Economic Modeling of Walleye and Hybrid Walleye Production Protocols

James A. Held
Jim Held Consulting LLC
Sun Prairie, WI

Introduction

Aquaculturists are considering two economically significant markets for farm-raised walleye products. First, an ever increasing demand for advanced fingerling size (>6 in.) walleye used for resource enhancement has resulted in commodity-scale prices of $0.25 – 0.30 per inch or greater. Second a growing consumer interest in locally farmed food fish has prompted the development of walleye production strategies based on faster growing hybrid walleye (walleye female x sauger male). Both of these market opportunities can incorporate RAS (recirculation aquaculture system) technology. Before industry investment and expansion can proceed, production strategies should be analyzed for economic viability. The purpose if this study is to develop flexible economic models that can be used to determine the cost of production for walleye and hybrid fingerling production as well as grow-out costs for walleye destined for stocking and hybrid walleye as a food fish.

Economic models

Users should start by downloading the four Excel spreadsheets that accompany this narrative. Open the models as *Read Only* documents. While each of the four models has a specific application and endpoint, they function in similar ways. Cells that are shaded light green are for user input. Cells in darker green require user attention to adjust water-heating costs and to choose gas or electric heat (see below). Entering data for both will result in inflated breakeven costs. Un-shaded cells are calculated values and should not be changed. In their basic form the models are infused with values based on our production data and costs. Users are invited to examine our values and adjust them to their experience or expectations. Changes in input variables will result in changes in the breakeven costs calculated by the models (yellow shaded cells). The excel spreadsheets are locked so that they will return to their default values upon closing. Saving the spreadsheet under a different name can retain simulations based on user inputs.

Within the spreadsheets pages labeled ***analysis*** provide breakeven costs based on input values. They also indicate the percentage of operating and total costs each variable represents. At the top of each ***analysis*** page is a list of parameters or assumptions under which the fish were cultured. Users are advised to examine and consider these values carefully since items like fingerling cost, feed conversion, mortality and initial fingerling size can have a significant impact on the breakeven price. Ownership costs are given as both pro-rated for the term of use, and annualized for operations that do not use their facilities for other purposes for the balance of the year. Pages labeled ***investment*** in each of the models are lists of capital needs, costs and useful lifetimes relevant to the specific process being modeled. These lists can be modified to fit existing systems and operations. Information from these pages is infused into the models as depreciation and interest costs. Certain values on the ***investment*** pages are un-shaded and will receive data fed-back from the ***analysis*** page (e.g. the number and size of tanks needed to satisfy production levels). Cells shaded in blue provide functionality to the model and will recalculate depending upon the simulation. Pages labeled ***values*** or ***projections*** provide functionality and should not be changed.

Our assumptions relevant to all models are as follows:

- Land appreciates at 5% per year.
- 100% of the money for investment is borrowed at an interest rate of 6.5% per year. Interest only is paid (i.e., any repayment of the original investment debt is considered profit beyond breakeven).
- 100% of the money for operating costs is borrowed at an interest rate of 6.5% per year. The money is borrowed at the beginning of the culture cycle and paid back in full at the end of the culture cycle.

Production steps

Regardless of the target market, spawning, incubation, hatching and early-life stage culture are critical components of the overall production strategy. These steps are essentially the same for walleye and hybrid walleye with the only difference being the use of sauger semen to propagate the hybrid.

Eggs

The first step in the production process is procurement of eggs. Since brood stock collection methods are widely varied and specific to individual operations, modeling such activity becomes virtually meaningless. Suffice it to say that whether wild-caught or captive, the fecundity of walleye females makes it reasonable to assume that adequate numbers of eggs will be available at a very minimal cost. Similarly egg fertilization, if done properly, can result in high numbers of fertilized eggs (>80%) at little cost. Unfortunately, poor technique can results in disastrous fertilization rates and jeopardize an entire years' production.

