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ECONOMIC ANALYSIS OF RURAL AND ARTISANAL AQUACULTURE IN ECUADOR

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Abstract

Three different types of culture and conditions were tested to determine the profitability of Rural and Artisanal Aquaculture Project in Ecuador: monoculture of the freshwater fish named locally cachama (*Piaractus brachypomus*), monoculture of red claw crayfish (*Cherax quadricarinatus*) and polyculture tilapia (*Oreochromis sp.*) – cachama (*Piaractus brachypomus*). The economic models used for this particular analysis were Net Present Value (NPV) and Internal Rate of Return (IRR). Using these methods in combination with a sensitivity analysis foresaw the feasibility on investment for the monoculture of red claw crayfish (*Cherax quadricarinatus*) showing a Net Present Value (NPV) of 11,458.80 USD, which was the highest among the trials, at 8.65% real interest rate and Internal Rate of Return 44%, followed by the monoculture of cachama (*Piaractus brachypomus*) with NPV of 10,130.82 USD at the same discount rate and IRR 35%, respectively. The third place in order of profitability goes for the polyculture tilapia (*Oreochromis sp.*) and cachama (*Piaractus brachypomus*) with NPV of 1,888.99 USD and 8.65% real interest rate. The IRR percentage registered on the last type of culture was 19%, being the lowest among the three types of production analyzed. Among the conditions tested in the sensitivity analysis, there were: the sudden increase in discount rate, 10% increase in costs, 10% decrease in benefits, simultaneous 10% increase in cost and 10% decrease in benefits, 10% increase in feed cost, 10% increase in price of fingerlings and larvae and reduction in survival rate to 73%, 50, 25.1% with 80% as optimal. On this sensitivity analysis, the monoculture of red claw crayfish (*Cherax quadricarinatus*) overcame most of the conditions tested being defeated by the reduction in survival rate in the order of 50 and 25.1% which NPVs turned out to be negative; -7,429.60 USD and -22,004.70 USD, respectively. On this case the IRR was indefinable. Nevertheless, still some speculations about certain conditions such as broad experience in the Aquaculture field and technological advantage might be serious factors to be considered at the moment to select this investment and they must be analyzed carefully.

Key words Net Present Value, Internal Rate of Return, Sensitivity Analysis, Nominal Interest Rate, Real Interest Rate, Benefit-Cost Ratio, Inflation Rate.

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1. INTRODUCTION

Aquaculture as a definition given by FAO on 2008 in the Glossary of Aquaculture represents the farming of aquatic organisms in inland and coastal areas, involving intervention in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated.

Rural aquaculture is entitled for the rearing of aquatic organisms by small-scale farming households with the application principally of extensive and semi-intensive husbandry for household consumption and/or income (FAO, 1998).

On the particular case of Ecuador, there is no tradition for small scale Aquaculture but the well-gained experience among years raising aquatic animals specifically Pacific White Shrimp; *Penaeus vannamei* and also red hybrid tilapia; *Oreochromis sp.*, can grant the success of this activity at rural level taking into account the reduction of operating costs and the intensification of productivity.

Although the Ecuadorian Aquaculture industry is well developed in the culture of shrimp and tilapia in the coastal area, the Aquaculture potentiality and development of other species with less commercial and export value compared to shrimp has been relegated with little or no government support. Nevertheless, some of these new and potential species such as chame (*Dormitator latifrons*), red claw crayfish (*Cherax quadricarinatus*), and cachama (*Piaractus brachypomus*) have a very high internal consumption (Romero, 2008).

The technology exists to produce very attractive rural-artisanal freshwater fish Aquaculture. On the other hand, the technology for red claw introduced to Ecuador during the 90's can be adapted to rural scale with simple expenses generating profits for producers (Romero, 2008). Ecuador also counts with the technology to raise this species as well as the interest of a particular enterprise which will buy from a million up to two millions pounds (lbs) per year to the price of 0.90 USD/lb (Romero, 2008).

The Ecuadorian Government as part of its intention to promote the reactivation of every productive sector all over the country as specified in the National Plan 2006-2010; the project of Rural-Artisanal Aquaculture was born to offer an opportunity for small and medium scale agriculturists to enter the Aquaculture business, in order to diversify the production through the introduction of this new alternative. The Rural and Artisanal Aquaculture promotes the generation of a cheap protein source for malnourish people even sometimes considered as unattended and not fair-treated population (Romero, 2008).

The Under-secretary of Aquaculture, through the Office of Projects and International Cooperation has a proposal of investment for the Agriculture sector with the installation of rural-artisanal Aquaculture farms to support the economical development of low income families living of short term Agriculture cycle (Romero, 2008).

Nevertheless, for each agriculturist on this activity it is advisable to use only one part of their land for Aquaculture purposes. The Ecuadorian Government does not intend to stop them doing what they are more knowledgeable to; instead the government promotes the integration of the Agriculture-Aquaculture production (Romero, 2008).

This pilot project is based on credits starting from $1,500 USD to $2,000 USD, in order for small scale agriculturists to increase their income and at the same time to complement their current cultivations (Romero, 2008).

As part of this thesis work, the investment analysis will be the main aim, trying to determine the internal rate of return and the net present value of the project cash flow. The opportunity cost of the utilized land is not included in the analysis. Reliable data are not available.

Aquaculture is considered an option for rural development because it can provide the basic needs of the rural poor (Jolly and Clonts 1993), an important opportunity to help solving problems of underdevelopment, poverty, and protein malnutrition of the poor (Edwards 2000). Pillay on 1990 mentioned that this activity offers part and full time employment, also support to sustain peasants and fishermen in rural areas while reducing the drift of populations to urban centers.

The term rural aquaculture comes from its application to development: rural or agricultural and urban or industrial. The main aim in rural development is to alleviate widespread poverty and inequity in developing countries (WCED, 1987).

Once farmers acquire knowledge and experience at lower levels of production, they may wish to increase their level of production from subsistence or artisanal to entrepreneurial or commercial and become expertise aquaculture farmers (FAO, 1998).

Nonetheless, it is very important to quote that as an important requirement for a successful aquaculture activity, it is the ability to produce sufficient economic revenues capable to finance all costs, including repayment of capital investment (Liu and Sumaila, 2007).

“It is important to realize the multi-level benefits and links that aquaculture offers to the national economies of poorer countries, its contribution to macroeconomic growth through trade and domestic resource mobilization, as well as the micro-level support to the incomes and livelihoods of the poor. Definitely, Aquaculture can play a broader role in developing countries through poverty elimination and food security (Dey and Ahmed, 2005)”.

Aquaculture has been considered as a ‘blue revolution’, with the potential to provide direct and indirect increases in consumption and/or income of poorer households (Edwards, 1999).

The main aim probably for traditional aquaculture facilities represents the supply of household needs but with the quick expansion of the market economy even in long distance places, farmers are likely to be encouraged as much by income-generating opportunities as for improved domestic food supply (FAO, 1998).

Fish culture represents an interesting alternative to alleviate either nutrition or income problems in developing economies such as the Ecuadorian Economy. But this alternative will be feasible only if it is competitive enough with other choices for limited resources, and if its activity increases the total welfare of rural households (Hishamunda *et* al., 1998).

Fish ponds are a complex and diverse aquatic resource with a variety of stocking strategies including either exotic or native species (Bush and Kosy, 2007).

Fish is widely considered as ‘‘poor people’s protein’’ (Williams, 1996). Countries having low gross domestic product per capita tend to rely on fish protein at higher proportion in their animal protein intake (Kent, 1997). “Although, less developed countries are not the biggest consumers of fish, they are the most dependent on it (Kent, 1997)”.

Fish is considered as a highly nutritious food, providing animal protein with all 10 essential amino acids in relatively high concentrations, as well as certain vitamins and minerals. Fish is low in cholesterol and saturated fats and they are high in poly-unsaturated fats and essential fatty acids (FAO, 1998).

The constantly growing demand and expanding markets are expected to increase fish prices (Delgado et al., 2003), and therefore there is a need to intensify the supply of low-value food fish to maintain low prices for the poorest population (Dey and Ahmed, 2005).

2. OVERVIEW OF THE ECUADORIAN AQUACULTURE INDUSTRY

Ecuador's area is approximately 283,560 square kilometers (176,204 square miles). Ecuador's nearest countries are Colombia to the north, Peru through the east and south border, and the Pacific Ocean to the west. The Ecuadorian coastline has an extension of 2,237 kilometers (1,390 miles). As part of Ecuadorian's nature heritage, the Galapagos Islands with an area of 960 kilometers (600 miles) is also located to the west of mainland Ecuador in the Pacific Ocean (Encyclopedia of the nations, 2007).

The Ecuadorian Economy is based on the exportation of products such as banana, shrimp, and other agriculture industries; even nowadays is well known that immigrant's money transfers especially from Spain and United States have contributed to the country income; and last but no less the oil production represents 40% of export earnings and one-third of the central government budget revenues (New Media Holdings, Inc., 2007).

Ecuador represents a country with an Aquaculture tradition, and it has been recognized as a world leader in the production of Pacific white shrimp (*Litopenaeus vannamei*). However, its shrimp production was affected in 1992 by the Taura Syndrome Virus (TSV), which rapidly spread out all over the shrimp industry and led to the abandonment of thousands of hectares of earthen ponds. This allowed the introduction of red-tilapia farming as an alternative for the affected areas, later improved by tilapia/shrimp polyculture in late 1995 (CORPEI & CBI, 2001).

The shrimp industry started in Ecuador by the late 70's, when a group of capitalists began to exploit the salt marsh. Because of this activity became very profitable, this started taking over agriculture and mangrove lands. On the 80's, this activity grew up intensively. On 1987, Ecuador was the first shrimp exporter in the world, but during the 90's, the exportation values started to decrease principally due to the incidence of the White Spot Syndrome Virus (WSSV) (Bravo, 2003).

The year 2000 represented a very critical year in the history of the shrimp industry. The impact caused by the White Spot disease was far beyond any pessimistic outcomes that could have existed even when the crisis began in May 1999 (CORPEI & CBI, 2001).

During this difficult period in the late 1990s when the Ecuadorian shrimp industry suffered from disease problems, the country started with tilapia farming. Since then, shrimp and tilapia farming have been raised side by side, sometimes in the same earthen pond, which is called polyculture (FISH INFO network Market Report, February, 2007).

Ecuador has gained a very interesting place as one of the world's leading tilapia producers and exporters along with other Latin American countries. The main buyer of Ecuadorian red tilapia is the United States, but the demand for this product has also reached European countries. More than 18 million metric tons are produced annually, equivalent to 20% of the world's fish requirements (CORPEI & CBI, 2001).

There are certain environmental conditions suitable to produce Tilapia, the province of Guayas (areas of Taura, Samborondon, Chongon, Daule, and El Triunfo) and El Oro have been considered the most appropriate for tilapia farming. However, production has extended to the coastal provinces of Manabi and Esmeraldas and to the Ecuadorian eastern provinces in the Amazonian jungle (CORPEI & CBI, 2001).

Nevertheless, in 2006, shrimp has become the main species for almost all big shrimp companies, while tilapia was considered as a by-product (FISH INFO network Market Report, February, 2007).

Nowadays, the industry seems to be adapted to the presence of WSSV and the exportation values has increased to higher values from 2005 up to now. Even though the disease caused a collateral damage to the industry at the same time, it helped to improve and change minds in the way the industry produces shrimp, improving technologies and above all pushing to high scale producers to apply techniques rather than just making them wealthier.

Ecuadorian shrimp industry between 1970's and 1980's was characterized principally by collection of wild PL to supply "seed" for grow-out ponds. Nowadays the industry is stocked by hatcheries along the Ecuadorian coast due specifically to disease outbreaks (Sonnenholzner et al., 2002).

On despite of the Ecuadorian agricultural census, it is estimated a number of 308 registered shrimp hatcheries with a productivity of 58 billion post larvae (PL) per year which is enough to supply a demand of 45 billion larvae.
Up to date research in Ecuador has demonstrated less reliance on wild PL providing several advantages to the Ecuadorian shrimp industry. This allows higher controls over the supply and price of PL. Also, this advantage permits farms to be stocked in a timely manner along with adequate costs estimation.
Other reliable advantage with the PL stock supply from hatcheries, it is the possibility to produce disease-free PL, with a high certainty on this fact the producers feel more confident knowing that they are not introducing white spot syndrome virus or other diseases into their ponds. Even more, every hatchery has the chance to establish breeding programs for lines of shrimp, showing enough efficiency in the grow-out phase in ponds (Sonnenholzner et al., 2002).

Studies related to productivity from commercial farms have shown no difference in growth rates or yields between ponds, where wild larvae were used against hatchery larvae. Among these advantages, it is important to recognize the protection to the natural shrimp fisheries and biodiversity, using hatchery PL (Sonnenholzner et al., 2002).
Regarding to the shrimp farming sector in Ecuador, the technology applied is extensive and semi-intensive culture systems. The stock density goes from 8 to 14 post larvae (PL)/m^2 and the shrimp harvesting after 90-120 days of grow-out stage, has recorded an average of 1,200 Kg/ha per year (Sonnenholzner et al., 2002).

The shrimp production in Ecuador began in tidal flats that included mangrove areas. The tidal flow was considered one of the most important criteria to select the most suitable place to start raising shrimp. Later on, this criterion drastically changed with a more knowledgeable application of techniques on soil and water quality management. Nowadays, many ponds constructed on mangrove soils are still in production. Soils of the ponds constructed on former mangroves areas have the main characteristic to be more acidic, even carbon and sulfur values are high comparing to those on ponds constructed in mangrove areas (Sonnenholzner et al., 2002).

On October 15th 2008, Rafael Correa Delgado, President of the Republic of Ecuador, and four Ministers of State, issued the Decree 1391. This decree regularizes industrial shrimp Aquaculture (Yepez & O'Riordan, 2008).

Ecuador is a country that pioneered shrimp certification. The German company, Naturland, has been certifying shrimp ponds in Ecuador since the 1990s (Yepez & O'Riordan, 2008).

According to statistics presented by the National Aquaculture Chamber in Ecuador, exportations of shrimp reached out the total value of 673,469,146.78 USD which represents 294,733,588 lbs in 2008 being in 2007 273,137,769 lbs (582,028,512.15 USD) respectively. On the case of Tilapia related to exportation values to US, statistics showed 20,170,218 lbs which represents 58,032,911 USD in 2008 being 27,315,395 lbs (77,013,521 USD) in 2007.

The Department of Management and Sustainable Development of the Undersecretary of Aquaculture constantly has been monitoring the development of the Ecuadorian Aquaculture Industry. For this reason, the statistics showed the following values at the end of 2008 regarding hectares of productive ponds alongside with hatcheries: Shrimp farms: Province of Guayas: 107,483 Has; Province of El Oro: 393,313 Has; Province of Manabi: 16,564 Has; Province of Esmeraldas: 12,388 Has; Hatcheries: 189 hatcheries in production. The same office has detected at the same time that the industry specifically what is related to hatcheries, has expanded its scope being nowadays exporting shrimp nauplii and larvae especially to Peru in a number of seven companies approximately. The selling price is as follows: exporting price: 2.10 USD/thousand larvae; local price: 1.20 USD/thousand larvae and a million nauplii for 150 USD (Crespo, 2008).

Although the main species cultured in Ecuador is *Litopenaeus vannamei* which represents 98% of total farming, there are others in lower range also considered for the industry, such is the case of *Litopenaeus stilirostrys* and *Litopenaeus occidentalis* but less than 5% each of them (Crespo, 2008).

