Downstream Fish Passage for Sturgeon

Great Lakes Lake Sturgeon Coordination Meeting

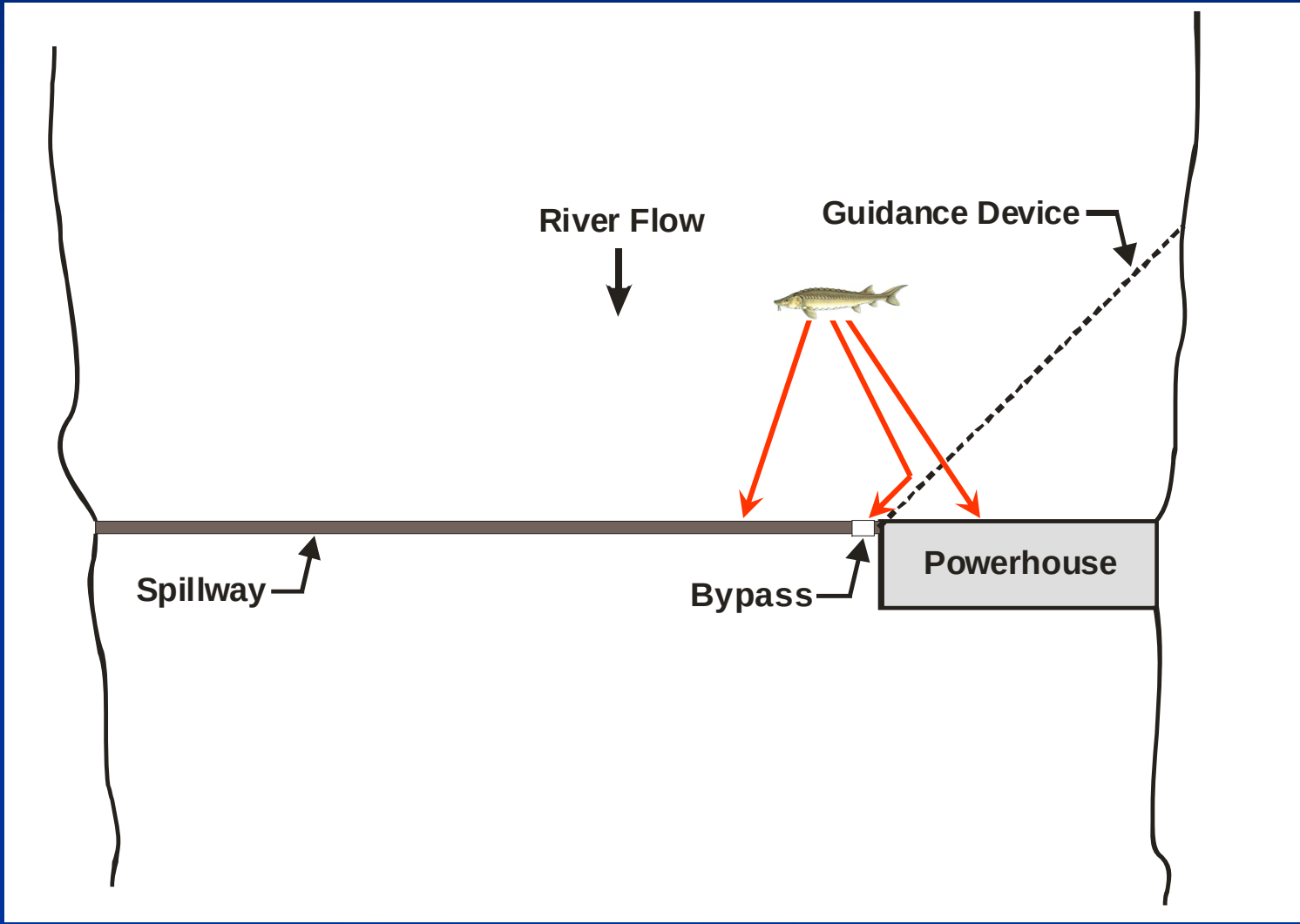
Steve Amaral and Tim Sullivan

ALDEN Research Laboratory, Inc.

Downstream Fish Passage for Sturgeon

- Downstream Fish Passage Technologies
- Assessing the Need for Downstream Passage
- Assessing Technologies for Use with Sturgeon: Biological Considerations
- Downstream Sturgeon Passage Research: Past, Present, and Future

Downstream Fish Passage Technologies



Downstream Fish Passage Technologies

- Physical barriers
- Diversion/Guidance systems
- Collection systems
- Behavioral deterrent technologies
- “Fish-friendly” hydro turbine designs

Downstream Fish Passage Technologies
Physical Barriers

- Narrow-spaced bar racks
- Aquatic filter barriers
- Barrier nets
- Flat panel screens
- Traveling screens
- Drum screens
- Cylindrical screens

Drum Screens

Downstream Fish Passage Technologies

Diversion/Guidance Systems

- Screening systems
- Angled bar racks
- Louvers
- Guide walls

Flat Panel V-Screen

Downstream Fish Passage Technologies

Collection Systems

- Surface collectors/galleries
- Modified traveling screens
- Fish pumps
- Bypass systems

Downstream Fish Passage Technologies

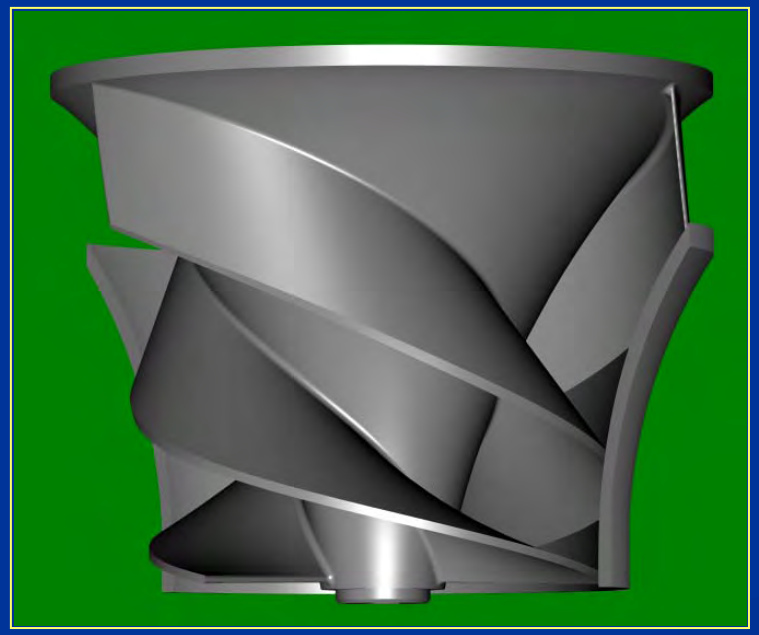
Behavioral Deterrents

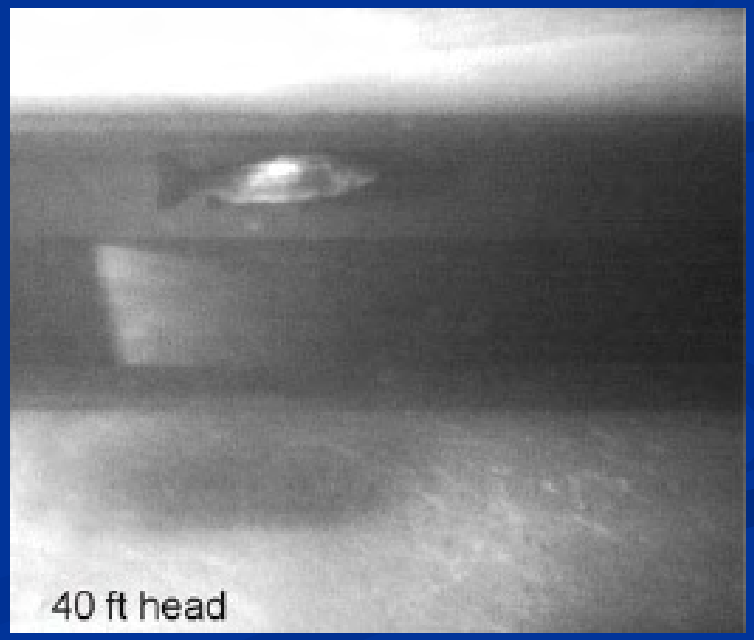
- Sound (infrasonic, sonic, ultrasonic)
- Light (mercury, strobe)
- Air bubble curtains
- Electrical barriers
- Combined systems

Strobe Light and Sound

Downstream Fish Passage Technologies
"Fish-friendly" Hydro Turbine Designs

- Alden/Concepts NREC
- Minimum Gap Runner
- Alstom Designs





Alden/Concepts NREC Turbine

Assessing the Need for Downstream Fish Passage

- Fisheries management objectives
  - River basin vs. smaller reaches
  - Prevent or facilitate downstream movement
- Migration delays and barriers
  - Effects on juvenile and adult migrations (feeding, over-wintering, spawning)
- Turbine passage mortality
  - Impact depends on mortality rate
  - Fish size and turbine design/operation
- Level of impact
  - Significant? Can resources be put to better use in addressing other restoration/enhancement issues?

