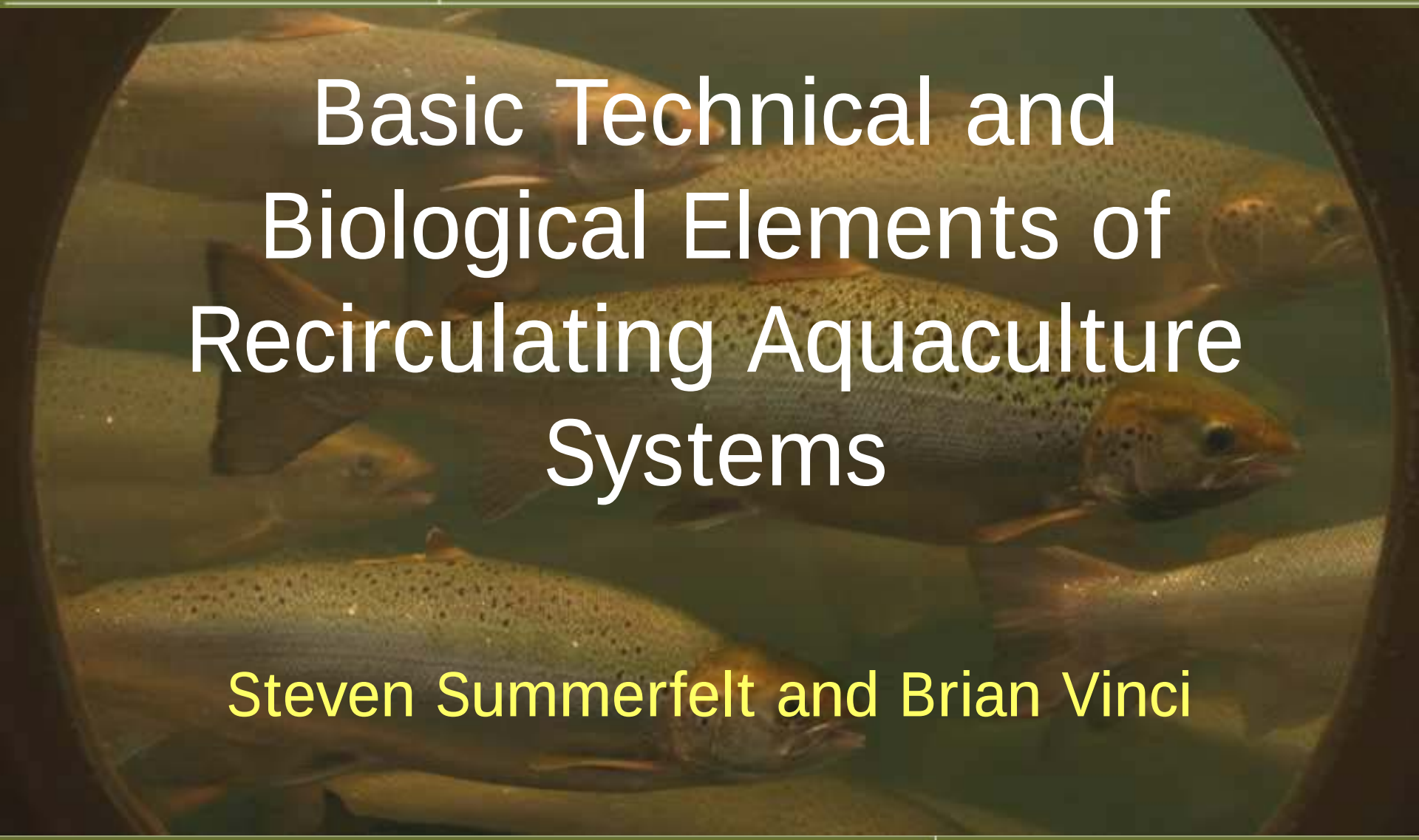
THE CONSERVATION FUND



Basic Technical and Biological Elements of Recirculating Aquaculture Systems

Steven Summerfelt and Brian Vinci

AIW#6, Vancouver,
October 27, 2014

THE CONSERVATION FUND

Acknowledgements

- Research support

Gordon and Betty MOORE FOUNDATION

USDA

TIDES canada

SalmoBreed

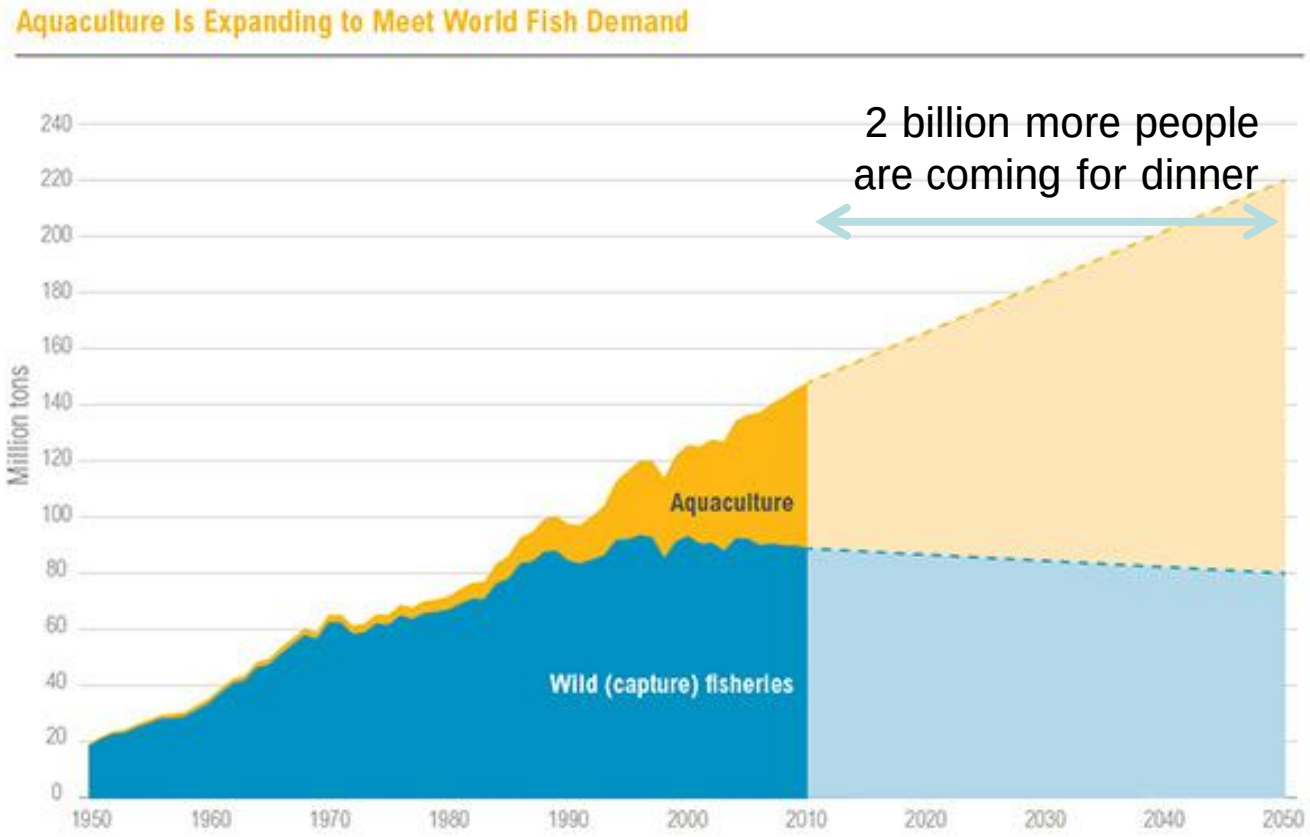
THE CONSERVATION FUND

Outline

- Why aquaculture and land-based RAS?
- RAS Basics
  - What fish need to survive & thrive
  - Water treatment processes
- Waste management and utilization
- Business and environmental risks
- Current Status of RAS
- Wrap-up

THE CONSERVATION FUND

Why Aquaculture



THE CONSERVATION FUND

Aquaculture Production Constraints

- All aquaculture
  - Siting and competing users
  - Marine fish meal and oil supplies
  - Water pollution and impacts on watersheds
  - Disease interaction between wild & farmed
- Land based aquaculture
  - Freshwater supplies
  - Stringent wastewater discharge permits

THE CONSERVATION FUND

Floating Systems

- Salmon net pens
  - 40,000 MT/yr in US
  - 2 Million MT/yr globally

- Production of other fresh-water & marine species

- Floating tanks/bag pens

Marine Harvest Norway
20,000 m^3 floating tank at Molnes

FutureSEA 'Sea System'

THE CONSERVATION FUND

Land-Based Systems

- Ponds
  - 200,000 MT/yr US catfish
  - Enormous global production of catfish, tilapia, shrimp, carp

- Flow-through raceways
  - 20,000 MT/yr US trout

THE CONSERVATION FUND

Land-Based Systems

- Recirculating Aquaculture Systems – RAS
  - Represents a small but rapidly growing segment
  - Scale of land-based projects is increasing
    - 1,000 to 6,000 ton/yr under one roof
    - smolt/post-smolt salmon and food-size fish

THE CONSERVATION FUND

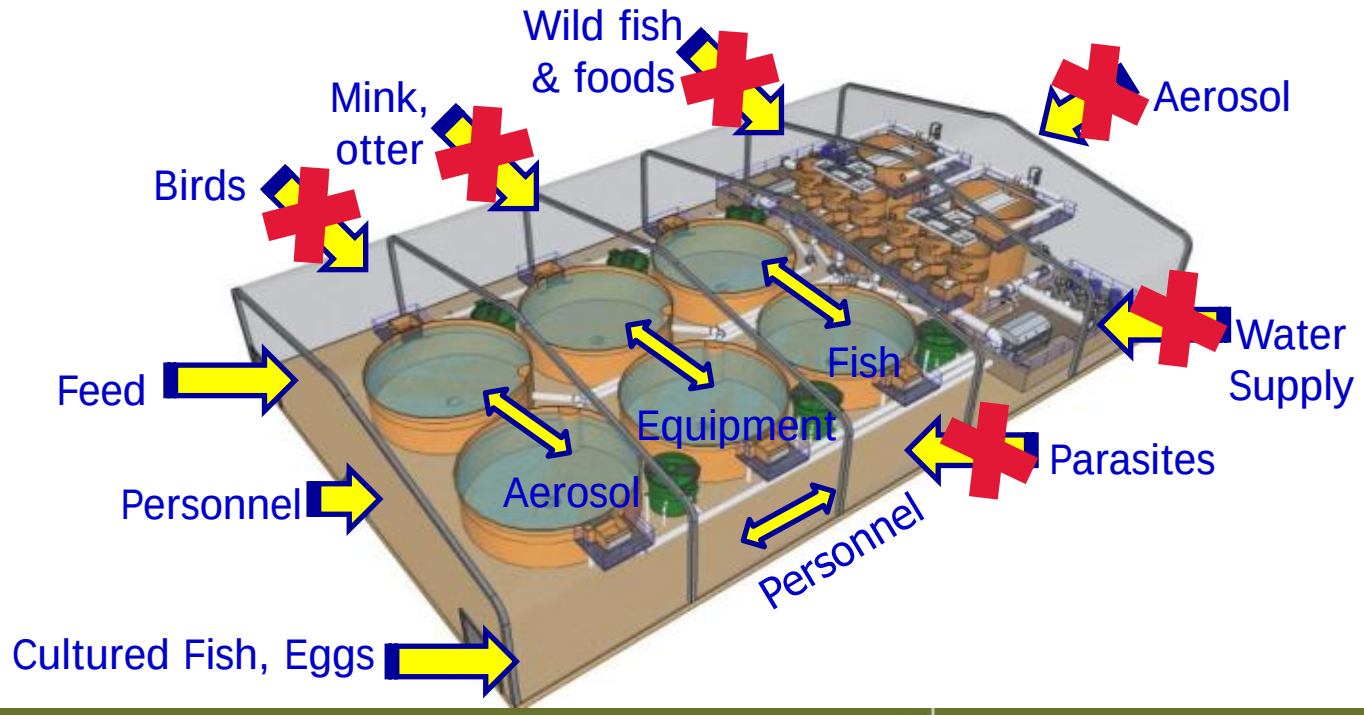
RAS Advantages

- Closed-containment systems improve food security & reduced environmental impact:
  - Small footprint
    - Less than 1% of the **land** required by pond culture
    - Less than 1% of the **water** required by flow-through trout culture
  - Most Efficient; feed conversion is near 1:1
  - Zero escapees
    - no interaction/impacts on wild population
  - Location, location, location

THE CONSERVATION FUND

RAS Advantages

- **Excludes obligate pathogens** = healthier fish
  - Reduce mortality. Improve health and performance
  - Reduce or eliminate vaccine, antibiotic, & pesticide use
  - Avoid losses from and costs of mitigating sea lice, viruses (ISA, PD), amoeba, bacteria, toxic algae, superchill



