Aliens Among Us … Success of Invasive Asian Carps in Midwestern Waterways

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Alien/Invasive/Introduced/Exotic/Non-indigenous/Non-native/Nuisance Species

- Terminology can be confusing and misused
- Invasive can also refer to native species that become overpopulated w/i native distribution

Modes of Introduction

- **Intentional**
  - Legal for management or control (e.g., Pacific salmon, grass carp)
  - Illegal (e.g., bucket stocking, aquarium releases, bait bucket releases)
- **Accidental/Unintentional**
  - Artificial waterways
  - Aquaculture pond overflows
  - Ballast water release

Aquatic Invasive Species (AIS) Facts

- **AIS often most successful in degraded systems (Moyle & Light 1996)**
- **Small percentage become established**
  - Generally <10% have significant impacts
- **Ecological impacts**
  - Compete with native species
  - Prey/parasitize on native species
  - Alter food web structure
- **Economic impacts**
  - Lost commercial and recreational fisheries
  - Industrial/commercial/recreational fouling

Aquatic Invasive Species (AIS)

- **Native species lost due to alien species:**
  - **Prey/parasitize native species (e.g., sea lampreys)**
  - **Competition**
    - **Difficult to demonstrate**
    - **E.g., whitefishes lost to competition from alewife**
  - **Disease**
    - **Parasites & pathogens carried by introduced fish**
    - **Contributes to inability of native fish to compete**
  - **Hybridization**

Aquatic Invasive Species (AIS)

- **Characteristics of successful invaders**
  - Abundant/widely distributed in native range
  - Wide environmental tolerance
  - High genetic variability
  - Short generation time
  - Rapid growth
  - Early sexual maturity
  - High reproductive capacity
  - Broad diet (opportunistic)
  - Rapid natural dispersal capability
  - Commensal with human activities

Continued Threats Despite Tighter Regulations

- High environmental tolerance of invading species
- Lack of compliance/incomplete compliance
- Lack of education
- Flagrant disregard of policy

Quick Background

- "Asian carp"
  - Bighead carp, *Hypophthalmichthys nobilis*
    - Zooplanktivore
  - Silver carp, *H. molitrix*
    - Phytoplanktivore
  - Grass carp

    Ctenopharygodon idella
    - Macrophytes
  - Black carp

    Mylopharygodon piceus
    - Molluscivore

Quick Background

- Bigheaded carp (*Hypophthalmichthys* spp) invasion history well-known (started in Arkansas 1972 & 1973)
- Invasion of Great Lakes Basin considered imminent (Jerde et al. 2011)
- Substantial economic & ecological consequences of invasion & establishment very likely (Cudmore et al. 2012)
- Considerable effort expended to prevent additional introductions that could lead to establishment and wider distribution (e.g., electric barriers)

Quick Background

- Ecosystem effects

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Quick Background

- Danger to humans

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Assessing/Predicting Threats

- **Prevent new introductions; halt, limit, slow dispersal**
- **Multiple efforts based on:**
  - Life history, habitat requirements, invasion histories, & human uses (Kolar & Lodge 2002; Cudmore et al. 2012)
  - Ecological niche & habitat suitability models (Chen et al. 2007; Herborg et al. 2007; Cudmore & Mandrak 2011; Cudmore et al. 2012; Kocovsky et al. 2012)
  - Bioenergetics modeling (Cook & Hill 2010)
- **Mixed results**
- **Constrained by knowledge of their ability to adapt to novel environments?**

Key Ecological Factors (Native)

- **Typically lentic & need "large" rivers to spawn**
- **80-100 km undammed river/channel (Kolar et al. 2007)**
  - BUT, eggs known to develop in static conditions
- **Rising hydrograph/water temps ≥18 °C**
  - Water velocity ≥0.7 m/s (Abdusamadov 1987)
  - Precipitation & discharge as proxies (e.g., Kocovsky et al. 2012)
  - BUT, reproductive needs may not be as restrictive in new environments (e.g., Kara Kum Canal, Turkmenistan)
- **Spring/early summer spawning**
  - BUT, spawning may occur multiple times throughout summer (Rasmussen 2002; Papoulias et al. 2006; Schrank & Guy 2002)

