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Determination of initial inflation of the swim bladder and vulnerability to barotrauma in white sturgeon

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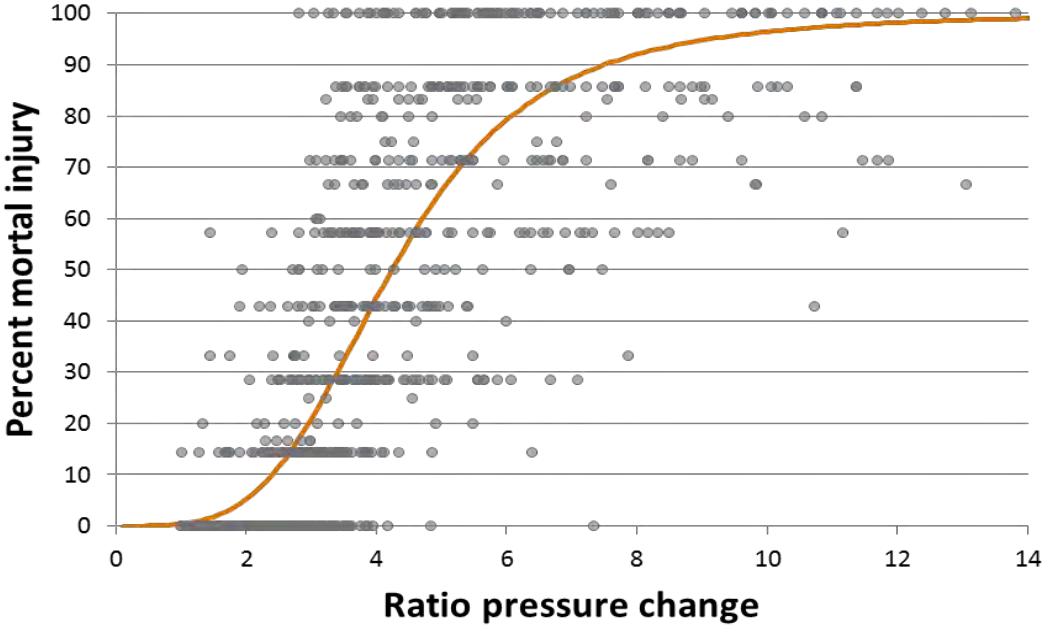
Barotrauma

- Damage to fish exposed to change in barometric pressure
  - Fish exposed to rapid decompression when passing turbines or deep spill
- PNNL / USACE done extensive research on barotrauma
  - Work primarily on juvenile Chinook salmon
    - Little work on other species
  - Established relationship between ratio pressure change and probability of mortal injury

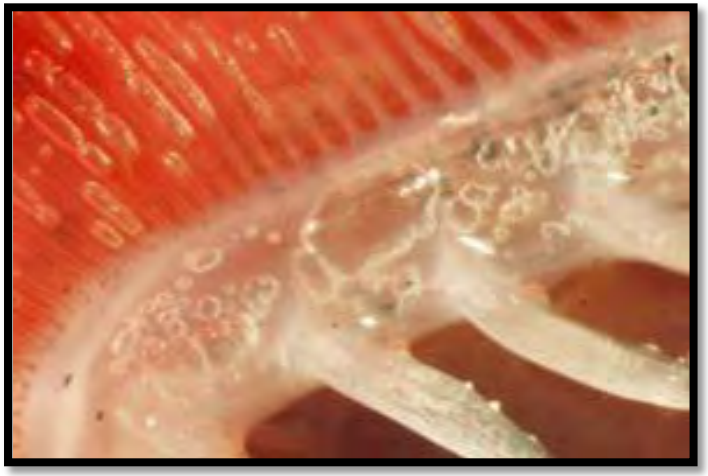


Injuries due to barotrauma

- Expansion and rupture of swim bladder a key cause of mortal injury in Pacific salmon
- Other common injuries:
  - Stomach evulsion
  - Exopthalmia
  - Bubbles in eyes, fins, gills
  - Blood vessel rupture

