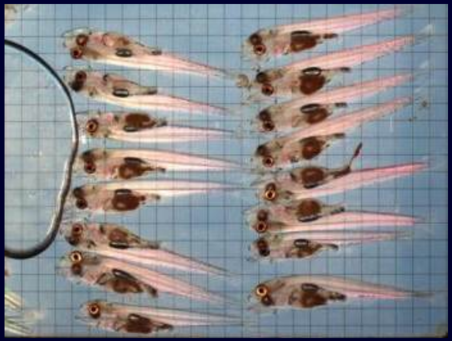
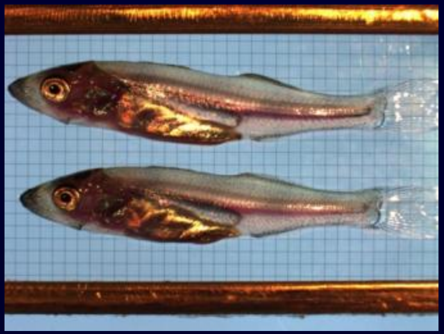


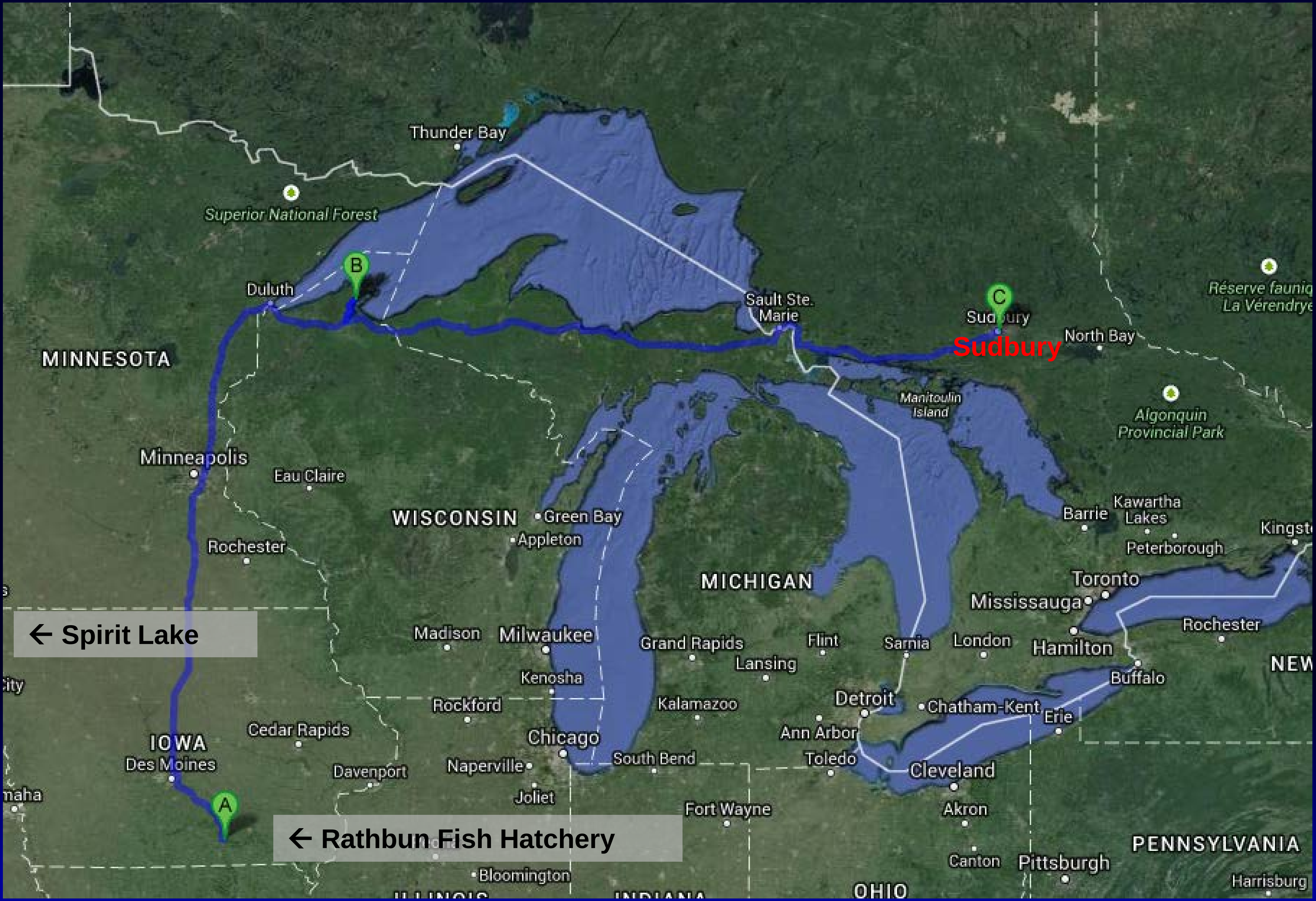


Intensive culture of walleye fry to fingerlings: Foundation of research in sport fish culture

J. Alan Johnson

Rathbun Fish Hatchery and Research Facility, Moravia, IA

Some slides prepared by Randy Esser, Jay Rudacille



← Spirit Lake
← Rathbun Fish Hatchery
Sudbury
A
B
C
Thunder Bay
Superior National Forest
Duluth
Sault Ste. Marie
Sudbury
North Bay
MINNESOTA
Minneapolis
Eau Claire
WISCONSIN
Green Bay
Appleton
Rochester
MICHIGAN
Manitoulin Island
Algonquin Provincial Park
Barrie
Kawartha Lakes
Peterborough
Toronto
Mississauga
Hamilton
Rochester
Buffalo
Madison
Milwaukee
Kenosha
Rockford
Chicago
Naperville
Joliet
Grand Rapids
Lansing
Flint
Sarnia
London
Kalamazoo
Detroit
Chatham-Kent
Erie
Ann Arbor
Toledo
Cleveland
South Bend
Fort Wayne
Akron
Canton
Pittsburgh
PENNSYLVANIA
Harrisburg
OHIO
IOWA
Des Moines
Cedar Rapids
Davenport
Bloomington

Rathbun Fish Hatchery

Rathbun Fish Culture Research Team:

"We don't produce the walleye, we make walleye production better."

Iowa's Walleye Culture Program

Stockings

Fry :

110-150 mil.

Pond fingerlings:

500,000-1.2 mil.

Nursery Lake fingerlings:

100-150,000

Advanced Intensive:

200,000

Walleye Culture

Walleye are a valued as sportfish and food fish.

- 3-4.5 million kg imported as food.
- 1.1 billion stocked in North American fisheries.

Fingerling production systems:

Intensive fry culture – Live or manufactured diets.

- 1972-79 Dry diet failures (Beyerle 1975, 1979)
- Live diet success (Howey et al. 1980)
- Currently:
  - Artemia to dry diets – Oneida Hatchery, NY
  - Dry diets only – experimentally by Iowa DNR, WI - NADF.

Pond fingerling habituation to dry diets

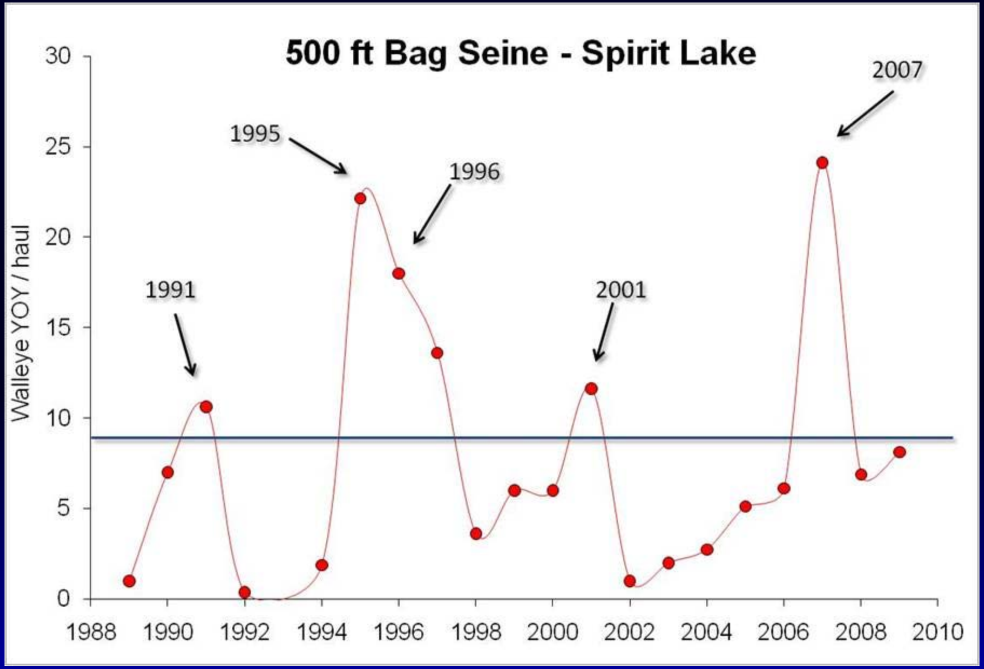
- 1965 – First reported (Cheshire and Steele 1972).
- 1970's Tim Nagel, Ohio DNR.
- Agencies currently in production: Iowa DNR , Ontario MNR, Vermont, Wisconsin.

Why 9-inch Fish?

- Pond to tank walleye culture began 1985 at RFH.
- Successfully rebuilt walleye population in Rathbun by 1989.
  - Biomass of walleyes longer than 17 inches was 0.9 lb/acre in 1987 and increased to 2.8 lb/acre in 1989; thus, the population biomass was tripled and the project goal was achieved (Mitzner 1992).
- Eight inch mean, six inch minimum - escapes predation.
- Better body condition, fat reserves for over-winter survival.
- Success in fisheries resulted in increased hatchery production goals.
- Stocked in broodstock lakes (10/ac.), other constructed lakes (5-10/ac).
- The densities of walleye in these lakes were not sufficient to meet the demands of the angler.
- Inconsistent recruitment, not over harvest, was the primary reason for the low densities and harvests of walleye.

Advanced Walleye Culture

- **Rear to 225 mm (9 inch) size.**
- **Purpose: sustain a fishery when fry recruitment is poor.**
  - **Fry recruitment highly variable – 3-5 yrs between yr classes.**
  - **50-mm fingerlings – poor survival, vulnerable to predation.**



Courtesy Michael Hawkins, IA DNR.

Fisheries Value

- Cost - $1.23 per 9-inch walleye. 10 fry/penny.
- What is the value of our walleye to a fishery?

- Iowa Great Lakes (Michael Hawkins data) –
  - Spirit, East and West Okoboji lakes,
  - 112,700 angler trips annually,
  - 36-40% of trips target walleye,
  - $23 per angler spent on a trip.
  - This walleye fishery generates
    - $18.30 per $1 spent on cultured walleye

Progress in walleye culture

In the past, the suitability of walleye for intensive production was questioned:

- **Poor survival on feed,**
- **Poor growth rates,**
- **Poor feed conversion,**
- **Prone to disease.**

Rathbun Fish Hatchery data is proof to the contrary.

- **1.4 feed conversion ratio.**
- **1.5 mm/d growth rate**
- **Survival >70% fry to 9”**

DNR

Research Projects

Research from fertilization to transportation.

Funded by Federal Aid to Sport Fish Restoration Grants.

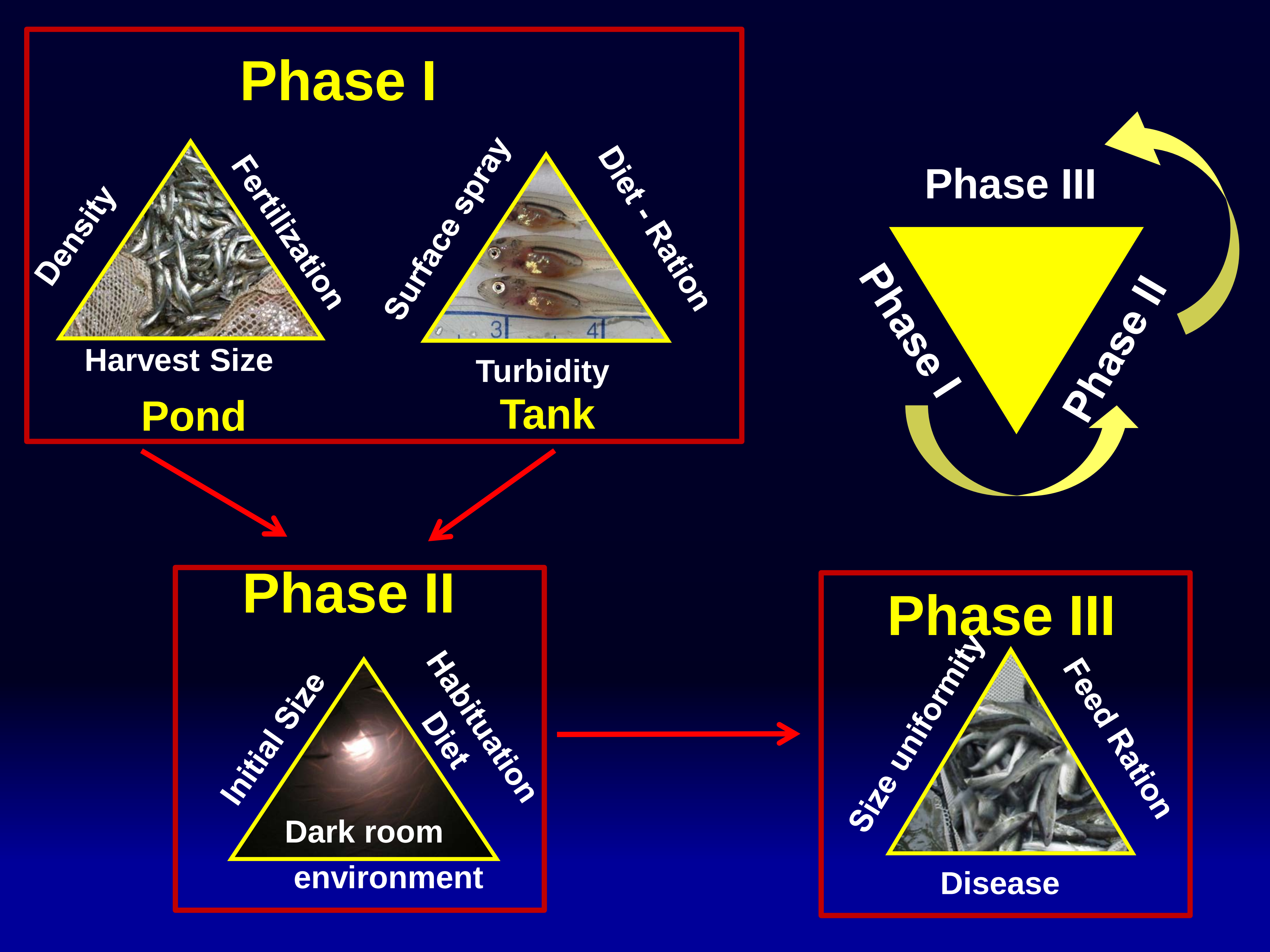
- Egg fertility - $0.001/fry
- Intensive culture - three phase system
  - 7022 - Pond reared fry to fingerlings
  - 7003 – Pond Fingerling Habituation to feed
  - 7034 - Growout to 225 mm
- Precious cargo – $5,000 per truckload.

Overview

Walleye production on formulated feed.

- **Consider challenging characteristics**
  - **Wild Broodstock sources.**

- **Feeding and culture techniques for walleye:**
  - **Larvaculture.**
  - **Grow out to 9-10”.**



Phase I
Density
Fertilization
Harvest Size
Pond
Surface spray
Diet - Ration
3
4
Turbidity
Tank
Phase III
Phase I
Phase II
Phase II
Initial Size
Habituation
Diet
Dark room
environment
Phase III
Size uniformity
Feed Ration
Disease

Keys to Success

Phase I Larval culture techniques

- Environment (tank, lights, water)
- Feeding (type and frequency)
- Husbandry

Phase II On growing

- Transition period
- Size grading

Phase III Growout

- Feed rates
- Control costs

Larviculture

Why intensive tank culture of fry?