Plasticity

- Sufficient anecdotal/preliminary/recently published evidence exists to suggest that bigheaded carps more plastic in novel systems
- Spawning habitats in native range different from North America (e.g., Missouri River, Deter et al. 2012)
- Bigheaded carps likely to be able to acclimate to a wide range of conditions (“adaptable,” Kocovsky et al. 2012)
- Relatively little ecological info on bigheaded carps in North American waters
- More quantitative understanding of ecology in North American waters could improve management strategies

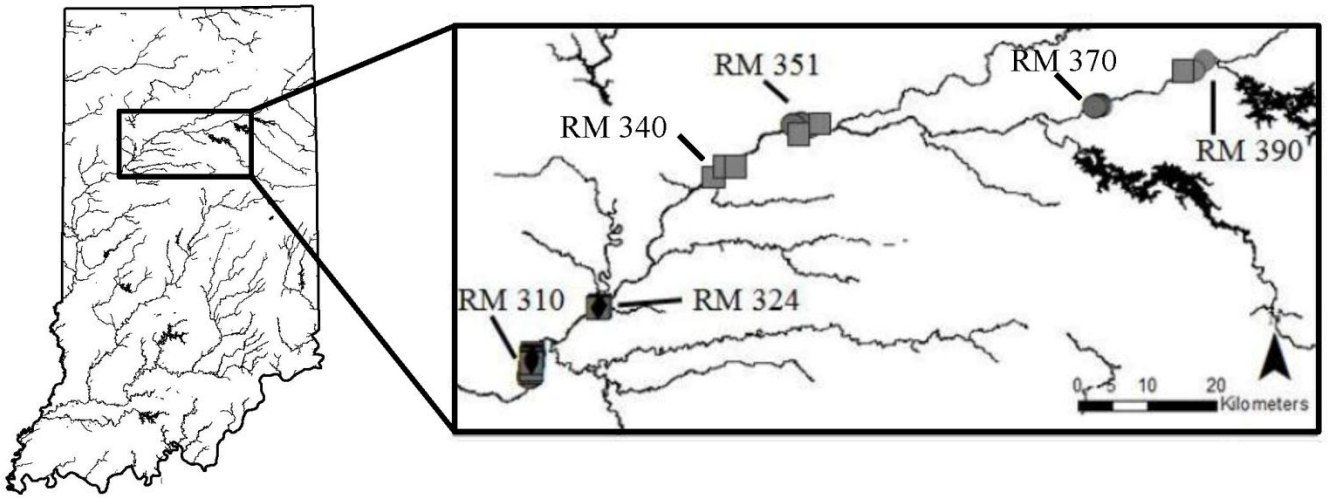
Objectives

- **Increase understanding of bigheaded carp spawning ecology in North American freshwaters**
- **Conduct surveys of drifting eggs in the Wabash River, IN**
  - Evaluate gage height, Δ gage height, water temperature as factors
  - Determine the temporal extent of spawning
  - Determine upstream-most extent of spawning