Eye popping in juvenile salmon

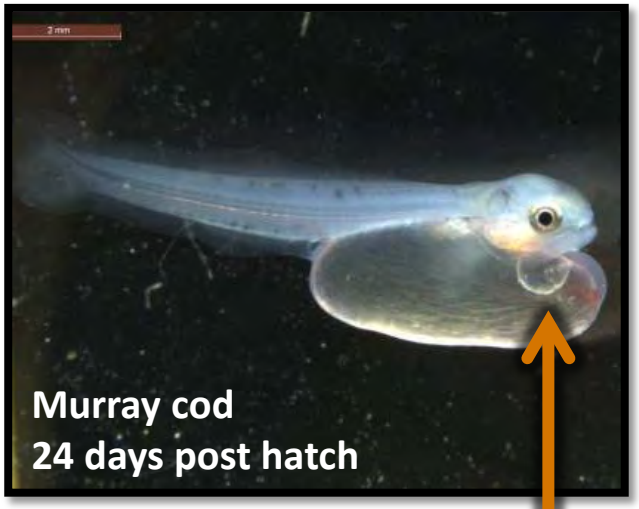
Stomach evulsion in juvenile salmon



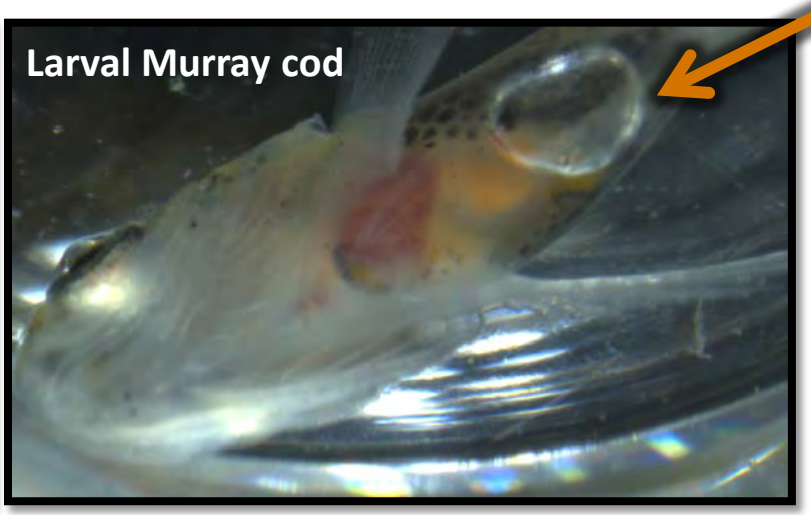
Gas bubbles in gills of juvenile salmon

Vulnerability to barotrauma

- In SE Australia 90% of native species lost
  - Many with larval drift
  - High mortality when passing under irrigation weir gates
    - Rapid decompression
- Many North American species with larval drift
  - Sturgeon
  - Paddlefish
  - Walleye

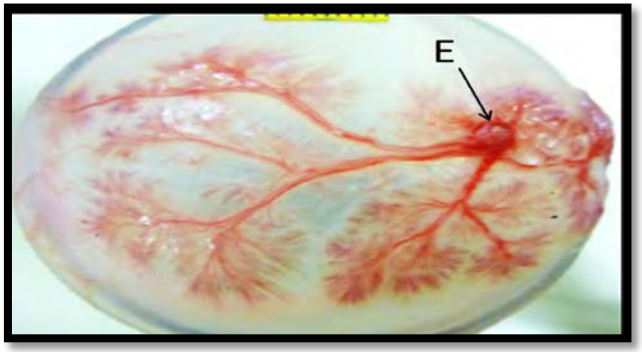


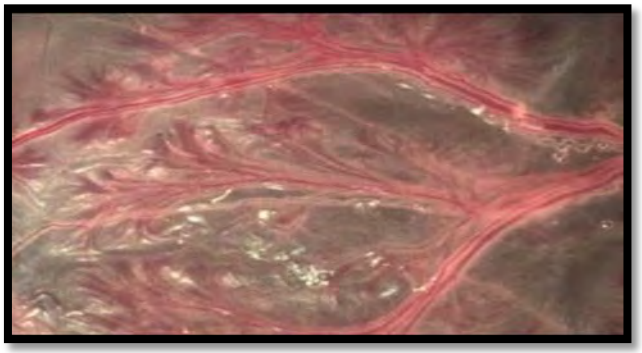
Barotrauma in larval Murray cod exposed to pressure decrease



Vulnerability to barotrauma

- Amount of gas in the body
  - Presence of a swim bladder
  - Type of swim bladder (open or closed)
  - Ability to expel gas when decompressed
  - Activity of rete
  - Acclimation depth ability
- Life history
  - Migratory
  - Drifting larvae
- Structural composition and integrity of swim bladder
- **Time of swim bladder inflation**
  - **Amount of gas in the swim bladder determines severity of barotrauma**





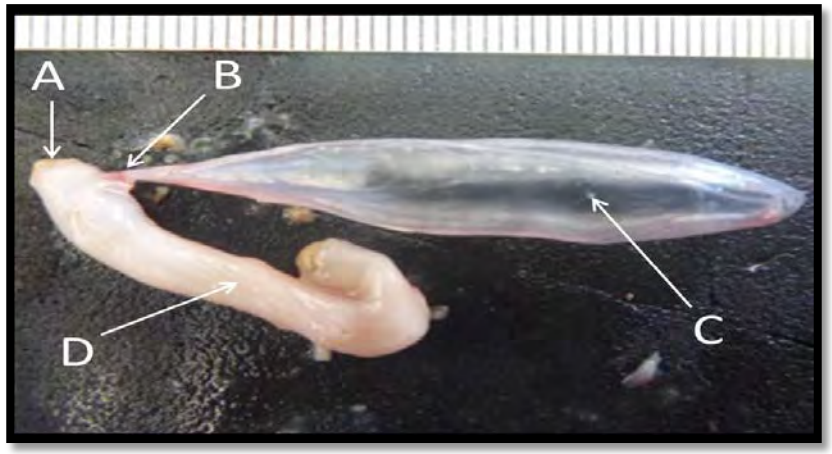
Initial swim bladder inflation

- Time of initial swim bladder inflation highly variable between species and is temperature dependent
  - 24 dph in rainbow trout
  - 4-5 dph in zebra fish
- Literature of sturgeon development focused on stage between hatching and feeding
  - Not clear when swim bladder develops enough for initial filling