THE CONSERVATION FUND

RAS Advantages

- Control and capture wastes and reclaim nutrients

THE CONSERVATION FUND

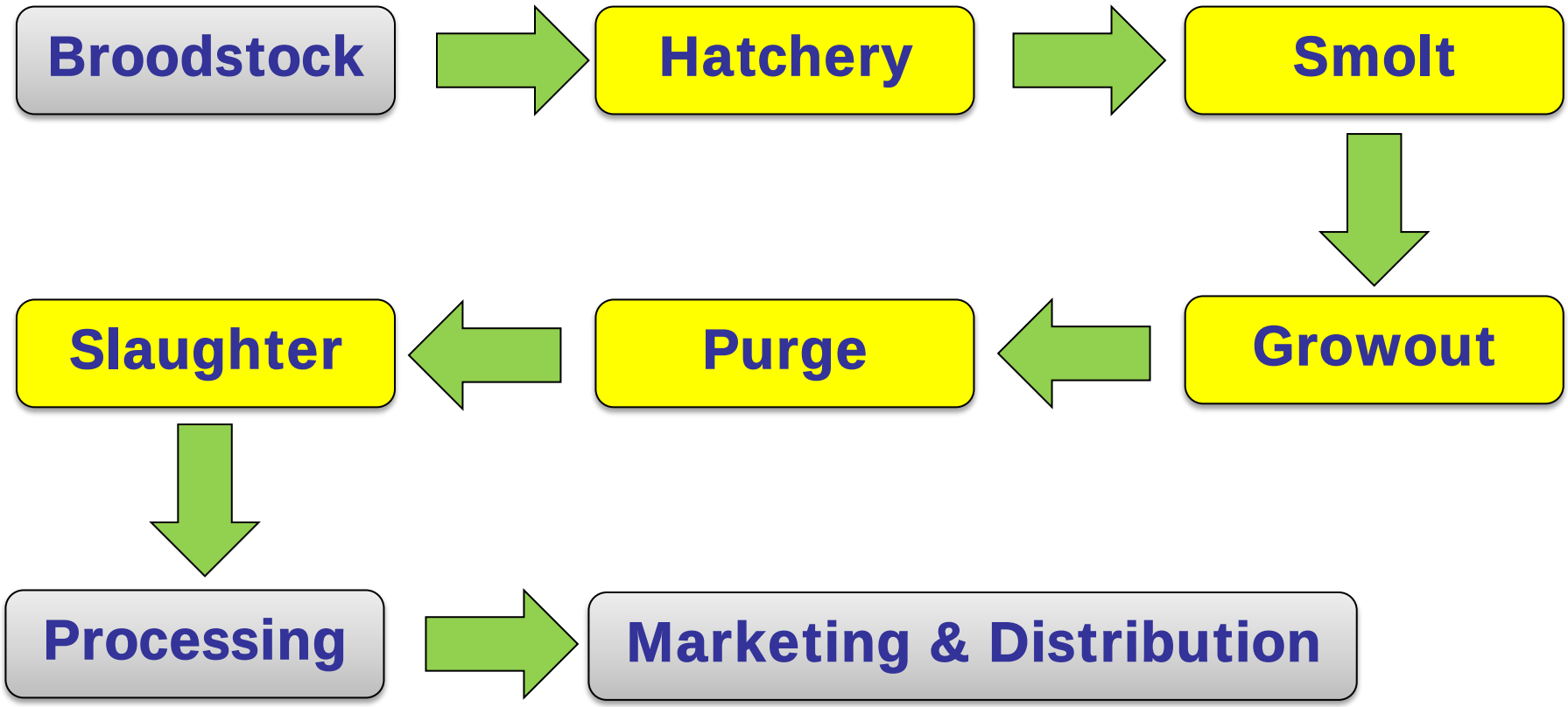
RAS Address Market Needs

- Consistent production
  - Similar product every week of the year
- Local & Fresh
- Highly traceable
- No pesticides and no (or reduced) antibiotics
- Environmentally friendly
- All are opportunities to market and brand

