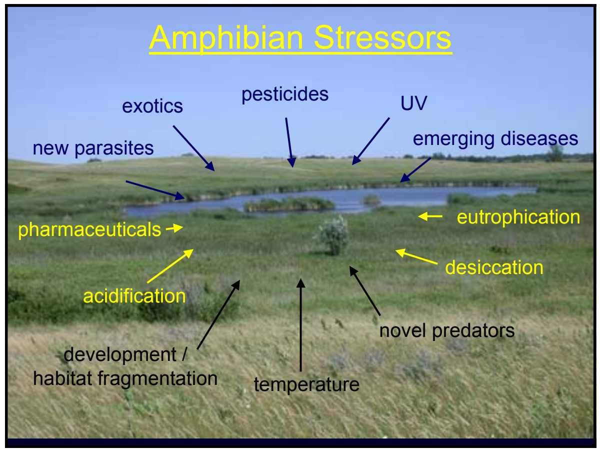
Effects of Multiple Stressors on Aquatic Communities in the Prairie Pothole Region

Patrick K. Schoff and Lucinda B. Johnson
Natural Resources Research Institute
University of Minnesota Duluth

Glenn Guntenspergen
US Geological Survey
Patuxent River, Maryland

Carter Johnson
South Dakota State University
Brookings, South Dakota

Amphibian Stressors



Indicators of Ecosystems in Jeopardy

population reductions

Emerging diseases of wildlife
- CWD
- BSE / vJCD
- AIDS
- SARS
- Ebola
- Avian Influenza
- West Nile Virus

Emerging diseases in humans

Human epidemiology
- cancers
- asthma
- heart disease

local extinctions

Wildlife epidemiology
- intersex
- parasites
- cancers
- malformation

species extinction

exotic / invasive species

Prairie Pothole Region

Critical freshwater resource
- habitat
  - breeding waterfowl
  - migration stopover
  - macroinvertebrates
  - amphibians
- flood water storage

Anthropogenic Stressors Affecting the Prairie Pothole Region

Climate change
- increased temperature
- decreased moisture

UV radiation
- reduced DOC inputs (?)

Agricultural practices
- excess nutrients
- pesticides

Habitat restructuring/destruction
- ~50% of wetlands drained in previous century
- remaining wetlands embedded in agricultural matrix

Stressor Effects on Amphibians

Stressors		Biological Effects
Global Climate Change	↑ temperature ↓ precipitation ↑ UV-B radiation	accelerated development immune dysfunction species diversity (?)
Agricultural Practices	habitat restructuring pesticides nutrients	physiological stress immune dysfunction disease susceptibility developmental anomalies

Objectives

1. Quantify relationships among differing land use, amphibian community structure and composition in the prairie pothole region.
   - hydroperiod (semi-permanent v. seasonal)
   - crop v. grassland
2. Quantify relationships among physical and chemical wetland attributes on amphibian organismal and community responses.
   - hydroperiod
   - thermal regime
   - pH

Objectives, cont.

3. Quantify the effects of multiple stressors on health and organismal responses of *Rana pipiens*.
   - shortened hydroperiod
   - increased UV-B radiation
4. Predict potential effects of multiple stressors on prairie pothole wetlands and associated amphibian communities.

Stressor Effects on Amphibians

Accelerated Hydroperiod (warmer, less water)
- faster development
- smaller metamorphs
- reduced fat stores = reduced fitness

Increased UV-B radiation (ozone depletion, +/- reduced DOC)
- edema
- malformations
- impaired immune function
- mutagenic effects

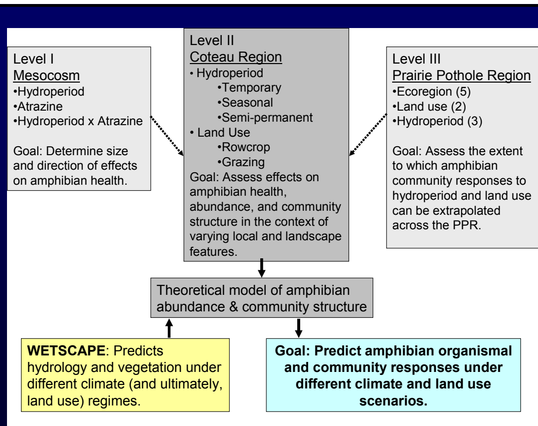
Atrazine (most commonly used herbicide)
- endocrine disruption (?)
  - gonadal dysmorphogenesis (♂♀)
  - laryngeal muscle reduction (♂)
- developmental delays