Physostomes

Fill swim bladders by gulping atmospheric oxygen

The pneumatic duct connects the swim bladder and gut



Objectives

- Develop tools to determine when larvae and small fish become vulnerable to barotrauma
- Determine when developing fish first have gas in their body (mainly the swim bladder)
- Test eggs, larvae and small juvenile white sturgeon
  - Conduct rapid decompression and X-rays
- Determining the point of first vulnerability will lay foundation for future work
  - Establish a relationship between pressure change and injury / mortality
  - Examine this point of vulnerability in terms of life history stage

White Sturgeon

- Many populations at risk
- Larvae drift up to 40 km/day
  - At least one drift stage
  - Free embryo, larval and juvenile drift stages
- Likely encounter hydropower or other water management facilities during downstream drift phases
  - Susceptible to barotrauma?

Photograph by Matt Howell, Colville Tribes

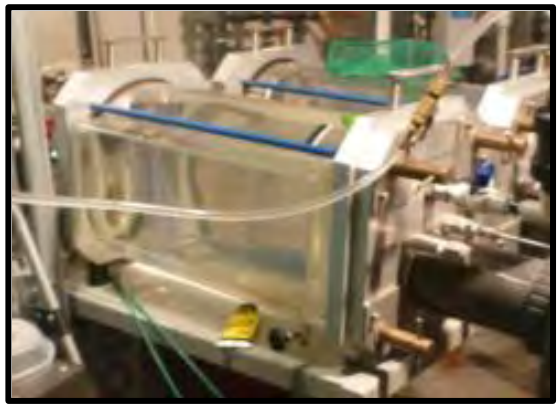
Methods

1- White sturgeon reared from eggs and developmental stages recorded

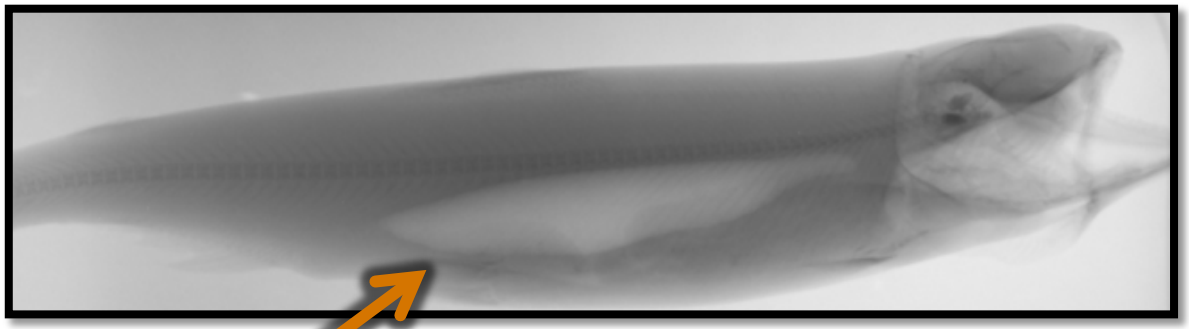
2- Fish exposed to rapid pressure decreases every second day until juvenile metamorphosis

3- X-rays conducted regularly to confirm findings from pressure experiments. Low density areas (e.g. swim bladder) appear white

