Aquat. Living Resour. 2020, 33, 2
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https://doi.org/10.1051/alr/2020001

Aquatic
Living
Resources
Available online at:
www.alr-journal.org

RESEARCH ARTICLE

Economic feasibility analysis of small-scale aquaculture of the endemic snail *Pomacea patula catemacensis* (Baker 1922) from southeast Mexico

Miguel Ángel Mejía-Ramírez[1], Verónica Valadez Rocha[1,*] and Carlos Iván Pérez-Rostro[2]

[1] División de Estudios de Posgrado e Investigación, Instituto Tecnológico de Boca del Rio. Kilómetro 12, Carretera Veracruz-Córdoba, Boca del, Río, Veracruz 94290, Mexico
[2] Laboratorio de mejoramiento genético, Instituto Tecnológico de Boca del Río, Mexico

Received 11 June 2018 / Accepted 19 December 2019

Handling Editor: Katell Hamon

Abstract – The snail *Pomacea patula catemacensis* is an endemic mollusk from the southeast Gulf of Mexico, which is commercially exploited and in decline since 2010. This decline is associated with an increasing market demand and illegal capture. We designed a small-scale production system for *P. p. catemacensis* and determined its financial feasibility for a base scenario. We used information gathered from stakeholders and stochastic modeling to predict the impact of uncertain variables on the economic indicators to assess the financial viability under varying conditions. The small-scale intensive production system, designed to yield 3.9 tons/year of unshelled product, requires an investment of about US $65,000. The production unit was financially assessed using the Modified Internal Return Rate and The Net Present Value of cash flow, considering a 14% discount rate and a 7% reinvestment rate. We obtained a Net Present Value of $67,000 and a Modified Internal Return Rate of 20% for the base scenario, which indicates the viability of the project. A Monte Carlo simulation was run to assess the robustness of the project to variability of three parameters: labor cost, energy cost, and market price; with random and simultaneous variation, resulting in 95% probability of getting a Modified Internal Return Rate larger than the current interest rate (8%) and a low probability (2.8%) to be financially unviable. This production system is worthy of consideration as an option to reduce the fishing pressure on the tegogolo natural populations of the Catemaco Lake while satisfying the market demand.

Keywords: Aquaculture economic assessment / endemic snail / aquatic resource conservation / financial assessment / human pressure on snail population / Monte Carlo / stochastic modelling / *Pomacea patula catemacensis* (*P. p. catemacensis*)

1 Introduction

In Mexico, there are more than 200 species of mollusks which are commercially exploited and most of the natural populations are collapsing, over-exploited, or exploited to the maximum (Baqueiro and Aldana-Aranda, 2003). Among them, freshwater snails from the genus Pomacea or "apple snails" constitute a considerable economic share (Lagunes, 1997). *Pomacea patula catemacensis* (Baker, 1922) is an endemic species from the southeast of the country, and one of the most important of this genus, known locally as "tegogolo". It inhabits the lake of Catemaco, Veracruz and it is highly consumed as one of the preferred local dishes. Currently, the price of 1 kg of unshelled snails ranges from US $10.5 during the high reproduction season in summer and autumn to $28 in winter, which is the low reproduction season (Mejia-Ramirez, 2018).

P. catemacensis is collected by hand, free diving in the lagoon at maximum depths of 4 meters. The catch of a single diver depends on the abundance of the natural populations and the skills and resistance of each diver (Lorán-Núñez et al., 2005). An average of 7.9 kg/fishermen/day, which is commercialized as boiled unshelled snails preserved on ice was reported for 2005 (Lorán-Núñez et al., 2005). Data for local fisheries, gathered by the National Commission of Fisheries and Aquaculture (CONAPESCA for its acronym in Spanish, 2017) shows that the catch of this species has declined. After historically high reported catch in 2006–2007 and 2009–2010,

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*Corresponding author: `veronicavaladez@bdelrio.tecnm.mx`

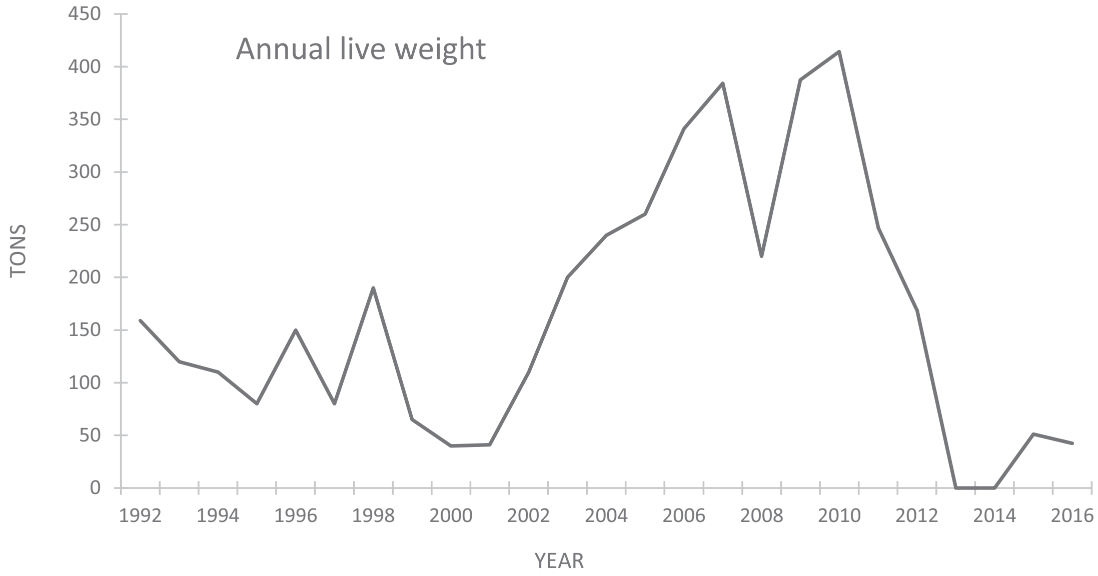

Fig. 1. Reported *Pomacea patula catemacensis* live weight catch from 1992 to 2016 (CONAPESCA, 2017). There was no reported catch for 2013 and 2014.

the catch crashed in 2013 with under 1 ton reported for two years and it has remained at a low level (around 50 tons) ever since, without showing signs of recovery (Fig. 1). The norm regulating the fishery of this and other endemic species (NOM-041-PESC-2004), which establishes output controls, including catch quota, the minimum landing size, and fishing practices, was implemented in 2004. According to the reported live weight catch (CONAPESCA, 2017) it had a positive effect until 2010. The population has grown 1.56% in the last year (INEGI, 2019), increasing the demand of the product. This has led to an increase in the number of fishermen, causing a negative effect on the natural populations resulting in the decline of tegogolo catch in recent years (2013–2018) (Lorán-Núñez et al., 2005; CONAPESCA, 2016). Regulation has proven to be unsuccessful in preventing illegal fisheries which have negative effects on the natural repopulation rate of *P. p. catemacensis*. One possible reason for this is the lack of personnel to inspect landings or to keep track of permits (*pers. com.* Local authority). The overall context, highlights the necessity of finding strategies to guarantee a better control of the tegogolo catch or to explore options to meet the demand, such as aquaculture.

