ECONOMIC ANALYSIS OF POLYCULTURE TILAPIA AND AUSTRALIAN REDCLAW CRAYFISH.

Eva Coronado-Castro, Laura Silva-Ledezma, Eucario Gasca-Leyva
Centro de Investigación y Estudios Avanzados del IPN, Unidad Mérida, México.
ecoronado@mda.cinvestav.mx, lsilva@mda.cinvestav.mx, eucario@mda.cinvestav.mx.

ABSTRACT

The present paper studied system viability of tilapia nilotica and Australian redclaw crayfish in polyculture, considering tialpia as main species. Three scenarios were analyzed: tilapia monoculture with 38.7 fish/m3 and tilapia and Australian redclaw polyculture, considering the same stocking density for fish in monoculture and 17.5 crustaceans/m2, of which one included a physical separation between species. Modelling and simulation was conducted with the PowerSim software. The results showed the polyculture without physical separation, generated sales revenue (3.261,30 dls) and net income (479,98 dls), a harvesting time and size of 197 days and 350.7 g for tilapia. Modeling data proved useful tools for decision-making allowing establish optimal harvest time for the monoculture and polyculture of the studied species.

Keywords: Tilapia, Australian Redclaw crayfish, economic analysis, polyculture.

INTRODUCTION

Polycultures represent a management strategy used in aquaculture to improve production yields per unit area. This technique has been shown to improve the efficiency of resource exploitation and supply use, and thus results in greater economic benefits for the producer [1, 2]. Under such a scenario, tilapia nilotica, *Oreochromis niloticus,* and Australian redclaw crayfish, *Cherax quadricarinatus*, represent two potentially viable freshwater species which can be grown in polycultures.
Tilapia is considered a suitable species for aquacultural because it is highly resistant to adverse conditions and has a rapid growth under a wide variety of management schemes [3]. Because of this, is the most studied species in aquaculture in terms of biological characteristics as well as marketing. The redclaw crayfish, on the other hand, has short life cycle and is also physiologically resistant. This species' growth rate allow it to reach commercial length in seven or eight months, while the market acceptance is high [4, 5]. It represents an ideal candidate throughout various tropical and subtropical regions, where temperatures are favorable for its development [6, 7].
Previous studies which have evaluated the profitability of tilapia polycultures have done so growing this species in association with carp [8], African catfish [9], shrimp [10, 11], crayfish [12, 13] and tambaqui [14]. These studies were based on harvests from one crop production cycle, after which an evaluation or profitability was conducted. Such studies have also shown the technical and economic feasibility of aquacultural polycultures in the regions where they were implemented. Nonetheless, in this context, only one study [12] has made use of bioeconomic modeling and was based on data from experiments conducted in Israel [15].

In Yucatan (Mexico), aquaculture programs implemented so far have made use of tilapia under semi-intensive management schemes. Such projects have been conducted in rural areas and most of them were conceived as a subsistence activity and complementary to agricultural activities. Unfortunately, production levels have been very low resulting in reduced economic benefits and subsequent abandonment of the projects [16, 17]. In addition, there is currently no available information in Yucatan regarding the use of Australian redclaw crayfish in commercial aquaculture.

Given that aquaculture represents a viable alternative to provide economic benefit to farmers and fishermen of the region, the development of this activity is fundamental in order to stimulate the economic growth of the state of Yucatan. However, due to the history of failures of breeding programs in the past, it is necessary to implement management options which result in greater economic benefits and make aquaculture projects more attractive and successful.
Based on this, the present work was aimed at determining the economic viability of an aquaculture system composed of monoculture and polycultures of tilapia nilotica (main species) and Australian redclaw crayfish (secondary species) using bioconomic modeling. Results from this study will allow the identification of the optimum harvest time and determination of the crop management scheme which offers the highest return.

MATERIAL AND METHODS

Bioeconomic-model

Data set: The data were obtained from a previous experiment with tilapia nilotica and Australian redclaw crayfish conducted at the Centro de Investigación y de Estudios Avanzados in Merida, Yucatan, Mexico and part of a master's thesis [18]. Such study included three different treatments: 1) monoculture of tilapia, 2) polyculture of tilapia and redclaw crayfish without a physical separation, and 3) polyculture of tilapia and redclaw crayfish with a physical separation between species (using a 1-cm plastic mesh). Physical separation was used to avoid interaction between fish and crustaceans, and involved the use of a mesh that was placed inside each experimental tank of this treatment, preventing the movement of fish to the bottom of the tank where the crayfish were found.