Upwell jars used to rear eggs



Pressure chambers

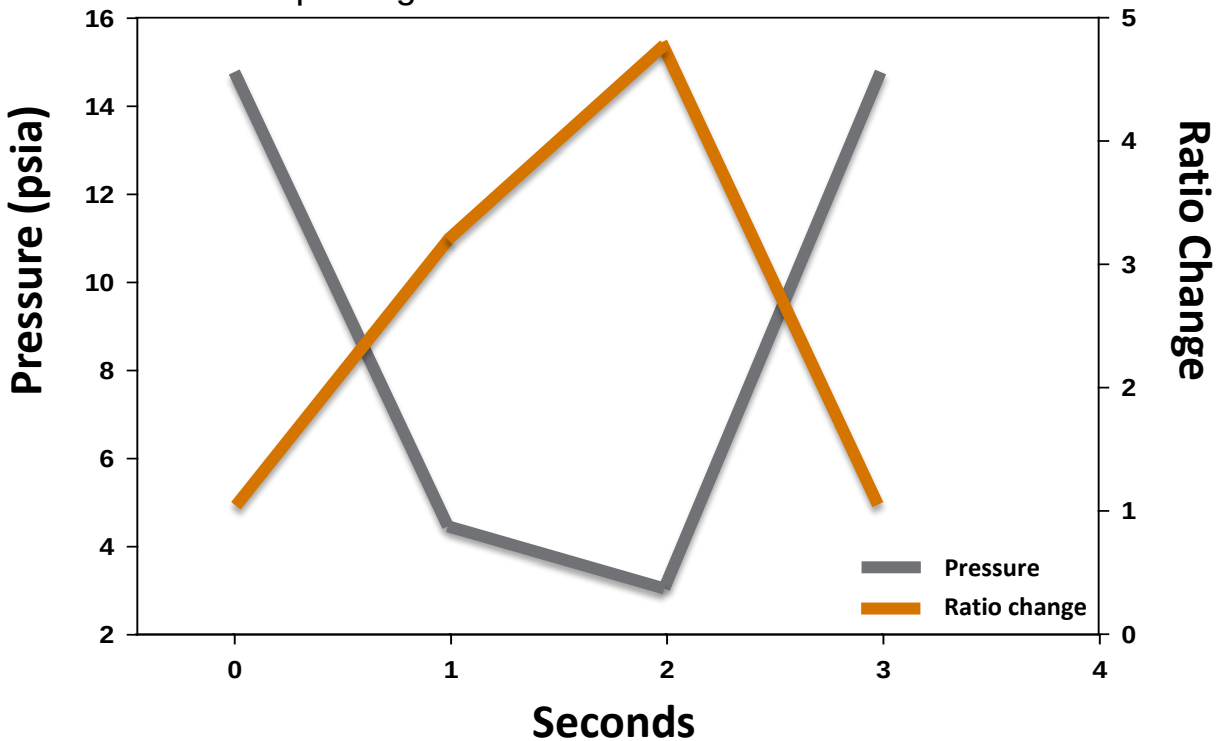


X-ray of juvenile Chinook salmon

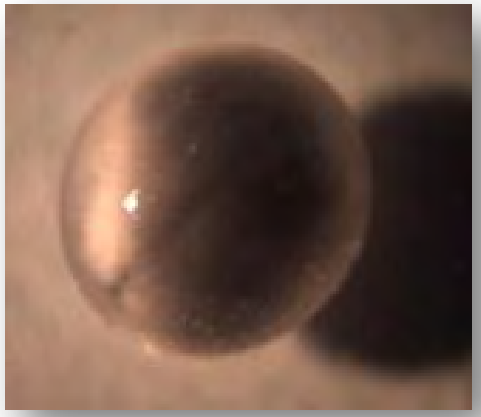
Swim bladder

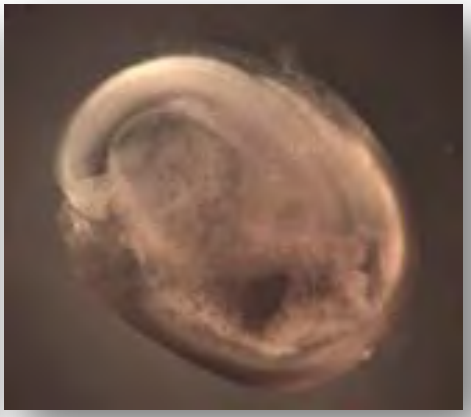
Exposures

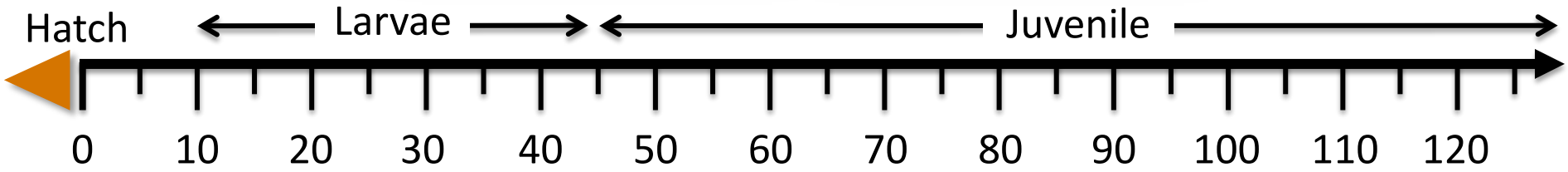
- Minimum 10 fish per exposure group
  - Exposure replicated if evidence of barotrauma observed
- Rapid pressure decrease
  - 14.7 to < 4 psia in ~ 2 *s*
- Pressure decreases by 4-5 x; any preexisting gas increases by this amount
  - Not meant to simulate turbine passage



Pre-hatch





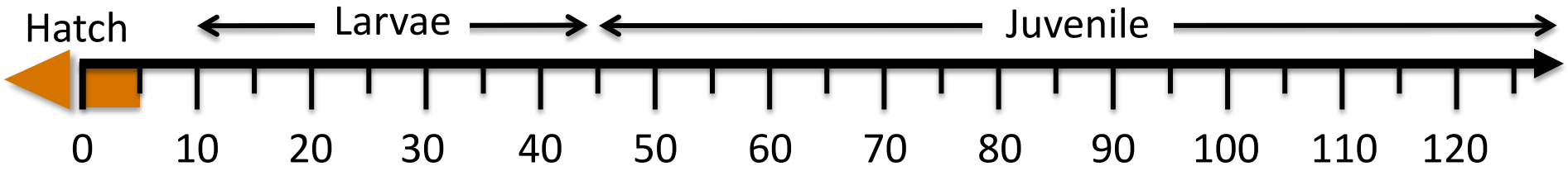


- No evidence of gas present during egg development
- Negatively buoyant even when decompressed
- No observed barotrauma