Aquaculture is one of the priority sectors in Mexico. There are government funds to support aquaculture projects that co-invest with producers, and it is relatively simple to be considered for these funds. Applicants are required to be registered in the National Revenue System (as individuals or under a legal figure), to have a National Producer Registry for Aquaculture (RNP by its acronym in Spanish), to have a water use permit for aquaculture, and to have a financially assessed project. This fund, depending on the degree of economic marginalization of the site for the project, grant from 30% to 70% of the total cost of the project (non-refundable). Some other programs, more socially oriented, which support small scale aquaculture production units, consider labor as the counterpart of the investment, making it possible for fishermen cooperatives or individuals to consider owning an aquaculture production unit (SADER, 2019).

There are some social and environmental advantages of small scale aquaculture production units for cultivating an endemic species in its place of origin. From the social perspective aquaculture production units offer a self-employment potential for current fishermen in a safer work environment and represent a source of a high quality product (Muir, 2005). This is particularly important for developing countries, since it offers diversification of employment and income (Edwards, 2000; de Graaf and Latif, 2002). From the environmental perspective, if current fishermen turn into producers the pressure on the natural populations may be lower, and part of the demand could be satisfied with cultivated organisms. Another environmental advantage would be the mitigation of the potential environmental negative impacts resulting from escapes and pathogen dissemination (Naylor et al., 2000; Ross et al., 2008).

Most of the available information on *P. catemacensis* is experimental and found either as published work, or as “gray literature” in the form of technical reports, graduate and postgraduate thesis, that cover some of the principal aspects of the species cultivation, such as diets, optimal stocking densities, reproduction ratios, gonadic maturity and fecundity (Carreon-Palau et al., 2003). The existing information allows us to establish the suitability of the species for aquaculture since it has a short incubation period (García-Ulloa et al., 2007), accepts formulated feed (Vasquez et al., 2012), has high resistance to handling and disease, shows rapid growth (Ruiz-Ramirez et al., 2005), tolerates high densities, has the ability to withstand large environmental variations, has market acceptability and achieves a high price (Saint-Paul, 1986, 1991; Van der Meer, 1997; Garcia-Trejo et al., 2014). This body of knowledge also allows us to design a small-scale intensive production system (SSPS) for *P. catemacensis*. However, the economic feasibility of cultivating *P. p. catemacensis* has never been tested. Most of the experiments were done at a laboratory scale and do not consider the economic indicators which are necessary to decide if aquaculture is a viable option.

To bring a new species to production, investment and time are needed (Young and Muir, 1995) and aquaculture ventures are inherently risky (Engle, 2007). To reduce this risk simulation may help to evaluate the viability of a particular production system (Engle and Neira, 2005; Moss and Leung, 2006a; Chen et al., 2017), which is desirable, particularly for those involving new species for aquaculture (Engle, 2007). Therefore, in this research, we designed a SSPS for *P. p. catemacensis*, determined its financial viability for a base scenario and used stochastic modeling to predict the impact of uncertain variables on the economic indicators to assess the financial viability. The results of this assessment will throw light on the economic strengths and weaknesses of culturing this endemic species in decline. This could help to support decision makers in the field of fisheries, conservation or development planning by providing information on aquaculture as a management tool.

2 Materials and methods

The research was conducted in two stages: the first stage included information generation, compilation and the design of the SSPS for *P. p. catemacensis*. The second stage included a simulated production plan, the financial assessment of a base scenario and the stochastic modeling to determine the financial viability under uncertain variables.

2.1 Data collection and production unit design

Research information collected from academic thesis and published papers was used to determine production variables such as stocking density, feed type, feeding rates, survival, culture systems, reproduction, and fecundity.

Based on this information we designed the SSPS for *P. p. catemacensis*. We collected fisheries and market information from primary sources (Kam and Leung, 2008), using a structured questionnaire. Two groups of stakeholders were used as primary sources. The first group was composed of 10 fishermen, members of different cooperatives with extraction permits for *P.p. catemacensis*, which were interviewed individually. The questionnaire topics for fishermen included a) product information, catches, availability of the product, price variations, and b) livelihood: fishing conditions, preferred catch size and variation, trends and perspectives for the fishery. The second group was composed of 10 clients, including registered restaurants or fast food selling station owners. The questionnaire topics for clients included (a) product: desired characteristics, current and desired presentation, consumed volume, availability, price variations and willingness to pay during scarcity and (b) perceptions on the fishery (trends and conflicts). This information helped to determine the uncertain variables that could affect market conditions.

The proposed SSPS for *P. p. catemacensis* is similar to the intensive production systems used for tilapia. Therefore, an additional group, which included producers and researchers specialized in tilapia culture and *P.p. catemacensis* researchers were interviewed (three producers and three researchers) to determine the initial investment cost, variable and fixed costs of tilapia commercial culture systems. The chosen primary sources of information comply with standard practice to assess financial risk of aquaculture projects (Kam and Leung, 2008).

2.2 Economic feasibility assessment

Based on the collected information and the design of the SSPS, a comprehensive list with infrastructure, operational activities, and materials was created to simulate the production plan and a specific base budget for the SSPS. The design, production plan and specific budget were validated with producers and aquaculture scientists. The annual return was calculated by taking the difference between income from expected sales and cost. A cash flow was constructed for ten years of operation. The Annual net cash flow (cash inflows and cash outflows) was used to calculate the Modified Internal Rate of Return (MIRR), which is one of the recommended indicators to analyze the feasibility of aquaculture projects (Sullivan et al., 2006; Rhodes et al., 2009; Watanabe et al., 2015). The other recommended indicator is the Net Present Value of cash flow (NPV) which is the generally accepted measure of the economic robusteness of any long-term investment program (Brealey et al., 2013). The NPV is the sum of all relevant expected future cash flows discounted at the appropriate rate. The discount rate or cost of capital conceptually represents the minimum compensation demanded by the investors (capital providers to companies). If the NPV is positive using a specific discount rate, then the project is desirable from the investor's perspective. To calculate the NPV we used a 14% discount rate, which was the average rate reported by Zuñiga-Jara and Ruiz (2017) as used for new aquaculture projects in developing countries. In developing countries, the high discount rate is related to the risk associated with the expected changes in currency rates, inflation, and political risk. To assess the MIRR we used the same 14% discount rate recommended by Zuñiga-Jara and Ruiz (2017) and a 7% reinvestment rate. Aquaculture projects re-investment rates are between 6% and 10% (Chen et al., 2017; Kumar and Engle, 2017). As an example, Zuñiga-Jara and Ruiz (2017) report a 7.7% reinvestment rate for mollusk aquaculture projects in developing countries. We used an exchange rate MXN-USD of 0.05635.