The labor, facility and material costs required to incubate eggs for even a large grow-out operation are minimal. As an example, 1,000,000 walleye eggs can easily be incubated in as few as 4 MacDonald jars using 4-5 gpm of water and requiring less than 1hr/day of labor for the 9 to 15 day incubation period (approx. $150.00). Iodine and formalin for egg disinfection may add $50.00 to the process and energy costs for heating and pumping another $2.00. Depreciation on the equipment would be negligible since it is only used for the 2 weeks of incubation. In this example, the total cost for incubation and hatching would be $202.00 for 1,000,000 eggs. If a hatch rate of 80% were considered, each hatched fry would cost $0.00025.

Fry-fingerling

The feed training process represents virtually all of the cost associated with small fingerling production. Early life-stage (fry to small fingerling) culture offers a choice of two protocols for producing feed trained fingerlings. Using the traditional pond-tank method, fry are cultured in fertilized production ponds and harvested at 1.5-2.5in for habituation to formulated feeds in flow-through tanks. Opinions vary as to the best size at which to harvest. Proponents of harvesting at a smaller size cite more fingerlings harvested per acre due to reduced cannibalism as fish grow from 1.5 to 2.5 inches. Culturists who prefer harvesting at larger sizes cite better training success. Our results indicated that regardless of length, feed training success was best when using well-conformed, robust fingerlings. Alternatively, a protocol in which newly hatched fry are trained to a series of diets in a clay-clouded environment (tank method) can be used. Models are provided for both the pond-tank and tank methods. The resulting breakeven costs for the feed-trained fingerlings can be entered into the grow-out models in the cell labeled fingerling cost per inch (G3 in both grow-out models). In the default versions of the models, a market price of $0.25/in has been entered for purchased fingerlings.

Pond-tank model

The default setting for the pond-tank model is presented in Fig.1. In this example 50,000 feed trained fingerlings (cell F7) are being produced with harvest from the pond at 2in (F9) and training to a size of 3.5in (F11). To demonstrate the use of the model we will vary the values in cell C10 (training success %). We might expect this to be a critical value since it impacts several calculations in the model and is crucial to the success of the overall process. The default value of 50% returns a breakeven total cost per inch (BTC/in) of $0.0892 in cell F51. Thus a 3.5in fingerling would cost about 31¢ to produce (F52). If the training success (C10) is adjusted to 70%, the resulting BTC/in (F51) is $0.0814 with a fingerling cost of 29¢ (F52). Be sure to transfer the new water heating cost (2405.43) from F14 to E26 (dark green cells). If the training success were 30% the BTC/in becomes $0.1073 with a fingerling cost of 38¢. The changes entered in E26 suggest that increased heating cost due to increased water usage is primarily responsible for the impact of training success on breakeven price. Examining columns H and I will give the user a good indication of the impact of certain expenses. The cost of heating water (F26) and labor (F28) represent about 80% of the operating costs (H26+H28). Pro rated ownership costs (F47) account for 47% of the total production cost (H47). This type of analysis can give the user insight into what expenses to control to improve the cost of production.

Fig 1. Break even cost analysis for pond-tank production of trained walleye-hybrid fingerlings

