SOUTHERN REGIONAL AQUACULTURE CENTER

SRAC Publication No. 456
August 2012
Revision

A Spreadsheet Tool for the Economic Analysis of a Recirculation Tank System

Matthew Parker[1], Dennis DeLong[2], Rebecca D. Dunning[3], Thomas M. Losordo[2], and Alex O. Hobbs[4]

A well-designed recirculating aquaculture system (RAS) offers a number of advantages over pond systems. Designed to conserve both land and water resources, recirculating systems can be located in areas not conducive to open pond aquaculture. Operators have a greater degree of control over the fish culture environment and can grow fish year-round under optimal conditions. The crop can be harvested at any time, and inventory can be much more accurately determined than in ponds. This latter characteristic is particularly beneficial when trying to gain financing or insurance for the crop. However, there can be disadvantages to an RAS, the most obvious being the higher capital cost associated with building it.

Interest in RASs for fish production continues to grow, despite the lack of economic information on their use. This publication and the spreadsheet it contains are designed to help prospective producers examine the economics of RASs. With modifications, the spreadsheet can be used to monitor costs and returns once a system is operating. The Excel spreadsheet can be downloaded from the following Internet address: *ftp://ftp.mdsg.umd.edu/Public/MDSG/SRAC_456_NCSURASS.xls*

The spreadsheet uses tilapia for the example species. However, the resulting figures on costs and returns are not meant to be used for the economic analysis of tilapia production. Each individual using the spreadsheet should input equipment and supply costs and the appropriate market price for the specific system and species being analyzed. Other than sales price, costs used in the example spreadsheet reflect average costs for inputs at the time of publication. Costs may have changed since publication and can vary widely by location. Users of the spreadsheet should research associated costs for the location where they plan to construct a facility.

System design

There is no single recommended design for growing fish in an RAS. In general, a system includes tanks to culture fish, pumps to maintain water flow, and some form of water treatment to maintain water quality. Following are a few considerations on system design and how design can affect profitability. For a more complete explanation of component options and management issues, see SRAC publications 451, 452 and 453.

Proper sizing of all system components is very important. If equipment is oversized for the application, the system will be more costly. If the equipment is undersized, the system will not be able to maintain the proper environment to sustain fish production.

Operators should size equipment according to the maximum daily amount of feed placed into the system. The estimated daily feed rate is based on the system carrying capacity, which does not usually exceed 1 pound of fish per gallon of water even for the most efficient system. Once carrying capacity and feed rate are defined, the operator estimates the size of equipment components by calculating the required maximum flow rate. The flow rate of each component must be sufficient to flush out and treat any wasted feed and by-products of fish metabolism, while supplying a uniform concentration of dissolved oxygen.

[1]Aquaculture Business Specialist, University of Maryland, Sea Grant Extension
[2]North Carolina State University
[3]North Carolina Dept. of Agriculture
[4]Carolina Power and Light Company

Because equipment is sized to maximum feeding rates, the most inefficient management method is to stock fingerlings at low densities and grow them to market size within the same tank. Most RAS operators try to make maximum use of each tank's carrying capacity by stocking fish at increasingly lower densities as the fish grow in size. The more efficient the use of system carrying capacity, the more fish can be moved through the system annually, which generally lowers the cost per pound harvested. The trade-off is that the more often fish are moved and restocked, the higher the labor cost and the greater the chance of mortality if fish suffer handling stress.

Operators also face a trade-off when determining both the size of tanks and the configuration of equipment for filtering and oxygenating water. The use of fewer, larger tanks, or several tanks sharing water treatment equipment, is usually much less expensive than having a number of smaller tanks that do not share water or components. Managing water quality and preventing disease, however, are usually easier when water is not shared between tanks. There is less risk of losing large numbers of fish when each tank has its own set of treatment equipment.