Assessing Technologies for Use with Sturgeon

Biological Considerations

- Identify target life stages and size classes
- Migration characteristics (temporal and spatial)
- Sensory perception (light, sound, flow fields)
- Behavioral responses to hydraulic conditions
- Swimming capabilities (burst, prolonged, and sustained)

Downstream Sturgeon Passage Research

Past Research

- Sensory Perception
- Swimming capabilities
- Migration Patterns
- Guidance Structures (angled bar racks, louvers)
- “Fish-friendly” Hydro Turbine Designs

Downstream Sturgeon Passage Research

Sensory Perception

- Hearing
  - Non-hearing specialist (no connection between air bladder and inner ear)
  - Vocalizations documented during spawning (shovelnose and pallid sturgeon)
- Vision
  - Positive and negative phototaxis depending on life stage
  - White sturgeon larvae have demonstrated negative phototaxis
  - Seek cover in day, continuous swimming at night
  - High intensity light can inhibit swimming activity
- Lateral Line and Electrosensory Perception

Downstream Sturgeon Passage Research

Behavioral Deterrent Studies

- Low-frequency sound (Patrick 1988)
  - Small juveniles
  - Pulsed hammer (20 – 1,000 Hz)
  - No avoidance observed; fish condition and experimental design may have affected results
- Air bubbles and water jets (McKinley and Kowalyk 1989)
  - No avoidance responses observed
- No studies with lights

Downstream Sturgeon Passage Research

Swimming Capabilities

- Lake sturgeon are weak swimmers, particularly when compared to salmonids (Peake et al. 1997)
- Heterocercal tail reduces thrust; scutes increase drag (Webb 1986)
- Similarity in swimming capabilities exists among sturgeon species

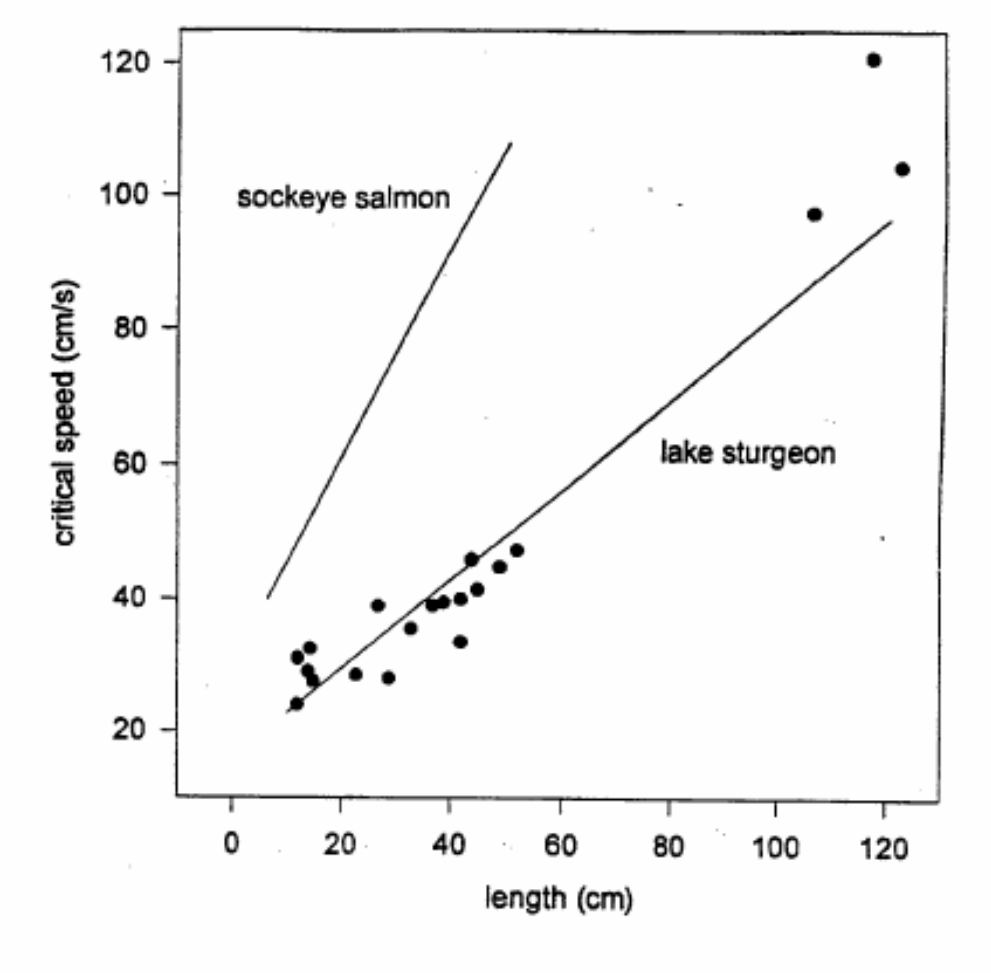
Downstream Sturgeon Passage Research

Swimming Capabilities

- Maximum sustained speeds (greater than 200 min):
  - 4 cm/s for 15 cm fish
  - 84 cm/s for 120 cm fish
- Prolonged speeds (20 sec to 200 min):
  - 39 cm/s (2.5 body lengths/s) for 16 cm fish for 2-minute period
  - 90 cm/s for 120 cm fish for 128-minute period at 14° C.
  - 90 cm/s for 45 cm fish for 9-second period.
- Burst speeds (<20 sec):
  - No discrete change in endurance between prolonged and burst swimming

Downstream Sturgeon Passage Research
Swimming Capabilities

- Lake sturgeon critical swimming speed based on increasing velocity after 10 minute intervals (Peake et al. 1995)



Downstream Sturgeon Passage Research
Lake Sturgeon Migration Patterns

- Mattagami River, Ontario (McKinley et al. 1998)
  - Post-spawning adult downstream movements during spring and summer
- Sturgeon River/Portage Lake, MI (Holtgren and Auer 2004)
  - Juvenile downstream movement during summer/fall
  - Inshore shallow areas (< 5 m) at night, offshore deeper water (>7.5 m) during day

Guidance Structures

Angled bar racks, louvers, and other Physical Structures

- Alden studies (EPRI 2001; Alden 2001; Amaral et al. 2002)
- Conte Center study (Kynard and Horgan 2001)
- Physical/perceptual barriers (Anderson et al. 1997)