Recirculating System Concepts

THE CONSERVATION FUND

Overview of System and Process Requirements



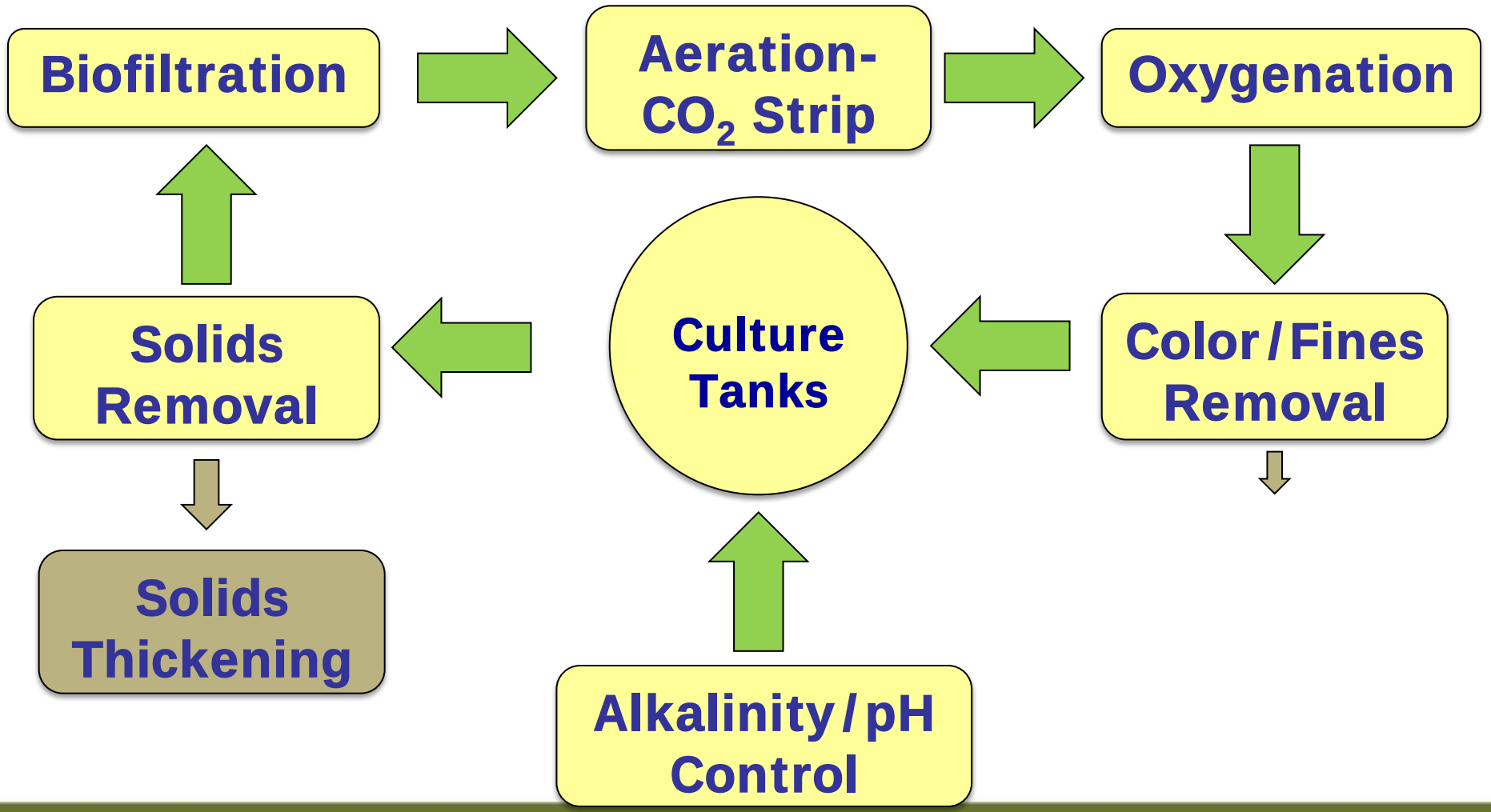
THE CONSERVATION FUND

Water Recirculation System

- Land-based closed-containment systems are essentially giant water treatment facilities
- Recirculating water is the engine powering the system
  - flow carries 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
  - flow creates the WATER ROTATION for fish performance

THE CONSERVATION FUND

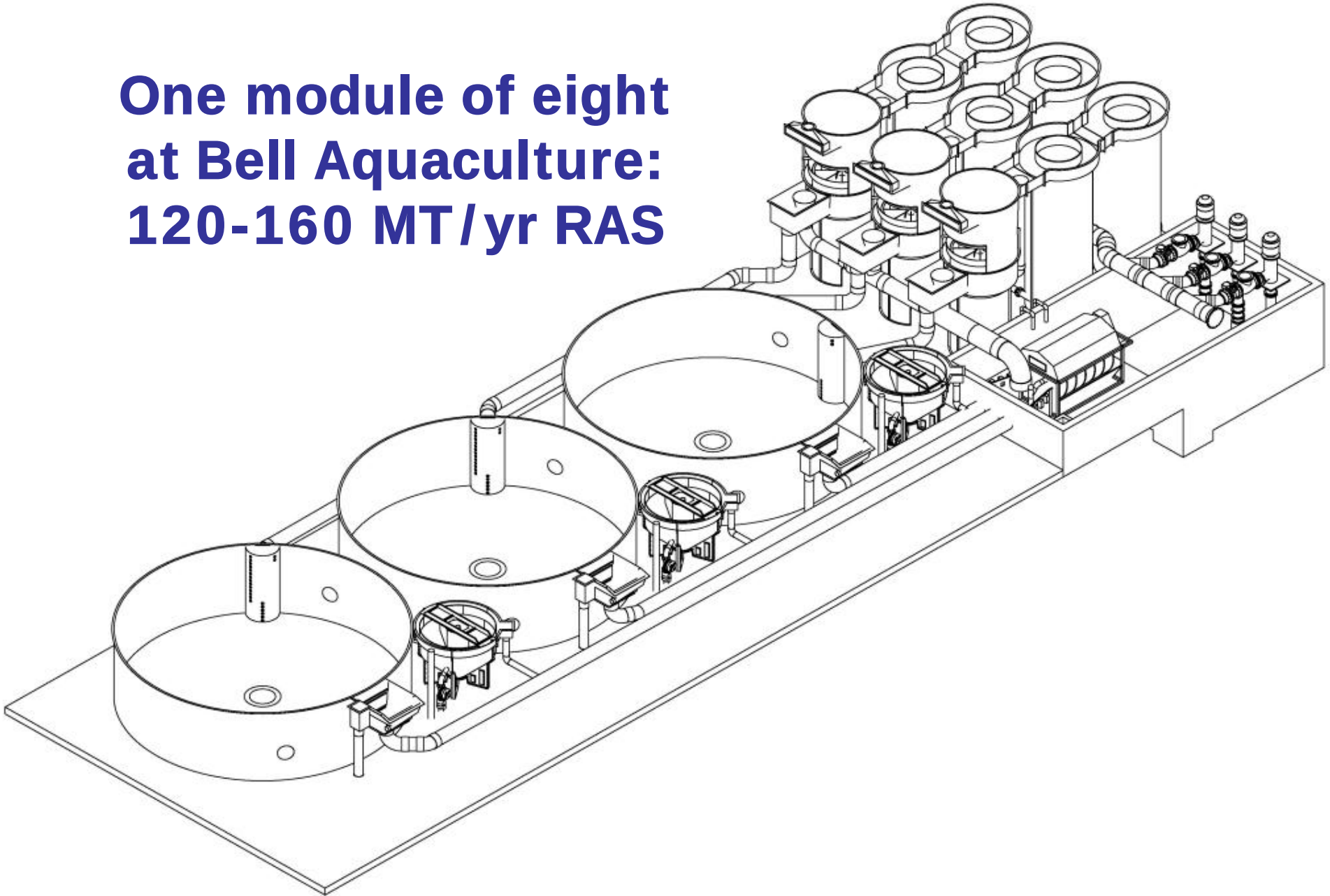
RAS Process Flow Diagram



THE CONSERVATION FUND

RAS - Example

One module of eight at Bell Aquaculture: 120-160 MT/yr RAS



THE CONSERVATION FUND

RAS Design & Operation

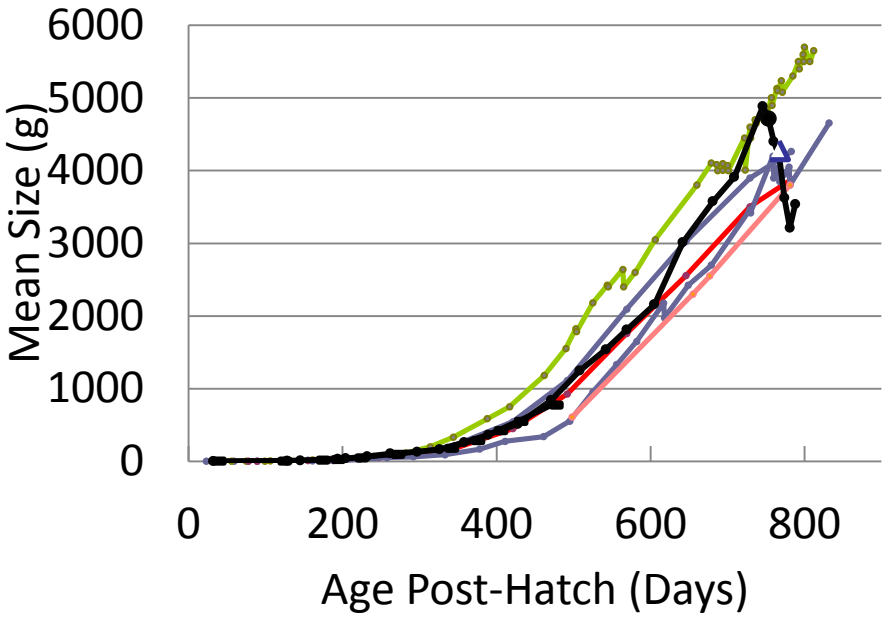
- Bioplan to define production system
- Water treatment and recirculation
- Fish harvest, purging, and humane slaughter
- Effluent treatment & biosolids dewatering