A sensitivity analysis was conducted, using Data analysis Excel Add-In (Microsoft), in order to calculate MIRR as a function of percent changes in parameter values (Moss and Leung, 2006b; Kam and Leung, 2008; Chen et al., 2017). We chose to address parameters which might have a negative impact on the economic outcome of the SSPS and which showed a larger variation in the period 2016–2017. Four parameters, labor cost, market price, feed cost, and energy cost were modified from −50% to +50% of the estimated cost for the base scenario. The percentage of variation from the MIRR of the base scenario was then calculated. The three parameters which showed a larger effect on the MIRR in the sensitivity analysis were selected for stochastic modeling.

The stochastic modeling was performed using the Monte Carlo simulation in RISK AMP excel Add-In (by Structured

Data, LLC) to calculate a range of MIRR and NPV for 1000 iterations. The simulation was run under the premise of three random parameters varying simultaneously. The three parameters were considered as triangularly distributed. The triangular distribution is a continuous distribution with a fixed minimum, fixed maximum and the average value, forming a triangle-shaped distribution which shows that values near the minimum and maximum are less likely to occur (Mun, 2010).

Maximum, minimum and average price, were calculated using the data from the questionnaires applied to fishermen and clients. Formulated feed price maximum, minimum and average, were based on data on price variations of tilapia pelleted feed in one year (data provided by one of the national feed brands, Pedregal, Silver Cup® for 2016–2017). The minimum price was set at the present value per kg; the maximum was the rate of price variability in one year, projected from the present cost per kg and the average price per kg. Labor cost variation was determined considering the variation of the minimum national wage in one year (2016–2017). The minimum, maximum average cost for labor was set in the same way as the price of formulated feed (Data from the Internal Revenue Service, SAT by its acronym in Spanish). The output results of the Monte Carlo simulation for 1000 iterations were assessed by calculating the basic statistic parameters for the results of the MIRR and NPV. A high probability (80–90%) of getting an MIRR larger than 15% for the 1000 iterations was considered an indicator of economic feasibility.

3 Results

3.1 Data collection, production unit design and production management

We used the seasonal established price and the following information collected from stakeholders: (1) the diving time to collect enough snails to produce 1 kg of unshelled snails has tripled since 2010. In 2019, a single fisherman dives for around six hours to collect enough sails to make 1 kg of unshelled product (during autumn); (2) there is a generalized perception that there are transgressions of the established regulation, particularly those regarding the minimum size and day-time for the catch. Also, industrial and human sewage and an increase in water temperature were referred to as additional causes for the decline in snail catch.

Based on available literature and corresponding information given on diet, feed rate, stocking density during reproduction, pre-growth and growth stages (Tab. 1) we proposed an SSPS for *P.p. catemacensis* that can yield 2.2 Tons of unshelled snail in the first year, with two full fattening cycles. The production may increase to 3.9 Tons from the second year onwards, because the production cycle is closed in the second year and infrastructure is used to the planned capacity. The SSPS requires 1⁄4 hectare for the production and processing of snails, and an oxidation lagoon for water treatment (Fig. 2). The indoor reproduction and growth areas consist of Geo-membrane lined and fiberglass circular tanks located indoors, with an aeration system composed of a 3 Horse Power blower and diffuser hose for reproduction tanks and diffuser stones for growth tanks.

The designed reproduction area (Fig. 3, #18, #9) includes 3, tanks with a diameter of 6 m (to be filled at 14 m^3). The following parameters were considered for the production plan: a stocking density of 1 pre-acclimated adult/m^3 (adult snails acclimated to the cultivation conditions for at least two months), an 85% hatching rate, from an average of 167 ± 41 eggs per female (Tab. 1), a feeding rate of broodstock of 5% body weight twice a day. This simulated reproduction system may produce around 19,000 juveniles quarterly, except for the months December and January, when a reduction to around 4500 juveniles is expected based on the known reproduction data from Mejia-Ramirez (2018). The reproduction area also considers a quarantine system, which consists of 3.3 m^3 tanks for new reproduction batches.

The nursery (Fig. 3, #7) consists of 14, 300 l tanks, filled at 250 l, and covered with a mosquito net to prevent other organisms to feed on *P.p. catemacensis* juveniles. The parameters considered in this stage in the production plan were: a stocking density of 25 organisms/l, a feeding rate of 15% in three servings per day, for one month. The system would operate on a recirculation system which requires a submersible pump, a physical filter, and a biological filter.

The grow-out system (Fig. 3, #10) consists of 22, 6 m (28 m^3) tanks. The parameters considered in the production plan for this stage were: a stocking density of 1 organism/l, a staggered schedule using two growth tanks per quarterly cohort and feeding rates of 10% of body weight for 0.1 to 0.5 g; 7.5% of body weight from 2 to 8 g.

The effluent from reproduction and growth stages will be treated using an oxidation lagoon of 270 m^3, which would have a residence time of 15 days. Treated water may be used for crops or wetlands (Fig. 3).

The initial investment cost for the proposed SSPS in equipment and infrastructure is around $60,000 (Tab. 2). The estimated fixed costs, including formulated feed, gasoline, highway fees and energy (electricity and gas) is $3000/year from the second year onwards. Variable costs, which include labor, administration, and maintenance of around $22,000/year from year two onwards. Since the proposed design is for an endemic species and explores aquaculture as an alternative to the fishery of “tegogolo”, some assumptions were based on the current conditions of most fishermen. To develop the economic feasibility assessment, we considered the producers own the land. In the region, most fishermen live in the surroundings of the Catemaco Lagoon and own land. We also considered that there is available water of good quality and permits for aquaculture production (National Producer Register, Water use for aquaculture). These permits are relatively simple to obtain and have no cost. The SSPS has projected sales of $31,500 in the first year and $55,200 in the following years (Tab. 3). The final product consists of boiled unshelled snails in 1 kg vacuum-sealed plastic bags, preserved in ice, which is the current market product offered by the local fishermen to restaurants and fast food establishments (from individual questionnaires to clients).