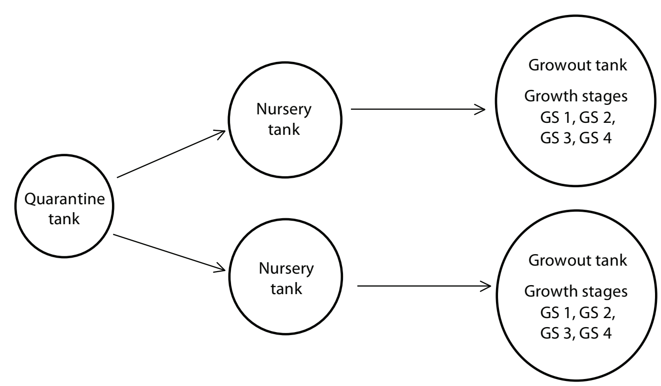
There are economies of scale for individual tank size and for the size of the entire system. Up to a point, the increase in system size generally results in lower cost per pound produced, because the fixed costs associated with the building and equipment can be spread over more pounds harvested.

The example system

The data used for this publication are taken from experiences at the North Carolina State University Fish Barn Project (NC Fish Barn).

The NC Fish Barn system grows fish in nursery tanks, then grades and splits the population into larger growout tanks as the fish gain weight. Recent economic analyses suggest that a similar size system will not produce enough income to cash flow, so a slightly larger operation is required. The NC Fish Barn system consists of a quarantine tank, nursery tank, and four growout tanks. The system represented in this example spreadsheet consists of nine tanks: one 1,500-gallon (5.68-cubic meter) quarantine tank (Q); two 4,000-gallon (15.14-cubic meter) nursery tanks (N1 and N2), and six 25,000-gallon (94.64-cubic meter) grow-out tanks (GT1, GT2, GT3, GT4, GT5, and GT6). The quarantine and nursery tanks have their own water filtration systems, while each set of three growout tanks shares a water treatment system. A more detailed description of the smaller NCSU system and equipment can be found in Hobbs et al. (1997).

Fish are initially stocked in the Q tank, grown and screened for diseases for 42 days, then harvested, divided into equal numbers, and restocked into the two N tanks. After 42 days of growth, the fish are transferred from one N tank into one of the six G tanks, where they are grown an additional 168 days until harvest. This 168-day period is divided into four distinct production stages of 42 days each (defined as GS1, GS2, GS3, and GS4 in the spreadsheet). Each of these stages has a different feed rate, oxygen demand, and water flow requirement. (An alternative to this configuration would be to move the fish into a different tank for each of the 42-day periods.) It is important to note that the spreadsheet reflects four stages of growth in the growout tank phase, so that changing production costs can be accommodated within the spreadsheet. This should not be confused with the need to have a total of six growout tanks in order to meet required production volumes for cash flow. Additionally, your total number of days to harvest may differ with species, culture temperature, and final average harvest size.



Fish are initially stocked in the quarantine tank, grown and screened for diseases for 42 days, then harvested, divided into equal numbers, and restocked into the two nursery tanks. After 42 days of growth, the fish are transferred from one nursery tank into one of the six growout tanks, where they are grown an additional 168 days until harvest. This 168-day period is divided into four distinct production stages of 42 days each (defined as GS 1, GS 2, GS 3 and GS 4 in the spreadsheet).

Figure 1. Diagram of fish flow through system.

Once the example system is fully stocked, one of the six G tanks is harvested for sale every 42 days. The system has a maximum culture density of 0.50 pound of fish per gallon of water (59.9 kilograms of fish per cubic meter of water) in each growout tank, and each harvest yields approximately 12,574 pounds (5703 kg) of fish. The maximum culture density is dependent on system filtering capacity, species, and the amount of feed used in the system. Depending on design specifications, your maximum culture density may be different. The author of this publication designs systems not to exceed a maximum culture density of 0.66 pound of fish per gallon of water (approximately 80 kilograms per cubic meter of water). With 8.69 harvests annually (one every 42 days once the facility is fully stocked), total production for the facility is approximately 219,000 pounds (99,337 kg) per year.

Using the spreadsheet

The Recirculating Aquaculture System Spreadsheet (RASS) must be supplied with accurate and realistic input data based on a properly designed system. Proper design means that the equipment components work together to maintain good water quality and to produce the amount of fish in the time period stated.