Bioplan

- Identify # fish, grouping, and timing of their movement through the systems
  - # stocked
  - Stocking size
  - Stocking frequency (e.g., monthly, quarterly, or annual)
  - Cold-banking
  - Biomass density for different sizes
  - # harvested
  - Harvest size
  - Weekly harvest
  - Cohort isolation at system or tank level
  - All in, all out versus comingled cohorts

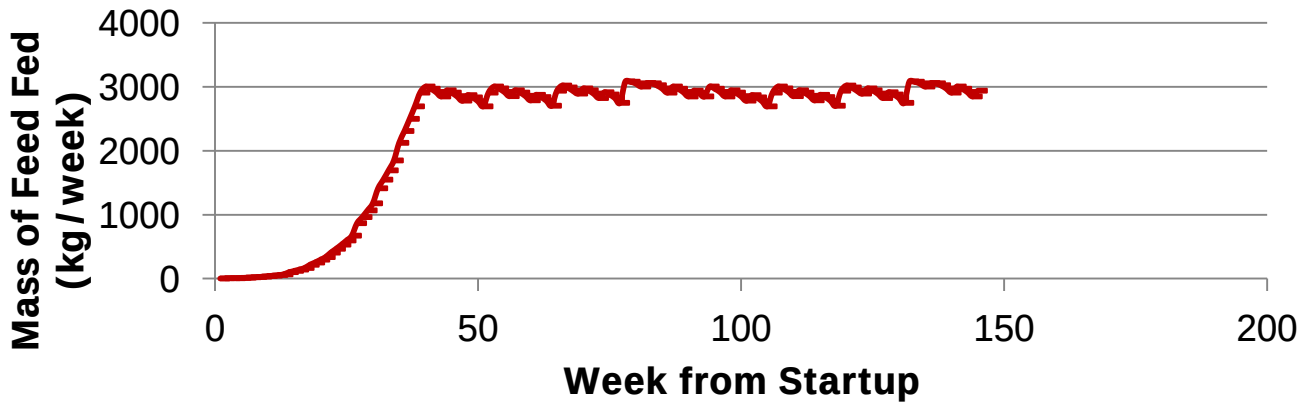
Bioplan

- Identify what fish need to survive & thrive
  - Culture water characteristics
    - Oxygen, CO_2, ammonia
    - Temperature regime
    - Salinity
  - Feed rates
  - **Growth rate**
  - Fish density limits
  - Photoperiod
  - Swimming speed
  - Number & size of culture tanks



Production Capacity

- **Annual Production** is directly proportional to:
  - Tons of feed fed annually
  - Feed conversion
  - Survival rate
  - Ability to maintain system near carrying capacity
    - Multiple egg, fingerling, smolt stocking each year with weekly harvests



THE CONSERVATION FUND

RAS Capacity

- Carrying capacity of RAS
  - defined by the feed level that it supports
    - maintains water quality
    - healthy & rapid fish growth

RAS Capacity

- Water quality within RAS depends on:
  - water flow,
  - waste production rate,
  - O_2 consumption rate, and
  - efficiency of waste removal at each process

  - RAS designers must have experience with these parameters

THE CONSERVATION FUND

RAS Capacity

- RAS must carry 90-100% of the waste treatment burden to maintain safe water quality for the fish.

THE CONSERVATION FUND

Magnitude of RAS Water Reuse

Open salmonid RAS:
2-5% makeup flow
0.2-0.5 kg feed per m^3 makeup water
Clear water, TSS 3-5 mg/L

Tight salmonid RAS:
0.2-0.5% makeup flow
2-10 kg feed per m3 makeup
Brown water, TSS of 10-20 mg/L
Suggest ozonation!