The conceptual and mathematical model: A bioeconomic model was developed based on system dynamics, which included three submodels: A biological submodel which described the growth of the species, a management submodel which included variables of influence on the development of organisms, and economic submodel, which described the main input and output variables of the economic environment.
The conceptual model showing the main variables and relationships between the three submodels is presented in Figure 1.

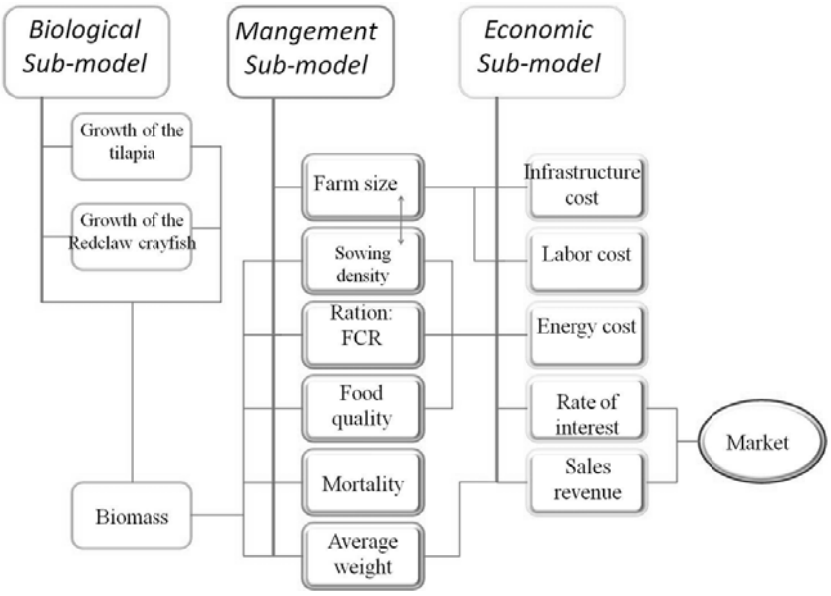

Figure 1. Conceptual bioeconomic model and relationships between submodel variables

The mathematical models presented below were parameterized in software InfoStat/Profesional, version 1.1. The bioeconomic model was constructed in Powersin 2.51 (Academic, Powersin AS) for the simulation of scenarios.

Biological submodel: To explain organism growth, the Von Bertalanffy, Gompertz, Logistic and Chapman Richards models were initially analyzed. Of these, the Von Bertalanffy growth model function had the best fit and was thus selected to describe the development of both tilapia (T) (Eq. 1) and redclaw crayfish (L) (Eq. 2):

$WT(t) = W_T\infty * (1+\beta*\exp-(\gamma*t))^3$ (Eq. 1)
$W_L(t) = W_L\infty * (1+\beta*\exp-(\gamma*t))^3$ (Eq. 2)

Where:
$W_T(t)$ = tilapia weight at time *t*
$W_T\infty$ = asymptotic weight of tilapia
$W_L(t)$ = redclaw crayfish weight at time t
$W_L\infty$ = asymptotic weight of redclaw crayfish
t = time
β y γ = parameters

Management submodel: This submodel considered the main control variables for both species. Specifically, it describes the biomass (Eq. 3 and 4) and mortality (Eq. 5 and 6), as well as variables that are closely related with the growth of organisms and the economic performance of the farm.
Three scenarios were studied: Tilapia monoculture (TM), polyculture of tilapia and redclaw crayfish without physical separation (PWOM) and polyculture of tilapia and redclaw crayfish with physical separation (PWM). Some of the main models used are:

$B_T(t) = N_T(t)*W_T(t)$ (Eq. 3)
$B_L(t) = N_L(t)*W_L(t)$ (Eq. 4)
$N_T(t) = N_T^0 *e^{-zT\,t}$ (Eq. 5)
$N_L(t) = N_L^0 *e^{-zL\,t}$ (Eq. 6)

