Jun 20th, 4:45 PM - 5:00 PM

Pushing and Pulling II: Temporal and Spatial Distributions of Out-migrating Juvenile Blueback Herring in the Presence of an Ultrasonic Fish Guidance System at a Hydroelectric Project

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BACKGROUND
Stock Assessment & Fishery Management Plan (FMP)

- Blueback Herring (*Alosa aestivalis*) is an important anadromous forage fish species
  - Migrate upstream into freshwater as adults in spring to spawn
  - Migrate downstream out to sea as juveniles
- Populations are depleted from historic levels (ASMFC 2012)
- The FMP identifies hydroelectric dams as contributors to their decline
  - Barriers to migration
  - Turbine mortality
- Management goal & regulatory requirement for hydroelectric dams to reduce mortality of herring

CRESCENT HYDROELECTRIC PROJECT

- Operated by New York Power Authority (NYPA)
- 100-MW, 8-unit facility
- Mohawk River near Waterford, NY
- 8 km upstream of confluence with Hudson River
- Upstream fish migration through Erie Canal System

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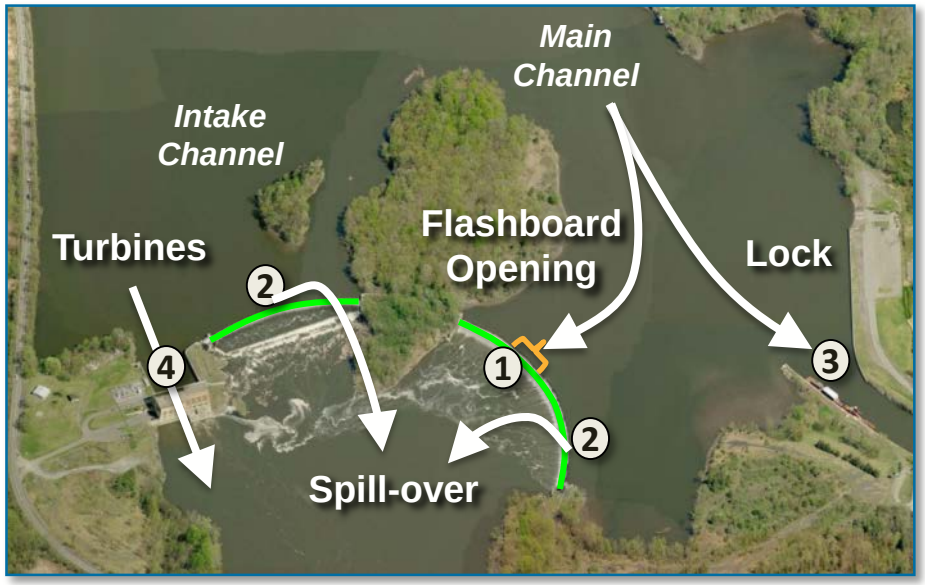
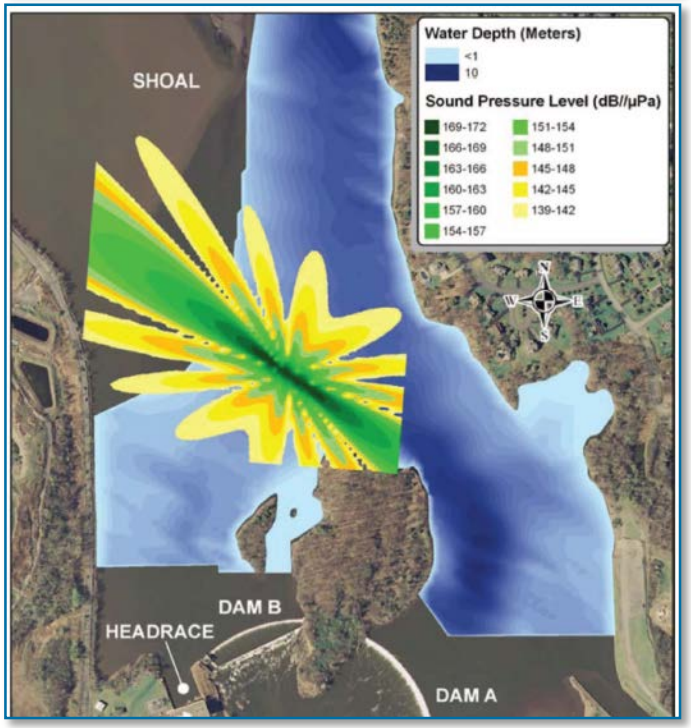
FISH DOWNSTREAM MIGRATION



- Four Downstream Passage Routes
  1. Flashboard opening (24.3 m x 0.3 m)
  2. Over the dam during high-flow
  3. Waterford Lock of Erie Canal System
  4. Hydroelectric turbines
- Higher flow through turbine intake channel, more attractive to out-migrating herring
- Short-term turbine passage survival
  - 96% for Kaplan turbines (Mathur et al. 1996)
  - 70% for Francis turbines (Cada 2001)
- NYPA proposed to reduce numbers passing through turbines using an ultrasonic fish deterrent system

ULTRASONIC FISH DETERRENT SYSTEM

Ultra Electronics Ocean Systems



- Herring within subfamily Alosinae can detect ultrasound (>20 kHz)
  (Mann et al. 1997; Popper et al. 2004)
- Alosine herring avoid loud ultrasound
  (Nestler et al. 1992; Dunning & Ross 2010)
- NYPA installed an ultrasonic deterrent system
  - 8 integrated projectors
  - 122-128 kHz
  - 13° x 30° beam width
  - SL=196 dB re 1 µPa at 1 m
  - 0.5-second pulses every second

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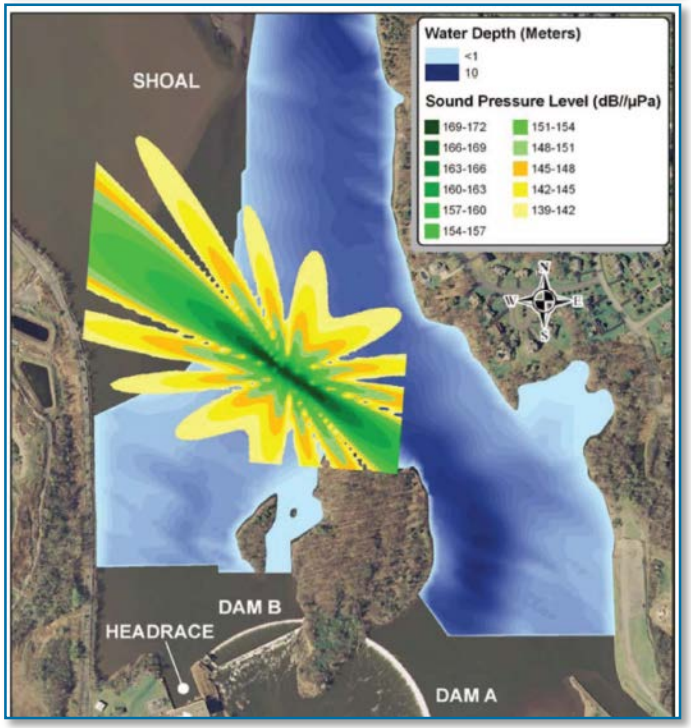
2008 EVALUATION OF THE ULTRASOUND
(Dunning & Gurshin 2012)



- 31.3% passed downriver in the main channel
- Significantly higher than the 11.5% expected if entrainment was proportional to river flow
- If valid, results indicate the ultrasound was partially effective at diverting fish
- Orientation relative to flow resulted in short encounter time - pass through before responding?
- A higher deterrence rate may be achieved if the projectors were re-directed upriver so fish encounter an increasing sound gradient.