According to the base cash flow, the investment can be recovered in the fourth year of operation. A Net Present Value of $52,462 and a MIRR of 18%, indicate the project is feasible

Table 1. Available information on production parameters for *Pomacea patula catemacensis* and the variables considered for the design of the production system based on available literature.

	Mejia-Ramirez (2018)	Vázquez et al., (2012)	García-Ulloa et al., (2007)	Espinoza-Chávez & Martínez-Jerónimo (2005)	Meyer-Willerer & Santos-Soto (2006)	Garcia-Ulloa et al., (2008)	Considered for design
Feed	Shrimp commercial diet	Commercial diets: catfish, shrimp, tilapia, and trout	Lettuce/ commercial fish diet	*Scenedesmus incrassatulus*/ trout commercial diet	Lettuce/alfalfa/ tilapia commercial diet	Commercial fish diet	Tilapia commercial diet
Stocking density for reproduction (org/l)	0.5	———	0.4	———	0.1	1	1
Reproduction culture system	Green water	———	Water Exchange	———	Green water	Water Exchange	Green water
Eggs/egg mass	———	———	167.19±40.93	———	90	———	167.19±40.93
Stocking density for growth (org/l)	1	0.5	———	1.6	———	5 (1st month) 2 (after 1st month)	1
Grow-out culture system	Water Exchange, and Biofloc System	Recirculation system	Water Exchange	Water Exchange	Green water	Water Exchange	Water Exchange
Diet protein content (%)	35	28, 25, 40	40	38	———	———	30
Feeding rate (%)	5, 10	1	*Ad libitum*	*Ad libitum*	*Ad libitum*	*Ad libitum*	5, 7.5
Feeding frequency	1/day	2/day	2/day	1/day	1/day	2/day	2/day
Survival (%)	100	86±13	100	———	89.7	———	85±5
Temperature (°C)	26±0.8	26±0.7	25-28	25	26	25-28	25-28
Dissolved Oxygen	6.71±0.5	———	———	———	———	4	6±0.5

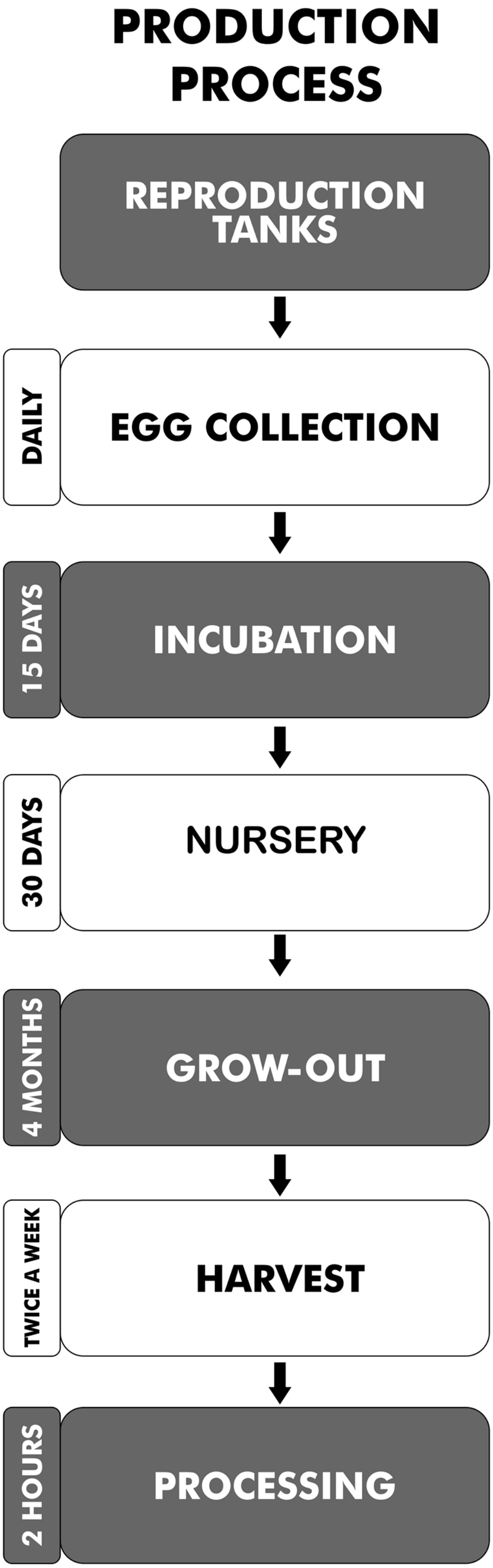

Fig. 2. General production process with time requirements.

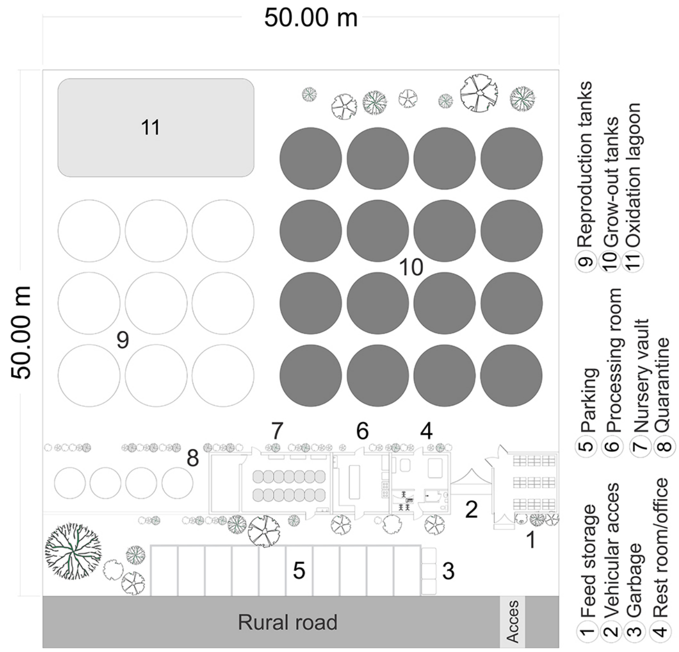

Fig. 3. General design of the proposed Small Scale Production System for *Pomacea patula catemacensis* with minimum space requirement of 1⁄4 Ha.