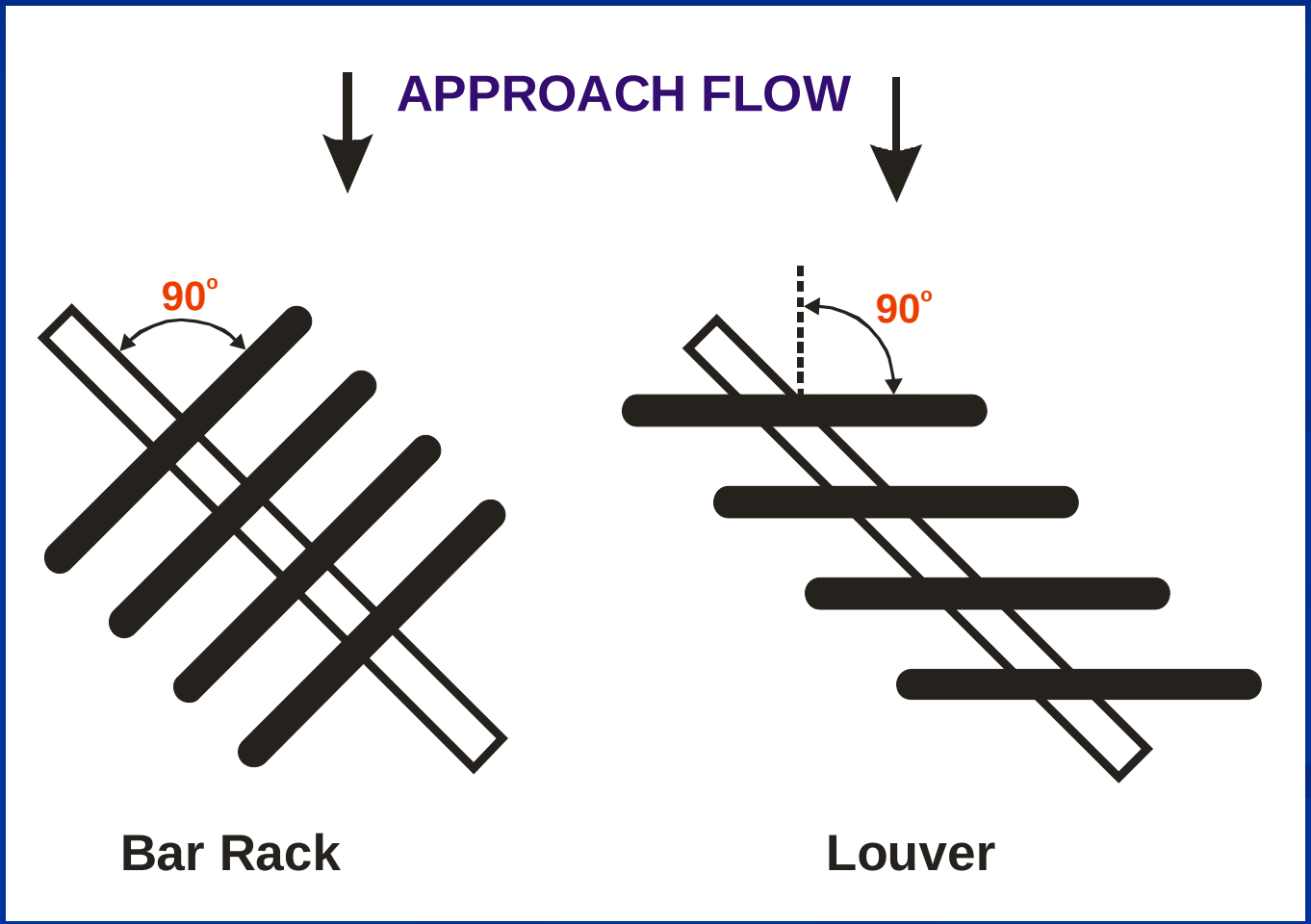
Downstream Fish Passage Research for Sturgeon

Guidance Structures

Study	Species	Length (mm)	Device	Angle	Slat Spacing (inches)	Approach Vel (ft/s)
Alden (EPRI)	LAS	142	BR	15	2	1, 2, 3
				45	1, 2	1, 2, 3
				90	2	2
			LV	15	2	1, 2, 3
				45	2	1, 2, 3
	SNS	319	BR	15	2	1, 2, 3
			LV	15	2	1, 2, 3
Alden (FWS, WE, MIT, MI/WI DNR)	LAS	345	BR	15	2	1, 2, 3
			LV	15	2	1, 2, 3
Conte Center	PAS	216	BR	45	1.5	1
			LV	20	1.5, 3.5	1
	SNS	275	BR	45	1.5	1
			LV	20	1.5, 3.5	1

Downstream Fish Passage Research for Sturgeon

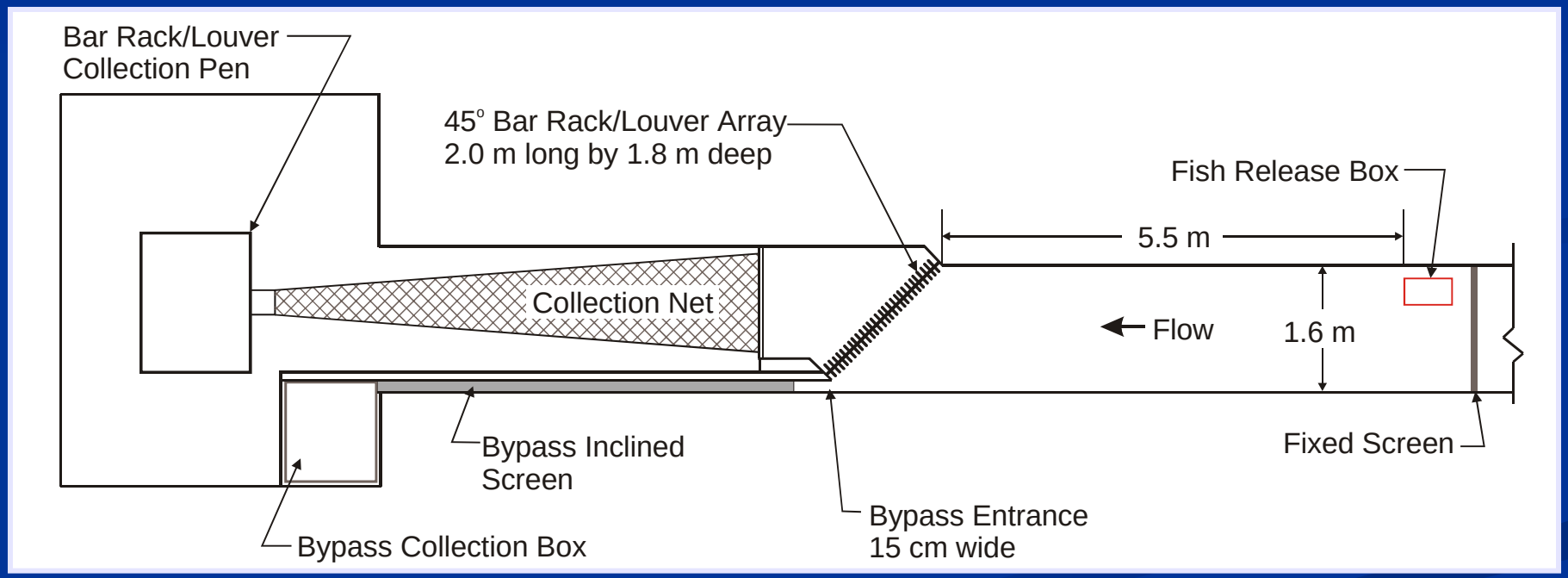
Guidance Structures



Downstream Fish Passage Research for Sturgeon

Guidance Structures

Alden Studies – Test Facility (EPRI 2001)



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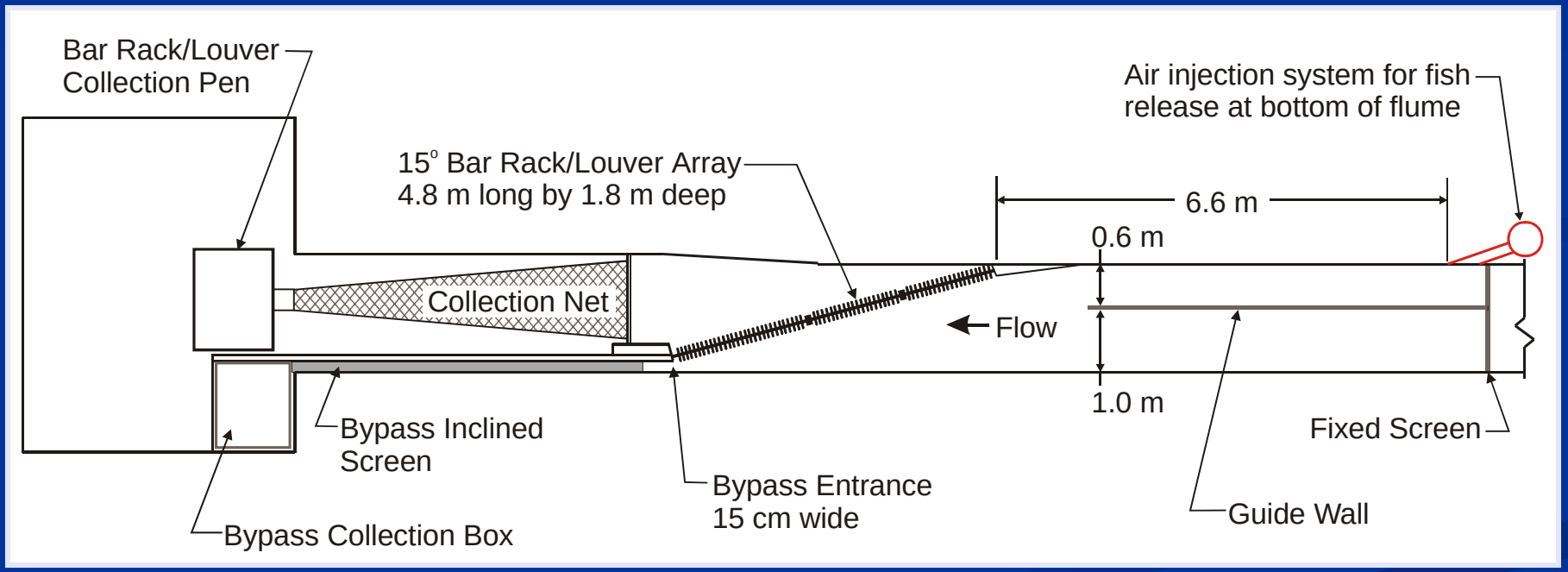
Guidance Structures