Where:
$B_T(t)$= Tilapia biomass at time t
$B_L(t)$= Redclaw crayfish biomass at time t
$N_T(t)$=Number of tilapia at time t
$N_L(t)$=Number of redclaw crayfish at time t
W(t)= Average individual weight of tilapia at time t
$W_L(t)$= Average individual weight of redclaw crayfish at time t
N_T^0= Initial number of tilapias
N_L^0= Initial number of redclaw crayfish
zT= Mortality rate of tilapia
zL= Mortality rate of redclaw crayfish

Economic submodel: This submodel considered the most important input and output variables for the model (i.e., those with greatest impact on the system's economic performance). The inputs were: the market price of both species, costs of tilapia fingerlings and juvenile redclaw crayfish, food, energy (pumping), labor (man hours). The output variables considered economic-financial indicators: Present value (PV) (Equations 7 to 15).

$$IT(t) = VB\,T + VB\,L(t) \quad \text{(Eq. 7)}$$

$$VBT(t) = BT(t) * P_T W \quad \text{(Eq. 8)}$$

$$VBL(t) = BL(t) * P_L W \quad \text{(Eq. 9)}$$

$$IN(t) = IT(t) - CT(t) \quad \text{(Eq. 10)}$$

$$CT(t) = CV(t) + Cf(t) \quad \text{(Eq. 11)}$$

$$Cv(t) = Ca(t) \quad \text{(Eq. 12)}$$

$$Cf(t) = Cmo(t) + Ce(t) + Ccr(t) + Cdep(t) \quad \text{(Eq. 13)}$$

$$IB(t) = Bb(t) - Ct(t) \quad \text{(Eq. 14)}$$

$$PV = \frac{IN(t)}{(1+T^{1/365})} \quad \text{(Eq. 15)}$$

Where:
IT (t) = Total net revenue in time t
VBT (t) = Value of tilapia biomass at time t
VBL (t) = Value of redclaw crayfish biomass at time t
PTw = Price of tilapia
PLw = Price of redclaw crayfish
IN (t) = Net income at time t
CT (t)= Total cost at time t
Cv (t) = Variable cost al time t
Cf (t) = Fixed cost at time t
Ca (t) = Cost of food at time t for tilapia and redclaw crayfish
Cmo= Labor cost at the time t
Ce= Daily energy cost
Ccr= Costs of pups and juveniles of tilapia and redclaw crayfish
IN (t)= Net income at time t
PV= Present value

Growth model parameters. The model was parameterized in Excel 2007 and built using Powersim 2.51 (Academic Powersim AS) for simulation of scenarios. A goodness-of-fit test was used to validate the growth functions of both species by contrasting results predicted with the model with those observed with real data using Theil stastistic [19, 20].

Assumption for the bioeconomic analysis: Tilapia initial density was 5469 per tank for the three scenarios. In the case of polycultures, redclaw crayfish density was 1374 organisms per tank in both cases. The assumptions used for the economic submodel (Table I) were obtained from the literature and from the market in Mexico.
The cost and input prices used were obtained from market values for aquaculture products in Yucatan; the price of redclaw crayfish was obtained from the literature as well as from the market price in Morelos, Mexico (Table I). In all cases prices are quoted in U.S. dollars.

Table I. Assumptions used for the economic submodel.

Concept	*Description*	*Value*	*Units*	*Reference*
Costs				
Labor	Man hours/day	0.16	$/day	[17]
Tilapia fingerlings	1 fish of 20 g	0.06	$/c/u	[17]
Juvenile redclaw crayfish	1 crayfish of 7 g	0.20	$/c/u	[5]
Tilapia feed	Balanced food	0.62	$/kg	
Redclaw crayfish feed	Balanced food	0.65	$/kg	[12]
Energy cost		0.31	$/day	[17]
Sale Price				
	Tilapia	1.71	$/kg	Local market, july 2009.
	Redclaw crayfish between 25 y 35 gr	13.96	$/kg	[5]
Rate of interest		6%		[17]

RESULTS

The parameters obtained for the growth models of each of the studied scenarios showed that the maximum weight for tilapia was 468.63 g for the polyculture without a physical separation (PWOM). The lowest asymptotic weight for tilapia was obtained with the tilapia monoculture (TM) (300.65 g). In the case of crayfish, the maximum asymptotic weight was 36.5 g for the polyculture with physical separation (PWM) (Table II).

Table II. Growth model parameters of each species for each cultivation scenario.

