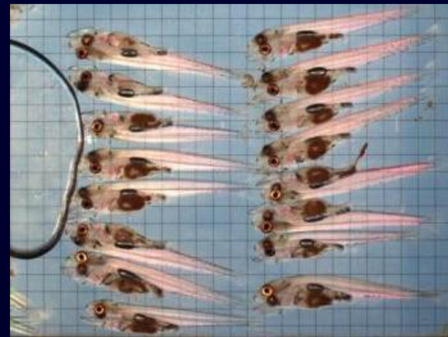



Walleye culture from fry to fingerlings:
Foundation of research in sport fish culture

J. Alan Johnson

Rathbun Fish Hatchery and Research Facility, Moravia, IA

Some slides prepared by Randy Esser, Jay Rudacille


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 million

Pond fingerlings:

500,000 -1.2 million

Nursery Lake fingerlings:

100-150,000

225 mm 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 walleye culture?

Demand for walleye

- Cultured primarily for sport fishery enhancement.
- Market for all life stages - egg to adult.
- Limited food fish production in the US.
  - Retail $11 to $16/lb
    - 2010 Des Moines, IA
    - R. C. Summerfelt

Photo by R. Summerfelt, June 26, 2008, Ames, Iowa

A story worth the telling:

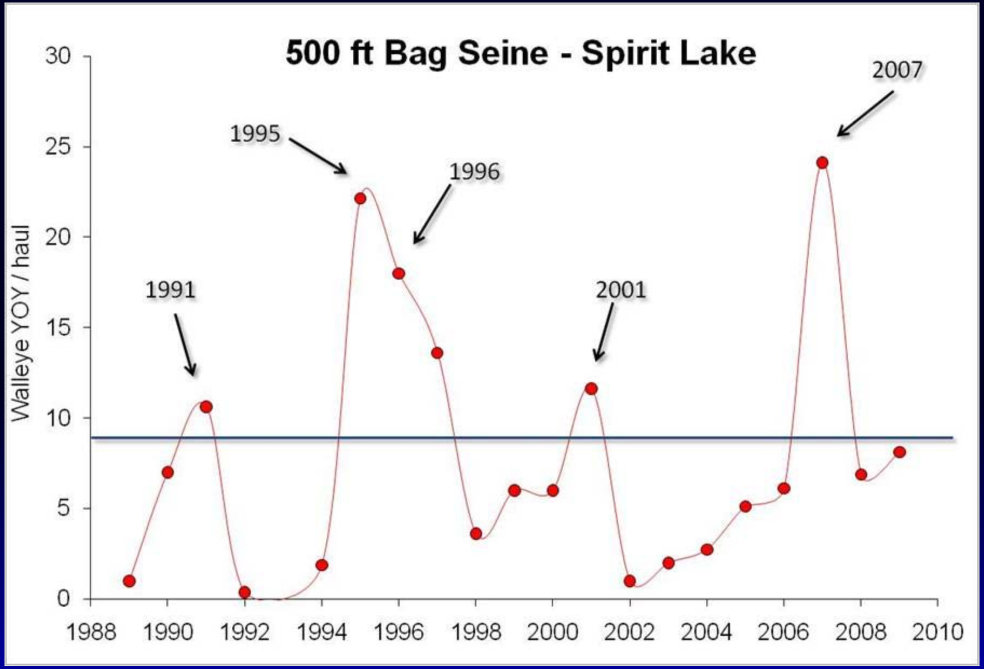
Rathbun Fish Hatchery produces 200,000, 9 to 10-inch walleye in five months, capable of >70% survival from fry.

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:**
  - **Fry culture.**
  - **Tandem pond-tank culture.**
    - **Habituation.**
    - **Grow out to 9-10".**

Characteristics

Gas bladder inflation – physoclistus

Diets

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

Coolwater species.

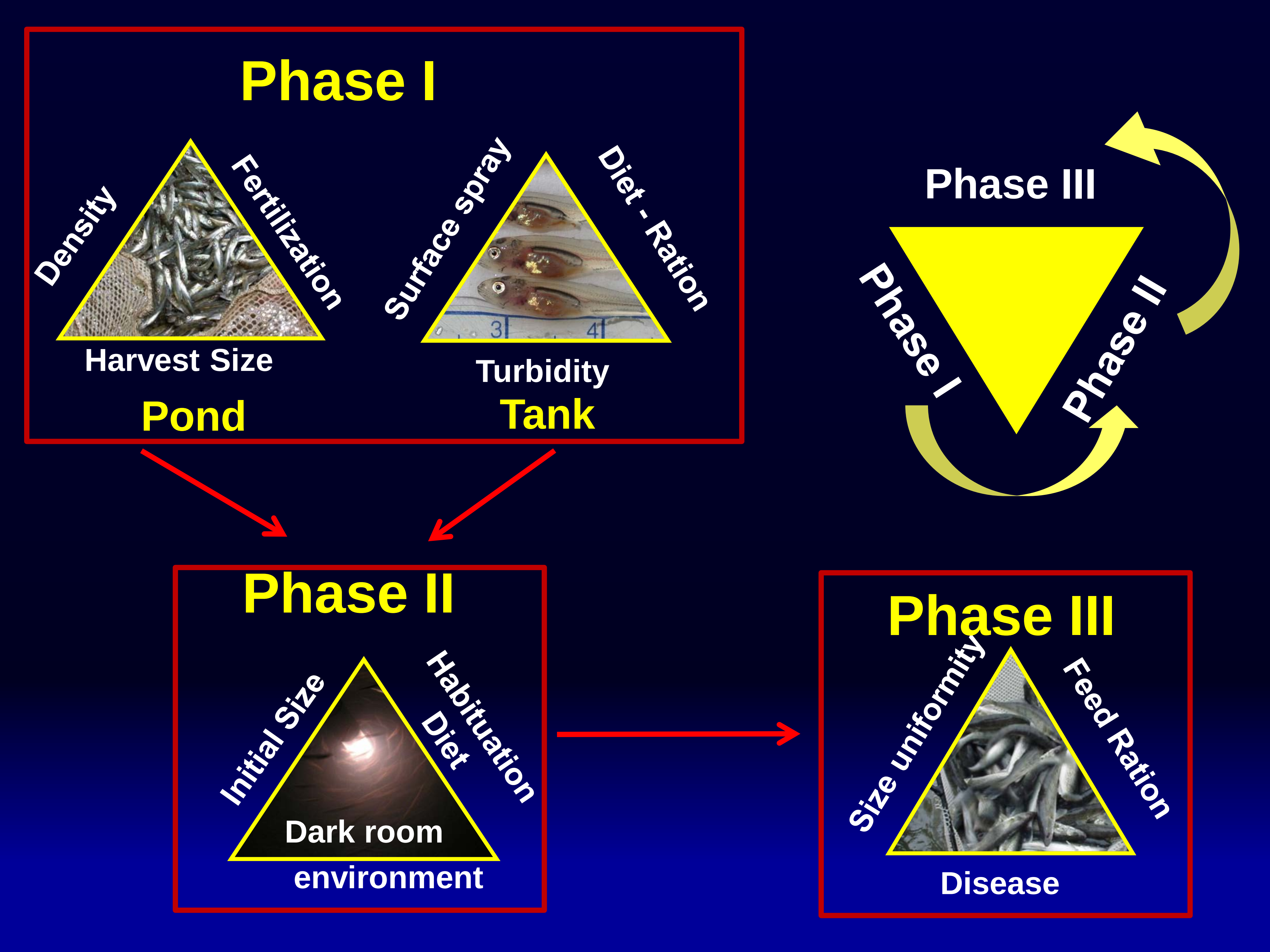
- Optimal growth 24-25ºC
- Upper lethal limit: 31-33ºC

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.


