16.25 ± 3.94	162	5.41 ± 0.08
pH Modified Lake Water	--------	13.75 ± 2.95	138	5.08 ± 0.19
Al Dose 1	1000	115.50 ± 8.00	1155	4.41 ± 0.07
Al Dose 2	500	17.75 ± 1.69	178*	4.49 ± 0.02
Al Dose 3	100	16.19 ± 1.27	162	5.03 ± 0.17
Al Dose 4	50	13.56 ± 1.66	136	4.99 ± 0.16
Experiment II				
Ambient Lake Water	--------	9.67 ± 0.16	97	4.61 ± 0.28
pH Modified Lake Water	--------	15.00 ± 2.00	150	5.31 ± 0.12
Al Dose 1	1000	113.50 ± 6.95	1135	4.52 ± 0.35
Al Dose 2	500	51.10 ± 14.13	511	5.32 ± 0.13
Al Dose 3	100	30.75 ± 8.18	308	5.06 ± 0.06
Al Dose 4	50	14.10 ± 1.51	141	5.10 ± 0.19

*Value lower than anticipated, presumed analytical error

Table 2. Toxic Responses of Four Freshwater Fish Species to Elevated Concentrations of Aluminum in Continuous-Flow Toxicity Tests

Fish Species	Test Conditions	Response	Reference
Brown trout	Fish from Tovdal River or hatchery reared, 25-200 gm, pH≈4.0, total Al 380 μg/L, test duration ~100 hrs.	Reduced blood salt loss compared to $[H^+]$ stressed fish alone	Muniz and Leivestad, 1980b
Brook trout	Fry following initiation of feeding, test duration until 50% mortality occurred or 14 days, pH≈4.0, total Al 0-1.0 mg/L	No mucous accumulation, no evidence of gill damage, no neg. effects of Al on survival	Schofield and Trojnar, 1980
White sucker	Fry following initiation of feeding, test duration 13-14 days, pH 4.6-4.8, total Al 0.1-0.2 mg/L	Mortality occurred within 145 hours	Baker, 1981 Baker, 1982 Driscoll, et al., 1980
Pumpkinseed sunfish	Fry 2-3 months, test duration 96 hrs., pH<5.0, total Al 500-1000 μg/L	No mucous accumulation, 50% mortality in 39 hrs.,	Present study
Brown trout	Fish from Tovdal River or hatchery reared, 25-200gm, pH≈5.0, total Al 190 μg/L test duration ~100 hrs.	High salt loss, mucous on gill lamellae, coughing	Muniz and Leivestad, 1980b
Brook trout	Fry following initiation of feeding, test duration until 50% mortality occurred or 14 days, pH 4.4-5.2, total Al 0.2-1.0 mg/L	Inactivity, mucous on gills, severity of damage incr. with incr. pH	Schofield and Trojnar, 1980
White sucker	Fry following initiation of feeding, test duration 13-14 days, pH 4.8-5.5, total Al 0.1-0.2 mg/L	Survival incr. with incr. pH, still less than without Al	Baker, 1981 Baker, 1982

Table 2. (Cont)

Fish Species	Test Conditions	Response	Reference
Pumpkinseed sunfish	Fry 2-3 months, test duration 96 hrs., pH 4.8-5.5, total Al 50-1000 µg/L	Extensive mucous on gills, inactivity of fish, mortality even at concs. 50-100 µg/L, 50% mortality in 6 hrs.	Present study
Brook trout	Fry following initiation of feeding, test duration 13-14 days, pH 4.4-5.5, total Al 0.2 mg/L	Survival 86% at pH 4.6, 68% at pH 5.2, mucous on gills at pH 5.2-5.4	Baker, 1981 Baker and Schofield, 1982
Brook trout	Fry following initiation of feeding, test duration 13-14 days, pH 4.4-5.5, total Al 0.3 mg/L	Survival 58% at pH 4.4, 39% at pH 4.9, and 45% at pH 5.5, mucous on gills at pH 5.2-5.4	Baker, 1981 Baker and Schofield, 1982
Brook trout	Fry following initiation of feeding, test duration 13-14 days, pH 4.4-5.5, total Al 0.5 mg/L	Survival 6% at pH 4.2, 18% at pH 4.6, and 0% at pH 5.2; mucous on gills at pH 5.2-5.4	Baker, 1981 Baker and Schofield, 1982

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Personal Vita

Marie Theresa BenKinney was born on January 7, 1959 in Quakertown, PA to Bruce and Arlene BenKinney. Her early school years were spent in the Southern Lehigh School District. While in high school, Marie was active in numerous sports and school organizations. She was a member of the National Honor Society and graduated from high school in June 1977 with high honors.

Marie attended the Pennsylvania State University, University Park Campus from September 1977 to June 1981 when she received a Bachelor of Science degree in Biology with a minor in Marine Science. While at Penn State, Marie participated in activities including the University Choir, Science Student Council, and Marine Science Society. During the spring semester, 1980, she participated in a three month marine science program at the Wallops Island Marine Science Consortium in Chincoteague, VA.

In Spetember 1981, Marie started in the Biology Master's Degree program at Lehigh University. Her major advisor was Dr. Jon I. Parker. She received a grant from the Energy Research Center to conduct her research on the influence of pH on Al toxicity in pumpkinseed sunfish fry. Additionally, Marie was a teaching assistant for the Biology Dept. where she conducted labs in Freshwater Ecology, General Biology, and Animal Physiology. She also served as an Atomic Absorption Spectrophotometer operator and assisted in field collection of data for a PP&L sponsored acid rain study.

Since March 1983, Marie has been employed in the Toxicology Division of Mobil Oil Corporation in Princeton, NJ. Her responsibilities include the day to day operations of the Aquatic and Ecotoxicology Section for Mobil. As an employee of Mobil Oil Corp., Marie has the opportunity to attend meetings and interact with other professionals in her field. The position is challenging and offers room for professional growth and advancement.