AQUACULTURE INTENSIFICATION:
1) PARTITIONED PONDS, SPLIT-PONDS AND INTENSIVE PONDS
2) IN-POND RACEWAYS & RECIRCULATING SYSTEMS

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Tilapia co-culture for management of algal production in a “High-Rate Pond” modified for fish production, increasing carry capacity to 19,000 lb/acre
OBJECTIVES; 2014 &2015
Comparisons of Split-Ponds (SP) and Intensive Ponds (IP) at MS-State Delta Branch Experiment Station vs. Conventional Ponds (CP) and Partitioned Aquaculture Systems (PAS) for production of hybrid catfish (*Ictalurus punctatus* x *I. furcatus*)
MS Split-Pond; 2014

1995-2008 Clemson PAS (0.05-2.0 ac)  

2014 MS Intensive Pond (2.0 ac)
MS Split Ponds and Intensive Ponds; 2015

IP-5W
3.9 ac
6.0 ft-deep
Three 10-hp aerators

IP-5W
3.8 ac

SP-H4
3.8 ac
6.0 ft-deep

SP-H3
5.5 ac
4.3 ft-deep

SP-H1

IP-5E
3.9 ac

Four 10-hp aerators

1.5 ac
6 ft-deep
## Carrying Capacity and Feeding

<table>
<thead>
<tr>
<th>Type</th>
<th>Max catfish carrying capacity (lbs/acre)</th>
<th>Feed loading ave/max (lbs/acre-day)</th>
<th>FCR lbs-feed/lbs-fish</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1995-2008</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAS</td>
<td>15,000-18,000</td>
<td>160/250</td>
<td>1.4-1.6</td>
</tr>
<tr>
<td>CP</td>
<td>5,000-7,500</td>
<td>100/150</td>
<td>~2.0</td>
</tr>
<tr>
<td><strong>2014</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP</td>
<td>14,032</td>
<td>120/280</td>
<td>1.66</td>
</tr>
<tr>
<td>IP</td>
<td>18,245</td>
<td>107/270</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>2015</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP</td>
<td>12,800-14,100</td>
<td>110/216</td>
<td>1.9-2.0</td>
</tr>
<tr>
<td>IP</td>
<td>9,200-13,800</td>
<td>84/161</td>
<td>1.8-1.9</td>
</tr>
</tbody>
</table>
SP vs. IP 2015 Feed Rates; Bird losses decreased SP to 70% stocking
Split-Pond Treatment Zones (day-time)

Water Treatment 4.3 ft, (72% of total volume)
Photosynthesis; Top 30%
Aerobic Treatment; Top 65%

Anoxic Treatment; Variable 15%
Anaerobic Treatment; bottom 35%

Fish Culture 6.0 ft, (28% of total volume)
12,000 gpm
5 fish-zone exchanges/day
Aeration = off
Split-Pond Treatment Zones *(night-time)*

<table>
<thead>
<tr>
<th>Water Treatment 4.3 ft, 72% of total volume</th>
<th>Fish Culture 6.0 ft, 28% of total volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaerobic ~ 100%</td>
<td>Exchange = off</td>
</tr>
<tr>
<td></td>
<td>Aeration capacity</td>
</tr>
<tr>
<td></td>
<td>=30 hp/acre</td>
</tr>
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</table>
## Algal Removal Mechanism, Density and Dominant Algal Species

<table>
<thead>
<tr>
<th>Type</th>
<th>Algal Density</th>
<th>Algal removal mechanism</th>
<th>Algal genera</th>
<th>Algal cell age (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAS</td>
<td>18 / 80</td>
<td>tilapia/sedimentation</td>
<td>green</td>
<td>3.3</td>
</tr>
<tr>
<td>SP</td>
<td>13 / 110</td>
<td>zooplankton/sedimentation</td>
<td>bluegreen(^1)</td>
<td>4.6</td>
</tr>
<tr>
<td>IP</td>
<td>12 / 115</td>
<td>zooplankton/sedimentation</td>
<td>bluegreen(^1)</td>
<td>3.8</td>
</tr>
<tr>
<td>CP</td>
<td>13 / 110</td>
<td>zooplankton/sedimentation</td>
<td>bluegreen(^2)</td>
<td>9.0</td>
</tr>
</tbody>
</table>

\(^1\) Oscillatoria  
\(^2\) Oscillatoria, Microcystsis Anabaena
Bluegreen dominance more sustained in Intensive-Pond vs. Split-Pond
PAS Bluegreen Biomass; 1999
(percent of total)

% Bluegreen
UNIT 3

Tilapia filter-feeding (@25% of catfish biomass) reduces bluegreen dominance late season
Zooplankton and Algal Settling (2014)

- High algal settling rates in SP and IP
- Bluegreen algae enmeshed in detritus
- Large zooplankton populations

Rapidly settling algae

High zooplankton numbers
Summary

Partitioned Aquaculture System
- Continuous paddlewheel mixing, 100% aerobic, 3.0 hp/acre aeration
- 18,000 lb/acre in 5% of system (raceway culture),
- Rapidly growing green algae controlled by tilapia, few zooplankton
- 80 mg/l algal density, 25% algal respiration,
- No nitrification.

