Lessons I have learned from AIS Research

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OUTLINE

• Examples of success
• Lessons learned
• A way forward
• Questions?
There has been notable Success
Control of the sea lamprey
(Petromyzon marinus)
Sea lamprey invasion in 1920s triggered collapse of the Great Lakes fisheries...
Early focus on barriers/ removal fails
Vern Applegate: Back to basics
Herculean search for a ‘larvicide’ (targeting)

- 6000+ compounds tested
- 3-trifluoromethyl-4-nitrophenol (TFM)
Deployment of TFM + allies

$1.5 million for treatments each year

$3 million assessment
Alternative control and IPM...
Success!? 

- 90%+ reduction in lamprey 
- Recovery of many fishes
Common carp in Tasmania, Australia

- Lake Sorell 5310 ha
- Lake Crescent 2305 ha
Population Dynamics

- Immigration
- Emigration
- Reproduction + Recruitment
- Mortality
- Ecological Damage
1. Block emigration/immigration
2. Remove adults en masse
2b. Target females (Judas fish)
3. Block recruitment (hot spots and pheromones)
Lake Crescent
Total of 7797 carp removed

Lake Sorell
Total of 2734 carp

Success
Overarching goal:
To develop biologically and economically sound plans for controlling carp in MN lakes over the long term...
Population Dynamics

Immigration

Emigration

Ecological Damage

Local Population

Reproduction + Recruitment

Mortality
Our Objectives

1. POPULATION SIZE: How many carp are there, and what level of damage do they do?

2. MOVEMENT: What is the typical rate of immigration/emigration, and how might it be controlled?

3. ADULT MORTALITY: What is a typical mortality rate and how might it be enhanced?

4. JUVENILE RECRUITMENT: What is a typical recruitment rate, what controls it, and how might it be enhanced?
1. How many carp?

Methods: Very large scale summer and winter mark-recapture studies
2. How/where do carp move (immigrate/emigrate)?

Methods: Radiotelemetry
Key results: Movement

1. Precise Spring movement

2. Summer spawning focused in wetlands

3. Winter aggregation

4. Little significant immigration

Bajer & Sorensen 2010. Biological Invasions
3. Mortality rates?

Methods: Survivorship of marked carp over time

Results: Low adult mortality (7%)

Bajer & Sorensen 2010. Biological Invasions
4. Recruitment?

Methods: Meticulous aging, trapping

*Bajer & Sorensen 2010. Biological Invasions*
Example Results: Recruitment history in Lake Susan

- Susan & Marsh winterkill
- Adjacent Rice Marsh winterkills
- Adjacent Rice Marsh winterkills
- Adjacent Rice Marsh winterkills

Number of carp

Bajer & Sorensen 2010 Biological Invasions
Why winter hypoxia?

Lakes that ‘winterkill’ have no predators to eat carp eggs and larvae in spring (similar to summer hypoxia in Australia?)
Implementing IPM

1. Suppress recruitment (shallow lakes that winterkill)
2. Remove adults (deeper connected refuges)
3. Monitor and adapt
1. Suppress recruitment by ‘rebalancing’ native fish communities by preventing hypoxia and managing in shallows.
2b. Remove adult carp in Lake Riley

- 94% population removed using Judas fish March 5, 2010

(´Bajer, Chizinski & Sorensen (2011). Fish Ecology and Management)
Success!
Lessons learned

1. Have faith (every species has a weakness)!
2. Every species and water-body is different
3. Know your enemy really well
   - Life history, physiology, population dynamics...*
   - Understand its habits in local waters*
4. Multidisciplinary studies to develop multiple tools*
5. Need to be systematic yet imaginative*
6. Need Time (more than money)
Invasive Species Research Center

To develop new, permanent solutions to aquatic invasive species
Center Objectives

1. To develop/ test new, reliable, useful monitoring programs
2. To develop new fish deterrence techniques
3. To develop new control techniques for local habitats
4. To develop new eradication techniques
5. To develop statistically sound strategies
6. To assist the DNR and others in the state with AIS
7. To work with, and enhance efforts of others.
Funding

- Riley Purgatory Bluff Creek Watershed District
- Legislative Citizens Commission for Minnesota Resources
- Ramsey Washington Metro Watershed District
- Invasive-Animals Cooperative Research Centre (Australia)
- National Science Foundation
- USGS
- GLFC
- Sea Grant
Questions?
Results: How Many