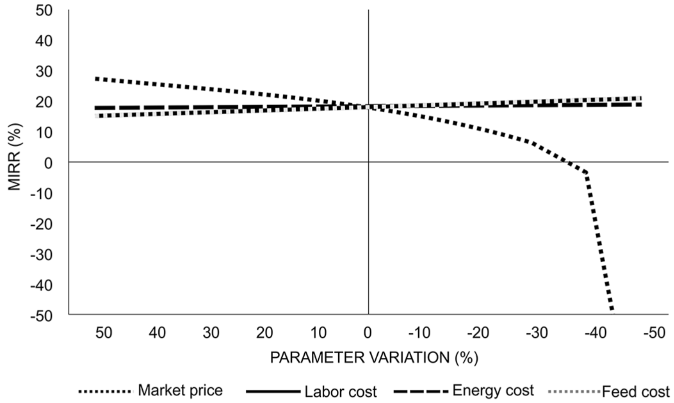

Fig. 4. Sensitivity analysis with −50% to 50% variation in four parameters and its effect on the Modified Internal Return Rate. *Note*: Labor and feed cost have a similar effect on the MIRR and they seem to overlap in the figure.

(Tab. 3). A Positive NPV indicates the project is desirable from the investor's perspective and a MIRR larger than the current bank interest rate (8%) also reinforces the feasibility of the project.

Market price, energy wage and labor cost were the parameters with a greater impact on the MIRR (Fig. 4). Market price caused a 100% reduction in the MIRR with a −50% variation. Labor and feed cost had less effect on the MIRR variation from 17% to 19%. Energy had the least effect on the MIRR variation.

Table 2. Investment Budget (based on costs for 2018).

	Investment Budget					
Item	Unit	Amount	Price without tax	Tax	Price	Total
Broodstock	Batch	1	$118.34	$22.54	$140.88	$140.88
Reproduction tanks 6 m	Piece	3	$733.72	$139.76	$873.47	$2,620.42
Quarantine tanks 3 m	Piece	2	$331.36	$63.12	$394.47	$788.94
Toolkit	Piece	1	$331.36	$63.12	$394.47	$394.47
Fiberglass tanks 300 L, nursery	Piece	14	$56.80	$10.82	$67.62	$946.73
Small diffuser stone	Piece	20	$3.41	$0.65	$4.06	$81.15
Mosquito net 30 m roll	Roll	2	$22.48	$4.28	$26.77	$53.54
Submersible pump for recirculation system	Piece	1	$71.00	$13.52	$84.53	$84.53
Water quality test kit	Piece	1	$56.36	$10.74	$67.09	$67.09
Oximeter	Piece	1	$281.46	$53.61	$335.07	$335.07
Mercurial thermometer	Piece	2	$14.20	$2.70	$16.91	$33.81
PH meter	Piece	2	$91.31	$17.39	$108.71	$217.41
Feed storage 6.0 × 12.0 m		1	$3,786.93	$721.32	$4,508.25	$4,508.25
Grow-out tanks 6 m	Piece	22	$733.72	$139.76	$873.47	$19,216.41
Poly Duct 0.25 mm (10 m roll)	Roll	2	$75.74	$14.43	$90.16	$180.33
Diffuser hose, 0.25 mm (Roll 10 m)	Roll	2	$92.31	$17.58	$109.89	$219.78
4″ PVC drainage tube (6 m piece)	Piece	22	$11.03	$2.10	$13.13	$288.87
4″ PVC adapters	Piece	45	$2.37	$0.45	$2.82	$126.79
Installation	None	1	$1,183.42	$225.41	$1,408.83	$1,408.83
Fishing net	m	132	$5.68	$1.08	$6.76	$892.63
3 HP submersible pump	Piece	1	$781.05	$148.77	$929.83	$929.83
3 HP Blower	Piece	1	$994.07	$189.35	$1,183.42	$1,183.42
Aeration 2″ PVC tube (6 m piece)	Piece	22	$5.68	$1.08	$6.76	$148.77
2″ PVC adapters	Piece	45	$2.37	$0.45	$2.82	$126.79
Feed storage house 6.0 × 6.0		1	$2,589.24	$493.19	$3,082.43	$3,082.43
Transport cooler	Piece	2	$165.68	$31.56	$197.24	$394.47
Truck Nissan NP300 mod. 2017	Piece	1	$14,952.71	$2,848.14	$17,800.84	$17,800.84
Digital scales 40 Kg (0.5 g precision)	Piece	1	$37.87	$7.21	$45.08	$45.08
Digital scale 0.01 g precision	Piece	1	$52.07	$9.92	$61.99	$61.99
Gas stove 3 burners	Piece	1	$118.29	$22.53	$140.83	$140.83
Gas tank 30 kg	Piece	1	$59.12	$11.26	$70.39	$70.39
50 l stainless steel pan	Piece	3	$25.99	$4.95	$30.94	$92.81
Kitchen appliances	Piece	3	$6.06	$1.15	$7.21	$128.00
Vacuum sealer	Piece	1	$213.01	$40.57	$253.59	$253.59
Etiquette machine	Piece	1	$97.04	$18.48	$115.52	$115.52
Dressing room/office 6.0 × 6.0		1	$2,520.35	$480.07	$3,000.42	$3,000.42
Processing room with gas, water and drainage 6.0 × 6.0 m		1	$2,548.34	$485.40	$3,033.74	$3,033.74
					Total	**$63,214.87**

Considering these results, only market price, labor, and feed were considered for the Monte Carlo simulation assigning the lowest value, maximum value, and average value as shown in Table 4, using the information from the survey for market price variance, labor minimum wage variation, and feed cost. The Monte Carlo simulations generated scenarios for 1000 iterations, we obtained a mean NPV of around $60,000 with a minimum of around $13,000 and a maximum of $140,000 with a Standard Deviation of $20,000

The values of the NPV ranged from $8,000.00 to $144,000.00, with a 0.03% probability of getting a value of or below zero (Fig. 5). Due to the very high probability of obtaining a positive NPV, we state the project is desirable from the investor's perspective.

The MIRR results from the Monte Carlo simulation showed a mean of 19% with a minimum of 9% and a maximum of 26%. There is a 2.8% probability to get MIRR values below 14%, which is the discount rate and a 95.2% probability to get MIRR values from 14 to 23% (Fig. 6).

4 Discussion

With its high hatching rate, acceptance of commercial feeds, tolerance to cultivation at high densities, lack of a larval stage, fast growth and high survival rate, the endemic snail, *P. p. catemacensis* is a suitable candidate for aquaculture (Garcia-Trejo et al., 2014; Mejia-Ramirez, 2018).

Table 3. Cash flow for ten years and calculation of Net Present Value (NPV) and Modified Internal Return Rate (MIRR) for the base scenario.

