CONTAINMENT SYSTEMS for Biosecurity, Escapes, Alien Species and other Environmental Factors

Steven Summerfelt
Containment is Necessary for Sustainable Aquaculture

• Land-based, closed-containment systems:
  – Exclude chemicals & obligate pathogens
    • No pesticides, antibiotics, & chemotherapeutics in closed-containments systems w/ over 10 yrs operation at TCFFI
  – Prevent escapees & disease interaction between wild & farmed fish
  – Minimize water use & release of pollution
  – Optimize water temperature & photoperiod
  – Locate farm where electric & land are cheap
    • US$ 0.02-0.03 / KWH
Containment is Necessary for Sustainable Aquaculture

• Land-based closed-containment systems are essentially giant water treatment facilities
• Water flow is the engine that powers the system:
  – flow carries dissolved oxygen to the culture unit,
  – flow receives wastes produced in the culture unit,
  – flow carries wastes out of the culture tank to the water treatment processes

Water flow exchanges the culture tank volume every 15-60 min.
Containment is Necessary for Sustainable Aquaculture

- Develop large-scale technologies
  - Reduce fixed & variable costs per MTON
  - Improve economics of production

1000 ton/yr facility, Phase I under construction
Concept Design and Cost for a 2,500 MT/yr Closed-Containment System

- Total RAS Systems: $21,126,000
- Processing: $1,878,000
- Total Buildings: $8,379,000

**TOTAL ± 30%** $31,383,000

**Growout Building**
- 21,320 m² (5.3 acre) Building
- 34,180 m³ Culture Volume
- 40 Tanks: 16 m dia. x 4.25 m deep
- 94.6 m³/min recycle flow per RAS
- 90 weeks production cycle to 5.0kg

Brian Vinci

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August 17, 2011
Cost of Salmon Production

Feed 53%
Electricity 11%
Oxygen 5%
Labor 6%
Processing 2%
Management 2%
20-yr Depreciation 14%
10-yr Depreciation 7%

$3.76 per kg HOG

Brian Vinci
Atlantic Salmon Growout Trial

- Good growth in freshwater
- Atlantic salmon appear to handle 80 kg/m³ density better than rainbow trout
- Minor fungus in ‘hard’ freshwater
- Use of all female eggs avoids precocious males

You don’t need the ocean to farm Atlantic salmon!
Atlantic Salmon Growout Trial

- Rapid Atlantic salmon growth (4 kg in best trt) in **freshwater** to 24-month post-hatch at 13°C

(10 m³ culture tanks)
Atlantic Salmon Growout Trial

- **FCR** averaged 1.05:1 using 40:30 feed
- **Survival** exceeded 95%
- **Condition Factor** averaged 1.7
  - net pen fish condition factor ~1.3
- **Thermal Growth Coefficient (TGC)** is 2.7 in most recent trial

6+ kg female
Taking Advantage of Large & Deep Circular Culture Tanks

- Large and deep tanks are more efficient in fixed & variable costs! (500-1200 m³/tank)

(Courtesy of Josh Goldman)
Optimized water rotation & mixing

Dual-drains improve management of rotation and provide for solids separation at tank and optimized swimming speed for fish.
Fish Harvest Technologies

- Developed sidewall harvest box
  - Clam-shell grader used to crowd fish so they slide into dewatering area

Grader nets could also be used
Solids Removal

- Integrate *dual-drain culture tanks, settlers, and drum filters*
Large-Scale Biofilters

• Developed theoretical and practical guidelines for a modified pipe-manifold **fluidized-sand biofilter**
  
  – Maintains lowest TAN & NO2-N concentrations; compact

Now designing for recirculating flows up to 100 m3/min
• Integration of $O_2$ & $CO_2$ technologies into RAS.
  - Air stripping column followed by low head oxygenator
  - BAT for many new commercial and state/federal RAS.
Ozonation of Recirculated Water

• Evaluated ozone, which creates clear ‘blue’ water even with zero water flushing
  ➢ Improves biofiltration & solids removal
  ➢ Removes color & fine solids
  ➢ Reduces flavobacteria problems

• Some call ozone
  – Vitamin ‘O’
  – The Silver Bullet

No Ozonation (80 kg/m³)  Ozonation (80 kg/m³)
Environmental Management

- **Escapees**
  - Exclude

- **Concentrated waste biosolids**
  - capture,
  - transfer,
  - store,
  - treat, or
  - utilize

- **Dissolved nutrients**
  - remove

- **Pathogens**
  - exclude

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Gravity Thickening Settler

- Designed for solids collection, thickening & storage (short-term or long-term)
- 95% TSS removal efficiency
- 9% biosolids concentration
- No coagulant / flocculant
- Lowest fixed & variable cost
- Low maintenance
Inclined Belt Filter

• Biosolids collect on belt and are scraped into a hopper
• Produced the cleanest discharge -- 96% TSS removal
  – Excellent TN, TP, cBOD5, COD removal
• 9% biosolids concentration  • highest fixed cost

• Requires Flocculent
Geotextile Bag Filters

• Large bags constructed of a high-strength, porous, woven material
• 95% TSS removal efficiency
• Most leaching of TAN, dis. P, & BOD
  - loss of nutrients
• 22% biosolids concentration
• Flocculent must be added
• Highest operating cost
  - (polymer + bag replacement costs)
• Intermediate fixed cost
Reclaim Nutrients in the Biosolids

• Agronomic application of biosolids to crops according to nutrient management plan

• Compost
Exclude Escapees: Fish Exclusion Screen

Screens exclude fish/eggs before discharge
Conclusions

• Closed-Containment Systems
  – Confidence in technology is increasing
  – Scale of investment has increased to $5-25 million/project
  – Current N. American projects being built or planned with projected capital investment of $50-100 million
    • Atlantic salmon, Coho salmon
    • sea bream, yellow perch, sturgeon
    • Arctic char, walleye, sablefish
Conclusions

• Closed-Containment Systems
  – N. America, expect production to increase by 10,000 to 50,000 ton during next 5-yrs, including several species
  – Worldwide, a number of 1000-10,000 ton/yr farms for Atlantic & Coho salmon are being built or planned
    • China (3), Denmark (1), USA (3), Chile (1), Canada (1)
    • Many smaller projects
Questions and Challenges Related to Upscaling

- Solids flushing & mixing in 2000-5000 m³ culture tanks
- Minimizing system energy consumption without sacrificing water quality
- Denitrification without supplementing carbon
  - NO₃ control in low flushing systems
- Pathogen free ‘All female’ Atlantic salmon eggs commercially available at least twice annually
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  - Atlantic Salmon Federation
    • 12 month salmon growout trial
  - Moore Foundation
    • 24 month salmon growout trial
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