The processing industry sets the market price for grow-out pond producers but it is also establishes by international tendencies. Ultimately, the prices being registered all over Ecuador are: Shrimp exporting price; size 26-30: 2.80 USD/kg (processing plants); International market: 3.40 USD/Kg; Size 31-35: 2.60 USD/kg (processing plants); International market: 3.15 USD; Size 36-40: 2.40 USD/Kg (processing plants);

International market: 2.95 USD/Kg; Size 41-50: 2.20 USD/kg (processing plants); International market: 2.55 USD/kg. The range in size represents grams (Crespo, 2008).

Despite of the world economy crisis affecting us nowadays, the Ecuadorian Aquaculture Industry still is producing and generating employment opportunities all over the country especially to the poorest areas. However, there is the need to diversify the production in Ecuador and that is in fact the intention of governmental organizations to promote environmental friendly practice and integrated culture such the case of the Agriculture-Aquaculture production.

3. MODELS AND METHODS

On the present study the models to be used are Net Present Value and Internal Rate of Return in the cash flow of the project. The software employed is Microsoft Office Excel 2003.

The Net Present Value (NPV) and Internal Rate of Return (IRR) were determined as indicators of profitability (Bhandari, 1986).

All these profitability indices: Internal Rate of Return and Net Present Value are sensitive to changes in production and market variables (Head *et* al., 1996).

These discounted cash flow methods such as net-present-value and internal-rate-of-return have been shown to offer decision rules that are consistent with the maximization of shareholder value and these methods have therefore received greater acceptance by theorists (Boyle and Guthrie, 1997).

The following are general aspects to be considered of both models.

NET PRESENT VALUE MODEL (NPV)

The value of a cost or benefit expressed in terms of cash today, it is considered as the present value (PV). On the other hand, the definition of net present value (NPV) of a project or investment represents the difference between the present value of its benefits and the present value of its costs (Berk and Demarzo, 2007):

Net Present Value

$NPV = PV$ (Benefits) **–** PV (Costs)

Using positive cash flows to represent benefits and negative cash flows to represent costs, and calculating the present value of multiple cash flows as the sum of present values for individual cash flows, it is possible to write this definition as

$NPV = PV$ (All project cash flows)

Then, the NPV is the total of the present values of all project cash flows (Berk and Demarzo, 2007).

The NPV Decision Rule

The NPV constitutes the value of the project in terms of cash today. Meanwhile, good projects are those with a positive NPV and they contribute the investor to become wealthier. Projects with negative NPVs have costs that exceed their benefits, and taking over them represent to losing money today (Berk and Demarzo, 2007).

Because NPV is expressed in terms of cash today, it makes easier the process of decision making. Decisions that increase wealth must be the priority rather than those that decrease wealth. “When making an investment decision, take the alternative with the

highest NPV; choosing this alternative is equivalent to receiving its NPV in cash today" (Berk and Demarzo, 2007).
The most important idea to be recovered from the NPV rule is that everybody should discard projects with negative NPVs and invest in all projects with positive NPVs. We add to this statement the fact that the project should be taken only if getting into the project does not prevent us from undertaking some other project (Ross, 1995).
In a capital budgeting approach dealing especially with a budget constraint issue, undertaking a project supposes taking on feasible combination of projects that maximizes the NPV (Ross, 1995).
As a matter of fact, NPV analysis applies only in those cases where the investment opportunity immediately could disappear if it is not instantly undertaken. The great majority of investments have not a small time period over they may be undertaken, and this implies that they have an automatic optionality on their own valuation that is applied when the initial investment is made. The NPV study is useful only in cases where an investment does not impede some alternative investment, because every investment competes with itself delayed in time (Ross, 1995).
This simple rule of investment, "invest if the net present value of such investment exceeds zero" is only applicable if the variance of the present value of future benefits and costs is zero or if the expected rate of growth of the present value is minus infinity; the value lost by following this suboptimal investment policy can be representative (McDonald and Siegel, 1986).

Accepting or Rejecting a Project.

A particular financial decision making is to accept or not a project. Because discarding the project generally implies $NPV = 0$ (there are no new costs or benefits from not doing the project), the NPV decision rule demands to:

- Accept those projects with positive NPV because undertaking them is equivalent to receiving their NPV in cash today, and
- Reject those projects with negative NPV; undertaking them would reduce the wealth of investors, whereas not doing them has no cost (NPV = 0) (Berk and Demarzo, 2007).

Choosing among projects

It is possible to use the NPV decision rule to determine the best option among projects. As an example, let's suppose it is necessary to select among three projects that have the risk-free cash flows indicated in Table 1. If the risk-free interest rate is 20%, which project is the best choice?

Table 1.Cash flows of three possible projects

Project	Cash flow today ($)	Cash flow in one year ($)
A	42	42
B	-20	144
C	-100	225

Source: Berk, Jonathan and Demarzo, Peter (2007) 'CORPORATE FINANCE', Pearson International Edition, Pearson Education, Inc.

On this example the best project can be determined by comparing the NPV of each one. According to the calculations in table 2, the three projects showed a positive NPV, and it is possible to accept all three practically. But, in the case it is necessary to select only one of them, the project B seems to have the highest NPV of $100 and therefore represents the best choice. With this result at hand, it is the same to say that the investor will receive $100 in cash today (Berk and Demarzo, 2007).

Table 2.Computing the NPV of Each Project

Project	**Cash flow today ($)**	**PV of Cash Flow in One Year ($)**	**Cash flow in one year ($)**
A	42	42 / 1.20 = 35	42 + 35 = 77
B	-20	144 / 1.20 = 120	-20 + 120 = 100
C	-100	225 / 1.20 = 187.5	-100 + 187.5 = 87.5

Source: Berk, Jonathan and Demarzo, Peter (2007) 'CORPORATE FINANCE', Pearson International Edition, Pearson Education, Inc.

NPV and Individual Preferences

When projects with different conditions of present and future cash flows are compared, it is possible to have preferences regarding when to obtain the cash. Some investors require the money today; others may choose to save for the future. However, the project B as it was shown on the previous example, still has the highest NPV; it does need a $20 cash outlay. If the investors pretend to avoid the negative cash flow today; would project A be a better selection on this particular scenario? Independently, if the investor intends to save for the future, would Project C be a better investment? Should our individual preferences about present versus future cash flows affect our decision for projects? The answer is no.

As long as it is possible to borrow and lend at the risk-free interest rate, Project B is superior whatever our preferences regarding the timing of the cash flows. To visualize why, suppose it is possible to invest in Project B and borrow $62 at the risk-free rate of 20%. The total cash flows are shown in Table 3, comparing these cash flows to those for Project A, this combination produces the same initial cash flow as it is in Project A, but with a higher final cash flow ($69.60 versus $42). Thus the investor could be better off by investing in Project B and borrowing $62 today than the investor would be by accepting Project A (Berk and Demarzo, 2007).

Table 3.Cash Flows from Combining Project B with Borrowing

Project	Cash flow today ($)	Cash flow in one year ($)
Project B	-20	144
Borrow	62	-62 x (1.20) = -74.4
Total	42	69.6

Source: Berk, Jonathan and Demarzo, Peter (2007) ‘CORPORATE FINANCE’, Pearson International Edition, Pearson Education, Inc.

Similarly, it is feasible to combine Project B with saving $80 at the risk-free rate of 20% (see Table 4). This analysis has the same initial cash flow as Project C (see Table 2), but one more time has a higher final cash flow (Berk and Demarzo, 2007).

Table 4.Cash Flows from Combining Project B with Saving

Project	Cash flow today ($)	Cash flow in one year ($)
Project B	-20	144
Save	-80	80 x (1.20) = 96
Total	-100	240

Source: Berk, Jonathan and Demarzo, Peter (2007) ‘CORPORATE FINANCE’, Pearson International Edition, Pearson Education, Inc.

Therefore, it does not matter what pattern of cash flows it is preferable, Project B still remains as the superior choice. This example shows the following general principle:

“Regardless of any preference for cash today versus cash in the future, it is always advisable to maximize NPV first. Then, it is possible to borrow or lend to shift cash flows through time and find our most preferred pattern of cash flows” (Berk and Demarzo, 2007).

The Net Present Value of a Stream of Cash Flows

As it was defined previously the net present value (NPV) of an investment decision is determined as follows (Berk and Demarzo, 2007):

$$NPV = PV\,(\text{benefits}) - PV\,(\text{costs})$$

The benefits represent the cash inflows and the costs are the cash outflows. It is suitable to represent any investment decision on a timeline as a cash flow stream where the cash outflows (investments) are negative cash flows and the inflows are positive cash flows.

Therefore, The NPV of an investment opportunity is also the present value of the stream of cash flows of the opportunity (Berk and Demarzo, 2007):

$$NPV = PV\,(\text{benefits}) - PV\,(\text{costs}) = PV\,(\text{benefits} - \text{costs})$$

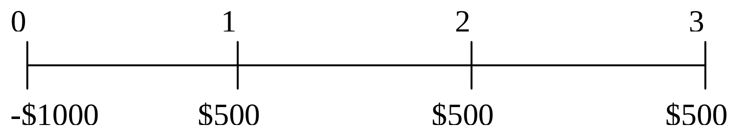
Net Present Value of an Investment Opportunity

Example

It is been offered the following investment opportunity: If the investor can invest $1,000 today, this person will receive $500 at the end of each of the next three years. If the investor could otherwise earn 10% per year on the money invested, should this investor undertake the investment opportunity? (Berk and Demarzo, 2007)

Analysis

It is necessary to start establishing the timeline of this particular investment as first step. The investment is located in the upfront of this timeline as the way of negative cash flow (because it represents the money necessary to be spent) and the money that it is received can be denoted as positive cash flow (Berk and Demarzo, 2007).



To determine whether it is possible to accept this opportunity or not, it is important to calculate the NPV by computing the present value of the stream as follows (Berk and Demarzo, 2007):

$$NPV = -1000 + \frac{500}{1.10} + \frac{500}{1.10^2} + \frac{500}{1.10^3} = \$243.43$$

Because the NPV is positive, the benefits exceed the costs and the investor should make the investment. As a matter of fact, the NPV shows to the investor that taking this opportunity is like getting an extra $243.43 that it is possible to be spent today. To illustrate better this example it is possible to imagine the particular case of borrowing $1000 to invest in the opportunity and an extra $243.43 to spend today. How much would the investor owe on the $1243.43 loan in three years? At 10% interest, the amount the investors owe would be (Berk and Demarzo, 2007):

$$FV = (\$1000 + \$243.43) * (1.10)^3 = \$1655 \quad \text{In 3 years}$$

At the same time, the investment opportunity produces cash flows. If the investor put these cash flows into a bank account, how much will he/she have saved three years from now? The future value of the savings will be (Berk and Demarzo, 2007):

$$FV = (\$500 * 1.10^2) + (\$500 * 1.10) + \$500 = \$1655 \quad \text{In 3 years}$$

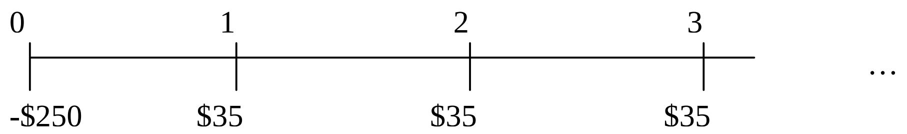
According to this result, the investor may use the bank savings to repay the loan. Taking the opportunity therefore allows him/her to spend $243.43 today without any extra payment (Berk and Demarzo, 2007).

NPV and Stand-Alone Projects

Let's begin this discussion of investment decision rules by considering a take-it-or-leave-it decision with a single, stand-alone project. By taking over this project, the firm does not minimize its ability to take other projects. Let's start analyzing the NPV rule (Berk and Demarzo, 2007);

NPV Rule

Researchers at Fredrick Feed and Farm (FFF) have made an important finding. They are considering producing a new, environmentally friendly fertilizer at a substantial cost saving over the company's existing line of fertilizer. The fertilizer needs a new plant that can be built right away at a cost of $250 million. Financial managers believe that the benefits of the new fertilizer will be $35 million per year, starting at the end of the first year and lasting for a life time, as shown by the following timeline (Berk and Demarzo, 2007):



The NPV of this cash flow stream, given a discount rate r, is

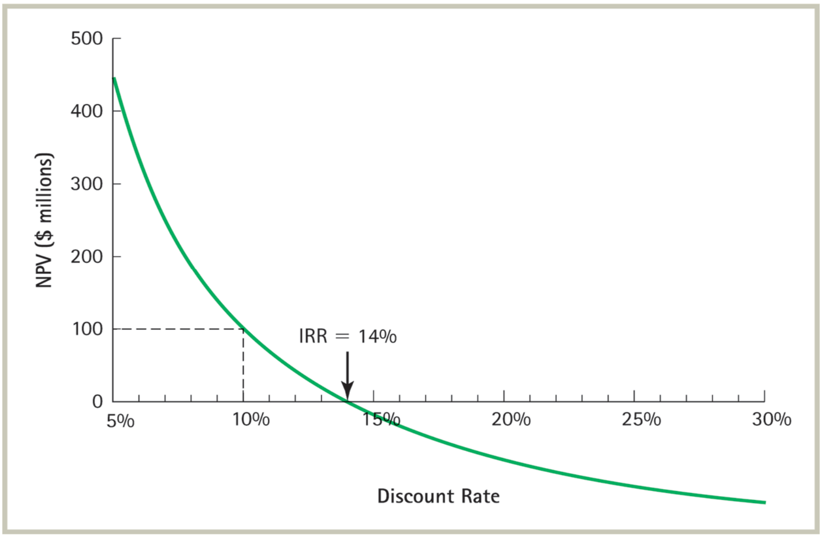
$$NPV = -250 + \frac{35}{r}$$

Figure 1 shows the NPV as a function of the discount rate, r. It is important to mention that the NPV is positive only for discount rates that are less than 14% the internal rate of return (IRR) (Berk and Demarzo, 2007).

To determine whether to invest or not (using the NPV rule), it is necessary to know the cost of capital (Berk and Demarzo, 2007).

The financial managers responsible for this project estimate a cost of capital of 10% per year. Referring to Figure 1, it is possible to see that when the discount rate is 10%, the NPV is $100 million, being positive. The NPV investment rule indicates that by making the investment, FFF will increase the value of the firm by $100 million, so FFF should undertake this project (Berk and Demarzo, 2007).

Figure 1.NPV of FFF's New Project The graph plots the NPV as a function of the discount rate. The NPV is positive only for discount rates that are less than 14%, the internal rate of return (IRR). Having the cost of capital of 10%, the project gets a positive NPV of $100 million.



Source: Berk, Jonathan and Demarzo, Peter (2007) 'CORPORATE FINANCE', Pearson International Edition, Pearson Education, Inc.

The software of preference amongst business professionals to find the NPV value is Microsoft Excel; the introduction of enhanced access to external data sources seen in the most recent versions, guarantees that Excel will continue to be the financial tool of choice for quite some time to come (Adair, 2005).

On Microsoft Office Excel, the NPV function calculates the net present value of an investment based on a series of periodic cash flows and a discount rate. The Net Present Value of any investment is today's value of some future payments (negative values) and income (positive values). Its representation in Excel is: =NPV (rate, value1, value2,…)

Where:

Rate represents the rate of discount over the length of one period.