The spreadsheet is divided into five sections. The user supplies information for the first three sections. Data in the final two sections are calculated from this information. Shaded areas in the tables indicate required information and are represented as bold type in the spreadsheet. "Spreadsheet cell range" and cell numbers refer to the location of information within the Excel spreadsheet

SECTION 1: Specify the initial investment—spreadsheet cell range B13:E25

The initial investment cost is supplied by the user in cells E16:E20. The total is calculated in cell E21. The investment includes the total value of purchased land, an effluent pond, building, equipment, and construction labor, as well as the current value of any owned assets used in the business.

Annual depreciation on building and equipment (E22) is the amount of money that must be earned each year by the business to eventually replace equipment when it wears out.

Interest rate on operating capital (E24) is used to calculate a cost of interest on variable inputs (oxygen, energy, bicarbonate, fingerlings, chemicals, maintenance and labor). The interest charge could be interest owed to a bank for the purchase of these inputs, or the charge could be for the cost of using the owner's own funds to purchase variable inputs. A cost of using the owner's funds is used because the investment of funds in the RAS means that the owner forgoes potential earnings from an alternative investment.

Interest rate on building and equipment (E25) is used to calculate an annual interest charge based on the average investment. Again, this could be interest owed on a bank loan used to finance the initial investment, or it can represent earnings that could have been made on an alternative investment.

Section 1. Specify the Initial Investment	
Initial investment	
Land	$20,000.00
Effluent pond	$10,000.00
Equipment	$700,000.00
Building	$180,000.00
Construction labor and overhead	$50,000.00
Total initial investment	$960,000.00
Annual depreciation on building and equipment	$19,100.00
Interest rate on operating capital	4%
Interest rate on building and equipment	6%

Figure 2. Graphic depiction of computer display of Section 1.

SECTION 2: Specify the cost of inputs, sale price, and system parameters—spreadsheet cell range B27:E54

Variable costs

Variable costs are those directly related to production. In the cell range E31:E38 the user specifies the cost per unit of oxygen, electricity, bicarbonate, fingerlings, chemicals, maintenance and labor. The quantity used of each of these inputs is defined in Section 3.

Fixed costs

Fixed costs are incurred regardless of whether or not production occurs. They are liquid oxygen tank rental (E41), electrical demand charge (E42), and building overhead (E43). Each of these is specified as a cost per month.

Sale price

Average overall sale price (E45) is the weighted average sale price per pound, taking into account the size distribution at harvest and differing prices for various sizes of fish. The example uses $1.37 per pound so the system will break even (with $0 profit and $0 losses).

System parameters

The remainder of this section (E48:E54) contains system parameters that will be needed for calculations related to costs and returns. Annual production (E48), average size at harvest (E49), and the survival rate (specified in the next section) are used to calculate the initial stocking density.

There are nine production units in this example (number of production units [E50] = 9). As discussed earlier, a production unit refers to a specific tank or life stage of the fish. Here, three tanks are used: a Q tank, an N tank, and a G tank. There are six G tanks in the spreadsheet example system. Fish remain in the Q tank and N tank for 42 days each. Within the G tank, the fish go through four 42-day stages. Note that the days per production unit (E51) must be the same for each unit in order for the spreadsheet to accurately calculate costs and returns in Section 5.

The kW h per pound of production (E52) is used to calculate energy costs for the total system and each production unit. This variable is calculated by adding up the total kW usage of the system—including energy usage for pumps, blowers and other equipment, as well as heating, ventilation and air-conditioning—converting this to kW h used per year, and then dividing by the number of pounds produced. (For the example, the total energy demand is 34 kW. Multiply by 24 hours per day and 365 days per year, then divide by annual production of 219,000 pounds to arrive at 1.36 kW h per pound of production.)

System volts (E53) is used to calculate required amperage in Section 5. This is a useful number for planning energy requirements for the facility.

Transfer/harvest labor (E54) is the number of hours of labor required per cycle in addition to labor: management (defined in E37).

