Fertilizers and the Effect They Have On Amphibian Populations

Glen Searcy
WFS 433
Amphibian Ecology and Conservation

Lecture Outline

- Introduction to Fertilizers
- Case Studies and Research
- Why Fertilizer Effects are So Damaging

Introduction to Fertilizers

- A fertilizer is a substance applied to soils or to plants that provides supplemental nutrients in order to optimize growth and development
- Plants need a number of different chemical elements
  - Carbon, Hydrogen, Oxygen (Found in the air)
  - Nitrogen, Phosphorous, Potassium
    - Needed in the Greatest Quantity
  - Sulfur, Calcium, Magnesium, Boron, cobalt, copper, iron, manganese, molybdenum and zinc
    - Found in Most soils

The Problem With Fertilizers

- Misuse and over application
  - Results in runoff of chemicals
  - Leaching of chemicals into water sources
- "Waterbodies situated within agricultural areas receive run off from surrounding land where fertilizers and pesticides are applied, and concentrations of nitrogen and phosphorus in these often exceed levels encountered in non-agricultural areas."(Hamer-2004)

The Problem With Fertilizers

- Fertilizers are extremely common
- Used on both large and small scales
  - Commercial and Residential

Problems With Fertilizers

- Direct application to water is often overlooked
- Used both for Agriculture and Aquaculture
  - Farm ponds connected to nearby drainages

The Research

Available online at www.sciencedirect.com

SCIENCE DIRECT®

Agriculture, Ecosystems and Environment 102 (2004) 299–305

Agriculture Ecosystems & Environment

www.elsevier.com/locate/agee

Amphibian decline and fertilizers used on agricultural land in south-eastern Australia

Andrew J. Hamer*, Julie A. Makings, Simon J. Lane, Michael J. Mahony

Discipline of Biological Sciences, School of Environmental and Life Sciences, The University of Newcastle, Callaghan, NSW 2308, Australia

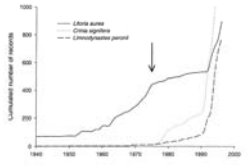
Received 10 April 2002; received in revised form 5 September 2003; accepted 9 September 2003

The Research

- Compared historical records of fertilizers with current and past frog populations
  - golden bell frog (Litoria aurea)
  - common eastern froglet (Crinia signifera)
  - Striped marsh frog (Limnodynastes peronii)

The Research

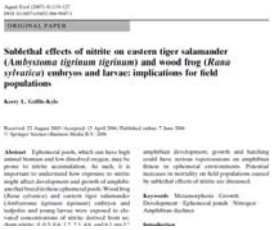
- Total Tonnage of fertilizers peaked between 1964-1973
- "All three species apparently increased from 1990 onwards when the issue of globally declining amphibian populations was first raised…"(Hamer-2004)



The Research

- The experimental evidence showed differential sensitivity to fertilizers between L. aurea and two non-declining frog species.
- Significantly fewer *L. aurea* tadpoles survived to metamorphosis in the two highest concentrations of ammonium nitrate (76 and 78% survival, 10 and 15 mg/l, respectively;F3,20 = 6.32, P = 0.003) and in 15 mg/l of calcium phosphate (82% survival; F3,20 = 3.44, P = 0.04) compared to the control (Fig. 3).

The Research



ORIGINAL PAPER

Sublethal effects of nitrite on eastern tiger salamander (*Ambystoma tigrinum tigrinum*) and wood frog (*Rana sylvatica*) embryos and larvae: implications for field populations

Kerry L. Griffis-Kyle

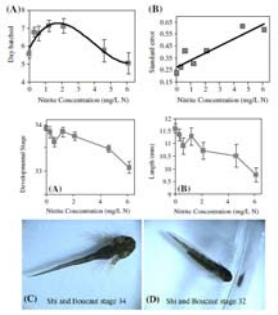
-This study explores the indirect effects of Nitrites and Nitrates on Amphibian Populations.

- "Nitrite can cause direct lethal effects in amphibians but the sublethal effects, especially on amphibians that breed in ephemeral ponds in agricultural regions, need to be explored."(Griffis-Kyle-2005)

The Research

- Three wood frog egg masses were collected from three ponds and18 eastern tiger salamander egg masses were collected from six ponds in 2004.
- Early tadpole and larval survival were tested at nitrite concentrations of 0, 0.3, 0.6, 1.2, 2.1, 4.6, and 6.1 mg l/ NO2–N.
- "For the eastern tiger salamander, nitrite has a significant negative effect on developmental stage at hatching controlling for the size of the hatchling"(Griffis-Kyle-2005)

The Research

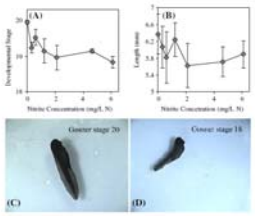


Results from Nitrite Exposure to tiger salamanders

-*Exposed salamanders hatched without branched gills- (reduces oxygen uptake)