Year	0	1	2	3	4	5	6	7	8	9	10
Production (Kg)		2239.1	3918.4	3918.4	3918.4	3918.4	3918.4	3918.4	3918.4	3918.4	3918.4
Market price/Kg		14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1
Sales		$31,545	$55,204	$55,204	$55,204	$55,204	$55,204	$55,204	$55,204	$55,204	$55,204
Fixed cost		-$2,791	-$3,002	-$3,002	-$3,002	-$3,002	-$3,002	-$3,002	-$3,002	-$3,002	-$3,002
Labor		-$11,834	-$11,834	-$11,834	-$11,834	-$11,834	-$11,834	-$11,834	-$11,834	-$11,834	-$11,834
Energy cost		-$2,045	-$2,993	-$2,993	-$2,993	-$2,993	-$2,993	-$2,993	-$2,993	-$2,993	-$2,993
Feed (Kg)		13048	19056	19056	19056	19056	19056	19056	19056	19056	19056
Feed price/Kg		$0.6	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6
Feed cost		-$8,088	-$11,813	-$11,813	-$11,813	-$11,813	-$11,813	-$11,813	-$11,813	-$11,813	-$11,813
Tax recovery		$6,453	$115	$115	$115	$115	$115	$115	$115	$115	$115
Balance	-$63,215	$13,240	$25,676	$25,676	$25,676	$25,676	$25,676	$25,676	$25,676	$25,676	$25,676
Horizon	-$63,215	-$49,975	-$24,299	$1,378	$27,054	$25,676	$25,676	$25,676	$25,676	$25,676	$25,676
Interest rate	14%										
NPV	$52,462										
IRR	33%										
Reinvestment rate	7%										
MIRR	18%										

Table 4. Basic statistics for the parameters considered for the sensitivity analysis. Sources of information: for labor, minimal wage, the Mexican Revenue Service (SAT, sat. gob. mx, 2017); for market price the questionnaire applied to fishermen and clients; for feed cost the historical price variation from Pedregal Silver Cup®

	Labor 2017	Market price 2017	Feed cost (2016-2017)
Mean ± S.D	3.55 ± 0.52	12.94 ± 5.58	0.63 ± 0.01
Minimum	2.85	8.45	0.62
Maximum	4.53	28.18	0.64

The financial assessment for the proposed SSPS for *P. p. catemacensis* resulted in financial indicators, NPV, and MIRR, which indicate the project is financially feasible. Considering this, it is profitable to invest in this species now and on a medium term (next 10 years) since, currently, the fishery is in decline (CONAPESCA, 2016) with no signs of recuperation and the demand is increasing (Mejia Ramírez, 2018). On the other hand, most of the current tegogolo fishermen have an adequate profile to be considered for government co-investment programs (SADER, 2019) for small scale aquaculture and might be interested in becoming producers. However, for them to venture into the production of a new species, which is inherently risky, the financial feasibility had to be tested theoretically. Early investors prefer to wait until the body of knowledge of a new species is very robust, to the point of understanding the operational efficiency in order to assure the profit is high enough to remunerate those who finance the project (Engle, 2007). However, in the case of an endemic species with declining wild population but high market demand it would be advisable to take advantage of the current market opportunity and to reduce the present fishing pressure. In cases like this one, simulation has a central role in constructing theoretical knowledge to make investment decisions, because it allows to explore the possible outcomes of the investment. However, it is important to consider that scientific research on the production of a new species is mostly conducted on a smaller scale and with greater control of production variables, in contrast to a commercial-scale operation (Engle, 2007).

In the case of tegogolo the simulation helped us to decompose the financial risk. Since the simulation was run using information collected from primary sources, we have well represented estimates of uncertainty and first-hand operation data to determine farm-level costs and volume estimations (Engle 2007; Kam and Leung, 2008). Since tegogolo is a new species for aquaculture, and there are limited available experimental data (Engle, 2007), we approached this problem by gathering operation scale information from a similar production system (intensive tilapia production).

Even when the market price variations have a considerable effect on profitability, the results of the Monte Carlo simulation indicate a low probability of not being economically feasible under the preconditions set in this study (2.8%). Other situations, which were not considered in this study could have an impact on profitability, such is the case of pathogen outbreaks which are associated with poor management practices. This project was considered to be operated under best management practices, which include water quality management, feed management, and sanitary management to prevent disease outbreak. However, since the species is still not cultured commercially there is a gap of information on pathogen outbreaks.

A SSPS for *P. p. catemacensis* can be operated by the owner (investor or potentially a group of fishermen) who actively participates in aquaculture activities, and

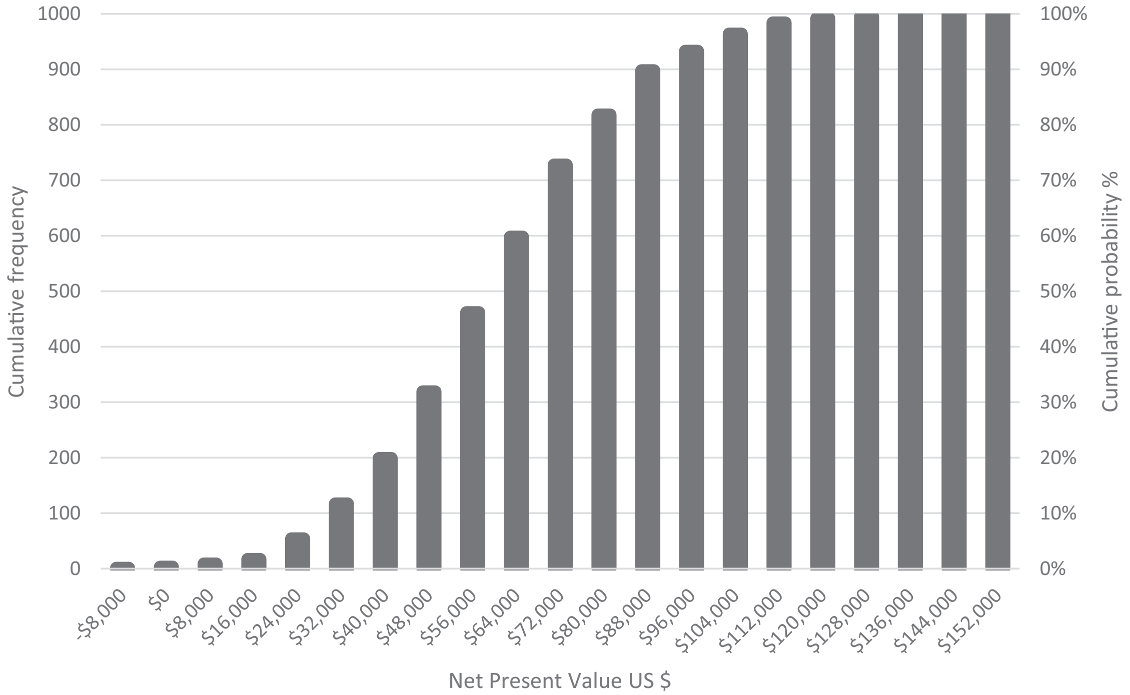

Fig. 5. Cumulative frequency of the simulated net present value for 1000 trials with market price, labor and feed cost with random and simultaneous variation.