Approach

Landscape scale (Extensive study)
- relationships among amphibian community structure, land use, and wetland hydrologic regime

Wetland scale (Intensive study)
- relationships among individual wetlands (hydroperiod, physico-chemical), land uses (e.g. pesticides), UV-B, amphibian abundance, community structure, and health

Mesocosm scale
- effects of multiple stressors (hydroperiod and pesticide) on *Rana pipiens* development and health



Multiple Stressors Study

Extensive study:
- Prairie Pothole Region
- goal = 120 wetlands (2004 = 63 wetlands)
- 2004, 2005

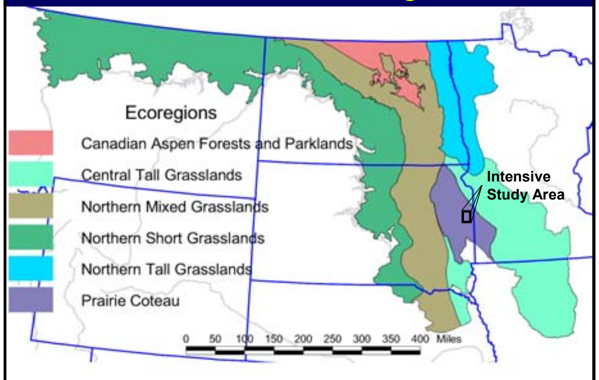
Intensive study:
- Prairie Coteau ecoregion
- goal = 60 wetlands (2003 = 27 wetlands)
- a portion under study in an ongoing hydrological research program
- 2003 - 2005

2 hydroperiod categories:
seasonal
semi-permanent

2 use classes:
row crop
grazing/pasture

Mesocosm study:
- 2003 pilot study
- 2004 – 2005 full-scale

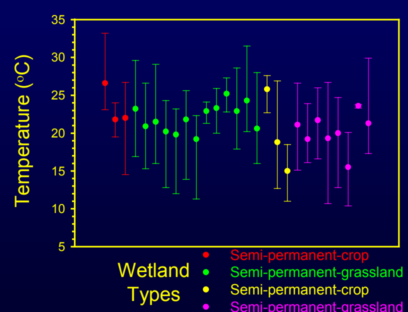
Prairie Pothole Region



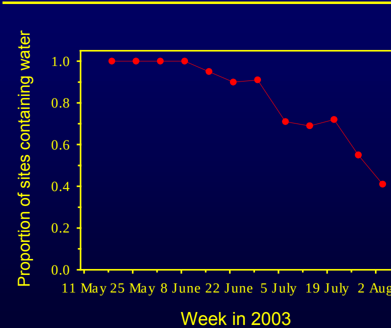
Intensive Study (2003 – 2005)

Category	Parameter
Wetland morphology	size; configuration; depth profile; hydrologic regime
Habitat	vegetative cover maps; land use; distance to wetlands, fields, roads & structures
Water column	continuous temp; sp. conductance; pH; depth (weekly); spectral scans; UV attenuation; pesticide analysis (atrazine); chlorophyll-A
Microclimate	temperature; humidity; precipitation; cloud cover; wind speed
Amphibian community	calling surveys; VES surveys & trapping for amphibian larvae (biweekly)