- Pictures taken of tiger salamanders 24 hours after hatching
- (**C**) 0 mg l–1 NO2–N and
- (**D**) 6.1 mg l–1 NO2–N

The Research



Results from nitrite exposure to wood frogs

- wood frog embryos exposed to higher concentrations of nitrite hatched at Gosner (1960) stages 18 and 19, before circulation begins in the gills
- Photographs taken 24 hours after hatching
- (C)0 mg l–1 NO2–N and
- (D)6.1 mg l–1 NO2–N

The Research

- "Nitrite may enter organisms with food, diffuse through dermal layers as HNO2, or enter by active diffusion through the gills of aquatic organisms through the chloride uptake mechanism."(Griffis-Kyle-2005)
- Ephemeral pools dry and can cause full mortality in the cohort of amphibians within the pool if they have not completed metamorphosis (Berven 1990)

The Research

SETAC PRESS

Environmental Toxicology and Chemistry, Vol. 18, No. 12, pp. 2830–2838, 1999
© 1999 SETAC
Printed in the USA
0730-7268/99 $9.00 + .00

SENSITIVITY TO NITRATE AND NITRITE IN POND-BREEDING AMPHIBIANS FROM THE PACIFIC NORTHWEST, USA

ADOLFO MARCO,*† CONSUELO QUILCHANO,‡ and ANDREW R. BLAUSTEIN§
*Departamento de Biología Animal, Universidad de Salamanca, Salamanca 37071, Spain
†Instituto de Recursos Naturales y Agrobiología, Consejo Superior de Investigaciones Científicas, Salamanca 37071, Spain
§Department of Zoology, Oregon State University, Corvallis, Oregon 97331, USA

(*Received* 27 July 1998; *Accepted* 11 March 1999)

Abstract—In static experiments, we studied the effects of nitrate and nitrite solutions on newly hatched larvae of five species of amphibians, namely *Rana pretiosa*, *Rana aurora*, *Bufo boreas*, *Hyla regilla*, and *Ambystoma gracile*. When nitrate or nitrite solutions were added to the water, some larvae of some species reduced feeding activity, swam less vigorously, showed disequilibrium and paralysis, suffered abnormalities and edemas, and eventually died. The observed effects increased with both concentration and time, and there were significant differences in sensitivity among species. *Ambystoma gracile* displayed the highest acute effect in water with nitrate and nitrite. The three canal species had acute effects in water with nitrite. In chronic exposures, *R. pretiosa* was the most sensitive species to nitrates and nitrites. All species showed 15-d LC_{50}s lower than 2 mg $N\text{-}NO_3/L$. For both N ions, *B. boreas* was the least sensitive amphibian. All species showed a high mortality at the U.S. Environmental Protection Agency–recommended limit of nitrite for warm-water fishes (1 mg $N\text{-}NO_2/L$) and a significant larval mortality at the recommended limit of nitrite concentration for drinking water (1 mg $N\text{-}NO_2/L$). The recommended levels of nitrate for warm-water fishes (90 mg $N\text{-}NO_3/L$) were highly toxic for *R. pretiosa* and *A. gracile* larvae.

Keywords—Amphibian decline Fertilizers Interspecific competition Nitrate Nitrite

The Research

- R. pretiosa, R. aurora, B. boreas, H. regilla, and A. gracile larvae tested
- Four Species of Amphibians tested for sensitivity to nitrate solutions and all five species tested for sensitivity to nitrite solutions.
- Both the nitrites and nitrates exposures eventually resulted in high rates of mortality, however, there was high variability between the species with regards to early sensitivity.

The Research

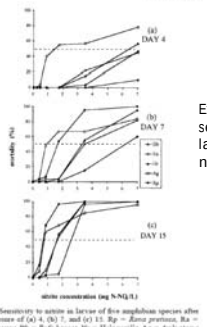


Fig. 2. Sensitivity to nitrite as larvae of five amphibian species after an exposure of (a) 4, (b) 7, and (c) 15. Rp = *Rana pretiosa*, Ra = *Rana aurora*, Bb = *Bufo boreas*, Hr = *Hyla regilla*, Ag = *Ambystoma gracile*.