For more details:

Dunning, D.J. and C.W.D. Gurshin. 2012. Downriver passage of juvenile blueback herring near an ultrasonic field in the Mohawk River. North American Journal of Fisheries Management. 32: 365-38

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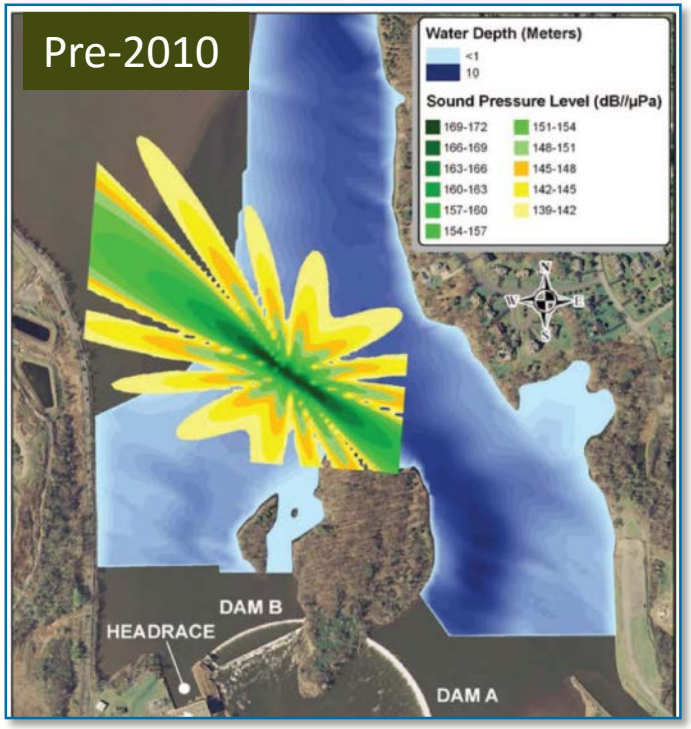
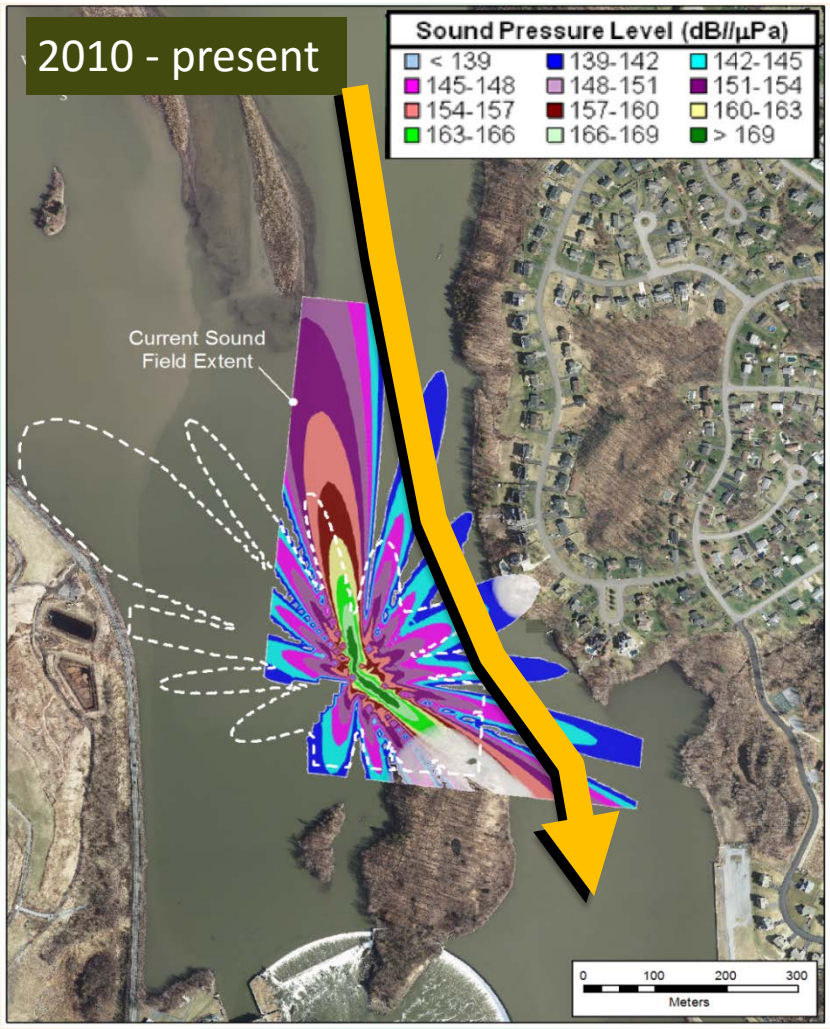
ULTRASONIC FISH DETERRENT SYSTEM
Adjusted orientation

- In 2010, NYPA re-aimed the western projectors 45° to point upriver
- Increasing sound gradient along western shore for downstream migrating fish





2012 OBJECTIVES
Weight-of-evidence Study Approach

1. Evaluate the effectiveness of the re-directed ultrasonic projectors for guiding out-migrating juvenile Blueback Herring away from the turbines to the main channel for downstream passage

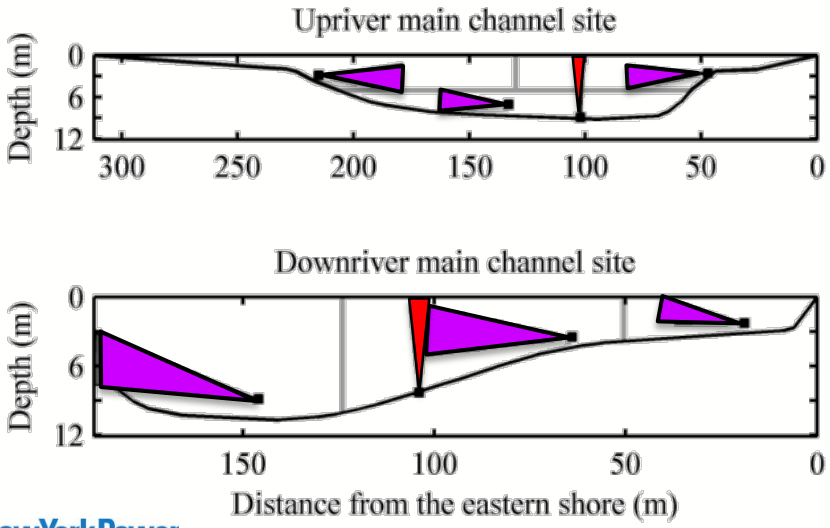
- Continuous stationary horizontal echosounding of fish passage
- Null hypothesis 1: # JBH downriver = # JBH upriver × 0.313 (Dunning & Gurshin 2012)
- Null hypothesis 2: # JBH downriver = # JBH upriver × (Flow downriver/Flow upriver)

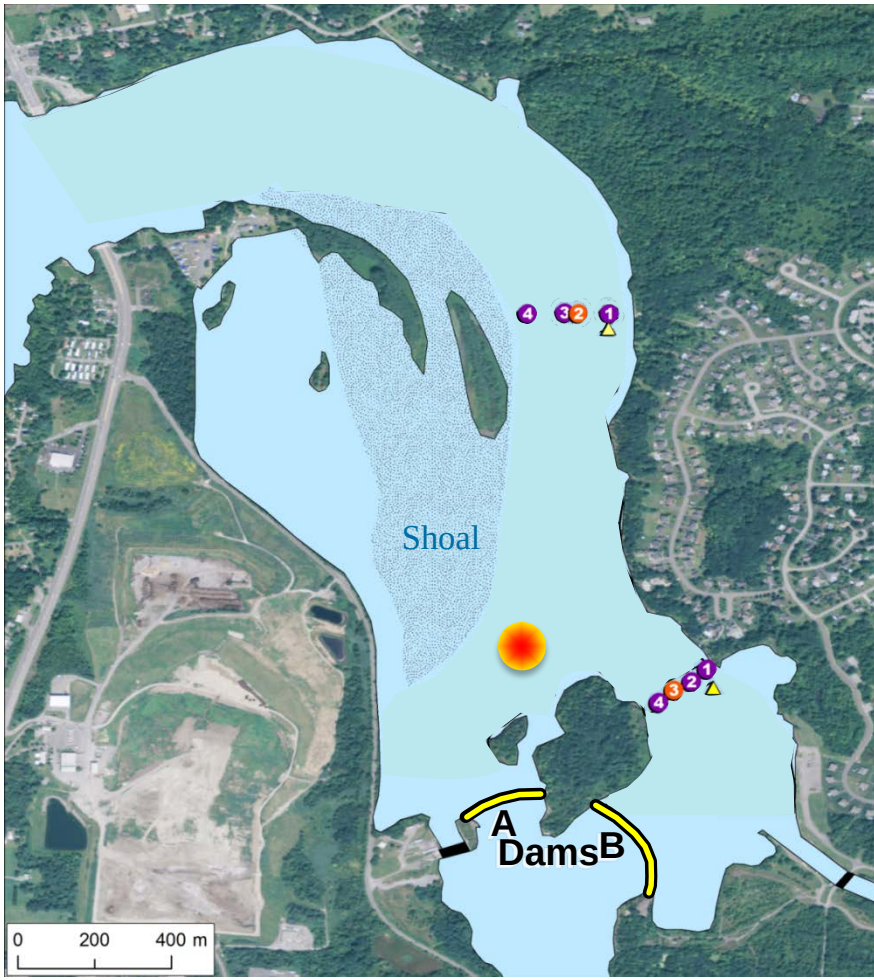
2. Determine whether the majority of juvenile Blueback Herring migrated down the main channel in the presence of ultrasound

