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

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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
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”
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 24-25°C
- Upper lethal limit: 31-33°C

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.
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 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 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.
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”
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
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 0°C
  - Sum of daily temperature mean in °F - 32
- 204 to 265 DTU °C (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 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 differences.
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

Insulated transport container with bubble wrap and ice packs.

Spawning a dry female into a container.
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.
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 decisions

<table>
<thead>
<tr>
<th></th>
<th>Pond Culture</th>
<th>Tank Culture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biosecurity</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Fingerling supply</td>
<td>Seasonal</td>
<td>Year round</td>
</tr>
<tr>
<td>Capitol costs</td>
<td>Land, ponds</td>
<td>Building, tanks</td>
</tr>
<tr>
<td>Larval care</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Deformity</td>
<td>Rare</td>
<td>Low</td>
</tr>
<tr>
<td>Controlled environment</td>
<td>Vulnerable</td>
<td>Controlled</td>
</tr>
<tr>
<td>Mechanical failure</td>
<td>Low</td>
<td>Vulnerable</td>
</tr>
</tbody>
</table>

**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

Harvest Size

Density

Fertilization

Weight (g)

Yield kg/ha

Density (1,000's/ha)

≥0.45 g

≥0.57 g

Ponds (%)

Yield

Weight
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
  - NO₃ & 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)
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.

<table>
<thead>
<tr>
<th>Year</th>
<th>No Fertilizer</th>
<th>Inorganic</th>
<th>Organic</th>
<th>I/O</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight (g)</td>
<td>Survival (%)</td>
<td>Weight (g)</td>
<td>Survival (%)</td>
</tr>
<tr>
<td>2000</td>
<td>0.206</td>
<td>28.5</td>
<td>0.415</td>
<td>29.8</td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td></td>
<td>0.64</td>
<td>78.9</td>
</tr>
<tr>
<td>2002</td>
<td>0.25a</td>
<td>84.5</td>
<td>0.36b</td>
<td>88.2</td>
</tr>
</tbody>
</table>

• Results
  • Lined Ponds need to be fertilized
  • Lined Ponds with organic fertilizer do better
### Fry Density in Ponds

<table>
<thead>
<tr>
<th>Year</th>
<th>123K/ha</th>
<th>185K/ha</th>
<th>247K/ha</th>
<th>370K/ha</th>
<th>494K/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight (g)</td>
<td>Survival (%)</td>
<td>Weight (g)</td>
<td>Survival (%)</td>
<td>Weight (g)</td>
</tr>
<tr>
<td>2000</td>
<td>0.56</td>
<td>35.7</td>
<td>0.36</td>
<td>26.1</td>
<td>0.60</td>
</tr>
<tr>
<td>2001</td>
<td>0.47</td>
<td>77.8</td>
<td>0.37</td>
<td>71.2</td>
<td>0.33</td>
</tr>
<tr>
<td>2002</td>
<td>0.71</td>
<td>94.4</td>
<td>0.51</td>
<td>88.2</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>0.50</td>
<td>94.9</td>
<td>0.44</td>
<td>75.8</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>0.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>90.0</td>
<td>0.56&lt;sup&gt;b&lt;/sup&gt;</td>
<td>87.7</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>0.52</td>
<td>*</td>
<td>0.43</td>
<td>*</td>
<td>0.29</td>
</tr>
<tr>
<td>2006</td>
<td>0.59&lt;sup&gt;a&lt;/sup&gt;</td>
<td>92.7</td>
<td>0.47&lt;sup&gt;b&lt;/sup&gt;</td>
<td>88.4</td>
<td></td>
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<tr>
<td>2007</td>
<td>0.68&lt;sup&gt;a&lt;/sup&gt;</td>
<td>97.3</td>
<td>0.49&lt;sup&gt;b&lt;/sup&gt;</td>
<td>93.3</td>
<td></td>
</tr>
</tbody>
</table>

• Are we fertilizing enough?
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

<table>
<thead>
<tr>
<th>Year</th>
<th>Alfalfa</th>
<th>Soybean Meal</th>
<th>Soybean Meal</th>
<th>Soy-Alf Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 lbs/acre/week</td>
<td>80 lbs/acre/week</td>
<td>80 lbs/acre/week</td>
<td>80 lbs/acre/week</td>
</tr>
<tr>
<td></td>
<td>50K fry per acre</td>
<td>50K fry per acre</td>
<td>75K fry per acre</td>
<td>75K fry per acre</td>
</tr>
<tr>
<td></td>
<td>Weight (g)</td>
<td>Survival (%)</td>
<td>Weight (g)</td>
<td>Survival (%)</td>
</tr>
<tr>
<td>2009</td>
<td>0.57</td>
<td>105.2</td>
<td>0.68</td>
<td>81.6</td>
</tr>
<tr>
<td>2010</td>
<td>0.69</td>
<td>94.6</td>
<td>0.68</td>
<td>90.8</td>
</tr>
<tr>
<td>2011</td>
<td>0.74</td>
<td>95.4</td>
<td>0.78</td>
<td>91.7</td>
</tr>
<tr>
<td>2012</td>
<td>0.51</td>
<td>90.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Soybean and alfalfa meal Mix: 47% more fish produced per pond.
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.

<table>
<thead>
<tr>
<th>Year</th>
<th>Density #/ha</th>
<th>Fertilizer</th>
<th>N (kg/ha)</th>
<th>W (g)</th>
<th>% Ponds ≥ 0.57 g</th>
<th>% Ponds ≥ 0.45 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>123K</td>
<td>ALF</td>
<td>16.8</td>
<td>0.74</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>123K</td>
<td>SBM</td>
<td>34.8</td>
<td>0.78</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>185K</td>
<td>SBM</td>
<td>34.8</td>
<td>0.66</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2013</td>
<td>123K</td>
<td>ALF</td>
<td>20.7</td>
<td>0.55</td>
<td>33</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>185K</td>
<td>Mix</td>
<td>30.4</td>
<td>0.69</td>
<td>85</td>
<td>100</td>
</tr>
</tbody>
</table>
Pond Fertilization

Fertilizer Applied (lbs)

- SBM
- AP

SBM/AP Cumulative Nitrogen
- AP Cumulative Nitrogen

Nitrogen (lbs)

- 4/9, 4/16, 4/23, 4/30, 5/7, 5/14
Total Ammonia Nitrogen (TAN)

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

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Maximum (mg/L)</th>
<th>Average (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa Pellets (2001-2011)</td>
<td>1.36</td>
<td>0.10 – 0.45</td>
</tr>
<tr>
<td>Soybean Meal (2010-2011)</td>
<td>1.32</td>
<td>0.48 – 0.73</td>
</tr>
</tbody>
</table>

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)
Un-ionized Ammonia

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

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<th>Average (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa Pellets (2001-2011)</td>
<td>0.349</td>
<td>0.007 – 0.055</td>
</tr>
<tr>
<td>Soybean Meal (2010-2011)</td>
<td>0.371</td>
<td>0.076 – 0.129</td>
</tr>
</tbody>
</table>
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.
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?

35 mm TL

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.