C-3.3 Effects of Acid Rain on Aquatic Organisms

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Abstract **Aquatic plants rose pH in ponds, but their growth and photosynthesis were inhibited at lower pH. In carp, secondary gill filaments were covered with chloride cells from a day after exposure, while serum osmosis, Na^+ and Cl^- remarkably decreased with decrease in pH. Additive effects of low pH and aluminium varied with temperature, increased with water hardness and more pronouced in fry than fertilized eggs. Maladjustment of osmoregulation was concluded to be caused by H^+ and not SO_4^{2-}, Cl^- or NO_3^- in masu salmon. Less than 24 hour exposure to acidic water was found to induce no effects on osmoregulation in sea-life of chum salmon. Catadromous salmon group fish were suggested to attain their osmo-regulating ability adaptable to both freshwater and marine lives in seaward migratory season. Additive toxicity of low pH and Cu or Al to sperms was recognized in ayu, charr and goldfish. Higher amounts of aluminium were elluted from finer particles of granite and andesite at lower pH. Acid tolerance of freshwater fish including salmon group and aquatic insects were evaluated. Rainbow trouts exposed to acidic environment produced eggs of lower eying and higher deformity rates. Model ecosystem experiment revealed acid loading to water causes change of species composition of plankton and delay of fish growth even when no remarkable decrease in pH is observed.**

Key Words Acid Rain, Freshwater Organisms, Osmotic Pressure, Aluminium, Model Ecosystem

1. Introduction

Acidification of freshwater ecosystems is recognized as a major and serious environmental problem in many parts of the world. In Japan, the recent increase in acid precipitation provides high possibility of

causing the same problem in near future, although no sign has become apparently in freshwater ecosystems for the present. It is neccessary to get informations about effects of acidification on freshwater organisms characteristic of Japan and about basic mechanisms not yet clarified.

2.Research Objective

The effects of acid rain on the freshwater organisms are evalu- ated to obtain informations for establishing the predicting method and the counter-measure for acidification in the freshwater environments.

In order to examine the effects of acidification on freshwater ecosystem, acid tolerance assay was conducted in some kind of aquatic plant, fishes and developmental stages of land-locked sockeye salmon, 6 salmonid species, 6 benthic invertebrates species as prey organisms and so on. The effects of acidification on additive toxicity with metals and on gametogenesis were also studied.

3.Reasearch Method

Effects of acidic exposure on 5 species of aquatic plants were investigated for clarifing acid tolerance, pH buffer action and effects on growth and photosynthesis. Morphological changes of gill after exposure to acidic condition, effect on serum osmotic pressure, effect of rearing temperature and of water hardness on additive toxicity to carp of low pH and Al were investigated controlling pH with pH controllers and peristatic pumps.

Experiments with salmonid fish were designed including three plans, A: Osmo-regulatory ability-Non anadromous japanese charr(*Salmo leucomaenis*)was exposed to acid water of pH3.5-7 with sulfuric acid. Concentrations of blood ions and osmolality of yolk were assayed in time-course. B: TEP(Transepitherial potential)-TEP of masu salmon(*Oncorhynchus masou*) was monitored after changes in ambient water from neutral water toacid water of pH3-7 containing sulfuric acid, nitric acid, hydrochloric acid,or acetic acid.C: Seawater adaptability of ocean migrators-Pacific salmon were exposed to acid water ofpH5, thereafter the fry were transferred into seawater. Plasma Na+ and Cl- were measured at 24 hours in the seawater.

Eggs and sperms of ayu, charr and goldfish were used for clarifying additive toxicity of low pH and Cu or Al. After the exposure, eying rate and sperm motility were investigated. The amounts of aluminium in the elutions from granite or andesite particles after exposure to acid water were measured and toxicity to sperms of the elutions were also investigated.

Eggs,developmental stages of ayu and so on,total 6 species of warm water fish and 3 species of prey organisms were exposed to acid water with pH 6.5-3.5 changing to newly pH adjusted water once a day. Model ecosystem experiment was conducted supplying

water with pH 5.5 or 4.0 for 14 weeks.

