การประยุกต์ใช้แบบจำลองการวิเคราะห์เพื่อประเมินศักยภาพการผลิตและความสามารถในการทำกำไรสำหรับการเลี้ยงปูม้า (*Portunus pelagicus*)

Application of Spreadsheet-Based Analytical Model to Assess Production Potential and Profitability of Blue Swimming Crab (*Portunus pelagicus*) Farming

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อพัฒนาแบบจำลองการวิเคราะห์โดยใช้สเปรดชีต (S-BSC โมเดล) สำหรับใช้เป็นแนวทางในการประเมินศักยภาพการผลิตและความสามารถในการทำกำไรของการดำเนินการเลี้ยงปูม้า (*Portunus pelagicus*) ทั้งนี้ S-BSC โมเดลนี้พัฒนาโดยใช้โปรแกรม Microsoft Excel โดยใช้ข้อมูลทุติยภูมิ ประกอบด้วย พื้นที่เลี้ยง อัตราปล่อย จำนวนที่หลบซ่อน ขนาดที่คาดว่าจะจับ รวมไปถึงต้นทุนด้านลูกพันธุ์ อาหาร ต้นทุนอื่น ๆ และราคาขายผลผลิต จากนั้นสเปรดชีตจะแสดงข้อมูลด้านการผลิต (วันที่เก็บเกี่ยวผลผลิต อัตราการรอดตาย ผลผลิตที่คาดว่าจะได้ อัตราการให้อาหาร ปริมาณอาหารที่ให้ทั้งหมด อัตราการเจริญเติบโตเฉลี่ยต่อวัน และอัตราการเปลี่ยนอาหารเป็นเนื้อ) ต้นทุน ผลตอบแทน และความสามารถในการทำกำไรตามหลักเศรษฐศาสตร์ (มูลค่าปัจจุบันสุทธิ อัตราส่วนต้นทุนผลประโยชน์ อัตราผลตอบแทนภายในโครงการ และความเสี่ยงของการลงทุน) ผลการทดสอบสรุปได้ว่า แบบจำลอง S-BSC นี้สามารถนำไปใช้เพื่อประกอบการตัดสินใจลงทุนประกอบกิจการเพาะเลี้ยงปูม้าได้

คำสำคัญ: ปูม้า, การเลี้ยง, แบบจำลองการวิเคราะห์

Abstract

The objective of the present study was to develop a spreadsheet-based analytical model (S-BSC model) to assess production potential and profitability to encourage blue swimming crab (*Portunus pelagicus*) farming. The S-BSC model has been developed base on Microsoft Excel program, and data used were obtained from various of secondary data including culture area, density of crab rearing, number of shelters, market size, crab larvae cost, feed cost, other costs and price of productivity. Then the outputs shown the data of productivity (date of harvest, survival rate, yield, feeding rate, total feeding, average daily growth and feed conversion ratio), cost and benefit, and profitability (i.e. net present value, benefit-cost ratio, internal rate of return, switching value tests of cost and benefit) in a spreadsheet. This finding indicated that the S-BSC model presented powerful capability to encourage both the potential and risk of crab farming.