<table>
<thead>
<tr>
<th>Lake</th>
<th>Sampling sessions</th>
<th>Marked</th>
<th>Recaps</th>
<th>Population Estimate (95% CI)</th>
<th>Biomass kg/ha (lbs/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dutch</td>
<td>11</td>
<td>2088</td>
<td>122</td>
<td>13,312 (11,300 – 16,100)</td>
<td>402* (358)</td>
</tr>
<tr>
<td>Echo</td>
<td>13</td>
<td>929</td>
<td>72</td>
<td>8,167 (6,244-11,866)</td>
<td>471* (419)</td>
</tr>
<tr>
<td>Susan</td>
<td>11</td>
<td>361</td>
<td>15</td>
<td>4,459 (3,661-5,700)</td>
<td>338* (301)</td>
</tr>
</tbody>
</table>

* Value is four times too high! (Bajer et al. 2008 Hydrobiologia)
Confirming that native fish eat carp eggs

Methods: Electrofish Lake Keller during carp spawning and pump stomachs

Results:

- carp eggs disappeared within 3 days, prior to hatch
- 1000’s of eggs found in bluegill sunfish stomachs
- no juvenile carp found in Lake Keller in summer

_Silbernagel 2011_
Increase in water clarity in the spring

Record clarity!

Sources: MPCA, UofM
‘Ecosystem engineer’

‘an organism that modifies, creates or destroys habitat and directly or indirectly modulates the availability of resources to other species, causing physical state changes in biotic or abiotic materials.’

Jones et al. 1994 Oikos

Aquatic invasives that function in this manner will alter water chemistry and quality (WQ)
Invasive common carp, ecological engineering

Carp exclusion zone in Lake Wingra, WI

No Carp (or waves)

Carp
Aquatic Invasive Species (AIS): A big threat to MN aquatic habitat and water quality

WHY?
- Inter-connectiveness
- Trade
- Recreation

Great Lakes Basin (180 species)

Mississippi River (140 species)
- 18 plants
- 3 microorganisms
- 4 crustaceans
- 5 molluscks
- 15 fishes
- 1 mammals
1870s: Common carp (*Cyprinus carpio*)

- 1870s: Stocked by US Fish Commission
- Eurasian river fish
- Roots in bottom- liberating plants, sediments
- Destroys water quality and waterfowl habitat
- 1000s of lakes, 100,000s of acres destroyed
  - Control being developed (later)
1. Actively feeding in the bottom
   i. **Uprooting plants** (cover-zooplankton, fish)
   ii. Taking food from birds and fish
   iii. Releasing nutrients from sediments

2. Growing
   iv. Releasing nutrients

Nutrients (P, N)

Bluegreen Algae bloom

Loss of cover-zooplankton

Plants decline

Shading

Uprooting Plants

‘Biological pump’
2000: Asian carps (*Hypophthalmichthys sp.*)

- Introduced for aquaculture
- Chinese river fish
- Planktivorous, feed in open water
- Destroys habitat, human activities
- Moving up the Mississippi
- No practical means of measuring or controlling
Asian carp are Ecosystem Engineers

Situation (foodweb) specific:
Complex effects:
1. Decrease in plankton
   - Blooms tiny plankton (BG) *Microystsis sp.*
   - Increased water clarity
2. Increase in benthic nutrients
3. Decrease in O2
4. Decrease in condition of native fishes
Next: Snakehead (*Channa argus*)

- Introduced by citizens
- China
- Vicious predators
- Destroys game-fish populations
- No practical means of sampling or controlling
1980s Zebra mussel (*Dreissena polymorpha*)

- 1988: Ballast water in Great Lakes
- Caspian Sea
- Filter-feeders, disrupt foodwebs, increase water clarity
- Greatly alters waterways, clogs pipes
- Spreading rapidly in MN
- No practical means of measuring or controlling
Quaga mussel (*Dreissena rostriformis*)

- 1988: Ballast water in Great Lakes
- Caspian Sea
- Filter-feeders,
- Greatly alters foodwebs, clogs pipes
- No practical means of measuring or controlling
Veneroidea: Ecosystem engineers
Zebra mussels and Water Quality

Situation and foodweb specific Complex
- Increase in benthic N and P
- Decrease in benthic O2-summer
- Increase in toxins and heavy metals
- Increase in certain bluegreens Microcystis sp.
- Increased clarity

Strayer et al. 1999. Bioscience

1 micron particles filtered!
1870s: Curly Pondweed (*Potamogeton crispus*)

- 1870s: Stocked with carp
- Eurasia
- Heavy vegetative mats, releases nutrients with summer die-off
- Destroys waterfowl habitat
- Few control measures, not practical
Lessons from failed MN experiments

• We can expect a continuous stream of invaders
  This is a war (not a battle—no time to lose)

• These species are going to do a lot of damage, the damage is complex and broad (ecosystem-wide), and includes water quality
  The stakes are very high

• These species are fundamentally different from native species
  Conventional approaches to control them do NOT work

• Aquatic environments are especially difficult to work in
  You cannot even see what you are working with!
Overarching goal:
To develop biologically and economically sound plans for controlling carp in MN lakes over the long term...
The way forward...