Study Area

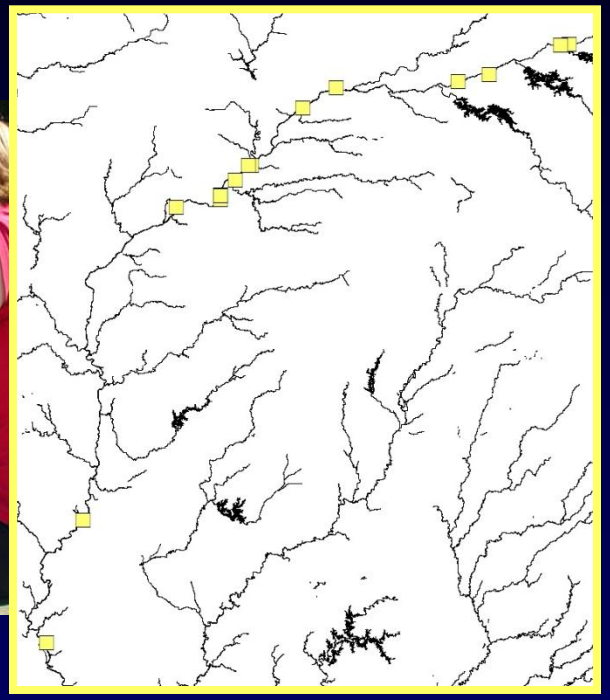
Upper Wabash River

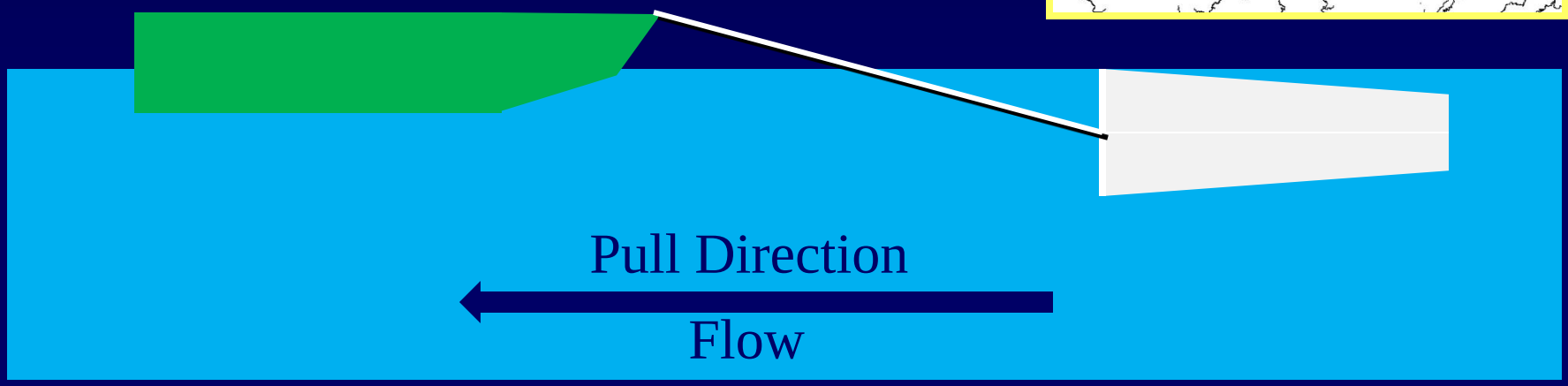
- Eagle Marsh



Drifting Egg Sampling

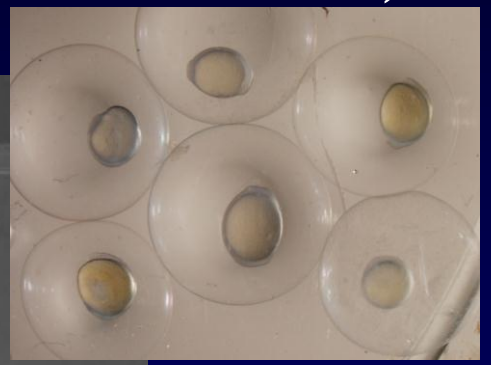
- **Bongo net pulls in triplicate (333 µm, 500 µm)**
  - Weekly pulls at RM310 (Summer 2011 & 2012)
  - 3-5 min pulls; velocity added in 2012