	Pond Culture	Tank Culture
Biosecurity	**Low**	**High**
Fingerling supply	**Seasonal**	**Year round**
Capitol costs	**Land, ponds**	**Building, tanks**
Larval care	**Low**	**High**
Deformity	**Rare**	**Low**
Controlled environment	**Vulnerable**	**Controlled**
Mechanical failure	**Low**	**Vulnerable**

Bottom Line: Year-round harvest of food fish will require intensive fry culture.

Characteristics

Gas bladder inflation – physoclistus

Diets

- Planktivorous Fry 8-9 mm at hatch.
- Piscivorous from fingerling to adult

Coolwater species.

- Optimal growth 24-25ºC
- Upper lethal limit: 31-33ºC

Tapetum lucidum

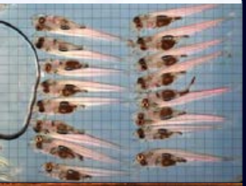
- Reflective surface at the back of the retina.
- Preadapted to life in low light environments (Moore 1944).

Phototaxis

- Positive - hatch to 21 days.
- Negative - 21 days through adulthood.

Important life stages

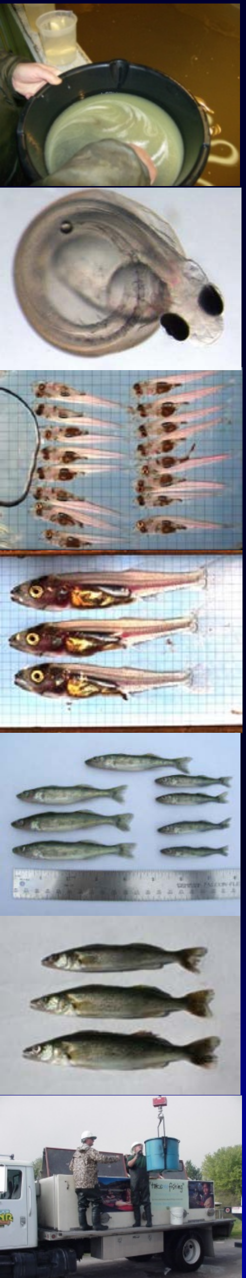


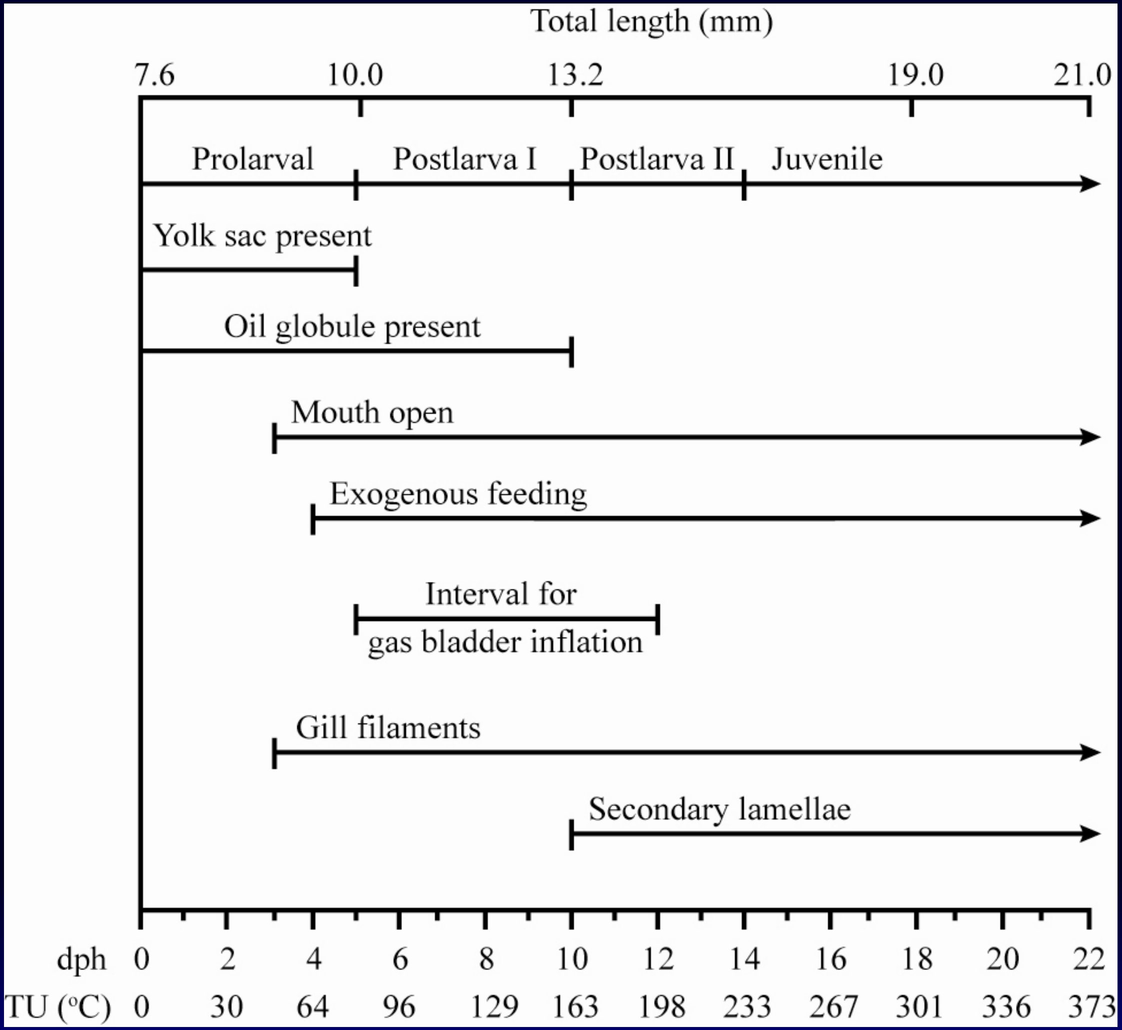




1. **Exogenous feeding: Feed intake by 4 to 5 dph.**
   1. **Oil globule absorption**
   2. **Yolk absorption.**
2. **Gas bladder inflation by 12 dph.**
3. **Shift in light response 21 dph.**

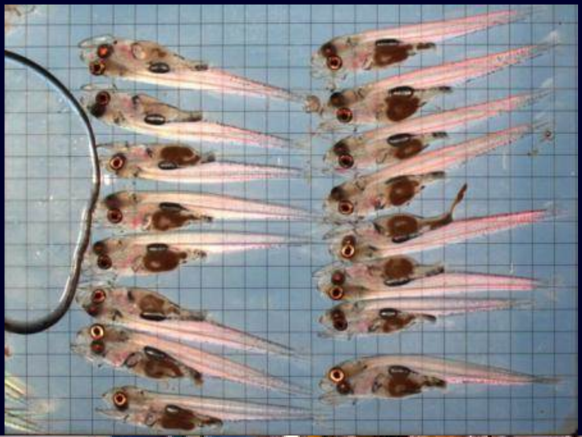
Important life stages

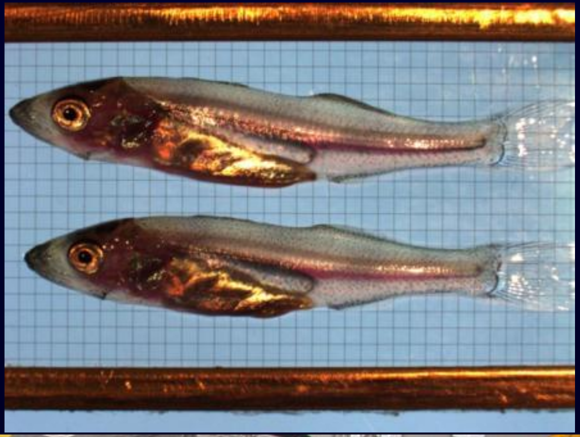




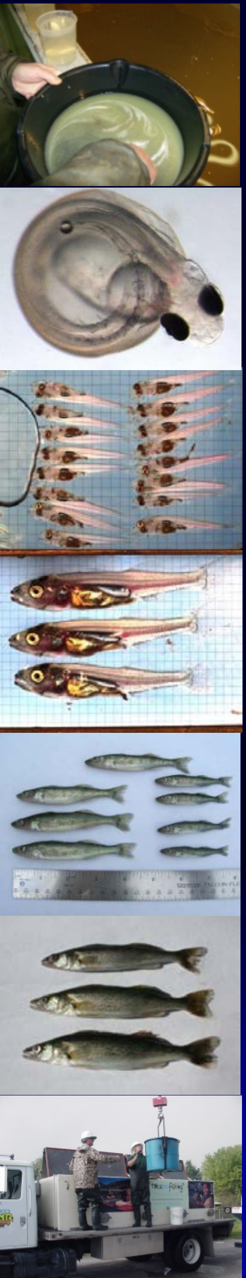
Ontogeny of walleye development through 22 d posthatch (dph). Temperature units (TU, ° C) are cumulative (e.g., 30 TU at 2 dph is sum of 2 d, each 15° C). Source FIGURE 13.1. Summerfelt et al. 2011.

Phase I Larviculture in tanks





Larvaculture - Artemia



1. **First feeding to 125 mm.**

Quebec's La Station Piscicole de Baldwin-Coaticook.

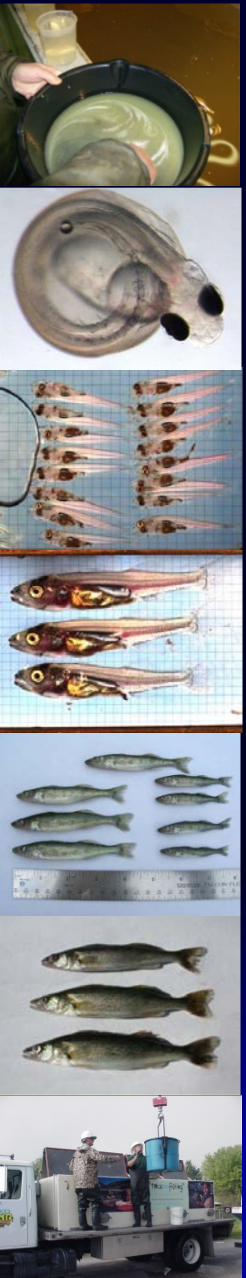
- 25% survival during habituation to feed.
- To a fall fingerling – 70% survival
- 17.5% overall survival – 107 mm.

New York's Oneida Hatchery

- 40 days of Artemia, 10 day habituation to diets (50d)
- 30-50% mortality during habituation to feed.
- 25% survival from fry to 125 mm.

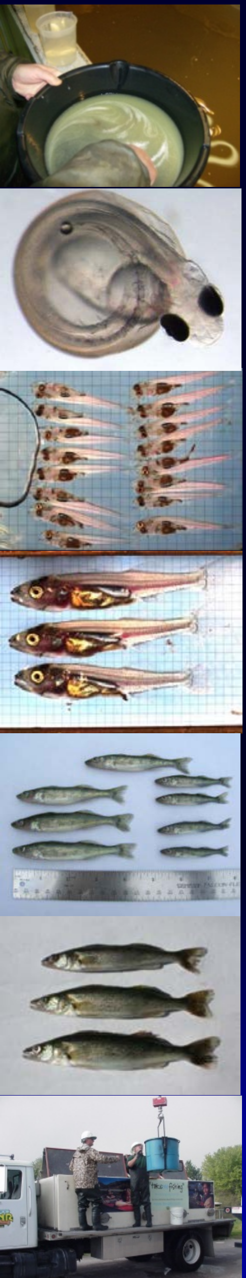
Oneida Fish Hatchery, NY

Larvaculture - Diets



2. **Manufactured diets.**
   - Research or production at Rathbun, ISU, NADF, and VT.
   - First feed at 2 days post hatch.
   - 50% to 80% survival at 35 days post hatch.
- Key techniques:
   - Surface spray
   - Turbid water
   - 100 lx light
   - Frequent feeding
   - Diet - Otohime.

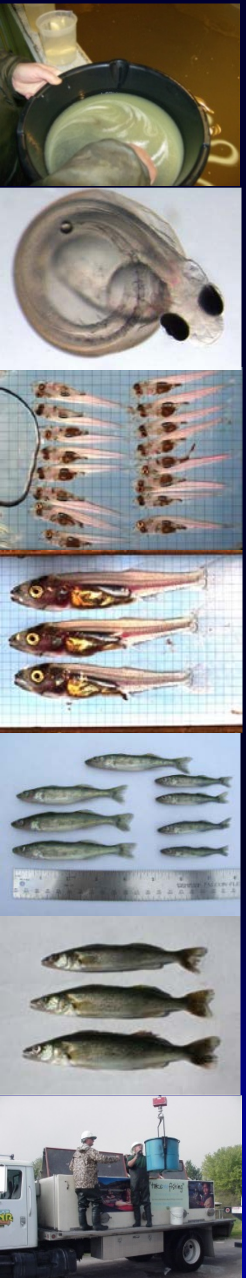
Fry system



Components for single pass culture

- Water source
- Water temperature control.
- Degassing for heated water.
- Clay slurry system
- Water process tank
- Pump or gravity flow
- Surface spray pump system.
- Culture tanks with screens.
- Fish feeders, timer.

Fry system



Water Source

- Surface water : Rathbun Fish Research
- Declorinated tap water: Iowa State University
  - Activated Carbon filters
  - pH modification, add dilute acid by pH controller.
- Well water: Wisconsin NADF
- Check your water suitability for fish culture…

Temperature control

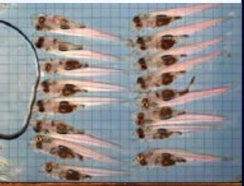
- Desired temperature range: 10 C to 21 C.
- Begin with incubator temperature: 10-15 C?
- Increase to 18.5 by day 5 to stimulate feeding.
- Increase to 21 C to increase growth.

Degassing for heated water

- Vertical degassing column.

Fry system







Clay slurry system

- Clay mixing tank (200 L)
- Agitator, stirrer.
- Clay delivery pump, peristaltic or centrifugal.

Two method of clay addition:

1. Direct injection to culture tanks by timed and pumped slurry loop.
2. Water process tank and delivery of mixed culture water.

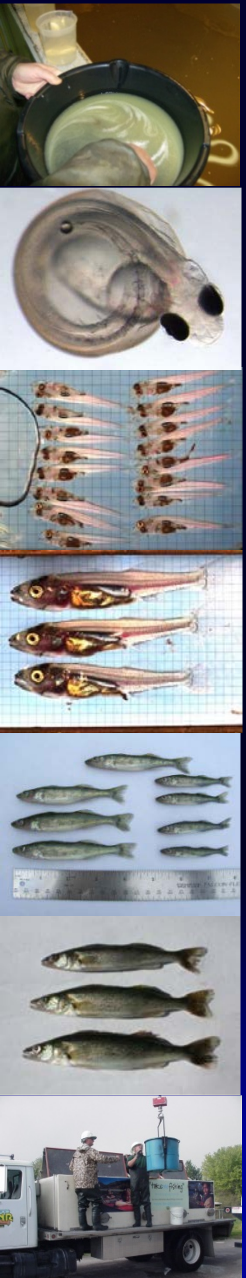
Water processing tank

- Tank to blend clay slurry with culture water.

Pump or gravity flow

- Pumping requirements or gravity head to be determined by culturist of engineer.

Clay Turbidity



Defined.

- **Optical property that causes light to be scattered and absorbed rather than transmitted in straight lines. APHA 1998.**

Clay turbidity

- **Larvae distribute in the water column and do not cling to the tank walls and surface.**
- **Improves feed acceptance, increases growth rate (2-3X)**
  Bristow and Summerfelt (1994); Bristow (1996).

Artificial turbidity

- **Achieved by OM-4 clay (K-T Clay Co.)**
- **50 NTU turbidity.**

Clay slurry tank

- **25 g/L stock solution.**

Clay Slurry System

Components.