- Multiple acoustic and net sampling methods were used in a complementary fashion to measure herring abundance at different scales in time and space

CONTINUOUS STATIONARY ECHOSOUNDING
Compare Abundance Upstream and Downstream of Ultrasound

- Upriver & downriver main channel sites
- 420 kHz echosounders (HTI Model 243)
  - 3 horizontal + 1 vertical transducer per site
- Sampled sequentially for 2.5 minutes at 5 or 10 pings/s
- Continuously 24/7 for 8 Sep through 26 Oct 2012
- Sampled 15-20% of channel cross section





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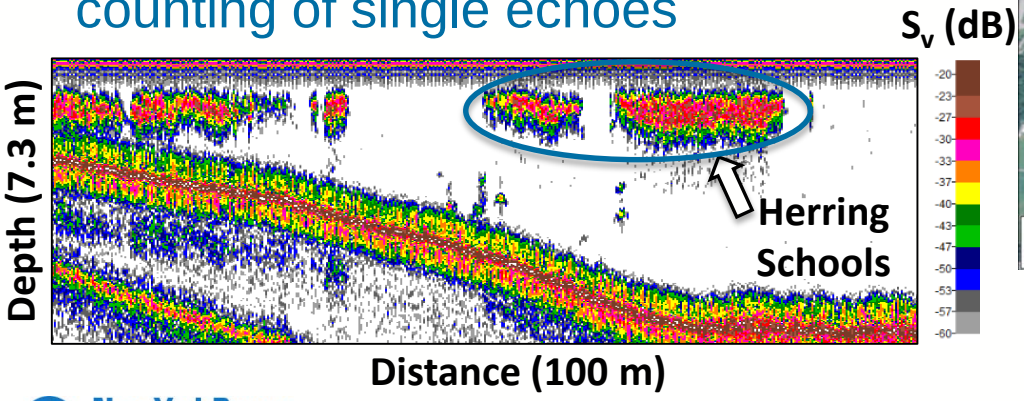
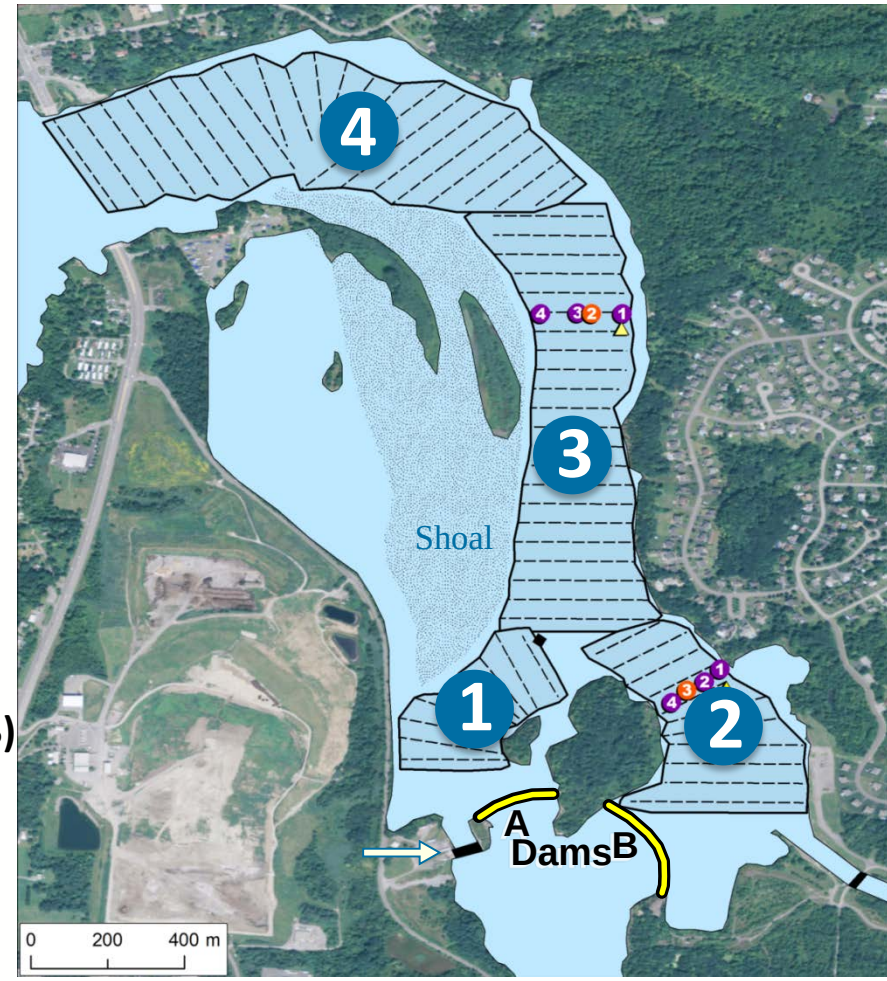
MOBILE ECHOSOUNDER SURVEYS DURING DAY

Map Distributions & Compare Herring Abundance Among Regions

- 420 kHz split-beam echosounder (HTI Model 244)
- 7 systematic surveys along transects in 4 regions
  1. **Intake Channel**
  2. **Main Channel "Downriver" of Ultrasonic Projectors**
  3. **Main Channel "Upriver" of Ultrasonic Projectors**
  4. **"Upriver Extension" of Main Channel**
- Fish density estimated by echo integration of "school" echoes & counting of single echoes