Pelagic Drift Phase (0-5 dph)

0 dph, ~13 mm

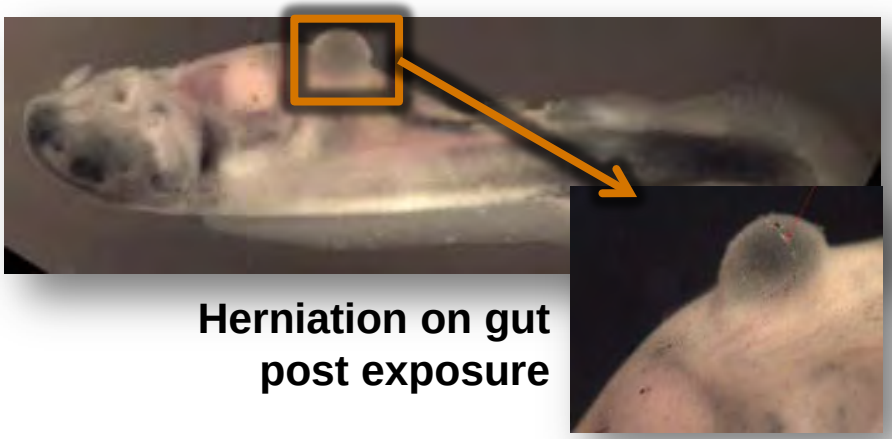
4 dph, ~15.5 mm



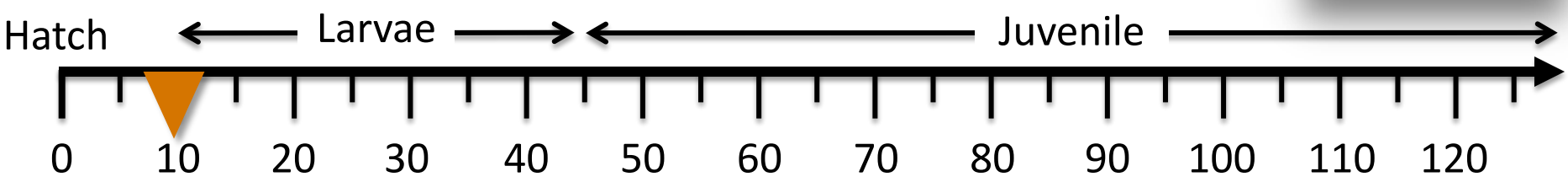
- Pelagic drift stage
  - Concern of passing hydropower facilities
- No evidence of gas present
- Negatively buoyant even when decompressed
- No observed barotrauma