Phase I
Density
Fertilization
Harvest Size
Pond
Surface spray
Diet - Ration
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

- **Pond stocking density (75K/ac) results in >0.56 g harvest size.**
- ***Fry culture techniques***

Phase II

- **Dark Room Submerged Light Environment**
- **Habituation diet – Otohime C2**

Phase III

- **Size grading**
- **Feed rates**
- **Control costs**

For more information

North Central Regional Aquaculture Center:

Walleye Culture Manual (1996)

R. C. Summerfelt, Editor

Production of walleye as potential food fish (2010)

R. C. Summerfelt et al. NCRAC Pub #116

American Fisheries Society

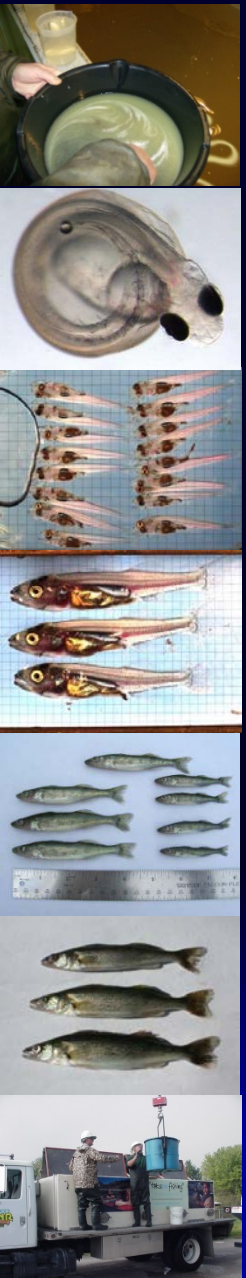
Biology, management, and culture of walleye and sauger. B. Barton Ed.

Walleye Culture Chapter

Summerfelt, Johnson, Clouse.

Broodstock to hatch

Broodstock Collection



Iowa DNR's Source:

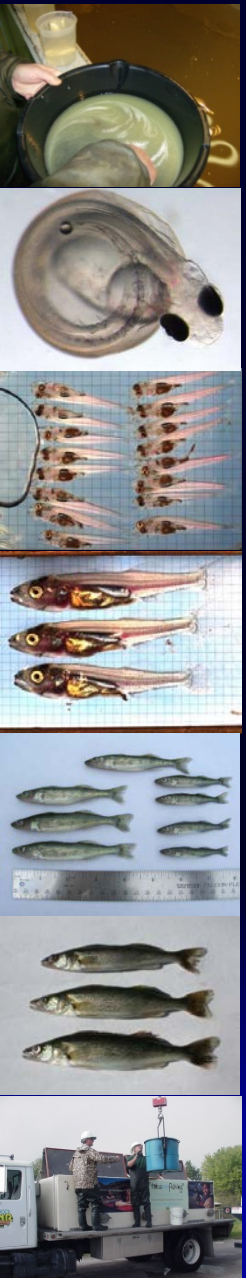
- Rathbun Lake, Spirit Lake, Clear Lake, Storm Lake.

Collection:

- Iowa DNR: Gillnets set perpendicular to shore.
- Colorado DW: Gillnets set parallel to shore.
- Kansas P&W: Fyke nets.
- Arkansas G&F: Electrofishing

Timing:

- Temperature: 5.6 to 10° C.
- Test netting in advance of the traditional season may assure the spawn is not missed.



Broodstock Collection

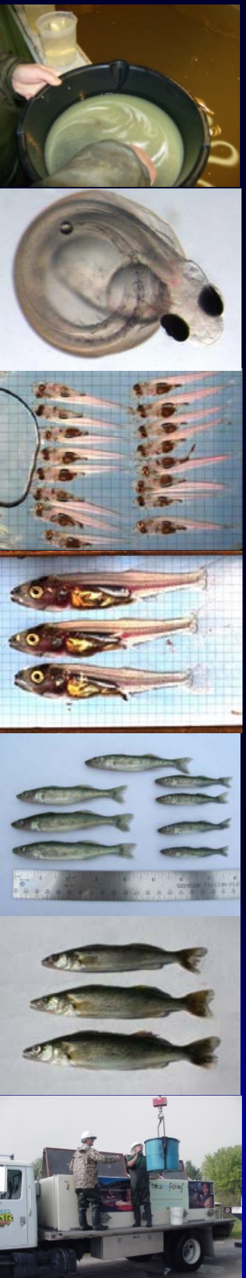
Night Crew:

- Set nets, run nets 5 pm to 9 pm to 12 am.
- Sort fish: male, female, ripe females.
- Ripe females spawned that night.

Day Crew:

- Check for ovulation of held females (5 days).
- Collect and extend semen.
- Spawn ripe females.

Spawning



Spawning by the "dry method":

- Eggs and semen collected dry, mixed, activated with water.

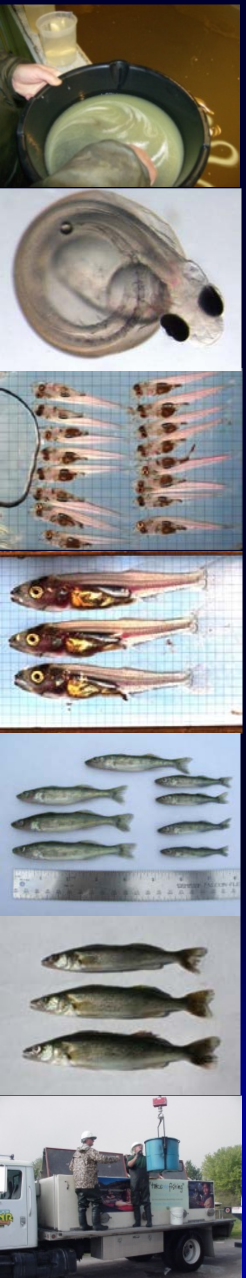
Semen collection:

- Dry males.
- Collect semen in chilled pan.
- Distribute into culture flasks – 3 mL.
- Extend with "Rathbun Walleye Extender" – 6 mL.
- Store in refrigerator no more than 2 weeks.

Advantages:

- Simplifies fertilization
- Less introduction of water, feces, urine to eggs.