Value1, value2,… are 1 to 29 arguments of payments and income. Value1, value2,… must be equally expressed in time and occur at the end of each period (Predo and James, 2006).

In Excel the NPV calculations employ the relationship of value1, value2,… to establish the sequence of cash flows. All commands must be clearly specified, mainly those related to payment and income values with the correspondent order. Commands indicating numbers, empty cells, logical values, or text representations of numbers are taken into account at the moment of calculating the NPV; arguments that represent error values or text that cannot be interpreted into numbers will be ignored. If an argument is an arrangement or reference, only numbers in that array or reference are considered. Empty cells, logical values, text, or error values in the array or reference are ignored (Predo and James, 2006).

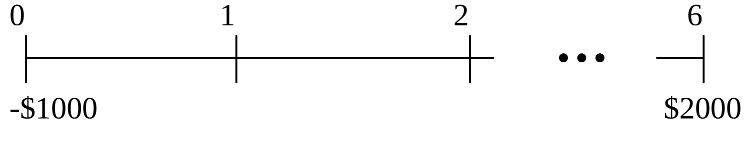
The NPV investment begins one period before the date of the value 1 of the cash flow and ends with the last cash flow in the list. The NPV calculation is based on future cash flows. If the first cash flow occurs at the beginning of the first period, the first value must

be added to the NPV result, not included in the values arguments (Predo and James, 2006).
It is important to mention the fact that Net present values (NPVs) from aquaculture operations are calculated or found depending on the expected revenues and the costs incurred over the time horizon of the project (Liu and Sumaila, 2007).
A discount rate defined as the minimum desired rate of refund for the project, it is necessary when the Net Present Value (NPV) is going to be determined. When the result of NPV is positive, it means that the project is economically feasible, and vice versa (Liu and Sumaila, 2007).
The methodology to select the most suitable discount rate is critic for the application of the NPV method for investment feasibility analysis. This is mainly because the future economic returns on the investment have to be discounted into present values in order to determine the time value and risks of investments. There are cases when discount rates are higher, on this particular case the NPVs decrease considerably because high discount rates consider future benefits less than low discount rates (Sumaila and Walters, 2005).
On the other hand, Aquaculture producers always choose a higher discount rate because investment in aquaculture is risky; they require higher rates of returns on their investment to serve as risk compensation (Sumaila, 2005).

INTERNAL RATE OF RETURN MODEL (IRR)

In some cases, it is easy to know the present value and cash flows of an investment opportunity but it is not the case of the interest rate that equates them. This interest rate is called the internal rate of return (IRR) (Berk and Demarzo, 2007).
Internal Rate of Return (IRR) determines the break-even rate of return from a capital investment, it means that IRR is the rate when the Net Present Value (NPV) equals zero. If the discount rate used to find NPVs is below IRR, it represents that the NPV is positive, and vice versa. The higher an IRR, the more desirable it is to invest (Liu and Sumaila, 2007).
Profitability indices like IRR are sensitive to changes in production and market variables (Head *et* al., 1996).
If environmental costs are included in any economic analysis, this will cause the IRR to be lower. The IRR is higher at larger production capacities (Liu and Sumaila, 2007).

As an example, let's suppose that one investor has an investment opportunity that requires a \$1000 investment today and will have a \$2000 payoff in six years. On a timeline (Berk and Demarzo, 2007),



One way to analyze this investment is to ask the question: What interest rate, r, would you need so that the NPV of this investment is zero? (Berk and Demarzo, 2007)

$$NPV = -1000 + \frac{2000}{(1+r)^6} = 0$$

Rearranging gives

$$1000 * (1+r)^6 = 2000$$

That is, r is the interest rate the investor would need to earn over $1000 to have a future value of $2000 in six years. It can be solved for r as follows (Berk and Demarzo, 2007):

$$1 + r = \left(\frac{2000}{1000}\right)^{1/6} = 1.1225$$

Or r = 12.25%. This rate is the IRR of this investment opportunity. If the investor proceed on making this investment is like earning 12.25% per year on his/her investment for six years (Berk and Demarzo, 2007).

When there are just two cash flows, as in the preceding example, it is easy to compute the IRR. Let's take into account the general case in which any person could invest an amount P today, and receive FV (future value) in N years (Berk and Demarzo, 2007). Then:

$$P * (1 + IRR)^N = FV$$

$$1 + IRR = \left(\frac{FV}{P}\right)^{1/N}$$

That is, if the total return of the investment over N years is taken, FV/P, and converts it to an equivalent one-year rate by raising it to the power 1/N (Berk and Demarzo, 2007).

Furthermore, let's suppose that certain firm requires acquiring a new forklift. The dealer offers two options: (1) a price for the forklift if the firm pays cash and (2) the annual payments if the firm takes out a loan from the dealer. To determine if the loan that the dealer is offering to the firm is adequate or not, it is necessary to compare the rate on the loan with the rate that the firm's bank is willing to grant to such firm. Given the loan payment that the dealer quotes, how is it possible to compute the interest rate charged by the dealer? (Berk and Demarzo, 2007).

On this particular case, it is necessary to compute one more time, the IRR of the dealer's loan. Let's suppose the cash price of the forklift is $40,000, and the dealer offers financing with no down payment and four annual payments of $15,000. This loan has the following timeline (Berk and Demarzo, 2007):

0	1	2	3	4
$40,000	-$15,000	-$15,000	-$15,000	-$15,000

From the timeline it can be said that the loan is a four-year annuity, which represents a stream of equal periodic cash flows over a specific time period, these cash flows can be inflows of returns earned on investments or outflows of funds invested to earn future returns; with a payment of $15,000 per year and a present value of $40,000. To set the NPV of the cash flows equal to zero, it is required that the present value of the payments equals the purchase price (Berk and Demarzo, 2007):

$$40{,}000 = 15{,}000 * \frac{1}{r}\left(1 - \frac{1}{(1+r)^4}\right)$$

The value of r that solves this equation, the IRR, is the interest rate charged on the loan. Unfortunately, in this case there is no simple way to solve for the interest rate r (with five or more periods and general cash flows, there is no general formula to solve for r; trial and error by hand or computer, is the only way to compute the IRR). The only way to solve this equation is to guess values of r until the right IRR can be determined (Berk and Demarzo, 2007).

Starting by guessing r = 10%. In this case, the value of the annuity would be (Berk and Demarzo, 2007):

$$15{,}000 * \frac{1}{0.10}\left(1 - \frac{1}{(1.10)^4}\right) = 47{,}548$$

The present value of the payments is too large. To lower it, it is needed the use of a higher interest rate, for example 20% this time (Berk and Demarzo, 2007):

$$15{,}000 * \frac{1}{0.20}\left(1 - \frac{1}{(1.20)^4}\right) = 38{,}831$$

Now the present value of the payments is too low, so it is demanding to select a rate between 10% and 20%. Guessing must continue until the right rate is found. Let’s see the results with 18.45% (Berk and Demarzo, 2007):

$$15{,}000 * \frac{1}{0.1845}\left(1 - \frac{1}{(1.1845)^4}\right) = 40{,}000$$

The interest rate charged by the dealer is 18.45% (Berk and Demarzo, 2007).

Computing the Internal Rate of Return Directly

Example

Pacific Bank offers Donna a second choice for repayment of the loan. She can pay $100,000 the first year, increase the amount by 4% each year, and continue to make these payments forever, rather than for 30 years. What is the IRR on this case? (Berk and Demarzo, 2007)

Solution
The timeline is:

The timeline shows that the future cash flows are a growing perpetuity which means a stream of equal cash flows that occurs at regular intervals and lasts forever, with a growth rate of 4%. Setting the NPV equal to zero requires (Berk and Demarzo, 2007):

$$1{,}000{,}000 = \frac{100{,}000}{r - 0.04}$$

It is possible to solve this equation for r

$$r = 0.04 + \frac{100{,}000}{1{,}000{,}000} = 0.14$$

The IRR on this investment is 14% (Berk and Demarzo, 2007).

Measuring Sensitivity with IRR

It is necessary to see how sensitive any analysis is to errors on the estimate when the cost of capital estimate is not clear enough. Through the IRR model, it is possible to obtain these data. For the earlier example of the enterprise Fredrick Feed and Farm (FFF), if the cost of capital estimate is more than 14% IRR, the NPV will be negative (see figure 1). In addition, the difference between the cost of capital and the IRR is the maximum amount of estimation error in the cost of capital estimate that can exist without changing the original decision (Berk and Demarzo, 2007).

The Internal Rate of Return Rule

The Internal Rate of Return (IRR) investment rule is established in a logical and simple way: if the return on the considered investment opportunity is greater than the return on other alternatives in the market with equivalent risk and maturity (i.e., the project's cost of capital) the investment opportunity should be undertaken.

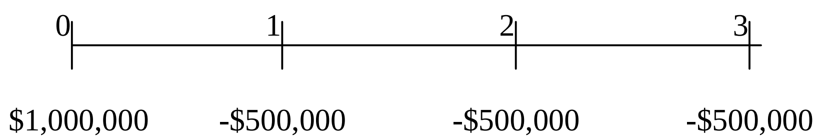
IRR Investment Rule: "Take any investment opportunity where IRR exceeds the opportunity cost of capital. Turn down any opportunity whose IRR is less than the opportunity cost of capital".

The IRR investment rule will give the correct idea (that is, the same answer as the NPV rule) in many -but not all- situations. Therefore, it gives the right answer for FFF's fertilizer opportunity. From Figure 1, if the cost of capital is below the IRR (14%), the project gets a positive NPV and therefore the investor should undertake this chance for investment. Certainly, the IRR rule helps for stand-alone projects if all of the project's negative cash flows precede its positive cash flows. But on the other hand, there are other cases when the IRR rule may disagree with the NPV rule and thus be incorrect (Berk and Demarzo, 2007).

Following there are several cases where the IRR does not work accordingly.

Delayed Investments

Let's say that one ex-CEO (Chief-Executive-Officer) from a very well-known and successful company has just retired from that position and one publisher has offered to this person a $1 million "how I did it" book deal. The publisher will pay this person $1 million if this person agrees to write a book about the experiences gained in the company as CEO. The person has calculated that approximately it will take three years to accomplish the book. The time this person must invest to write the book could cause to give up other alternative ways of income and available investment opportunities. This person has reached into conclusion that the opportunity cost of capital on this deal might be 10%. The timeline of this person's investment opportunity seems to be as follows (Berk and Demarzo, 2007):



The NPV of this person's opportunity is

$$NPV = 1{,}000{,}000 - \frac{500{,}000}{1+r} - \frac{500{,}000}{(1+r)^2} - \frac{500{,}000}{(1+r)^3}$$

Considering the NPV equal to zero and solving for r, it is possible to determine the IRR. The most direct way is using the annuity spreadsheet (Berk and Demarzo, 2007):

Table 5.Annuity spreadsheet

	NPER	RATE	PV	PMT	FV	Excel Formula
Given	3		1,000,000	-500,000	0	
Solve for I		23.38%				RATE(3, 500000, 1000000, 0)

Source: Berk, Jonathan and Demarzo, Peter (2007) 'CORPORATE FINANCE', Pearson International Edition, Pearson Education, Inc.

NPER = Annuity spreadsheet notation for the number of periods or dates of the last cash flow.
RATE = Annuity spreadsheet notation for interest rate.
PV = Present value; annuity spreadsheet notation for the initial amount.
PMT = Annuity spreadsheet notation for cash flow.
FV = Future value.

The 23.38% IRR is larger than the 10% opportunity cost of capital. If it is considered only the IRR rule, this person should undertake the deal. But what does the NPV rule say? (Berk and Demarzo, 2007)

$$NPV = 1{,}000{,}000 - \frac{500{,}000}{1.1} - \frac{500{,}000}{1.1^2} - \frac{500{,}000}{1.1^3} = -\$243{,}426$$

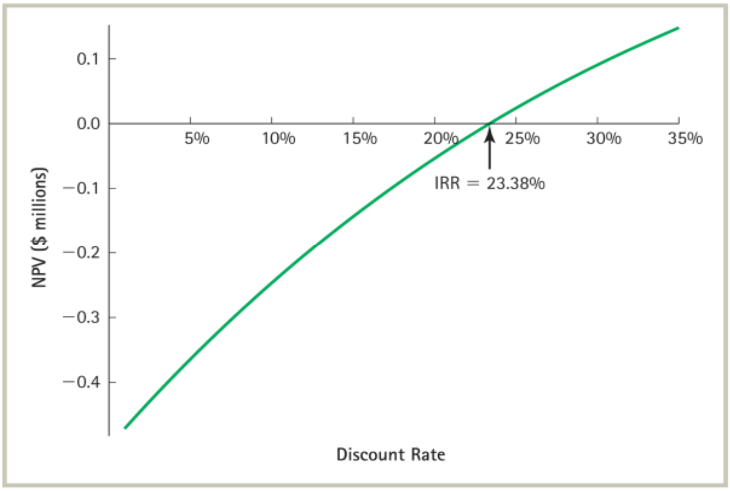
At a 10% discount rate, the NPV is negative, so considering this opportunity would reduce this person's wealth. This person should not sign the book deal (Berk and Demarzo, 2007).

Figure 2 shows the NPV of the investment opportunity. It plots that, no matter what the cost of capital is, the IRR rule and the NPV rule will result in opposition. That is, the NPV is positive only when the opportunity cost of capital is above 23.38% (the IRR). This person should take into account the investment only when the opportunity cost of capital is greater than the IRR, the opposite of what the IRR rule suggests (Berk and Demarzo, 2007).

Figure 2 also illustrates the problem with using the IRR rule in this case. For most investment opportunities, expenses occur initially and cash is received in a later date. On the previous example, this person gets cash upfront and experiences the costs of producing the book later. It is as if this person borrowed money, and when any person borrows money you prefer as low a rate as possible. This person's optimal rule is to borrow money so long as the rate at which he/she borrows is less than the cost of capital.

Even though the IRR rule fails to give the right answer on this particular case, the IRR itself still provides useful information in conjunction with the NPV rule. The IRR gives information on how sensitive the investment decision is to uncertainty in the cost of capital estimate. In this case, the difference between the cost of capital and the IRR is large 13.38%. This person has underestimated the cost of capital by 13.38% to make the NPV positive (Berk and Demarzo, 2007).

Figure 2.NPV of the person's $1 million Book Deal example
When the benefits of an investment occur before the costs, the NPV is an increasing function of the discount rate.



Source: Berk, Jonathan and Demarzo, Peter (2007) 'CORPORATE FINANCE', Pearson International Edition, Pearson Education, Inc.

In Excel the IRR function calculates the internal rate of return for a series of cash flows. This Internal Rate of Return (IRR) value is the interest rate received for an investment consisting of payments (negative values) and income (positive values) that occur at regular periods. Its representation in Excel is as follows:

IRR (values, guess)
Where:
Values= is an array or a reference to cells that contains numbers for which it is intended to calculate the internal rate of return.
Guess= is a number that it is needed to guess and it will be closed to the result of the actual IRR.
In most cases, it is not necessary to provide guess for the IRR calculation. If guess is omitted, it will be assumed to be 0.1 (10 percent) (Predo and James, 2006).
One important quotation is the fact the internal rate of return of any investment project is determined by the following equilibrium condition: at the end of the project, let's say after n periods, the sum of the accumulated values of all the cash flows is zero; in other words, at the end of the project the sum of the accumulated values of all the inflows is balanced numerically by the sum of the accumulated values of all the outflows (Promislow and Spring, 1996).