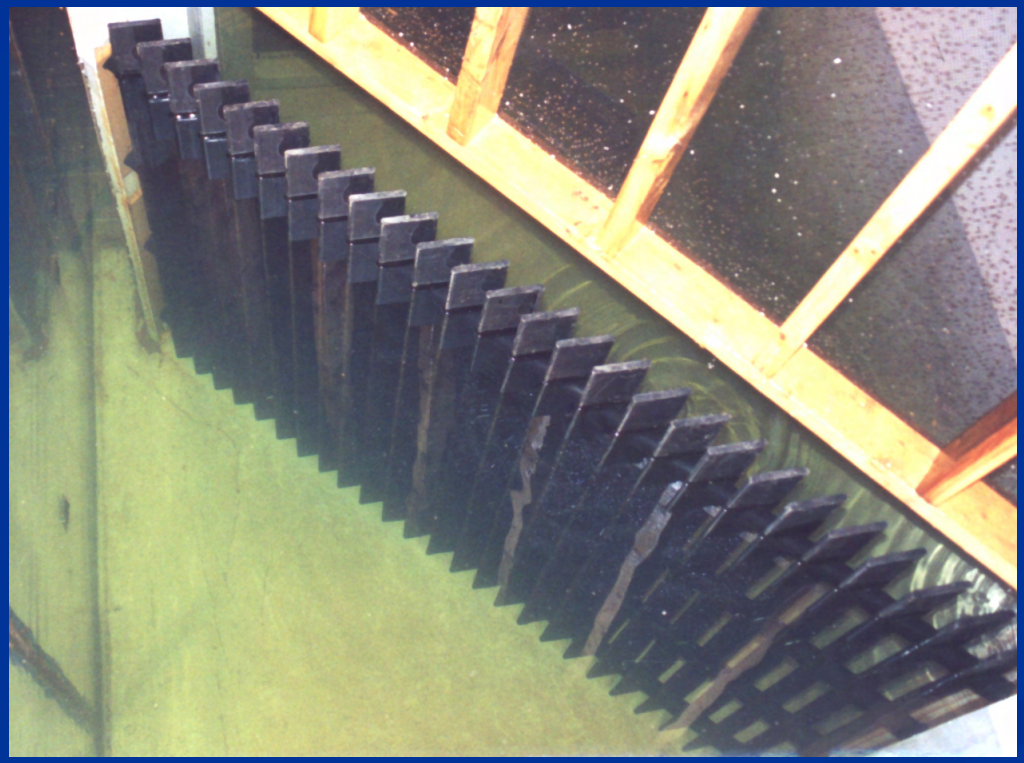
Alden Studies – Test Facility (EPRI 2001; Alden 2001)



Downstream Fish Passage Research for Sturgeon

Guidance Structures

Alden Studies – Test Facility



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Guidance Structures

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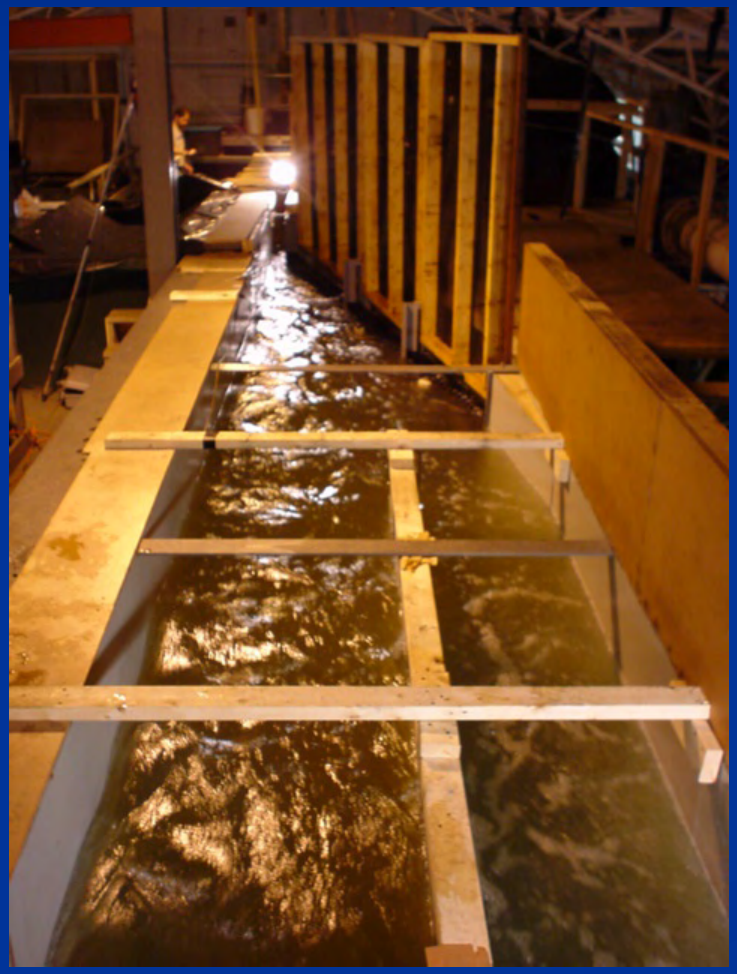
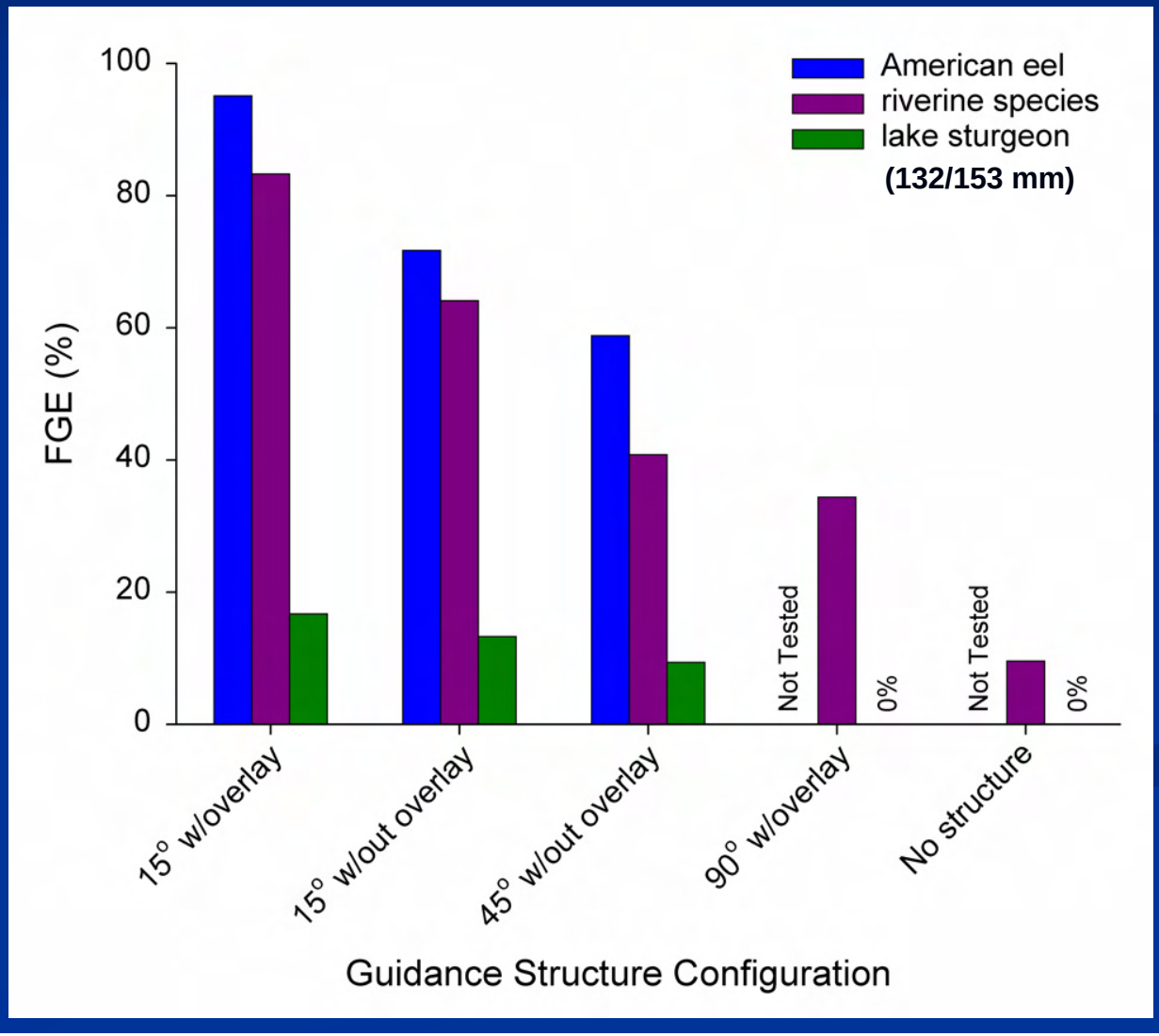