Spawning



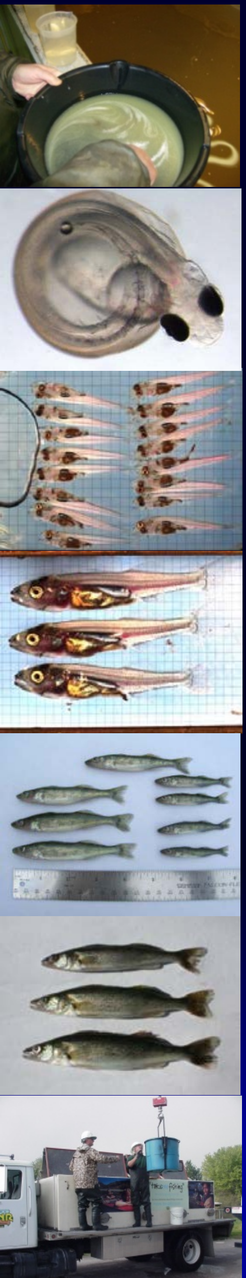
Spawning by the “dry method”:

- Eggs and semen collected dry, mixed, activated with water.

Egg collection:

- Dry females, gently.
- Collect eggs in a oil pan.
- Pay attention to eggs depth; ratio of eggs to semen.

Fertilization



Spawning by the "dry method":

- Eggs and semen collected dry, mixed, activated with water.

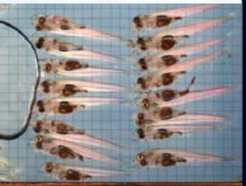
Fertilization procedure:

- One pan of eggs and one flask of Ext. semen (9 mL).
- Add half of the Ext. semen to eggs, stir.
- Add 500 mL of water, stir for 30 seconds.
- Add remaining semen, stir for 90 seconds more.
- Total stir time 2 minutes.

**Water activates eggs and sperm

Then proceed to "mudding"







Removing eggs adhesiveness

Walleye eggs are adhesive

- **Between 2 and 5 minutes post fertilization, eggs will stick to each other and surfaces.**
- **Removal methods: clay, protease, tannic acid.**

Mudding in clay solution:

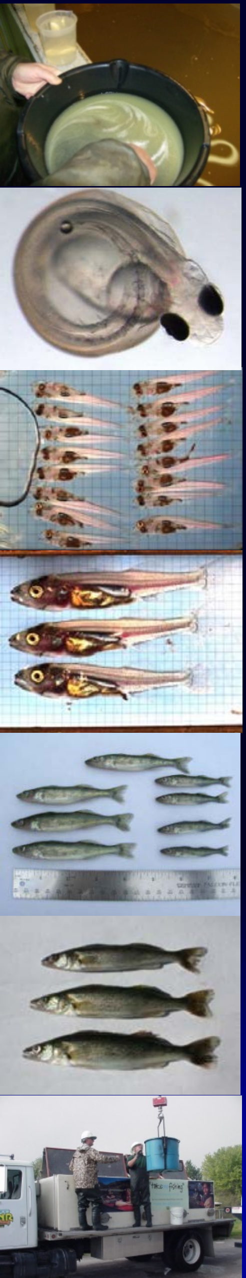
- **Pre-mix Fullers Earth (g) into 1L water in dish pan.**
- **Two standard eggs pans after fertilization procedure.**
- **Gently stir eggs, water and clay mixture for 3 minutes.**
  - **Soft bristle paint brush, some use a turkey feather.**

Proceed to Water Hardening


FISH IOWA!
C1

STATE
15

Water Hardening, Jars



Eggs are water hardened for 4 hours

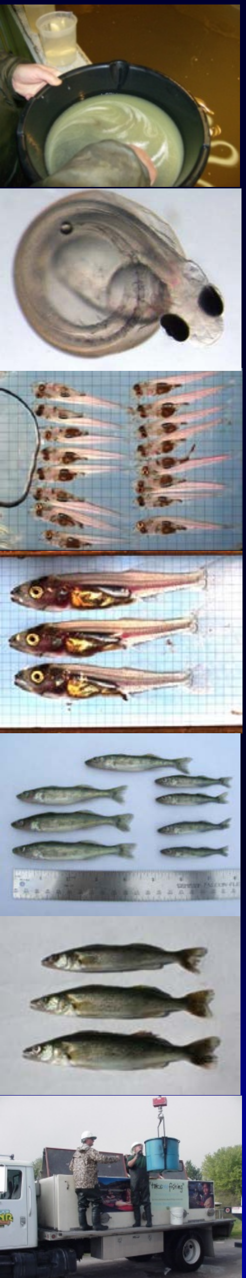
- Place mudded eggs in a “keep”, fluff to remove clay.
- Remove extraneous feces, blood clots, ovary.

Place eggs in incubation jar:

- 3 to 3.5 L of eggs volume.
- Place on incubator battery.
- Flow rate: art and science.
  - Initially eggs are gently rolled. Subject to some personal preferences.

Proceed to Water Hardening

Incubation



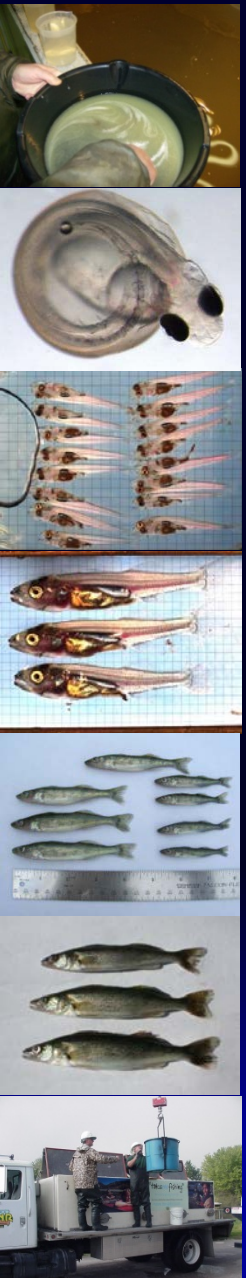
Incubation period

- Varies with water temperature. 12-27 days….
- Expressed as Daily Temperature Units
  - Sum of daily temperature mean above 0ºC
  - Sum of daily temperature mean in ºF - 32
- 204 to 265 DTU ºC (Summerfelt et al. 2011).

Husbandry:

- Monitor egg “rolling”, gently. Prevent quiescent areas.
- Siphon off dead eggs – begin 1 to 3 days post jarring.
  - Take care to not remove live eggs
- Treatment to prevent fungus.
  - Rathbun uses 35% Perox-Aide at 500 mg/L flow through for 15 minutes – daily .

Fry



Fry collection

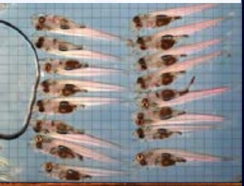
- Walleye fry are 8 mm at hatch.
- Tank screens 700 micron mesh or smaller.
- Crop uniform age cohorts for tank and pond culture to prevent cannibalism.

Fry stocking or transport:

- Short trips (1-2 h bag time) : 200,000 fry per bag.
- Longer trips (3-6 h bag time) : 100,000 fry per bag.
- Bag: 3 gallons water, fill remaining bag with pure oxygen.
- Temper fry for temperature and pH diffrences.