	A	B	C	D	E	F	G	H	I
1		Breakeven cost for feed trained walleye fingerlings (pond-tank)							
2	Inputs/Variables								
3		Pond area (acre)	2.86		Hatch success (%)	80			
4		Pond stocking rate (fing/acre)	70,000		Number of eggs	250,000			
5		Pond return (%)	50		Number of fry	200,000			
6		Pond culture period (day)	42		Number of untrained fingerlings	100,000			
7					Number of trained fingerlings	50,000			
8		Training tank volume (gal)	3333						
9		Training tank stocking rate (fing/gal)	30		Fingerling length at harvest (in)	2	choose 1, 1.5, 2, 2.5, 3 in		
10		Training success (%)	50		Fingerling weight at harvest	1.03			
11		Training period (days)	32		Length of trained fingerlings	3.5	choose 2, 2.5, 3, 3.5, 4 in		
12		Training labor per day	8		Weight of trained fingerlings	5.85			
13		Training feed conversion	1.5						
14		Well water temperature (°F)	52		Units of hot water (gas)	3,367.60			
15		Culture water temperature (°F)	65		Units of hot water (electric)	4,818.94			
16		Water changes/hr	0.5					% of total	% of operating
17	Category	Item	Unit	Unit cost	No. of units	Cycle cost	Annualized cost	cost	cost
18	Pond phase costs								
19		fertilizer	$/acre	$100.00	2.9	$286		1.8	3.5
20		fuel (mower, ATV)	gal	$2.09	100	$209		1.3	2.5
21		electricity (well pump, aeration)	kwh	$0.09	1,100	$99		0.6	1.2
22		labor (unskilled, $7.50 + 25%)	hr	$9.38	23	$216		1.4	2.6
23	Feed training phase costs								
24	(flow-through tanks)	feed	lb	$0.70	796	$557		3.6	6.8
25		salt	lb	$0.37	500	$185		1.2	2.2
26		hot water (gas) from F14	therm	$0.93	3,368	$3,368		21.6	40.9
27		hot water (electric) from F15	kwh	$0.09	0	$0		0.0	0.0
28		labor (semi-skilled, $10.00 + 25%)	hr	$12.50	256	$3,200		20.5	38.9
29									
30	Total production costs					$8,119		52.0	98.7
31									
32	Miscellaneous								
33		interest on operating capital	%	6.5		$107			1.3
34		for pond-tank culture period							
35	Total operating cost					$8,226		52.7	100.0
36	Production (fingerlings)					50,000			
37	Breakeven operating cost per inch					$0.0470			
38									
39	Ownership costs								
40		total depreciation				$1,776	$8,761	11.4	
41		(investment/useful life)							
42									
43		interest on investment				$2,565	$12,652	16.4	
44		r.e.taxes				$405	$2,000	2.6	
45		insurance				$608	$3,000	3.9	
46		repairs				$2,027	$10,000	13.0	
47	Total ownership cost					$7,382	$36,413	47.3	
48									
49	Total cost					$15,609	$44,639	100.0	
50	Production (fingerlings)					50,000	50,000		
51	Breakeven total cost per in.					$0.0892	$0.2551		
52	Breakeven total cost per fingerling					$0.31			

Tank model

The default setting for the tank model is presented in Fig.2. Like our first example 50,000 feed trained fingerlings (cell F7) are being produced to a size of 3.5 inches (F11). With this protocol newly hatched fry are used as a starting point rather than pond harvested fingerlings. Once again training success % (C5) will be varied. Our experimental data indicated that training success for tank culture was highly variable (15-56%). The default value of 20% (C5) is a reasonable starting point. At a success rate of 20% the model returns a cost of $0.0991 (F44) or 35¢ (F45) for a 3.5in fish. A success rate of 50% lowers the cost to $0.0867 with a price of 30¢ (a transfer of newly generated water heating data from cell F11 to E19 is required). Reducing the success rate (C10) to 10% along with adjusting cell E19 raises the cost to $0.1197 and fingerling price to 42¢. The driving forces behind the breakeven cost are once again heating water (F19) and labor (F21). As in our first example the flow-through culture is being conducted at 0.5 water changes per hour (30gpm) in 60 gal tanks. This was on the low end of our experimental protocol. Changing the water flow (C12) to 1.5 changes per hour (our highest experimental value) raises the fingerling cost from 35¢ to 48¢ each, a significant increase.

Fig 2. Break even cost analysis for tank production of trained walleye-hybrid fingerlings