Downstream Fish Passage Research for Sturgeon

Guidance Structures

Guidance Efficiency

- 2 ft/s approach velocity
- 2 inch slat spacing

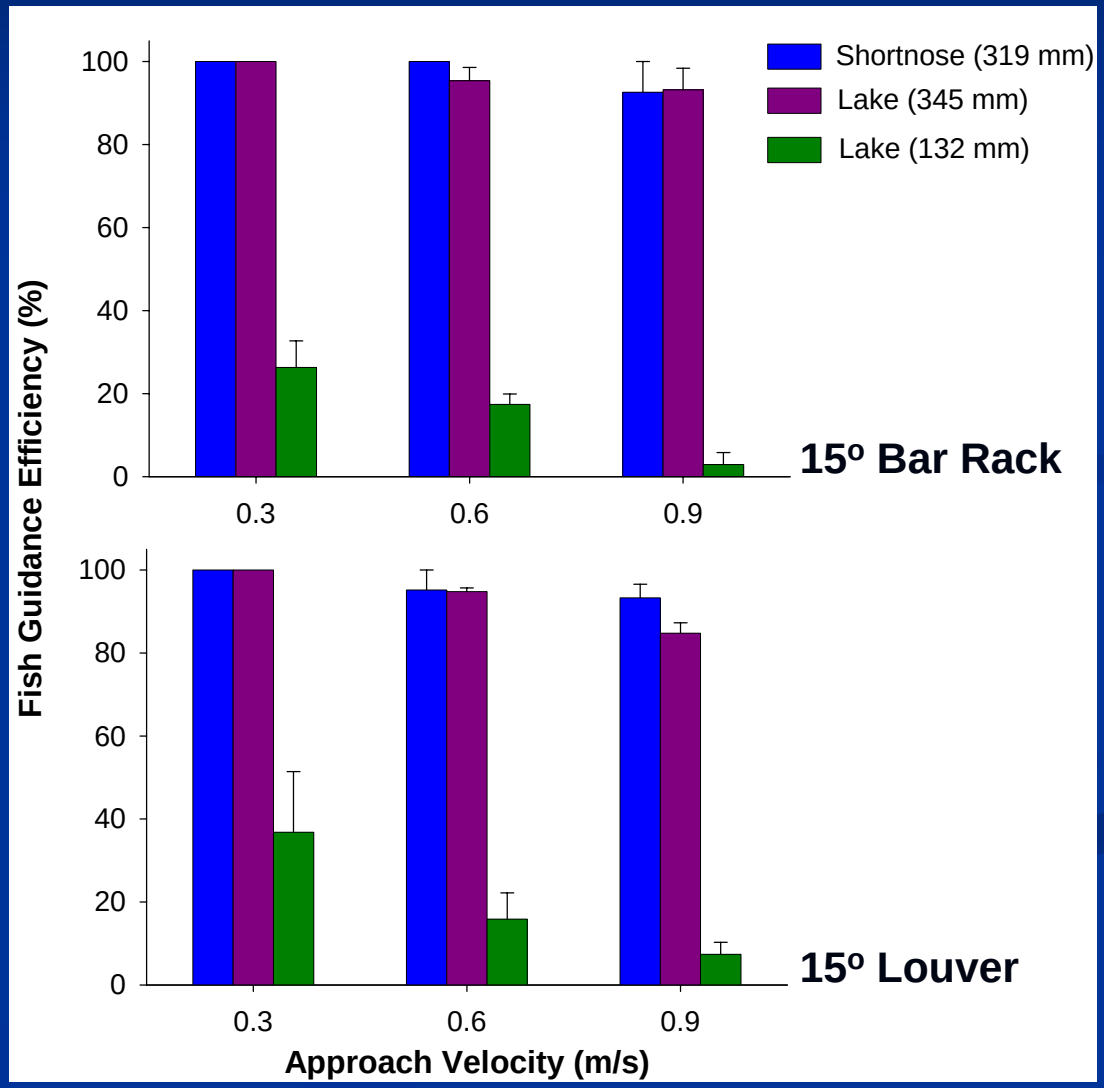


EPRI (2001)

Downstream Fish Passage Research for Sturgeon

Guidance Structures

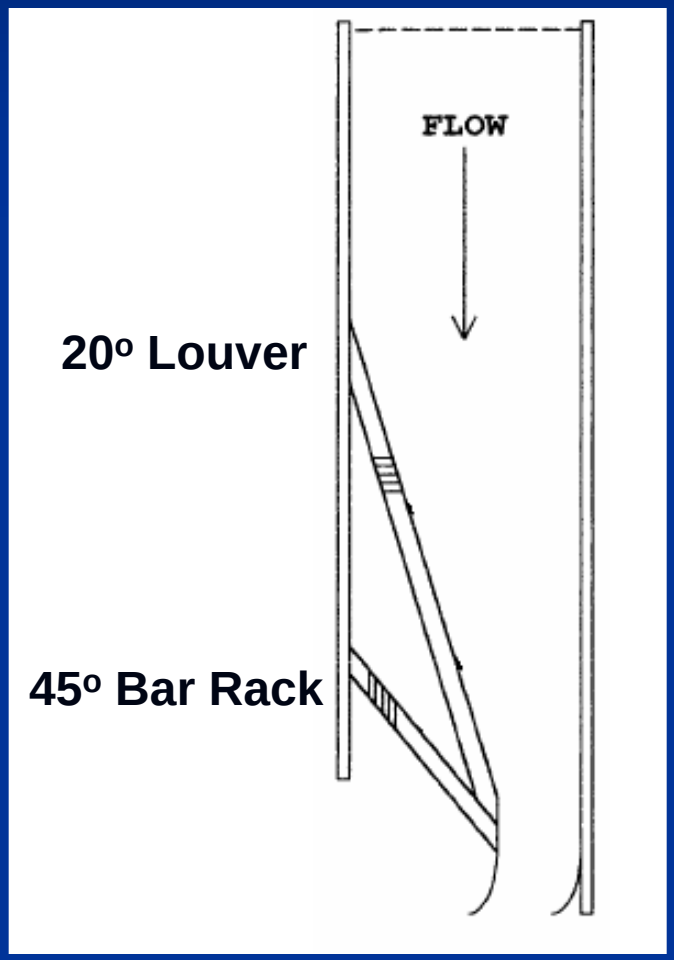
Guidance Efficiency



EPRI (2001)
Amaral et al. (2001)