Delayed Fertilization







Delayed Fertilization Technique (DFT)

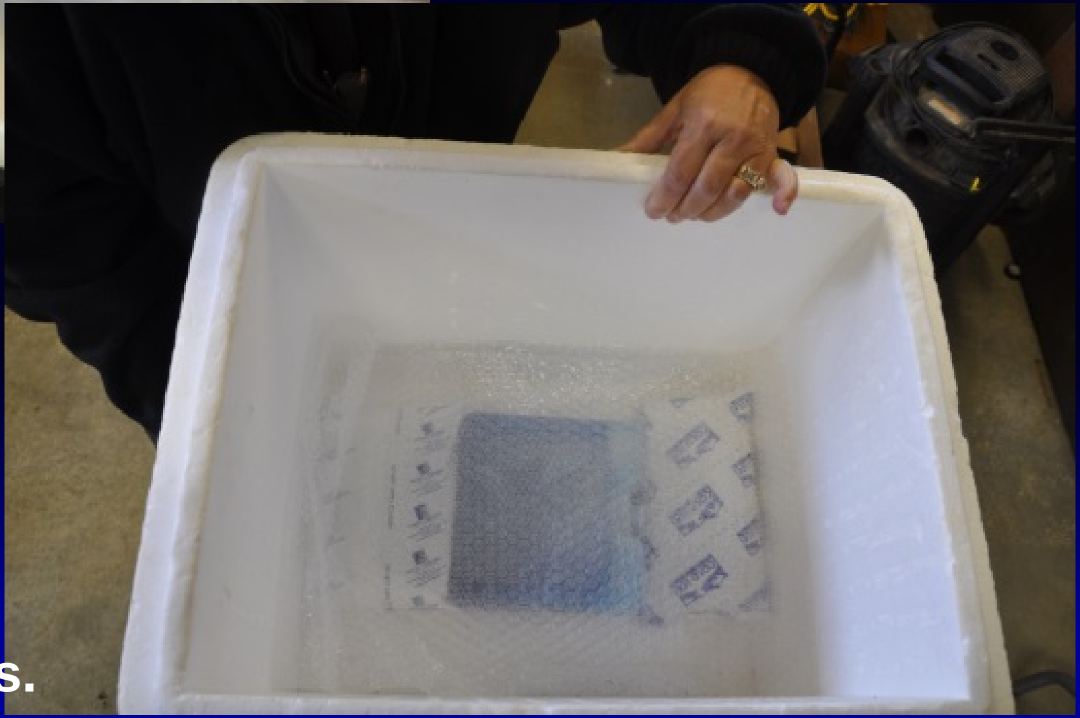
- Used in salmonids for remote eggs takes.
- Keeping eggs dry chilled during a transport period.
- Beginning the fertilization process at the hatchery.

Methods:

- Completely dry females.
- Spawn eggs into sealable transport container
  - 2.25 L plastic sandwich container.
- Place several containers into a cooler.
- Keep chilled.
- Rathbun uses this method for eggs from Clear Lake;
  - Transport time 4 hours (delay of 4 hours until fertilization)
  - 73% hatch rate.

Delayed Fertilization Technique

Spawning a dry female into a container.



Insulated transport container with bubble wrap and ice packs.

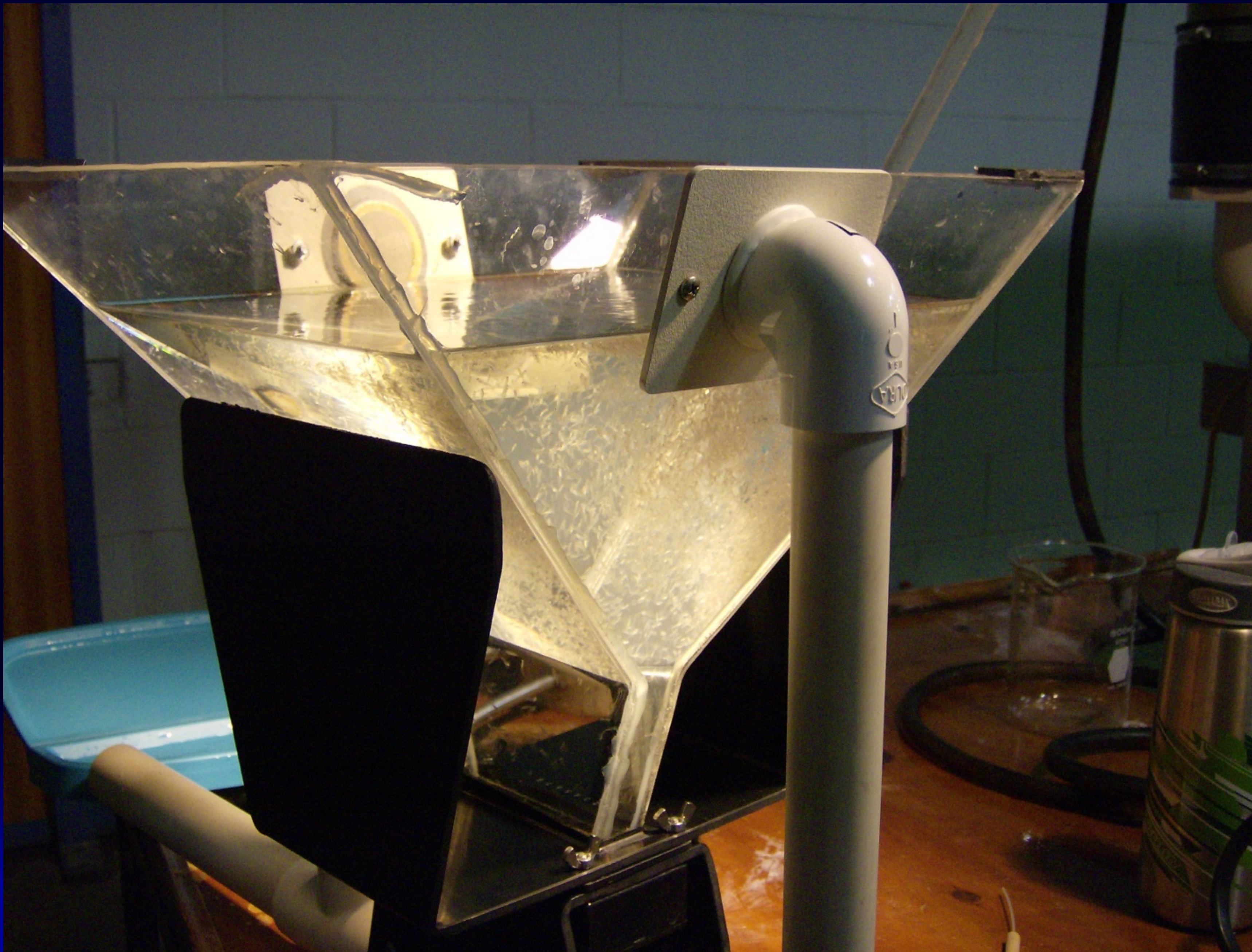
Fry Quantification

- Gravimetric method: use a scale to measure a weight of fry; known fry per gram.
- Volumetric method: use a graduated cylinder and measure displacement of fry; known fry/mL.
- Electronic counting: Rathbun Fish Hatchery since 2000.
  - Fry Counter, Model FCM – Jensorter (Bend,OR)
  - Principle of Operation
    - Electronic eye counts anything that interrupts path of light

Fry Quantification
at Rathbun Fish Hatchery

- Calibration is the Key accuracy
  - Probe each channel to ensure LED lights
  - Hand count at least 500 fry
  - Place them in the hopper; let the fry counter count them; capture them in catch container
  - Compare the hand count and electronic count
  - If hand count and electronic count are similar, then repeat two times
  - If hand count and electronic count are not similar, then adjust sensitivity setting
  - Minor adjustments using a correction factor.