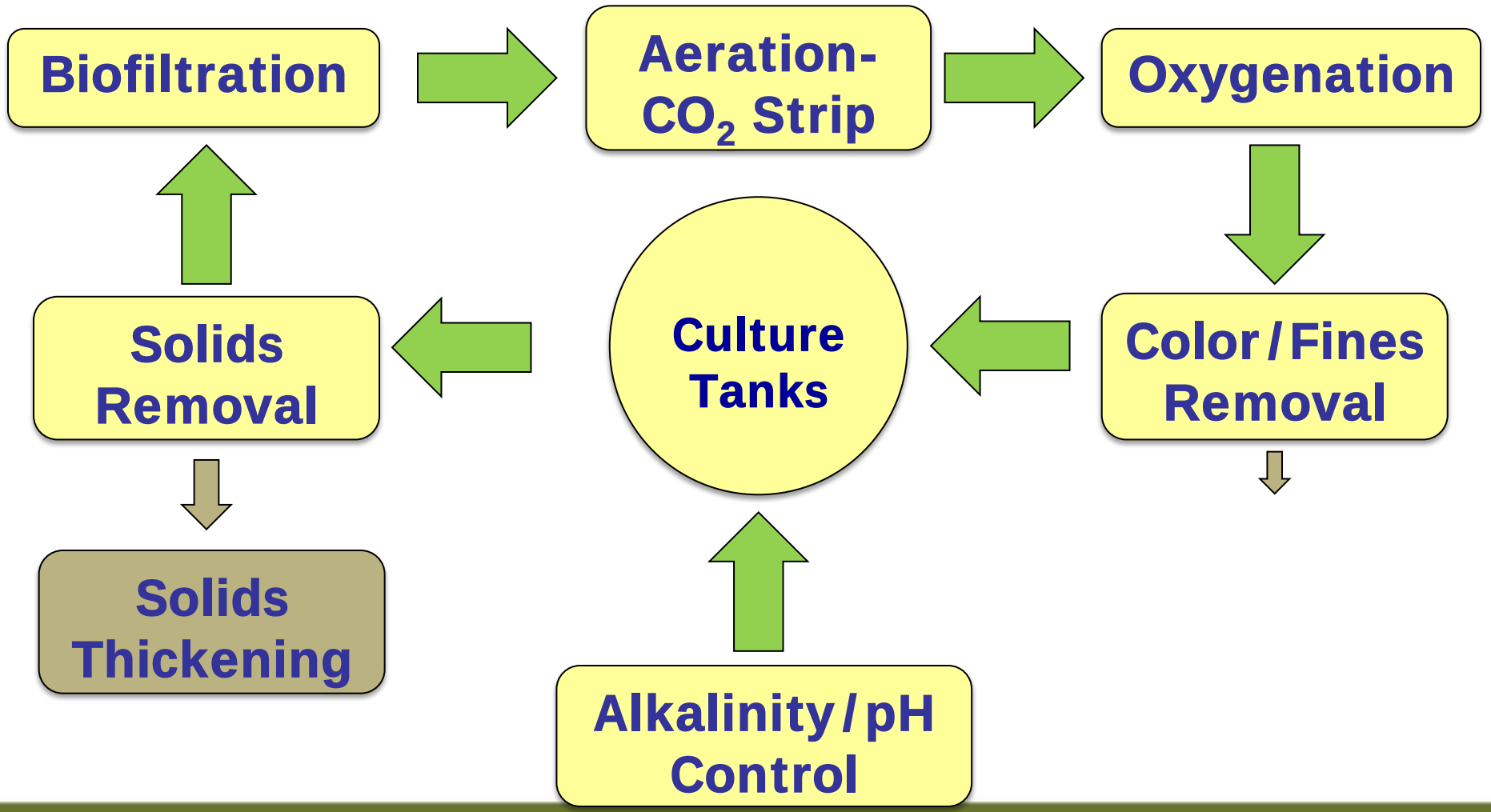
THE CONSERVATION FUND

RAS Water Requirements

- Water Supply for Most Open RAS
  - Closed-containment system can increase production on a limited water supply by 100+ fold
  - Many commercial examples
- Water Supply for RAS with Denitrification & Solids Digestion
  - Very small water requirement
  - Water leaves with digested solids, evaporation
  - Few commercial examples