THE INTEREST RATE: AN EXCHANGE RATE ACROSS TIME

When any individual deposits money into a savings account, money today into money in the future without any risk can be converted. At the same time, when someone borrows money from the bank, exchanging money in the future for money today can be accomplished. The rate at which it is possible to exchange money today for money in the

future is found by the current interest rate. On the same way that an exchange rate allows to convert money from one currency to another, the interest rate allows to convert money from one point in time to another. Practically, an interest rate is like an exchange rate across time. It represents the market price today of money in the future.
As an example, if the current annual interest rate is 7%, by investing or borrowing at this rate, it is possible to exchange $1.07 in one year for each $1 today. The idea of risk-free interest rate, rf, for a certain period, is the interest rate that money can be borrowed or lent without risk over that particular period. It can be exchanged (1+rf) dollars in the future per dollar today, and vice versa, without risk. It is referred (1+rf) as the interest rate factor for risk-free cash flows; it defines the exchange rate across time, and has units of "$ in one year / $ today" (Berk and Demarzo, 2007).

As with other market prices, the risk-free interest rate depends on supply and demand. Certainly, at the risk-free interest rate the supply of savings equals the demand for borrowing. After the risk-free interest is known, it can be used to evaluate other decisions in which costs and benefits are separated in time without knowing the investor's preferences (Berk and Demarzo, 2007).

Interest Rate Quotes and Adjustments

To determine the useful discount rate from an interest rate, it is necessary to understand the ways that interest rates are quoted. Also, because interest rates may be quoted for different time intervals, such as monthly, semiannual, or annual, it is often necessary to determine the interest rate to a time period that fits with the particular cash flows (Berk and Demarzo, 2007).

The Effective Annual Rate

Interest rates are often mentioned as an effective annual rate (EAR), which represents the total amount of interest that will be earned at the end of one year. The effective annual rate is often referred to as the effective annual yield (EAY) or the annual percentage yield (APY). For example, with an EAR of 5%, a $100,000 investment goes to (Berk and Demarzo, 2007)

$$\$100{,}000 * (1+r) = \$100{,}000 * (1.05) = \$105{,}000$$

In one year. After two years it will grow to

$$\$100{,}000 * (1+r)^2 = \$100{,}000 * (1.05))^2 = \$110{,}250$$

Adjusting the Discount Rate to Different Time Periods

The following example explains that earning an effective annual rate of 5% for two years is equivalent to earning 10.25% in total interest over the entire period:

$$\$100{,}000 * (1.05)^2 = \$100{,}000 * 1.1025 = \$110{,}250$$

As a matter of fact, by raising the interest rate factor (1+r) to the appropriate power, the calculation of interest rate for a longer time period can be determined (Berk and Demarzo, 2007).

To calculate the interest rate for periods shorter than one year, the same methodology can be used. On this case, the interest rate factor (1+r) is raised to the appropriate fractional power. For example, earning 5% interest in one year is equivalent to receiving

$$(1+r)^{0.5} = (1.05)^{0.5} = \$1.0247$$

for each $1 invested every six months. That is, a 5% effective annual rate is equivalent to an interest rate of approximately 2.47% earned every six months. This result can be verified by computing the interest possible to be earned in one year by investing for two six-month periods at this rate (Berk and Demarzo, 2007):

$$(1+r)^2 = (1.0247)^2 = \$1.05$$

In general, the discount rate of r can be converted for one period to an equivalent discount rate for n periods using the following formula (Berk and Demarzo, 2007):

$$\text{Equivalent n-Period Discount Rate} = (1+r)^n - 1$$

In this formula, n can be larger than 1 (to compute a rate over more than one period) or smaller than 1 (to compute a rate over a fraction of a period). When calculating present or future values, it is convenient to define the discount rate to match the time period of the cash flows. This adjustment is necessary to apply in the perpetuity or annuity formulas (Berk and Demarzo, 2007).

Annual Percentage Rates

Banks also consider interest rates in terms of an annual percentage rate (APR), which indicates the amount of simple interest earned in one year, that is, the amount of interest earned without the effect of compounding (computing the return on an investment over a long horizon by multiplying the return factors associated with each intervening period), the APR quote is typically less than the actual amount of interest that someone can earn. To compute the actual amount that someone will earn in one year, the APR must first be converted to an effective annual rate.

As an example, let's say that the Pacific Bank informs about savings accounts with an interest rate of "6% APR with monthly compounding." On this particular example, the interested person to acquire such savings account will earn 6% / 12 = 0.5% every month. Then, an APR with monthly compounding is actually a way of quoting a monthly interest rate, rather than an annual interest rate. Because the interest compounds each month, this person will earn

$$\$1 * (1.005)^{12} = \$1.061678$$

at the end of one year, for an effective annual rate of 6.1678% (Berk and Demarzo, 2007). The 6.1678% that this person earns on the deposit is higher than the quoted 6% APR due to compounding: In later months, this person earns interest on the interest paid in earlier months (Berk and Demarzo, 2007).

It is necessary to remember that because the APR does not reflect the true amount someone will earn over one year, the APR itself cannot be used as a discount rate. Instead, the APR with k compounding periods is a way of quoting the actual interest earned each compounding period (Berk and Demarzo, 2007):

$$\text{Interest Rate per Compounding Period} = \frac{APR}{kperiods / year}$$

Once, the interest earned per compounding period have been computed from the previous equation, it is possible to compute the equivalent interest rate for any other time interval using the Equivalent n-Period Discount Rate equation. Thus the effective annual rate corresponding to an APR with k compounding periods per year is given by the following conversion formula (Berk and Demarzo, 2007):

Converting an APR to an EAR

$$1 + EAR = \left(1 + \frac{APR}{k}\right)^k$$

The Determinants of Interest Rates

How are interest rates determined? Basically, interest rates are presented in the market based on individuals' willingness to borrow and lend. Some of the factors that may influence interest rates are: inflation, government policy and expectations of future growth (Berk and Demarzo, 2007).

Inflation and Real versus Nominal Rates

The interest rates that are quoted by banks and other financial institutions are nominal interest rates, which indicate the rate at which the money will grow if invested for a certain period. If prices in the economy are also growing due to inflation, the nominal interest rate does not show the increase in purchasing power that will be obtained from investing. The rate of growth of purchasing power, after adjusting for inflation, is found by the real interest rate, which is denoted by r_r. If *r* is the nominal interest rate and *i* is the rate of inflation, it is possible to calculate the rate of growth of purchasing power as follows (Berk and Demarzo, 2007):

$$\text{Growth in Purchasing Power} = 1 + r_r = \frac{1+r}{1+i} = \frac{Growth of Money}{Growth of\ \mathrm{Pr}ices}$$

Then, if the previous equation is arranged, the following formula can be obtained for the real interest rate, together with a convenient approximation for the real interest rate when inflation rates are low (Berk and Demarzo, 2007):

The Real Interest Rate

$$r_r = \frac{r-i}{1+i} \approx r - i$$

That is, the real interest rate is approximately equal to the nominal interest rate less the rate of inflation (Berk and Demarzo, 2007).

4. DATA

The data required by the present analysis was entirely provided by The Office of Projects & International Cooperation of The Under-secretary of Aquaculture in Ecuador. The spreadsheets are actual summaries of the Rural-Artisanal Aquaculture Project budgets from three specific cultivations: one polyculture Cachama (*Piaractus brachypomus*)-Tilapia (*Oreochromis sp.*), Cachama monoculture and Red claw Crayfish (*Cherax quadricarinatus*) monoculture. The criterion employed to select these three cultivations lies on the idea to diversify the production in the Ecuadorian scenario for Aquaculture. As explained before the Ecuadorian Aquaculture is mainly based in Pacific White Shrimp Culture (*Litopenaeus vannamei*) and Tilapia (*Oreochromis sp.*). The opportunity on this project to intensify the production of these two species considered as non-traditional is an important breakthrough in the industry especially with the conception of small and medium scale production combining Agriculture activities, which allows gaining experience on the technology required for such cultivations to the rural and artisanal level.

Table 6.Economic and technical aspects for Cachama culture (*Piaractus brachypomus*)

Indicators	**Values**
Stocking density (Juveniles/Ha)	10,000
Cost/Juvenile USD	0.05
Total cost juveniles	$ 500[a]
Stocking Area (Ha)	1.00
Survival rate	80%
Final weight gr	600
Kgs/ha/Cachama	4,800[b]
Total Lbs	10,560[c]
Selling price lb/USD	0.6

Source: The Office of Projects & International Cooperation of the Under-secretary of Aquaculture, Guayaquil - Ecuador.
a This value is calculated by the product between stocking density (juveniles/Ha), the individual cost per juvenile and the stocking area.
b This value was found multiplying the stocking density (juveniles/Ha), the stocking area, the survival rate and the final weight in grams divided by 1000, being this last one the conversion factor to Kgs.
c This value is determined by the conversion factor of 2.2 lbs for each Kg.

In table 6, it is shown some economic and technical aspects to be considered at the moment to start in the culture of Cachama (*Piaractus brachypomus*). One of the most important aspects that determine the success of every Aquaculture production is the stocking density, as seen above the stocking density for this species is 10,000 juveniles/Ha, this is taken from previous experience raising this freshwater fish. Because of lack of experience in agriculturists, it is important to seriously rely on this value. The overcrowding in ponds results of reduction in survival rates or high mortality percentage. There are always a top and a bottom in values; it is advisable for producers to consider the optimal stocking density at the moment to start the cultivation. The survival rate must be estimated also depending on previous observations regarding to the production of this species. The unit cost of fingerlings at the moment of stocking was 0.05 USD. This value was considered constant on every further calculation. Taking into account this price per unit of fingerlings, stocking density and the stocking area, the total cost of fingerlings was $ 500 USD. The commercial weight expected for Cachama is 600 gr, with this value, the survival rate, the stocking density, the stocking area and considering the conversion factor into kgs (1 Kg = 1,000 grs), the productivity (Kgs/Ha) of Cachama is determined in 4,800 which represents 10,560 lbs. The market price considered for this species is about 0.60 USD per lb.

Continuing with the description of economic and technical aspects in table 7, it is stated all operational considerations for the polyculture cachama (*Piaractus brachypomus*) and tilapia (*Oreochromis sp.*). On this case, there is not much difference with the previous case of monoculture, being the stocking density 10,000 juveniles/ha on tilapia and a bit increment with the particular case of cachama (12,000 juveniles/Ha) because the main species to obtain revenue with is the latter. The price of juveniles differs 0.02 USD per unit on each particular case of cachama (0.05 USD) and tilapia (0.0300 USD), respectively. Related to the total cost of fingerlings which calculations are similar as the previous case in table 6, these values are 30.00 USD for the case of tilapia and 60.00 USD for cachama. On this particular case, the stocking area is 0.10 Ha and the survival rate similar as on cachama monoculture (80%). The estimated final weight in grams for tilapia is 350 and 550 for cachama. The productivity values for each case varies 248 Kgs/Ha being this one 280 for tilapia and 528 for cachama; like in the previous case the methodology in calculations is standard for every particular case. Using the conversion factor of 2.2 lbs for each Kg, the total lbs at the end for tilapia is 616 lbs and 1,162 lbs in the case of cachama. The market price on this case gives a value added to the original price in table 6 for cachama, being this time 0.90 USD per lb of cachama particularly because of the advantage of polyculture, the increment of the offer in the market and for the secondary species 0.60 USD per lb of tilapia.

For the particular case of Red Claw Crayfish monoculture (*Cherax quadricarinatus*) as shown in table 8, the stocking density increases up to 50,000 larvae/Ha because of its high resistance to overcrowding as well as extreme environmental conditions. The price per piece is 0.01 USD being its total cost 750.00 USD. On this time, the stocking area is 1.50 Ha and the standard survival rate is 80% but this factor is put into evaluation at the moment of sensitivity analysis, challenging the consequences of reducing the survival rate in 73%, 50% an 25.1%, respectively for the income and expenditure values. The reference for this species regarding market size is 40 grams and the total harvesting registered is 3,760 Lbs. The market price imposed by the foreign company Phillips is 0.90 USD per lb. This company is annexed to the project because of its willingness to acquire the production of every small and medium scale farmers.

Table 7.Economic and technical aspects for Polyculture Cachama (*Piaractus brachypomus*) - Tilapia (*Oreochromis sp.*)

Indicators	**Tilapia**	**Cachama**
Stocking density (Juveniles/Ha)	10,000	12,000
Cost/Juvenile USD	0.0300	0.05
Total cost juveniles	$ 30.00[a]	$ 60[a]
Stocking Area (Ha)	0.10	0.10
Survival rate	80%	80%
Final weight gr	350	550
Kgs/ha	280[b]	528[b]
Total Lbs	616[c]	1,162[c]
Selling price lb/USD	$ 0.60	$ 0.90

Source: The Office of Projects & International Cooperation of The Under-secretary of Aquaculture, Guayaquil-Ecuador.
a This value is calculated by the product between stocking density (juveniles/Ha), the individual cost per juvenile and the stocking area.
b This value was found multiplying the stocking density (juveniles/Ha), the stocking area, the survival rate and the final weight in grams divided by 1000, being this last one the conversion factor to Kgs.
c This value is determined by the conversion factor of 2.2 lbs for each Kg.

Table 8.Economic and technical aspects for red claw crayfish (*Cherax quadricarinatus*) culture

Indicators	**Values**
Stocking density (Larvae/Ha)	50,000
Cost/Larvae USD	$ 0.01
Total cost Larvae	$ 750[a]
Stocking Area (Ha)	1.50
Survival rate	80%
Final weight gr	40
Total Lbs	3,760[b]
Selling price lb/USD	$ 0.9

Source: The Office of Projects & International Cooperation of the Under-secretary of Aquaculture, Guayaquil-Ecuador.
a This value is calculated by the product between stocking density (larvae/Ha), the individual cost per larvae and the stocking area.
b This value was taken from an estimation of partial harvesting yield starting from the third month of cycle (320 lbs) plus 640 lbs (fourth month), 800 lbs (fifth month) and 2000 lbs (sixth month) and considering the survival rate on each case independently.

In table 9, the summary of benefit and costs incurred during a year productive cycle of cachama, being the principal benefit, selling activities from farmers. This value is obtained with the multiplication of total lbs 21,120 lbs times the market price per lb of cachama monoculture (0.60 USD); this product registers a value of 12,672 USD. Among cost items, the highest amount corresponds to feeds (4,896 USD) after this pump fuel, transportation/various and labor cost with 1,200 USD each of them. The total cost for fingerlings is 1,000 USD and fertilizer necessary to produce the optimal algae bloom on ponds is 60 USD. The basic salary of labors working in cachama farms is 100 USD monthly with a total 1,200 USD a year. The total cost to produce cachama per year dropped a value of 9,556 USD.

Table 9.Summary of the cachama culture budget over a year production cycle

Indicators	**Values**
Production (Lbs)	21,120
Benefit (Cachama selling)	$ 12,672[a]
Cost Items	
Pump fuel	$ 1,200
Transportation/various	$ 1,200
Cachama fingerlings	$ 1,000
Feeds	$ 4,896
Fertilizer	$ 60
Labor cost	$ 1,200
Total Costs/year	$ 9,556.00

Source: The Office of Projects & International Cooperation of The Under-secretary of Aquaculture, Guayaquil-Ecuador.

a This value is obtained multiplying the price per lbs of Cachama ($ 0.60) with the total production 21,120 lbs.