- 200 L Tank
- Agitator - 0.33 hp.
- Peristaltic pump.
- Can run a 12 gpm system for over 24 h.

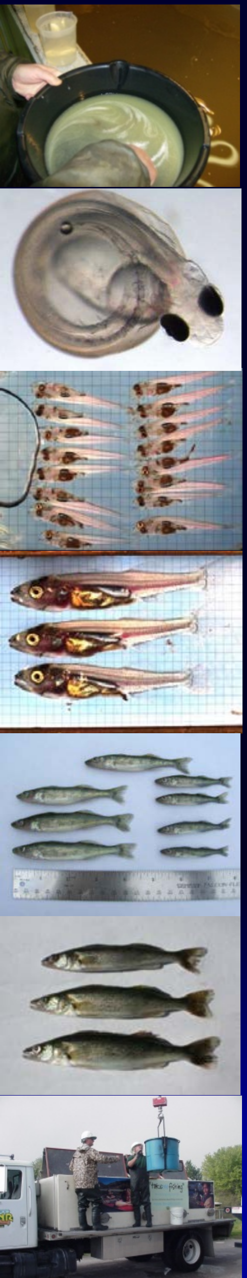
Slurry added to water process tank then pumped to culture tanks.

Water process tank

Components

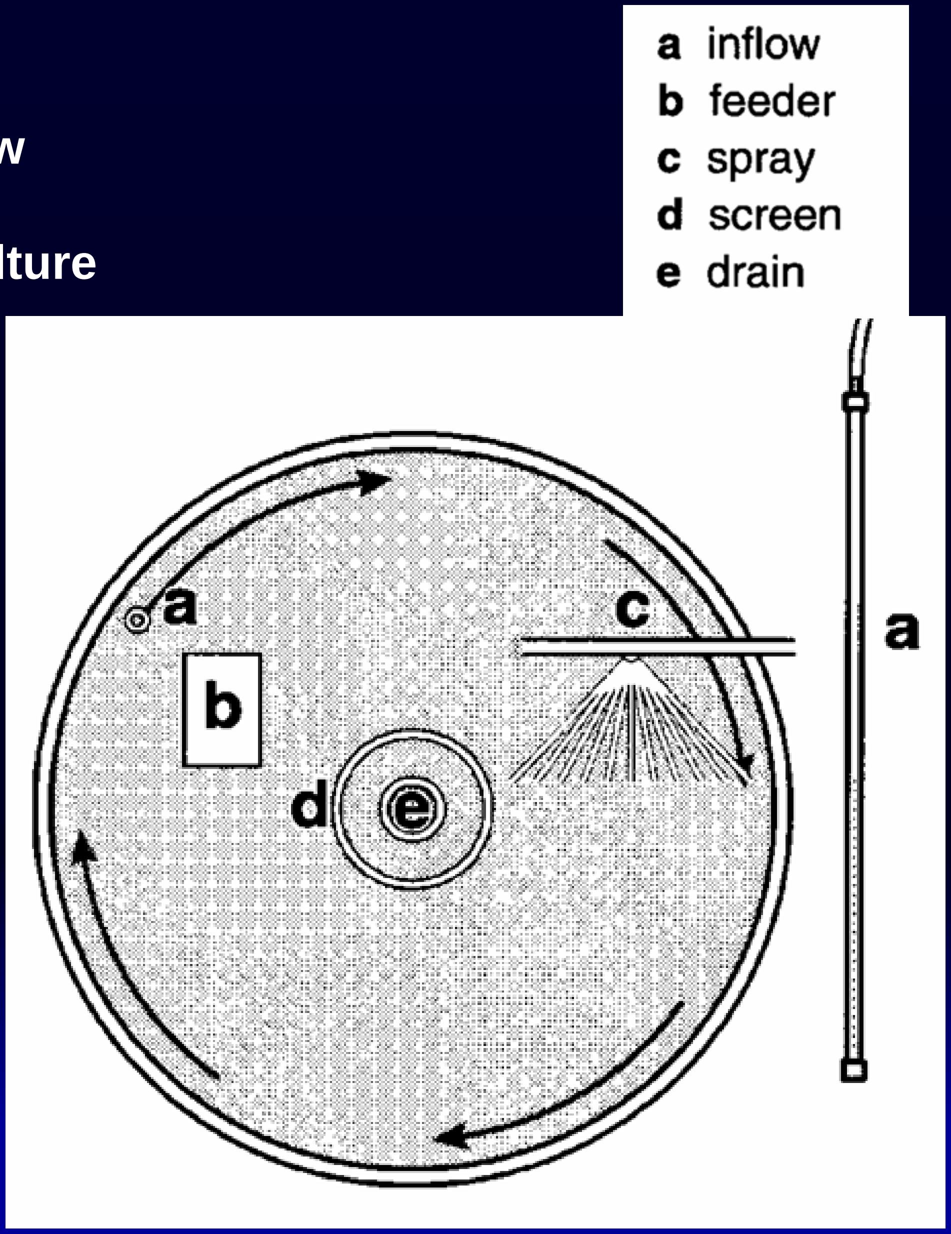
- Drop in heaters, 36 KW total.
- Two 0.5 hp Teel pumps
- Water level switch.
- Degas column
- Submersible Pump
- 15 gpm upper limit

Tank Design



Tank

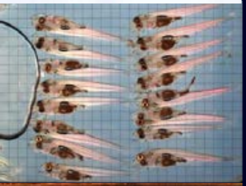
- Cylindrical, circular flow pattern.
- Diagrams of a 275 L culture tank.
- Surface spray bar.




I-2-3

Tank Design

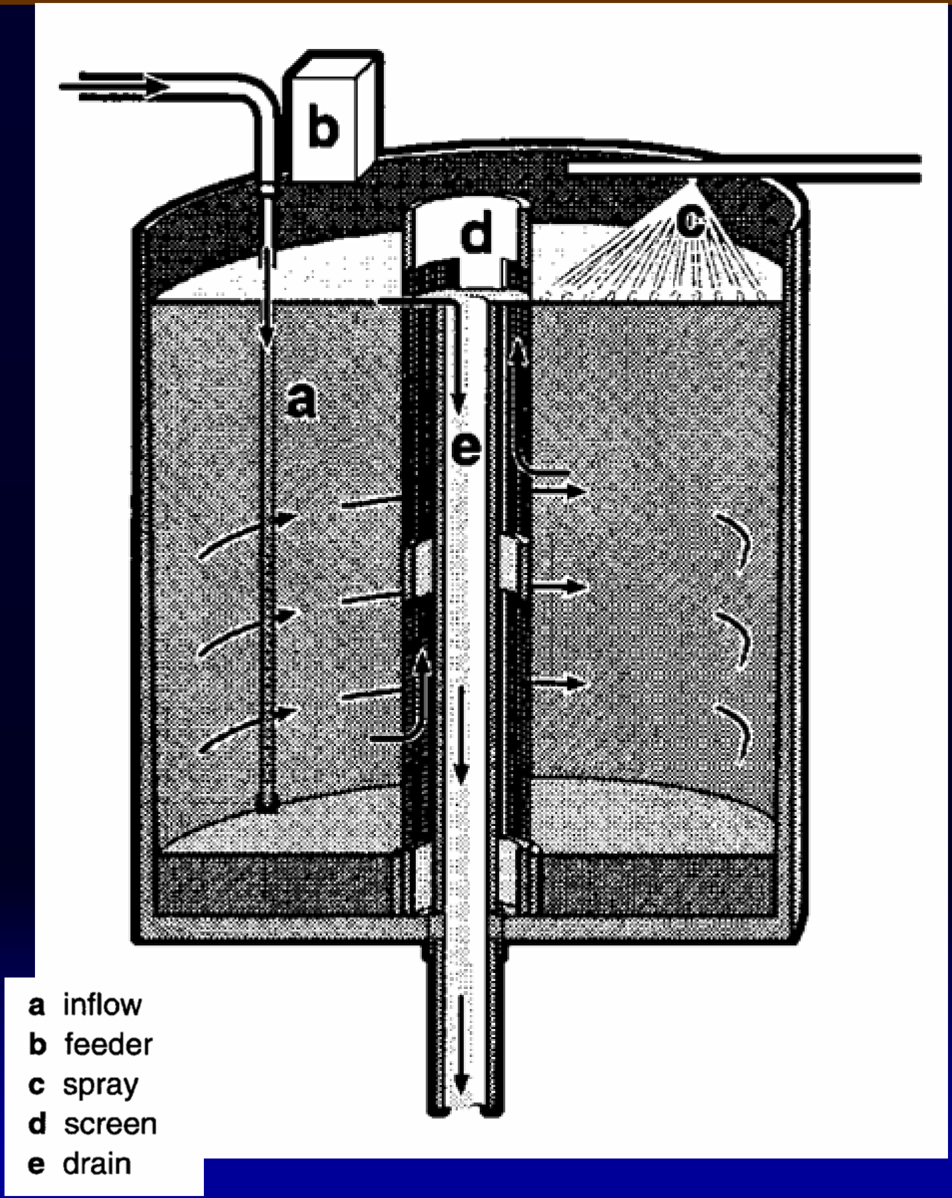






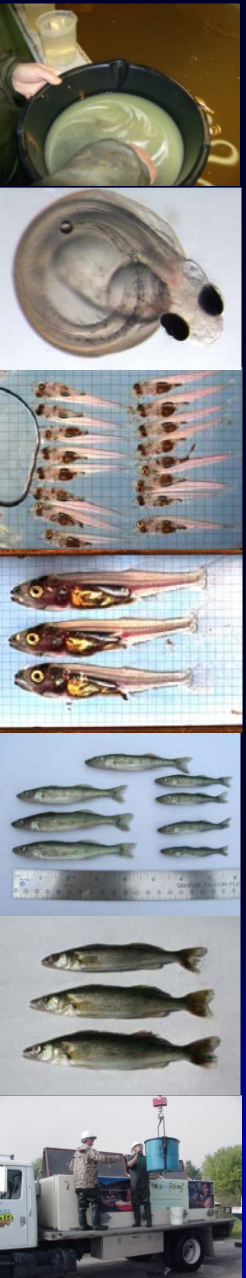
Note

- Black side walls to prevent reflection and fry cling.
- Grey bottom.
- Stand pipe screen to prevent fry escape.




1-2-3

Screens

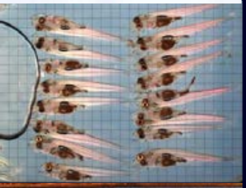


Tank Screens

- Proper size?
- Set a mort on the screen and visually compare before increasing screen size.
- Note the red warning color of 1 mm screen.
- Large surface area due to small size, biofilms, fungus that can plug screens.

Surface spray







Gas bladder inflation

- Must initiate GB inflation by 12 DPH.

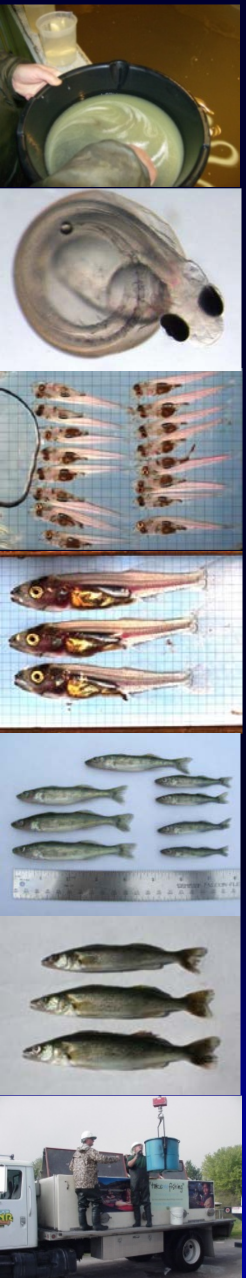
Surface film

- Oils from dead fish
- Waste feed oils
- Prevents walleye from breaking surface tension to ingest an air bubble to inflate their gas bladder.
- After initial gas bladder inflation, gas gland regulates inflation.

Surface Spray

- Force of downward spray clears surface film.
- Allows fry to ingest air bubble.
- Crucial development in culture technique to produce fish with functional air bladders.
- Surface spray continues after inflation to aid in feed dust removal.

Tank Environment



Larvae are photopositive.

- Light reflected on water surface and tank walls concentrated the larvae on the walls and surface.

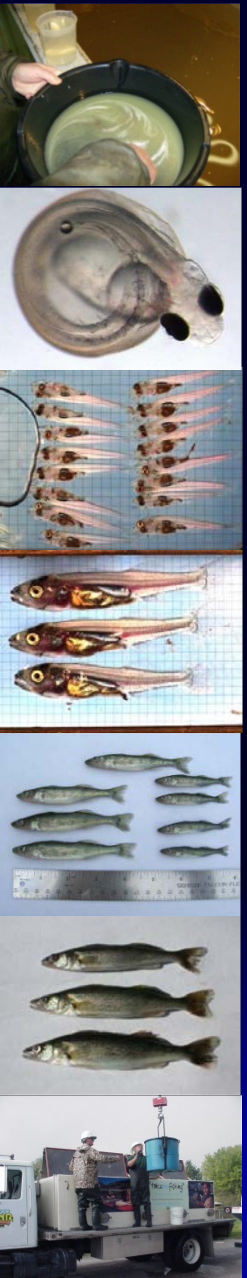
Overhead lighting

- Each tank has an overhead light, adjustable lux.
- Set light to about 100 lux at the tank surface.

Black tank walls

- Reduces light reflection on tank walls.
- Prevent surface and sidewall cling.

Stocking density



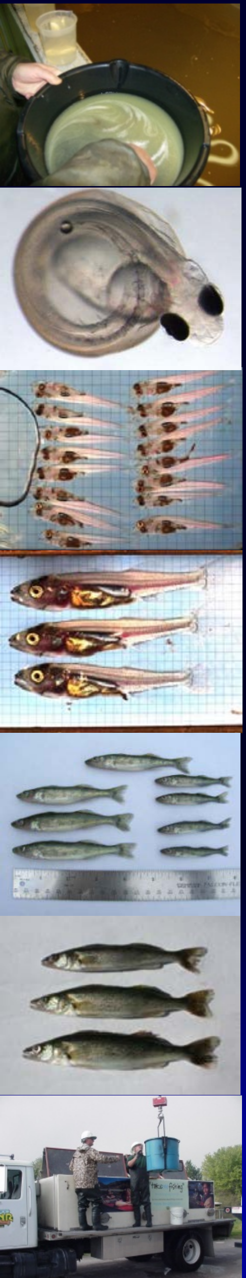
Initial stocking of tanks

- Range of 10 to 1,000 fry /L (multiple sources).
- Successful studies used 15-100 fry/L
- Rathbun uses 30 – 40 fry/L.

Consider final density

- Previously at Rathbun we used 40 fry/L:
  - Typical temperature 18.5 C, duration was 28 dph, 28 mm fish.
- To successfully rear fry to a larger size we reduced density.
  - Temperature was increased to 20 C
  - Duration increased to 35 dph, and density was reduced to dphReduced initial density to 30 fry/L.
  - Achieved 42 mm fish.
  - Density of 15 g/L

Feeders



Feed

- Dry micro-particulate feed.
- Sizes: 300 microns to 1 mm during fry culture interval.

Frequency

- Frequent feedings: 5 minute intervals

Amounts: 4 g/1000 fry and up.

Need for a precise feeder:

- 8,000 fry; 32 grams/day
- 5 minute intervals (288 feedings)
- 0.11 g/drop.

Feeders

Types:

- **Vibratory (Sweeney Feeder) –not precise**
- **Solenoid (AMD Feeder) – precise**
- **Auger-type (no current manufacturer) – precise.**

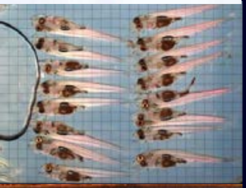
Husbandry

Daily Tank Cleaning

- Squeegee side walls
- Siphon tank bottom, waste collection, mortality counts.
- Daily screen cleaning.

Water quality







Daily

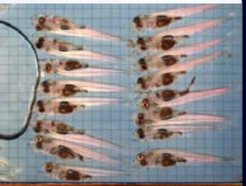
- Dissolved oxygen.
- Temperature (DO meter and logger).