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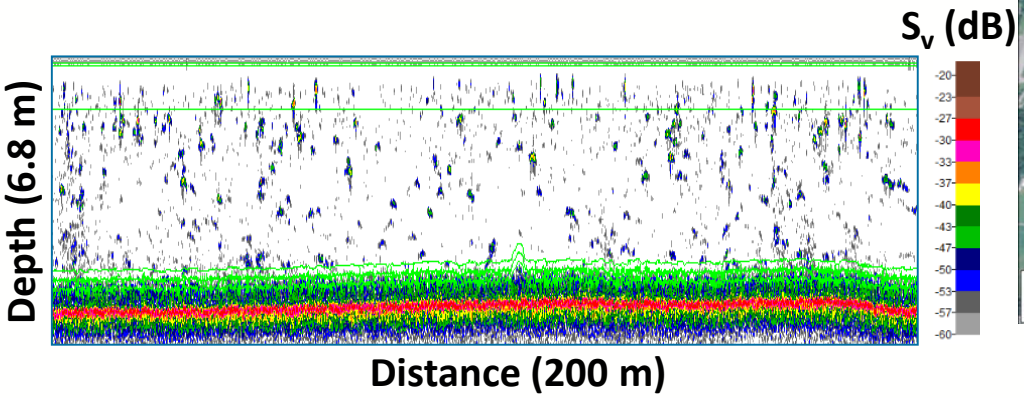
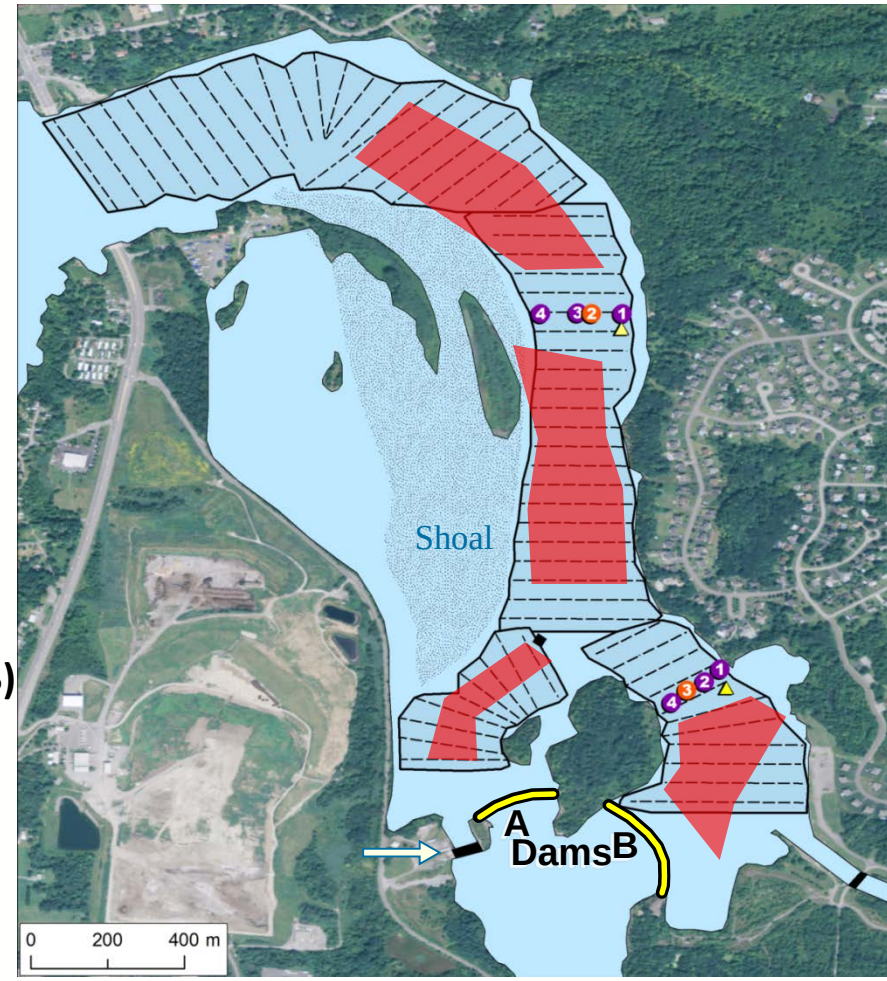
STRATIFIED-RANDOM TRAWL SURVEYS AT NIGHT

Directly Verify Species & Size Composition & Compare Catch

- 11 nights, 9 Sep-25 Oct 2012
- 3 random 200 m tows per region
- Fixed frame, 117 cm W x 114 cm H
- Sampled approx. Surf to 1 m depth
- 13 mm stretch mesh
- 4 mm cod end
- Simultaneously sampled with 420 kHz split-beam echosounder (HTI Model 244) sonar





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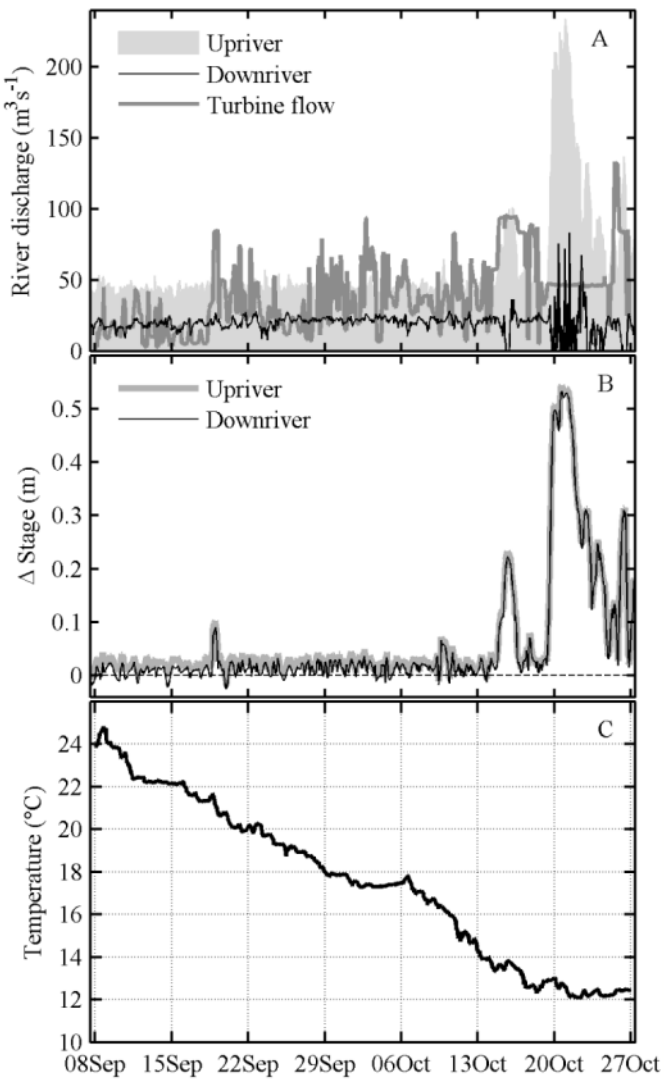
RIVER DISCHARGE MEASUREMENTS
Continuous Monitoring — Acoustic Doppler Current Profiling (ADCP)



- 500 kHz Sontek Argonaut-SL ADCP
- Continuously averaged water current, direction, & stage every 2 to 2.5 min
- Estimate river flow (discharge) across the river near each array
- Created velocity index from mobile ADCP transects across entire cross-section

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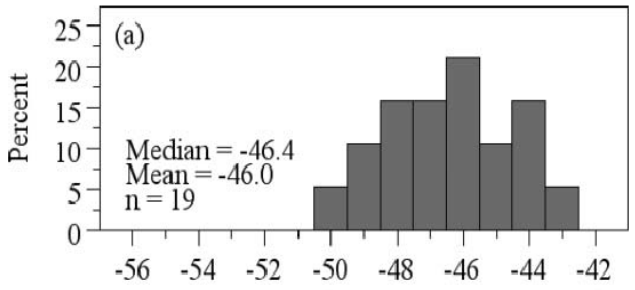
INDIVIDUAL TARGET STRENGTH (TS)
Verification of JBH in acoustic data

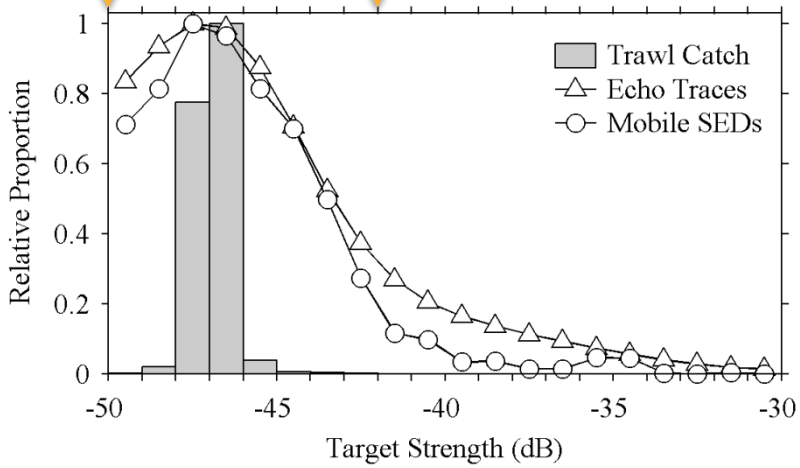
2008 Study*

- Target strength of tethered juvenile Blueback Herring



2012 Study

- Trawl catch lengths converted to TS
- Mean TS of echo traces from fixed-location transducers (all sites)
- TS of all single echo detections (SEDs) for Day and Night Mobile Surveys