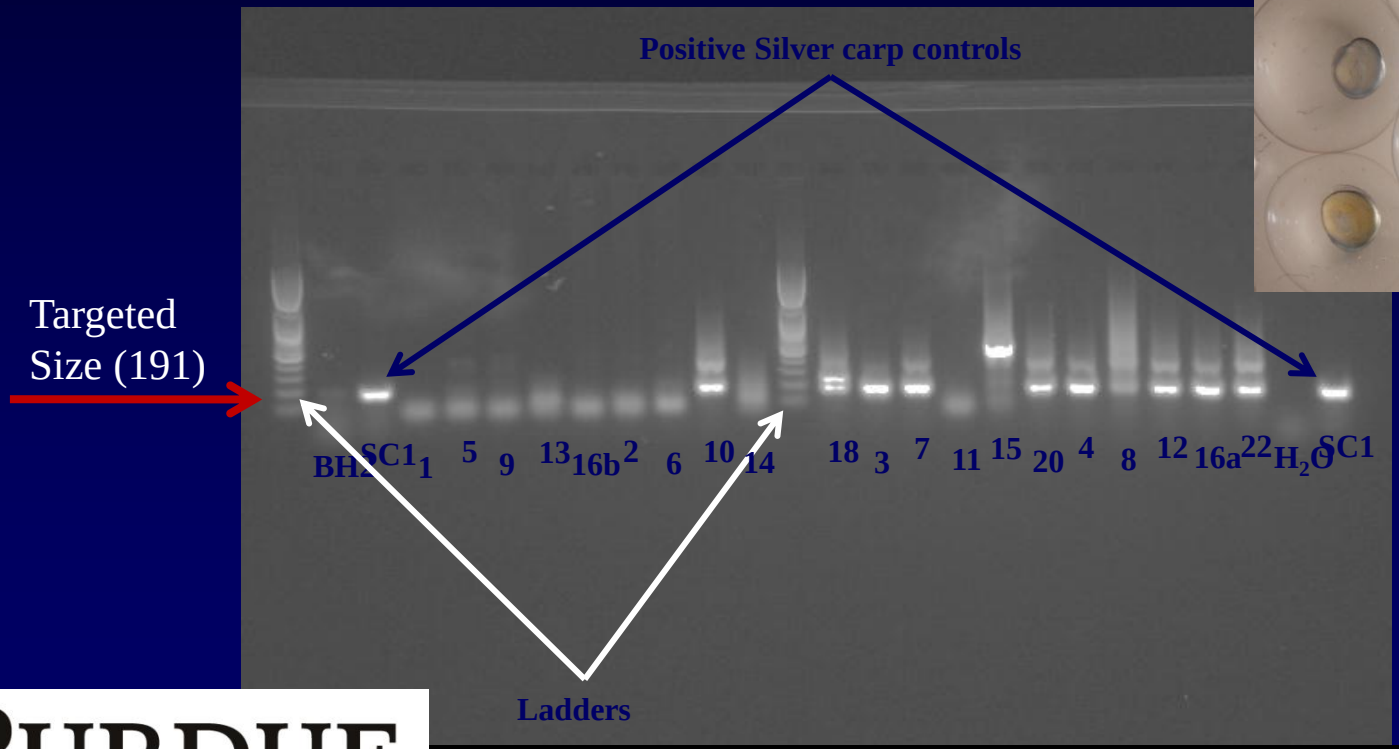




Egg Verification

- **Chapman 2006; Chapman & George 2011**
- **DNA**
  - PCR & qPCR (Jerde et al. 2011); 2011 samples
  - qPCR D-loop region of mitochondrial DNA (Coulter et al. *In Press*); late 2011 & 2012





Results

- **2011**
  - Eggs detected on 19 of 25 sample dates
  - Some hydrological variability early, but largely stable from mid-July – September
  - Eggs detected @ water temps from 18.5 – 29.7 °C
  - Eggs detected as late as 01-Sep
  - DNA –confirmed eggs exclusively silver carp