Weekly

- pH
- Total Ammonia Nitrogen (calculate NH_3)
- Turbidity (or as needed).

Performance







Check ontogeny and performance regularly

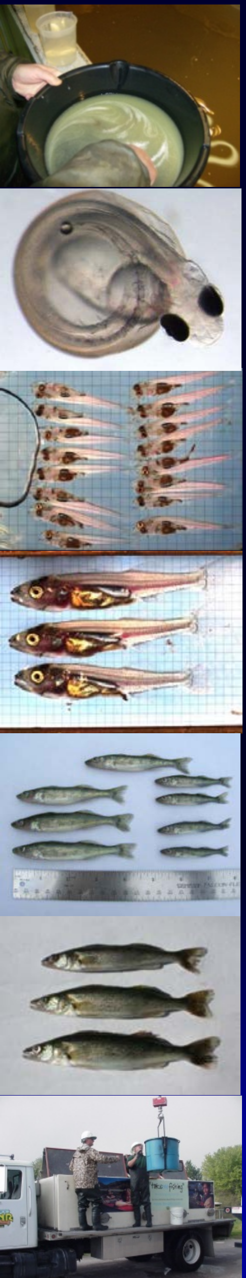
- Gas bladder inflation (GBI).
- Food in the gut (FIG).
- Growth: total length, weight.
- Deformity
- Typically 25 fish per tank.

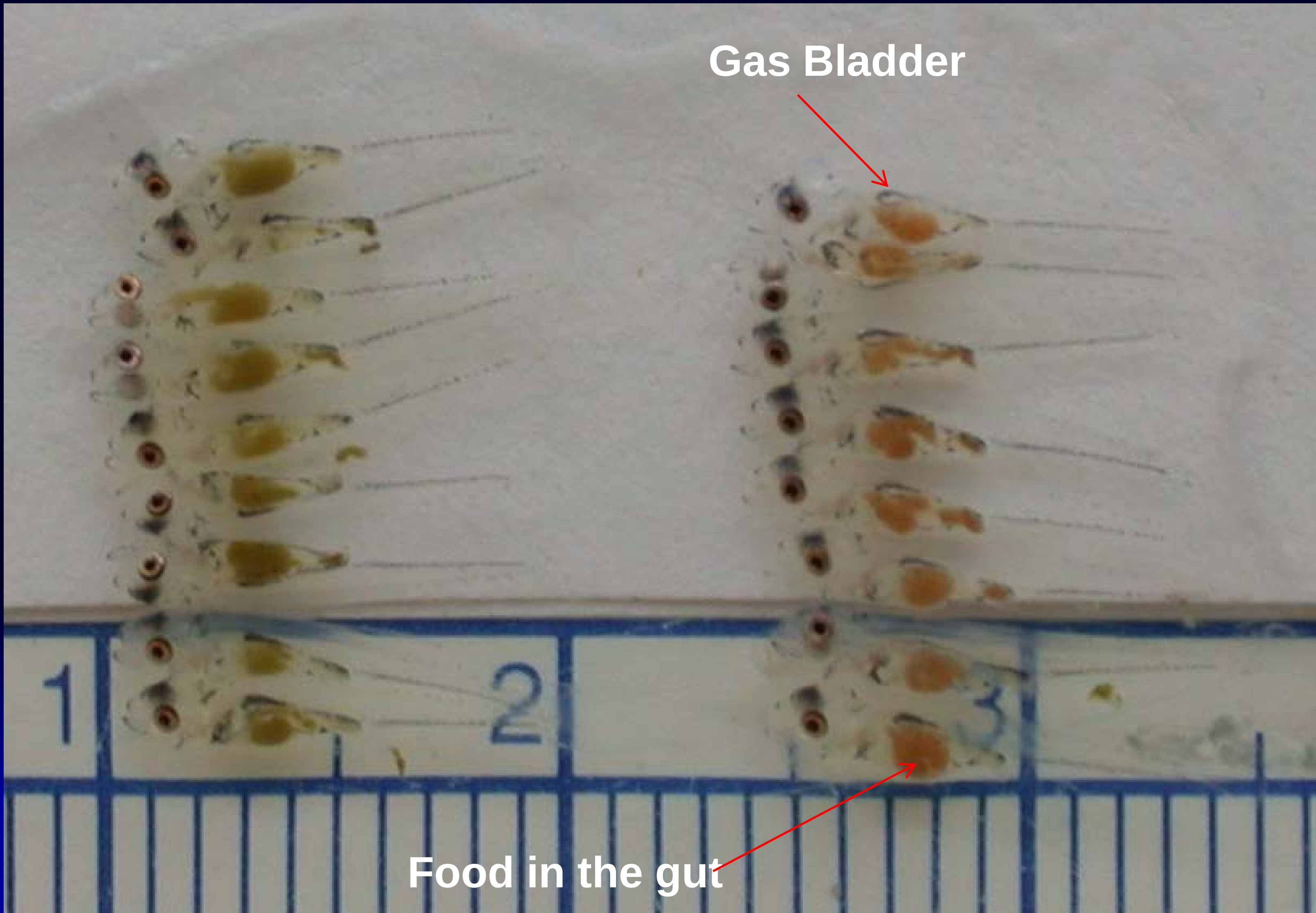
Records are important for post analysis of success and failures.

DPH →	3	7	14	21	28	35
TL (mm)	✓	✓	✓	✓	✓	✓
FIG/GBI	✓	✓	✓	✓	✓	✓
W (mg)	✓		✓		✓	✓
Deformity			✓	✓	✓	✓

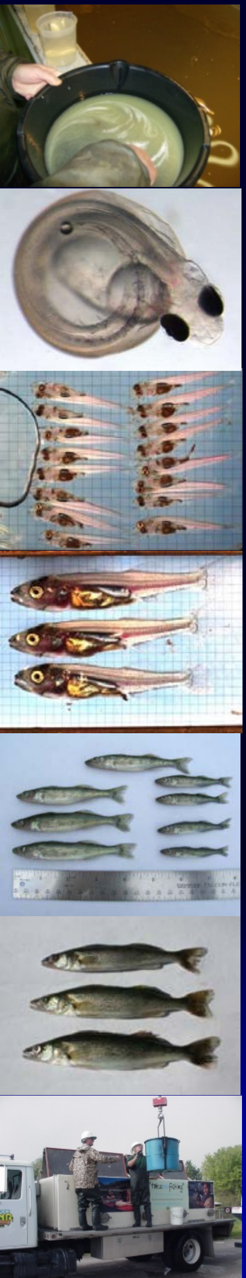
Performance

7 day old larva (11 mm)

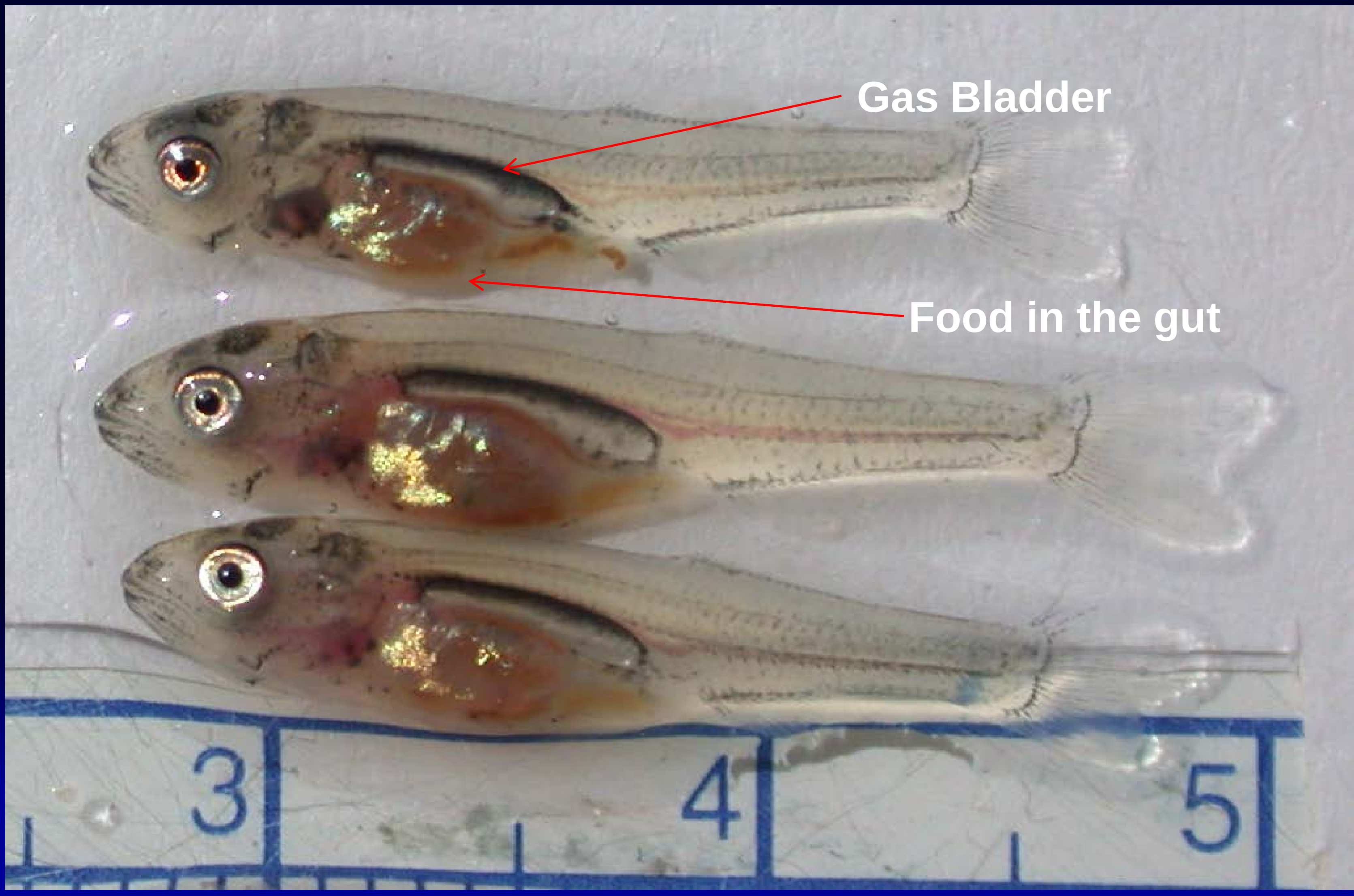




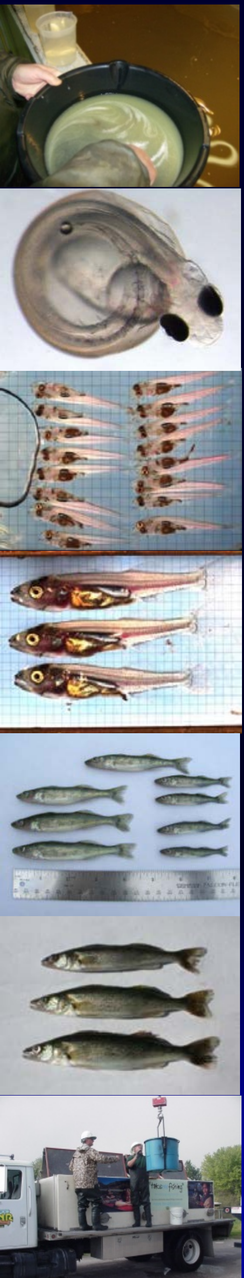
Performance

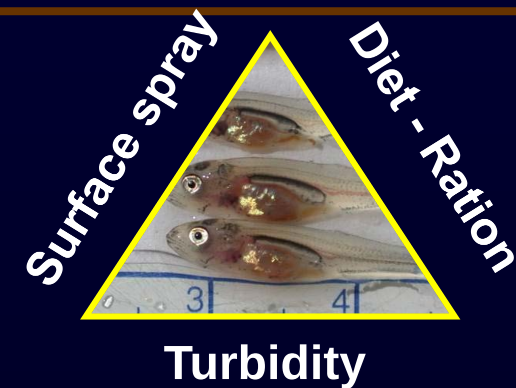


21 day old larva (23 mm)



Diets and feeding





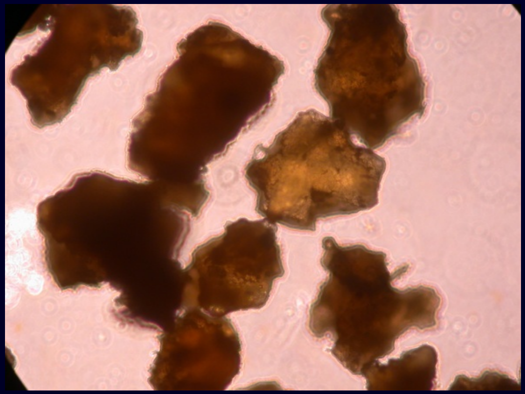
Changing strategies:

- Goal to produce 42 mm fish, 0.57 g.
- Reduce density from 40 fry/L to 30 fry/L.
- Increase temperature from 18.5˚ C to 21˚ C.
- Longer culture interval: up to 35 dph.
- Flow rates from 0.5 to 2 exchanges/hour.
- Started on grower diet.

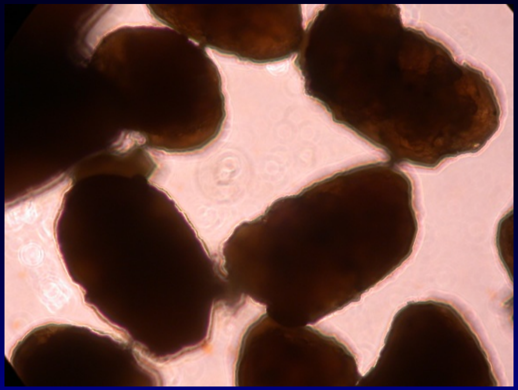
Larval diets

Diet formulation research.

- 1997-2002 Rick Barrows formulated 10 diets.
- BioKyowa: 61% survival, 23.5 mm length
- Walleye Starter: 50% survival, 18.3 mm length.



Ingredient	WS 2000
Krill meal	27.0
Fish meal	26.3
Invert powder	14.0
Liver meal	9.0
Wheat gluten	5.7
Fish oil	5.5
Vit. Premix	3.0
Iso paste	3.5
Tetra-paste	2.7
Nano-paste	2.8
Stay-C	0.5



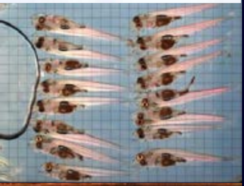
Larval diets

Commercial diets.

- BioKyowa pre-2001 was the standard.
- We have evaluated five commercial diets.
- Otohime is currently the best diet we have evaluated that is on the market today.