DNR
TIDY CATS
SCOOP

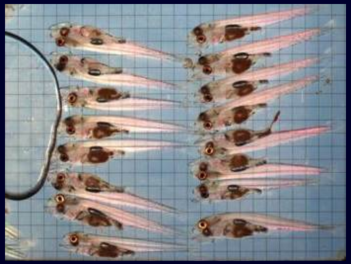


Phase I Larviculture

Phase I Larviculture

Larva

- **Prolarval to early juvenile stage** (Summerfelt et al. 2011).
- **"ends when all organs and structures related to food acquisition are completely developed and functional."** (Yufera 2011)



Culture: maintain in conditions suitable for growth.

Tank = Intensive culture

Production can be increased at will.

Pond = Extensive culture

Production is limited by the food web.

Larviculture

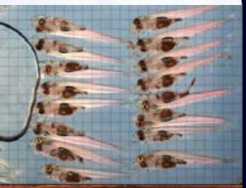
Management descisions

	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.

Pond culture







Extensive culture:

- FFFH; Fill, Fertilize, Forget about 'em until Harvest.

Intensified extensive culture:

- Optimize fertilization.
- Monitor water quality.
- Manage/monitor food web.

Predictable production.

Quality vs. quantity.

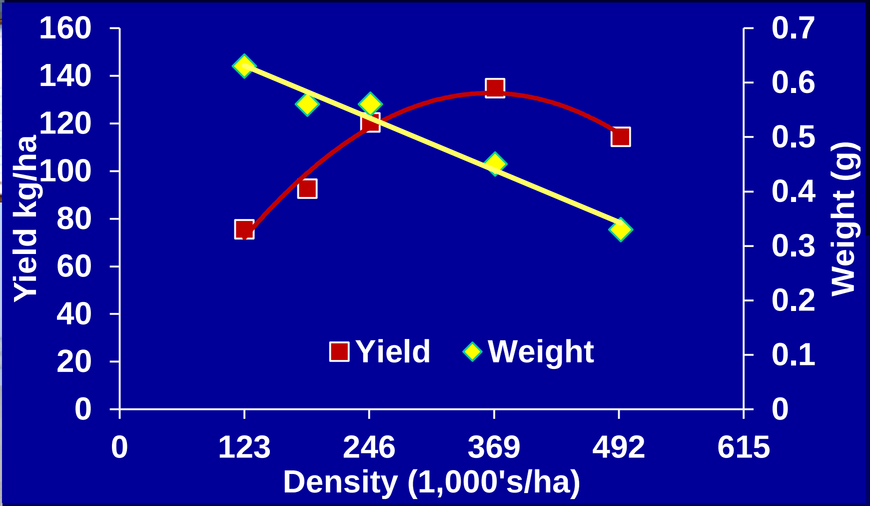
Science and effort.

Quality: 0.57 g fish for habituation;

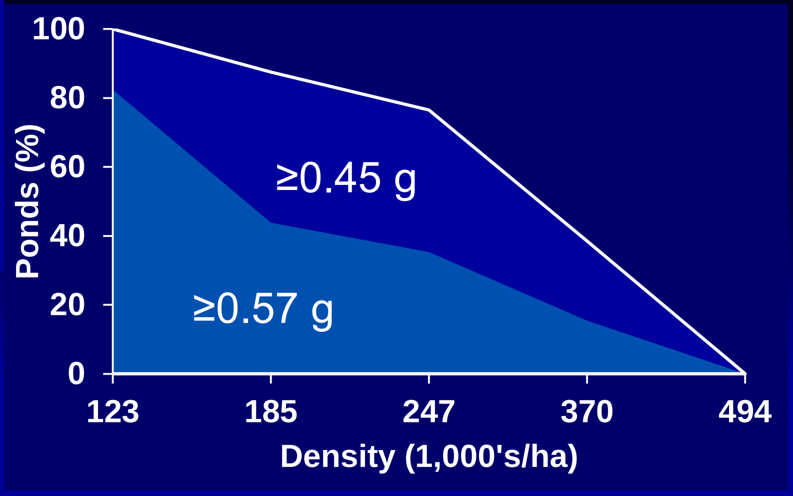
0.45 g for fisheries enhancement.

Pond culture

- 1-ac plastic-lined ponds.
- Alfalfa pellet fertilization
  - 100 lbs initial, 100 lbs/wk.
- Producing quality fingerlings.
  - Quality = size.