	A	B	C	D	E	F	G	H	I
1	Breakeven cost for feed trained walleye (and hybrid) fingerlings (tank culture)								
2	Inputs/Variables								
3		Training tank volume (gal)	1389		Hatch success (%)	80			
4		Training tank stocking rate (fry/gal)	180		Number of eggs	312,500			
5		Training success (%)	20		Number of fry	250,000			
6		Training period (days)	74		Number of trained fingerlings	50,000			
7		Labor hours per day	8						
8		Training feed conversion	3		Length of trained fingerlings	3.5	choose 2, 2.5, 3, 3.5, 4 in		
9					Weight of trained fingerlings	5.85			
10		Well water temperature (°F)	52						
11		Culture water temperature (°F)	65		Units of hot water (gas)	3,245	choose F11 or F12		
12		Water changes/hr	0.5		Units of hot water (electric)	4,643	to fill E19 or E20		
13									
14								% of total	% of operating
15	Category	Item	Unit	Unit cost	No. of units	Cycle cost	Annualized cost	cost	cost
16	Feed training costs								
17	(flow-through tanks)	feed	lb	$1.00	1,933	$1,933		11.1	14.9
18		salt	lb	$0.37	500	$185		1.1	1.4
19		hot water (gas) from F14	therm	$0.93	3,245	$3,245		18.7	25.1
20		hot water (electric) from F15	kwh	$0.09	0	$0		0.0	0.0
21		labor (semi-skilled, $10.00 + 25%)	hr	$12.50	592	$7,400		42.7	57.2
22									
23	Total production costs					$12,763		73.6	98.7
24									
25	Miscellaneous								
26		interest on operating capital	%	6.5		$168			1.3
27		for pond-tank culture period							
28	Total operating cost					$12,931		74.6	100.0
29	Production (fingerlings)					50,000			
30	Breakeven operating cost per inch					$0.0739			
31									
32	Ownership costs								
33		total depreciation				$617	$3,045	3.6	
34		(investment/useful life)							
35									
36		interest on investment				$750	$3,700	4.3	
37		r.e.taxes				$405	$2,000	2.3	
38		insurance				$608	$3,000	3.5	
39		repairs				$2,027	$10,000	11.7	
40	Total ownership cost					$4,409	$21,746	25.4	
41									
42	Total cost					$17,340	$34,677	100.0	
43	Production (fingerlings)					50,000	50,000		
44	Breakeven total cost per in.					$0.0991	$0.1982		
45	Breakeven total cost per fingerling					$0.35			
46									

Stocker model

Stocking of walleye for resource enhancement has been practiced in the U. S. for over 100 years. Until recently, virtually all of the stocked fish were based on eggs from wild-capture brood stock with the fry and fingerlings reared in earthen ponds. Protocols for spawning, incubation and fingerling culture are well established and have remained unchanged for decades. This is particularly true for the culture of walleye up to a small fingerling size (1.5in) that are usually stocked in early summer. While the demand for advanced size fingerlings (>6in) has always been high due to a presumed better recruitment and return to creel, the forage costs associated with producing such fish has limited their availability. A two stage culture protocol using ponds for fry to fingerling culture followed by feed training to formulated feeds and grow out to advanced size in RAS may prove to be an economically viable method for producing fall stocked walleye fingerlings.

The breakeven cost analysis for the production of advanced fingerling size walleye in a RAS is presented in Fig. 3. Default values describe the culture of trained walleye fingerlings starting at 3.5in to the point at which 95% of the fish in the cohort are equal to or exceed 6in. It should be noted that this is *not* the same as a median size of 6 inches, where by definition half of the fish are larger than 6 inches and half are smaller. The model describes culture in a RAS at 66°F with a maximum loading of the system of 0.5lbs/gal. While the model can accommodate variability in the loading of the system (C3), water temperatures other than 66°F will impact the growth of the fish and therefore the accuracy of the model. Future versions of the model will offer temperature as a variable once sufficient data has been compiled to account for a variety of water temperatures.

The starting point for working this model can be found on the ***investment*** page where the capacity of the system is calculated. The user inputs the number of each size tank available for culture (dark green cells) and the model returns the system capacity (C4) on the ***analysis*** page. Once the system capacity is established the other culture parameters can be set.

Using the default values for the model, the cost of fingerlings represents 56% of our total cost (H10). Since fingerling price is such an important variable in this protocol we will use it as our example. In this simulation 3.5-inch (G2) fingerlings are purchased for $0.25/inch (G3). This gives us a breakeven cost per fish of $1.26 (F45). System capacity (C4) and loading (C3) allow for a production of 46,358 fish (F44). If we assume a market price of $1.50 per fish we show a net return of $11,125.92. If we infuse our breakeven cost from the pond-tank model ($0.0892/inch) into the stocker model (G3) the breakeven cost goes to $0.66 per fish and the profit increases to $38,940.72. Even at only 10% success for the tank method (see our second example above), a fingerling cost of $0.1573/inch returns a stocker cost of $0.92/fish and profit of $26,887.64. It is left to the user to determine if these numbers are attainable given their particular system and experience. Our experimental maximum system loading of 0.5lbs/gal may be unrealistic for some operators who feel more comfortable at 0.33lbs/gal or less.