Diets	Survival (%)	Length (mm)	Age (dph)
BioKyowa	62.4	24.2	24
Gemma	39.4	27.3	27
Otohime	54.7	34.0	31



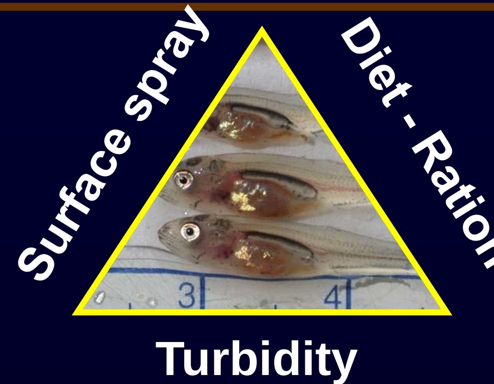


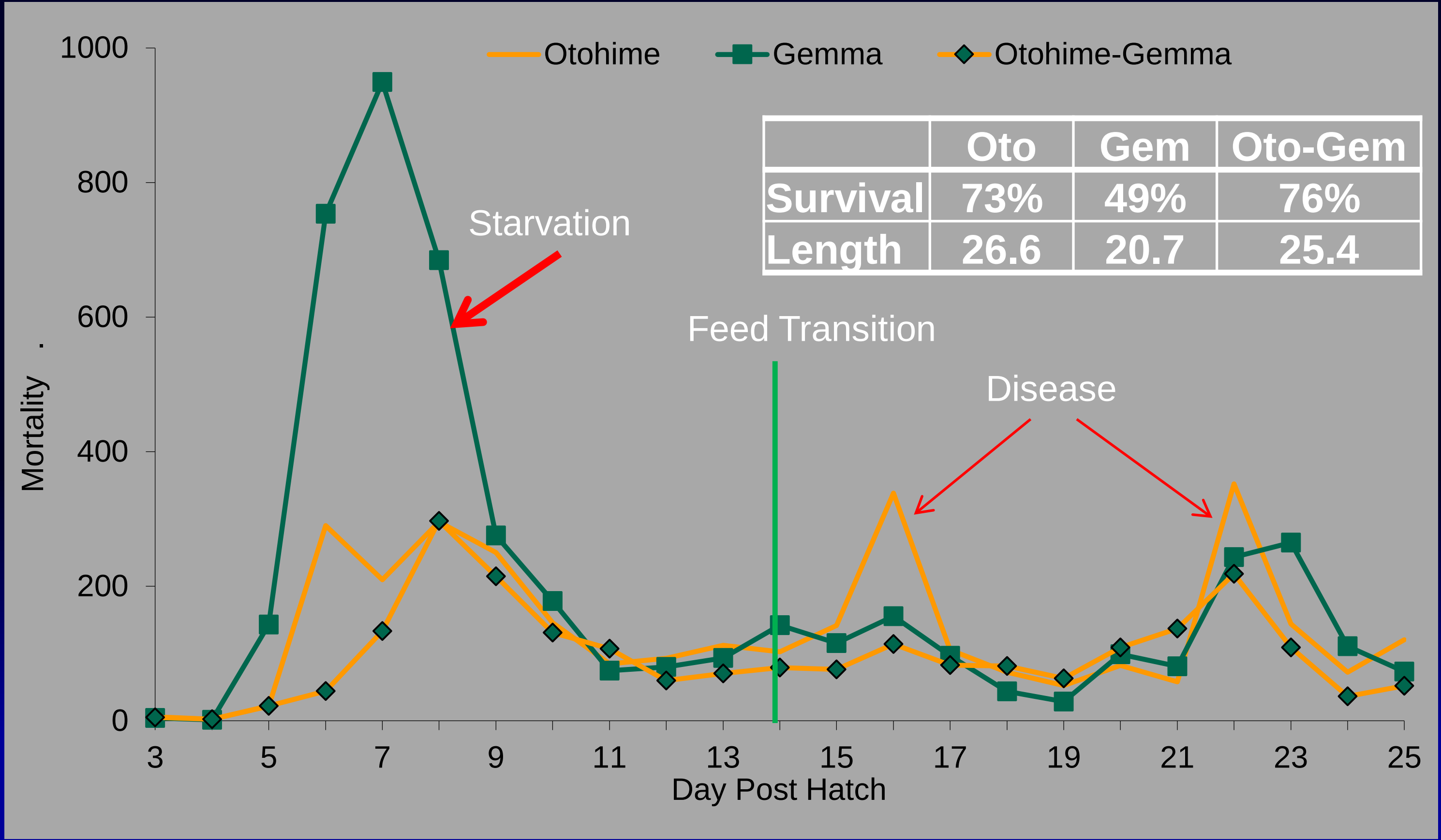


Larviculture - diets

Starvation vs disease:

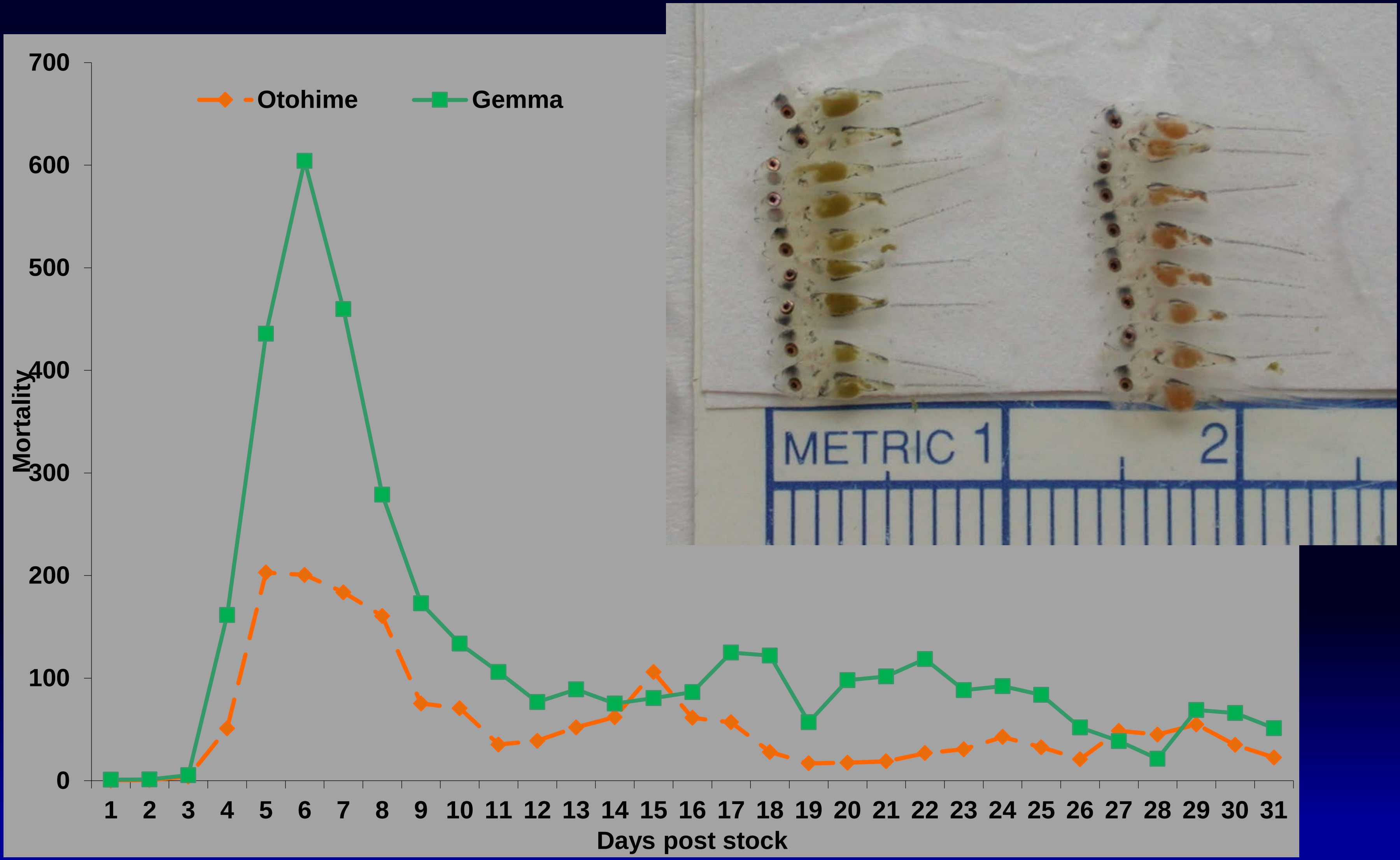
- Palatability differences in diets.
- 2007 diet trial.



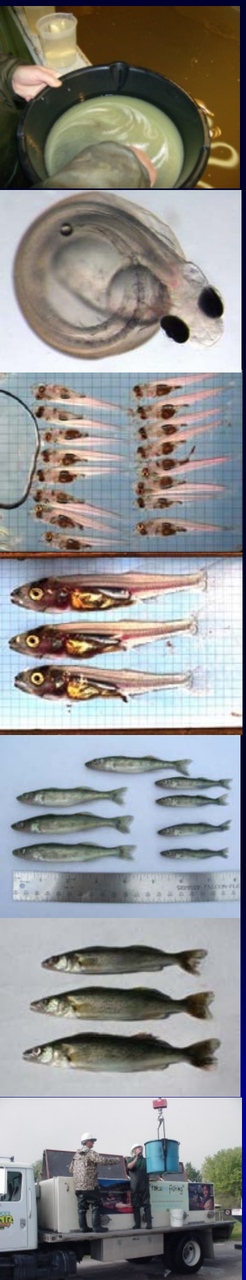


	Oto	Gem	Oto-Gem
Survival	73%	49%	76%
Length	26.6	20.7	25.4

Larval diets

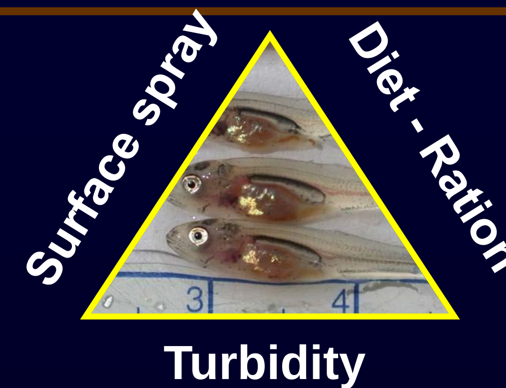


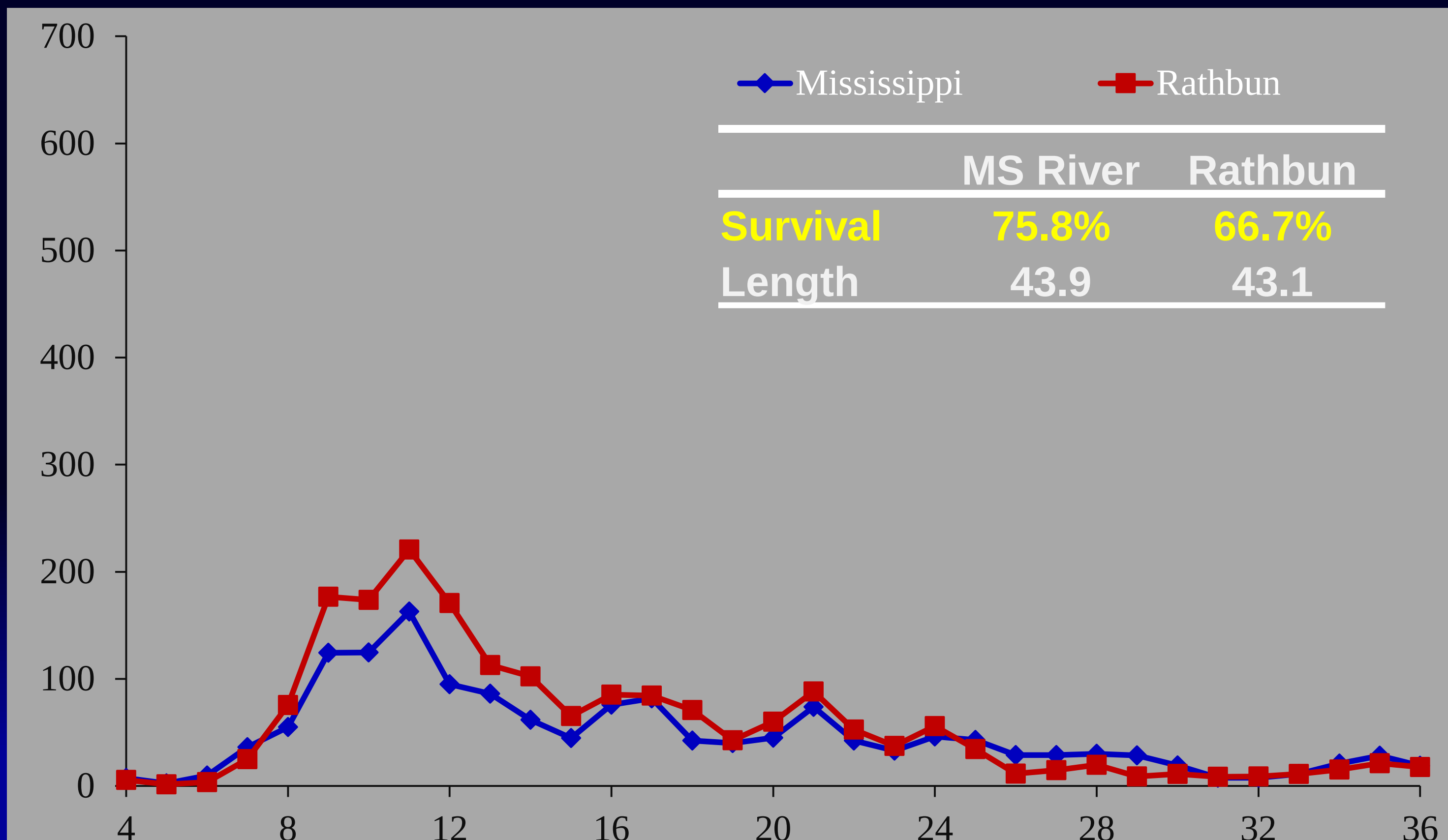
Stock difference?

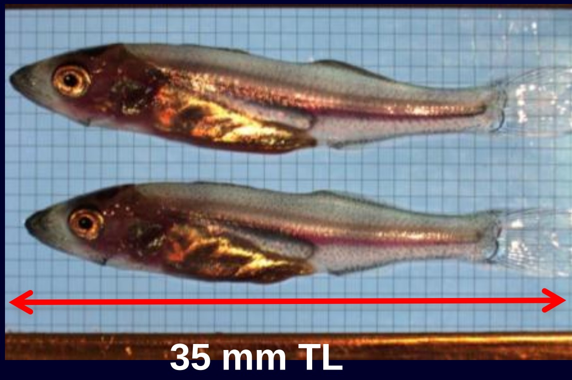


Broodstock sources:

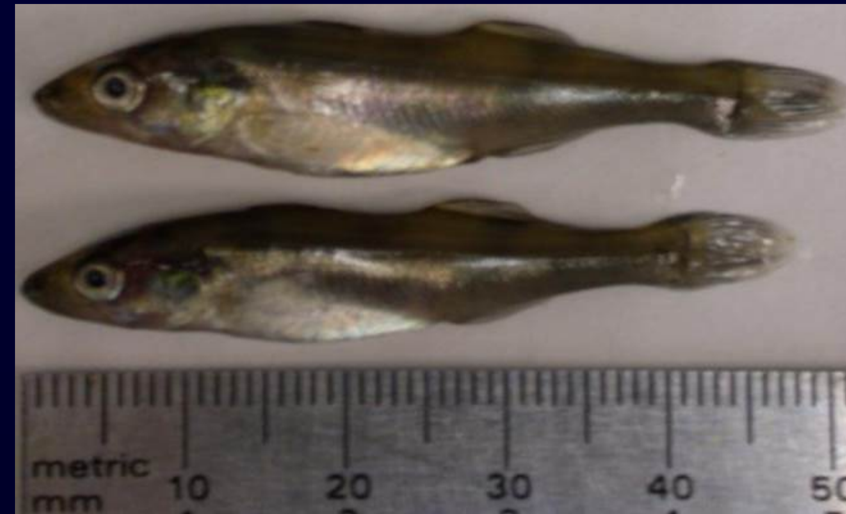
- Mississippi River or Rathbun
- 2012





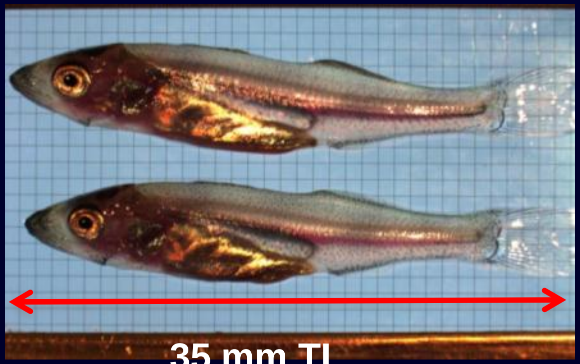


Pictures are equal scale



Intensive reared fry had less than expected survival in transition to grower diets.