THE CONSERVATION FUND

RAS Process Flow Diagram



THE CONSERVATION FUND

Culture Tanks

THE CONSERVATION FUND

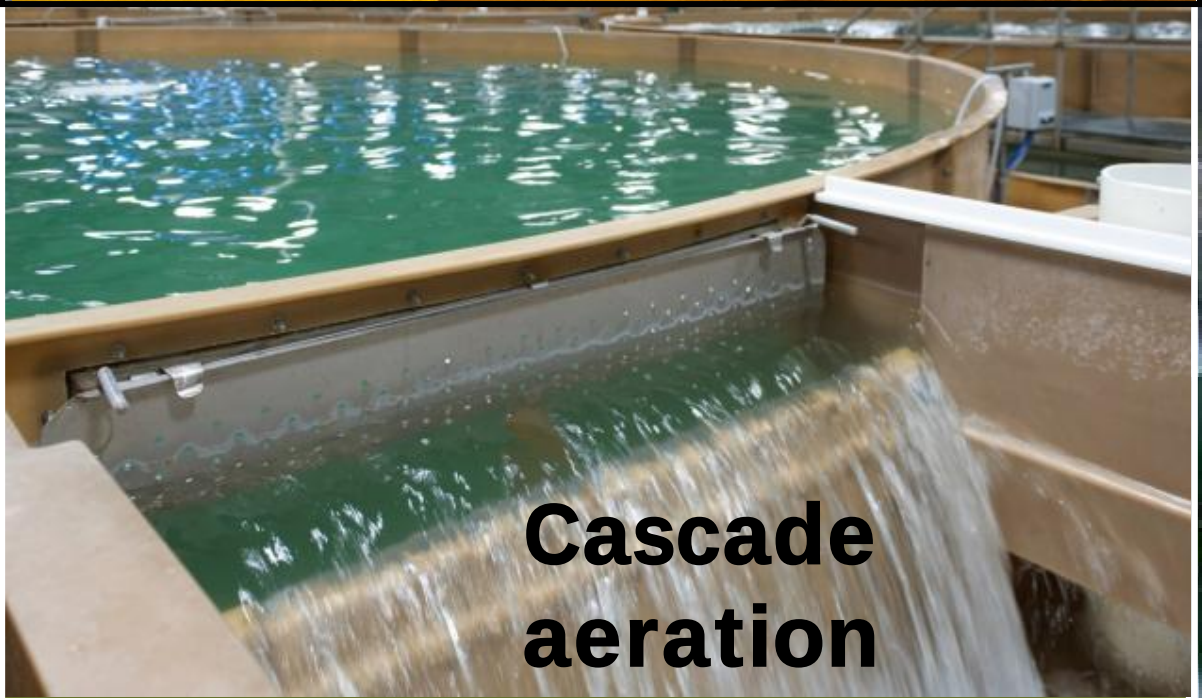
Solids Removal

Integrated dual-drain culture tanks, settlers, & drum filters

Biofiltration

THE CONSERVATION FUND

Aeration – CO_2 Stripping



THE CONSERVATION FUND

Oxygenation

THE CONSERVATION FUND

Fish Transfer & Grading

THE CONSERVATION FUND

Depuration Systems

- System(s) to purge harvested fish of off-flavor

THE CONSERVATION FUND

Humane Slaughter

Processing & Transport

- Fish must be transported to processing

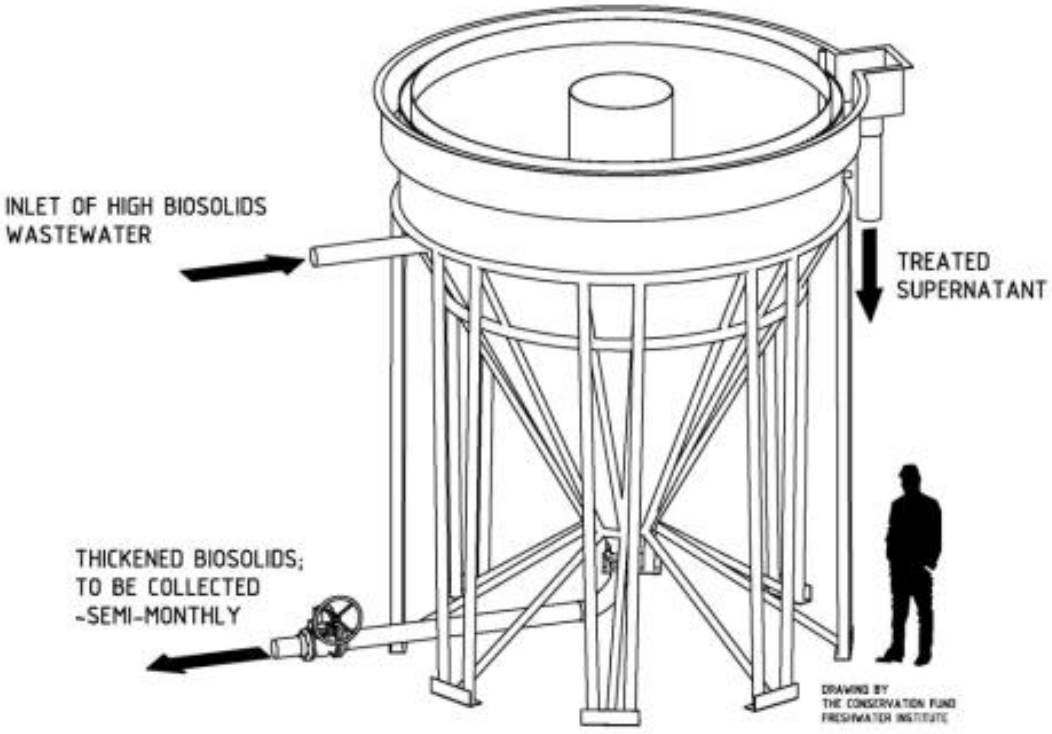
Waste Management & Utilization

- Closed-containment
  - Limits waste discharge
- Place wastes into concentrated effluent flows
  - Increase waste treatment efficiency,
    - > 90-99% waste capture is possible;
  - Improved waste capture will **reduce Total Maximum Daily Load** discharged
  - Reduce the size and cost of effluent treatment

THE CONSERVATION FUND

Capture & Dewater Biosolids

- Gravity thickening settling units
  - **Lower fixed & variable costs**
  - No coagulant / flocculants required to 5-10% solids
  - Low maintenance
  - **Farmer friendly**



THE CONSERVATION FUND

Dewater & Dry Biosolids

BELT FILTER PRESS

ROLLER PRESS

- Dry biosolids to avoid storage lagoons (odor), reduce transport volume, & prepare for composting

THE CONSERVATION FUND

Reclaim Nutrients

- Nutrients can be reclaimed
  - Agronomic application of biosolids to crops
  - Compost
  - Aquaponics