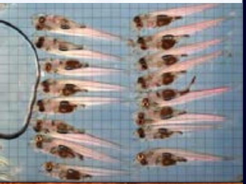


Meeting size goals



Phase I: Pond culture



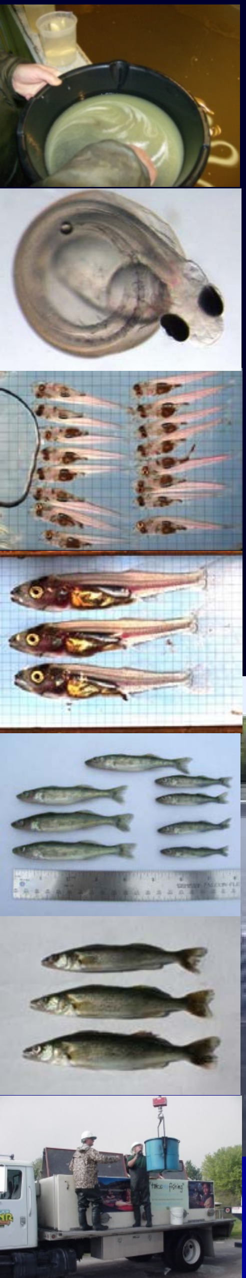




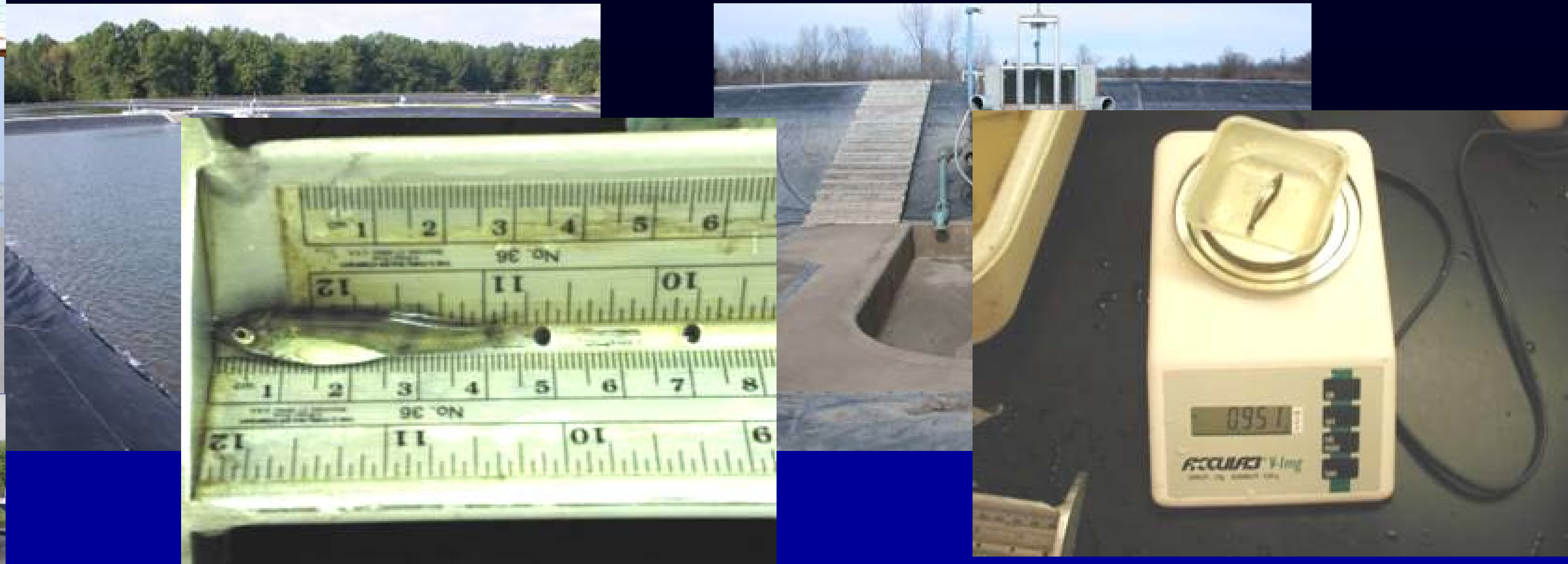
- **Fry enumeration**
  - **50,000 – 75,000 fry/acre**
  - **Electronic fry counter**
- **Organic fertilization regime**
- **Zooplankton monitoring.**
- **Water Chemistry**
  - **DO/temp/pH**
  - **NO_3 & P**
  - **Ammonia**



Phase I: Pond culture

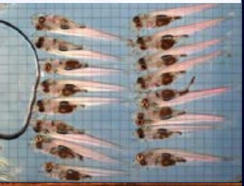


- Ten one acre plastic-lined ponds
  - reinforced polypropylene
  - Kansas-style kettles
- Results
  - Consistent survival: >90%.
  - Consistent size: 600 – 800 fish/lb (0.57 - 0.75 g)



Filling and Fertilization







Water screening:

- RFH uses 300 micron screen of lake water.
- Crops zooplankton down, seeds with immature stages.

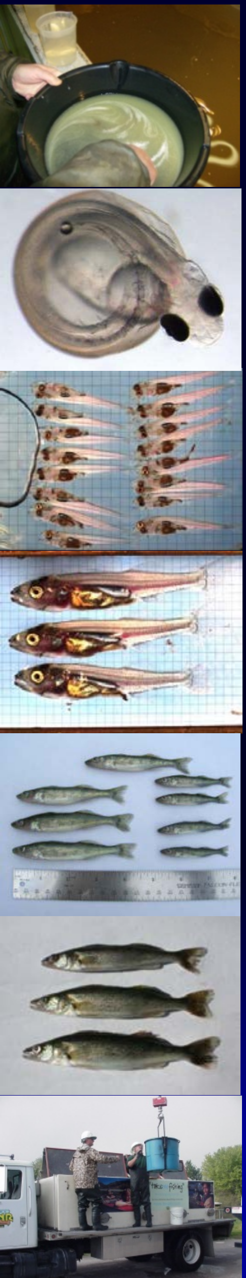
Prestocking interval:

- Tested 5, 8, and 11 day delay between fill and stock.
- Factors such as source, temperature influence duration.

Fertilization

- Inorganic method: David Culver - OSU
  - Weekly adjusting N:P to maintain 600: Monitor water quality.
  - All Ohio DNR walleye ponds are managed by this method.
- Organic only
  - Weekly additions of fertilizers.
  - Sources: Alfalfa, soybean, or cotton seed meals, brewers yeast.
- Inorganic – Organic combination.

Pond fertilization

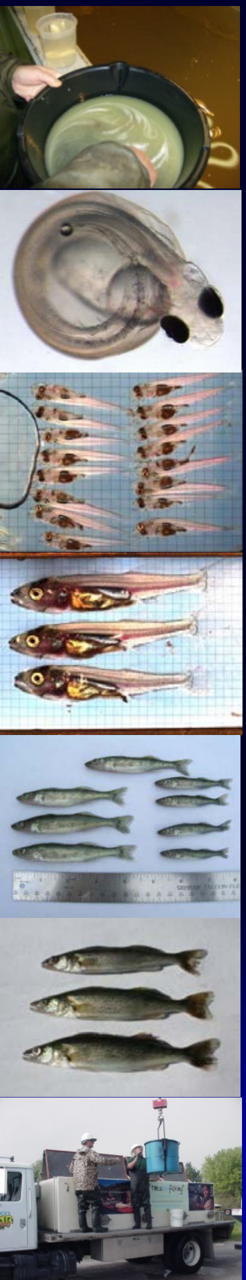


Fertilizer type for lined ponds.

Year	No Fertilizer		Inorganic		Organic		I/O	
	Weight (g)	Survival (%)	Weight (g)	Survival (%)	Weight (g)	Survival (%)	Weight (g)	Survival (%)
2000	0.206	28.5	0.415	29.8	0.691	24.1		
2001					0.64	78.9	0.56	74.8
2002			0.25[a]	84.5			0.36[b]	88.2

- Results
  - Lined Ponds need to be fertilized
  - Lined Ponds with organic fertilizer do better

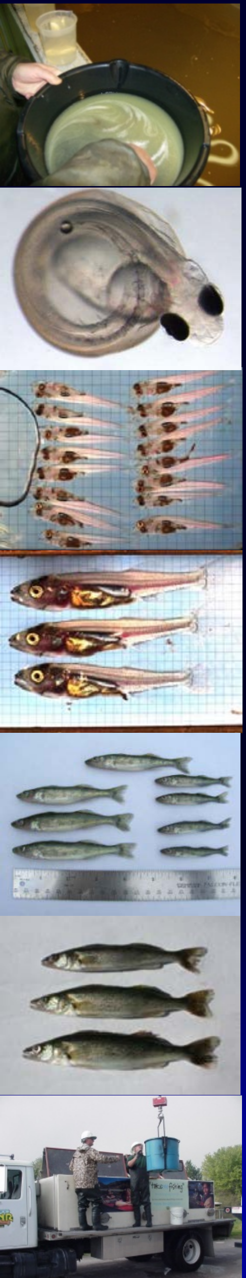
Fry Density in Ponds



Year	123K/ha		185K/ha		247K/ha		370K/ha		494K/ha	
	Weight (g)	Survival (%)	Weight (g)	Survival (%)	Weight (g)	Survival (%)	Weight (g)	Survival (%)	Weight (g)	Survival (%)
2000					0.56	35.7	0.36	26.1	0.60	13.9
2001					0.47	77.8	0.37	71.2	0.33	68.1
2002					0.71	94.4	0.51	88.2		
2003					0.50	94.9	0.44	75.8		
2004			0.69[a]	90.0	0.56[b]	87.7				
2005	0.52	*	0.43	*	0.29	*				
2006	0.59[a]	92.7	0.47[b]	88.4						
2007	0.68[a]	97.3	0.49[b]	93.3						

- Are we fertilizing enough?