**Gurshin, C. W. D. 2012. Target strength measurements of juvenile blueback herring from the Mohawk River, New York. North American Journal of Fisheries Management 32:381-386.*

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PRIMARY METRICS: FISH ACCOUNTING 101

Index for Number of Downstream Juv. Blueback Herring Migrants

Net Passage (# JBH) = # Passing downstream - # Passing upstream

FISH MIGRATION DIEL PERIODICITY
Fixed location hydroacoustics

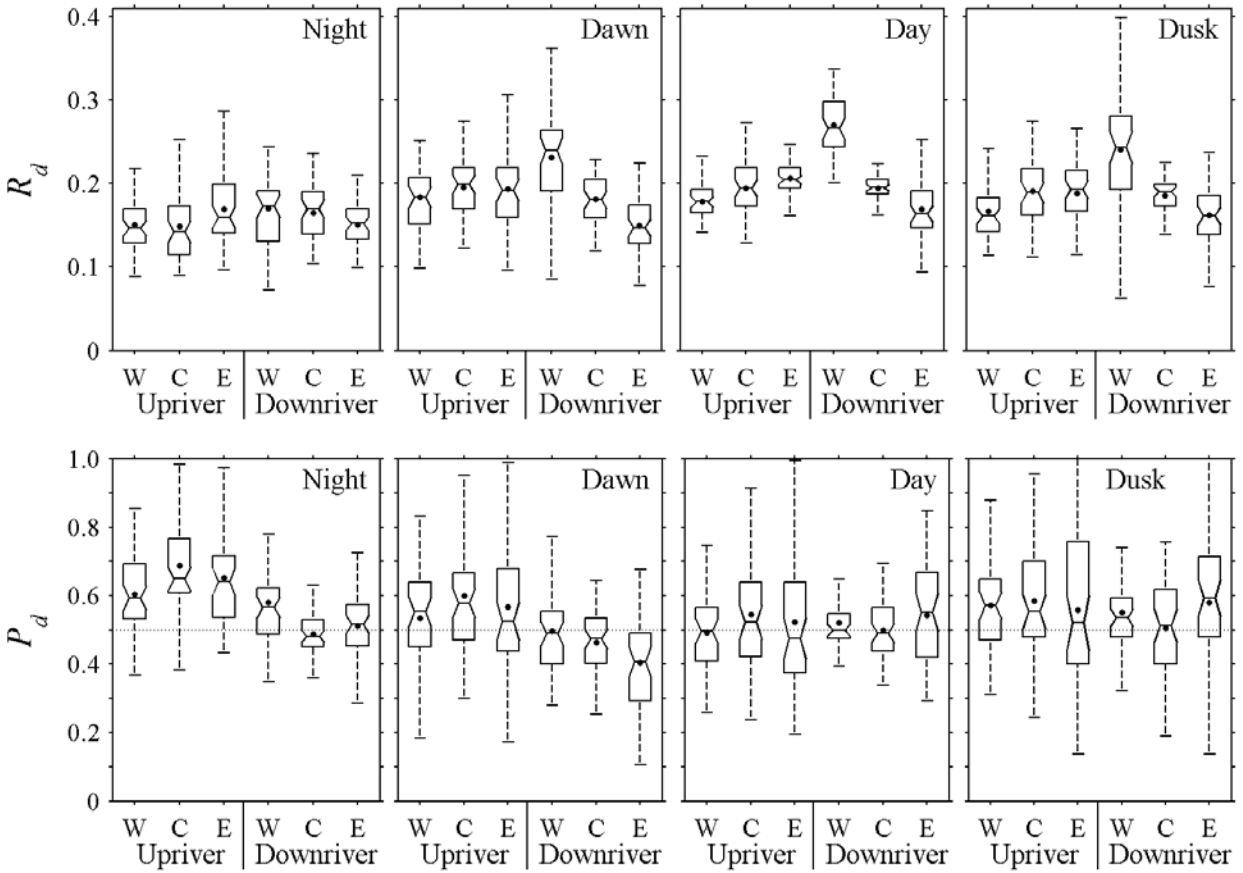
Net Passage (# JBH) = # Passing downstream - # Passing upstream

Split-beam acoustics provides 3-D position for each echo within beam.

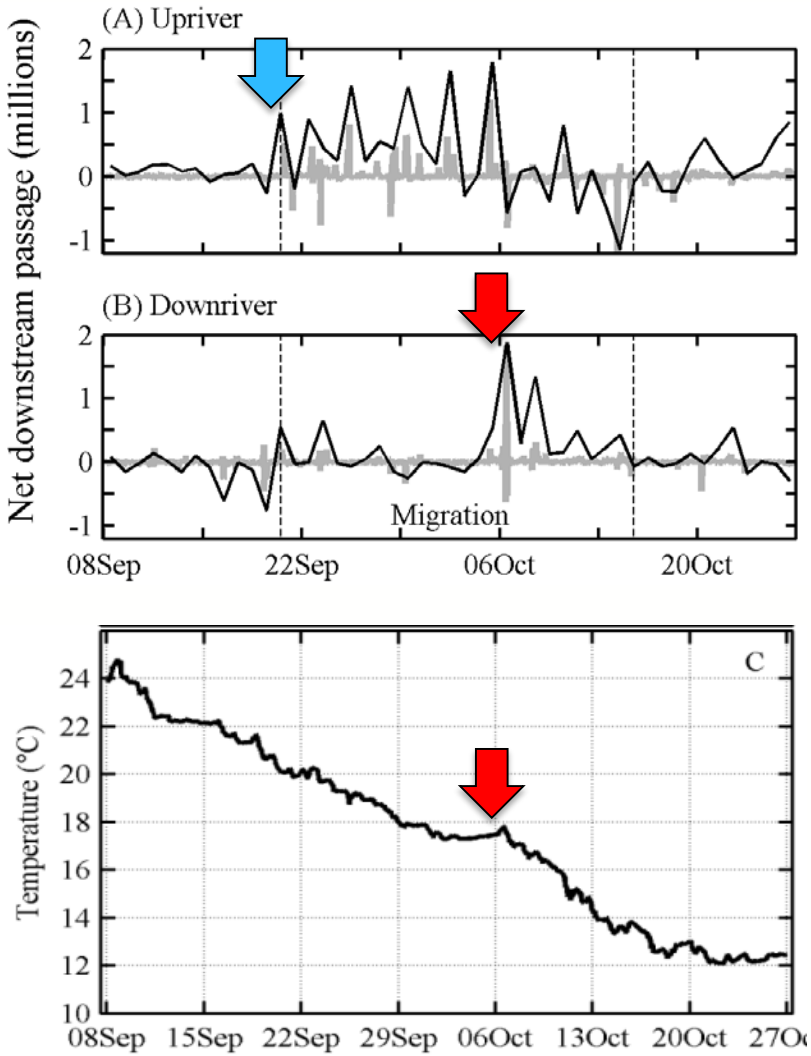
Tracking algorithm to identify attributes of individual fish.