Keywords: blue swimming crab, culture, spreadsheet-based analytical model

Introduction

The blue swimming crab, *Portunus pelagicus*, is a commercially important marine crustacean species. This species is distributed throughout the coastal waters of tropical regions of the western Indian Ocean and the Eastern Pacific. The crab is highly demanded of domestic consumption and export products of many countries in Asia, especially Thailand. However, overfishing problem shown a downward trend of total catch of overall marine crabs since 2009 (Department of Fisheries, 2019; Hamid *et al.*, 2016). Therefore, many countries are actively involved in crab aquaculture and associated research, e.g. the Philippines, Indonesia, India, Australia, Malaysia and Thailand (Josileen and Menon, 2005; Romano and Zeng, 2008; Oniam and Arkronrat, 2013. For aquaculture, understanding of female reproductive biology and the development of crab broodstock rearing were successful in larval production (Tanasomwang *et al.*, 2002; Xiao and Kumar, 2004; Arshad *et al.*, 2006; Oniam *et al.*, 2010, 2012; Oniam and Arkronrat, 2014, 2015; Epifanio and Cohen, 2016). Unfortunately, up to now the crab culture have not been established on a commercial farm scale because of low productivity (Maheswarudu *et al.*, 2008; Andrés *et al.*, 2010; Liao *et al.*, 2011; Oniam *et al.*, 2011a; Oniam and Arkronrat, 2013; Ravi and Manisseri, 2013; Azra and Ikhwanuddin, 2015). This is a major bottleneck of commercial marine crab aquaculture development.

Previous studies on the culture of *P. pelagicus* in grow-out ponds has identified the main causes that bring the low survival rate, which are cannibalism (Marshall *et al.*, 2005; Oniam *et al.*, 2011b), nutritional quality of feed (Soundarapandian and Dominic Arul Raja, 2008; Oniam *et al.*, 2012), water quality (Romano and Zeng, 2007; Liao *et al.*, 2011) and pond bottom soil quality (Oniam and Arkronrat, 2013; Oniam *et al.*, 2016). To improve income of crab farming, more knowledge about optimal farm management is essential, e.g. investigated the effect of feeding frequency (Oniam *et al.*, 2016), impact of the type and number of shelters (Oniam *et al.*, 2020), and the impact of different pond bottom soil substrates (Oniam *et al.*, 2018). In addition, to meet this goal, an alternative simulation for crab production is essential to be used. The result of this study is one of alternative design and decision support for crab farm management of farmers.

Materials and Methods

Spreadsheet review and description

The spreadsheet-based analytical model for blue swimming crab culture implementation (S-BSC model) was executed on Microsoft Excel program platform, i.e. production potential and profitability. This spreadsheet equation was also shown in a display formula format. Data processing in this spreadsheet were based on input information both scientific and economic data.

Data management and analysis

The scientific knowledge of *P. pelagicus* production from the grow-out system and simulated earthen pond conditions of the Klongwan Fisheries Research Station, Prachuap Khiri Khan province, Thailand during 2011–2016 (Oniam *et al*., 2011a, 2012, 2016; Oniam and Arkronrat, 2013, 2015) and the other literature review of this crab culture that a similar conditions, e.g. salinity ranged between 29 to 33 ppt, temperature between 28 to 31 °C, DO between 4.5 to 6.0 mg L^{-1}, pH between 7.8 to 8.5, total ammonia between 0.0 to 0.4 mg-N L^{-1}, nitrite between 0.0 to 0.2 mg N L^{-1}, and alkalinity between 100 to 140 mg L^{-1} as $CaCO_3$ (Marshall *et al*., 2005; Chaiyawat *et al*., 2008; Maheswarudu *et al*., 2008; Soundarapandian and Dominic Arul Raja, 2008; Oniam and Arkronrat, 2015) were synthetic and were generated to be used for developing models of crab farming in the example spreadsheet in this paper.

Normally, the rapid assessment technique base on the S-BSC model was used for evaluation exercise, including descriptive statistics and quantitative methods. Simple descriptive statistics such as environmental conditions, crab production, cost and benefit as the mean and percentages were used to achieve production potential.