	TM	*PWOM*		*PWM*	
Parameters	*Tilapia*	*Tilapia*	*Redclaw crayfish*	*Tilapia*	*Redclaw crayfish*
α	300.65	468.63	22.66	365.1	36.5
β	-0.64	-0.66	-0.11	0.67	-0.25
γ	0.01	0.01	0.02	0.01	0.02

The optimum harvest time was obtained for each of the cultivation scenarios using the maximum present value for each crop cycle; variation in the maximum present value (PV) was observed between scenarios (Table III). The PWM scenario exhibited the shortest crop cycle with 161 days, while the PWOM scenario had the longest cycle with 197 days. The TM scenario showed an intermediate crop cycle length.

Although all the three scenarios showed net incomes and positive present values, the polyculture scenarios (PWOM and PWM) showed much higher values relative to the tilapia monoculture, which was taken as evidence of the advantage of using polycultures as a cultivation strategy (Table III). Thus, we considerer that the polyculture of tilapia and redclaw crayfish is economically viable based on the assumptions considered (Figures 2 and 3). The tilapia monoculture (TM) generated the lowest sale revenues, net incomes and PV; therefore, this scenario can be seen as the least efficient from both a technical and economic standpoint.

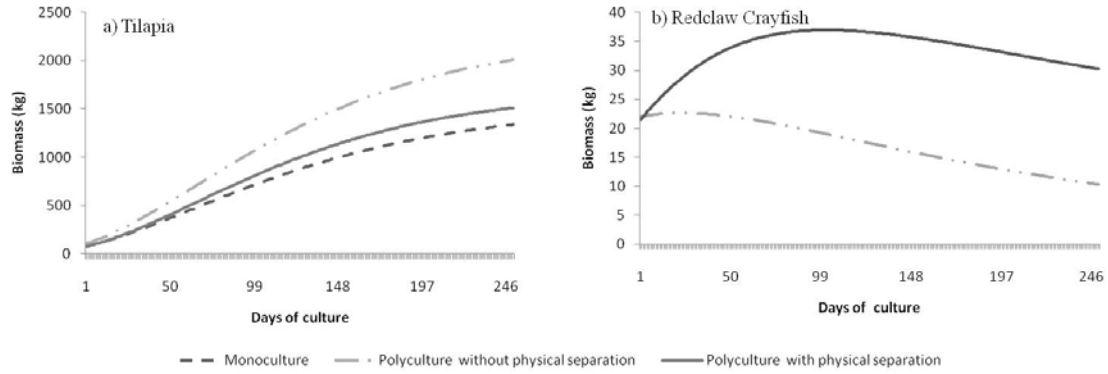

Figure 2. Biomass achieved by each of the species in the three cultivation treatment. a) tilapia and b) redclaw crayfish.

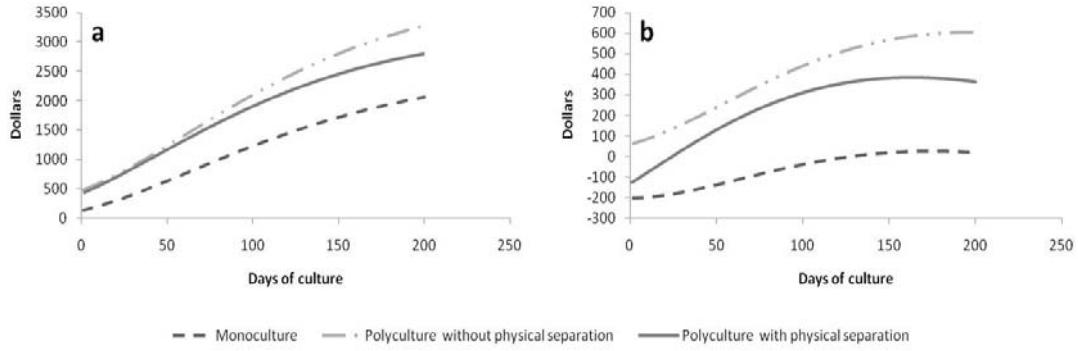

Figure 3. Results: a) Income from sales and b) net income for the three cultivation treatment generated by the bioeconomic model of tilapia and redclaw crayfish.