24hLC$_{50}$ pH in sulfuric acid water was compared between eyed embryo, alevins, fry and fingering in sockeye salmon. LC$_{50}$ was also compared among alevins and fingerings of 6 salmonid species, and 6 benthic invertebrate species. Mature male and female rainbow trout were tested with low pH(4.5) for 0,1,2 weeks. Secondly, mature female were treated with pH4.5,5.5,6.5 and natural water for 2 weeks. After these treatment eggs and sperm were fertilized and survival rates of embryo were observed.

4.Results and Discussion

Order in acid tolerance of 5 species of aquatic plant and injury pH were evaluated and buffer action of aquatic plant against low pH was demonstrated. Carp gill secondary epitherium began to be covered with chloride cells from a day after acid exposure. Serum osmotic pressure, Na^+ and Cl^- were affected severer with day progress. Newly hatched out carp alevins affected more lethally at pH:5.2•Al:0.2ppm than eggs,notlethally at this condition. Mortality due to the additive toxicity of low pH and Al varied depending on water temperature or water hardness. It is noticed that 25℃ induced low mortality or 25 ppmCaCO$_3$ induced high mortality similar to 5ppm.

The exposure of newly hatched charr alevins decreased yolk osmolarity significantly. Similar decrease in plasma ions of Na^+ and Cl^- were also observed in juve-niles at pH 3.9,4.6. Transepitherial potential(TEP)of masu salmon increased significantly immediately after the transfer from freshwater to acidwater less than pH 6. The decrease of TEP returned to the normal level after the water neutralized with alkaline(NaOH). The decrease of TEP was not different with the different acid chemicals except acetic acid. In the spring migratory period of young salmons, chum(O.keta) fry, masu and steelhead(O. mykiss) decresed plasma Na^+ and Cl^- concentrations after the acidwater exposure, but not in nonanadromous rainbow trout. The following transfer into seawater of control fish increased the ion concentrations to the similar levels of control fish transfered from freshwater to seawater without acidwater stress.

Acidwater stress induces an acute inbalance of the osmotic regulatory mechanisms. Under the acidic stress, especially plasma Na^+ and Cl^-,therefore osmolality, defused at the pH less than pH5. This abnormal eflux of major blood ions occurrs at branchial epithelium by the great concentration of H+ ion at anbient water. Although acute stress of acid water is severe in migratory species than freshwater resident rainbow trout, the osmoregulatory organs are not destroyed within 24 hour acid water stress at pH 5 and the fishes are adaptable to seawater after migrating down to the ocean.

Cu and Al showed additive toxicity to sperms of charr,ayu and gold fish. The tolerance of sperm was in the order of charr>ayu>gold fish. Al was eluted remarkably from granite and andesite under the condition of pH below 4.5 and the concentration of Al reached 4.44ppm after 15 day exposure at pH4.0. This concentration was 100 times higher

than the concentration affected the sperms.

The order of acid tolerance in warm water fish is concluded to be smelt > japanese minnow > japanese dace > crucian carp≒carp > ayu > gold fish. Chironomid larvae were highly tolerant to acidic condition. With model ecosystem experiment, it was clarified that delay of fish growth occurrs in not so severe acidic condition(pH >6.4 after 14 weeks of pH5.5 water supplying) and there is a possiblity of disturbance in ecosystem occurs in such a condition.

Fry stage was more sensitive to low pH. Species sensitivity of alevins were ranked as sockeye salmos > masu salmon > rainbow trout > charr > brook trout > brown trout. The prey organisms were generally more tolerant to low pH than salmonid fishes. These results suggest that acidification will directly damage salmonid populations, especially anadromous species such as Oncorhynchus, if they feed on such acid-tolerant preys.

The low pH less than 5.0 induced deteriolation of egg and sperm quality in mature trout, resulting in increase in mortality and deformation rates of embryo. Levels of maturation inducing hormone in eggs were significantly lower in acidified females. These results suggest acidification of mature fish affects endocrinological mechanisms of maturation, and will damage also survival of the second generation.