SECTION 3: Specify operating parameters per production unit—spreadsheet cell range B56:E64

Each column in this section represents a production unit, which could be a tank or group of tanks managed in the same manner, or it could refer to a particular life stage. For example, two tanks stocked at the same time with the intent to transfer and harvest fish at the same time, and in which fish are fed and managed in the same manner, could be treated as one production unit. Or, as in the spreadsheet example, two of the columns (Quarantine Stage and Nursery Stage) refer to particular tanks while the remaining four (Growout Stage 1, Growout Stage 2, Growout Stage 3, and Growout Stage 4) refer to a production stage for fish that remain within the same tank.

Water volume, gallons (D59:I69) is used to calculate the maximum standing biomass, pounds per gallons of water (D73:L73) for any one tank, as discussed in Section 4.

Size stocked (D60:I60) is the average size of the fish stocked into that production unit. Size harvested (D61:I61) is their average size when transferred or harvested from the system. In the example, fish are initially stocked at 1.0 gram into the quarantine tank and transferred into the nursery tank when they reach 15 grams.

Survival rate (D62:I62) is the percentage of survival for that production unit. In the example, the lower survival rate for the Q tanks includes the discarding of undersized fish (runts) when fish are graded into the N tank.

Feed cost, per pound (D63:I62) is the average cost per pound of feed fed to that production unit. Feed cost, per pound and feed conversion (D64:I64) are used to calculate

Section 2. Specify the Cost of Inputs, Sale Price and System Parameters

Item	Unit or description	Cost or amount
Variable costs:		
Liquid oxygen	$ per 100 cubic feet	$0.75
Energy	$ per kW h	$0.100
Bicarbonate	$ per pound	$0.26
Fingerlings	$ per fingerling	$0.15
Chemicals	$ per cycle	$120.00
Maintenance	$ per month	$637.00
Labor: management	$ per month	$3,000.00
Labor: transfer & harvest	$ per hour	$9.00
Fixed costs:		
Liquid oxygen tank rental	$ per month	$440.00
Electrical demand charge	$ per month	$–
Building overhead	$ per month	$150.00
Average overall sale price	$ per pound	1.37
System parameters		
Annual production	pounds	219,000
Average size at harvest	pounds	1.5
Number of production units	number	9
Days per production unit	days	42
kW h per pound of production	kW h per pound of production	1.36
System volts	volts	230
Transfer/harvest labor	hours per cycle	64

Figure 3. Graphic depiction of computer display of Section 2.

Section 3. Specify Operating Parameters per Production Unit						
Note: This information is for each growing stage of the fish, not for each tank.						
	Quarantine stage	**Nursery stage**	**Growout stage 1**	**Growout stage 2**	**Growout stage 3**	**Growout stage 4**
Water volume, gallons	1,500	4,000	25,000	25,000	25,000	25,000
Size stocked (grams)	1	15	60	135	250	385
Size harvested (grams)	15	60	135	250	385	680
Survival rate	95%	99%	99%	99%	99%	99%
Feed cost, per pound	$0.52	$0.38	$0.35	$0.35	$0.35	$0.35
Feed conversion	1.00	1.10	1.30	1.60	1.60	1.60

Figure 4. Graphic depiction of computer display of Section 3.

the cost of feed for each production unit, for each cycle, and annually. Feed usage is also used to calculate the amount of energy used, as discussed in the following section.

SECTION 4: Use of primary inputs and costs per production stage—spreadsheet cell range B66:N87

This section summarizes the quantity and costs of primary operating inputs—fingerlings, feed, energy, oxygen and bicarbonate—used over one cycle and extrapolates this information to an annual basis. No user input is required in this section.

In the example, once the fish culture system is fully stocked after 252 days, the system will have 8.69 harvests per year (365 days ÷ 42 days). Thus, each number in the cycle total (column M) is multiplied by 8.69 to calculate the annual total (column N).

Beginning number of fish in each tank (D69:L69) begins with the original stocking density and adjusts the number according to the survival rate (D62:I62).

