Production Economics of Summer Flounder Aquaculture in a Marine Recirculating System

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An Important Constraint

Biological Needs

Engineering Systems

Economic Viability?

Objectives

- Develop an economic model of summer flounder production in a RAS based on pilot-scale grow-out trials at UNCW
  - Conduct Sensitivity Analysis
  - Conduct Monte Carlo Analysis
  - Optimize Management Decisions

Model Development

- System Scale
  - 0.5-acre, 1-acre, and 3 x 1-acre systems
- Grow out Cycle
  - 13.4 and 20-month cycles
- Tank Size
  - 15, 20, and 27 ft diameters
- Outdoor vs. Indoor
  - Security Fence vs. Building
- Tank Type
  - Fiberglass, Steel, Glass Coated Steel
- Fish Transfer Schedule (between tanks)

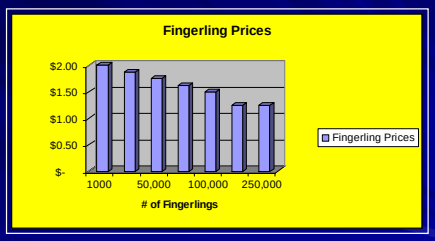
Model Development

- Biological, engineering, and economic parameters
- Capital, variable, fixed, and total costs
- Break even price and returns to management per grow out cycle; returns to management per year

System Scale

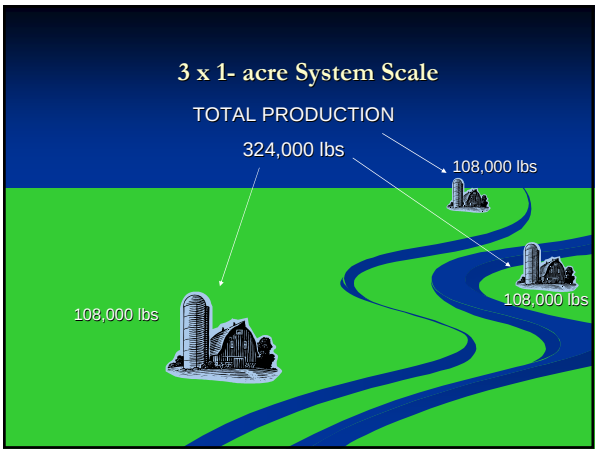
Scale of System	0.5-acre	1-acre	3 x 1-acre systems
15 ft diameter			
Number of Tanks	12	24	(3) 1-acre replicates
Number of Gallons	47,568	95,136	(3) 1-acre replicates
Final System Biomass (lbs)	24,000	48,000	(3) 1-acre replicates
20 ft diameter			
Number of Tanks	10	20	(3) 1-acre replicates
Number of Gallons	34,498	140,920	(3) 1-acre replicates
Final System Biomass (lbs)	34,498	68,995	(3) 1-acre replicates
27 ft diameter			
Number of Tanks	8	16	(3) 1-acre replicates
Number of Gallons	102,752	205,504	(3) 1-acre replicates
Final System Biomass (lbs)	54,000	108,000	(3) 1-acre replicates

Fingerling Constraints
(come from single supplier)



No Cost Savings/fingerling after 200,000

3 x 1- acre System Scale



Grow-Out Cycle Length

- All models assume fish reach an average of 1.5 lbs (marketable size), with 80 % survival, and an FCR of 1.8 (average of all growth phases and lowest FCR during first 7 months of UNCW study)
- Two alternative grow-out periods analyzed:
  - 20-month cycle (UNCW grow-out period)
  - 13.4 month cycle (top 5% fastest growers reached marketable size in study)

Alternative Tank Sizes

Scale of System	0.5-acre	1-acre	3 x 1-acre systems
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Outdoor vs. Indoor

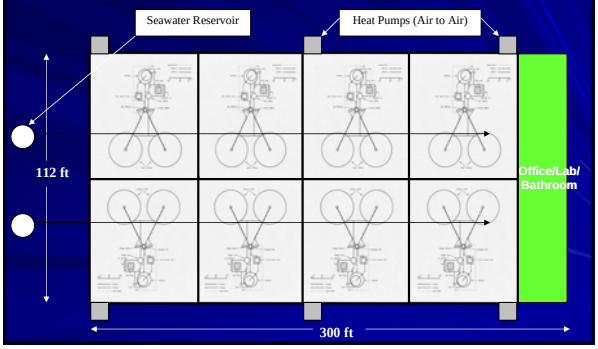
- Outdoor System
  - Security Fence ($10,000/ acre)
  - Camera System ($3,500/ acre, $50 monthly monitoring fee)

Source: Seegars Fence Co.