In table 10, it is summarized the list of benefits and cost items for the polyculture tilapia-cachama over a year. The total harvest for a year period registered for tilapia is 1,232 lbs and for cachama 2,324 lbs. Polyculture has an interesting advantage, the additional income for one extra species in the pond. It is necessary at the same time, to establish the specifications regarding which fish will be the main value to obtain revenues with, this one must be determined before the culture is started. On this project cachama represents the main species, because of the intention of the Ecuadorian government to diversify the production and its attractiveness to customers as well as its fillet yield. Tilapia has already settled an important market in the Ecuadorian Aquaculture business. On this particular culture the market price for cachama increases up to 0.90 USD per lb principally because of the implicit value added for polyculture and in the case of tilapia 0.60 USD, then the revenues are 740 USD for tilapia and 2,090 USD for cachama which totally represents 2,830.00 USD per year. Once again, feeds are on the top of the cost list for this polyculture (872.64 USD) within a year. The pump fuel reaches a value of 120 USD per year. Fuel price in Ecuador has the characteristic to maintain constant prices along the year. Fuel prices are re-evaluated at the beginning of each fiscal year but for the sensitivity analysis fuel prices are kept stable on every case.

The transportation cost on this particular case is lower than the cachama monoculture, mainly because of the proximity to the fish market from the farms. The main objective is to sell the product in local markets and in fresh presentation. The total cost of fingerlings is higher in the case of cachama (120 USD); because it represents the main species in the culture and the stocking density consequently is higher as well. Tilapia total fingerlings cost are in the order of 60 USD per year and finally the fertilizer cost maintained constant like in the previous case with cachama monoculture (60 USD). The total cost though per year in the polyculture cachama-tilapia is 1,472.64. One interesting condition to quote about on this culture is the absence of labor cost, the main reason why is not considered on the list of cost items is because of lack of labor force and this pushes to farmers to hire temporarily especially during the harvesting, workers from neighboring locations and the payment is not representative. In other cases the farmers use the same labor force from their agriculture activities. The availability of laborers in the Ecuadorian country side is a big issue nowadays mainly because of migrations to the big cities with the objective to find a better job or opportunities which most of the time are not guaranteed.

Table 10.Summary of the polyculture cachama-tilapia budget over a year production cycle

Indicators	**Values**
Production (Lbs) Tilapia	1,232
Production (Lbs) Cachama	2,324
Benefit Tilapia	$ 740[a]
Benefit Cachama	$ 2,090[a]
TOTAL BENEFITS	$ 2,830.00
Cost items	
Pump fuel	$ 120
Transportation/various	$ 240
Tilapia fingerlings	$ 60
Cachama fingerlings	$ 120
Feeds	$ 872.64
Fertilizer	$ 60
Total Costs/year	$ 1,472.64

Source: The Office of Projects & International Cooperation of The Under-secretary of Aquaculture, Guayaquil - Ecuador.

a This value is obtained multiplying the price per lbs of tilapia ($ 0.60) and cachama ($0.90) with the corresponding total production.

The summary of benefits and costs for one year production of red claw crayfish (*Cherax quadricarinatus*) are listed in table 11. The productivity presents a value of 7,520 lbs per year which benefits are in the order of 6,768 USD mainly commercialized to the foreign company Phillips. Among cost items the feed cost is the highest like in the previous cases being on this particular culture 1,085.00 USD per year. The cost per sack of feed varies around the year mainly because of raw materials that need to be imported for example additives and ingredients but for purpose of Net Present Value and Internal Rate of Return analysis this cost is maintained constant. The cost of larvae per year is 1,500 USD and the expenditures per year of fuel and transportation/various are 180 USD and 360 USD, respectively. Fertilizer has a cost per year of 60 USD and the labor cost registers a value of 500 USD per year; totally the cost to produce red claw crayfish per year is 3,685 USD.

Table 11.Summary of the red claw crayfish culture budget over a year production cycle

Indicators	**Values**
Production (Lbs)	7,520
Benefit (Crayfish selling)	$ 6,768[a]
Cost Items	
Pump fuel	$ 180
Transportation/various	$ 360
Larvae	$ 1500
Feeds	$ 1,085.00
Fertilizer	$ 60
Labor cost	$ 500
Total Costs/year	$ 3,685

Source: The Office of Projects & International Cooperation of the Under-secretary of Aquaculture, Guayaquil - Ecuador.
a This value is obtained multiplying the price per lb of Crayfish ($ 0.90) times total production.

The summary of initial investment to start in the Cachama monoculture business is listed in table 12. The most important values to be considered on this analysis are the cost of water pump and pond preparation. For the first case is important to mention that this equipment must be in possession of the farmer willing to enter in Aquaculture, principally this is the case because of their main activity Agriculture but for reasons of Net Present Value and Internal Rate of Return, this value is taken into account. The price of the water pump along with the necessary material for installation is 3,000 USD with a useful life of 5 years. The pond preparation which mainly consists of digging process, dikes reinforcement, pendant establishment and harvesting box construction has an initial cost of 3,500 USD with a useful life of 10 years. As part of the equipment for harvesting procedures, the heavy duty harvesting nets represent a total investment of 302.80 USD with a useful life of 5 years. At the same time, the heavy-duty seines have a cost of 726 USD with a useful life of 5 years. As a matter of fact the total investment cost for machinery and equipment for cachama (*Piaractus brachypomus)* culture is 4,028.80 USD; what it is regarded to buildings and general improvements for the facilities, the total value for investment is in the order of 3,700 USD.
Additionally, the salvage value for equipments, the amount of money that the investor recovers by selling the equipment after accomplishing its useful life in years; it is considered to be zero (0) since the equipment is discarded after this period.

Table 12.Summary of Initial Investment costs for cachama culture

Item		useful life(yrs)	Salvage value
MACHINERY & EQUIPMENT	**cost**		
2" in/out Water pump with slip unions	$ 3,000.00	5	0
Heavy-duty Harvesting nets	$ 302.80	5	0
Heavy-duty Seines	$ 726.00	5	0
TOTAL	***$ 4,028.80***		
BUILDING LAND & IMPROVEMENT			
Pond preparation	$ 3,500.00	10	
Post harvest shed	$ 200.00	10	
TOTAL	***$ 3,700.00***		
GRAND TOTAL	**$ 7,728.80**		

In table 13, the summary of initial investment incurred in the polyculture cachama – tilapia, the investment as in the previous case is distributed into machinery and equipment which total investment cost represents the value of 4,078.80 USD, having each equipment a useful life in years of 5, respectively. Among machinery and equipment, the highest value as in the case of monoculture of cachama goes for the 2" in/out Water pump with slip unions, the price is 3,000 USD. For the heavy-duty harvesting nets and heavy-duty seines costs are 302.80 USD and 726 USD, respectively. Additionally as part of the harvesting equipments on this case, the use of post-harvest ice recipients instead of the post-harvesting shed has a cost of 50 USD. The second part of this analysis contents buildings and improvements with a total investment cost of 400 USD, having a 10 years useful life years. There are 2 main fixed costs considered at this point, the pond construction with a cost of 300 USD and pipes and general installations which cost is 100 USD. The grand total for initial investment required to start on this polyculture is estimated in 4,478.80 USD.

As in the previous case, the salvage value on this investment is settled to zero (0), the equipment will be discarded after completing the useful life in years; it is not entitled to be sold.

Table 13.Summary of Initial Investment costs for the Polyculture tilapia-cachama

Item		**useful life(yrs)**	**Salvage value**
MACHINERY & EQUIPMENT	**cost**		
2" in/out Water pump with slip unions	$ 3,000.00	5	0
Heavy-duty Harvesting nets	$ 302.80	5	0
Heavy-duty Seines	$ 726.00	5	0
Post-harvest Ice recipients	$ 50.00	5	
TOTAL	***$ 4,078.80***		
BUILDING LAND & IMPROVEMENT			
Pond construction	$ 300.00	10	
Pipes/installations	$ 100.00	10	
TOTAL	***$ 400.00***		
GRAND TOTAL	**$ 4,478.80**		

On the case of red claw crayfish (*Cherax quadricarinatus*) total investment cost as it is indicated in table 14; this value is 6,391.05 USD including machinery, equipment, buildings and more improvements to the facilities. For the first case of machinery and equipments constituted by pump (the highest investment) with 3,000 USD and 5 years of useful life. Harvesting nets maintain their cost (302.80 USD). One more equipment necessary for harvesting labors is the plastic nest, because of the natural behavior of this species to go to the bottom of the earthen pond and make nests. The total cost to plot nests all around the pond is estimated in 50 USD for a useful life of 5 years, same as the water pump, the harvesting nets and net crayfish traps, being the price of the latter 128.25 USD. For buildings and improvements, the pond preparation registered a value of 1,500 USD with a 10 years useful life. The post-harvest shed has a value of 200 USD and 10 years useful life. The last two values are alternative on this culture but those have been considered for analysis purposes, they are the construction of an artisanal well (1,000 USD) and artisanal aeration tower (210 USD) with 10 and 5 years of useful life, respectively. The artisanal aeration tower is build up from simple materials like river stone and plastic baskets and it is optional for this culture. For cash flow and sensitivity analysis of the rural and artisanal Aquaculture project, the depreciation value is not considered because it does not represent real cash, this value constitutes a yearly deduction the project has to afford from the value of its fixed assets (other than land) over time according to a depreciation schedule that depends on an asset’s life span.
The salvage value is considered to be zero (0); the equipment will be discarded as well; same as in the previous investments.

Table 14.Summary of Initial Investment costs for red claw crayfish culture

Item		**useful life(yrs)**	**Salvage value**
MACHINERY & EQUIPMENT	**cost**		
2" in/out Water pump with slip unions	$ 3,000.00	5	0
Heavy-duty Harvesting nets	$ 302.80	5	0
Plastic nests	$ 50.00	5	0
Net Crayfish traps	$ 128.25	5	
TOTAL	***$ 3,481.05***		
BUILDING LAND & IMPROVEMENT			
Pond preparation	$ 1,500.00	10	
Post-harvest shed	$ 200.00	10	
Artisanal well	$ 1,000.00	10	
Artisanal Aeration Tower	$ 210.00	5	
TOTAL	***$ 2,910.00***		
GRAND TOTAL	**$ 6,391.05**		

In table 15, the inflation rate registered by the Department of Statistics in the Central Bank of Ecuador, the average value counting from the period January 2008 to February 2009 was used to calculate the real discount rate in the analysis of cash flow for every type of culture.

Table 15.Inflation rates registered by the Central Bank of Ecuador corresponding to the period from January 2008 to February 2009

Period	**Inflation rate**
January 2008	4.19%
February 2008	5.10%
March 2008	6.56%
April 2008	8.18%
May 2008	9.29%
June 2008	9.69%
July 2008	9.87%
August 2008	10.02%
September 2008	9.97%
October 2008	9.85%
November 2008	9.13%
December 2008	8.83%
January 2009	8.36%
February 2009	7.85%
Average value	**8.35%***

Source: Central Bank of Ecuador
http://www.bce.fin.ec/resumen_ticker.php?ticker_value=inflacion
*Value of inflation rate used to calculate the value of Real interest rate or real discount rate. This rate is employed because of the fact of using constant prices to determine the cash flow for a 10 years life-time project.

5. RESULTS

For the present study a life span of 10 years has been put into analysis on the three types of culture in the Rural Aquaculture project in Ecuador: monoculture of cachama (*Piaractus brachypomus*), polyculture cachama (*Piaractus brachypomus*) and tilapia (*Oreochromis sp.*) and finally the red claw crayfish (*Cherax quadricarinatus*) monoculture. On each particular case the Net Present Value, Internal Rate of Return and the Benefit-Cost Ratio has been determined, being the basics to complement the study with the sensitivity analysis on particular scenarios to be discussed later on this chapter.

In table 16, the summary of cash flow for the monoculture of cachama (*Piaractus brachypomus*) with a life span of 10 years is showed. As it is expected on period 0, the net benefit presents a negative value because of the initial investment at that time and of course there are no benefits to be counted for. Because of constant prices analysis, a constant benefit value of 12,672 USD at the end of every year is considered. The initial investment for this culture counts a value of 7,728.80 USD, but at the end of the first year to the fifth year the operational costs drop a value of 9,556 USD. Suddenly this value changes on year 6 because of the useful life of equipments and machinery, then at this point replacement is necessary to continue working on the project. The equipments necessary to be replaced are: 2" in/out water pump with slip unions, heavy-duty harvesting nets and heavy-duty seines. At the year of replacement, costs raise up to 13,584.80 USD, being as expected the net benefit -912.80 USD, a negative value for the acquisition, the constant income and the operating cost running for that particular period. From the year 7 to the end of the cash flow analysis benefits and costs return to the original amount, 12,672 USD for benefits and 9,556 USD for costs. For this particular system, the Net Present Value shows an interesting result (10,130.82 USD) which means the project is profitable and combining this result with the actual obtained Internal Rate of Return (35%), the project is feasible. The NPV rule says: every project showing a positive value represents an interesting option for investment plus the high IRR compared to the discount rate, the project is a good option. Later on this chapter, it will be shown the effects of introducing certain scenarios to the current condition and how this affects the results of both NPV and IRR. The benefit cost ratio obtained for this project, which means the ratio of discounted stream of benefits and discounted stream of costs over the lifetime of the project, is 1.14.

As part of the calculations, it must be considered the discount rate. As a result of dealing with constant prices and benefits, the technique demands the use of real interest rate or real discount rate. For this particular interest rate, it must be considered the nominal interest rate or nominal discount rate (interest rate before adjustment for inflation) and the inflation rate in the country, and then the nominal rate (17%) minus the inflation rate in Ecuador (8.35%), the result of this operation (8.65%) represents the real interest or real discount rate used on the analysis.

Table 16.Summary of the cash flow of Cachama Culture for a 10 years life-time project including Net present Value (NPV) and the corresponding Internal Rate of Return (IRR)

Year	Benefit	Cost	Net Benefit	Discount Factor	Present Value
0	0	$ 7,728.80	$ -7,728.80	1	$ -7,728.80
1	$ 12,672.00	$ 9,556.00	$ 3,116.00	0.92	$ 2,867.91
2	$ 12,672.00	$ 9,556.00	$ 3,116.00	0.85	$ 2,639.56
3	$ 12,672.00	$ 9,556.00	$ 3,116.00	0.78	$ 2,429.40
4	$ 12,672.00	$ 9,556.00	$ 3,116.00	0.72	$ 2,235.98
5	$ 12,672.00	$ 9,556.00	$ 3,116.00	0.66	$ 2,057.95
6	$ 12,672.00	$ 13,584.80	$ -912.80	0.61	$ -554.86
7	$ 12,672.00	$ 9,556.00	$ 3,116.00	0.56	$ 1,743.29
8	$ 12,672.00	$ 9,556.00	$ 3,116.00	0.51	$ 1,604.49
9	$ 12,672.00	$ 9,556.00	$ 3,116.00	0.47	$ 1,476.74
10	$ 12,672.00	$ 9,556.00	$ 3,116.00	0.44	$ 1,359.16

NPV=	$ 10,130.82
NPV(excel formula)=	$ 10,130.82
IRR=	35%
PV benefit=	$ 82,589.95
PV cost=	$ 72,459.12
BCR=	1.14

Real Discount Rate = 0.0865[b] Inflation Rate = 0.0835*

Nominal Discount Rate = 0.17[a]

*The inflation rate considered for the present analysis represents the average value registered by The Central Bank of Ecuador from January 2008 to February 2009.

a Nominal interest rate, nominal rate of interest or nominal discount rate is defined as the rate of interest before adjustment for inflation (Berk and Demarzo, 2007).

b The real interest rate is determined approximately with the nominal interest rate minus the inflation rate (Berk and Demarzo, 2007). This value was considered for every calculation to determine the Net Present Value (NPV), Internal Rate of Return (IRR) as well as the sensitivity analysis of the project.