Ending number of fish in each tank (D70:L70) is based on density and survival for each production unit.

Beginning biomass, pounds of fish (D71:L71) is based on the number of fish and average weight stocked into that production unit.

Ending biomass, pounds of fish (D72:L72) is based on the number of fish and weight transferred or harvested from that unit.

Maximum standing biomass, pounds per gallon of water (D73:L73) gives the pounds of fish per gallon of tank water at the end of that production period.

Feed used (D74:L74) is calculated from the specified feed conversion ratio (D63:I63) and the difference between the beginning biomass (D71:L71) and ending biomass (D72:l72).

The kW h used is calculated for each production unit as a weighted percentage of the feed usage for that unit multiplied by the total amount of kW h used for the cycle. Since feed applied to the system dictates the amount of filtration and flow required, feed amount is the best indicator of flow requirements and electrical energy consumption required by production stage. The total kW h for the cycle is based on the estimated electricity usage of 1.36 kW h per pound of production. For example, one cycle yielding 12,574 pounds (5,703 kg) of fish requires an estimated 17,100 kW h of electricity. Growout tank 1 consumes 93.5 percent of feed used during the cycle (17,414 pounds feed ÷ 18,634 pounds feed), so the estimated electrical use during that 168-day unit is 15,980 kW h (93.5 percent x 17,091), given in cell G75. The cost of electricity for that period, given in G82 as $1,598, is calculated using the user-specified electricity cost of $0.10 per kW h (E32).

Oxygen used, cubic feet (D76:L76) is calculated as follows: pounds of feed (D74:L74) x 50 percent (the amount of oxygen used per pound of feed, this is system specific) x 12.05 (a conversion factor, pounds of oxygen to cubic feet of oxygen). It is based not only on oxygen used for normal operating conditions, but also that extra oxygen used during times of sampling and harvesting when normal oxygenation is disrupted temporarily.

Bicarbonate used (D77:L77) allows for 0.175 pound of sodium bicarbonate used per pound of feed fed.

Costs by production stage (D80:L87) are calculated using the cost per input specified in Section 2.

Section 4. Use of Primary Inputs and Costs for each Production Stage

Note: This section provides the inputs and costs for each tank in the example 9-tank system.

Inventory and input use	Quarantine tank	Nursery tank 1	Nursery tank 2	Growout tank 1	Growout tank 2	Growout tank 3	Growout tank 4	Growout tank 5	Growout tank 6	Total per harvested cohort	Annual total
Beginning number of fish	18,596	8,833	8,833	8,745	8,745	8,745	8,745	8,745	8,745	18,596	161,604
Ending number of fish	17,666	8,745	8,745	8,400	8,400	8,400	8,400	8,400	8,400	16,800	146,000
Beginning biomass, pounds of fish	41	291	291	1,154	1,154	1,154	1,154	1,154	1,154	41	356
Ending biomass, pounds of fish	583	1,154	1,154	12,574	12,574	12,574	12,574	12,574	12,574	25,147	219,000
Maximum standing biomass, pounds per gallon of water	0.39	0.29	0.29	0.50	0.50	0.50	0.50	0.50	—	—	—
Feed used, pounds	542	949	949	17,414	17,414	17,414	17,414	17,414	17,414	37,269	323,884
kW h used	497	871	871	15,980	15,980	15,980	15,980	15,980	15,980	34,200	297,214
Oxygen used, cubic feet	3,266	3,431	3,431	62,953	62,953	62,953	62,953	62,953	62,953	136,033	1,182,194
Bicarbonate used, pounds	95	166	166	3,048	3,048	3,048	3,048	3,048	3,048	6,522	56,680
Costs											
Fingerlings	$2,789									$2,789	$24,241
Feed	$282	$361	$361	$6,095	$6,095	$6,095	$6,095	$6,095	$6,095	$13,193	$114,655
Energy	$50	$87	$87	$1,598	$1,598	$1,598	$1,598	$1,598	$1,598	$3,420	$29,721
Oxygen	$24	$26	$26	$472	$472	$472	$472	$472	$472	$1,020	$8,866
Bicarbonate	$25	$43	$43	$792	$792	$792	$792	$792	$792	$1,696	$14,737
Total of above costs for this production unit	$3,170	$517	$517	$8,958	$8,958	$8,958	$8,958	$8,958	$8,958	$22,119	$192,220
Cumulative cost for cycle	$3,170	$2,102	$2,102	$11,059	$11,059	$11,059	$11,059	$11,059	$11,059	$22,199	$192,220
Cumulative cost per pound	$5.44	$1.82	$1.82	$0.88	$0.88	$0.88	$0.88	$0.88	$0.88	$0.88	$0.88