Evidence of Barotrauma: 9 dph

Expulsion of fluid from body cavity

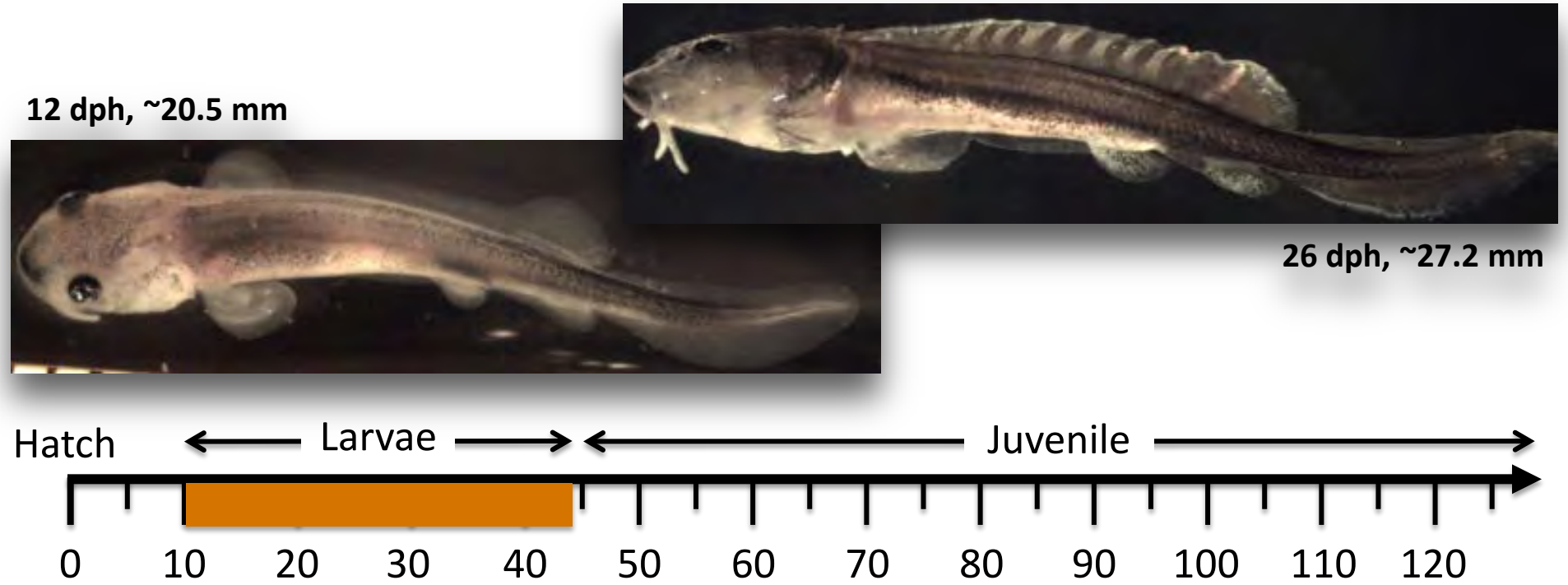


Herniation on gut post exposure



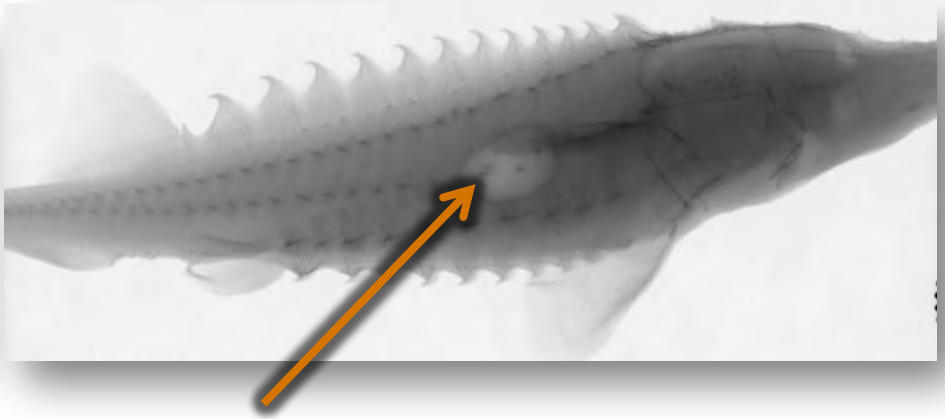
- 15% mortality (3 of 20 exposed fish)
- Several fish appeared aggravated and showed erratic swimming behavior
- Two mortalities showed obvious physical evidence of barotrauma
  - Expelled yellow lipid when decompressed
  - Herniation on gut (possible tear)
- X-rays at 7 dph depict low density area of yolk sac but no gas
- Feeding began at 8 dph

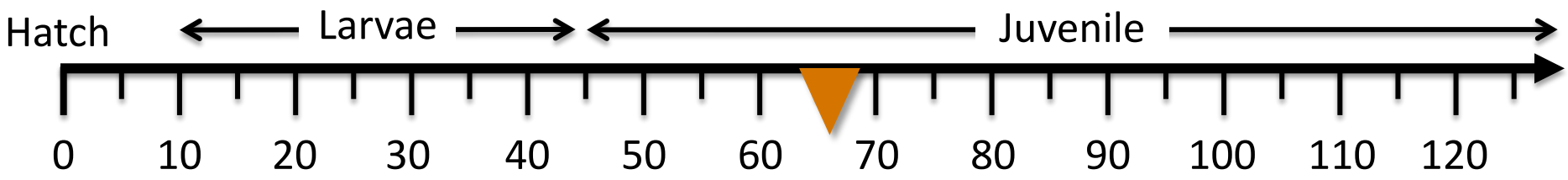
Larvae Phase (~10- 44 dph)



- Foraging swimming with current (~10-24 dph)
  - Potentially subject to passage of hydropower facilities
- No evidence of gas present
- No observed barotrauma

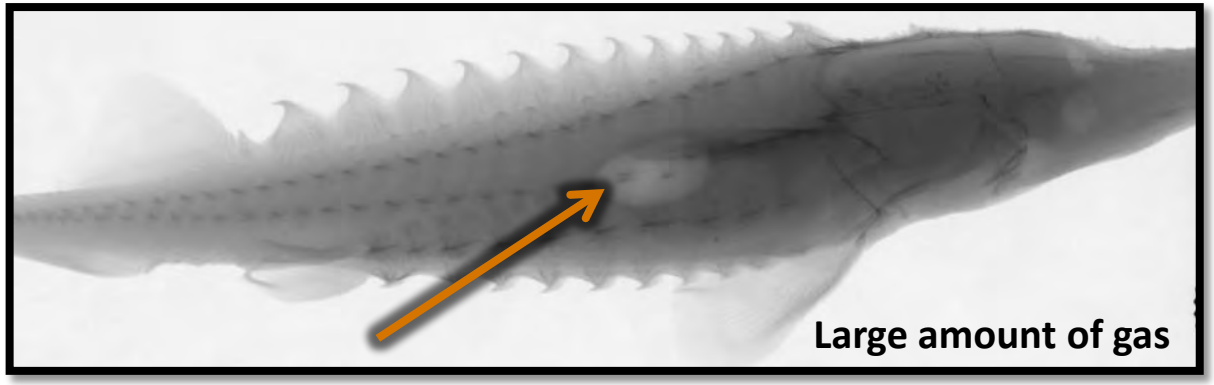
Swim Bladder Inflation (75 dph)