Specifically, the PWOM scenario showed the greatest revenues from sales, as well as the greatest net income and PV on day 197 (end of the culture cycle). This was despite the fact that this scenario presented the longest culture cycle compared to TM and PWM. Such result is explained by the higher average weight reached by the tilapia (350 g) with the PWOM scenario, which contributed to a higher biomass at the end of the culture cycle.
The PWOM scenario also resulted in the highest percentage of tilapia survival (compared to the PWM), reaching 94%. In contrast, redclaw crayfish survival was lowest under the PWOM scenario (42%).

On the other hand, the PWOM scenario resulted in the highest costs of operation compared to the TM and PWM scenarios. This finding can be attributed to the longer crop cycle for the PWOM, despite the fact that initial assumptions were the same for all three scenarios.
Thus, increasing the number of culture days, also increased overall costs for the PWOM scenario given that the cost of food for both species represents the main input which affects the costs of operation.

According to the results obtained from the bioeconomic model, it can be determined that the scenario which generated the greatest present value was the PWOM, followed by PWM. For this reason, the polyculture is considered a more profitable cultivation method for tilapia compared to the monoculture (Table III).

Table III. Results technical, biological and economic of three culture treatment.

	TM	*PWOM*		*PWM*	
Parameters	*Tilapia*	*Tilapia*	*Redclaw crayfish*	*Tilapia*	*Redclaw crayfish*
Seeding	5469	5469	1374	5469	1374
Feeding convertion rate	1.708	1.577	1.19	1.586	1.06
Mortality	-0.00017	-0.00305	-0.0044	-0.00436	-0.0020
Days of culture	175	197	197	161	161
Average individual weight (g)	211.08	350.77	22.51	237.18	35.41
Survival (%)	96.98	94.15	41.93	93.21	72.13
Initial organisms number	5304	5149	576	5098	992
Biomass (kg)	1119.64	1806.26	12.96	1209.06	35.11
Feed cost	$1.072,82	$1.698,02		$1.179,43	
Total cost of fry and fingerling	$339,16	$552,19		$552,19	
Energy cost	$54,26	$61,09		$49,92	
Cost of labor	$370,74	$417,35		$341,08	
Total costs of operation	$1.883,79	$2.781,32		$2.165,68	
Depreciation costs	$46,80	$52,68		$43,05	
Sales revenue	$1.909,48	$3.261,30		$2.551,98	
Net income	$25,69	$479,98		$386,30	
PV	$25,55	$477,43		$384,30	

DISCUSSION AND CONCLUSIONS

The crop cycle length and time of harvest estimated for each of the management scenarios based on economic results generated by the bioeconomic model, indicated that the profitability was highest for the polycultures. Such finding was related to a more efficient resource use in polycultures because the inputs and the tank are shared by both species. This results in greater differences between scenarios in terms of costs and revenues. Specifically, revenues increased for polycultures compared to the monoculture because economic benefits of the former resulted from the sale of both species [12].

The PWOM scenario generated the highest sales revenue, net revenue and PV. This finding was based on the average weight of fish at the time of harvest for this scenario (350 g), which in turn resulted in the highest tilapia biomass (1806 kg) when compared with the PWM and TM scenarios. This result can be explained by fish feeding patterns in this scenario. Without physical barriers between tilapia and Australian redclaw crayfish, and given tilapia's omnivorous feeding habits, fish consumed not only their food, but also that provided to crustaceans, as well as crayfish molts, excretes and organic matter produced in the tank. This interpretation agrees with findings from previous studies [3, 21] which suggest that higher tilapia biomass is observed for polycultures because fish consume the excretes and food offered to the subordinate species in question, resulting in increased growth rates for this cichlid.

Such condition of overfeeding also influences the feeding conversion rate, which was lowest for the PWOM scenario (1.577), compared with the TM (1.708) and PWM (1.586) scenarios.

Under the PWOM scenario, however, the Australian redclaw crayfish exhibited its lowest biomass (12.96 kg), highest mortality (58.07%), as well as lowest growth rate and weight at the time of harvest (22.51 g). These results are directly attributable to the increased stress of organisms of this species derived from their interaction with tilapia. Moreover, in some cases predation of crustaceans by tilapia was observed in the absence of a physical separation, which agrees with reports from previous studies [18, 22]. These authors suggest that, given the passive nature of the crayfish, these do not avoid predation by tilapia which results in a significant impact on the survival of this crustacean.
Despite the low production of crayfish under the PWOM scenario, such a condition was offset by the high sale price of this species (600% higher compared with tilapia [5, 12]). Here we assumed a sale price for crayfish, of 180 Mexican pesos/kg [5]. Although crayfish sizes range between 25 and 35 g, and such size was not reached by the crayfish in this scenario, a price of 180 pesos was maintained because of the steady increase in market prices and demand for this product.