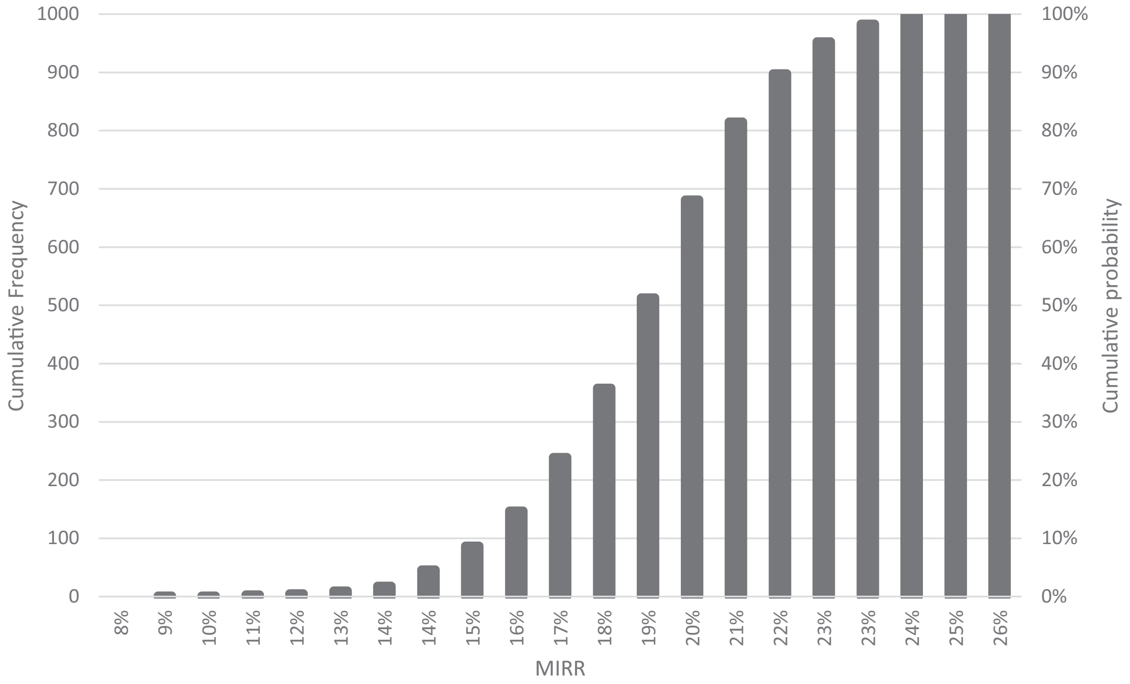

Fig. 6. Cumulative frequency of the simulated modified internal return rate for 1000 trials with market price, labor and feed cost with random and simultaneous variation.

therefore receives hourly wages in addition to profits, as proposed for other species (Chen et al., 2017). The option of using a similar SSPS to restock natural populations with cultivated juveniles could also be explored as an alternative.

5 Conclusion

The proposed small-scale production system was designed to exploit the "tegogolo" snail in a sustainable manner while reducing the pressure on natural populations. The financial assessment indicates it is economically feasible and profitable and with a low financial risk. Our results also indicate that it could have social and environmental advantages since it considers the cultivation of this endemic species in its place of origin and gives some insight on how the current situation of aquaculture in Mexico could favor fishermen to turn into producers of this endemic species.

Conflict of interests and ethical statement

We declare that this manuscript is original and is not currently being considered for publication elsewhere. We also confirm that all the research meets the ethical guidelines, including the adherence to the legal requirements of the study country. We wish to confirm that there are no known conflicts of interest associated with this publication.

Acknowledgments. We acknowledge the Consejo Nacional de Ciencia y Tecnologia (CONACYT) for the fellowship #584350 granted to Miguel Mejia-Ramirez and Dr. Yuriditzi Pascasio Montijo for correcting the manuscript.

References

Baqueiro E, Aldana-Aranda D. 2003. Patrones en la biología poblacional de moluscos de importancia comercial en México. *Rev Biol Trop* 51: 97–102.

Brealey RA, Myers SC, Allen F. 2013. Principles of corporate finance (11th edn.). New York, NY: The McGraw-Hill/Irwin Series in Finance, Insurance and Real Estate.

Carreon-Palau A, Uria-Galicia E, Espinosa-Chavez F, Martinez-Jeronimo F. 2003. Desarrollo morfológico e histológico del sistema reproductor de *Pomacea patula catemacensis* (Baker 1922) (Mollusca, Caenogastropoda: Ampullariidae). *Rev Chil Hist Nat* 76: 665–680.

Chen JQ, Haws MC, Fong QSW, Leung PS. 2017. Economic Feasibility of producing Oysters using a small-scale Hawaiian Fishpond model. *Aquacult Rep* 5: 41–51.

de Graaf G, Latif A. 2002. Development of freshwater fish farming and poverty alleviation: a case study from Bangladesh. *Aquacult. Asia* VII (5/7).

Edwards P. 2000. Aquaculture, poverty impacts, and livelihoods. Natural resource perspectives (56). London: Overseas Development Institute.

Engle C. 2007. Investment and farm modeling for feasibility assessment and decision-making in aquaculture. In: Leung P, Lee CS, Bryen PJO (Eds.), Species & System Selection for Sustainable Aquaculture. 1st edm. USA: Blackwell Publishing.

Engle CR, Neira I. 2005. Tilapia farm business management and economics: a training manual. Pine Bluff, University of Arkansas 41pp.

Espinoza-Chávez F, Martínez-Jerónimo F. 2005. Growth and fecundity of *Pomacea patula catemacensis* (Caenogastropoda: Ampulariidae) when fed on gel diets of Scenedesmus incrassatulus (Chlorophyceae). *The Veliger* 43: 213–217.