Fig 3. Break even cost analysis for RAS culture of advanced walleye fingerlings

	A	B	C	D	E	F	G	H	I
1		Breakeven per fish cost for walleye stocker production in an RAS at 19°C							
2	Days per cycle		111.0		Initial fingerling size	inch (choose 2 ,2.5 ,3, 3.5, 4)	3.5	grams	6.0
3	Maximum loading	lbs/gal	0.5		Initial fingerling cost	$/inch	0.25		
4	System capacity	gal	9,680		Final fish size	inch	> 6	grams	47.4
5	Feed to gain ratio		1.2		Mortality rate	%	5		
6	labor/day	hr	2						
7								% of total	% of operating
8	Category	Item	Unit	Unit cost	No. of units	Batch cost	Annualized cost	cost	cost
9	Production costs								
10		fingerlings	each	$0.88	48,676	$42,591		55.9	75.1
11		feed	lb	$0.70	5,326	$3,729		4.9	6.6
12		chemicals	asst.			$400		0.5	0.7
13		oxygen	liter	$0.00041	537,240	$220		0.3	0.4
14		LOX system rental	month	$335.00	4	$1,223	$4,020	1.6	2.2
15		electricity	$/kwh	$0.09	6,447	$580		0.8	1.0
16		labor (semi-skilled)	hr	$12.50	222	$2,775		3.6	4.9
17		($10.00 + 25% fringe)							
18	Total production costs					$51,518		67.7	90.8
19									
20									
21	Sales/Marketing costs								
22		delivery charge	mile	$1.25	150	$188		0.2	0.3
23	Total sales/marketing costs					$188		0.2	0.3
24									
25	Miscellaneous								
26		interest on operating capital	%	6.5		$1,022		1.3	1.8
27		cycle length	days	111					
28	Total operating cost					$52,727	$56,747	69.3	100.0
29	Production (number of fish)					46,358			
30	Breakeven operating cost per fish					$1.14			
31									
32	Ownership costs								
33		total annual depreciation				$1,628	$5,354	7.0	
34		phone/internet service	month	$70.00	12	$255	$840	1.1	
35		heat	month	$200.00	6	$365	$1,200	1.6	
36		interest on investment				$2,108	$6,933	9.1	
37		r.e.taxes				$608	$2,000	2.6	
38		permits/licensing				$15	$50	0.1	
39		insurance				$912	$3,000	3.9	
40		repairs				$0	$0	0.0	
41	Total ownership cost					$5,893	$19,377	25.5	
42									
43	Total cost					$58,620	$76,124	100.0	
44	Production (number of fish)					46,358	46,358		
45	Breakeven total cost per fish					$1.26	$1.64		

Hybrid food fish model

Operations to culture walleye as a food fish have met with little success. This is primarily due to the fish's inherent slow growth to presumed market size. Growth studies in the 1990's concluded that hybrid walleye (walleye female x sauger male) displayed superior growth characteristics when compared with walleye. The data generated in our study unequivocally supports this conclusion and suggests that an economically viable food fish product may be available for RAS culture using hybrid walleye grown to a small (0.5 lb.) market size. While these smaller fish do not conform to the traditional market size of fish weighing 700-1,000 g yielding 180-300 g fillets, the U.S. walleye market has expanded to include smaller fillets weighing ~ 50g each from wild-caught Eurasian pikeperch. These fillets are now effectively competing in the marketplace with both traditional-sized walleye fillets, and with fillets from the closely related yellow perch. Based on this, it is clear that the traditional U.S. walleye market has changed, and that a large and growing market now exists for small (50 g) walleye fillets.

To get the maximum use of the capacity of the RAS, this protocol employs a strategy in which market size fish are culled from the population as they appear. The removal of these fish allows the operator to approach but not exceed the maximum density for the system. The timing and number of fish culled from the system was based on our experimental data.

The hybrid food fish model (Fig. 4.) describes the culture of hybrid walleye from trained fingerlings (3.5in) to small market size (12in). The default value for fingerling price per inch (G3) is the purchase price of \$0.25/inch. This value returns a breakeven price of \$7.70/lb. for whole dead fish on ice. Adjusting the fingerling price to our pond-tank default of \$0.0892 reduces the cost to \$6.47/lb adjusting to the default tank fingerling price (\$0.1179) returns a cost of \$6.69/lb. Whether these costs can be profitable will depend on the development of the walleye food fish market.