Downstream Fish Passage Research for Sturgeon

Guidance Structures



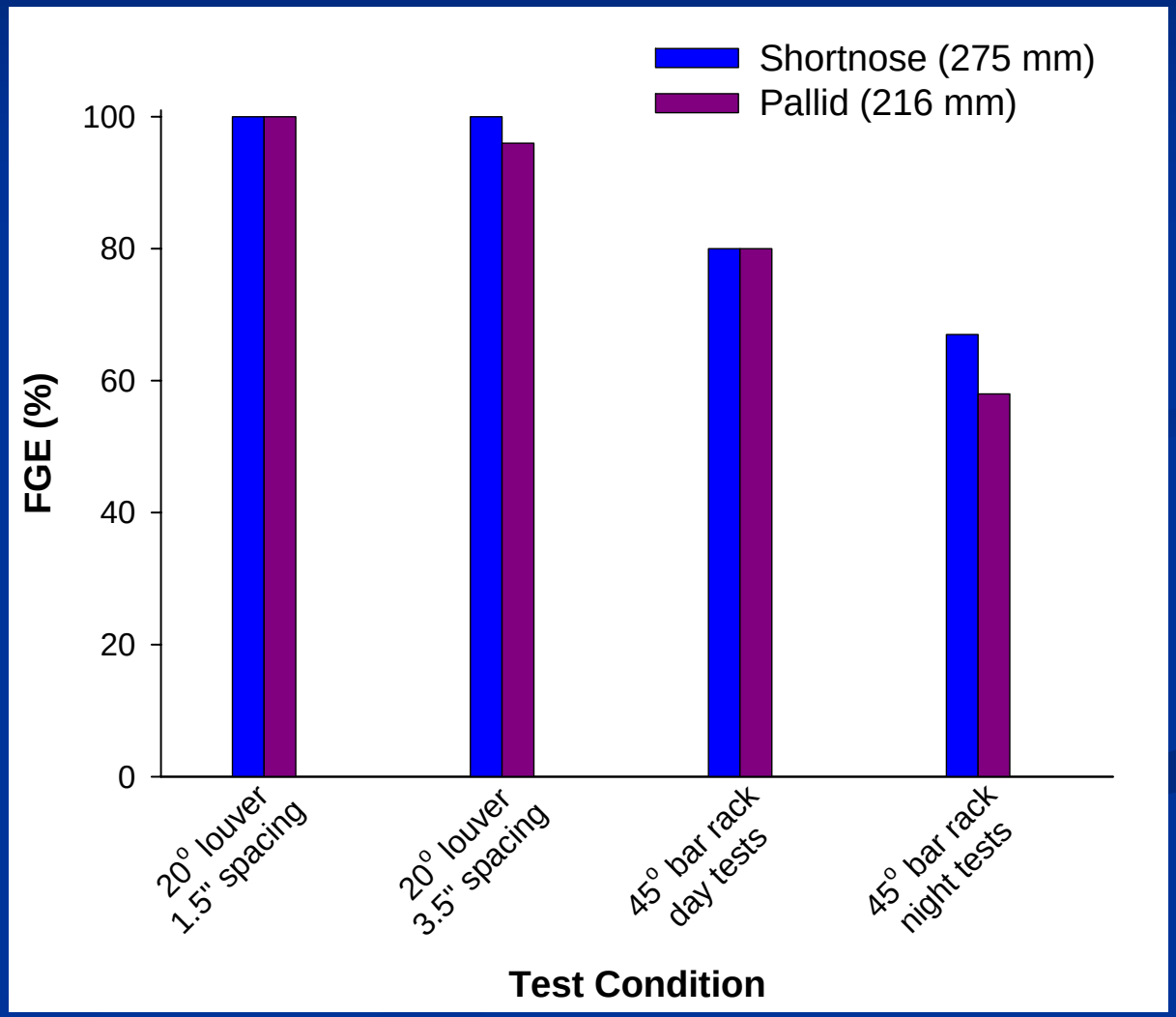
Conte Center Study

- Bar rack spacing: 1.5 inch
- Louver spacing: 1.5 and 3.5 inch
- 1 ft/s approach velocity
- Full depth bypass (1.5 ft wide x 1.2 ft deep)
- Day/night testing with bar rack

Downstream Fish Passage Research for Sturgeon

Guidance Structures

Guidance Efficiency



Kynard and Horgan (2001)

Guidance Structures

Bar Racks and Louvers - Laboratory Study Conclusions

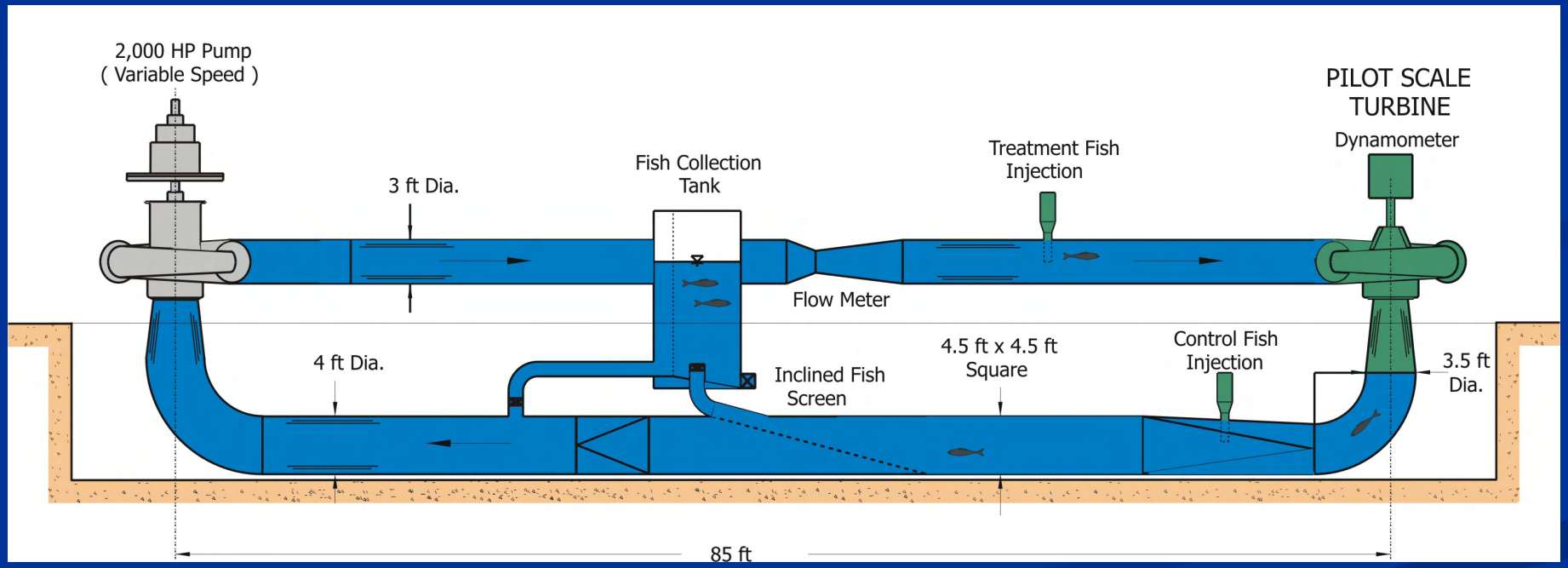
- Size matters (i.e., swimming capabilities); sturgeon < 200 mm exhibited poor guidance
- Ambient light conditions matter
- Structure angle and approach velocity matter
- FGE is similar among sturgeon species tested (size range: 200-350 mm)
- Bottom overlay improved FGE
- Field studies are needed to verify lab results

Downstream Sturgeon Passage Research
"Fish-friendly" Hydro Turbines

- **Alden/Concepts NREC Turbine**
  - Juvenile white sturgeon (mean TL = 103 mm)
  - 40 ft operating head
  - Best efficiency point
  - Wicket gates installed
  - 9 paired releases
  - 100 fish per treatment and control group
  - Estimated turbine passage survival (immediate and 96 hr) and external injury rates

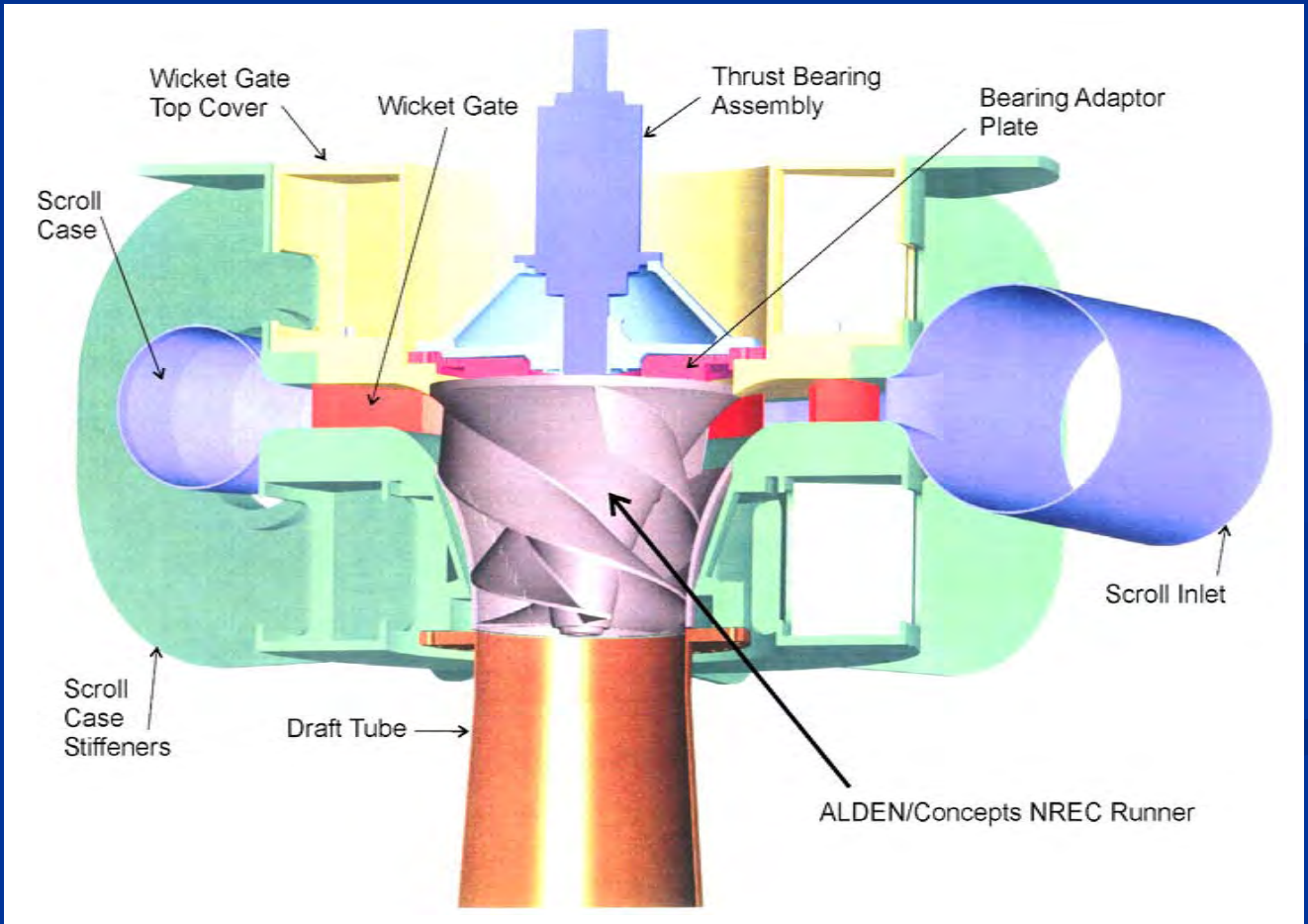
Downstream Sturgeon Passage Research
"Fish-friendly" Hydro Turbines