Garcia-Trejo F, Hurtado-Gonzalez S, Soto-Zarazua GM, Gutierrez PJ. 2014. Development of freshwater native species with aquaculture potential. In: Hernandez-Vergara MP, Perez-Rostro CI (Eds.), Sustainable aquaculture techniques, Intechopen, http://dx.doi.org/10.5772/57215, available at https://www.intechopen.com/books/sustainable-aquaculture-techniques

Garcia-Ulloa M, Gallo-Garcia MC, Rodriguez-Gonzales H, Góngora-Gomez A, Ponce-Palafox J. 2008. Morphometric relationship of weight and length of cultured freshwater snail, *Pomacea patula* (Baker, 1922), at three different life stages. *J. World Aquacult. Soc.* 39: 842–846.

García-Ulloa M, Ramnarine I, Gallo-García M, Ponce-Palafox J, Góngora-Gómez A. 2007. Spawning and hatching of the edible snail *Pomacea patula* (Baker 1922) (Gastropoda: Ampullaridae) in the laboratory. *J. World Aquacult. Soc.* 38: 50–52.

Kam LE, Leung P. 2008. Financial risk analysis in aquaculture. In: Bondad-Reantaso MG, Arthur, JR Subasinghe RG (Eds.), Understanding risk analysis in Aquaculture. Rome, FAO: FAO Fisheries and Aquaculture No. 19.

Kumar G, Engle C. 2017. Economics of Intensively Aerated Catfish Ponds. *J. World Aquacult. Soc.* 48: 320–332.

Lagunes B. 1997. Aprovechamiento de los cuerpos de aguas tropicales para la crianza intensiva del caracol dulceacuícola Pomacea sp. (Mollusca, Gastrópoda) en corrales flotantes, para su integración en programas acuícolas. Tesis que para obtener el título de Ingeniero en Acuacultura. Secretaría de Educación Pública, Subsecretaría de Educación e Investigación Tecnológica. Unidad de Educación en Ciencias y Tecnologías del Mar. Instituto Tecnológico del Mar.

Lorán-Núñez RM, Martínez-Izunza FR, Valdéz-Guzmán AJ, Gaspar-Dillanes MT. 2005. Lago de CATEMACO. In: Gaspar-Dillanes MT, Aguilar-Montaño D (Eds.), Pesquerías Continentales de México, 1st Edition, Instituto Nacional de Pesca, 93–118.

Meyer-Willerer AO, Santos-Soto A. 2006. Temperature and light intensity affecting egg production and growth performance of the Apple Snail Pomacea patula (Baker, 1922). Avances en Investigación Agropecuaria, 10: 41–58.

Moss SM, Leung PS. 2006. Comparative cost of shrimp production: earthen ponds versus recirculating aquaculture systems. In: Leung PS, Engle (Eds). Shrimp culture: economics, market, & trade. Blackwell Publishing: Ames.

Mejia-Ramirez MA. 2018. Productive Performance and Bacterial Profile of Freshwater Snail *Pomacea patula Catemacensis* (Baker, 1922) Cultivated in Biofloc. Instituto Tecnologico de Boca del Río, Veracruz, Mexico (in Spanish).

Moss SM, Leung PS. 2006. Comparative cost of shrimp production: earthen ponds versus recirculating aquaculture systems. In: Leung PS, Engle C (Eds). Shrimp culture: economics, market, & trade. Ames: Blackwell Publishing, pp. 291–300.

Muir J. 2005. Managing to harvest? Perspectives on the potential of aquaculture. *Philos Trans R Soc Lond B: Biol Sci* 360: 191–218.

Mun J. 2010. Modeling risk: Applying Monte Carlo, risk simulation, strategic real options, stochastic forecasting, and portfolio optimization, 2nd edn, Wiley & Sons. ISBN: 978-0-470-59221–2.

Naylor RL, Goldburg RJ, Primavera JH, Kautsky N, Beveridge MCM, Clay J, Folke, C, Lubchenco J, Mooney H, Troell M. 2000. Effect of aquaculture on world fish supplies. *Nature* 405: 1017–1024.

NOM-041-PESC-2004. Available at: http://www.dof.gob.mx/normasOficiales/1943/sagarpa/sagarpa.htm

Rhodes R, Hanson TR, Dasgupta S. 2009. Economics and Business Management. In: New MB, Valenti JH, Tidwell LR, D'Abramo LR, Kutty MN (Eds.), Freshwater Prawns: Biology and Management. USA: John Wiley & Sons.

Ross LG, Martinez Palacios CA, Morales EJ. 2008. Developing native fish species for aquaculture: the interacting demands of biodiversity, sustainable aquaculture, and livelihoods. *Aquacult Res* 39: 675–683.

Ruiz-Ramirez R, Espinosa-Chávez F, Martínez-Jerónimo F. 2005. Growth and reproduction of *Pomacea patula* catemacensis Baker, 1922 (Gastropoda: Ampullariidae) when fed calothrix sp. (Cyanobacteria). *Jour World Aquacult Soc* 36: 87–95.

Saint-Paul U. 1986. Potential for aquaculture of South American freshwater fishes: a review. *Aquaculture* 54: 205–240.

Saint-Paul U. 1991. The potential for Colossoma culture in Latin America. *Infofish Int* 2: 49–53.

Sullivan WG, Wicks EM, Luxhoj JT. 2006. Eng Econ. 13th edn. New Jersey: Pearson Prentice Hall.

Van der Meer MB. 1997. Foods and feeding strategies for Colossoma macropomum (Cuvier 1818). Fish growth as related to dietary protein. PhD thesis, Wageningen Agricultural University. Ponsen & Louijen, Wageningen.

Vázquez G, Castro T, Castro J, Mendoza G. 2012. Effect commercial diets on growth, survival and chemical composition of the edible freshwater snail Pomacea patula catemacensis. *J Agric Technol* 8: 1901–1912.

Watanabe WO, Dumas CF, Carroll PM. 2015. Production economic analysis of black sea bass juveniles to support finfish mariculture grow out industry development in the southeastern US. *Aquacult Econ Manag* 19: 1–25

Young JA, Muir JF. 1995. Diversity in adversity? The case of the UK aquaculture sector. In: International Cooperation for Fisheries and Aquatic Development. 7 th Bien.Conf. Int. Inst. of Fisheries Economics and Trade. Taiwan, July 1994, vol. 11, pp. 82–95.

Zuñiga-Jara S, Ruiz S. 2017. Reviewing capital cost estimations in Aquaculture. *Aquacult Econ Manag* 22: 72–93.

Cite this article as: Mejía-Ramírez MÁ, Valadez Rocha V, Pérez-Rostro CI. 2020. Economic feasibility analysis of small-scale aquaculture of the endemic snail *Pomacea patula catemacensis* (Baker 1922) from southeast Mexico. *Aquat. Living Resour.* 33: 2