Figure 5. Graphic depiction of computer display of Section 4.

SECTION 5: Summary of annual costs and returns to system in full production—spreadsheet cell range B89:I122

This section summarizes the costs and returns per cycle and annually for this system once it is in full production (after 252 days). Returns are calculated before tax.

Days per production unit (D91) repeats information given in cell E51.

The number of cycles per year (D92) is simply 365 days divided by days per production unit.

Required system amps (D93) is calculated from system volts (E53) and kW h usage assuming a power factor of 1.0.

Overall survival (F91) is calculated using survival given in D62:I62. Cycle FCR (F92) is calculated from feed conversion ratios in D64:I64.

The cell range C99:J119 calculates system costs per cycle, annually, and per pound based on information specified previously in the spreadsheet.

Section 5. Summary of Annual Costs and Returns to System in Full Production

Days per production unit =	42	Overall survival	90%
Number of cycles per year =	8.69	Cycle FCR	1.5
Required system amps =	148		

	Unit	Cost/unit	Quantity/ harvest cycle	$/harvest cycle	$/year	$ per lb of fish	% of total
Gross receipts	pound	$1.37	25,147	$34,568	$300,411	$1.37	
Variable costs							
Fingerlings	each	$0.15	18,596	$2,789	$24,241	$0.11	8%
Feed	pound	$0.35	37,269	$13,193	$114,655	$0.52	38%
Energy	kW h	$0.10	34,200	$3,420	$29,721	$0.14	10%
Oxygen	100 cubic feet	$0.75	1,360	$1,020	$8,866	$0.04	3%
Bicarbonate	pound	$0.26	6,522	$1,696	$14,737	$0.07	5%
Chemicals	$ per harvest cycle	$165.70	1	$166	$1,440	$0.01	0%
Maintenance	$ per harvest cycle	$879.58	1	$880	$7,644	$0.03	3%
Labor: management	$ per harvest cycle	$4,142.47	1	$4,142	$36,000	$0.16	12%
Labor: transfer & harvest	hour	$9.00	64	$576	$5,006	$0.02	2%
Interest on variable costs	$	4%	15,336	$635	$5,521	$0.03	2%
Subtotal, variable costs				$28,518	$247,831	$1.13	82%
Fixed costs							
Oxygen tank rental	$			$608	$5,280	$0.02	2%
Electrical demand charge	$			$-	$-	$-	0%
Building overhead	$			$207	$1,800	$0.01	1%
Interest on bldg. & equip.	$			$3,038	$26,400	$0.12	9%
Depreciation on bldg. & equip.	$			$2,198	$19,100	$0.09	6%
Subtotal, fixed costs				$6,050	$52,580	$0.24	18%
Total costs				$34,568	$300,411.05	$1.37	100%
Returns above variable costs				$6,050	$52,580	$0.24	
Returns above total costs				$-	$-	$-	

Figure 6. Graphic depiction of computer display of Section 5.

Interpreting the spreadsheet results

This publication is not an evaluation of the economics of tilapia production. A sale price of $1.37 was chosen so that the example system would have annual costs nearly equal to annual returns.