- **Fingerlings at 25-30 dph are 25-32 mm.**
- **Scale development initiated at 24 mm complete at 45 mm.**
  - **Priegel (1964)**
- **Mechanical damage allows entry of Columnaris.**
  - **Huissain and Summerfelt (1991)**
- **“Transition period” has been a problem for larviculture.**
  - **Barrows (1996) discussed need for transition diets.**
- **Tank culture of pond reared fingerlings best above 0.57 g. (about 42 mm).** **Johnson and Rudacille (2010).**



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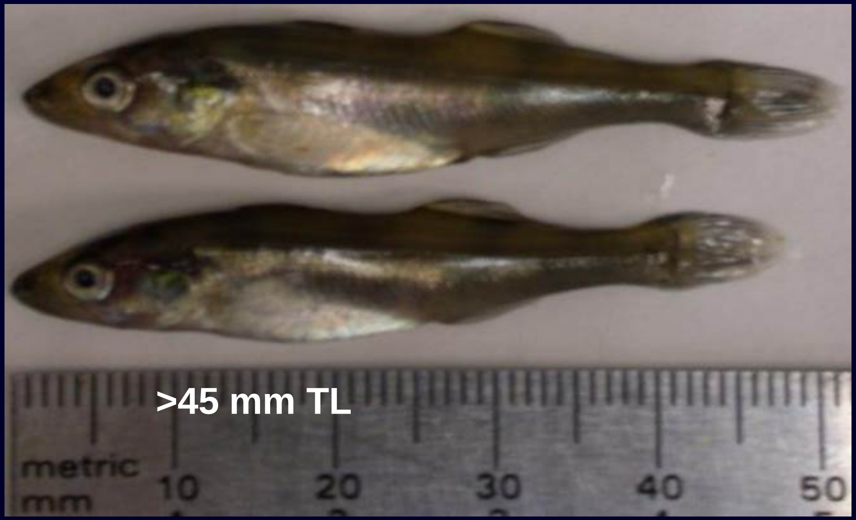


Theory: To improve survival after tank larviculture, produce larger fish, 0.57 g or 42 mm fish.

2012 Methods to increase growth:

- **Increased temperature. Previous standard was 18.5˚C. While pond temperatures average 21˚C.**
- **Feed, growth rate predictions. Monitor waste.**
- **Water flow increase as needed.**
- **Room for growth – reduce density from 40 to 30 larvae/L.**

2012 Larviculture

Study design:

Tank | **Pond**

MS River Broodstock
Exelon, Cordova, IL

Spirit Lake Broodstock
Rathbun Lake, IA

2012 Larvaeculture

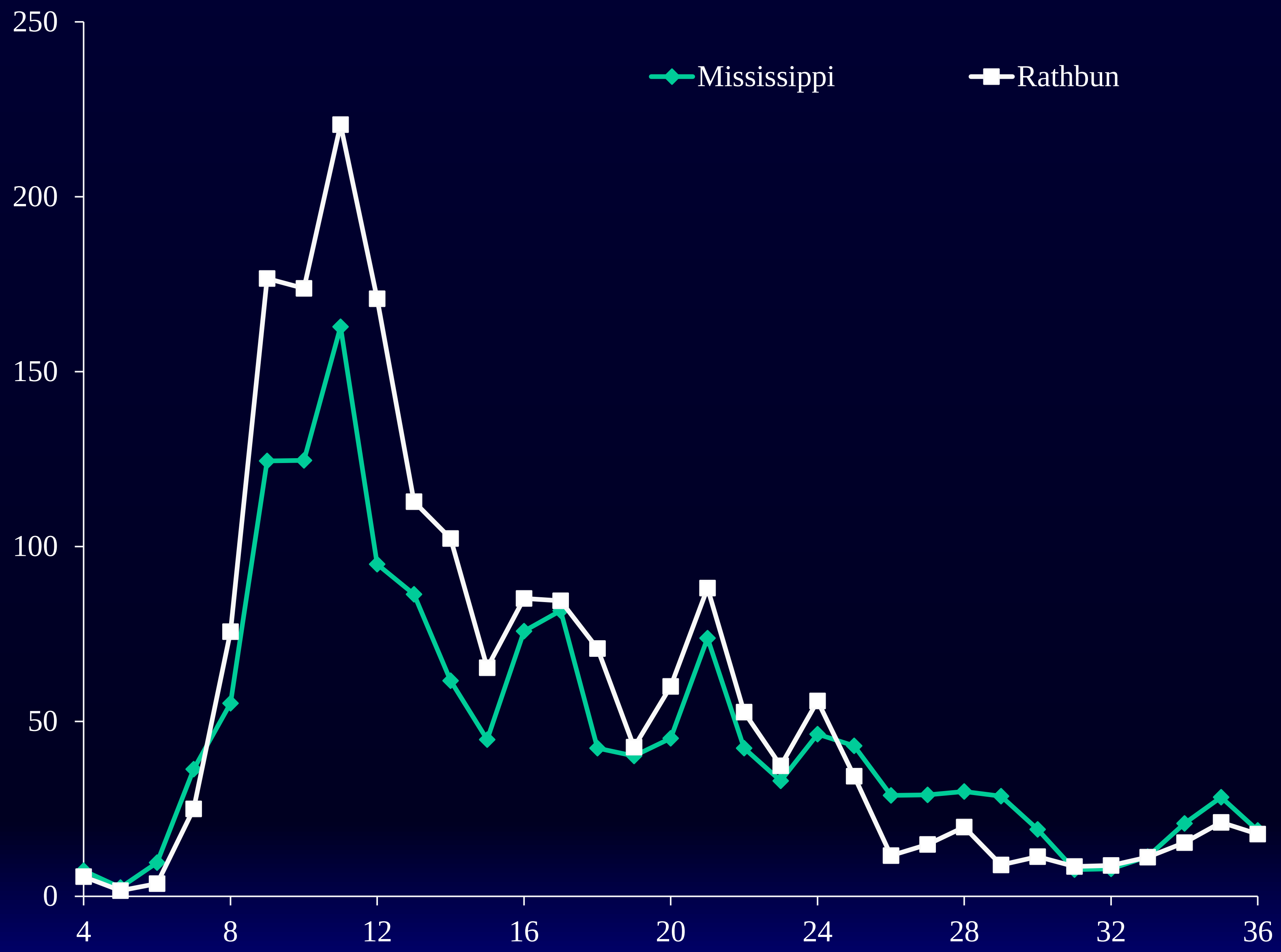
Larvae were from the same lot (jars) of eggs for respective strains.

Tanks were stocked on 19-April (2-3 DPH)

- Standard procedures, exception of temperature and density.
- Culture period: goal to reach 35 DPH.

Ponds were stocked on 20-April (3-4 DPH)

- Mixed Alfalfa-Soybean meal fertilization
- Culture period: reach 0.57 g size.



2012 Mortality Curve - stock

Results

Performance comparison of walleye strains in tank larviculture.

	MS River	Spirit Lake	*P*-value
Survival (%)	75.8%	66.7%	0.0095
Mortality (%)	19.2%	23.3%	0.0105
Unaccounted (%)	5.0%	10.0%	0.0862
Length	43.9	43.1	0.2683
Weight	0.665	0.684	0.5272
W_R D35	83.9	87.2	0.5338
Deformity (%)	7.5%	5.6%	0.5060
Density (g/L)	15.6	14.2	0.0290
mm/d 28-35 DPH	1.51	1.38	0.2355

Results

Performance comparison of walleye strains in tanks and ponds.

	Tank		Pond	
	MS River	Spirit Lake	MS River	Spirit Lake
Survival (%)	75.8%	66.7%	88.7%	87.6%
Length	43.9	43.1	40.3	44.2
Weight	0.66	0.68	0.47	0.56
W_R	83.9	87.2	75.1	70.6
Culture DPH	35		30.5	36
Temperature (C)	19.7		20.6	

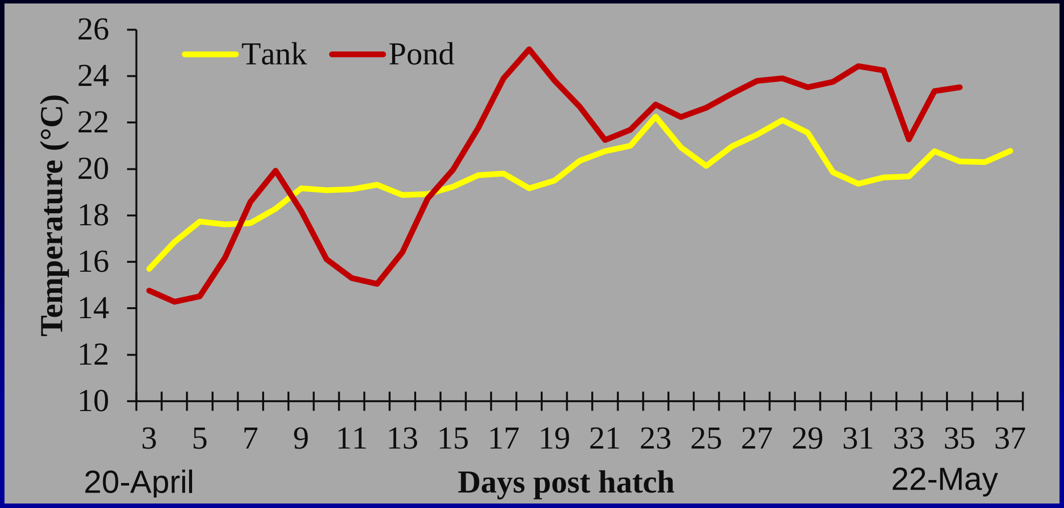


Table 2. Feed ration fed, temperature, and tank water exchange rate (R) during 3-35 days post hatch (DPH) at Rathbun Fish Culture Research Facility, 2012. Johnson and Esser (2012) Annual Federal Aid Report.

		Flow		Fry	Fry	Otohime (% of ration)			
DPH	° C	R	Feed Rate	L	W	B1	B2	C1	C2
3	15.7	0.44	4g/1000	8.4		50	50		
4	16.9		4g/1000			50	50		
5	17.7		4g/1000			50	50		
6	17.6		4g/1000			50	50		
7	17.7		4g/1000	10.8		50	50		
8	18.3		4g/1000			50	50		
9	19.2		4g/1000			75	25		
10	19.1		4g/1000			75	25		
11	19.1		4g/1000			50	50		
12	19.3		4g/1000			50	50		
13	18.9	0.65	5g/1000			50	50		
14	18.9		5g/1000	16.4	0.03	25	75		
15	19.2		5g/1000			25	75		
16	19.7		5g/1000			25	75		
17	19.8	0.87	6g/1000				75	25	

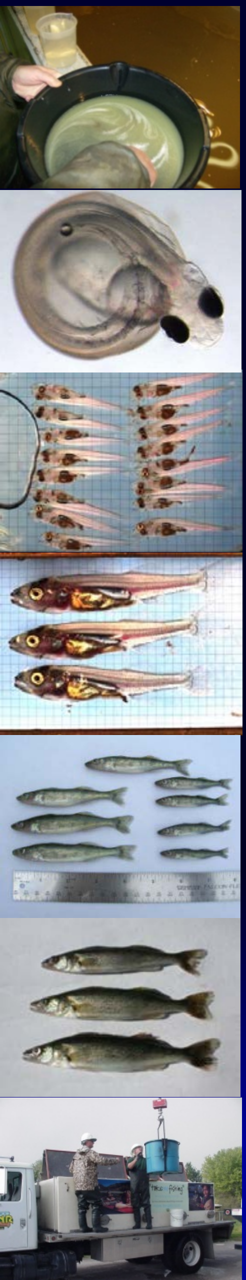
Table 2. Feed ration fed, temperature, and tank water exchange rate (R) during 3-35 days post hatch (DPH) at Rathbun Fish Culture Research Facility, 2012. Johnson and Esser (2012) Annual Federal Aid Report.

		Flow		Fry	Fry	Otohime (% of ration)			
DPH	° C	R	Feed Rate	L	W	B1	B2	C1	C2
18	19.2		6g/1000				75	25	
19	19.5		6g/1000				75	25	
20	20.4		6g/1000				50	50	
21	20.8		10% BW/d	24.0	0.10		50	50	
22	21.0		10% BW/d				50	50	
23	22.3	1.09	10% BW/d				25	75	
24	20.9		10% BW/d					100	
25	20.1		10% BW/d					100	
26	21.0		10% BW/d					100	
27	21.5		10% BW/d					100	
28	22.1		10% BW/d	33.4	0.29			75	25
29	21.6		10% BW/d					75	25
30	19.9		10% BW/d					50	50
31	19.4		10% BW/d					50	50
32	19.6	1.75	10% BW/d					25	75
33	19.7		10% BW/d					25	75
34	20.8		10% BW/d					25	75
35	20.3		10% BW/d	43.5	0.67			25	75

Pond vs Tank

2009: Compared fingerling production in intensive fry culture and pond culture.

	Fry culture	Pond culture	P-value
Phase I (3-31 dph)			
Survival	65.1	105.2	0.0012
Final L	32.7	42.3	<0.0001
Phase II (31-58 dph)			
Survival	81.0	84.0	0.7775
Final L	72.3	73.9	0.6152
Phase III (58-120 dph)			
Survival	84.0	82.0	0.1004
Final L	173.2	176.7	0.3618

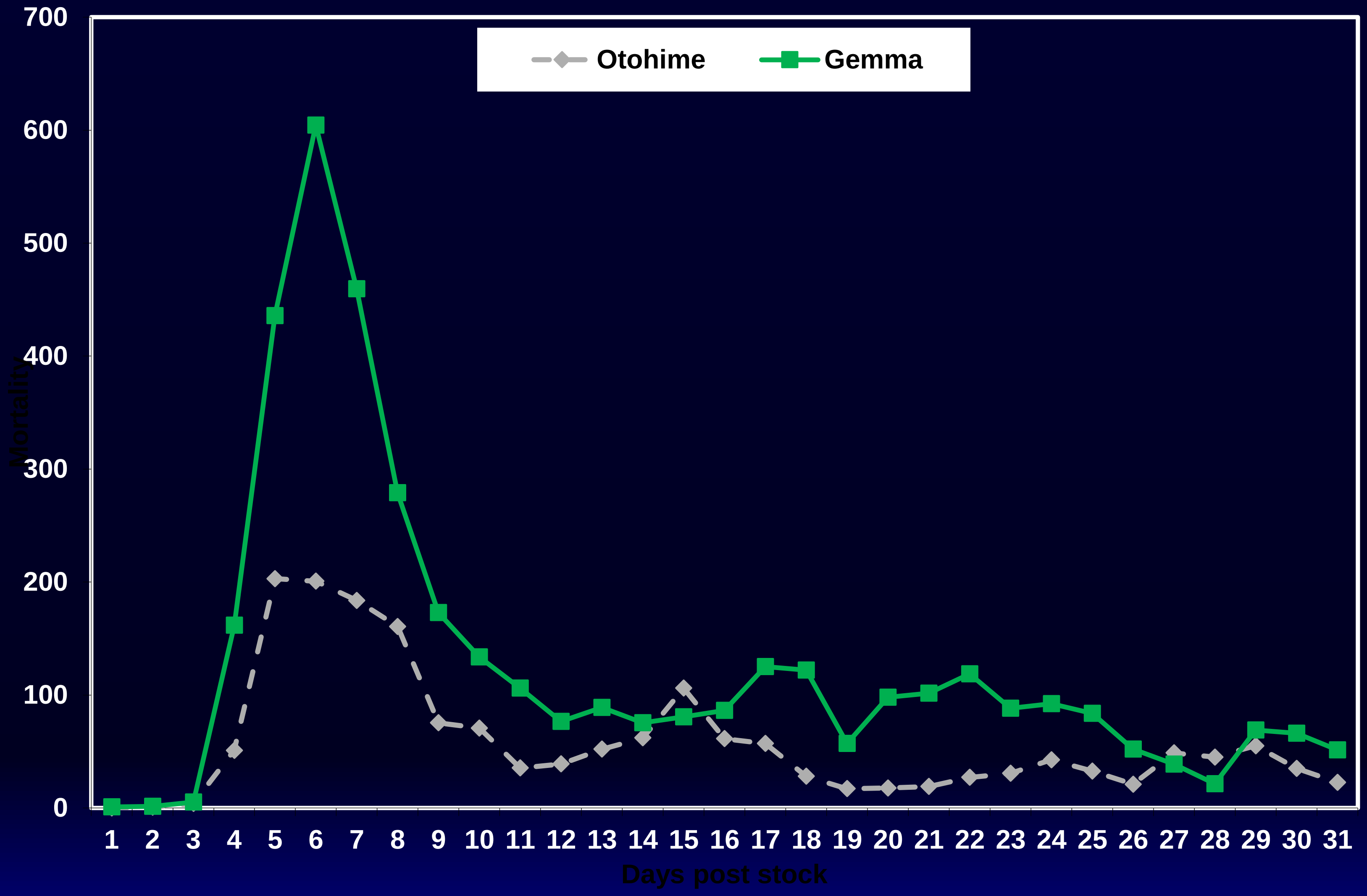


Larvaculture

2011 Growout to 200 mm

2011 Data	Fry culture	Pond – Tank[a]
Phase I	3-37	3-35
Survival (%)	46.3	91.9
Final L (mm)	42.3	50.6
Phase II	38-67	36-67
Survival (%)	69.4	71.5
Final L (mm)	91.6	93.8
Phase III		
Survival (%)	91.4	88.6
Final L (mm)	207.5	209.7
Deformity (%)		
Opercula	0.60	<0.01
Jaw	0.30	<0.01
Sloped head	1.60	<0.01
Normal	97.40	100.0

[a] Values for Phase I and III pond culture fingerlings were obtained from Rathbun Fish Hatchery production averages for 2011. Phase II results were obtained in a research trial at Rathbun Fish Culture Research Facility.