Real interest rate = Nominal interest rate – Inflation rate.

Continuing with the analysis of cash flow for the project, next on the list is table 17 containing the benefit, cost and net benefit values of the polyculture tilapia (*Oreochromis sp.*) – cachama (*Piaractus brachypomus*). For this type of culture the initial investment (4,478.80 USD) is 3,250 USD lower than the previous case with the monoculture of cachama. Starting for the year 1, the cost reduces to 1,472.64 USD and benefits started to be 2,830.08 USD. These benefits come principally from selling the cachama at the end of the cycle. Every year the culture has 2 cycles of 6 months each. This benefit is estimated to be constant from year 1 to year 10, assumption taken for every case. These benefits come principally from selling the cachama at the end of the cycle. Every year the culture has 2 cycles of 6 months each. This benefit is estimated to be constant from year 1 to year 10, assumption taken for every case. Year 6 corresponds to the period of equipment and machinery renewal. Equipments considered to be replaced at that time are: 2" in/out water pump with slip unions, heavy-duty harvesting nets, heavy-duty seines and post-harvest ice recipients because of their useful life-time. Costs raised up to 5,551.44 USD on year 6, taking into account the price of each equipment plus the running operating cost. After this period and starting from year 7 to year 10, costs are considered to be as before (1,472.64 USD). Net benefits necessary to calculate in the Excel worksheet through the formula are from year 1 to 5 1,357.44 USD. On year 6, because of the effect of equipment replacement the net benefit turned out to be negative (-2,721.36 USD), same as in period 0, the net benefit is -4,478.80 USD which represents particularly the initial investment of this culture. From year 7 to year 10 the net benefits are the same 1,357.44 USD. The discount factor for each period was calculated through the formula:

$$Discountrate = \frac{1}{(1+i)^n}$$

Being:

$1 + i$ = interest rate factor; i represents the real interest rate or real discount rate

n = number of period (year); here it is considered period starting from 0 to year 10.

The other way to determine the Net Present Value (NPV) is through the sum of present values showed in table 17. The calculation to determine the present value on each case is:
Present value = Net benefit * Discount factor
As a way to confirm the result from the formula in Excel, it can be summed these present values and the result should be equal to the one obtained through the formula. The net present value on this type of culture ($ 1,888.99 USD) presents a difference of 8,241.83 USD with respect to the previous case but still the value of NPV remains positive and the IRR is 19%, still higher than the actual real interest rate offered for this project. The benefit cost ratio has a value of 1.11.

Table 17.Summary of the cash flow of Polyculture Tilapia-Cachama for a 10 years life-time project including Net present Value (NPV) and the corresponding Internal Rate of Return (IRR)

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Year	Benefit	Cost	Net Benefit	Discount Factor	Present Value
0	0	$ 4,478.80	$ -4,478.80	1	$ -4,478.80
1	$ 2,830.08	$ 1,472.64	$ 1,357.44	0.92	$ 1,249.36
2	$ 2,830.08	$ 1,472.64	$ 1,357.44	0.85	$ 1,149.89
3	$ 2,830.08	$ 1,472.64	$ 1,357.44	0.78	$ 1,058.33
4	$ 2,830.08	$ 1,472.64	$ 1,357.44	0.72	$ 974.07
5	$ 2,830.08	$ 1,472.64	$ 1,357.44	0.66	$ 896.52
6	$ 2,830.08	$ 5,551.44	$ -2,721.36	0.61	$ -1,654.21
7	$ 2,830.08	$ 1,472.64	$ 1,357.44	0.56	$ 759.44
8	$ 2,830.08	$ 1,472.64	$ 1,357.44	0.51	$ 698.97
9	$ 2,830.08	$ 1,472.64	$ 1,357.44	0.47	$ 643.32
10	$ 2,830.08	$ 1,472.64	$ 1,357.44	0.44	$ 592.10

NPV=	$ 1,888.99
NPV(excel formula)=	$ 1,888.99
IRR=	19%
PV benefit=	$18,445.09
PV cost=	$16,556.10
BCR=	1.11

In table 18, the summary of benefits, costs and net benefits from the red claw crayfish culture (*Cherax quadricarinatus*) for a life span of 10 years in the project. On period 0 of this culture the value of -6,391.05 USD corresponds to the initial investment to start the production and on this time there is no benefit at all, furthermore the net benefit is negative -6,391.05 USD and the same amount obtained for the present value. The benefits being constant from period 1 to the end of the project analysis is 6,768 USD and the operating (running) costs from this period up to year 5 is 3,685 USD and net benefit 3,083 USD, respectively. On year 6, the cost raised up to 7,376.05 USD that is related to the period of machinery and equipments required to be replaced for useful life accomplishment. These equipments necessary to be replaced are: 2" in/out water pump with slip unions, heavy-duty harvesting nets, net crayfish traps, plastic nests and artisanal aeration tower, everything with a total acquisition price of 3,691.05 USD, this amount plus the running cost of the project (3,685 USD) totalized the value registered on period 6. After period 6 the operating cost is considered the same to the end of the life span. The NPV value (11,458.80 USD) registered is the highest of the previous two projects and the IRR is 44 % higher as well than the previous cases. The benefit cost ratio registered for red claw crayfish is 1.35. To determine this benefit-cost ratio was necessary to calculate first the present value (PV) of benefits and the present value (PV) of costs, these two values were determined with the formula of Excel to calculate NPV. The benefit-cost ratio represents the relationship between PV of benefits over PV of costs.

Table 18. Summary of the cash flow of red claw crayfish culture for a 10 years life-time project including Net present Value (NPV) and the corresponding Internal Rate of Return (IRR)

Year	Benefit	Cost	Net Benefit	Discount Factor	Present Value
0	0	$ 6,391.05	$ -6,391.05	1	$ -6,391.05
1	$ 6,768.00	$ 3,685.00	$ 3,083.00	0.92	$ 2,837.53
2	$ 6,768.00	$ 3,685.00	$ 3,083.00	0.85	$ 2,611.61
3	$ 6,768.00	$ 3,685.00	$ 3,083.00	0.78	$ 2,403.68
4	$ 6,768.00	$ 3,685.00	$ 3,083.00	0.72	$ 2,212.30
5	$ 6,768.00	$ 3,685.00	$ 3,083.00	0.66	$ 2,036.15
6	$ 6,768.00	$ 7,376.05	$ -608.05	0.61	$ -369.61
7	$ 6,768.00	$ 3,685.00	$ 3,083.00	0.56	$ 1,724.83
8	$ 6,768.00	$ 3,685.00	$ 3,083.00	0.51	$ 1,587.50
9	$ 6,768.00	$ 3,685.00	$ 3,083.00	0.47	$ 1,461.10
10	$ 6,768.00	$ 3,685.00	$ 3,083.00	0.44	$ 1,344.77

NPV=	$	11,458.80
NPV(excel formula)=	$	11,458.80
IRR=		44%
PV benefit=	$	44,110.54
PV cost=	$	32,651.74
BCR=		1.35

For the sensitivity analysis, it was necessary to test many conditions in the investment of the project in order to determine its profitability and how the project goes even with uncertainty scenarios. Basically, the scenarios tested were: the original case or base case as quoted in the tables (no uncertainties), 10% increase in total costs, 10% decrease in total benefits, simultaneously 10% increase in total costs and 10% decrease in total benefits, increase in feed costs, increase in price of fingerlings and larvae, 73% survival rate, 50% survival rate and 25.1% survival rate. These criteria were selected based on the main characteristics governing every productive cycle in Aquaculture, these are: fingerlings cost or larvae cost, price of feed, and the survival rate as well, that ultimately will define the benefits and costs, respectively. Additionally, one extra period was added to the analysis to see whether the project can continue with the actual benefits and it can afford the costs or not, especially regarding to the renewal of equipments, buildings and more facilities. At the same time, the differences on real interest rate or discount rate were tested on this analysis. The results were estimated either with the original rate 8.65% or 13.65% to deal with the uncertainties of the project as well.

In table 19, the sensitivity analysis in the cachama (*Piaractus brachypomus*) monoculture, the Net Present Value (NPV) at 8.65% for real interest rate, decreased 1,851.58 USD with respect to the original amount with a 10 years period in the life span of the project. The NPV was affected principally in the scenarios of uncertainties either with the decrease of 10% in benefits or simultaneously increase of 10% for costs and 10% decrease in benefits, then automatically the NPV turned out to be negative; -488.75

USD and -8,428.58 USD, respectively. On the second point, the survival rate had an influence starting from 50% and the last percentage (25.1%), the NPV suffered the same fate -11,896.76 USD and -28,642.61 USD for each particular case. The highest IRR registered is for the base case with 34 %. At 10% decrease in benefits the IRR reduced to 6%, this is the reason why the NPV came up to be negative (discount rate higher than the IRR). Simultaneously 10% decrease in benefits and 10% increase in costs and with survival rates of 50% and 25.1%, the IRR came to be indefinable. The lowest benefit cost ratio registered at this real discount rate (8.65%) is 0.49 with 25.1% survival rate. With the real discount rate of 13.65%, the highest value of NPV is in the base case like in 8.65%, 5,750.11 USD. Even with 10% increase in the price of fingerlings, the NPV remains positive, 5,196.84 USD. At this rate, the project cannot afford 10% increase in costs, the NPV turned out to be negative (-685.97 USD), the same outcome occurred for a 10% decrease in benefits (-1,260.99 USD) and with simultaneous 10% increase in costs and 10% decrease in benefits (-7,697.07 USD). On the other hand, the side effect in the survival rate had the same result on this rate, reducing the survival rate to 50 % and 25,1%, the NPV is negative; -10,383.38 USD and -23,774.17 USD, respectively. On the case of IRR on this rate, this turned out to be indefinable at simultaneous 10% increase in cost and 10% decrease in benefits, same result with 50% and 25.1% survival rate. The lowest BCR (Benefit Cost Ratio) registered at this rate was 0.48 at 25.1% survival rate.

In table 20, it is plotted out the results from the sensitivity analysis done for the polyculture cachama (*Piaractus brachypomus*) and tilapia (*Oreochromis sp.*). As before, they included an extra year in the life span of the project to seek for results about the possibility to continue further with the project. The NPV for the base case (no uncertainties) and with 8.65% as real discount rate, showed a value of 635.89 USD, which represents the lowest registered compared with the other two types of analyzed cultures. Comparing to the original scenario (only 10 years for life span in the project), the difference is 1,253.10 USD for the NPV. The IRR registered a value of 14% and a BCR of 1.03. The NPV at 13.65% for real discount rate, this variable drastically dropped off to 42.65 USD, the IRR remained the same at 14%. The BCR obtained for the first rate is 1.03 and 1.00 for 13.65%, respectively. In general, the NPV dropped off to 511.35 USD when it is introduced a 10% increase in the fingerlings cost and 32.11 USD for 10% in the feed cost. When it was introduced a 10% increase in costs, 10% decrease in benefits and simultaneously both scenarios, the NPV on each case resulted to be negative, the same happened with the case of survival rate. It is important to mention that this type of culture could not even bear the decrease of 7% in survival rate and the reduction to 50% and 25.1%, all NPVs showed up negative for 8.65% in real interest rate. For the IRR on the cases mentioned previously, this factor could not be determined and at 73% in survival rate the IRR turned out to be zero; the same result was obtained for 13.65% of real interest rate. With the real interest rate of 13.65%, in all uncertainty scenarios, NPVs resulted to be negative and IRR values were indefinable for all the cases except in 10% increase in feed cost (9%), 10% increase in fingerlings cost (13%) and the mentioned before 73% survival rate (0%). The lowest BCR (0.40) at 13.65% of interest rate was registered in the case of 25.1% of survival rate. Practically, calculating these factors through Excel, the major differences for each uncertainty scenarios as well as 8.65% and

13.65% real interest rates are for NPVs and BCR values. The IRRs do not vary in between different scenarios and interest rates with the formula in Excel.

In table 21, the summary of results for the sensitivity analysis in the red claw crayfish (*Cherax quadricarinatus*) monoculture is presented. On this particular activity, the registered NPV (10,130.75 USD) showed an interesting similarity with the case of cachama monoculture in a 10 years life span project (10,130.82 USD). The difference with 8.65% of interest rate and 10 years of life span with the current table is 1,328.05 USD in the NPV. Nevertheless, this culture still shows higher results with a base case (no uncertainties) in comparison with the previous two cultures. With 13.65%, the NPV resulted to be 7,389.42 USD. The IRR for both interest rates in the base case is 44%; this internal rate of return did not have any difference with a 10 years life span project and still the IRR showed to be the highest among the other two previous cases. The BCR for 8.65% interest rate is 1.28 and 1.25 for 13.65%. On the last two scenarios of uncertainty (50% and 25.1% in survival rate), the NPV values turned out to be negative; -7,429.60 USD and -22,004.70 USD, respectively. As a matter of fact, even with these uncertainties scenarios, the project showed to have resistance to changes. The IRRs for these last scenarios were unable to determine and the BCRs registered were 0.40 for 8.65% and 0.39 for 13.65%. The lowest values of NPV obtained for this culture were in the case of simultaneously 10% increase in costs and 10% decrease on benefits, being 1,778.31 USD for 8.65% and 639 USD for 13.65% of interest rate. The IRR for both interest rates registered a value of 17%; the BCR was 1.04 for 8.65% and 1.02 for 13.65% on this uncertainty scenario as well.