The quantitative method was used to assess profitability. This component shows financial indicators that measure the profitability of the project (Chucheep, 2001). Mainly was the net present value (NPV), the benefit-cost ratio (BCR) and the internal rate of return (IRR). The output of the NPV, BCR and IRR in S-BSC model were calculated based on Equations 1 to 3, respectively:

$$NPV = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} \quad \text{.......................... (1)}$$

$$BCR = \sum_{t=1}^{n} B_t(1+r)^{-t} \Big/ \sum_{t=1}^{n} C_t(1+r)^{-t} \quad \text{or} = \frac{PVB}{PVC} \quad \text{.......................... (2)}$$

$$\sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} = 0 \qquad \text{.......................... (3)}$$

In addition, the sensitivity analysis concerning was done to assess the financial risk of crab farming operation, using a switching value tests of cost (SVT_C) and benefit (SVT_B). The output of SVT_C and SVT_B in S-BSC model were calculated based on Equations 4 to 5, respectively:

$$SVT_C = \frac{NPV}{PVC} \times 100 \qquad \text{.......................... (4)}$$

$$SVT_B = \frac{NPV}{PVB} \times 100 \qquad \text{.......................... (5)}$$

where PVC = present value of costs, PVB = present value of benefits, t = time period of the project (1 year), B_t = benefit of project at time "t", C_t = cost of project at time "t", r = discount rate (7.50 % per year).

Results and Discussion

The S-BSC model as it displays shown in Figure 1. Various areas of the spreadsheet are grouped and have headings displayed in bolds. Required input data (i.e., culture area, the density of crab rearing, number of shelters in the pond, market size, crab larvae cost, feed cost, other costs and price of productivity) are in Column B (cell B3–B10) of the spreadsheet. Then the results of output data calculations (i.e., productivity, cost and benefit, and profitability) are shown in Column B (cell B13–B43) of the spreadsheet. The spreadsheet equations are also shown in a 'display formula' format in Column D of Figure 1, so that it can be recreated by someone who wants to modify for specific uses. To start using the S-BSC model, the user must input required data information as following. In the example of the spreadsheet as obtainable in (Figure 1), the user inputs the crab culture area (m^2) in cell B3. The density of crab rearing is input in cell B4, and recommend that crab larvae with a carapace width of 1.5–2.0 cm at 3–7 crabs per m^2 (Maheswarudu *et al.*, 2008; Oniam *et al.*, 2010; Oniam and Arkronrat, 2013). The number of shelters in the pond is inputted in cell B5 (0–5 shelters per m^2). Many researchers have recommended that when rearing brachyuran crabs some shelters should be applied in the culture pond to increase the survival rate, and the survival of crab increased with increasing numbers of shelter, e.g. the stems of coconut leaves and 90° bent-plastic plates as shelters (Luppi *et al.*, 2001; Marshall *et al.*, 2005; Oniam *et al.*, 2011b; Shelley and Lovatelli, 2011; Mirera and Moksnes, 2013; Oniam and Arkronrat, 2013; Oniam *et al.*, 2020). The user then inputs the market size, crab larvae cost and feed cost (shrimp feed, 38% protein) in cell B6, B7 and B8, respectively. The other costs (e.g. materials, not labor and public utility value) are input in cell B9. Finally, the user inputs the price of productivity in cell B10.