THE CONSERVATION FUND

Permitted Discharge

Aquaculture Discharge to Spring Pond at Freshwater Institute

Infiltration Basins at ‘Namgis 1st Nation

Prevent Escapees

Screens exclude fish/eggs before discharge

Mitigating Business and Environmental Risks

Risk #1 – loss of flow, power, oxygen

- Solutions:
  - Modularize several RAS instead of one large RAS
  - Redundant pumps on each RAS
  - Diffused oxygen system for emergency
  - Backup electric generator
  - Dial-out alarms to key personnel
  - Prepare and train the operations team

THE CONSERVATION FUND

Mitigating Business and Environmental Risks

Risk #2 – bacteria, virus, algae, or parasite creates high mortality

- Biosecurity Solutions:
  - Enclose RAS in a building
  - Use only pathogen-free groundwater as makeup
  - Use only certified pathogen free eggs
  - Include hygiene barriers
  - Limit access to facility
  - Pest control plan

Mitigating Business and Environmental Risks

Risk #3 – Inconsistent product quality due to grilse or off-flavor

- Solutions:
  - SOP's to purge fish
  - All female egg source

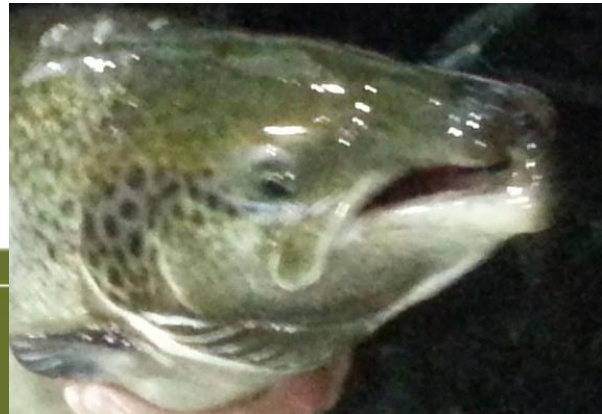
THE CONSERVATION FUND

Early Maturing Males

- Example from Freshwater Institute research

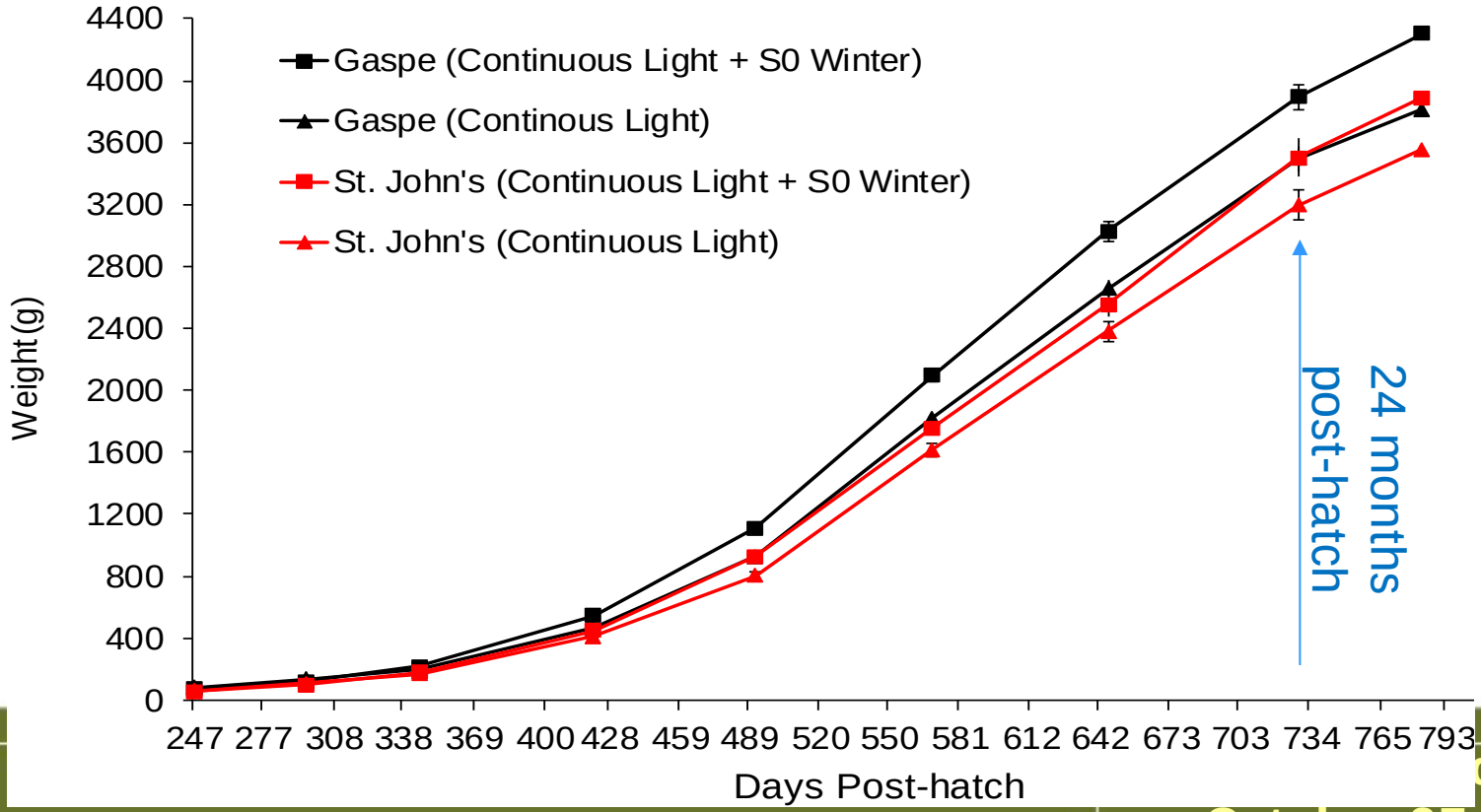
	Trial #2★	Trial #3★	Trial #4	Trial #5
	St John River	Cascade	Cascade	SalmoBreed
Grilse harvest size, kg	2.7 & 3.7	2.6	2.1	2.2
Prevalence, %	**36.6**	**38.5**	**17.1**	**18.0**
Post-harvest use	**Hot smoked**	**Cold smoked**	**Fresh fillets & smoked**	**Fresh fillets**