Experiments showed a strong sensitivity of R. pretiosa and A. gracile larvae to relatively low levels of both nitrate and nitrite

The Research

- "Many public water supplies in the United States contain levels of nitrate that routinely exceed concentrations of 10 mg N/L [8]. In the Willamette Valley, average nitrate concentrations of 17.8 and 21.9 mg N/L were recorded in water samples from some crop soils receiving recommended rate of nitrogen fertilization." (Brandi-Dohrn-1997)

Table 3. Median lethal concentrations (LC50 ± SE) of nitrite (mg N-NO_2/L) for aquatic larvae of five amphibian species at 4, 7 and 15 days of exposure. Standard errors for LC50 are in parentheses

Day	*R. pretiosa*	*R. aurora*	*B. boreas*	*H. regilla*	*A. gracile*
4	6.82 (0.615)	5.59 (1.446)	>7.0	5.50 (0.742)	1.90 (0.737)
7	1.30 (0.345)	4.00 (1.021)	5.38 (0.646)	3.60 (0.650)	1.54 (0.598)
15	0.57 (0.033)	1.19 (0.268)	1.75 (0.612)	1.23 (0.312)	1.01 (0.279)

Marco-1999

The Research

SETAC PRESS

Environmental Toxicology and Chemistry, Vol. 18, No. 1, pp. 046-049, 1999
© 1999 SETAC
Printed in the USA
0730-7268/99 $9.00 + .00

THE EFFECTS OF NITRITE ON BEHAVIOR AND METAMORPHOSIS IN CASCADES FROGS (*RANA CASCADAE*)

ADOLFO MARCO*† and ANDREW R. BLAUSTEIN‡
†Departamento de Biología Animal, Universidad de Salamanca, Salamanca 37071, Spain
‡Department of Zoology, Oregon State University, Corvallis, Oregon 97331, USA

(*Received* 26 *May* 1998; *Accepted* 27 *July* 1998)

Abstract—Amphibian metamorphosis is a period of drastic morphologic reorganization, during which larvae experience a decrease in locomotor ability and are more vulnerable to predation. Our results indicate that exposure to sublethal concentrations of nitrite in the water induces behavioral and morphologic changes in the Cascades frog (*Rana cascadae*). Tadpoles exposed to a nitrite concentration of N-NO_2 at 1.5 mg/L transformed more slowly than control tadpoles exposed to dechlorinated tap water. No difference was found in time at emergence and snout–vent length at emergence between experimental and control tadpoles, but development was retarded in tadpoles exposed to nitrite and they emerged at an earlier developmental stage. Also, tadpoles exposed to nitrite occupied shallow water more frequently than did control tadpoles.

Keywords—Amphibian Fertilizers Metamorphosis Nitrite *Rana cascadae*

The Research

- Egg masses of Cascades frog (*Rana cascadae*)collectedand exposed to nitrites in water
- "When nitrites contact blood plasma, they transform hemoglobin to methemoglobin, decreasing the oxygen carrying capacity of the blood"(Marco-1998)
  - Methemoglobinemia
- Tadpoles exposed to nitrite were less developed and were observed in shallower water with heads out of the water.
  - Shows lack of ability to efficiently get oxygen
    - Ponds that experience algal blooms
  - Creates chances for increases in predation

The Research

ELSEVIER

Agriculture, Ecosystems and Environment 61 (1997) 69–74

Agriculture Ecosystems & Environment

Short communication

The effect of ammonium nitrate fertiliser on frog (*Rana temporaria*) survival

R.S. Oldham [a,*], D.M. Latham [a], D. Hilton-Brown [a], M. Towns [a], A.S. Cooke [b], A. Burn [b]

[a] *Department of Biological Sciences, De Montfort University, Leicester LE7 9SU, UK*
[b] *English Nature, Northminster House, Peterborough PE1 1UA, UK*

Accepted 17 June 1996

Abstract

The toxicity of ammonium nitrate fertiliser to common frogs (*Rana temporaria*) was tested in the laboratory and field. Granular ammonium nitrate is the most commonly used fertiliser in Britain, especially during the spring, when adult frogs migrate over land. Ammonium nitrate was acutely toxic to frogs at concentrations well below those recommended for field application. However, it lost its acute effect when dissolved in the soil and even on relatively dry soil (7% moisture), granules dissolved in less than 3 hours. A potentially high mortality rate owing to ammonium nitrate is probably mitigated by the fortuitous asynchrony between fertiliser application during daylight, and frog migration at night. It remains to be determined whether there are sublethal effects and whether fertilisers that dissolve more slowly are implicated in the widespread amphibian declines in agricultural areas observed since the Second World War.

The Research

- Common frogs (Rana temporaria) were exposed to multiple levels of concentration of ammonium nitrate
- All subjects exposed to concentrations over 3 g/m² showed significant signs of effect

The Research

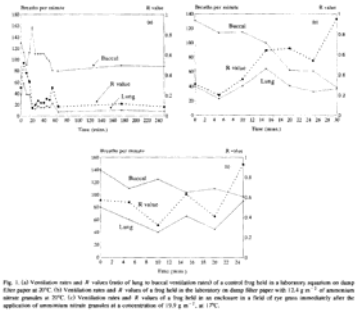


Fig. 1. (a) Ventilation rates and R values (ratio of lung to buccal ventilation rates) of a control frog held in a laboratory aquarium on damp filter paper at 20°C. (b) Ventilation rates and R values of a frog held in the laboratory on damp filter paper with 12.4 g m^{-2} of ammonium nitrate granules at 20°C. (c) Ventilation rates and R values of a frog held in an enclosure in a field of rye grass immediately after the application of ammonium nitrate granules at a concentration of 19.8 g m^{-2}, at 17°C.