	A	B	C	D
1	**Spreadsheet-based analytical model for blue swimming crab culture implementation (S-BSC model)**			
2	**Input**	*Values*	*Units*	
3	Culture area	1,600	m^2	
4	Density of crab rearing (recommend that 3-7 crabs/m^2)	5	crabs/m^2	
5	No. of shelter in pond (0-5 shelters/m^2)	3	shelters/m^2	
6	Market size (crab weight)	70	g/crab	
7	Crab larvae cost	1.5	THB/crab	
8	Feed cost	28	THB/kg	
9	Other costs (not labor and public utilities value)	3,000	THB	
10	Price of productivity	150	THB/kg	
11	**Output**			
12	***1. Productivity Calculations***	*Values*	*Units*	*Calculation Formula*
13	Total seed used	8,000	crabs	=B4*B3
14	Culture period	117	days	=(B6+15.981)/0.7379
15	Survival rate	64.6	%	=IF(B5=0,(-0.4401*B14)+99.455,IF(B5=1,(((-0.4401 *B14) +99.455)*118.6)/100,IF(B5<6,(((-0.4401 *B14)+99.455) *134.1) /100)))
16	Crab yield	361.8	kg	=(((B15*B13)/100)*B6)/1000
17	Feeding rate (feeding program)			
18	at 1-30 days of culture	2.9	kg/day	=((((((-0.4401*30)+99.455)*B13)/100)*1.4)*30) /100)/1000
19	at 31-60 days of culture	4.3	kg/day	=((((((-0.4401*30)+99.455)*B13)/100)*12.6)*5) /100)/1000
20	at 61-90 days of culture	9.0	kg/day	=((((((-0.4401*30)+99.455)*B13)/100)*43.7)*3) /100)/1000
21	at 91-120 days of culture	15.2	kg/day	=((((((-0.4401*30)+99.455)*B13)/100)*73.4)*3) /100)/1000
22	at 121 days onwards	21.8	kg/day	=((((((-0.4401*30)+99.455)*B13)/100)*105.2)*3) /100)/1000
23	Total feeding	944.6	kg	=IF(B14<90,(B18*30)+(B19*30)+(B20*30),IF(B14< 121,(B18*30)+(B19*30)+(B20*30)+(B21*30),IF(B1 4>122,(B18*30)+(B19*30)+(B20*30)+(B21*30)+ ((B14-121)*B22))))
24	ADG	0.60	g/day	=B6/B14
25	FCR	2.61		=B23/B16
26	***2. Cost and Benefit Calculations***	*Values*	*Units*	*Calculation Formula*
27	Seed cost	12,000	THB	=B13*B7
28	Feed cost	26,448	THB	=B8*B23
29	Other costs	3,000	THB	=B9
30	Total cost (not labor and public utilities value)	41,448	THB/pond	=B27+B28+B29
31	Total revenue	54,265	THB/pond	=B16*B10
32	Net cash return	12,817	THB/pond	=B31-B30
33	***3. Profitability Calculations***	*Values*	*Units*	*Calculation Formula*
34	Cost	82,896	THB/year	=IF(B14<100,B30*3,IF(B14>100,B30*2))
35	Revenue	108,530	THB/year	=IF(B14<100,B31*3,IF(B14>100,B31*2))
36	Net cash return	25,635	THB/year	=IF(B14<100,B32*3,IF(B14>100,B32*2))
37	Present value of costs (PVC)	652,029	THB	=((B34/1.075)+(B34/1.155)+(B34/1.242)+(B34/1.3 35)+(B34/1.435)+(B34/1.543)+(B34/1.659)+(B34/1 .783)+(B34/1.917)+(B34/2.061))+B34
38	Present value of benefits (PVB)	745,134	THB	=(B35/1.075)+(B35/1.155)+(B35/1.242)+(B35/1.33 5)+(B35/1.435)+(B35/1.543)+(B35/1.659)+(B35/1. 783)+(B35/1.917)+(B35/2.061)
39	Net present value (NPV)	93,104	THB	=B38-B37
40	Benefit cost ratio (BCR)	1.14		=B38/B37
41	Internal rate of return (IRR)	30.92	%	=((B35-B34)*100)/B34
42	Switching value tests of cost (SVT_C)	14.28	%	=(B39/B37)*100
43	Switching value tests of benefit (SVT_B)	12.49	%	=(B39/B38)*100

Figure 1 The spreadsheet-based analytical model for blue swimming crab farming (S-BSC model).

Then the output of total seed used, culture period, survival rate, yield, feeding rate, total feeding, average daily growth (ADG) and feed conversion ratio (FCR) were calculated, and shown in cell B13–B25, respectively. In addition, the output of cost and benefit calculations, including profitability calculations were also shown in cell B27–B43.