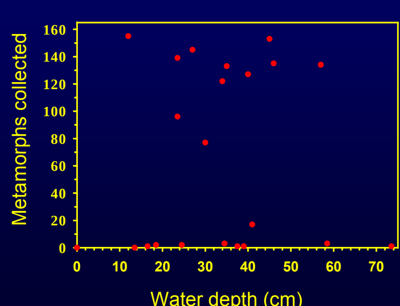
Wetland Temperatures - 2003



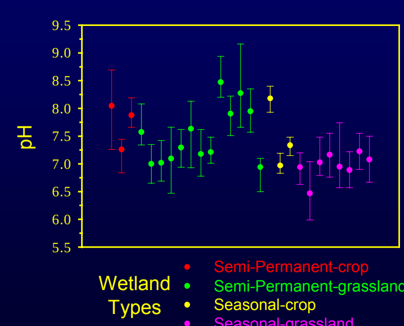
Water Loss in Wetlands - 2003



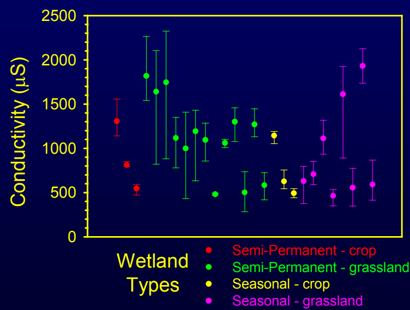
Metamorphs Captured – Week 10



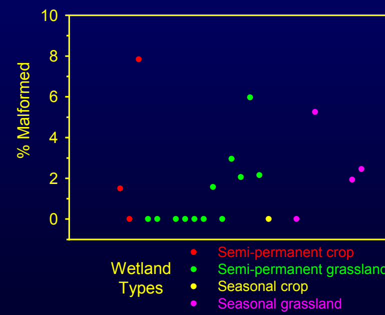
Wetland pH - 2003



Wetland Conductivity - 2003



Malformation Prevalence - 2003



Malformations - 2003

Survey

- 27 wetlands
- 7 dry
- 8 with < 10 metamorphs captured (n = 14)
- 12 with >10 metamorphs captured (n = 1475)
  (avg. = 123; range = 22 - 155)

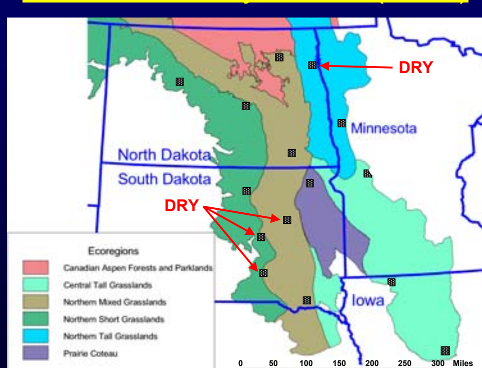
Malformation prevalence:

- metamorphs 1475
- malformed individuals 45
- prevalence range 0 – 7.8%
- overall prevalence 3.1%
  (Midwest study = 2.0%)

Malformation Prevalence by Wetland Type

Wetland Category	Wetlands	Metas.	Malfs.	Prev. (%)
Semi-permanent crop	1	132	2	1.5
Semi-permanent grassland	8	913	25	2.4
Seasonal crop	1	153	12	7.8
Seasonal grassland	2	277	6	2.2
Total	**12**	**1475**	**45**	**3.1%**

Extensive Study Blocks (2004)



Extensive Study (2004 – 2005)

Category	Parameter
Wetland morphology	size; configuration; depth profile; hydrologic regime
Habitat	vegetative cover maps; land use; distance to wetlands, fields, roads, & structures
Water column	temperature; pH; spectral scans; water color @ 440 nm
Microclimate	temperature; humidity; precipitation; cloud cover; wind speed
Amphibian community	calling surveys; VES surveys & trapping for amphibian larvae

Mesocosm Scale

Goal – replicate environmentally relevant multiple stressor exposure under controlled conditions:

1. accelerated hydroperiod
2. atrazine

Hydroperiod

1. normal hydroperiod – drawdown tied to field conditions
2. accelerated hydroperiod – drawdown at increased rate

Atrazine

1. 0.1 µg/L – found by Hayes and others to cause gonadal dysmophogenesis
2. 20 µg/L – commonly found in ground and surface water in corn-growing areas
3. 200 µg/L – occasionally found in surface water

Mesocosms - 2003

"Pilot year" for mesocosms (late start limited options)