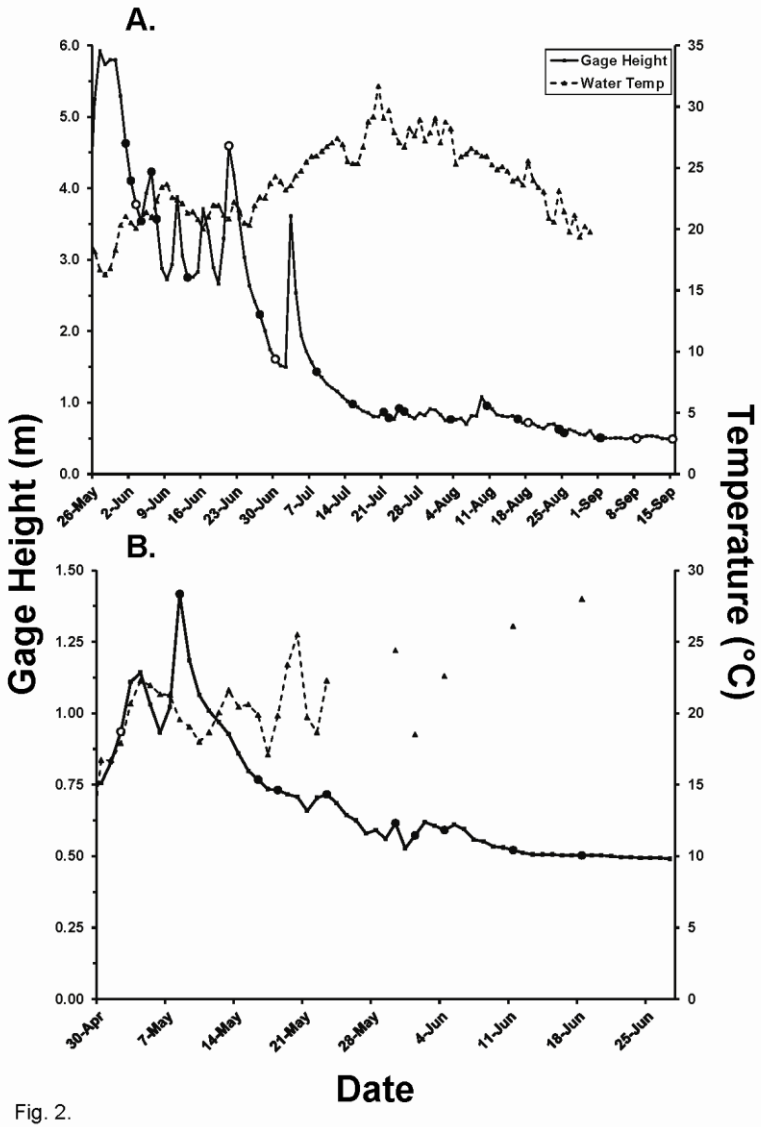
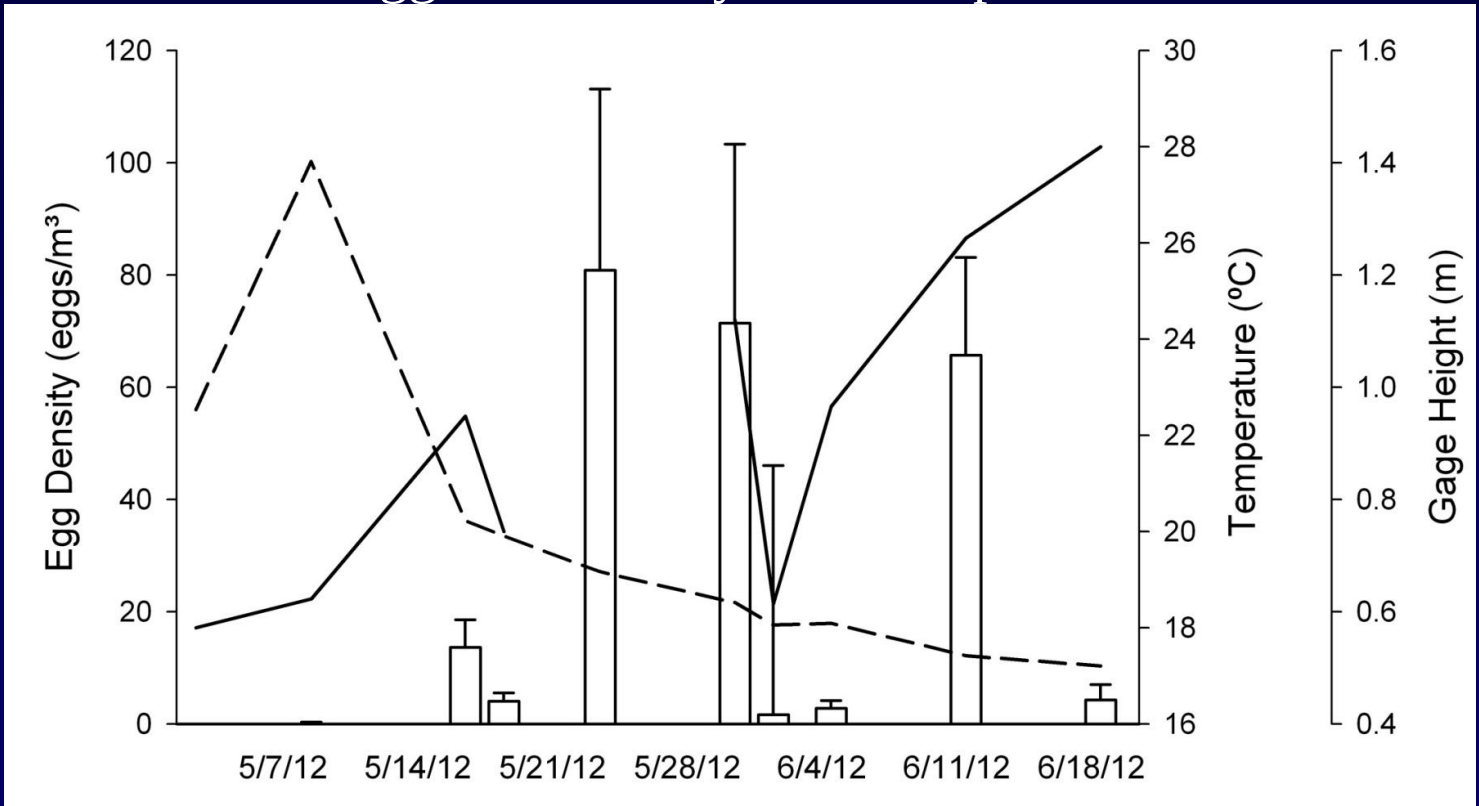


Fig. 2.