- Indoor System
  - System enclosed in 33,600 ft2 building
  - $369,914 (materials and labor)

Source: Heritage Building Co.

27 ft diameter tanks, 1-acre scale, enclosed in building
Note: 1 drumscreen for every 4 tanks not pictured



Tank Type

- Fiberglass
  - $5,000 / tank

- UNCW tank

- Steel
  - $2,284 / tank

Aquatic Ecosystems -

- Aquacare System
  - glass-coated steel
  - $3,747 / tank

Aquacare Environment Inc. -

Break-Even Prices ($): Comparing Systems

Tank Size & Tank Type	Grow-Out Cycle (months)	System Type (outdoor / indoor)	System Scale		
			0.5-acre	1-Acre	3 x 1-Acre
15 ft Fiberglass Tank	20	outdoor	$12.35	$9.92	$8.51
	13.4	outdoor	$9.70	$8.06	$7.02
20 ft Fiberglass Tank	20	outdoor	$10.21	$8.24	$7.10
	13.4	outdoor	$7.73	$6.36	$5.48
27 ft Fiberglass Tank	20	outdoor	$7.69	$6.93	$6.15
	20	indoor	$6.48	$5.59	$5.25
	13.4	outdoor	$6.40	$5.57	$4.96
	13.4	indoor	$5.20	$4.52	$4.22
27 ft Steel Tank	20	indoor	$6.38	$5.46	$5.17
	13.4	indoor	$5.13	$4.45	**$4.05**
25 ft Aquacare Tank	13.4	indoor	$5.34	$4.74	$4.43

Energy-Saving Fish Transfer Schedule

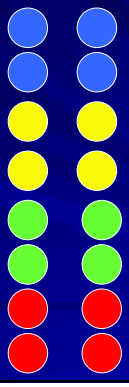
Day 0
0.04lbs/gal

20% mortality rate

Day 40
0.49lbs/gal

Day 150
0.55lbs/gal

Day 250
0.53lbs/gal



Initial weight
1,980 lbs

*Key: - reduces electricity break-even

$0.10

Harvest Weight
108,000lbs

Break-Even Price ($) Effect of Fish Transfer Schedule

Fish Transfer Schedule	Grow-Out Cycle	Break-Even Price ($)
Standard	20-month cycle	5.17
	13.4-month cycle	4.05
Energy saving	20-month cycle	5.06
	13.4-month cycle	3.95

Economic Assumptions per 1-acre Unit

- Market value of 1-acre of coastal land (already owned) $125,000
- Interest rate of alternative investment is %3.6
- 10-yr loan on building and equipment is %5.6
- Operating capital is borrowed at an interest rate of %7.6

Economic Assumptions per 1-acre Unit

- There is an owner which has a manager and technician at each facility
- Returns before taxes
- No waste disposal permit needed (less than 100,000 lbs per year, per 1-acre facility)
- Niche marketing (high end markets and live-haul pick up)
- No fee for drawing sea water
- No paid benefits to workers

Economic Parameters per 1-acre unit

Parameter	13.4-month	20-month
Product price ($/lb)	5.00	5.00
Fingerling cost ($/10 g fingerling)	1.25	1.25
Total fingerlings needed per cycle	90,000	90,000
Feed cost ($/lb feed)	0.30	0.30
Electricity cost per kWh ($/kWh)	0.05	0.05
Interest rate on 10-yr secured line of credit	7.6%	7.6%
Interest rate on unsecured bank line of credit	5.6%	5.6%
Return on owner's next best investment	3.6%	3.6%

Engineering Parameters per 1-acre unit

Parameter	13.4-month	20-month
# Months/cycle	13.4	20
# Days/cycle	406	609
Cycles/year	0.6	0.9
Number of tanks	16	16
System volume (gal)	205,504	205,504
Flow rates (gal/min)	85	85
Oxygen rates (ft^3/cycle)	887	887
Feed used (lbs)	196,128	196,128
kWh used	282,662	528,527

Biological Parameters for both the 13.4 and 20-Month Cycle

Parameter	Per cycle
Initial size of fish	0.02 lb
Average harvest size	1.5 lb
Harvest density	0.53 lb/gal
Initial biomass	1,984 lbs
Final biomass	108,000 lbs
Survival	80%
Feed Conversion Ration	1.8