2010 Mortality Curve – Diets

Larviculture

	12 Tanks (275 L)	1 ac pond (0.4 ha)
Fingerlings produced	69,627	66,038
System volume (L)	3,300	3,785,000
Culture volume used (L)	2,583,360	3,785,000

	4 tank (890 L)	1 -1 ac pond
Water amendments	$35 (Clay)	$192 (Fert.)
Otohime Feed	$725	
Electric	$73	$16
Labor	$5,376	$1,135
Facilities (20 yrs)	$794	$12,500
Total Annual Cost	$7,003	$13,843
Cost per fish	$0.10	$0.21

In the Rathbun Research Facility floor space (40’X52’), 36 tanks (890L) could produce 624,000 0.66 g fish (65% survival) which exceeds walleye production in 10 acres (2012).

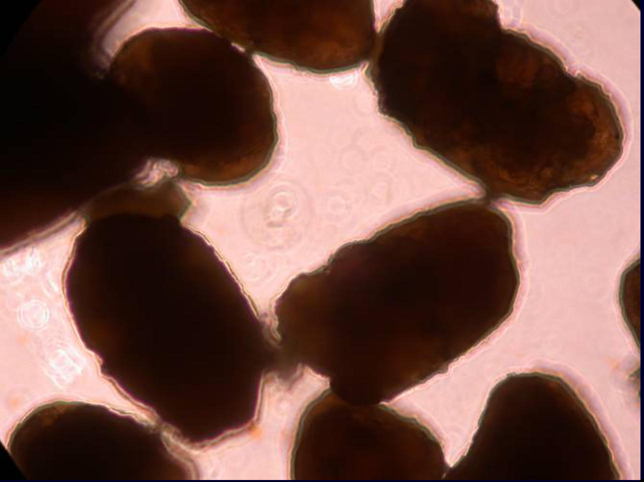
A case study:
What went wrong.

Methods

Diets

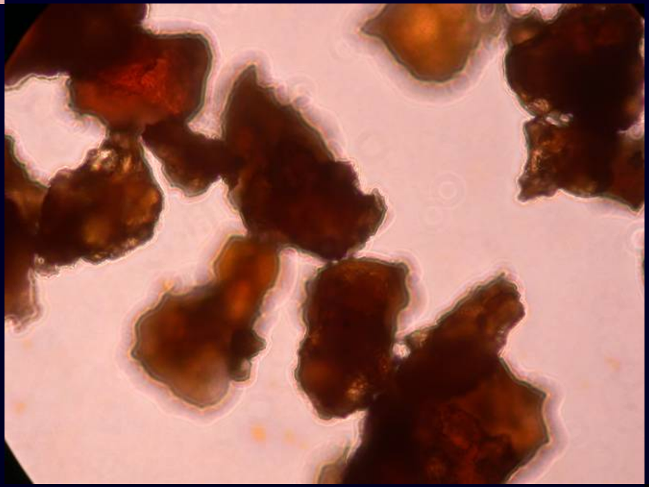
- **Lansy**
  - Lansy 2/4 (INVE Aquaculture Inc, Ogden UT).
  - EPAC CW 4/6
  - EPAC CW 6/8
- **Gemma**
  - Gemma 0.3 (Skretting, Inc Vancouver, BC, Can.)
  - Gemma 0.5
- Proximate, amino acid, and vitamin analysis performed by commercial laboratory.


Lansy 2/4
EPAC 4/6
Gemma 0.3
Gemma 0.5

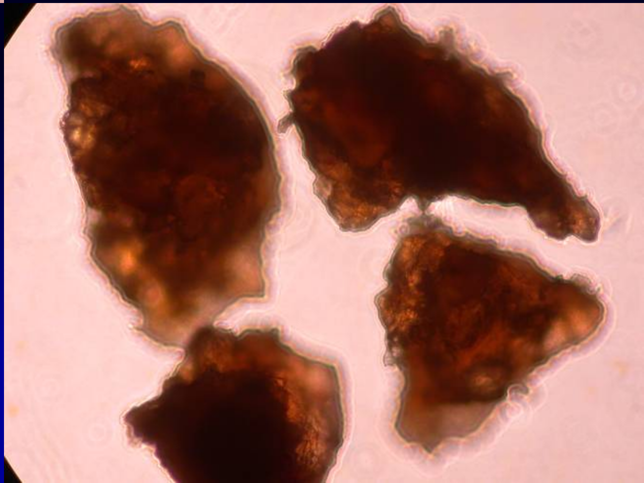


Gemma 0.3

Lansy2/4



BioKyowa
FFK B-400



Results

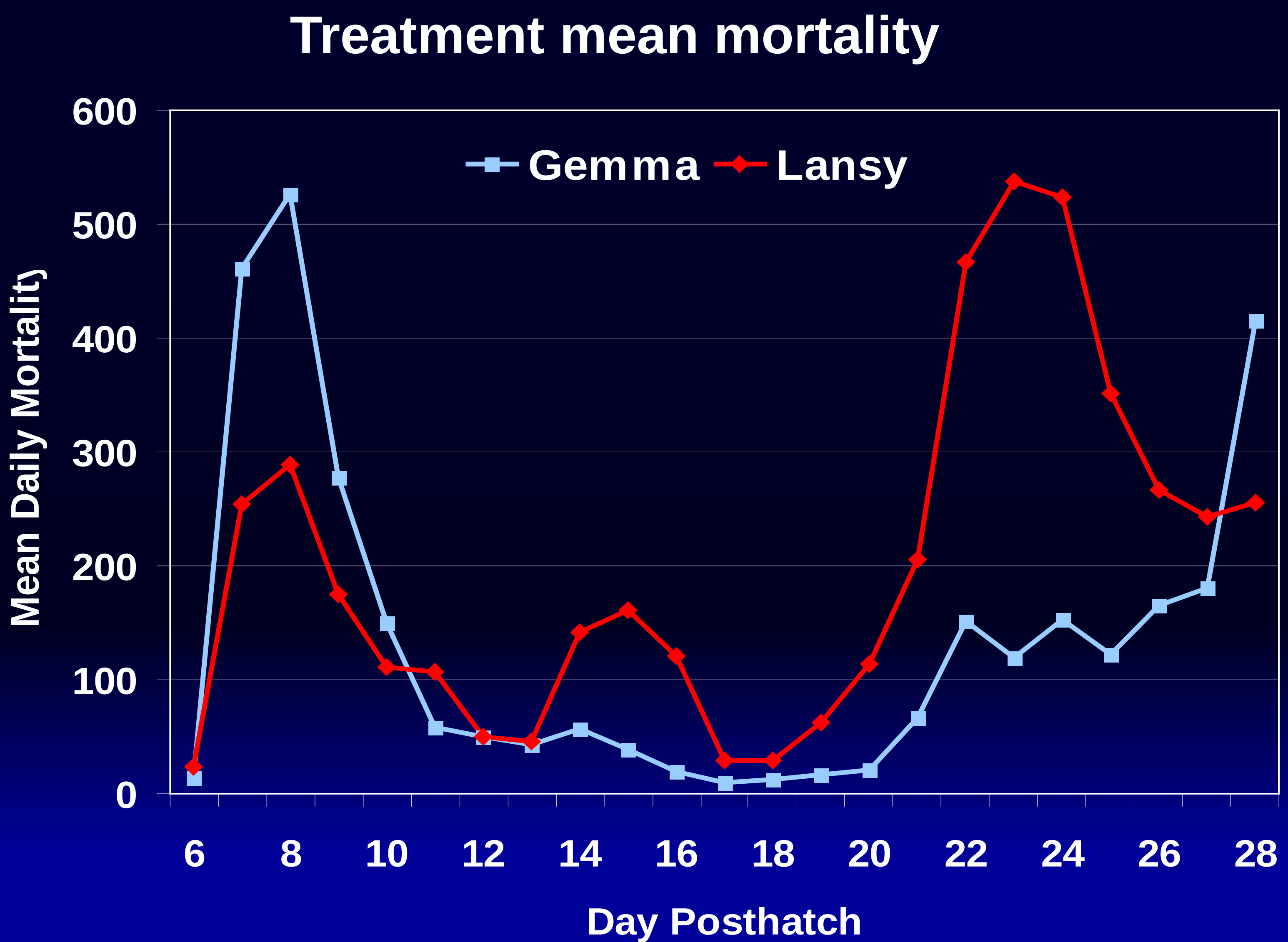
Gas bladder inflation (%)

DPH	Lansy	Gemma	P-Value
7	98.7	92.0	0.0668
14	94.6	94.6	-
21	98.7	100	0.3739
28	93.3	98.6	0.4135

Feed in the gut (%)

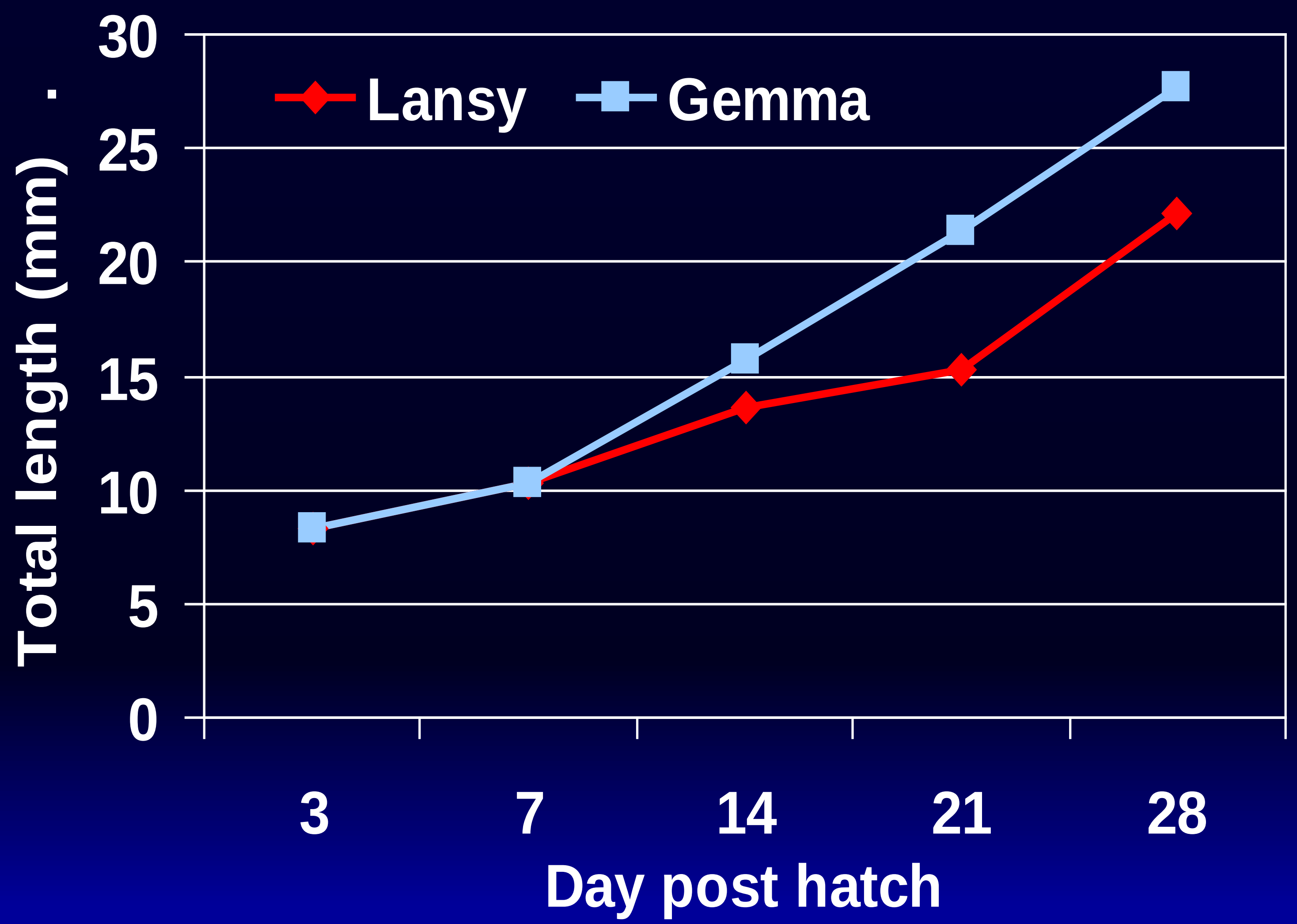
DPH	Lansy	Gemma	P-Value
7	92.0	69.0	0.0435
14	61.3	98.6	0.0665
21	46.7	92.0	0.0002
28	88.6	94.6	0.4211

Results



Treatment mean mortality
Gemma
Lansy
Mean Daily Mortality
Day Posthatch
0
100
200
300
400
500
600
6
8
10
12
14
16
18
20
22
24
26
28