Split-Pond
- Daytime mixing with paddle wheels, 80% anaerobic at night, 5.7 hp/acre aeration
- 12,800 - 14,100 lb/acre in 28% of system
- Rapidly growing bluegreen algae, rapid sedimentation, high zooplankton numbers
- 115 mg/l algae density, 50% algal respiration
- Nitrification = 20% of treatment
- More consistent algal bloom, lower bluegreen dominance vs. Intensive-Pond
- Lower capital cost compared to PAS
Summary continued

**Intensive Pond**
- Night-time mixing and aeration at 7.9 hp/acre, anaerobic % unknown
- 9,200-18,200 lb/acre in 100% of system volume
- Rapidly growing bluegreen algae, rapid sedimentation, high zooplankton numbers
- 110 mg/l algae density, 50% algal respiration,
- No nitrification
- Bird predation harder to control
- Lower capital cost compared to SP

**Conventional Pond**
- Night-time mixing and aeration at 2.6 hp/acre, anaerobic % unknown
- 7,500 lb/acre in 100% of system volume
- Slowly growing bluegreen algae, sedimentation & zooplankton variable
- 110 mg/l algae density, 50% algal respiration,
- Nitrification unknown
- Lower capital cost compared to IP
Questions

- Raceway culture with higher degree of control over algal population justify higher PAS cost?
- Reduced cost of SP and IP given lower degree of control with bluegreen dominance justified? Is system behavior reproducible?
- Reduced cost, lower production, and lower level of control of CP justified? Will variable algal dominance lead to off-flavor issues?
- PAS control vs. CP low-cost: Systems-wide cost/lb vs. risk comparison?
Recirculating Aquaculture Systems

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³) Pinnacle Aquatics LLC, Jamestown, Missouri
Simplified Process Flow Diagram for Recirculating Aquaculture Systems (RAS)

1. Grow-Out Tank
   These are the large culture tanks where fish (or shellfish) are raised.

2. Solids Removal
   Solids, such as fecal material and uneaten feeds are removed by mechanical filtration.

3. Biofiltration (Ammonia Removal)
   Beneficial bacteria consume ammonia, which, converted into nitrogen, is released harmlessly into the atmosphere.

4. Dissolved Gas Control (Oxygenation)
   The final step, and the most crucial for the fish, is to reoxygenate the culture water as it returns to the grow-out tank. Pure oxygen is injected to the returning water. Carbon dioxide is also removed.
RAS typically used for cold-water, clean-water species

AKVA Group, Norway
Hybrid Stripped Bass Production
Kent SeaTech, LLC Temecula, CA 92593
Recirculating System for Largemouth Bass (retrofit of swine facility)

Carrying capacity; 12,000 lbs largemouth bass, FCR = 2.0/1
Aeration: Rotary screw compressor with oxygen separators
   Tanks; 4,200 gal grow-out, 300 gal fingering
Biofilters; 1,500 gallon tanks with 12x25 mm plastic media
CO₂ stripping; 4 ft tall x 2 ft diameter columns
   Solids removal; 30 micron rotating drum
Capital costs ~ $5.00/gallon, Selling price ~ $6.00/lb
Limited-Discharge Recirculating System;
Biofilters, CO₂ - Stripping, Fingerling Grow-out, Solids removal, Oxygenation
In-Pond Raceways

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\textsuperscript{2}Fisheries and Wildlife, University of Missouri
\textsuperscript{3}Pinnacle Aquatics LLC, Jamestown, Missouri
Auburn In-pond Fixed Raceway
Auburn In-pond Floating Raceway

Floating Raceway System

Here is the system in operation. It is easy to observe the water flow in this Exchange rate of water through this unit is about every 2.5 minutes.
Masser and Lazur; In-pond Floating Raceway

Figure 3c. Drawing of IPR in cross section and top view showing attachment of air-lifts, tube settler, demand feeder, and emergency oxygen tubing system.
ELLENTON, FL Private System reported in Fish Farming News, #4, 2015
In–Pond Raceway

Carrying Capacity; 1,500+ lb fish
Raceway; 20’ x 4’ x 4’
Overall Dimension; 8 ft x 22 ft
Weight; 1,800 lbs
Aeration; Two-1.75 hp blowers
Floatation; 12” x 2’ x 4’ floats
Water Exchange; one vol/30min
Air-lift: 3 inch PVC pipes
Capital cost ~ $12,000/unit
Sale price ~ $6.00/lb
(live haulers ~1.5 lb fish)

1) Pinnacle Aquatics LLC
In–Pond Raceway (0.67 fpm velocity); Water Inlet (9-airlift tubes), Outlet for Solids Capture/Removal (80 gpm) and Blowers (1.75 hp)
TABLE 1. Economic comparisons between the IPR, cages and open-pond catfish culture (1-acre pond).\(^1\)

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Open-pond(^2)</th>
<th>Cage</th>
<th>IPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>yield (lbs)</td>
<td>3,806</td>
<td>2,830</td>
<td>5,352</td>
</tr>
<tr>
<td>death loss (%)</td>
<td>6</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>feed conversion</td>
<td>1.8</td>
<td>1.6</td>
<td>1.45</td>
</tr>
<tr>
<td>% protein feed</td>
<td>32</td>
<td>36</td>
<td>36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Economic parameters (dollars)</th>
<th>Open-pond(^2)</th>
<th>Cage</th>
<th>IPR</th>
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</thead>
<tbody>
<tr>
<td>variable costs</td>
<td>3,135.63</td>
<td>2,391.27</td>
<td>4,160.25</td>
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<tr>
<td>fixed costs</td>
<td>787.72</td>
<td>850.16</td>
<td>1,111.26</td>
</tr>
<tr>
<td>total costs</td>
<td>3,923.35</td>
<td>3,241.43</td>
<td>5,271.51</td>
</tr>
<tr>
<td>breakeven price (cents per pound)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>to cover variable costs</td>
<td>82.39</td>
<td>84.50</td>
<td>77.73</td>
</tr>
<tr>
<td>to cover total costs</td>
<td>103.08</td>
<td>114.54</td>
<td>98.50</td>
</tr>
</tbody>
</table>

\(^1\)Pond construction and management costs have not been included in the budgets.

\(^2\)Open-pond production yields are based on actual average production values observed in the catfish industry in Alabama.