Initial Investment

Building - $369,914

- sheet metal/siding/doors ($98,840)
- electrifying/HVAC ($74,151)
- concrete foundation ($67,200)
- labor cost ($60,000)
- plumbing, bathroom, septic ($18,000)
- insulation ($14,784)
- heat pumps ($13,800)
- feed bins ($9,600)
- light fixtures ($7,539)
- ductwork ($6,000)

Equipment - $302,681

- drum screen filters ($40,000)
- tanks/liners ($36,544)
- belt filter for waste ($30,000)
- generator ($22,000)
- air to air heat pumps ($19,600)

Labor (tanks & equipment) $36,000

Total Initial Investment $718,595

Interest Rate on Initial Investment %5.6

Variable Costs ($)

	Unit Cost	Units/ 13.4 mo cycle	Costs/Cycle 13.4 mo	20 mo
Oxygen refill	$0.40/100 ft3	887	355	355
Oxygen tank rental	$325/mo	13.4	4,355	6,512
Bicarbonate	$0.19/lb	19,613	3,726	3,726
Energy	$0.05/kwh	282,662	14,416	29,965
Sludge floculators	$1,742/cycle	1	1,742	1,742
Waste removal	$80/trip	18	19,296	19,296
Fingerlings	$1.25/fingerling	90,000	112,500	112,500
Feed	$0.30/lb	196,128	58,838	58,838
Freshwater	$20/mo	13.4	268	400
Labor				
Technical assistant	$12/hr	2,144	25,728	38,400
Manager	$20/hr	2,144	42,880	64,000
Interest on Variable Costs			11,260	20,344
Total Variable Costs			**295,364**	**353,066**

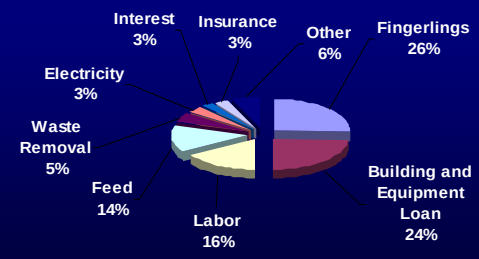
Fixed Costs ($)

	Unit cost ($/mo)	Cost/cycle 13.4 mo	20 mo
Opportunity Cost of Land (~125,000/acre)	375/mo	5,031	7,509
Electric Demand Charge	400/mo	5,360	8,000
Miscellaneous Overhead	300/mo	4,020	6,000
Insurance (fish)	378/mo	5,063	5,063
Insurance (Property, Liability, Workers Comp)	455/mo	6,098	9,101
Interest on Fixed Costs		814	1,722
Total Fixed Costs		**26,385**	**37,395**

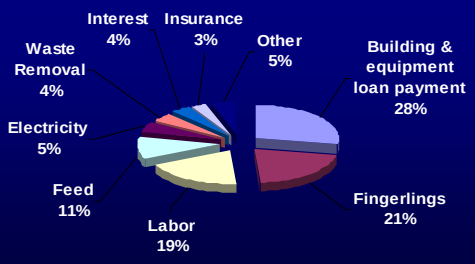
Returns ($)

	Per/Cycle 13.4 mo	20 mo
Total Variable Costs	295,364	332,723
Total Fixed Costs	26,385	37,395
Building & Equipment loan	104,512	155,988
Total Costs	**426,116**	**546,232**
Total Revenue $5.00/lb	540,000	540,000
Returns to owner above variable costs	244,636	186,933
Returns to owner above total costs	**113,884**	**(6,232)**
Break-even price	**3.95**	**5.06**

Production Cost per 13.4-Month Cycle



Production Costs per 20-Month Cycle



Sensitivity Analysis 13.4 month cycle

% Change in Break-Even Price $3.95/lb

	Waste Removal Costs	*Feed Costs*	*Initial Investment*	*Fingerling Costs*	*Growth Rates*
Baseline Parameter Value	$21,038/cycle	$0.30/ lb	$718,595	$1.25/fingerling	13.4-month
Impact of 5% Change in Parameter on Break-Even Price	$0.01	$0.03	$0.05	$0.06	$0.11
Percent Change in Break-Even Price	0.25%	0.76%	1.27%	1.52%	2.78%

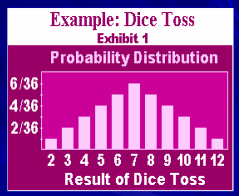
Sensitivity Analysis 20 month cycle

% Change in Break-Even Price $5.06/lb

	Electric Costs	*Feed Costs*	*Fingerling Costs*	*Initial Investment*	*Growth Rates*
Baseline Parameter Value	0.051/kw	$0.30/ lb	$1.25/fingerling	$718,595	20-month
Impact of 5% Change in Parameter on Break-Even Price	$0.02	$0.03	$0.05	$0.06	$0.17
Percent Change in Break-Even Price	0.40%	0.59%	0.98%	1.19%	3.36%