- survival
- density
- temperature
- feeding
- atrazine exposure tests:
    1) control, no addition
    2) solvent (acetone)
    3) atrazine, 20 µg/L
    4) atrazine, 200 µg/L

Results:

- limited development
- no metamorphs

Interpretation:

- suspect water source
- late collection of tadpoles
- long holding time in aquarium
- high temperatures in mesocosms

Mesocosms - 2004

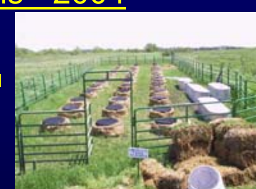
Modifications:

- lake water
- addition of shade cloth
- insulated tubs with straw
- successful early egg mass collection
- limited holding time (larvae transferred at Gosner stage 20+)

Mesocosms - 2004

Treatments (stressors):

hydrology: normal or accelerated
atrazine: 0, 0.1, 20,200 µg/L

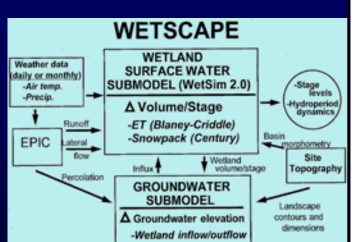


9 treatment categories:

1.	normal hydrology,	no additions
2.	accelerated hydrology,	no additions
3.	normal hydrology,	solvent control (acetone)
4.	normal hydrology,	atrazine 0.1 µg/L
5.	normal hydrology,	atrazine 20 µg/L
6.	normal hydrology,	atrazine 200 µg/L
7.	accelerated hydrology,	atrazine 0.1 µg/L
8.	accelerated hydrology,	atrazine 20 µg/L
9.	accelerated hydrology,	atrazine 200 µg/L

Modeling

- Multi-basin wetland complex model based on WETSIM (Poiani et al. 1996)
- Consists of interacting submodel components: surface water, groundwater, and vegetation.
- Simulates changes in water level and vegetation cover for prairie wetland complexes that include 3 hydrologic classes:
    - semi-permanent,
    - seasonal,
    - temporary
- HADCM3 climate scenarios will be used to parameterize model.



Modeling Climate Change

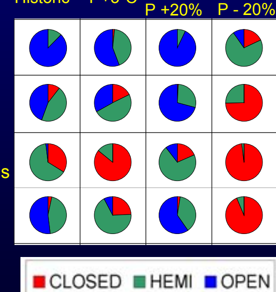
Historic | T +3°C | T +3°C P +20% | T +3°C P - 20%

Algona, IA
Central Tall Grasslands

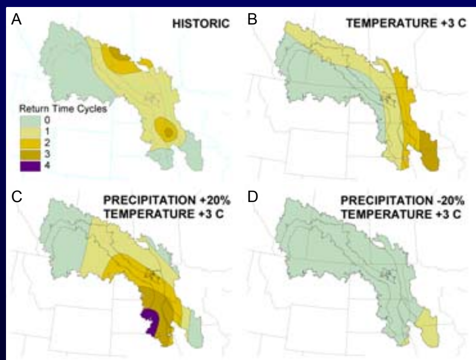
Crookston, MN
Northern Tall Grasslands

Minot, ND
Northern Mixed Grasslands

Watertown, SD
Prairie Coteau



Modeling Climate Change



Challenges

1. Site availability and landowner cooperation.
   - farmer/rancher sensitivity to researchers
   - lack of “crop” wetland sites
2. Who would do wetland research in a drought?
3. UV monitoring in continually windy conditions.
4. Availability of target frog (*Rana pipiens*) eggs for mesocosms; variability due to local weather & short-term climate conditions.
5. Mesocosms:
   - frog survival
   - metamorph development

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD-83087901-0

This research has been supported by the U.S. EPA Science to Achieve Results (STAR) Multiple Stressors Initiative.

Acknowledgments

Dr. Catherine Johnson, National Forest Service
Dr. Nels Troelstrup, South Dakota State University

Jennifer Olker Milan
Angela Rohweder

Dena Shelley
Katie Brown
Deborah Endriss
Chandler Schmutzer
Denise Gregorie
Janna Goldrup
Sarah Syria
Patti Kramer