Pond Fertilization



Find the optimal fertilization regime

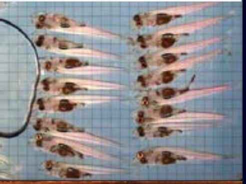
- Pond carrying capacity determined by fertilization.
- Fertilization can increase productivity, within limits

Experiments:

- Soybean meal rather than alfalfa meal.
- Pond feeding
- Both resulted in increased nitrogen inputs, and larger fish.

Pond Fertilization







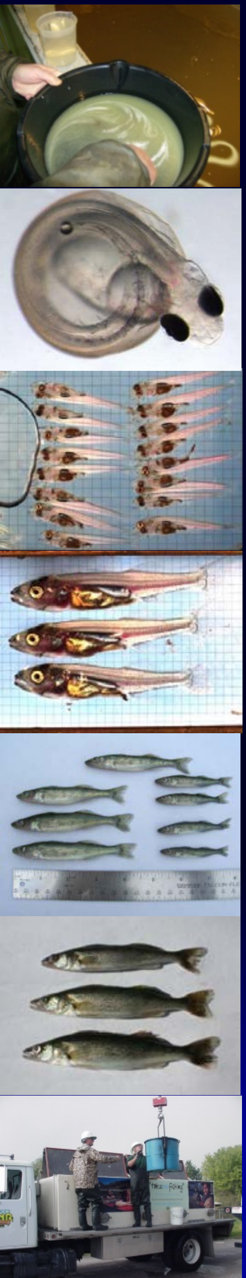
Increasing N from organic sources

Year	Alfalfa 100 lbs/acre/week 50K fry per acre		Soybean Meal 80 lbs/acre/week 50K fry per acre		Soybean Meal 80 lbs/acre/week 75K fry per acre		Soy-Alf Mix 80 lbs/acre/week 75K fry per acre	
	Weight (g)	Survival (%)	Weight (g)	Survival (%)	Weight (g)	Survival (%)		
2009	0.57	105.2	0.68	81.6				
2010	0.69	94.6	0.68	90.8				
2011	0.74	95.4	0.78	91.7	0.66	85.9		
2012	0.51	90.4					0.56[2]	87.6

Soybean and alfalfa meal Mix:

47% more fish produced per pond.

Pond Fertilization



Can higher nitrogen application result in more quality fish?

YES

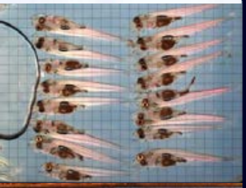
Definition of quality fish revised:

- 800/lb (0.57 g) for habituation to feed.
- 1000/lb (0.45 g) for stocking in stream fisheries.

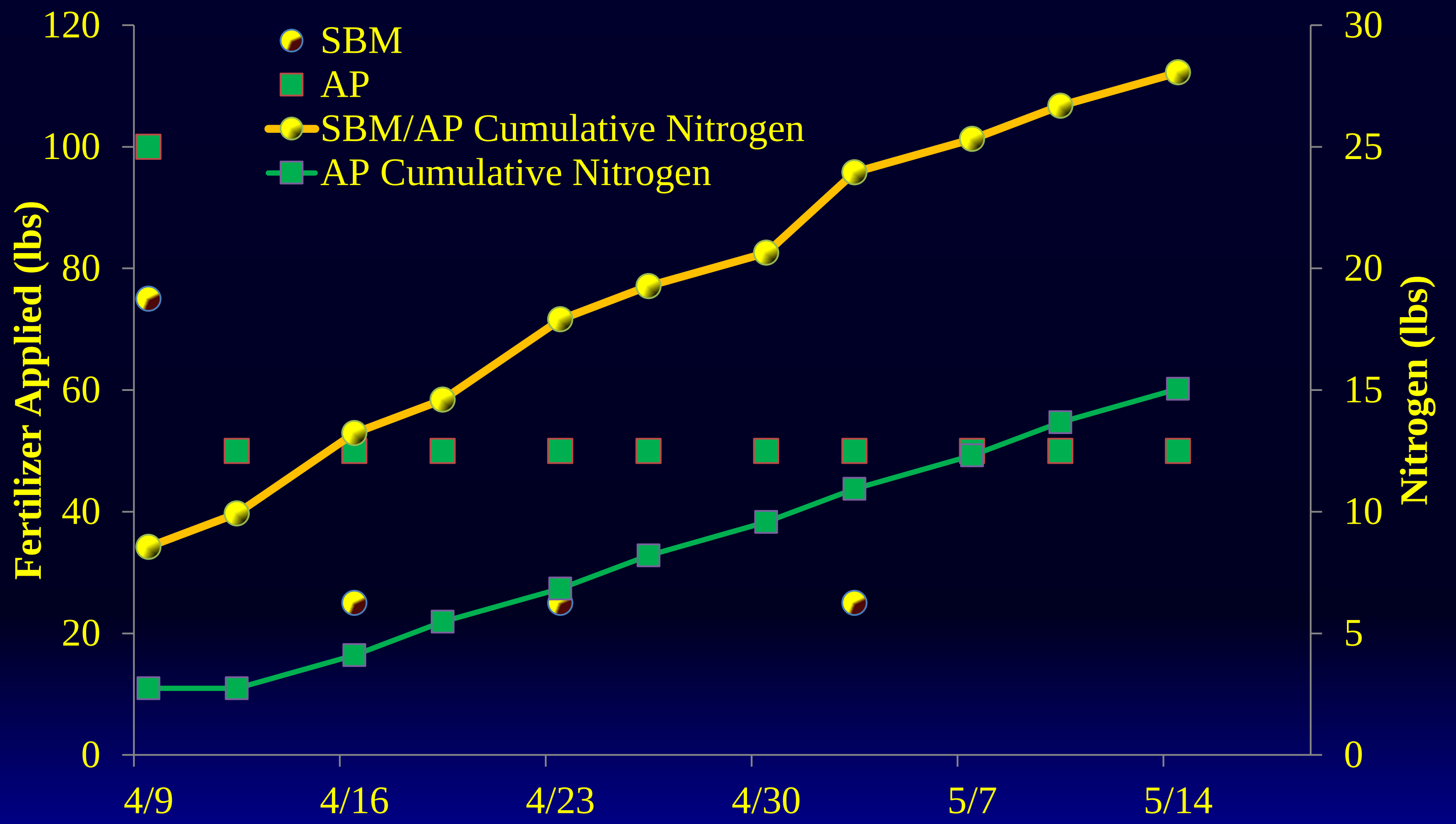
Year	Density #/ha	Fertilizer	N (kg/ha)	W (g)	% Ponds ≥ 0.57 g	% Ponds ≥ 0.45 g
2011	123K	ALF	16.8	0.74	100	100
	123K	SBM	34.8	0.78	100	100
	185K	SBM	34.8	0.66	100	100
2013	123K	ALF	20.7	0.55	33	100
	185K	Mix	30.4	0.69	85	100