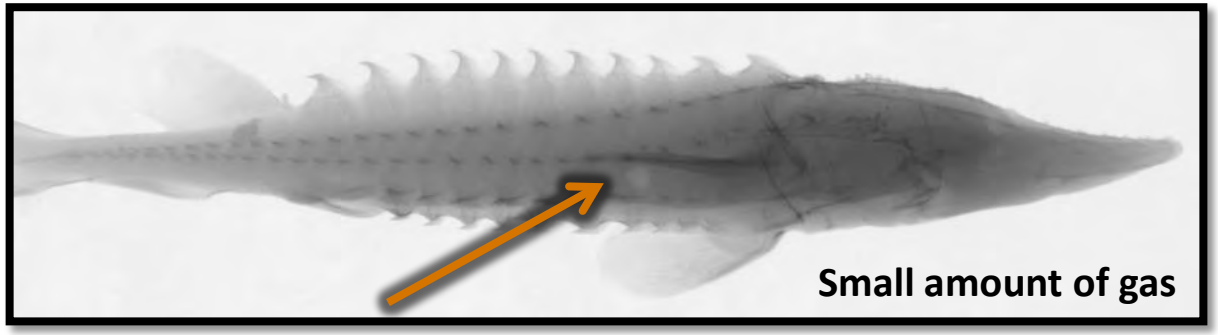


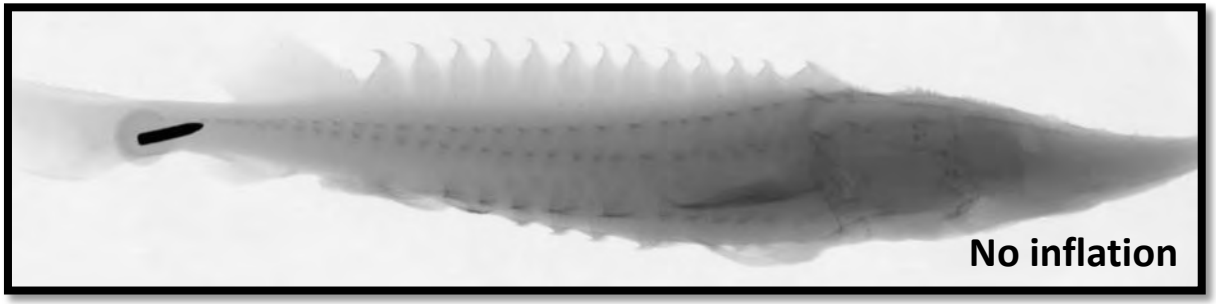


- Fish expelled gas from mouths with decompression at 75 dph
- X rays confirm inflation at 78 dph
- Second drift stages thought to be present in some species

Swim Bladder Inflation







- Large variation in the amount of gas in swim bladder and timing of inflation
- At time of study completion (91 dph), 58% of fish with inflated swim bladders
- Neither presence or amount of gas related to fish size