It is important to keep in mind that before the end of the first cycle on day 252, costs are incurred while no fish are harvested and sold. Until that time the cost of operations must either be paid by additional owner funds or by bank financing. To calculate the point at which the system becomes self-supporting (can pay all fixed and variable costs), divide the total costs per cycle by the net returns per cycle. For example, if the sale price were $2.00 per pound, total costs per cycle would be $34,578 and returns above total costs would be $15,726. This is equal to 2.20 cycles ($34,578 ÷ $15,726) or 554 days (2.20 cycles x 252 days per cycle). The system would not become self-supporting until approximately 1.52 years from startup.

The above example assumes that 100 percent of the project is financed through outside sources. In reality, very few, if any new aquaculture ventures will be financed without any private equity inputs. If 50 percent of the total initial investment is provided from owner's equity, the total cost and time before the system will become self-supporting can be greatly reduced. For example, with a sales price of $2.00 per pound, if the owner contributes $480,000 of the $960,000 estimated total investment, the following changes should be seen. Total cost of production will drop from $1.37 per pound to $1.31 per pound. Total costs per cycle would drop from $34,578 to $32,911. Returns above total costs would increase from $15,726 to $17,383. Additionally, the time for the system to become self-supporting will drop from 1.52 years from startup to approximately 1.31 years from startup.

Differing amounts of owner equity will also affect the return on investment for the owner's contributed capital; however, the return on the total investment of the project should remain unchanged. One should consider not only the return of their invested capital, but also the return on investment for the total project when evaluating a recirculating aquaculture system. In our previous example, if the owner contributes 50 percent of the initial investment, the 10-year modified return on investment (or modified internal rate of return—MIRR) for contributed capital at a sales price of $2.00 per pound would be 11 percent, while the return on the total investment would be -12 percent (see Fig. 7).

This spreadsheet can be used to test the effect on costs and returns of changes in sale price, feed conver-