1. Prevent introduction

2. Delay invasion

3a. Reduce numbers
3b. Control
   - poisons
   - genetic engineering
   - disease
   - ecosystem management

4. Eradicate
1. To develop new, reliable, and useful molecular tests and monitoring programs

- Develop superior tests for species of immediate local concern
  - Common carp, silver carp, zebra mussel
  - eDNA, pheromones, other
- Quickly validate these tests
- Interpret these tests
2. To develop new deterrence techniques

- New, affordable barrier systems optimized for local species
  - Common carp, silver carp
  - Bubble curtains, light, velocity w and w/o barrier
  - large rivers (ex. Minnesota River)
  - tributaries (ex. creeks leading into Minnesota)

- Evaluate efficiency of these systems (SAFL)
Experimental Air Barrier (Maplewood)
3. To develop new control techniques

3a. Zebra mussel physiology, biology and control

3b. Invasive fish ecology and control
3c. Invasive fish behavior and physiology

3d. Invasive plants
3a. Zebra mussel physiology, biology and control

- Search for Achilles heel
- New faculty expertise
- Cutting-edge advice and help for DNR
3b. Invasive fish ecology and control

- Integrated pest management:
- Search for natural controls for Asian carp
- Further development/application of common carp strategy
- New faculty expertise
- Expert advise and help for DNR, watershed districts, lake associations
3c. Invasive fish behavior, physiology and control

- Integrated pest management:
- Search for behavioral attracts and repellents for Asian and common carp
- Judas fish and robotic tracking
- Further development and application of common carp
- Cutting-edge advise and help for DNR
3d. Invasive plant control

- Integrated Pest Management
- Search for predators and control
- Further development and application of IPM control plants
- Cutting-edge advise and help for DNR

Eurasian Watermilfoil

Milfoil Weevil
(Euhrychiopsis lecontei)
4. Develop eradication techniques

- Search for species-specific viruses via international networks
- New faculty and facility (Vet School)
- Protection from exotic viruses
- Expert advise and help for DNR
5. Perfect sampling and treatment protocols

- Perfect application protocols through statistics
- Expert advice and help for DNR
5. Information and technology transfer

• New position and expertise
• Transfer and testing of new expertise
• Expert advise and help for watershed districts, lakeshore associations, DNR, etc.
Budget

Startup

(new labs, equipment and refurbishing)

Operations ($1,990,000/yr x 8)

1. Monitoring $294,000
2. Deterrence $258,000
3. Control $940,000
4. Eradication $290,000
5. Statistical guidance $77,000
6. Extension $129,000
Carp vs Submerged Plants

\[ y = 67.309e^{-0.007x} \]

\[ R^2 = 0.8242 \]
Options for Sustainable Control

1. Do nothing (and hope it goes away)
2. Commercialize removal
3. Poison
4. Augment native predators
5. Large scale, non-targeted removal

6. Targeted removal
7. Spawning sabotage (eggs or sterile male)
8. Targeted biocides
9. Augment native pathogens

10. Introduce exotic parasites (classical bio-control)
11. Introduce exotic predator
12. Genetic manipulation of pest
13. Introduce exotic diseases
14. Introduce genetically modified predator
15. Introduce genetically engineered diseases
Invasive Animals Cooperative Research Centre (IA CRC)

Organisational Structure

- Partnership of around 40 Australian and international natural resource management agencies, universities, research organisations and industry stakeholders.

- Core funding from Australian Federal Government with cash and in-kind contributions from partners

- Exploring genetic and pathogen control of aquatic invasives with a 10 year horizon and $40,000,000
1900’s: Eurasian Milfoil (*Myriophyllum spicatum*)

- Aquarium trade
- Europe
- Destroys shallow ecosystems/habitat
- Can be controlled with poison/cutting

**BUT $100,000/lake per year to control**
Water clarity 2011

Season and lake effects:

- Springtime clarity was good to very good (Riley and Susan) in all lakes except Staring
- Summertime clarity was poor in all lakes except Ann
1990s: *Pterois volitans*

1990s appeared in the Caribbean

Indo-Pacific teleost fish

Voracious and poisonous predators

Aquarium fish?

Spreading rapidly:
  Bahamas to North Carolina

Fishing Derbies
Invasive Species

an alien [nonnative / exotic / introduced] species whose introduction does or is likely to cause economic or environmental harm or harm to human health

(Executive Order 13112)