The PWM scenario resulted in the second highest net income value ($4.957). Moreover, this management scenario resulted in higher crayfish biomass (35.11 kg) compared to the PWOM scenario. This is explained by the absence of crayfish predation by tilapia due to the barrier (net) which did not allow direct contact between species. For this scenario, crayfish mortality was lower (27.87%) and individual weight at the time of harvest was higher (35.41 g) compared to the PWOM, presumably due to reduced stress from not being in contact with tilapia.
Despite such finding, the PWM scenario was less profitable compared to the PWOM scenario, because tilapia biomass was lower (1209.6 kg) and income from the sale of both species was lower. Finally, the tilapia monoculture showed the lowest net income ($329) compared with the two polyculture scenarios, and this was due to higher costs of operation and because economic benefits were obtained from only one species.
The creation of aquaculture farms in rural areas of the state of Yucatan usually takes place throughout six-year periods, as this is how long politicians' terms last. Thus, the amount of time allowed for the consolidation of a project of this type is very limited [12, 16, 17]. In this way, and based on results from this study, the implementation of polycultures with crop cycles of less than a year can be considered a suitable strategy which results in greater economic benefits for producers, and therefore provides a greater incentive for local people to pursue this activity in the long term.

The use of polycultures of tilapia and Australian crayfish as a strategy to increase the profitability of a semi-intensive tilapia farm is feasible, given that polycultures had a greater profitability than the monoculture. In particular, the PWOM scenario was more profitable compared to the PWM scenario and this was attributed to the larger size attained by tilapias at an optimal time of harvest of 197 days. The physical separation present for the PWM scenario protected the Australian crayfish from tilapia, resulting in greater survival and growth of the former. However, this did not result in an overall greater profitability compared to the PWOM scenario.
Findings from this study showed that bioeconomic modeling represents a useful tool in aquaculture management, as it was possible to evaluate and compare the viability of three different scenarios of cultivation. Such models provide a description of potential biological and economic trends as well as overall benefits obtained from using different types of management schemes.

This type information can then be used a priori to inform the producer on how to design a farm, reduce risks, and increase the profitability of aquaculture activities, particularly in the state of Yucatan, Mexico where this type of management tool could be widely used.

REFERENCES

[1]Bardach, J. E., Ryther, J.H. and Mclarney, W. O. 1972. Aquaculture; the farming and husbandry of freshwater and marine organisms, Viley-interscience.

[2]Landau, M., 1992. Introduction to aquaculture. John Wiley & Sons, inc. pp 3-20; 290-305.
Martínez-Cordero J. F., Duncan N. Fitzsimmons K., 2004. Feasibility of shrimp and tilapia poly-culture in the north-west of Mexico with special reference to an economic study of a hypothetical polyculture farm, 6th International Symposium on Tilapia in Aquaculture Philippine International Convention Center Roxas Boulevard, Manila, Philippines September 12-16.

[3]Brummett, R., E. and Alon. N. C. 1994. "Polyculture of nile tilapia (*Oreochromis niloticus*) and Australian red claw crayfish *(Cherax quadricarinatus)* in earthen ponds", *Aquaculture*, Vol. 122, 47-54.

[4]Villarreal, H., 2002. Avances en la nutrición de *Cherax quadricarinatus*. In: Cruz-Suárez, L. E., Ricque-Marie, D., Tapia-Salazar, M., Gaxiola-Cortés, M. G., Simoes, N. (Eds.). Avances en Nutrición Acuícola VI. Memorias del VI Simposium Internacional de Nutrición Acuícola. 3 al 6 de Septiembre del 2002. Cancún, Quintana Roo, México.

[5]Villarreal Colmenares H. 2007. Avances en la Nutrición de *Cherax quadricarinatus.* Laboratorio de Nutrición Acuícola. Centro de Investigaciones Biológicas del Noroeste, S. C. Mar Bermejo No. 195, Col. Playa Palo Santa Rita. La Paz, B.C.S., México.