Fig 3. Break even cost analysis for RAS culture of food size hybrid walleye.

	A	B	C	D	E	F	G	H	I
1	**Breakeven cost for hybrid walleye grow-out to food size in an RAS at 19°C**								
2	Days per cycle		313.0		Initial fingerling size	inch (by .5 in)	3.5	grams	6.1
3	Maximum loading	lbs/gal	0.5		Initial fingerling cost	$/inch	0.25		
4	System capacity	gal	9,680		Final market size	inch (by .5 in)	12	grams	230
5	Feed to gain ratio		1		Mortality rate	%	5		
6	labor/day	hr	2		Weight gain/day	grams	0.93		
7								% of total	% of operating
8	Category	Item	Unit	Unit cost	No. of units/cycle	Cycle cost	Annualized cost	cost	cost
9	Production costs								
10		fingerlings	each	$0.88	13,041	$11,411	$11,411	22.3	35.8
11		feed	lb	$0.70	6,292	$4,404	$4,404	8.6	13.8
12		chemicals	asst.			$400	$400	0.8	1.3
13		oxygen	liter	$0.00041	1,969,396	$807	$807	1.6	2.5
14		LOX system rental	month	$335.00	10	$3,447	$4,020	7.8	10.8
15		electricity	$/kwh	$0.08	18,179	$1,454	$1,454	2.8	4.6
16		labor (semi-skilled)	hr	$12.50	626	$7,825	$7,825	15.3	24.6
17		($10.00 + 25% fringe)							
18	Total production costs					$29,749	$30,322	59.2	93.4
19									
20	Sales/Marketing costs								
21		ice	lb	$0.07	3,146	$220	$220	0.4	0.7
22		pickup charge	mile	$1.25	150	$188	$188	0.4	0.6
23	Total sales/marketing costs					$408	$408	0.8	1.3
24									
25	Miscellaneous								
26		interest on operating capital	%	6.5		$1,681	$1,681	3.3	5.3
27		cycle length	days	313					
28	Total operating cost					$31,838	$32,411	63.3	100.0
29	Production (lbs)					6,292			
30	Breakeven operating cost per lb.					$5.06			
31	Breakeven operating cost per fish					$2.56			
32	Annual ownership costs								
33		total annual depreciation				$4,591	$5,354	10.5	
34		phone/internet service	month	$70.00	12	$720	$840	1.6	
35		heat	month	$200.00	6	$1,029	$1,200	2.3	
36		interest on investment				$5,945	$6,933	13.5	
37		r.e.taxes				$1,715	$2,000	3.9	
38		permits/licensing				$43	$50	0.1	
39		insurance				$2,573	$3,000	5.9	
40		repairs				$0	$0	0.0	
41	Total annual ownership cost					$16,616	$19,377	37.8	
42									
43	Total annual cost					$48,454	$51,215	100.0	
44	Production (lbs)					6,292	6,292		
45	Breakeven total cost per lb.					$7.70	$8.14		
46	Breakeven total cost per fish					$3.90	$4.12		
47									

Discussion and Conclusions

The default values supplied in the models were based on actual costs and production experienced by Northside Enterprises and the Northern Aquaculture Demonstration Facility during the course of this study. Breakeven costs calculated by the models should not be taken as absolutes but rather as examples of the costs that would be generated based on our systems and production performance. Users are invited to infuse the models with their own capital expenses and performance expectations to generate breakeven costs that are unique to their operation. Once baseline costs are established, users are advised to examine their operations and develop simulations to assess the impact changes can have on their breakeven costs.

Acknowledgements
This publication was produced under the USDA-NIFA Small Business Innovative Research (SBIR) phase II award number 2014-33610-22606 and was undertaken with the cooperation of Northside Enterprises (Black Creek, WI) and the University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility (NADF). I appreciate the support and assistance of Dr. Jeffrey Malison, Dr. Chris Hartleb, Dan Gruendemann, as well as Greg Fischer and the staff at NADF in helping to complete this report