Results

- **2012**
  - Very little hydrological variability
  - Eggs detected @ water temps from ≈ 18– 26 °C (to date); egg abundance increased markedly @ 25 °C despite absence of Δ gage height
  - DNA –confirmed eggs exclusively silver carp



Results

- **Logistic Regression Analysis on Presence/absence**
  - Presence/absence of bigheaded carp eggs at Wabash RM310 not related to change in gage height from 48-24 h prior to sampling, gage height at the time of sampling, or water temperature

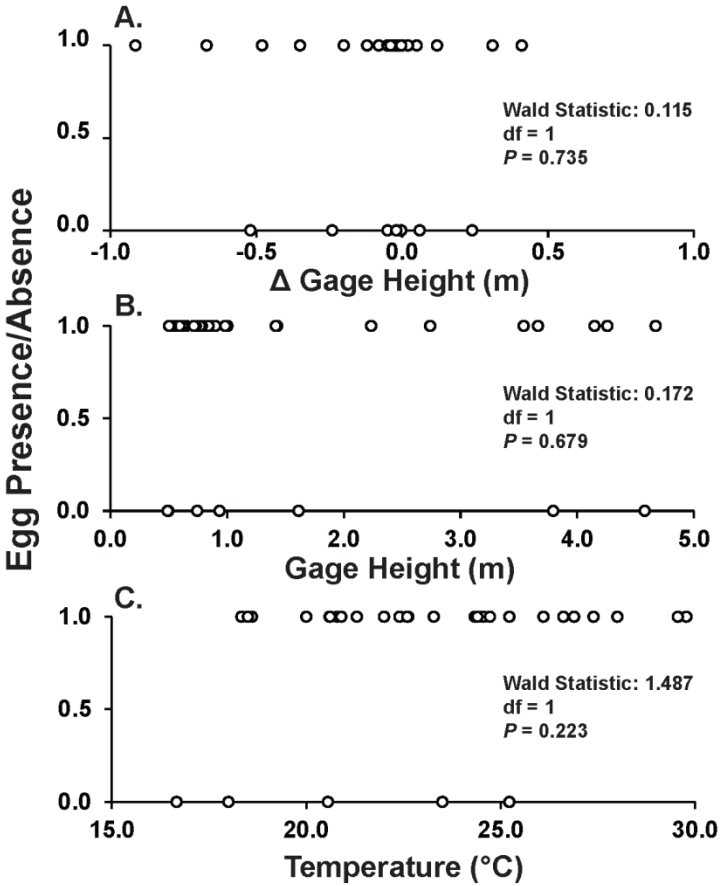


Fig. 3

Results

- **Spatial Extent of Spawning (2011)**
  - Conducted bongo net tows @ 5 additional sites upstream from Wabash RM310 (RM324, 340, 351, 370, & 390)
  - Limited to June due to water levels
  - Tows on 01-Jun & 02-Jun-11 yielded eggs @ 351, 370, & 390
  - Wabash River @ RM390 ≈30 m wide & drains 4,750 km^2