[6] Hutchings, R. W., Villarreal, H., 1996. Biología y Cultivo de la langosta de agua dulce *Cherax quadricarinatus*. Manual de Producción. Navimar, S. A. 500 pp. Guayaquil, Ecuador.

[7]FAO, 2005. Fisheries Topics: Resources. State of world aquaculture. Text by Rohana Subasinghe. In: FAO Fisheries and Aquaculture Department [Electronic edition:http://www.fao.org/docrep/003/x8002e/x8002e00.htm]. Rome.

[8]Karplus I., Milstein A., Cohen S., Harpaz S., 1996, The effect of stocking different ratios of common carp, Cyprinus carpio L., and tilapias in polyculture ponds on production characteristics and profitability, Aquaculture Research, 27 Issue 6, 447 – 453.

[9] De Graaf, G.J. and Prein, M., 2005 Fitting growth with the von Bertalanffy growth function: a comparison of three approaches of multivariate analysis of fish growth in aquaculture experiments. Aquaculture Research, 36, 100-109.

[10]Yuan, Derun, Yi, Yang, Yakupitiyage, Amararatne, Fitzimmons, Kevin, Diana, James S. 2010. Effects of addition of red tilapia (*oreochromis spp*.) at different densities and sizes on production, water quality and nutrient recovery of intensive culture of white shrimp (*litopenaeus vannamei*) in cement tanks, Aquaculture, Volume 298, 7, 226-238.

[11]Banchuen Muangkeow, Kou Ikejima, Sorawit Powtongsook and Yang Yi , 2007, Effects of white shrimp, *Litopenaeus vannamei* (Boone), and Nile tilapia, *Oreochromis niloticus* L., stocking density on growth, nutrient conversion rate and economic return in integrated closed recirculation system, Aquaculture, 269, Issues 1-4, 363-376.

[12]Ponce D, Hernández J y Gasca E., 2006, Simulating the economic viability of Nile tilapia and Australian redclaw crayfish polyculture in Yucatan, Mexico, Aquaculture 261; 151–159.

[13]Uddin, M.S., 2007. Mixed culture of tilapia (*Oreochromis niloticus*) and freshwater prawn (*Macrobrachium rosenbergii*) in periphyton-based ponds. PhD Thesis, Wageningen University, The Netherlands.

[14]Recalde Ruiz, Jose Renato. 2009, Economic analysis of rural and artisanal aquaculture in Ecuador, Universitetet i Tromsø, Norway.

[15]Karplus, I. Harpaz, S. Hulata, G., Segev, R. and Barki, A. 2001. "Culture of the Australianred-claw crayfish *(Cherax quadricarinatus)* in Israel VI. Crayfish incorporation into intensive tilapia production units", *The Israeli Journal of Aquaculture-Bemidgeh*, Vol. 53, Nº1, págs.23-33.

[16]Flores-Nava, A. 1998, La acuicultura industrial en el estado de Yucatán, situación actual y perspectivas. In: Caro-Caro, C. I., Sosa-Cordero, E. (Eds). La acuicultura en el sureste de México. El Colegio de la Frontera Sur, ECOSUR, México, pp 167–173

[17]Poot Lopez G. and Gasca E. 2008. Partial substitution of balanced feed by chaya leaves in nile tilapia production: a bioeconomic analysis. Vietnam Proceedings.
[18]Vargas, M., K., 2007. Viabilidad Del policultivo de tilapia (*Orechromis niloticus*) y langosta australiana (*Cherax quadricarinatus*) en un sistema con separación espacial. Tesis de Maestría. CINVESTAV-IPN. Mérida, Yucatán. 74 pp.
[19]Pindyck, R., Rubinfeld, D. 1981. Econometric models and economic forecasts. Second edition. McGraw-Hill. 621pp.
[20]Barlas Y, 1989, Multiple test for validation of systems dynamics type of simulation models, European journal of operational research, 42, 59-87.
[21]Bjørndal T, Lane D., Weintraub A., 2004, Operational research models and the management of fisheries and aquaculture: A review, European Journal of Operational Research 156. 533–540.
[22]Olvera-Novoa, M.A., Gasca-Leyva, E., Salas, S., 2005. Programa maestro del sistema producto tilapia –Yucatán. CONAPESCA/CINVESTAV.