R_d = net rate of movement of tracked downstream migrants (m s^{-1})

P_d = proportion of tracked migrants classified as JBH moving downstream

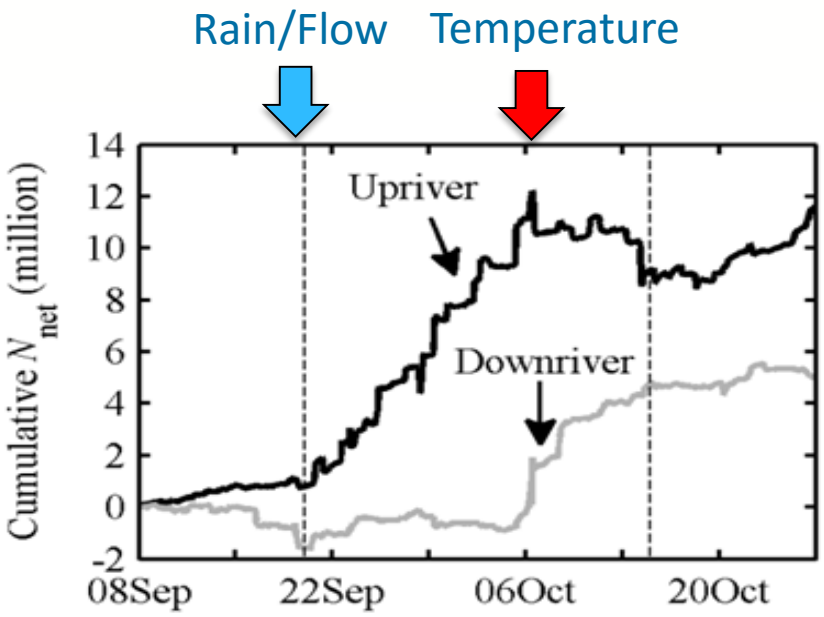


DOWNSTREAM FISH PASSAGE ESTIMATE
Fixed location hydroacoustics



- 8.2 cm rain 18-19 Sep = high flows, start of downstream migration
- Not translated to net downstream passage at downriver site; “milling” behavior
- Early Oct – increase in water temp followed by drop appeared to be the cue to head out to sea

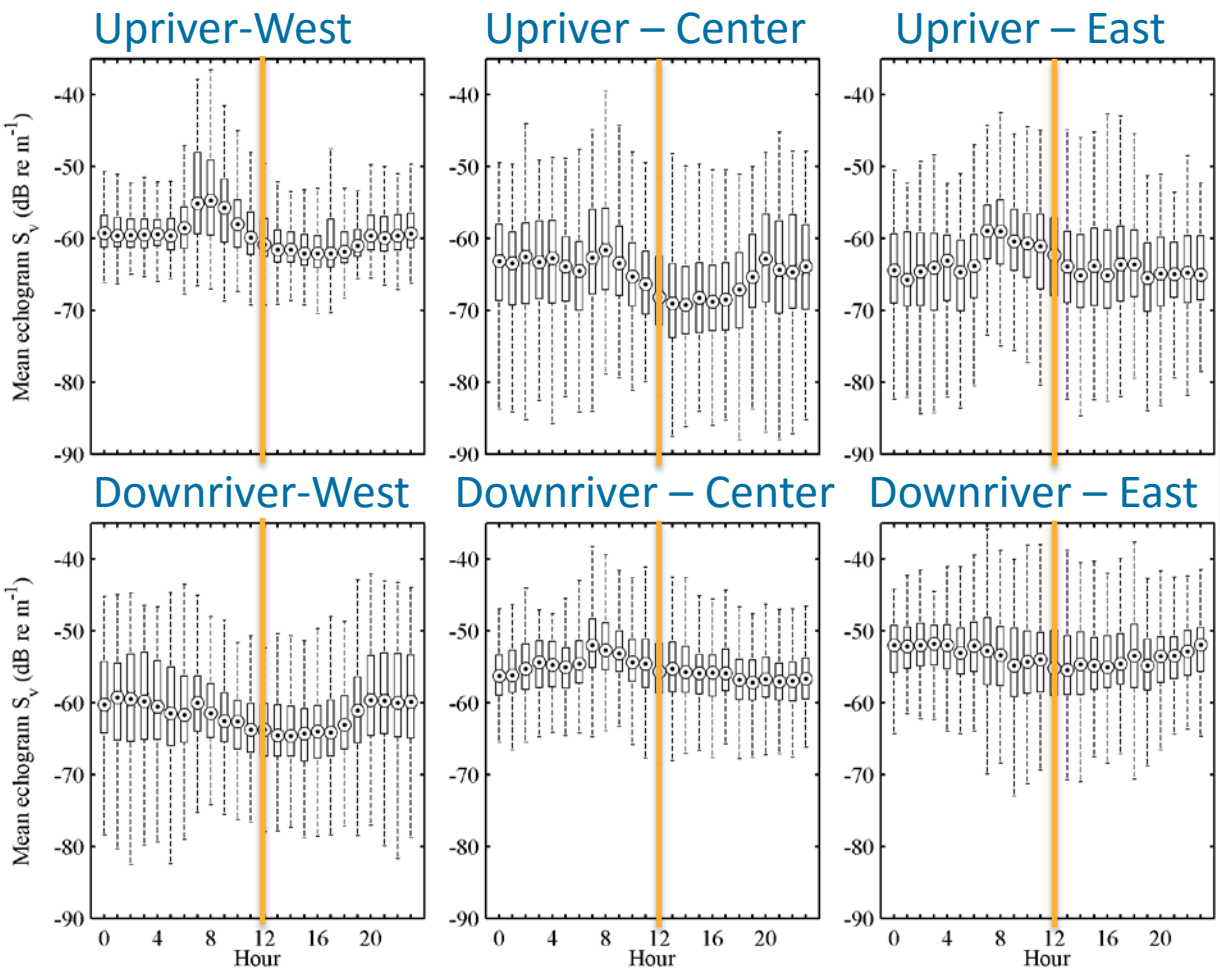
DOWNSTREAM FISH PASSAGE ESTIMATE
Fixed location hydroacoustics

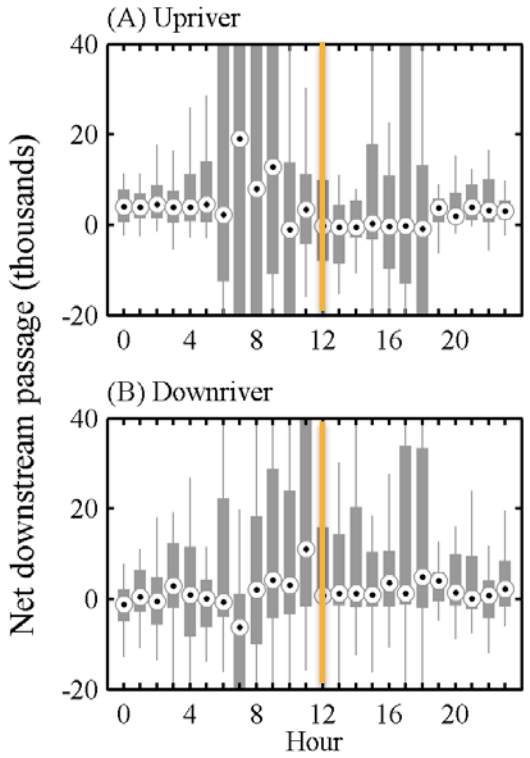


- 77% bypassed the turbines during active migration period
- Significantly higher than the 31% in 2008 for original barrier design ($\chi^2 = 7{,}905.8$; $P < 0.001$)
- Significantly higher than expected assuming entrainment is proportional to flow (49.1%) ($\chi^2 = 2{,}499.8$; $P < 0.001$)