Fertilizers: A Widespread Problem

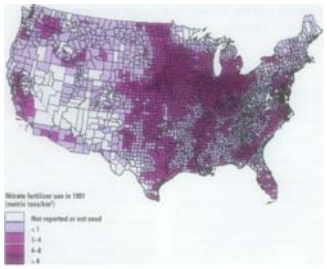
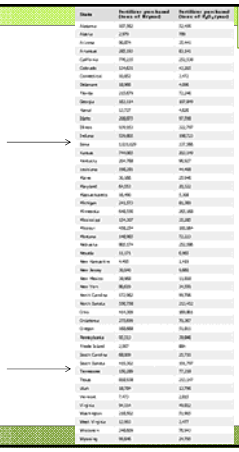


Figure 1. Nitrogen fertilizer use in the continental United States, 1991 (J2).

Rouse et. al -1999



Average commercial fertilizer purchased by states per year (EPA)

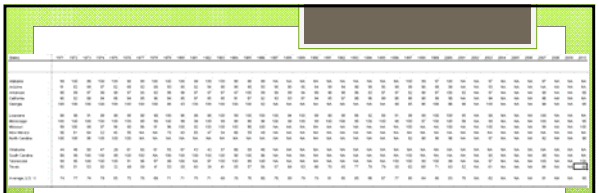


Table 15—Percentage of cotton acreage receiving nitrogen fertilizer, selected States, 1964-2010 (USDA)

-Studies have shown that 10-25% of nitrogen fertilizers run off into adjacent running running water. (Maitland-1984)

-In areas where there are intensively fertilized lands, this is a huge problem

Fertilizers: Residential Use

- Increasing impermeable surfaces results in higher amounts of runoff
- Must consider the watershed approach

Fertilizers: The Big Picture

- Its Both Residential and Commercial Use

Aquaculture and Fertilizers

- Application of Fertilizers to ponds
  - Common practice Is to add nitrogen and phosphorous
  - This spike in nutrients results in high amounts of zooplankton and can result in an algal bloom
  - Without constant fertilization, these algae will die.
  - Bacteria will decompose and consume all of the oxygen in the water.
  - This application of fertilizers is not always intentionally

Summary

- Exposure to Nitrates and Nitrites have devastating effects on early development that result in mortality
  - Effects predation rates, oxygen uptake efficiency, risk of desiccation etc…
- Adult Anuran Species can also be affected(Need more research to be done)
- Fertilizers are a problem from misuse and over-application
- Fertilizers are the significant cause for amphibian declines because it effects a wide range of distributions and causes many complications that eventually lead to mortality

References

- Berven KA (1990) Factors affecting population fluctuations in larval and adult stages of the wood frog (Ranasylvatica). Ecology 71:1599–1608
- Brandi-Dohrn FM, Dick RP, Hess M, Kauffman SM, Hemphill DD Jr, Selker JS. 1997. Nitrate leaching under a cereal rye cover crop. J Environ Qual 26:181–188.
- Maitland, P.S.1984. The effects of eutrophication on aquatic wildlife. Jenkins, D., (ed.) Agriculture and the environment. Cambridge, NERC/ITE, 101-108. (ITE Symposium, 13).
- Marco, A., Quilchano, C., Blaustein, A.R., 1999. Sensitivity to nitrate and nitrite in pond-breeding amphibians from the Pacific northwest. USA Environ. Toxicol. Chem. 18, 2836–2839.
- Marco, A., Blaustein, A.R., 1999. The effects of nitrite on behavior and metamorphosis in cascades frogs (Rana cascadae). Environ. Toxicol. Chem. 18, 949–949.
- Oldham RS, Latham DM, Hilton-Brown D, Towns M, Cooke AS, Burn A. The effect of ammonium nitrate fertiliser on frog (Rana temporaria) survival. Agric Ecosyst Environ 61:69-74 (1997).
- Oldham RS, Latham DM, Hilton-Brown D, Towns M, Cooke AS, Burn A. The effect of ammonium nitrate fertiliser on frog (Rana temporaria) survival. Agric Ecosyst Environ 61:69-74 (1997). Rouse et al. 1999. Nitrogen Pollution: An assesment of its threat to amphibian survival. Environmental Health Perspectives 107.10: 799-803

Questions?