Assessing a restoration project for lake sturgeon spawning habitat: use of habitat suitability and 3D numerical modeling

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**Presentation outline**

1. Lake sturgeon spawning niche
2. Evaluation of Ouareau River spawning site using 3D numerical modeling
3. Lessons learned
Why are lake sturgeon important?

Lake sturgeon conservation status

Data retrieved from:
COSEWIC (2006)
NatureServe (2012)
Describing the lake sturgeon spawning niche

Project Goal:
- First range wide assessment of lake sturgeon spawning habitat
- 4 key spawning habitat characteristics indicated in the literature:
  - Flow velocity
  - Temperature
  - Substrate
  - Depth

Why?
- Spawning habitat is a limiting factor to population growth

Lake sturgeon spawning on the Wolf River, Wisconsin (Dean Barth 2016)
Describing the lake sturgeon spawning niche

- Lack of published data
- 48 sites used in analyses
- Method to summarize data: Habitat suitability Index

Lake sturgeon historic range with major watersheds and sites used in analyses
What is a habitat suitability index?

• Method to determine suitable habitat for a life-stage of a species (Bovee 1982)
• 3 Types
  • Type I – Expert opinion
  • Type II – Utilization functions
  • Type III – Preference indices
Constructing Habitat Suitability Index – Velocity

Data point = measure of central tendency; error bars = range; red dashed line = mean; grey fill indicates mean range
Constructing Habitat Suitability Index – Depth-averaged velocity

Data point = measure of central tendency; error bars = range; red dashed line = mean; grey fill indicates mean range

Frequency distribution using bin size of 0.1; dashed line = type II utilization curve; grey fill indicates mean range; black solid line indicates threshold for excellent quality habitat
Estimate of peak suitability used in Quebec restorations

Dashed line = type II utilization curve; grey fill indicates mean range; black solid line indicates threshold for suitable habitat
Results for Habitat Suitability Index

Depth HSI

Substrate HSI

Temperature HSI
Interesting findings

• No significant differences in: published/unpublished data; river magnitude (except depth) or major watershed.
• Lake sturgeon tend to spawn at lower temperatures as latitude increases.
• The majority of spawning sites (55%) are found within 1 km of impediments to upstream migration, and an additional 15% within 10 km.
Using numerical modeling to analyze the availability of lake sturgeon spawning habitat on the Ouareau River (Quebec)

Project goals

• Use a 3D numerical model to simulate hydraulic conditions within spawning site

• Retroactively simulate pre-restoration conditions

• Compute the suitability model using a fuzzy-logic overlay method
Ouareau River spawning site

- Bankfull width: 94 m
- Bankfull depth: 4.4 m
- Bankfull discharge = 151 m³/s
- Surficial geology: fine textured glaciomarine deposits (Champlain sea quick clays)
Ouareau River Restoration

- Landslide in 1990 covered 2/3 of the traditional spawning bed with clay and silt
- Restoration project undertaken in ‘04 and ‘07
  - Clean substrate from traditional site (‘04)
  - Installation of 3 artificial spawning beds (‘07)
  - Installation of 2 weirs (‘07)
Numerical Modeling

Field Data
- Bathymetry - retrieved with DGPS, precise to ± 2 cm.
- Substrate – Wolman pebble count at 17 zones
- Flow stage (pressure transducer)

Building the Model
- Bathymetric grid created in Delft 3D
- Compartmentalized into 17 zones with specific roughness coefficient’s (Manning’s n)
Why use a 3D Model?

- At weirs vertical velocity has a profound influence.
- Because spawning sites are located immediately downstream and upstream of weirs, 3D model was selected.

**Downsides of using 3D models?**

- Require more computational capacity than 1D or 2D models.
- Generally more expensive than 1D or 2D models, which can be obtained for free.
Univariate results: Velocity

Velocity is too high at artificial spawning sites
Results: Depth-averaged velocity

• Mean difference = 0.05 m·s⁻¹
Fuzzy habitat suitability model

Building the model

1. Raw data converted to suitability using criteria established through meta-analysis

2. Multivariate suitability index created using weighted linear combination

3. Weights determined from literature review, and sensitivity analysis.

• Final weight:
  • Velocity = 0.4, Substrate = 0.5, Depth = 0.1
Hypothesis 1 - Fuzzy habitat suitability model

Next step = Defuzzification

• Apply a threshold suitability value determined from the weighted linear combination of thresholds determined in Chapter 1.
• 0.77 = threshold suitability index score

Total suitability results

55m³·s⁻¹
Model results: Total suitability

- Mean suitability always greater in natural sites
- Most suitable area found outside known beds
Shortcomings of suitability models

• Does not address connectivity of a given cell to other cells
• Does not take into account influence of habitat beyond the cell in question, such as resting pools.

Potential Alternatives:
  • Larval/Egg surveys
  • Telemetry

Assessment of Lake Sturgeon (*Acipenser fulvescens*) Spawning Efforts in the Lower St. Clair River, Michigan
S. Jarrine Nicholas, Gregory Kennedy, Eric Crawford, Jeffrey Allen, John French III, Glen Black

Biology of lake sturgeon (*Acipenser fulvescens*) spawning below a dam on the Richelieu River, Quebec: behaviour, egg deposition, and endocrinology
J.D. Thiem, D. Hatin, P. Dumont, G. Van Der Kraak, and S.J. Cooke

The migratory and reproductive response of spawning lake sturgeon to controlled flows over Kakabeka Falls on the Kaministiquia River, 2011

Timing and Location of Spawning Based on Larval Capture and Ultrasonic Telemetry of Atlantic Sturgeon in the Saint John River, New Brunswick
Andrew D. Taylor & Matthew K. Litvak
Lessons Learned

1. Hindsight is 20/20
   • Lack of recruitment to spawning area at the Ouareau River may not be the result of a lack of available habitat.

2. Lessons for the future
   • Models can help predict availability of spawning habitat within a site, albeit with some constraints.
   • Emerging technologies create new opportunities to determine the necessity for, predict the outcomes of and evaluate the effect of restoration projects.
Thanks very much for listening!

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References


References


Hypothetical situation showing advantages of Fuzzy Suitability

• Assume equal weight of factors
• Suitable threshold > 0.8 index score
• Habitat suitability index > 0.8:
  • for Velocity = 0.6 – 1.1
  • for Depth = 0.8 – 1.5
  • Substrate = Pebble, Cobble

Conditions at this cell
Velocity = 0.5 (Boolean score 0, Fuzzy score 0.7)
Depth = 1.1 (Boolean score 1, Fuzzy score 0.9)
Substrate = Cobble (Boolean and Fuzzy Score 1)

Boolean Results
Velocity = 0
Depth = 1
Substrate = 1
Total suitability = 2/3 = 0.66
Cell is unsuitable

Fuzzy Results
Velocity = 0.7
Depth = 0.9
Substrate = 1
Total suitability at this cell = 2.6/3 = 0.9
Cell is suitable