Alden/Concepts NREC Turbine



Downstream Sturgeon Passage Research
"Fish-friendly" Hydro Turbines

Alden/Concepts NREC Turbine



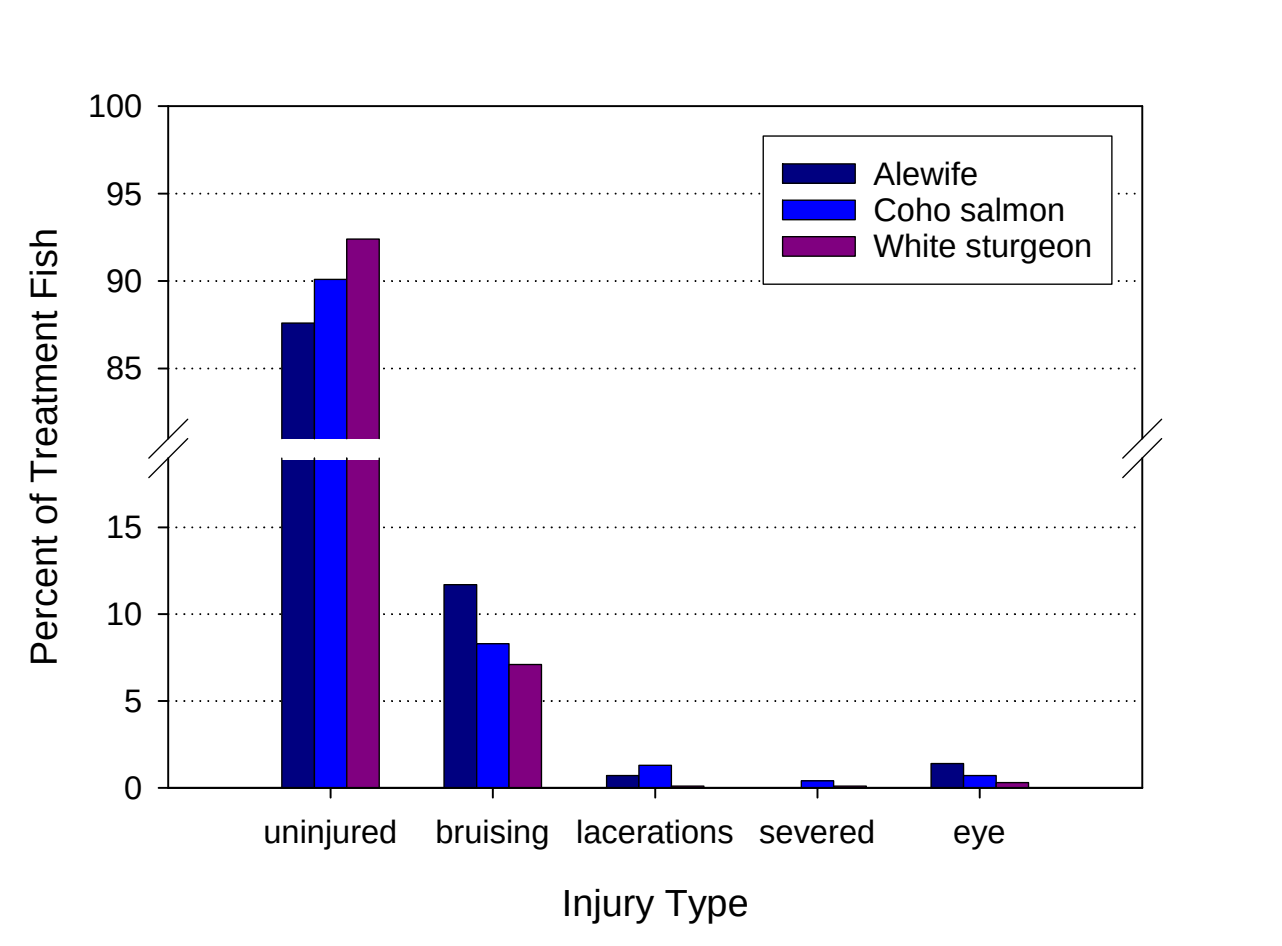
Downstream Sturgeon Passage Research
"Fish-friendly" Hydro Turbines

Alden/Concepts NREC Turbine
Turbine Passage Survival Rates

Species	Mean Length (mm)	Immediate Survival (%) ± 95% CI	Total Survival (%) ± 95% CI
Alewife	75.5	95.5 ± 1.4	93.7 ± 1.7
Coho Salmon	102.0	95.4 ± 1.4	93.3 ± 1.8
White Sturgeon	103.0	98.3 ± 0.9	97.0 ± 1.3

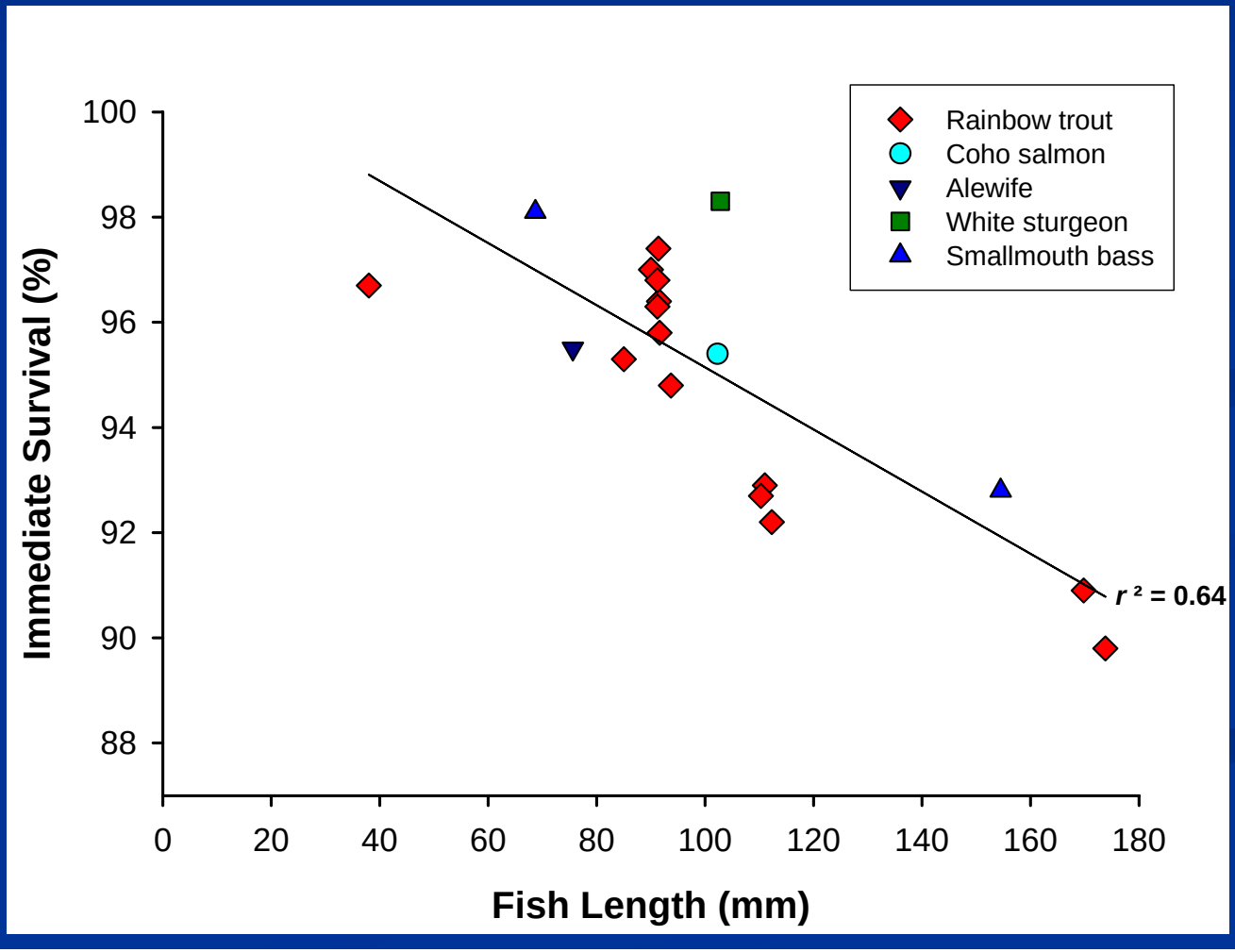
Downstream Sturgeon Passage Research
"Fish-friendly" Hydro Turbines