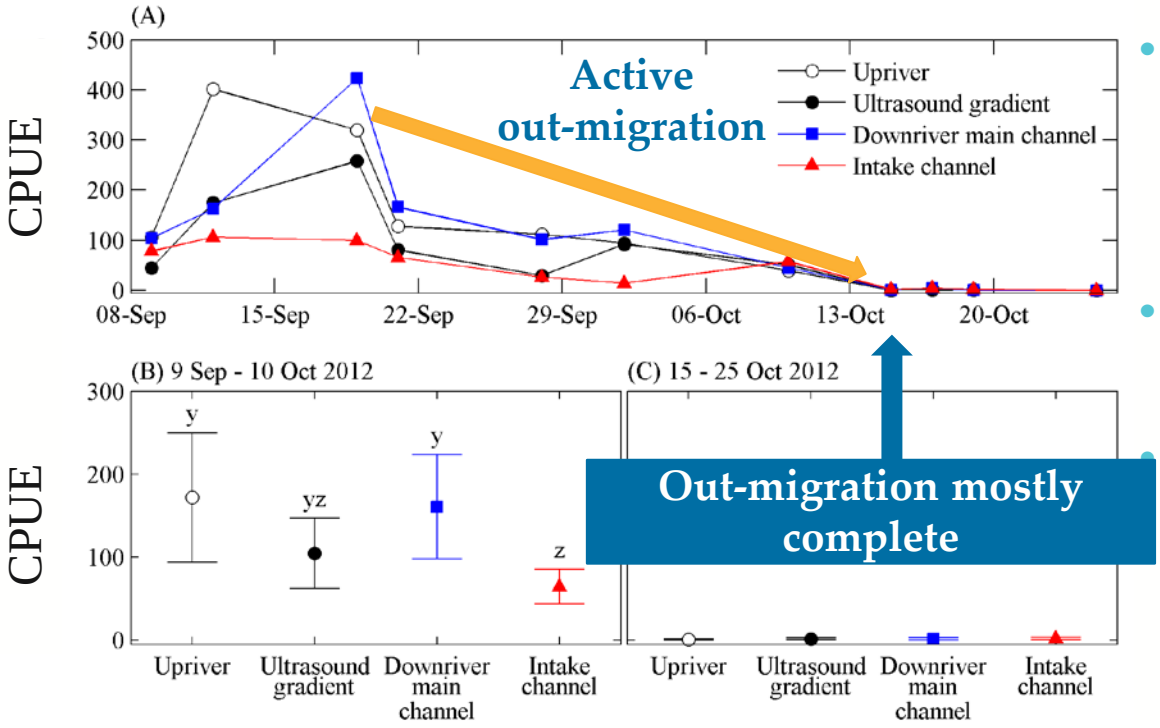
FISH MIGRATION DIEL PERIODICITY
Fixed location hydroacoustics

Out-migration period 20 Sep – 14 Oct





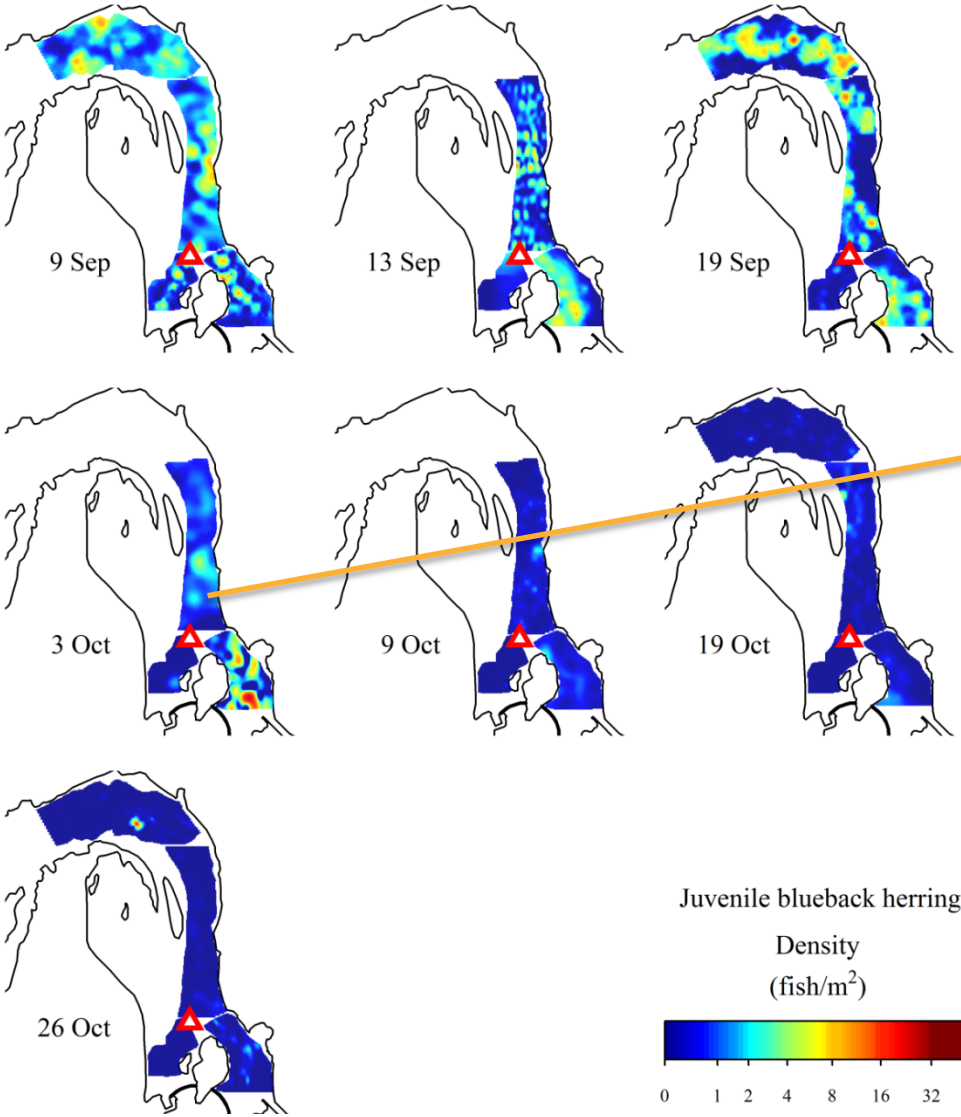
TRAWL CATCH PER UNIT EFFORT
(CPUE, Number of Herring per 200-m Tow)

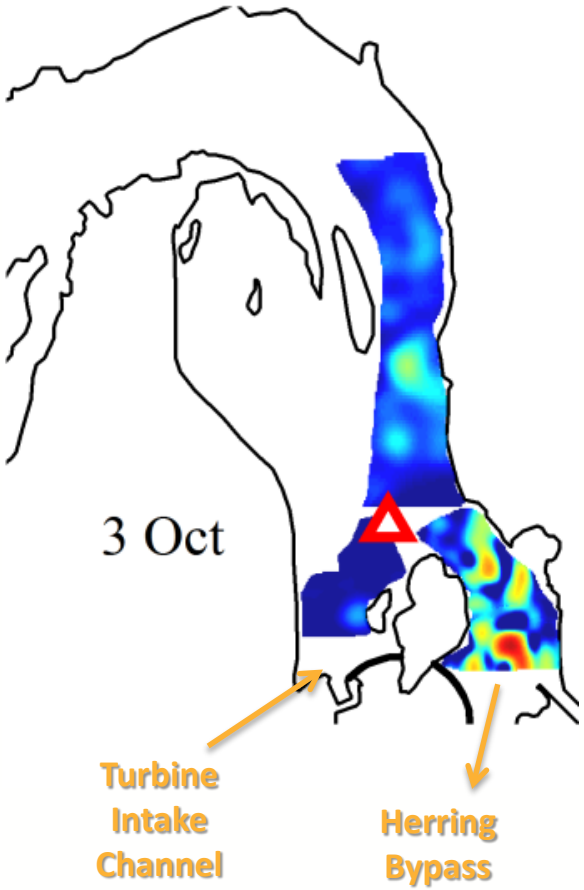


- 10,717 fish & 9 species
- 98.8% were juvenile Blueback Herring
- CPUE was significantly different among regions during 9 Sep-10 Oct (ANOVA, $P = 0.001$)
- CPUE in downriver region = 94% of upriver
- CPUE in downriver region 2.5 time higher than intake channel