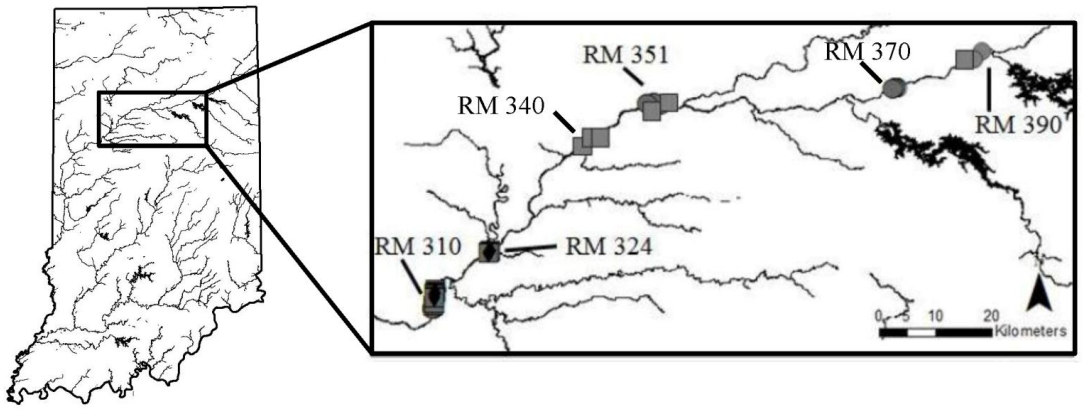
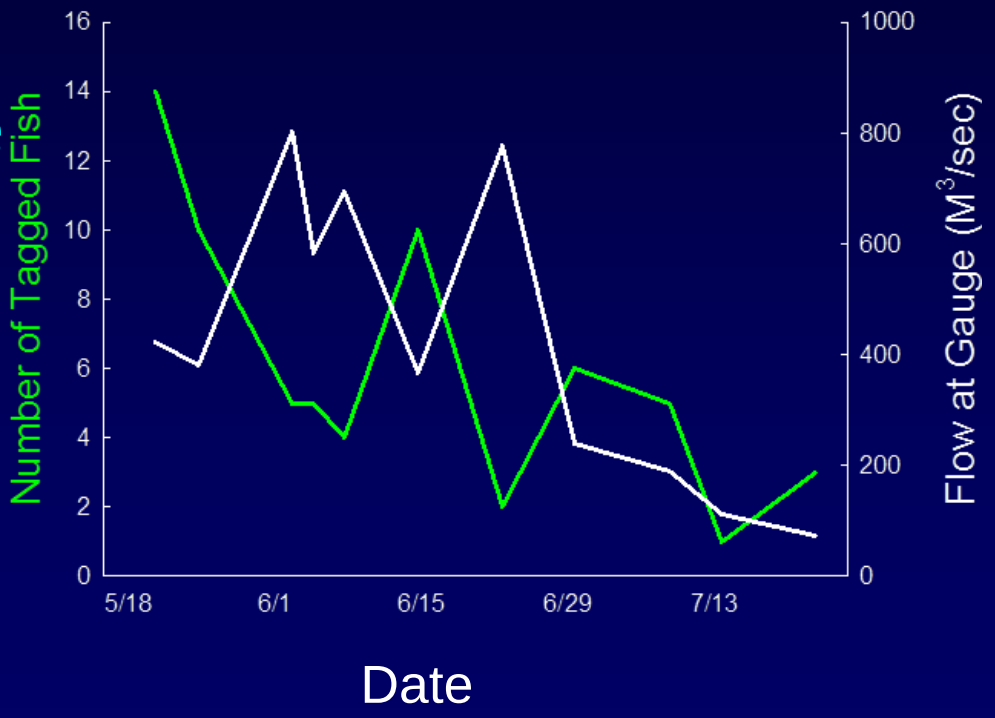


Fig. 1

Discussion

- **Rising/changing hydrograph not essential for successful spawning**
  - ➢ Confirms Deter et al. (2012) & Kocovsky et al. (2012) suggestions that a rising hydrograph can be sufficient, but not required for spawning
- **A wider range of rivers may be more susceptible to invasion/establish-ment than previously thought**



Discussion

- **North American bigheaded carps demonstrate protracted spawning**
  - Confirms suppositions by earlier authors based on multiple size classes within YOY & variably developed eggs within ovaries of females
  - There is no question that reproductive effort is reduced over protracted period, although recruitment related to protracted events unknown
  - Also unknown are spawning habits of individuals

Discussion

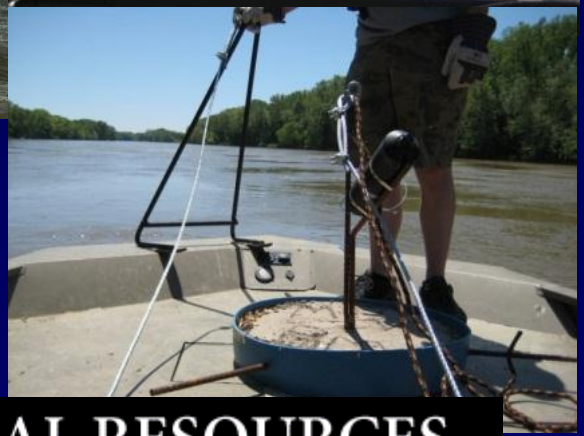
- **Detection of eggs @ Wabash RM390**
  - Considerably smaller channel width & watershed area than spawning rivers in native range
  - May confirm observations by Deter et al. (2012) even though they suspected cross contamination in their samples (e.g., Lamine River (6,860 km^2) and Bonne Femme Creek (464 km^2) in the Missouri River basin)
  - Smaller rivers may be susceptible to invasion/establishment than originally thought