Alden/Concepts NREC Turbine
Turbine Passage Injury Rates



Downstream Sturgeon Passage Research
"Fish-friendly" Hydro Turbines

Turbine Passage Survival Rates



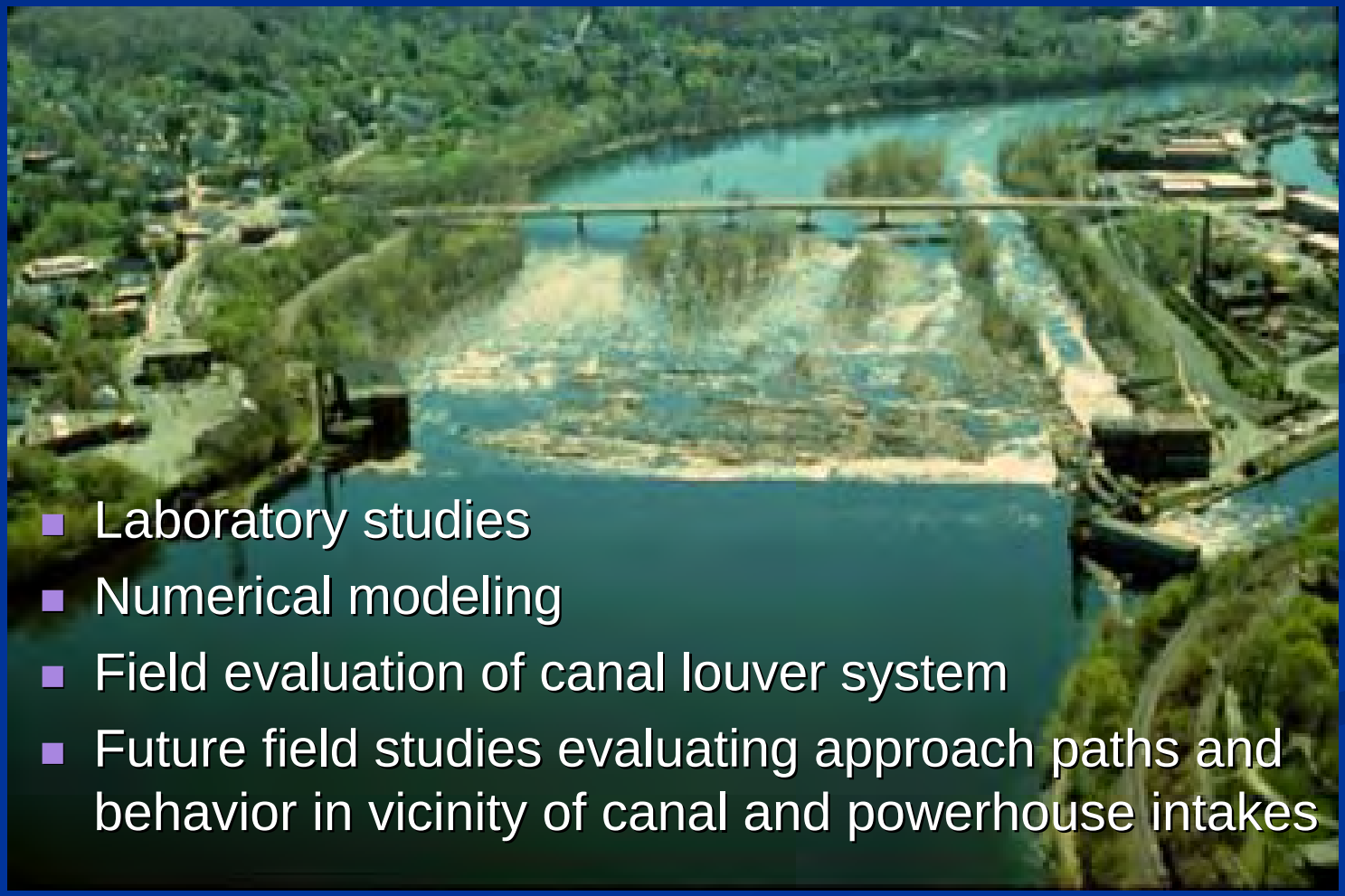
Downstream Sturgeon Passage Research

Present Research

- Bar racks, louvers, and bypasses
  - Holyoke Project (shortnose sturgeon)
- Columbia River Basin – white sturgeon?
- Other studies?

Downstream Sturgeon Passage Research

Hadley Falls Project – Bar Racks, Louvers, and Bypasses



- Laboratory studies
- Numerical modeling
- Field evaluation of canal louver system
- Future field studies evaluating approach paths and behavior in vicinity of canal and powerhouse intakes

Downstream Sturgeon Passage Research

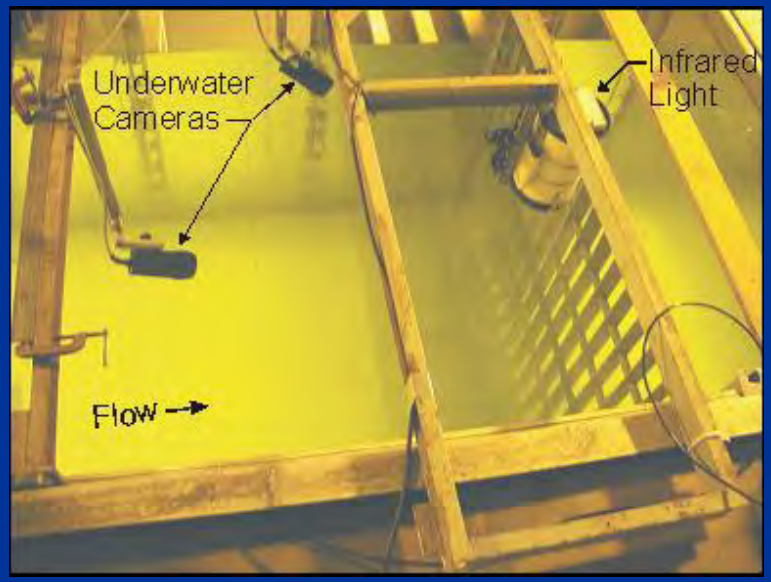
Future Research

- Sensory perception: basic research on hearing/vision capabilities
- Behavioral responses to hydraulic conditions at hydro projects
- Swimming capabilities and behavior in the presence of downstream passage technologies
- Migration timing (seasonal/diel) and routes by life stage
- Downstream fish passage technologies
  - Behavioral deterrents
  - Diversion systems and physical barriers (e.g., barrier nets)
  - Bypasses
  - “Fish-friendly” turbine designs

Downstream Sturgeon Passage Research

Future Research

- Laboratory Studies
  - Sensory perception and responses to behavioral stimuli
  - Swimming capabilities and behavior in the presence of downstream passage technologies



Downstream Sturgeon Passage Research

Future Research

- Field Studies
  - Migration timing and routes by life stage
  - Pilot-scale studies evaluating performance of downstream fish passage technologies
- Numerical Modeling
  - Characterize flow fields experienced by fish