★High maturation: Post-smolt initially comingled with previous cohort that were maturing



Early Maturing Males

- Example from research Trial #1
  - **All female eggs** obtained for Gaspe strain,
  - 1 to 2% sexually mature at harvest



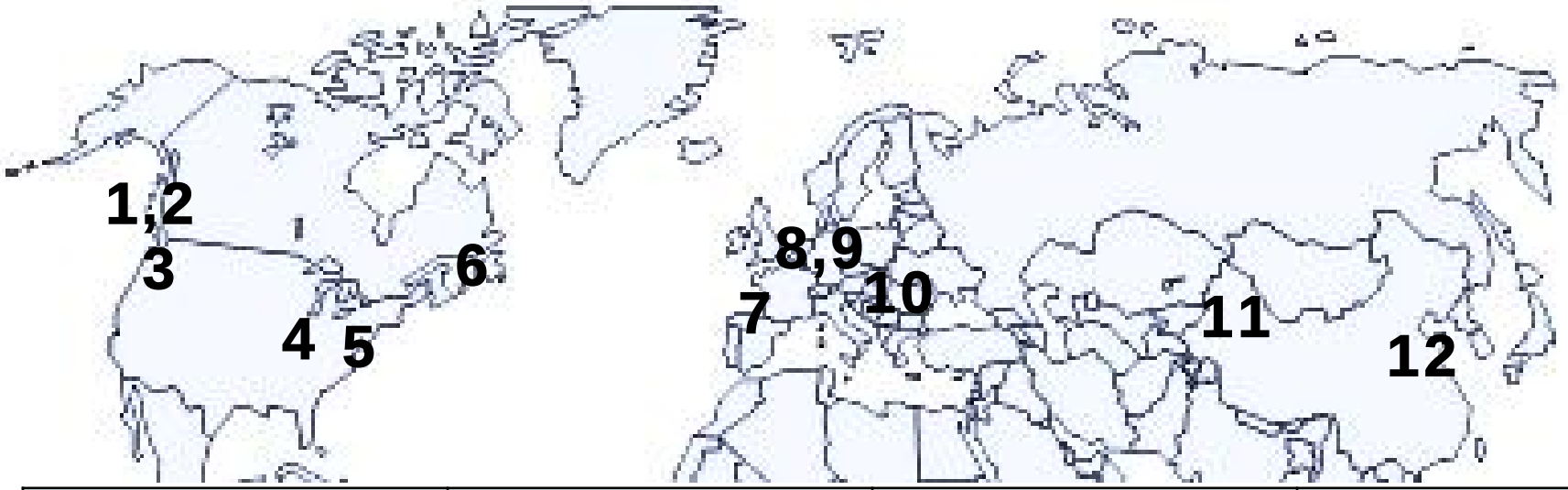
THE CONSERVATION FUND

Current Status

- ✓Producing salmonids in RAS is **biologically** and **technically** viable
  - Not just a concept, this works
  - Real systems are in operation
- ✓Industry is now evaluating **economic viability**

THE CONSERVATION FUND

Land-Based **Salmon** Growout



1. KUTERRA (Canada)	**2. Golden Eagle Aqua** (Canada)	**3. Spring Salmon** (USA)	**4. Bell Aqua** (USA)
5. Freshwater Institute (USA)	**6. Sustainable Blue** (Canada)	**7. BDV** (France)	**8. Langsand Laks** (Denmark)
9. Danish Salmon (Denmark)	**10. Jurrasic Salmon** (Poland)	**12. Xinjiang Ehe** (China)	**11. Shandong Oriental OT** (China)

(Facilities harvesting fish or at least with eggs stocked)

THE CONSERVATION FUND

Land-Based Growout: **Other** Species

1. Target Marine, sturgeon (Canada)	**2. Stolt Sea Farm, sturgeon** (Canada)	**3. Bell Aqua , steelhead** (USA)	**4. FL Organic Aqua, shrimp** (USA)
5. American Maricult, shrimp (USA)	**6. Blue Ridge, tilapia** (USA)	**7. Australis, barramundi** (USA)	**8. Sustainable Blue, char** (Canada)
9. Canaqua – Scotia Halibut (Canada)	**10. Stolt Sea Farm, turbot** (Spain)	**11. Danish Model Farms, trout** (Denmark)	**12. Aquatir, sturgeon** (Moldova)

THE CONSERVATION FUND

Wrap-Up

Developments in biologically sound technical systems have made closed-containment RAS an emerging opportunity – success is dependent only on market and economic factors

THE CONSERVATION FUND

THANK YOU