Conclusions/Implications

- Biology/ecology of bigheaded carps in native ranges do not accurately reflect the adaptability/plasticity of these species in novel systems
- The plasticity of bigheaded carps makes them moving targets for management (plastic OR microevolution?)
- Efforts to predict invasion/establishment of these species can likely benefit from information based on existing North American populations
- Adaptive modeling & management will likely be key for achieving goals & objectives

Other AC Work in Goforth Lab

- **Movements of AC in Wabash River, IN**
  - Tag 300 AC using Vemco V16-4L acoustic tags
  - Monitor movements over ≈350 river miles
  - Evaluate where spawning taking place in Wabash



- **Collaboration w/Dr. Andrea Liceaga (Dept. of Food Science, Purdue)**

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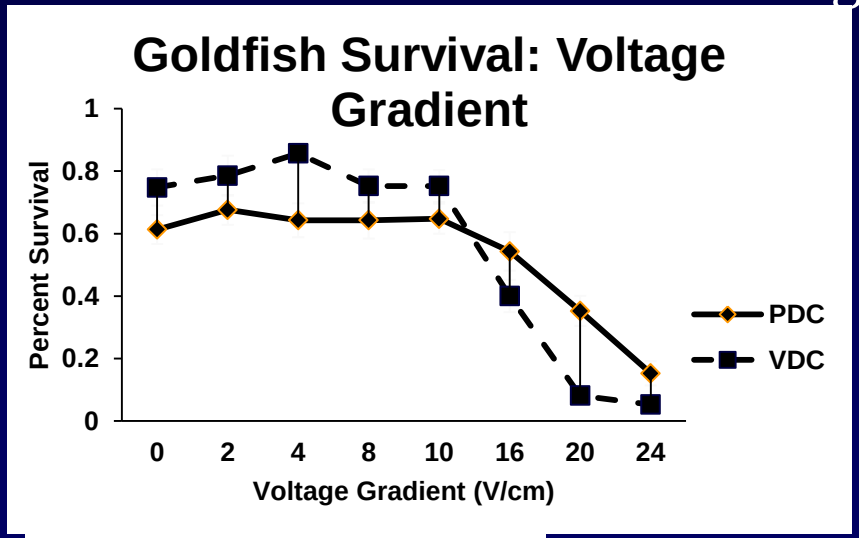
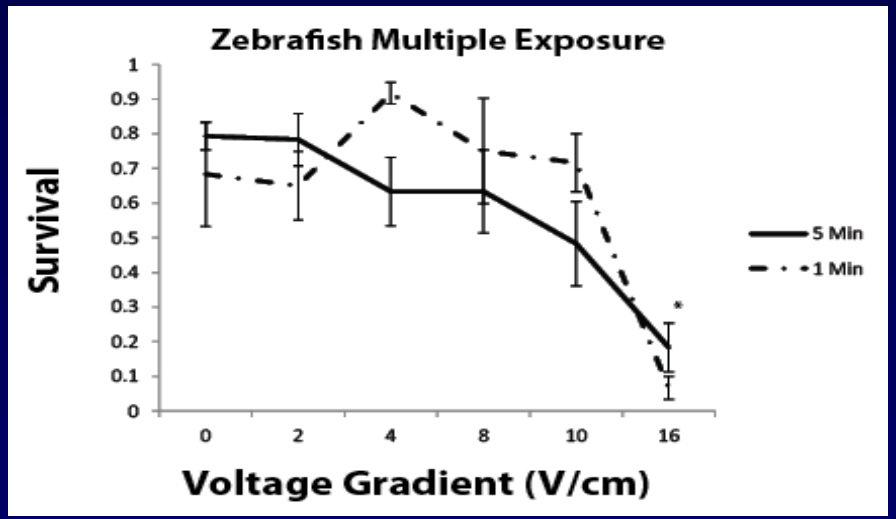
Control of Early Life History

- Voltage gradients ≥16 V/cm necessary to significantly impact mortality of all three model species
  - Stages during epiboly particularly sensitive
- Multiple exposures had no effect on survival of zebrafish embryos
  - Survival related to voltage gradient alone





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THANKS AGAIN!!!

Questions?

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