For example, in the current S-BSC model, if the implementation of crab culture in a 1,600 m^2 earthen pond at the density of 5 crabs per m^2 with 3 shelters per m^2 and want a market size is 70 g $crab^{-1}$. Crab larvae, feed and other costs were 1.5 THB $crab^{-1}$, 28 THB kg^{-1} and 3,000 THB, respectively, and price of productivity was 150 THB kg^{-1}. Results reported that:

(i) *Productivity*, can harvest at 117 days of the culture period, the survival rate of crab was about 64.6 % and yield was about 361.8 kg per pond. For feeding program, during the culture period of 1–30, 31–60, 61–90 and 91–120 days, crabs were fed (marine shrimp feed, 38 % protein) at about 2.9, 4.3, 9.0 and 15.2 kg day^{-1}, respectively. The total feeding was about 944.6 kg per pond. ADG and FCR of crab reared were about 0.60 g day^{-1} and 2.61, respectively.

(ii) *Cost and benefit*, seed, feed and other costs of this crab culture implementation were 12,000, 26,448 and 3,000 THB, respectively. Total cost, total revenue and net cash return were 41,448, 54,265 and 12,817 THB per pond.

(iii) *Profitability*, NPV, BCR, IRR, SVT_C and SVT_B of this crab culture implementation were 93,104 THB, 1.14, 30.92 %, 14.28 % and 12.49 %, respectively. This mean investment of this crab culture implementation covers the cost (according to NPV was a positive value and IRR higher than the discount rate, 7.50 %), and have a low risk of crab farming operation.

These outputs were alternative design and decision support for crab farm management strategies of farmers. After the simulation results were obtained, it was often of interest to the crab farmer to see which inputs have affected the outputs the greatest and by how much. The profitability analysis was performed on the S-BSC model in order to see which of the analyzed inputs affect net income. This model can be used to test the effect on costs and returns of changes in culture area, the density of crab rearing, market size, feed cost, other costs and price of productivity.

Previous studies on the culture of crab found that revenue from crab production of 50–70 g $crab^{-1}$ (15–20 crabs kg^{-1}) in earthen ponds would not cover the cost, and it had a relatively high risk due to the changes in cost and benefit of investments (Oniam *et al.*, 2011a). But from the spreadsheet example of current study estimated that if the investment of this crab culture implementation, i.e. culture of crab in a 1,600 m^2 earthen pond at the density of 5 crabs per m^2 with 3 shelters per m^2 and at harvest size of 70 g $crab^{-1}$ while in case of the costs of crab larvae, feed and others were 1.5 THB crab^{-1}, 28 THB kg^{-1} and 3,000 THB, respectively, and sale price is 150 THB kg^{-1}, the result shows this investment obtains profit. This indicated that the S - BSC model would be helpful to further encourage crab culture implementation to assess potential and risk of crab farming.

For aquaculture, the facility design and management planning require expertise in a variety of disciplines and an ability to perform the computationally intensive analysis; the quantitative procedures were required to model these processes. To address these challenges, computer software tools for management planning can embody expertise in aquaculture science (Ernst *et al.*, 2000; Losordo and Hobbs, 2000; Kankainen *et al.*, 2014; Moran *et al.*, 2016). The production and profitability decision tools aim to assist farmers and potential investors understand the costs and benefits, and risks involved in the production. In the current study, all data in the S-BSC model were also used to estimate the production potential and profitability analysis as well as for the method that can help identify those management strategies conducive to the maximization of farm income. The model provided by this analysis is a simulation type model that tries to quantify the risk and uncertainty associated with crab production. This may be a guideline for crab farmers in order to develop their own models based upon their experiences and further apply it to decision-making and crab farm management. However, validity of this technique depends on the accruing and completely of data inputs.

Conclusions

In conclusion, this paper has been able to provide an overview of the components, methods and capacities by using the spreadsheet-based analytical model for blue swimming crab, *P. pelagicus* culture design and planning. This preliminary finding indicated that S-BSC model would be helpful to further encourage crab culture, and to assess potential and risk of the crab farming. The authors recommend that this technique should be more developed for modern commercial farming.

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