Pond Fertilization



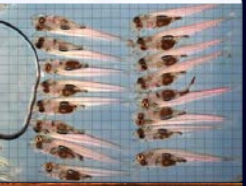






Pond Fertilization







Total Ammonia Nitrogen (TAN)

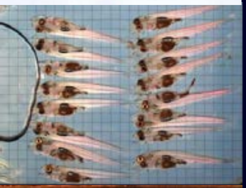
- High positive correlation between cumulative nitrogen and TAN ($r^2 = 0.713$)

Fertilizer	Maximum (mg/L)	Average (mg/L)
Alfalfa Pellets (2001-2011)	1.36	0.10 – 0.45
Soybean Meal (2010-2011)	1.32	0.48 – 0.73

- What is a safe level of TAN for walleye?
  - < 1.0 mg/L for cool-water fish, 2-3 mg/L for warm-water fish (Timmons and Ebeling 2007)
  - “A truly safe, maximum acceptable concentration of un-ionized, or of total ammonia, for fish culture systems is not known.” Meade (1985)

Pond Fertilization







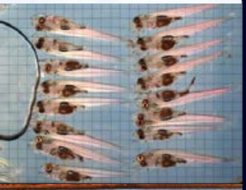
Un-ionized Ammonia

- What level is toxic for walleye?
  - LC_{50}
    - 0.51 - 1.10 mg/L (USEPA 1985)
    - 1.06 mg/L (Mayes et al. 1986)

Fertilizer	Maximum (mg/L)	Average (mg/L)
Alfalfa Pellets (2001-2011)	0.349	0.007 – 0.055
Soybean Meal (2010-2011)	0.371	0.076 – 0.129

Pond Harvest

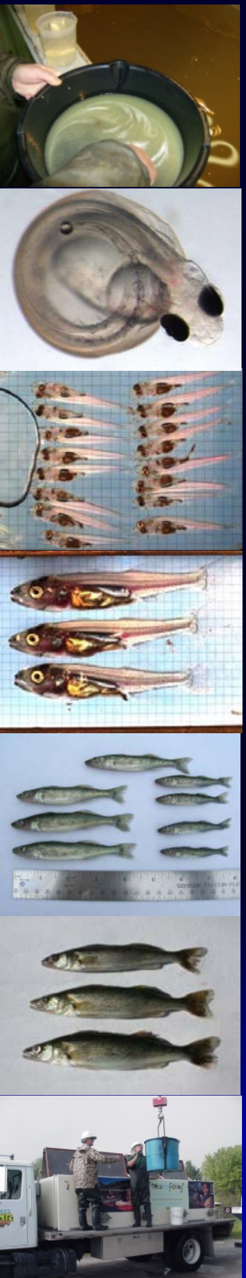






- Monitor food web: zooplankton
  - Zooplankton tows twice per week.
  - Imhoff Cone for rapid quantification.
  - Plot trends in abundance.
  - Chironomid abundance difficult to measure.
- Monitor fish size.
  - Sample with a seine, measure.
  - Plot growth rates.
- Decision time:
  - Are fish a desirable size?
  - Is zooplankton abundant?
  - Other factors:
    - Weather,
    - Double cropping species needs.

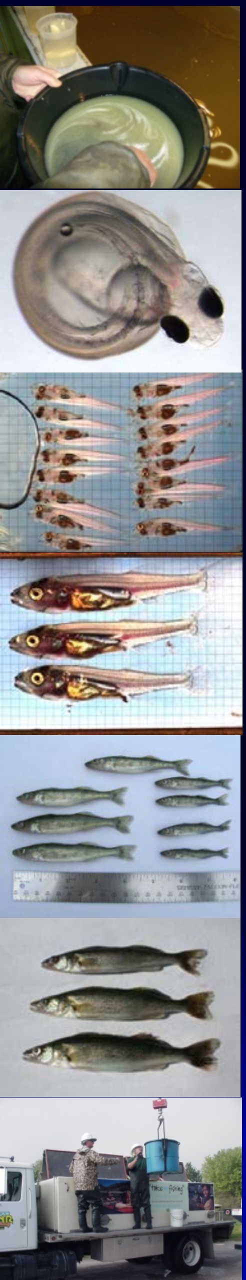
Pond Culture

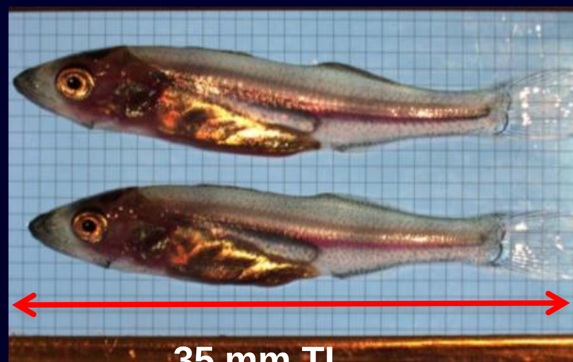


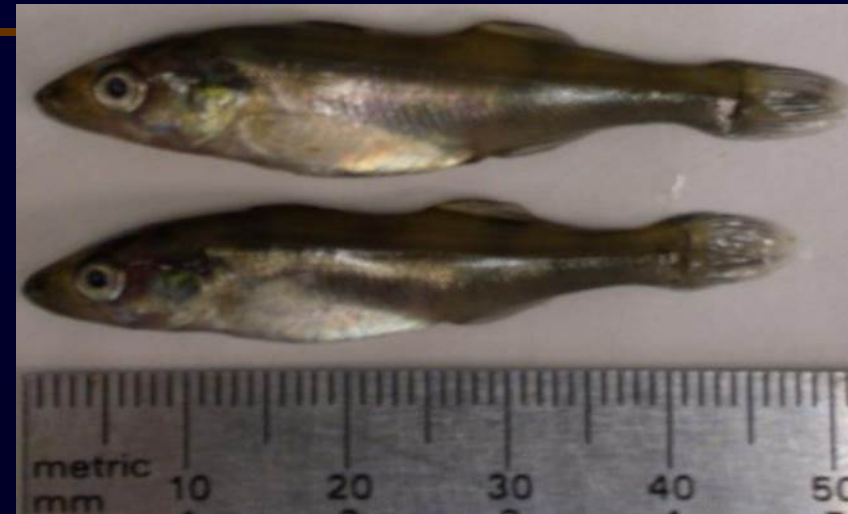
Summary

- Increasing nitrogen inputs resulted in:
  - Greater pond productivity
    - Increased yield (58%)
    - Similar size and condition
    - Enhanced food web
      - More primary productivity
        - » Higher pH
        - » Similar zooplankton volumes
  - Increased TAN/UIA
  - Increased pond efficiency
- Stocking density: 75,000 fry/ac for > 0.56 g fish

Why >0.56g?







800/lb = >42 mm; 1000/lb= 37 mm.

- **Habituation of pond reared fingerlings best above 0.57 g. (about 42 mm).** Johnson and Rudacille (2010).
- **Scale development initiated at 24 mm complete at 45 mm.**
  - Priegel (1964)
- **Mechanical damage allows entry of Columnaris.**
  - Huissain and Summerfelt (1991)

Theory: fingerlings larger than 0.57 g are fully scaled and therefore more resilient to handling.