Results

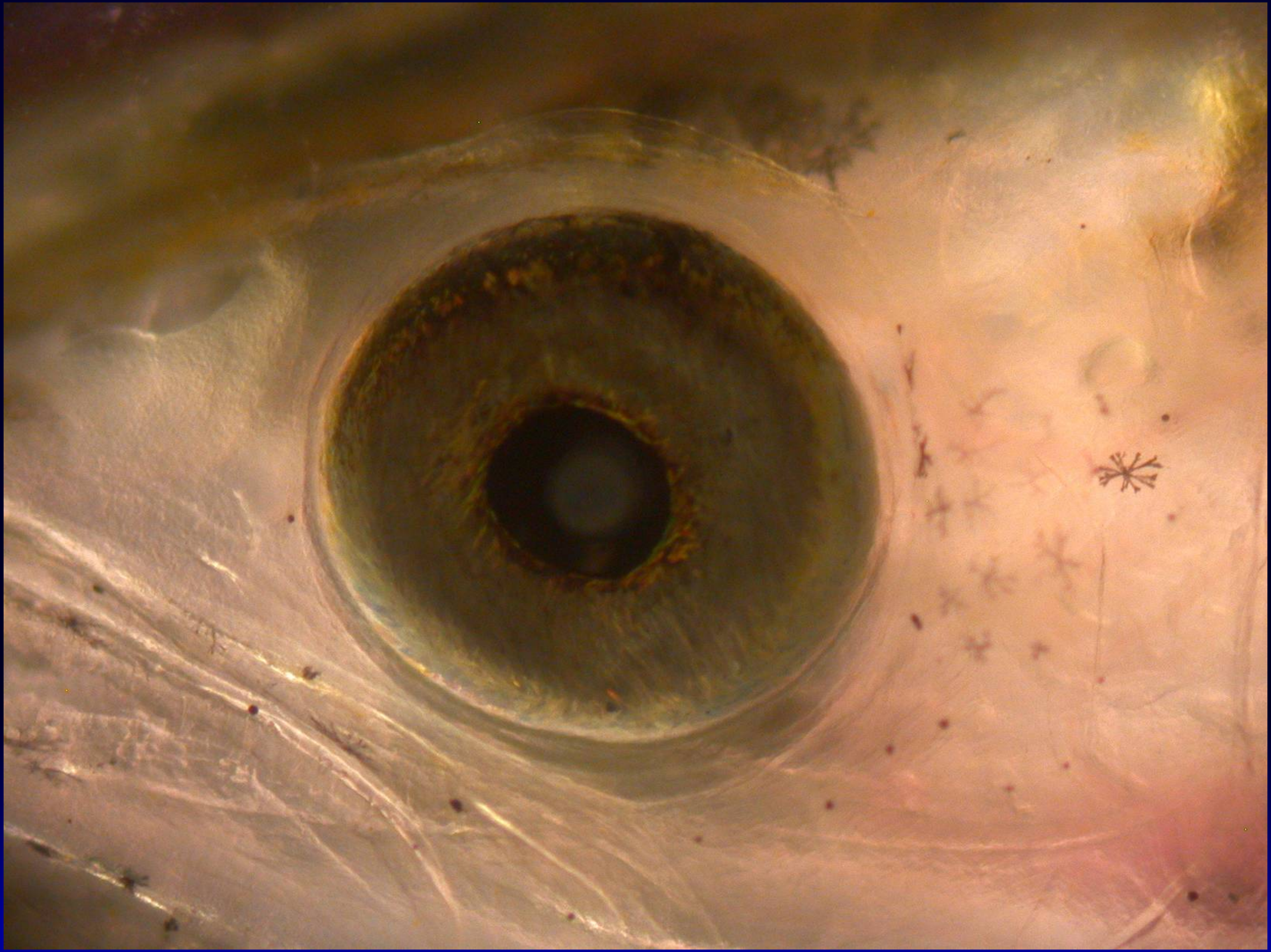


Total length (mm)
30
25
20
15
10
5
0
Lansy
Gemma
3
7
14
21
28
Day post hatch

Results

Survival, final length, weight and growth rates, and total deformity rate on day 28 post hatch

	Lansy	Gemma	P-Value
Survival	21.6	56.7	0.0008
Mortality	55.7	28.7	0.0001
Unaccounted	22.7	14.6	0.0528
Length	22.15	27.72	0.0004
Weight	81.73	156.97	0.0001
mm/d	0.553	0.776	0.0004
mg/d	3.119	6.128	0.0001



Results

Deformity rate

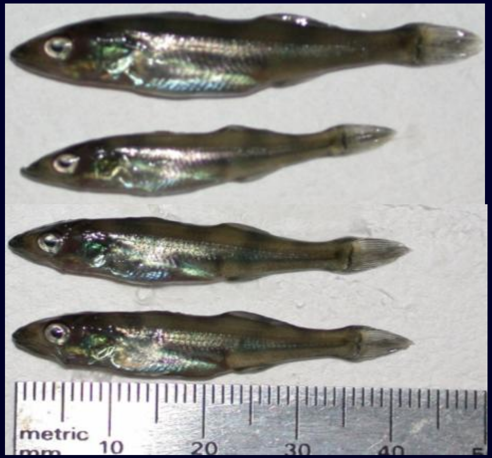
	Lansy	Gemma	P-value
D14			
Cataract	34.7 ± 11.6	0.0	0.0406
Short operculum	97.3 ± 1.3	94.7 ± 5.3	0.6530
Long mandible	1.3 ± 1.3	0.0	0.3739
Lordosis	0.0	1.3 ± 1.3	0.3739
D21			
Cataract	74.7 ± 1.3	0.0	<0.0001
Short operculum	72.0 ± 14.0	73.3 ± 3.5	0.9311
Long mandible	5.3 ± 2.7	0.0	0.1161
Pughead	16.0 ± 8.0	2.7 ± 2.7	0.1890

Results

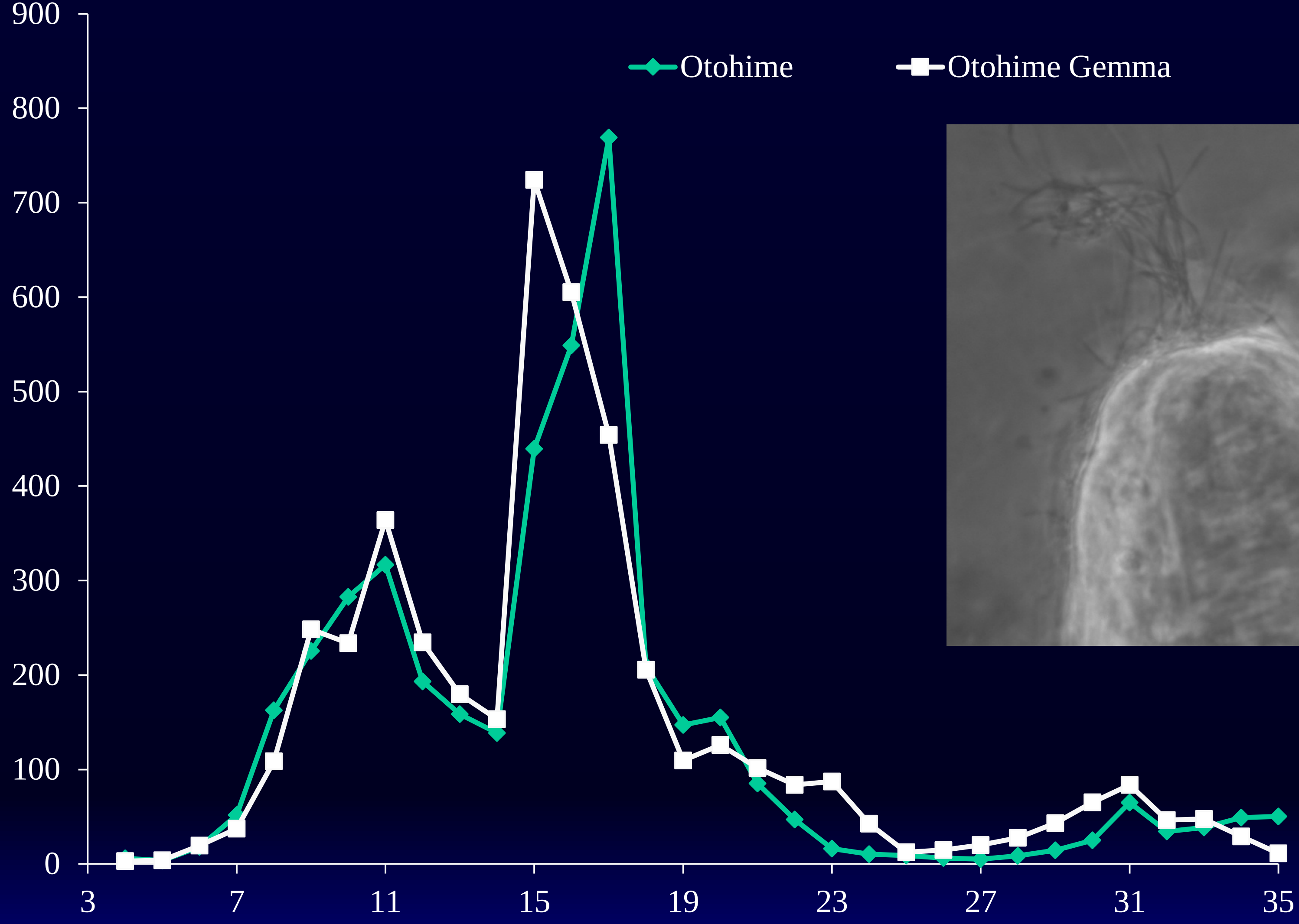
	Lansy	Gemma	P-value
D28			
Cataract	26.7 ± 2.4	0.0	0.0004
Small pupil	24.0 ± 9.2	0.0	0.0589
Short operculum	96.7 ± 3.3	44.0 ± 4.6	0.0008
Long mandible	2.7 ± 2.7	0.7 ± 0.7	0.3486
Broken isthmus	1.3 ± 0.7	4.0 ± 3.0	0.4418
Jaw deformity	0.7 ± 0.7	2.7 ± 2.7	0.5072
Parrot beak	0.7 ± 0.7	2.7 ± 1.8	0.3486
Hump back	1.3 ± 1.3	0.0	0.3739
Lordosis	2.0 ± 2.0	0.7 ±0.7	0.5614
Scoliosis	0.0	0.7 ± 0.7	0.3739
Total deformity rate	98.7 ± 1.3	50.0 ± 5.3	0.0009

Deformity

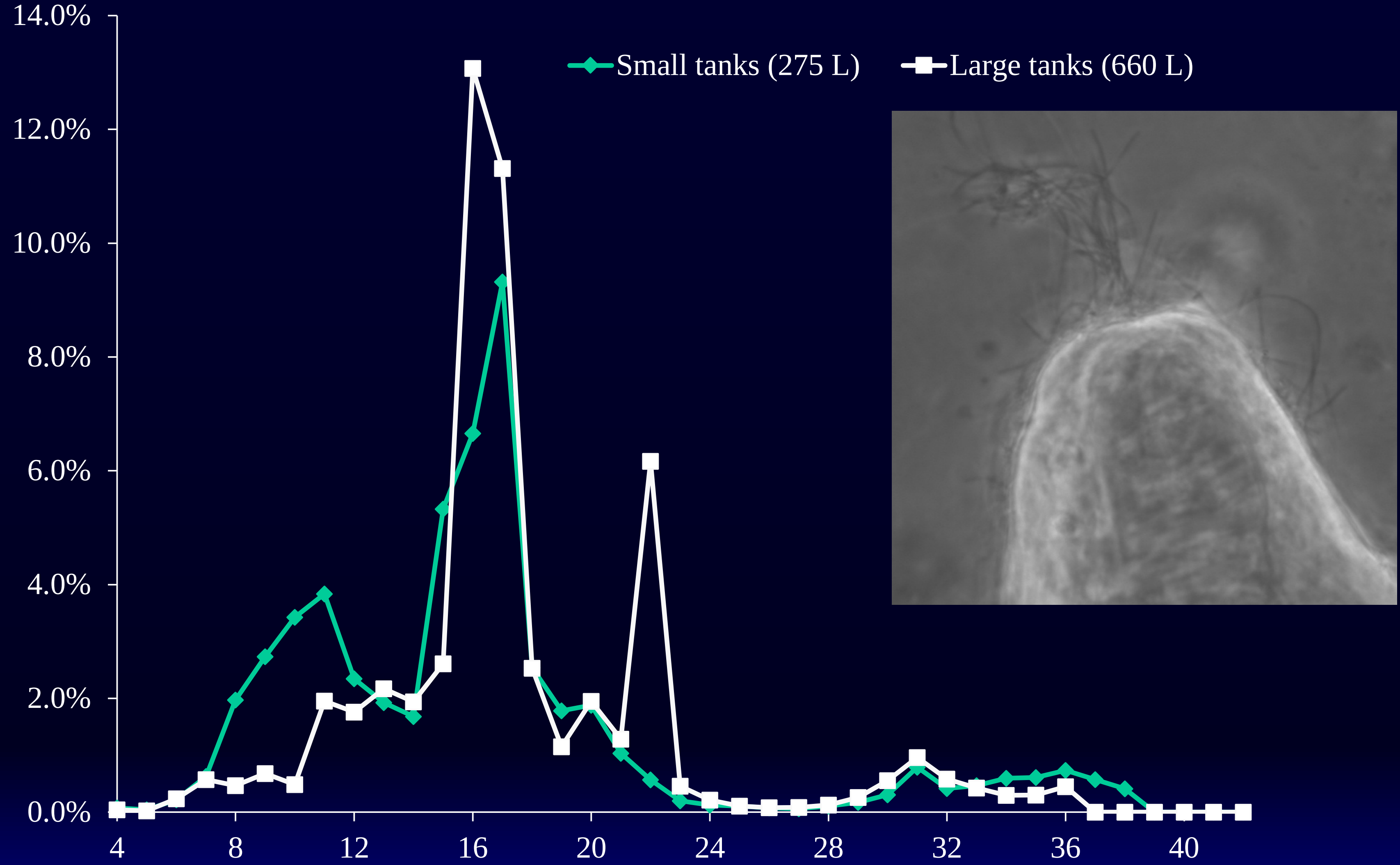
Intensive culture:
2009: 20.6% at 120 DPH.
2011: 2.6% at 147 DPH.
2012: 5.6% to 7.5% at 35 DPH.



200 mm pond to tank reared fingerlings.
Eye blindness: 5.7 to 10.2%
2012: two grow-out tanks had 9% shortened opercula at 167 DPH.

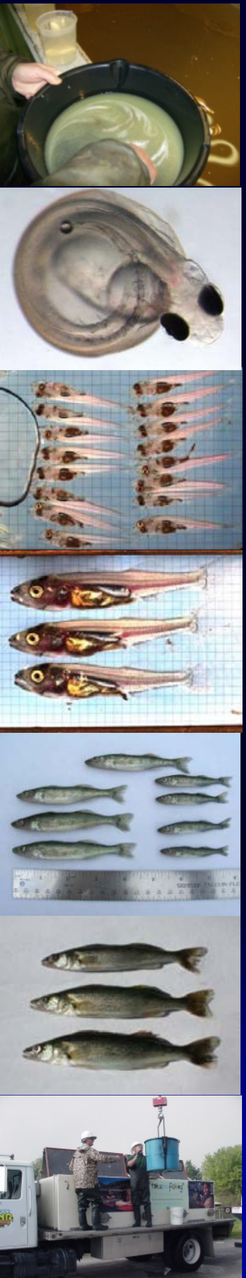


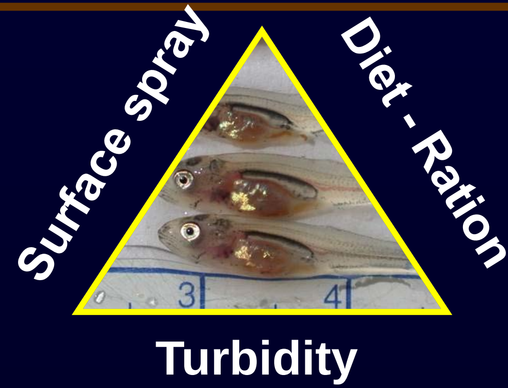
2013 Mortality Curve - Diets



2013 Mortality Curve – Tank size

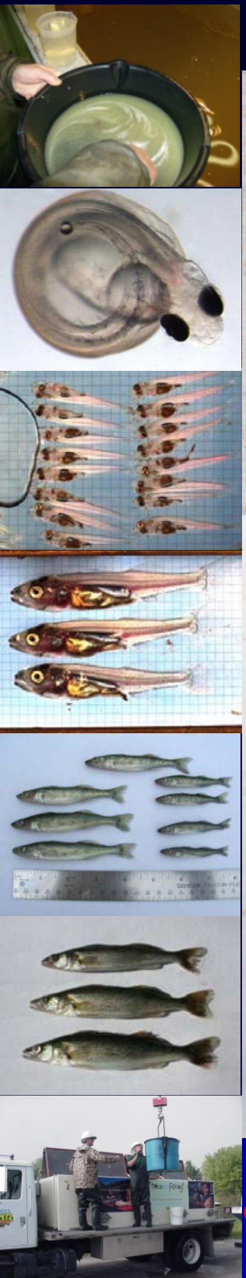
Research needs





- Consistent survival rates
- Diet formulations
- Water Reuse systems, with clay.
- Shortened clay duration.
- Evaluate other clay types.
- Post-stocking survival fisheries.
- Production scale tanks and systems
- Mechanical cleaning systems for tanks.
- All female production systems
- Genetic improvement.
- Cold banking

Self cleaning tanks



- Oceans Design Inc. San Diego, CA.