MOBILE ACOUSTICS FISH DENSITY MAPS

Repeated Daytime Surveys Along Transects





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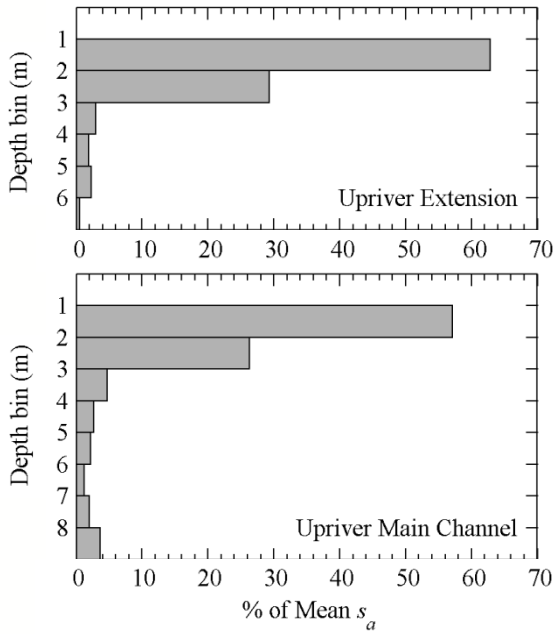
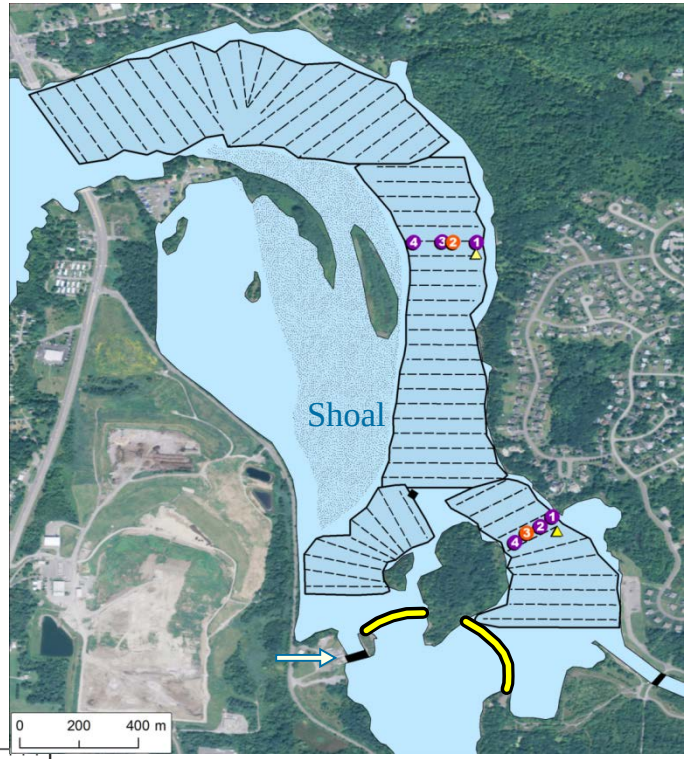
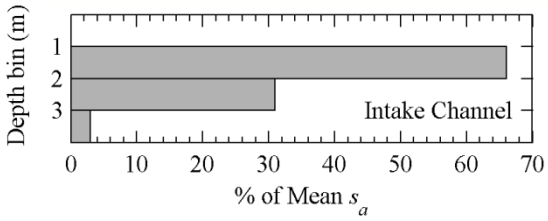
JUV. BLUEBACK HERRING DEPTH DISTRIBUTION

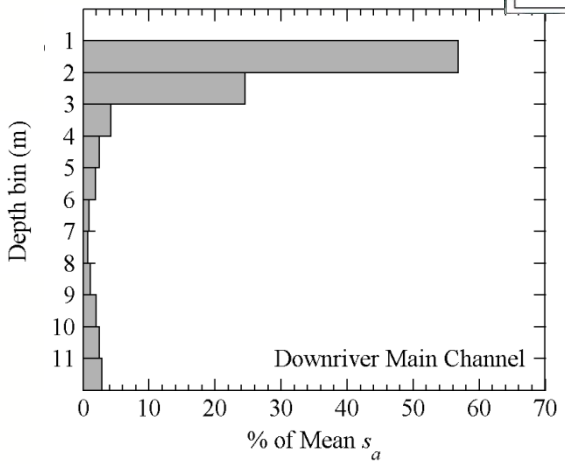
Daytime Mobile Hydroacoustics

Out-migration period
20 Sep – 14 Oct









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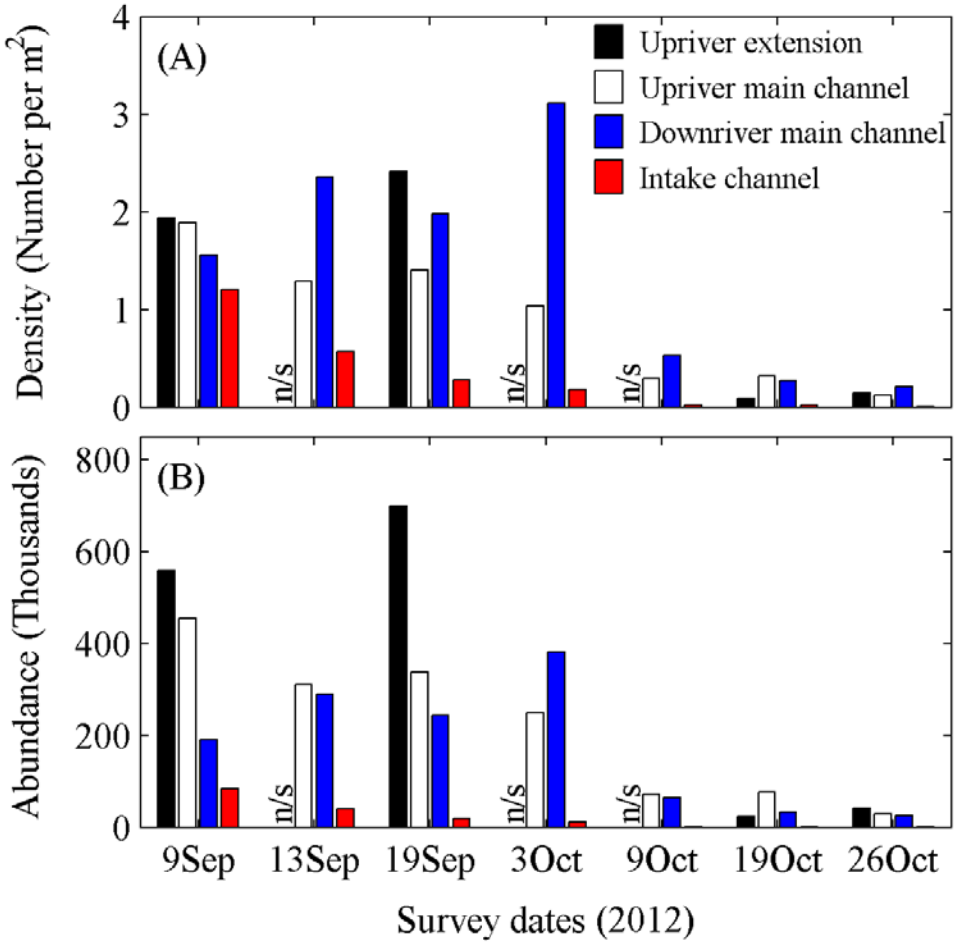
JUV. BLUEBACK HERRING DISTRIBUTION MAPS
From Repeated Mobile Echosounder Surveys

- Herring density & abundance was significantly higher in the downriver main channel than in the intake channel (paired *t*-test, $P < 0.05$)
- Averaged 35x more than intake channel
- Averaged 91% of combined abundance in the intake and downriver main channel



SUMMARY
3 Indices Each Show More Herring in Downriver Main Channel

1. Mobile echosounder surveys: Main vs Intake Channel
   - **BEFORE : 5-fold abundance difference**
   - **AFTER: 35-fold abundance difference**
2. Trawl CPUE in downriver main channel
   - **94% of upriver CPUE**
   - **250% of intake channel CPUE**
3. Continuous Echosounding: % Passed Downriver Main Channel
   - **BEFORE: 31% for original ultrasonic field**
   - **AFTER: 77% for re-directed ultrasonic field**

Significantly greater proportion in downriver main channel after re-direction of the ultrasound

CONCLUSIONS

- Pulsed ultrasound can improve downstream passage of juvenile Blueback Herring
- Direction is important for optimizing effectiveness of an ultrasonic deterrent system
- At Crescent, this improvement from 31% to 77% downstream passage represents survival of about 77,000 more fish for every 1 million
- The improved survival from ultrasonic fish deterrent systems can help restore Blueback Herring populations
  - Especially at multiple dams on the same river or at sites with high turbine mortality

CONCLUSIONS

For more details:

Gurshin, C. W. D., M. P. Balge, M. M. Taylor, and B. E. Lenz. 2014. Importance of ultrasonic field direction for guiding juvenile Blueback Herring past hydroelectric turbines. North American Journal of Fisheries Management 34:1242-1258.