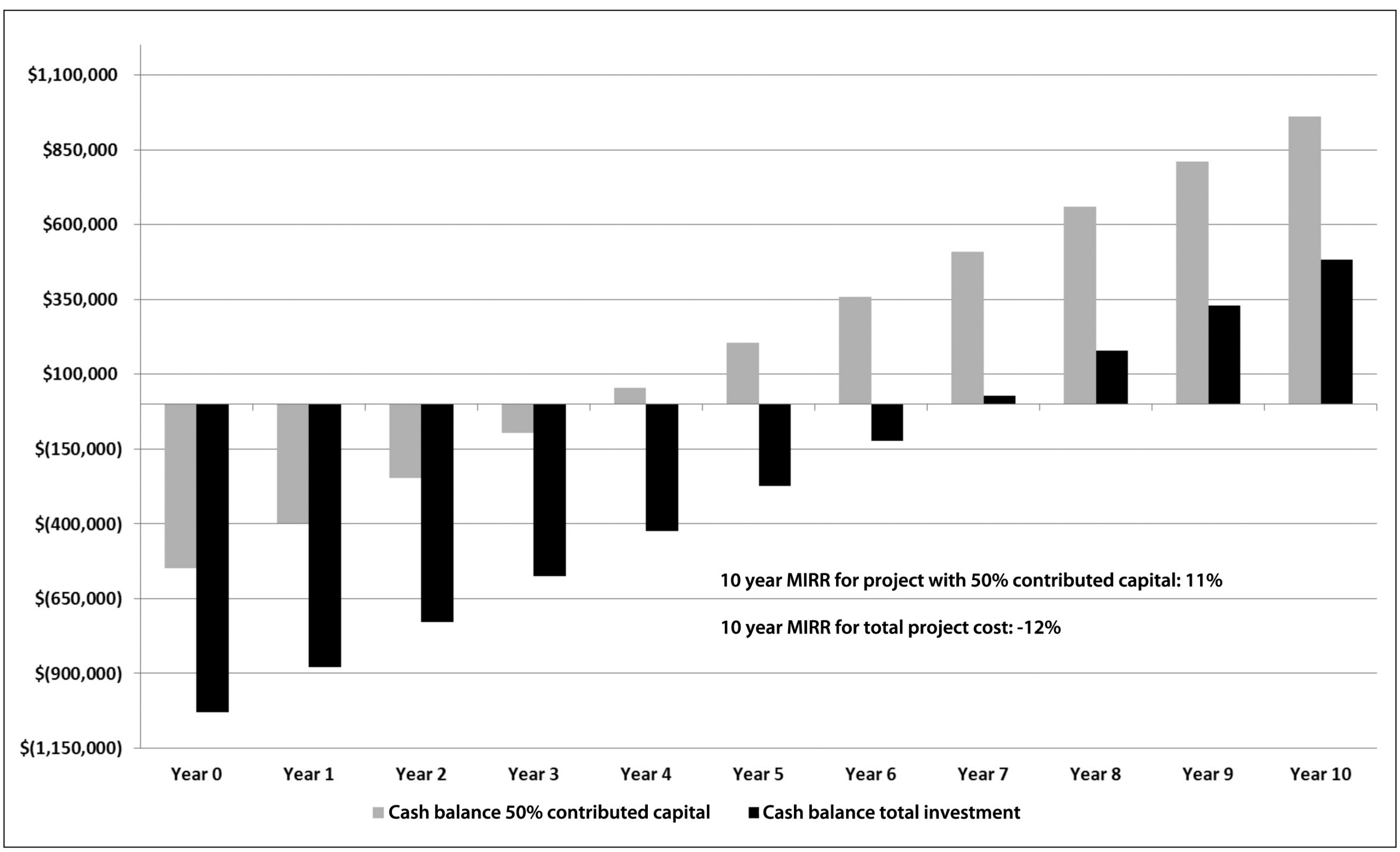


Figure 7.

sion, survival, or the costs of electricity and other inputs. Users can also examine the change in profitability based on a change in the stocking and transfer of fish or overall size of system. For example, more frequent moves of fish between tanks could make better use of tank carrying capacity, increasing the amount of fish that could be harvested annually. Or, a more energy-intensive system might support a higher carrying capacity per tank. Either of these may increase profit if the costs associated with each (higher labor cost, stress that may result in lower survival in the case of more frequent moves, and a higher electricity cost if the system were reconfigured) do not outweigh the increase in production. Larger systems—more tanks and larger tanks—also increase the profitability of recirculating systems.

Caveats

There is no single recommended design for RASs. Therefore, it is impossible to supply a ready-made cost/return spreadsheet that will be suitable for every system. Operators with existing or proposed systems similar to the example presented here can use this spreadsheet. Radically different systems may require extensive modifications of the spreadsheet structure by the user. The example spreadsheet is simple in design and does not contain any macro programming. It can be modified once cells are unprotected. **When working with the original spreadsheet or a modified version, keep in mind that it can evaluate the economics only of a properly designed system and cannot correct for flaws in design.**

Additionally, this spreadsheet does not take into account the opportunity cost of investing in recirculating aquaculture due to the inability to predict future economic conditions. One should take care to evaluate all investment opportunities to meet individual financial goals.

Suggested reading

Hobbs, A., T. Losordo, D. DeLong, J. Regan, S. Bennett, R. Gron and B. Foster. 1997. A commercial, public demonstration of recirculating aquaculture technology: the CP&L/EPRI Fish Barn at North Carolina State University. pp. 151-158 *in* M.B. Timmons and T.M. Losordo, editors. Advances in aquacultural engineering. Proceedings from the aquacultural engineering society technical sessions at the fourth international symposium on tilapia in aquaculture. NRAES-105. Northeast Regional Agricultural Engineering Service, Ithaca, NY.

Losordo, T.M., A.O. Hobbs, and D.P. DeLong. 2000. The design and operational characteristics of the CP&L/EPRI fish barn: a demonstration of recirculating aquaculture technology. *Aquacultural Engineering* 22: 3-16.

For additional suggested reading, see this internet site: *https://srac.tamu.edu/*

USDA United States Department of Agriculture National Institute of Food and Agriculture

The work reported in this publication was supported in part by the Southern Regional Aquaculture Center through Grant No. 2008-38500-19251 from the United States Department of Agriculture, National Institute of Food and Agriculture.