Evidence of Barotrauma

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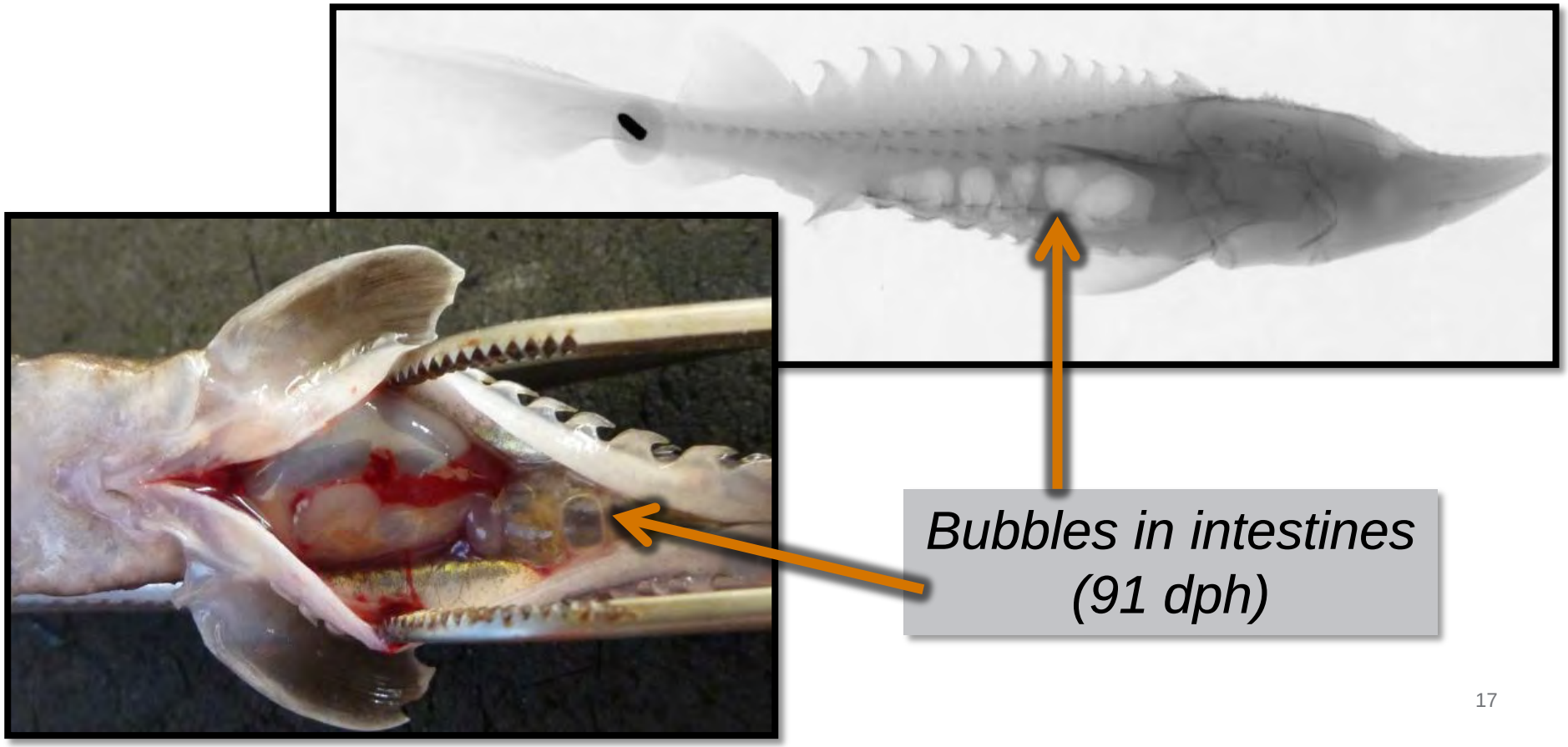
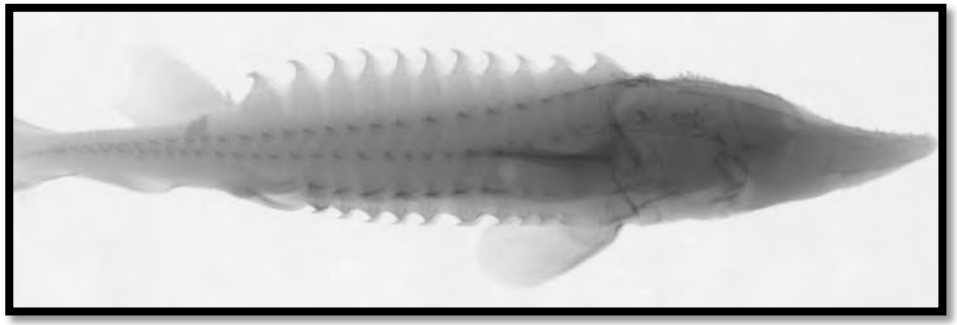
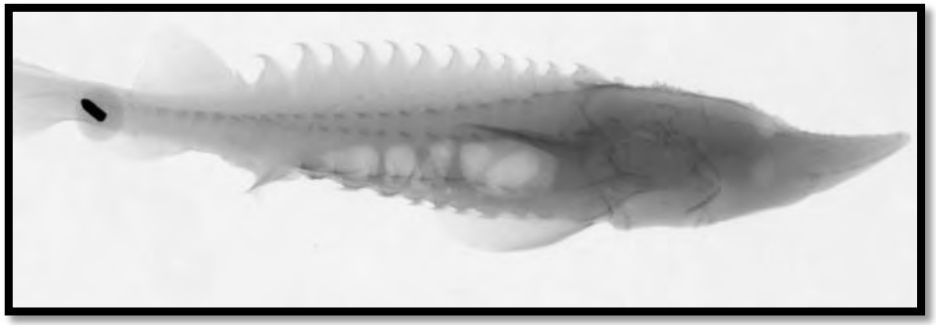
- After swim bladder inflation, gas seen throughout body cavity following exposures on several occasions
  - Confirmed with necropsies and X rays



Conclusions

- No evidence of gas in swim bladder during larval stage
- Possible link between the beginning of feeding and metabolic related barotrauma
- Swim bladder filled in juvenile stage
- May be dependent on temperature, behavior, or habitat
  - Fill sooner in deep habitats? With warmer temperatures in river?
  - Delay inflation in hatchery conditions?

Inflated swim bladder

Future directions

- Determine size that juveniles can carry a downsized transmitter
- Determine if behavior as larvae or juveniles involves dam passage
- Follow up with more detailed study of larval and juvenile fish
  - Swim bladder inflation temperature dependent or vary in field conditions
  - Derive relationships between pressure change and injury / mortality
- Use of these techniques on other species and in other regions