Monte Carlo Analysis

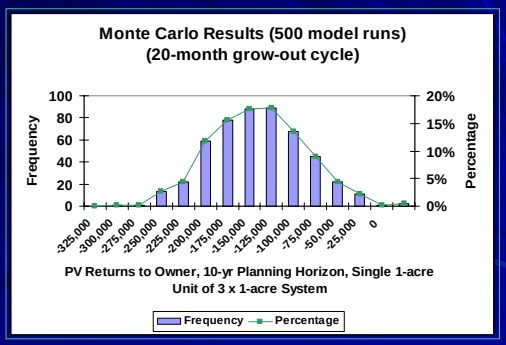
- Used to analyze uncertainty on value of a Parameter
- It translates uncertainties of parameters into probabilities of outcome profit variable



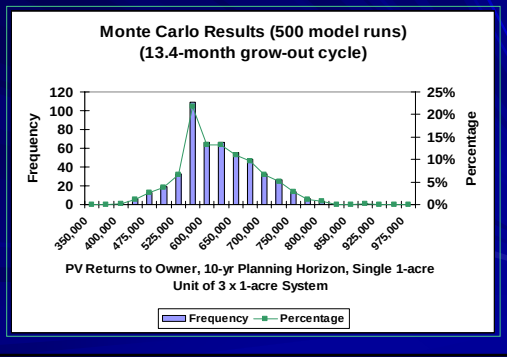
Monte Carlo Results

- Uncertain Parameters used: Electric Rates, Interest Rates, Output Price
  - Electric Rates: $0.045 to $0.08 per kWh (USDE, 2003)
  - Interest Rates: 3% to 15% (Federal Reserve, 2003)
  - Output Prices: $4.50 to $6.00 (Various Retail Markets, NC)

Monte Carlo Results: 20-month cycle



Monte Carlo Results: 13.4-month cycle



Discussion – Growth Rate

- Fingerling Growth Rate
  - 13. 4-month cycle achievable in 5% of UNCW study
  - 20-month cycle reflects average current growth rate
- Monte Carlo Simulation
  - 20-month run: $-17802/yr/facility or $53,406/yr for all three 1-acre facilities
  - 20-month run: 99% chance of negative returns
  - 13.4 month run: returns always positive; $60,252/yr/facility or $180,756/yr all three

Discussion-Economy of Scale

- Tank size and facility scale
- Fingerling cost
  - $2.00 to $1.25 depending on quantity purchased
- Market demand and EPA regulations limit scale
  - (Federal Register, 40 CFR Part 451)
  - Increase production cost ~$300,000 with installation of BMP's
- Break even price decreased from $12.35 to $3.95

Discussion-Production Cost

- Equipment Costs
  - Integrate equipment where feasible
    - 1 drumscreen filter for every 4 tanks
    - reduce number of heat pumps
  - Integration of bio-filtration may be risky
- Fingerling Cost
  - Currently single supplier
  - Construct hatchery "in house" or supply multiple grow-out facilities

Discussion-Production Cost

- Feed Costs
  - Normally highest cost in commonly cultured species
  - General expansion of mariculture industry may decrease cost
- Waste Removal
  - Flocculating waste and hauling off
  - Waste could be used as fertilizer for saline tolerant plant nursery; cuts break-even price by ~ $0.18 in both 13.4 and 20-month grow-out cycles

Discussion-Production Cost

- Insurance
  - Covers property liability, and workers compensation
  - Fish mortality insurance = 4.5% of fingerling cost
    - Covers loss of fish due to disease, mechanical and electrical failure, frost, and flood.

Conclusions

- The most cost effective system produces a break even price of $3.53/lb, which is less than the current product price of $5.00/lb, implying that flounder production using RAS could be profitable
- Sensitivity and Monte Carlo analyses reveal that growth rate is most critical component of financial performance
  - Future research needs focus on selective breeding for all female culture, which may improve growth rates
  - Summer Flounder culture is promising at the 13.4-month cycle
  - Note: The modern broiler chicken reaches slaughter in just 42 days. Twice as fast as 30 years ago.

Conclusions

- Future studies need focus on integrating recirculating components with multiple tanks
  - Reduce capital costs, without compromising survivability
- Reduce fingerling cost
  - Specialized hatcheries

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Aquatic Ecosystems