Table 19.Sensitivity analysis of the cash flow of cachama culture for a 10 years life-time project including Net present Value (NPV) and the corresponding Internal Rate of Return (IRR)

Year	**Benefit**	**10% decreased in benefits**	**Cost**	**10%increased in costs**	**Base case Net Benefit**	**Net Benefit 1**	**Net Benefit 2**	**Net Benefit 3**
0	0	0	$ 7,728.80	$ 8,501.68	$ -7,728.80	$ -8,501.68	$ -7,728.80	$ -8,501.68
1	$ 12,672.00	$ 11,404.80	$ 9,556.00	$ 10,511.60	$ 3,116.00	$ 2,160.40	$ 1,848.80	$ 893.20
2	$ 12,672.00	$ 11,404.80	$ 9,556.00	$ 10,511.60	$ 3,116.00	$ 2,160.40	$ 1,848.80	$ 893.20
3	$ 12,672.00	$ 11,404.80	$ 9,556.00	$ 10,511.60	$ 3,116.00	$ 2,160.40	$ 1,848.80	$ 893.20
4	$ 12,672.00	$ 11,404.80	$ 9,556.00	$ 10,511.60	$ 3,116.00	$ 2,160.40	$ 1,848.80	$ 893.20
5	$ 12,672.00	$ 11,404.80	$ 9,556.00	$ 10,511.60	$ 3,116.00	$ 2,160.40	$ 1,848.80	$ 893.20
6	$ 12,672.00	$ 11,404.80	$ 13,584.80	$ 14,943.28	$ -912.80	$ -2,271.28	$ -2,180.00	$ -3,538.48
7	$ 12,672.00	$ 11,404.80	$ 9,556.00	$ 10,511.60	$ 3,116.00	$ 2,160.40	$ 1,848.80	$ 893.20
8	$ 12,672.00	$ 11,404.80	$ 9,556.00	$ 10,511.60	$ 3,116.00	$ 2,160.40	$ 1,848.80	$ 893.20
9	$ 12,672.00	$ 11,404.80	$ 9,556.00	$ 10,511.60	$ 3,116.00	$ 2,160.40	$ 1,848.80	$ 893.20
10	$ 12,672.00	$ 11,404.80	$ 9,556.00	$ 10,511.60	$ 3,116.00	$ 2,160.40	$ 1,848.80	$ 893.20
11	$ 12,672.00	$ 11,404.80	$ 17,284.80	$ 19,013.28	$ -4,612.80	$ -6,341.28	$ -5,880.00	$ -7,608.48

	Real Discount Rates	**0.0865**	**0.1365***
NPV=		$ 8,278.97	
NPV(excel formula)=		$ 8,278.97	$ 5,750.11
IRR=		34%	34%
PV benefit=		$ 87,677.24	$ 70,110.96
PV cost=		$ 79,398.27	$ 64,360.85
BCR=		1.10	1.09

	Real Discount Rates	0.0865	0.1365*
PV benefits1=		$ 87,677.24	$ 70,110.96
PV cost1=		$ 87,338.09	$ 70,796.93
BCR1=		1.00	0.99
PVbenefits2=		$ 78,909.51	$ 63,099.86
PV costs2=		$ 79,398.27	$ 64,360.85
BCR2=		0.99	0.98
PVbenefits3=		$ 78,909.51	$ 63,099.86
PV costs3=		$ 87,338.09	$ 70,796.93
BCR3=		0.90	0.89

Summary results of Sensitivity Analysis

Scenario	0.0865 *NPV*	0.0865 *IRR*	0.0865 *BCR*	0.1365* *NPV*	0.1365* *IRR*	0.1365* *BCR*
1) Base case	$ 8,278.97	34%	1.10	$ 5,750.11	34%	1.09
2) 10% increase in total costs	$ 339.15	10%	1.00	$ -685.97	10%	0.99
3) 10% decrease in total benefits	$ -488.75	6%	0.99	$ -1,260.99	6%	0.98
4) Simultaneous 10% increase in total costs and 10% decrease in total benefits	$ -8,428.58	Indefinable	0.90	$ -7,697.07	Indefinable	0.89
5) 10% increase on feed costs	$ 4,891.44	26%	1.06	$ 3,041.28	26%	1.05
6) 10% increase in fingerlings cost	$ 7,587.08	33%	1.09	$ 5,196.84	33%	1.08
7) 73% survival rate	$ 3,571.30	22%	1.05	$ 1,985.63	22%	1.03
8) 50% survival rate	$ -11,896.76	Indefinable	0.82	$ -10,383.38	Indefinable	0.81
9) 25.1% survival rate	$ -28,642.61	Indefinable	0.49	$ -23,774.17	Indefinable	0.48

* In case of uncertainties, for the sensitivity analysis 5% more is added to the original real interest rate (0.0865) to determine the effect behind this increment being the value of this new real interest rate 0.1365.

Table 20.Sensitivity analysis of the cash flow of Polyculture tilapia-cachama for a 10 years life-time project including Net present Value (NPV) and the corresponding Internal Rate of Return (IRR)

Year	Benefit	10% decreased in benefits	Cost	10%increased in costs	Base case Net Benefit	Net Benefit 1	Net Benefit 2	Net Benefit 3
0	0	0	$ 4,478.80	$ 4,926.68	$ -4,478.80	$ -4,926.68	$ -4,478.80	$ -4,926.68
1	$ 2,830.08	$ 2,547.07	$ 1,472.64	$ 1,619.90	$ 1,357.44	$ 1,210.18	$ 1,074.43	$ 927.17
2	$ 2,830.08	$ 2,547.07	$ 1,472.64	$ 1,619.90	$ 1,357.44	$ 1,210.18	$ 1,074.43	$ 927.17
3	$ 2,830.08	$ 2,547.07	$ 1,472.64	$ 1,619.90	$ 1,357.44	$ 1,210.18	$ 1,074.43	$ 927.17
4	$ 2,830.08	$ 2,547.07	$ 1,472.64	$ 1,619.90	$ 1,357.44	$ 1,210.18	$ 1,074.43	$ 927.17
5	$ 2,830.08	$ 2,547.07	$ 1,472.64	$ 1,619.90	$ 1,357.44	$ 1,210.18	$ 1,074.43	$ 927.17
6	$ 2,830.08	$ 2,547.07	$ 5,551.44	$ 6,106.58	$ -2,721.36	$ -3,276.50	$ -3,004.37	$ -3,559.51
7	$ 2,830.08	$ 2,547.07	$ 1,472.64	$ 1,619.90	$ 1,357.44	$ 1,210.18	$ 1,074.43	$ 927.17
8	$ 2,830.08	$ 2,547.07	$ 1,472.64	$ 1,619.90	$ 1,357.44	$ 1,210.18	$ 1,074.43	$ 927.17
9	$ 2,830.08	$ 2,547.07	$ 1,472.64	$ 1,619.90	$ 1,357.44	$ 1,210.18	$ 1,074.43	$ 927.17
10	$ 2,830.08	$ 2,547.07	$ 1,472.64	$ 1,619.90	$ 1,357.44	$ 1,210.18	$ 1,074.43	$ 927.17
11	$ 2,830.08	$ 2,547.07	$ 5,951.44	$ 6,546.58	$ -3,121.36	$ -3,716.50	$ -3,404.37	$ -3,999.51

Real Discount Rates	**0.0865**	**0.1365**
NPV=	$ 635.89	
NPV(excel formula)=	$ 635.89	$ 42.65
IRR=	14%	14%
PV benefit=	$ 19,581.25	$ 15,658.11
PV cost=	$ 18,945.36	$ 15,615.46
BCR=	1.03	1.00
PV benefits1=	$19,581.25	$15,658.11
PV cost1=	$20,839.89	$17,177.01
BCR1=	0.94	0.91

Real Discount Rates	0.0865	0.1365
PVbenefits2=	$17,623.12	$14,092.30
PV costs2=	$18,945.36	$15,615.46
BCR2=	0.93	0.90
PVbenefits3=	$17,623.12	$14,092.30
PV costs3=	$20,839.89	$17,177.01
BCR3=	0.85	0.82

Summary results of sensitivity analysis

	0.0865			0.1365		
Scenario	*NPV*	*IRR*	*BCR*	*NPV*	*IRR*	*BCR*
1) Base case	$ 635.89	14%	1.03	$ 42.65	14%	1.00
2) 10% increase in total costs	$ -1,258.64	Indefinable	0.94	$ -1,518.90	Indefinable	0.91
3) 10% decrease in total benefits	$ -1,322.23	Indefinable	0.93	$ -1,523.16	Indefinable	0.90
4) Simultaneous 10% increase in total costs and 10% decrease in total benefits	$ -3,216.77	Indefinable	0.85	$ -3,084.71	Indefinable	0.82
5) 10% increase in feed costs	$32.11	9%	0.97	$ -440.16	9%	0.93
6) 10% increase in fingerlings cost	$511.35	13%	1.03	$ -56.94	13%	1.00
7) 73% survival rate	$ -549.16	0%	0.97	$ -904.98	0%	0.94
8) 50% survival rate	$ -4,442.91	Indefinable	0.73	$ -4,018.61	Indefinable	0.71
9) 25.1% survival rate	$ -8,658.32	Indefinable	0.42	$ -7,389.45	Indefinable	0.40

Table 21.Sensitivity analysis of the cash flow of Red Claw Crayfish culture for a 10 years life-time project including Net present Value (NPV) and the corresponding Internal Rate of Return (IRR)

Year	**Benefit**	**10% decreased in benefits**	**Cost**	**10%increased in costs**	**Base case Net Benefit**	**Net Benefit 1**	**Net Benefit 2**	**Net Benefit 3**
0	0	0	$ 6,391.05	$ 7,030.16	$ -6,391.05	$ -7,030.16	$ -6,391.05	$ -7,030.16
1	$ 6,768.00	$ 6,091.20	$ 3,685.00	$ 4,053.50	$ 3,083.00	$ 2,714.50	$ 2,406.20	$ 2,037.70
2	$ 6,768.00	$ 6,091.20	$ 3,685.00	$ 4,053.50	$ 3,083.00	$ 2,714.50	$ 2,406.20	$ 2,037.70
3	$ 6,768.00	$ 6,091.20	$ 3,685.00	$ 4,053.50	$ 3,083.00	$ 2,714.50	$ 2,406.20	$ 2,037.70
4	$ 6,768.00	$ 6,091.20	$ 3,685.00	$ 4,053.50	$ 3,083.00	$ 2,714.50	$ 2,406.20	$ 2,037.70
5	$ 6,768.00	$ 6,091.20	$ 3,685.00	$ 4,053.50	$ 3,083.00	$ 2,714.50	$ 2,406.20	$ 2,037.70
6	$ 6,768.00	$ 6,091.20	$ 7,376.05	$ 8,113.66	$ -608.05	$ -1,345.66	$ -1,284.85	$ -2,022.46
7	$ 6,768.00	$ 6,091.20	$ 3,685.00	$ 4,053.50	$ 3,083.00	$ 2,714.50	$ 2,406.20	$ 2,037.70
8	$ 6,768.00	$ 6,091.20	$ 3,685.00	$ 4,053.50	$ 3,083.00	$ 2,714.50	$ 2,406.20	$ 2,037.70
9	$ 6,768.00	$ 6,091.20	$ 3,685.00	$ 4,053.50	$ 3,083.00	$ 2,714.50	$ 2,406.20	$ 2,037.70
10	$ 6,768.00	$ 6,091.20	$ 3,685.00	$ 4,053.50	$ 3,083.00	$ 2,714.50	$ 2,406.20	$ 2,037.70
11	$ 6,768.00	$ 6,091.20	$ 10,076.05	$11,083.66	$ -3,308.05	$ -4,315.66	$ -3,984.85	$ -4,992.46

	Real interest rates	**0.0865**	**0.1365**
NPV=	$	10,130.75	
NPV(excel formula)=	$	10,130.75	$ 7,389.42
IRR=		44%	44%
PV benefit=	$	46,827.62	$ 37,445.62
PV cost=	$	36,696.86	$ 30,056.21
BCR=		1.28	1.25
PV benefits1=	$	46,827.62	$ 37,445.62
PV cost1=	$	40,366.55	$ 33,061.83
BCR1=		1.16	1.13

Real interest rates		0.0865	0.1365
PVbenefits2=	$	42,144.85	$ 33,701.06
PV costs2=	$	36,696.86	$ 30,056.21
BCR2=		1.15	1.12
PVbenefits3=	$	42,144.85	$ 33,701.06
PV costs3=	$	40,366.55	$ 33,061.83
BCR3=		1.04	1.02

Summary results of sensitivity analysis

	0.0865			0.1365		
Scenario	*NPV*	*IRR*	*BCR*	*NPV*	*IRR*	*BCR*
1) Base case	$ 10,130.75	44%	1.28	$ 7,389.42	44%	1.25
2) 10% increase in total costs	$ 6,461.07	32%	1.16	$ 4,383.79	32%	1.13
3) 10% decrease in total benefits	$ 5,447.99	30%	1.15	$ 3,644.85	30%	1.12
4) Simultaneous 10% increase in total costs and 10% decrease in total benefits	$ 1,778.31	17%	1.04	$ 639	17%	1.02
5) 10% increase in feed costs	$ 9,380.04	42%	1.22	$ 6,789.11	42%	1.18
6) 10% increase in larvae cost	$ 9,092.91	41%	1.24	$ 6,559.50	41%	1.21
7) 73% survival rate	$ 6,033.34	32%	1.16	$ 4,112.92	32%	1.14
8) 50% survival rate	$ -7,429.60	Indefinable	0.80	$ -6,652.69	Indefinable	0.78
9) 25.1 survival rate	$ -22,004.70	Indefinable	0.40	$ -18,307.64	Indefinable	0.39

6. DISCUSSION AND CONCLUSIONS

DISCUSSION

The Project of Rural and Artisanal Aquaculture offers great opportunities and challenges to the sector. But these opportunities demand at the same time some requirements, firstly the active participation and support from the Government to finance and maintain extension programs that complement the background and award the effort of agriculturist. Secondly, to encourage small and medium scale producers in the Agriculture sector to take part in the Aquaculture business.

The inexperience in Aquaculture activities may threaten the interest of Agriculturists to enter the business. Fortunately, the Ecuadorian Under-secretary of Aquaculture has started training programs and workshops all over the country to salvage the inability to produce aquatic animals. These training programs include general approaches to aquatic animal health, nutrition, engineering aspects like dikes construction, equipments and facility installations and technical matters such as monitoring and harvesting techniques. The group entering to these training programs is adequately oriented and evaluated as well. The training programs include the possibility to prepare them as facilitators in extension programs. The original idea of the project was to prepare certain amount of clients and then these clients will be on charge to act as facilitator to spread out the information all over the community they belong to; in this way, the continuity of the project and the creation of Rural Aqua culturist Cooperatives are granted.

Nevertheless, there are some issues that must be addressed in order to avoid certain delays on the project. These particular issues include: trustful fingerlings and larvae supply with prices that can fit with the available budget of the farmers to culture the target species; cachama (*Piaractus brachypomus*), red claw crayfish (*Cherax quadricarinatus*) and tilapia (*Oreochromis sp.*). It is necessary the establishment of some entity to support activities such as a breeding stations for constant fingerling and larvae provision, it means a rural Aquaculture program that provides of this and other supplies for the development of this activity, under jurisdiction of The Under-secretary of Aquaculture acting as an Office of Artisanal Aquaculture.

One important aspect also to be considered is the marketing activity. Even though there is an actual buyer for the production of red claw crayfish (*Cherax quadricarinatus*), but also there is a necessity to introduce this product to the local market, as a way to enhance the channel of distribution and to create the culture of consumption of this exotic variety of aquatic animal, first around the community where the farm is located in and later on in important supermarkets all over Ecuador.

Other major obstacles that the project must afford can be summarized as follows: adequate weather conditions allowing pond construction. In Ecuador, there are two seasons around the year: dried season, starting from June to October and rainy season, from November to May. Also, there is the influence from “El Nino” current on weather conditions which enhances the rainy period and it can cause major flooding in the coastal area where the farms are mostly located. These flooding conditions can severely cause delays on pond construction because of lacking proper ways of communication among farmer villages and communities; the mood and water coming from the river make it difficult to proceed and conclude with the schedule. This is the reason why the Government should be aware of this situation at the moment of making arrangements and preparing the machinery to start working on the farm lands, principally for the money that must the be invested per hour on these machines, labor cost and proper preparation of ponds to resist the weather conditions.

The commercialization network must be entitled to promote and facilitate the marketing aspects of products from rural farms but the main idea is to offer a good quality product with right prices to enter the competition and smoothly gaining terrain in the Ecuadorian market aside to high preferences aquaculture offers such as tilapia (*Oreochromis sp.*) and pacific white shrimp (*Litopenaeus vannamei*). This competition could be tough for the entrance of some new products specifically the case of cachama (*Piaractus brachypomus*) and red claw crayfish (*Cherax quadricarinatus*) but proper advertisement campaigns can salvage these conditions and grant the interest and acceptance of the product from the general public. Later on the business, the product can enter in process of quality assurance to expand both target groups and the industry as well, transforming what in the beginning was focused to small and medium scale production to become a large and solid industry in the future, creating new sources of employment for the poor people in the country.

Some of the risks involved with the project and important to mention on this discussion are the following: lack of control on investment destination and surveillance of the operational phase. Even the farmers are free to make their own investments through financial aids from the government but at the same time, the interest of the Ministry of Agriculture is to promote this Rural Aquaculture activity among the farmers. It is important to salvage the funds to this activity in particular, especially at the moment to evaluate if the particular farmer is subject to credit otherwise there are many people seeking for the same aid and that they might use wisely the money the government can grant to them. The Department of Credit in the National Development Bank should strictly supervise the final destination of this money and to program periodic visits to the farmers to evaluate the performance and improvement among them.

As any activity, always the first time represents the pilot test. On this prior evaluation, some outcomes could be a bit discouraging and some performance from extension programs could show up poor efficiency among evaluators. Even so, the project should be prepared for such outcomes through the proper evaluation and training system, helping Agriculturist to survive and progress on their activities. The organization of workshops must be focused on specific topics necessary to start into the business, such as General fish and crustacean Pathology aspects, Nutrition, Aquaculture Principles, Fundamentals in Aquatic Engineering and Marketing could be some of those topics required for the farmer to handle the production and this information can possibly be deepened in the future.

Another risk involves with the project is regarded to the funds from the National Development Bank to small and medium scale farmers, applying to financial aid from the government even being perfectly subject of credits. These funds are available and the delivery of such funds is in function of execution of the project. Any delay in the schedule and execution of any activity in the project can obstruct the delivery of funds to beneficiaries. Supervision and corrective actions must be established in such situation of delay in execution of any work to avoid any possible blockage on delivering the funds from the government or even worse the total cancellation of aids for lack of responsibility from farmers in their acquired obligations.

Finally, the production of red claw crayfish shows to be promissory but at the same time there are several aspects to be considered in between. Some of these aspects and that might highly influence the participation from farmers is the fact Ecuador has already attempted to produce this species unsuccessfully in 1990. Starting from this point, farmers should be extremely careful on those aspects failing before to find the remedy, to obtain perfect adaptation from animals to the conditions in the culture and gain confidence on every stage in the productive cycle. The technological capacity of every farm adapted to produce this aquatic animal can be also a very stressful point of view but experiences from other developing countries in Rural Aquaculture such as Bangladesh, Vietnam and Thailand with similar or even less investment and highly success on their cycles can inject trust among farmers.

CONCLUSIONS

NET PRESENT VALUE

The production of red claw crayfish (*Cherax quadricarinatus*) showed the most outstanding Net Present Value (NPV) of 11,458.80 USD at 8.65% real interest rate. Nevertheless, some technological aspects should be considered at the moment of taking into account the project's viability.
Second on the list, the cachama (*Piaractus brachypomus*) monoculture obtained 10,130.82 USD in NPV at the same 8.65% real interest rate; 1, 327.98 USD difference with the previous case. However, the results might differ but the same technical considerations and even labor demand should be observed at the moment to determine the profitability of this culture, since the labor and technical aspects might be lower than the previous case with crayfish.
The third place in order of feasibility goes for the polyculture cachama (*Piaractus brachypomus*) and tilapia (*Oreochromis sp.*) with 1,888.99 USD and 8.65% real interest rate. Also, this NPV represents the lowest amount between the previous cachama and crayfish monocultures. As an extra analysis to this case, labor cost was deliberately included in the cost analysis and the result was a straight up negative NPV. It is clear that this type of culture must be considered only as an optional activity for medium scale farmers who already succeeded on previous trials and those who are simultaneously running monocultures in the same land. In this way, they can utilize the same labor force in the polyculture. Related to feeds, they have to be prepared by the farmers in order to not rely on artificial diets.

INTERNAL RATE OF RETURN

According to the internal rate of return, the highest value observed in the results goes for the red claw crayfish (*Cherax quadricarinatus*) culture with 44%. Comparing this result with the current real interest rate (8.65%) in the investment at 10 years life span project, this type of culture represents a profitable activity. Even, combining the result of NPV (11,458.80 USD) discussed earlier, the project remains feasible to be invested in.

The freshwater fish cachama (*Piaractus brachypomus*) culture got an IRR (Internal Rate of Return) of 35% following very closely with 9% difference to the previous case of crayfish (*Cherax quadricarinatus*). Still, this activity is profitable if it is compared the IRR with the interest rate (8.65%) of the investment, since the IRR exceeds the opportunity cost of capital and even including the analysis of NPV (10,130.82 USD), the project maintains its feasibility on investment.

The polyculture cachama (*Piaractus brachypomus*) and tilapia (*Oreochromis sp.*); the IRR result was 19% which represents the lowest Internal Rate of Return in relation with the previous two cases; even so this project's IRR has a 10.35% difference with the opportunity cost of capital. The NPV (1,888.99 USD) was positive for this project as well. It is necessary to make some adjustments especially on those higher values in operating costs for example feeds, being the most representative in the project. The encouragement and training for the utilization of agricultural byproducts seems to be an alternative to save money on this variable.

SENSITIVITY ANALYSIS

Adding an extra year in the life span of the project to the first case of crayfish monoculture, the NPV dropped to 10,130.75 USD, similar to the original case of cachama monoculture (10,130.82 USD). The IRR remains the same 44% as the original case with 10 years life span in the project. The Benefit-cost-ratio (BCR) the ratio of discounted stream of benefits and discounted stream of costs over the lifetime of the project, showed a value of 1.28.

The same project was tested with 13.65% increase in real interest rate to deal with uncertainties, the NPV value depleted to 7,389.42 USD and the BCR reduced to 1.25, respectively.

At the same time the sensitivity analysis counted with some scenarios to prove the possible liability of the project under certain circumstances either 8.65% or 13.65% real interest rate. The first scenario tested; 10% increase in total costs at 8.65% interest rate, showed a NPV of 6,461.07 USD and the IRR reduced to 32% (for both interest rates) and the BCR to 1.16. The same condition with 13.65% in real interest rate resulted in a NPV of 4,383.79 USD and BCR of 1.13. Up to this level, still both NPV and IRR showed positive results under this particular scenario.

At 10% decrease in benefits the NPV, IRR and BCR at 8.65% of interest rate showed the following values: 5,447.99 USD, 30% (also for 13.65%) and 1.15, respectively. At 13.65% the value of NPV reduced to 3,644.85 USD and the BCR to 1.12. Simultaneously, forcing the project to an imminent 10% increase and 10% decrease in costs and benefits, respectively; the NPV drastically dropped to 1,778.31 USD and the IRR to 17% (both 8.65% and 13.65% real interest rate) and BCR to 1.04. At 13.65%, the result of NPV was much lower; 639 USD, practically the project value in terms of cash today reduced significantly and the BCR turned out to be 1.02.

Between 10% increase in feed and larvae costs, the NPV, IRR and BCR did not show a representative difference on each particular case and both interest rates, being those 9,380.04 USD, 42% and 1.22 for the case of 8.65% interest rate and 6,789.11 USD, 42% and 1.18 for the case of 13.65% in the sudden 10% increase in feed costs. For larvae costs the NPV resulted to be 9,092.91 USD, the IRR was 41% and BCR was 1.24 on the original interest rate (8.65%) and 6,559.50 USD, 41% and 1.21 for 13.65% on interest rate on NPV, IRR and BCR, respectively.

Testing one of the most important parameters on the field which is survival rate and actually this latter determines total benefits for the project, at 73% survival rate and 8.65% interest rate the values for NPV, IRR and BCR were 6,033.34 USD, 32% and 1.16, respectively. The same percentage in survival rate but at 13.65%, NPV, IRR and BCR turned out to be as follows 4,112.92 USD, 32% and 1.14, respectively being IRR the only constant value.

At 50% survival rate and 8.65%, immediately the result of NPV became negative; -7,429.60 USD, which means the project turned to be not profitable and the IRR could not be identified and it was considered as indefinable, because of the small percentage gotten from excel formula and practically being this one the reason why the NPV turned negative; it means the cost of capital is higher than the IRR. The BCR turned out to be

0.80. At 13.65%, the NPV turned out to be negative as well; -6,652.69 USD, the IRR maintained its characteristic of being indefinable and the BCR became 0.78.
Finally, the final rate tested was at 25.1% survival rate. At this rate, the NPV kept negative, -22,004.70 USD, the IRR was indefinable and the BCR was 0.40 for the interest rate of 8.65%. At 13.65%, the resulted NPV was -18,307.64 USD; the IRR was indefinable on this rate as well, and the BCR showed a value of 0.39.
The same considerations were taken individually for the other two cases and those will be mentioned as follows;

For the second project in matter, the monoculture of cachama (*Piaractus brachypomus*) with one extra year in life span, the NPV turned out to be 8,278.97 USD with 8.65% of real interest rate and the IRR was 34% (basically the same value and procedure to calculate this factor with 13.65% real interest rate) and the BCR turned out to be 1.10. For the same base case scenario at 13.65% of real interest rate, the NPV (5,750.11 USD) varied 2,528.86 USD and the BCR reduced to 1.09.
At 10% increase in costs, the NPV turned out to be 339.15 USD and the IRR became 10% (both interest rates) and the BCR resulted to be 1.00. It is very noticeable the representative reduction on NPV from 8,278.97 USD to 339.15 USD, counted to be 4.09% less at 8.65% real interest rate. At 13.65% the NPV became negative obtaining -685.97 USD; the actual project cannot bear this increase in the order of 10% in costs at this rate and the BCR resulted to be 0.99, respectively.
At 10% decrease in benefits with 8.65% in real interest rate, the NPV had not changed at all on its negative result, being this one -488.75 USD with 6% IRR (also with 13.65%) and 0.99 in BCR. At 13.65%, the NPV became -1,260.99 USD and the BCR turned out to be 0.98.
Simultaneously 10% increase in costs and 10% decrease in benefits, the NPV on the original interest rate (8.65%) was -8,428.58 USD and the IRR on both interest rates turned out to be indefinable and the BCR became 0.90. With the 13.65% real interest rate the NPV resulted to be -7,697.07 USD and the BCR was registered as 0.89.
Analyzing then, sudden variations on the cost of both feeds and fingerlings, the NPV for the first interest rate (8.65%) became 4,891.44 USD and the IRR came to be 26% (both interest rates) and the BCR resulted to be 1.06, at 10% increase on feeds. The same condition but this time at 13.65%; the NPV came to be 3,041.28 USD and the BCR became 1.05, At 8.65% interest rate and 10% increase in fingerlings cost the NPV became 7,587.08; the IRR was 33% and BCR turned out to be 1.09. At 13.65% the NPV reduced to 5,196.84 USD and the BCR came to be 1.08. This increase condition in fingerlings cost had not significant effect with the original NPV value (8,278.97 USD) at 8.65%.
Taking into account the survival rate at 73, 50 and 25.1 %, respectively either with 8.65% or 13.65% real interest rates, the results for NPV, IRR and BCR on this order resulted to be: 3,571.30 USD, 22% and 1.05 with the first interest rate and 1,985.63 USD, 22% and 1.03 at 13.65% interest rate. The NPV became negative at 50% survival rate being this one -11,896.76 USD, the IRR turned out to be indefinable and the BCR was 0.82, at 8.65% real interest rate. At 13.65% interest rate the NPV continued to be negative; -10,383.38 USD, the IRR maintained its condition of indefinable and the BCR turned out to be 0.81. With 25.1% survival rate at 8.65% the NPV was -28,642.61 USD, the IRR was indefinable and the BCR resulted to be 0.49. At 13.5 % interest rate on this survival rate the NPV resulted to be -23,774.17, the IRR was indefinable and the BCR resulted to

be 0.48. This production can bear the reduction to 73% survival rate but only at 8.65% interest rate, if the interest rate goes up to 13.65% this activity became unprofitable.

Finally with the polyculture cachama (*Piaractus brachypomus*) and tilapia (*Oreochromis sp.*) and one extra year in the life span of the project, the base case scenario and considering only variation on interest rates, the NPV reduced to 635.89 USD, being 1,253.10 USD less than the original value (1,888.99 USD) with 10 years life span. The IRR was 14% and the BCR resulted to be 1.03, all these values at the interest rate of 8.65%. The same case but at 13.65% the NPV came to be 42.65 USD, and the BCR was 1.00. This NPV value represents the lowest on this sensitivity analysis.
At 10% increase in costs and 8.65% interest rate the NPV immediately turned out to be negative, being this value -1,258.64 USD, the IRR became indefinable and the BCR was 0.94. At 13.65% with the same condition in the analysis, the NPV value resulted to be -1,518.90 USD, the IRR remained indefinable and the BCR turned out to be 0.91.
At 10% decrease in benefits and 8.65% real interest rate, the NPV was -1,322.23 USD and the IRR came to be indefinable with 0.93 of BCR. The same condition but this time at 13.65%, the NPV value became -1,523.16 USD, still IRR being indefinable and the BCR was registered with 0.90 in value.
Simultaneously 10% increase in total costs and 10% decrease in benefits with the first interest rate, the NPV value was -3,216.77 USD, the IRR was indefinable and the BCR turned out to be 0.85. At 13.65% and the same condition in the analysis; the NPV became -3,084.71 USD, the IRR remained indefinable and the BCR registered a value of 0.82, respectively.
Now analyzing sudden changes (10% increase) on critical variables such as feed cost and fingerlings cost, the sensitivity analysis showed in the first interest rate (8.65%) a NPV value of 32.11 USD, IRR of 9% and a BCR of 0.97. At 13.65%, the NPV resulted to be -440.16 USD, the IRR 9% and 0.93 as BCR value, all these results counted to be in the case of feed costs. For the case of 10% increase in fingerlings cost and 8.65% real interest rate, the NPV, IRR and BCR resulted to be 511.35 USD, 13% and 1.03, respectively. At 13.65% interest rate, the NPV, IRR and BCR on that order were $ -56.94, 13% and 1.00.
Taking into account the final and one important scenario, especially what it is related to benefits or revenues from the activity; the survival rate at 73, 50 and 25.1% were analyzed, as well resulting to be as follows: the NPV at 73% survival rate and 8.65% interest rate was -549.16 USD, the IRR became 0% and the BCR turned out to be 0.97. At 13.65% the NPV, IRR and BCR with the same survival rate were on that order -904.98 USD, 0% and 0.94, respectively. At 50% survival rate and 8.65%, the NPV was-4,442.91 USD, IRR came to be indefinable and the BCR became 0.73. At the same survival rate but with variation in the interest rate (13.65%), the NPV was -4,018.61, the IRR registered the condition of indefinable and the BCR was 0.71. At 25.1% survival rate and 8.65% real interest rate, the NPV, IRR and BCR were in that order -8,658.32, indefinable and 0.42, respectively. At 13.65% real interest rate and maintaining the same survival rate (25.1%) the values of NPV, IRR and BCR on that order were registered as: -7,389.45 USD, indefinable and 0.40. These results allow defining this part of the project as extremely sensitive to tough conditions in the ongoing business and they might cause a disruption lately in the feasibility of the activity. This type of culture should be entitled to medium scale producers with strong and representative outcomes from previous experiences in the Aquaculture field.

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